Investigating Coral Bleaching Using Real Data

Summary

Five lessons at increasing levels of sophistication incorporate real data from the National Oceanic and Atmospheric Administration (NOAA) to help students understand coral bleaching.

Grade Level: 6-8

Aligned to Next Generation Science Standards. See page 7.

Introduction

Coral reefs are incredibly diverse and important ecosystems. Yet current estimates show that 19% of all coral reefs are beyond recovery and another 15% are in critical condition and may die within 10 to 20 years[1]. Middle school students will use the authentic learning environment of coral reefs and real data to monitor coral bleaching events in order to determine what is happening to the health of coral reefs in the world's oceans. They will also learn about and consider the importance of coral reefs in their own lives.

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1 Wilkinson, C. 2008. *Status of the Coral Reefs of the World: 2008*. Townsville, Australia. Global Coral Reef Monitoring Network and Reef and Rainforest Research Centre.

NODE Pedagogical Approach

The NOAA Ocean Data Education (NODE) project was designed to help teachers develop skills to access and use real scientific data in order to integrate more data usage into instructional practices. To accomplish this, the designers present real online data as part of a systems approach to learning. In the development of the original National Science Education Standards, the National Research Council recommended that programs designed for middle and high school students incorporate ways in which students can utilize the concept of systems to organize how they understand and manipulate the natural world .

Students need to learn how to interpret phenomena beyond separate components and to see the world in terms of an interactive system about which they can gather information and to which they can apply data. Many times students do not recognize the differences between parts of a system and whole systems. Many sources of scientific data are available on the Internet, but often these data tools have not been successful in presenting ways to integrate isolated information into an overall system. In response, the NODE project materials tightly connect the use of online data tools to specific curriculum activities.

Further, the development of NODE curriculum modules and the choice of scientific topics have been driven by compelling “stories” that highlight and dramatize the importance of systems at work. Students will use actual research stories to study both the natural and human initiated events that influence our oceans. These stories will illustrate the need for manipulating real data to monitor these interactions.

The importance of a compelling research story cannot be overestimated. The story provides a common experience within which students and teachers can build knowledge and manipulate scientific tools. The real story context creates an incentive for students to practice core subjects and share what they learn with others, especially through the virtual world of the Internet.

Lesson Overview

This curriculum incorporates a scaled approach to learning. Each module offers activities at five different levels of student interaction, sometimes referred to as Entry, Adoption, Adaptation, Interactivity, and Invention. The early levels are very directed and teacher driven, providing structured first steps, important when learning new concepts. The levels of Adaptation through Invention are more student directed and open up opportunities for student inquiry. The following chart illustrates the five levels of this module.

5 **Invention: Design Your Own Investigation:** Students will design an investigation and use real data to try to answer a research question of their choosing.

4 **Interactivity: Citizen Scientists Mission - In Search of Evidence:** Students will use knowledge and satellite data skills gained in the first three levels to identify data needed to support a simple hypothesis.

3 **Adaptation: Degree Heating Weeks: Duration and Intensity Matter:** Students will examine how stress on corals depends not only on temperature rise, but also on the duration of time the coral is subjected to temperature anomalies.

2 **Adoption: Monitoring Coral Reefs - Establishing a Baseline:** This lesson invites students to become "citizen scientist" scuba divers to learn how researchers monitor coral reef health over time and in situ in assigned reef locations.

1 **Entry: Coral Reefs, Satellites, and Sea Surface Temperature (SST):** Students will become citizen scientists to explore stress on corals that results in coral bleaching. Students begin by examining temperature ranges needed for corals to survive and use maps to read sea surface temperature data collected from satellites.

The levels serve a dual purpose. They are designed to engage students in increasingly sophisticated modes of understanding and manipulating data. They are also intended to help you, as a teacher, familiarize yourself with online tools for accessing real data and to provide you with models for integrating the use of this data into your classroom practice.[2]

The levels provide a natural opportunity for you to adapt and customize

2 For more information about the research behind this approach, consult these papers:
Dwyer, D. C., Ringstaff, C., & Sandholtz, J. H. (1990). Teacher beliefs and practices, Part I: Pattern of change. ACOT Report # 8. Cupertino, CA: Apple Classroom of Tomorrow Advanced Technology Group, Apple Computer, Inc.
Bransford, J.D., Goin, L., Hasselbring, T.S., Kinzer, C.K., Sherwood, R.D., & Williams, S.M. (1999). Learning with technology: Theoretical and empirical perspectives. Peabody Journal of Education. 5-26.

the curriculum module as needed. For example, if students already have experience with the topic, you may find that you can skip the entry level activities.

Web Links

For links to helpful websites about coral bleaching, visit dataintheclassroom.noaa.gov.

Coral Bleaching Basics

Coral reefs and the extraordinary biodiversity they support are under thermal stress, which can result in a phenomenon called coral bleaching. Only one thing causes coral bleaching on a regional or global scale, and that is sea surface temperature! When the water gets hot and stays hot, corals will bleach.

Reef-building corals do need warm, tropical water. Generally, most corals cannot grow in oceans where the water temperature dips below 18°C (64°F) for extended periods in the winter. But how warm is too warm? Scientists discovered that corals start getting stressed if the water gets only 1°C warmer than the highest temperature expected in the summer. This temperature is called the "bleaching threshold," because the stress caused by warmer-than-normal water can cause the corals to bleach.

What happens to coral when it bleaches? Each polyp in the coral community has tiny algae, called zooxanthellae, that grow in the polyp's body tissue. Normally, these algae absorb energy from the sun and use it for photosynthesis. When the water gets too warm, however, these plants cannot use the sun's energy as efficiently. The algae turn this excess energy from sunlight into chemicals that can damage them and their host polyps. While polyps normally need the zooxanthellae, they have to get rid of them to survive the temperature stress. As a result, a polyp will expel most of the zooxanthellae from its body. The polyp's body tissue is transparent, and the rock underneath it is white, so when the zooxanthellae are expelled, what you see is the polyp's white skeleton instead of the normal golden-brown of the zooxanthellae that were in the interconnecting tissue. Because the entire coral soon looks pale or white, we say that it is "bleached."

Climate Literacy

Climate plays an essential role in the overall health of coral reefs. School curricula usually point out the differences between weather and climate, with weather being specific atmospheric conditions expected for a location in the short-term future, whereas climate shows long-term averages of conditions in the atmosphere or oceans, which are described by statistics such as means and extremes. The Coral Bleaching Module examines coral health over a long period of time. The module integrates ***Climate Literacy, The Essential Principles of Climate Sciences*** [3] by NOAA partners as a guide to understand how climate can influence coral health seasonally or change reef health due to extreme events over time. The appropriate Essential Principle is referenced in the Teacher pages for you to consider.

Assessment Strategies

Each activity level (Levels 1 through 5) is designed around specific performance tasks based on Common Core Standards (CCS). CCS stress that students need authentic learning experiences to prepare presentations using multimedia graphs, maps, video, and text, which support their claims and findings. Common Core Standards used in the Coral Bleaching Module are listed at the end of this guide. These Standards provide a way for teachers to judge and measure student progress.

For example, in Level 2, students meet CCS WHST.6-8.2 Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. (MS-LS2-2)

In addition, individual activities (Levels 4 and 5) include student self-assessments and peer review opportunities so that students can give feedback and guidance on each other's designs.

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3 *Climate Literacy, The Essential Principles of Climate Sciences*; March 2009, A Climate-Oriented Approach for Learners of All Ages, US Global Change Research Program.

About the Data

Data utilized in this curriculum was developed by NOAA's Coral Reef Watch. The mission of Coral Reef Watch is to utilize remote sensing and in situ tools for near-real-time and long-term monitoring, modeling, and reporting of physical environmental conditions of coral reef ecosystems.

Using the Technology

Teaching using technology presents some challenges. Because this curriculum demonstrates strategies for using real scientific data available on the Internet, its use assumes that you and your students will have access to the Internet at some point during the investigation. Because the level and availability of Internet access varies widely from setting to setting, however, you may need to adapt the activities to suit your particular situation. To help you, the activities are designed to be flexible.

For example:

- When access to real data is needed, the Preparation section describes steps that can be performed outside of class. Data and results can be saved for use in class.
- Data can be accessed through the dataintheclassroom.noaa.gov website using special forms that have been designed for this project. While it is recommended that you familiarize yourself with how to access data using these tools, the early lessons also contain blackline masters of important maps, graphs, and other data products, which can be used in settings where live Internet access is not available.
- An important outcome of these activities, especially at the higher levels, is for students to learn how to access and manipulate data themselves. In the ideal case, students will access the Internet individually or in groups in order to generate maps and graphs using real data. In settings where this is not possible, the curriculum provides student masters, which can be reproduced and used in class. To fully explore the questions posed in the highest level activities, however, students in these settings will need to access the Internet in a library or computer center outside of class.

Standards

All NODE modules follow guiding principles found in the Next Generation Science Standards (NGSS)* and Common Core State Standards**. They are based on the notion of learning as a developmental progression. Coral Bleaching activity levels are designed to address the NGSS and Common Core in the following ways:

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Performance Expectations

NGSS MS-LS2 Ecosystems: Interactions, Energy, and Dynamics

MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

Common Core ELA-Literacy: Science and Technical Subjects

RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). Suggestion: Encourage students to synthesize information from data products generated online into their own representations (e.g. time series, charts comparing two locations, etc.).

Common Core ELA-Literacy: Writing

WHST.6-8.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. Suggestion: Encourage students to document the research process in their own words.

WHST.6-8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. Suggestion: If students are having trouble formulating their own research questions, refer them to model questions used in earlier activities.

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* NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.
Next Generation Science Standards is a registered trademark of Achieve. Neither Achieve nor the lead states and partners that developed the Next Generation Science Standards was involved in the production of, and does not endorse, this product.

** National Governors Association Center for Best Practices, Council of Chief State School Officers Title: Common Core State Standards. Publisher: National Governors Association Center for Best Practices, Council of Chief State School Officers, Washington D.C. Copyright Date: 2010.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and interpreting data: students read and interpret remote sensing data products (Levels 1 & 3); students interpret data from in-situ monitoring simulation (Level 2); students interpret data products generated to investigate a research question (Levels 4 & 5). **Developing and using models:** students engage in role play to model data gathering techniques for in-situ monitoring of corals (Level 2). **Using mathematics and computational thinking:** students develop a working definition of temperature “anomalies, and use a Degree Heating Week calculator to examine the relationship of derived DHW to satellite-collected sea surface temperature data (Level 3). **Constructing explanations and designing solutions:** students develop presentations to communicate findings from their data gathering (Levels 4 & 5). **Engaging in argument from evidence:** students present data in support of a research question (Levels 4 & 5). **Obtaining, evaluating, and communicating information:** students construct query to select and generate remote sensing data products (Levels 1 & 3); students record, evaluate, and report on findings from in-situ monitoring simulation (Level 2); students develop presentations to communicate findings from their data gathering (Levels 4 & 5). **Planning and carrying out investigations:** students design their own investigation using real data to try to answer a research question of their choosing (Level 5).	**LS2.A: Interdependent Relationships in Ecosystems:** students construct models to understand the symbiotic relationship of corals and zooxanthellae (Level 2) . **LS2.C: Ecosystem Dynamics, Functioning, and Resilience:** students examine evidence from in-situ coral monitoring to assess changes in the population over time (Level 2); students examine how temperature anomalies contribute to accumulated thermal stress in corals (Level 3); students generate data products to investigate whether ecosystem changes produce conditions for thermal stress at coral locations (Level 4); students design their own investigation using real data to to examine factors related to thermal stress in coral ecosystems (Level 5).	**Patterns:** Observed patterns of forms and events guide organization and classification, and prompt questions about relationships and the factors that influence them (Levels 1 & 2). **Systems and System Models:** Defining the system under study - specifying its boundaries and making explicit a model of that system - provides tools for understanding and testing ideas that are applicable throughout science and engineering (Level 3). **Scale, Proportion, and Quantity:** In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance (Level 4). **Stability and Change:** For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study (Level 5).

Level 1: Entry

Coral Reefs, Satellites, and Sea Surface Temperature (SST)

Summary

Grade Level: 6-8

Teaching Time:
Two 45-minute periods

The study of coral reefs will provide an authentic learning environment for students to access and interpret data collected by remote sensing satellites. The activities in these lessons will prepare students to monitor corals using real data as a way to examine what is happening to the health of corals on a global scale.

Objectives

- Students will identify coral reef ecosystems, their locations, and their importance.
- Students will examine temperature ranges needed for coral reefs to survive.
- Students will use false-color maps to read sea surface temperature data collected from satellites.
- Students will color code a map to represent isotherms.

Focus Questions

- What are we investigating and why should we care?
- Where are coral reefs located?
- What tools do I need to examine coral health?

Climate Literacy

Climate is determined by the long-term pattern of temperature and precipitation averages and extremes. Climate descriptions can refer to areas that are local, regional, or global (CL4A)[4].

4 *Climate Literacy: The Essential Principles of Climate Science*, Second Version: March 2009. http://www.globalchange.gov/browse/educators

Background (Teacher)

Coral reefs face numerous hazards and threats both globally and locally. In this study, we will focus on the threat of mass coral bleaching produced by rising sea surface temperatures.

Students begin their study of coral bleaching by identifying the location of coral reefs, typically in climate zones between 30° N and 30° S latitudes. They will also establish why coral reefs are naturally adapted to conditions in these zones, where water temperatures typically range from 18°C to 29°C.

Once students locate the reefs, they will look at sea surface temperature (SST) data to identify any patterns and changes in water temperature.

To monitor SST on a large scale, students will use data from instruments on orbiting satellites that measure infrared radiation from the ocean surface. These data can be represented on maps. Students will map temperature zones by examining lines on the maps, called isotherms, which connect areas of the same temperature. They will use colors to represent temperature zones, producing what is called a false-color map, to make it easier to see and measure relative differences in SST.

Once students learn to access and read satellite-generated maps of SST, they will use them to identify and track stresses causing coral bleaching.

Vocabulary

Climate - the long-term 30-year average of conditions in an area—atmosphere, oceans, ice sheets—described by statistics, such as means and extremes.

Coral Reef - a seafloor biological community that forms a solid limestone (calcium carbonate) structure, built upon many generations of dead coral. The predominant organisms in most reef communities are corals.

False-Color Map - an image that uses colors, rather than true appearance, to represent differences in measured values. The color is "false" in that the land, water, or other surface shown is not really the color on the map.

Isotherm - a line connecting areas of equal temperature.

Range - determined by upper and lower limits. All living things have a range of conditions in which they thrive. Corals thrive within a temperature range of 18°C to 29°C.

Remote Sensing – measuring the property of something without touching it.

Sea Surface Temperature - the average temperature at the uppermost layer of the ocean, only a few millimeters deep. Sea surface temperature, often referred to as SST, can be globally monitored through satellite remote sensing.

Weather - The specific conditions of the atmosphere at a particular place and time, measured in terms of variables that include temperature, precipitation, cloudiness, humidity, air pressure, and wind.

Activity 1: Identifying and Mapping Coral Reef Locations

Materials

- **Computer, whiteboard, or projector**
- **Student Master 1.1: Calling Citizen Scientist Researchers!** (1 per student)
- **Teacher Master 1.1: World Coral Reef Locations saved to computer**
- **Student Master 1.2: World Coral Reef Locations** (1 per student)
- **Teacher Master 1.2: Monthly Average Sea Surface Temperature**
- **Student Master 1.3: Monthly Average Sea Surface Temperature (with Isotherms)** (1 per student)
- **Colored pencils**

Preparation

If you have access to a computer and projector, you can display a color version of the SST maps you create online. Use the following steps:

1. Visit www.dataintheclassroom.noaa.gov, and find the Coral Bleaching module.

2. Follow the link to "Get Data."

3. You will be requesting data for the region displayed on the map. Using the controls on the left side of the map, zoom out until the map displays the entire Earth.

3. Select "Sea surface temperature" under "Which dataset?"

4. Using the form, specify the date 15-July-2014.

5. Select “Map” on the menu labeled "Which view?"

6. Select an output format: Image.

7. Click the "Get Data" button.

8. Save the map to your computer. On a PC, right click with the mouse and select "Save as...." On a Mac, hold down the Ctrl key and click with the mouse.

Alternatively, you can save a master from page XYZ for display using a projector.

Procedure

1. Pass out a copy of **Student Master 1.1: Calling Citizen Scientist Researchers!** to each student. Have the students read the invitation to

study coral health. Explain that that they are being invited to find evidence to identify reasons why coral reef health is declining on a global scale. In order to do this, they will learn where coral reefs are located and explore the biotic and abiotic characteristics of their environment.

2. Project an image of **Teacher Master 1.1: World Coral Reef Locations**. Point out that coral reefs are distributed around the planet, but only in limited locations. Ask students the following questions about reef locations and record student answers.

Where do the reefs seem to be located?

Possible answer:

- *waters near the shore or on either side of the equator*

Where do corals seem to be absent?

Possible answers:

- *large areas on the west coast of South and Central America, and the west coast of Africa*
- *upper part of the North American continent, Greenland, Asia, and to the south near Antarctica*

3. Distribute **Student Master 1.2: World Coral Reef Locations** to each student. Challenge students to use latitude and longitude to locate the listed coral reefs on the map. Review how to read latitude and longitude.

- x axis = longitude, degrees east and west of the prime meridian.
- y axis = latitude, degrees north and south of the Equator.

Ask students to answer the questions regarding coral reef location at the bottom of the master.

Review with students the answers to the questions:

- Where are corals located?
- Between what latitudes do most corals live?

Possible answers: Corals live in the tropical climate zone, which is determined by the distance north and south of the Equator (between 30° N and 30° S latitude).

Then ask:
Why do you think corals are limited to certain locations on the planet?

Possible answers:

- *water too cold or too hot*
- *water too shallow*
- *water too deep*
- *not enough sunlight*
- *too much salt*
- *too much sediment in the water*

Tell students that they have hit on some of the major physical factors that limit coral reef development: depth, light, salinity, sedimentation, the emergence of coral into air, and temperature.

4. Display **Teacher Master 1.2: Monthly Average Sea Surface Temperature** on a whiteboard or computer screen. Explain that the map has been generated using real data collected from orbiting satellites using a technology called remote sensing.

Tell students that they will compare and relate the maps of coral reef locations with the map of sea surface temperatures.

Introduce the map's key features by pointing them out on the screen:

- x axis = longitude, degrees east and west of the prime meridian.
- y axis = latitude, degrees north and south of the Equator.
- Isotherms are connected lines of equal temperature.
- The temperatures indicated by each isotherm are measured in degrees Celsius.
- On the color map, the color key at the right also indicates temperatures in degrees Celsius.

5. Tell students that they will create a color-coded SST map, also known as a false-color map. They will then answer questions that demonstrate their ability to read and interpret the false-color maps.

Give each student a copy of **Student Master 1.3: Monthly Average Sea Surface Temperature**. Ask students to use colored pencils to color code the regions on the map defined by each isotherm. The isotherms are already labeled in degrees Celsius. Students should begin by choosing colors to represent bands of temperature on the scale to the right of the map. Traditionally, warmer temperatures are represented in shades of red while cooler temperatures are blue or purple.

Ask students to use their completed maps to answer the four questions on the master. Review the answers with students.

Answers:

1. b. degrees north and south of the equator

2. 28°C

3. 24°C

4. 23°C - 27°C

6. Compare the SST map that students colored with the SST map you displayed.

Ask: How are the maps alike and how are they different? Hint: Look at the size of the areas of high temperature.

7. Discuss the following questions:

How can using satellite data help researchers to study water conditions over time?

Possible answer:

- *Track changes in SST from one year to another and look for patterns.*

Why is it important for researchers to look at data for more than one year to determine sea surface temperature changes?

Possible answer:

- *Using SST satellite data from different time periods can show trends and how the climate changes over time.*

8. Discuss the following reflection questions (Level 1 Focus Questions):

What are we investigating and why should we care?
Where are coral reefs located?
What tools do I need to examine coral health?

9. Once students are comfortable reading maps, they can use the online "Get Data" tool to examine more sea surface temperature data. If you have Internet access in class, go to dataintheclassroom.noaa.gov and repeat the Preparation procedure with different dates to generate and discuss new maps.

Have students consider changes that occur in sea surface temperature at different times of the year, such as winter compared to summer.

Tell students to generate additional maps from different seasons and discuss.

Student Master 1.1

Calling Citizen Scientist Researchers!

Dear Citizen Scientist Researcher:

Are you fascinated by coral reefs where every surface, nook, and cranny is bursting with life? These oases of life are found near the Equator, where sunlight and sea surface temperature are fairly even throughout the year.

But there's a problem! Something is happening to the health of coral reefs around the planet. Scientists estimate that 10 percent of all coral reefs are degraded beyond recovery and 30 percent are in critical condition and may die within 10 to 20 years.

What's going on?

Is the problem caused by local threats, such as overfishing, destructive fishing practices, nutrient runoff, sedimentation, and anchors from boats ripping into the corals? Or is something much bigger at work, a global threat of coral bleaching linked to rising sea surface temperature?

Why should you care? You may not even live near a coral reef or the ocean!

The health of coral reefs can be used to study changes in our climate over time. Changes in the climate may influence us all, no matter where we live. As you research coral health, see if you can identify more reasons why you should care about the reef systems.

What can we do?

We need you to investigate. Your challenge is to use real-time sea surface temperature (SST) satellite data and in situ, right on the coral reef, observations to find evidence to answer this question:

What are the consequences of rising sea surface temperature on coral reefs, and why should you care?

How can you get started?

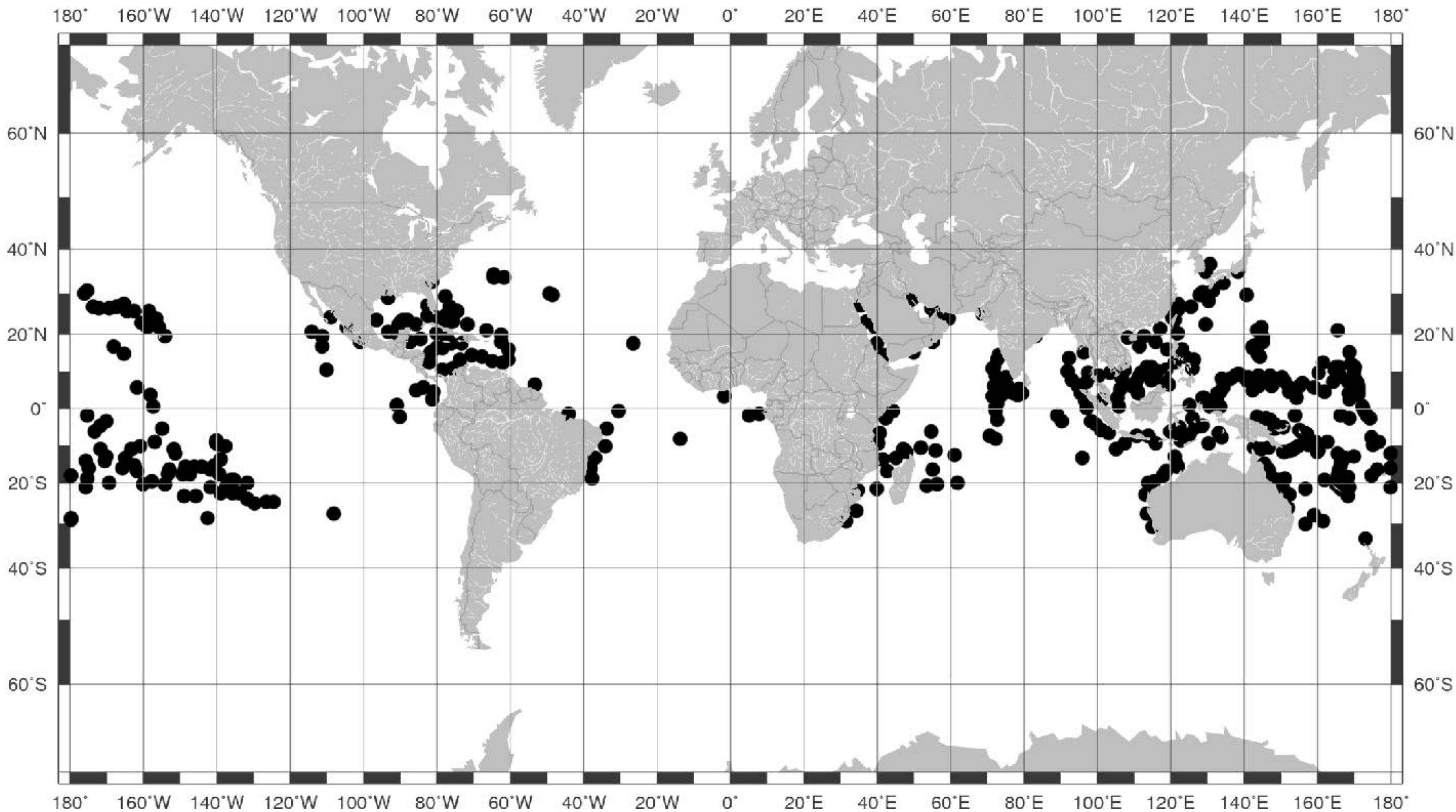
You will analyze and interpret data streams from instruments on orbiting satellites, which measure infrared radiation from the ocean surface. These powerful tools are at your fingertips, allowing you to monitor corals and figure out what is happening to coral health over time.

You will collect evidence for this scientific problem by learning to monitor globally, locally, and regionally using the power of satellites, scuba gear, maps, and your love of coral reefs. Are you ready?

Welcome to the NOAA Ocean Data Education (NODE) Project. Get ready to start exploring!

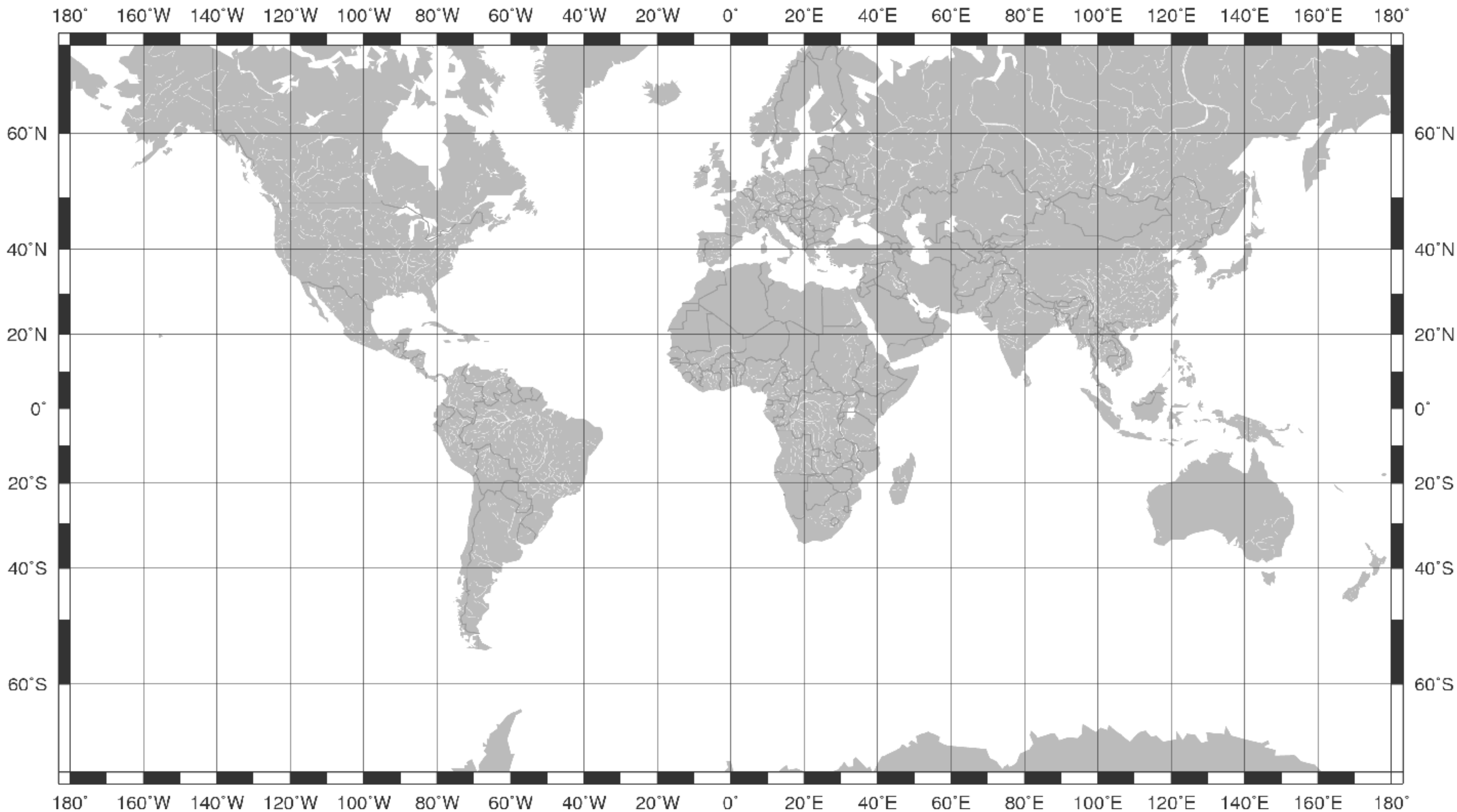
Teacher Master 1.1

World Coral Reef Locations



Student Master 1.2

World Coral Reef Locations



Student Master 1.2

World Coral Reef Locations (continued)

Directions: Locate each listed coral reef by latitude and longitude and mark it with an "X" on the map.

Location	Latitude	Longitude
Buzios, Brazil	22.5°S	41.5°W
Cayman Islands	19.5°N	80.5°E
Puerto Rico	18.0°N	67.5°W
Dry Tortugas, Florida	24.5°N	83.0°W
Galapagos, Ecuador	1.0°S	90.0°W
Hilo, Big Island, Hawaii	2.0°N	154.5°W
North Torres Reef, Great Barrier Reef	10.5°N	141.5°E
Red Sea	25°N	38°E

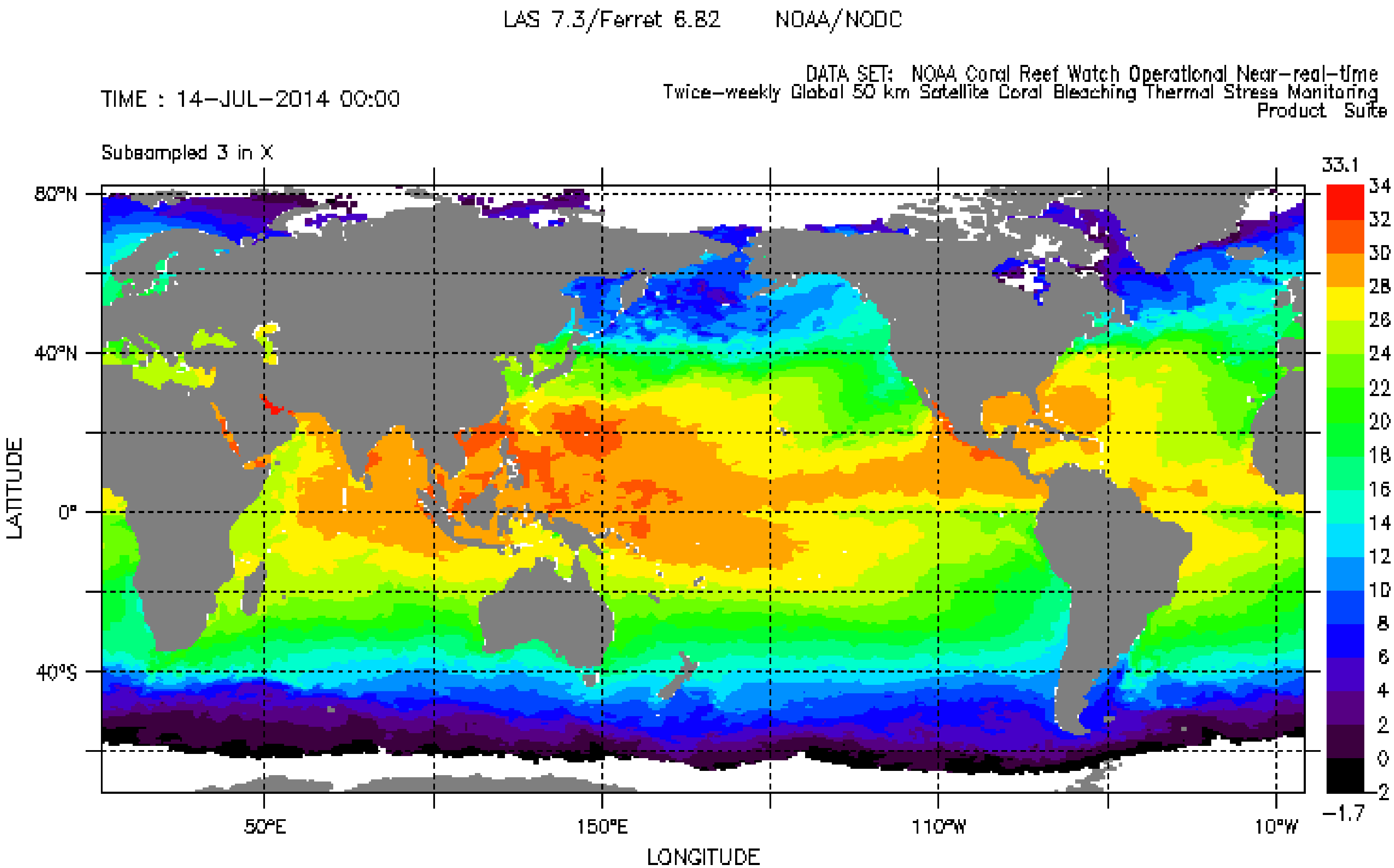
Questions:

1. Where are corals located?

2. Between what latitudes do most corals live?

Teacher Master 1.2

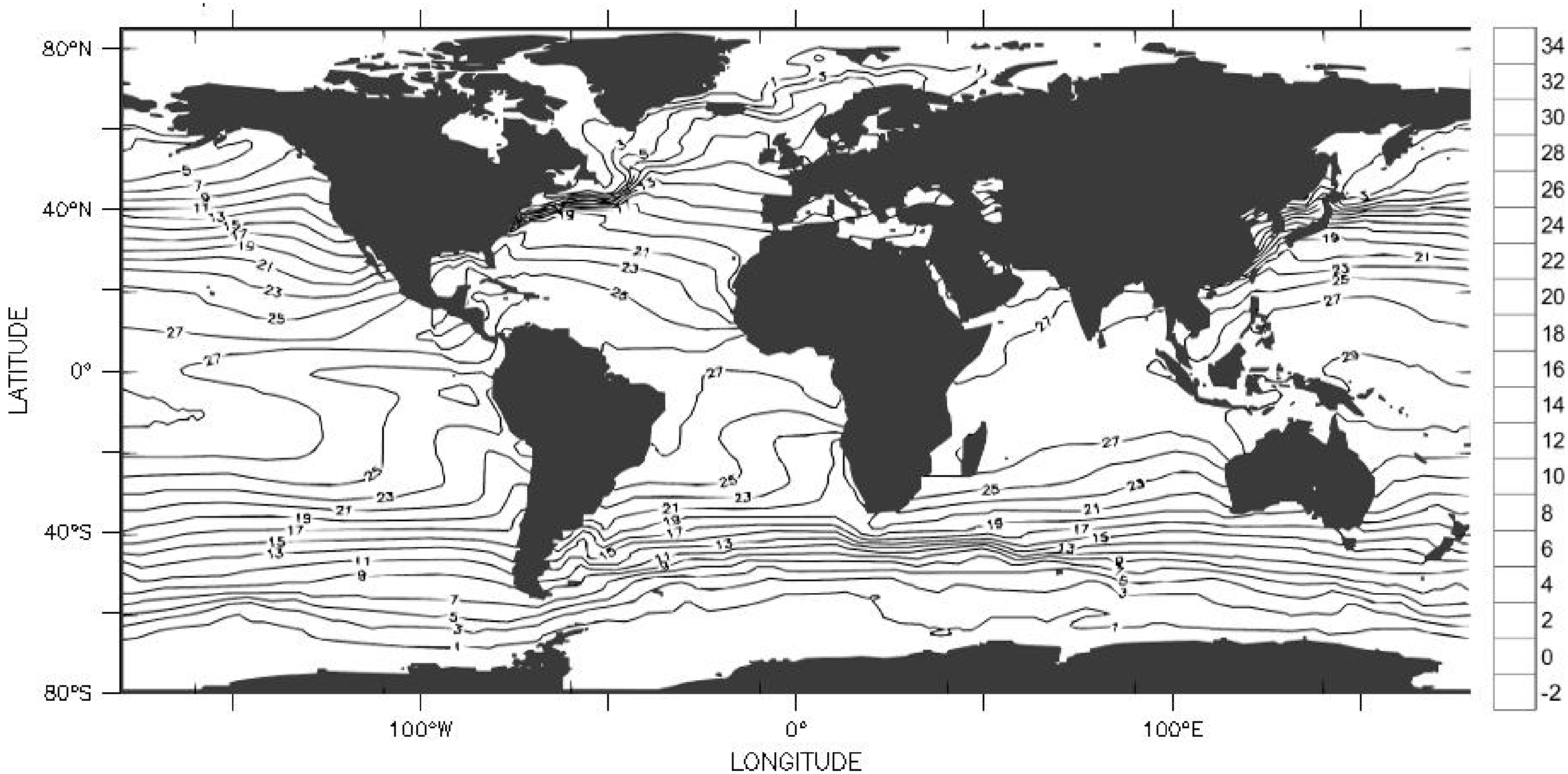
Monthly Average Sea Surface Temperature



Night Time Sea Surface Temperature (degrees Celsius)

Student Master 1.3

Monthly Average Sea Surface Temperature (with Isotherms)



1. Lines of latitude indicate:
a. degrees of temperature
b. degrees north and south of the equator
c. areas of equal temperature
d. representations of color to indicate temperature

2. What was the monthly average temperature at 160° E and 10°N?

3. What was the monthly average temperature along 100° W and 10° S

4. What is the range in monthly average temperature along the line 10°S between 150°E and 100°E?

Level 2: Adoption

Monitoring Coral Reefs - Establishing a Baseline

Summary

Grade Level: 6-8

Teaching Time:

Three 45-minute periods

This teacher-led lesson invites students to become “Citizen Scientist” scuba divers to monitor corals in situ in actual assigned reef locations over a period of years. The lesson will introduce students to coral reef biology, how to identify conditions of stress in coral reefs, and how researchers monitor coral reef health.

Objectives

- Students will learn about the particular susceptibility of corals to stress caused by changes in temperature.
- Students will understand the basic processes behind coral bleaching.
- Students will learn how to establish baseline information.

Focus Questions

- What does a healthy coral reef look like?
- Why is the process of symbiosis important to the health of corals?
- What is coral bleaching?
- How do scientists monitor the health of a coral reef?
- Why is the collection of baseline data important?

Climate Literacy

Organisms survive in specific ranges of temperature, precipitation, humidity, and sunlight. Organisms exposed to climate conditions outside their normal range must adapt or migrate, or they will perish (CL 3a)[5].

5 *Climate Literacy: The Essential Principles of Climate Science*, Second Version: March 2009. http://www.globalchange.gov/browse/educators

Background (Teacher)

As highlighted in the previous lesson, part of the value of remote sensing is that sea surface temperature data can be analyzed over large areas to determine patterns and changes in reef system health. However, researchers also need to monitor coral reefs in situ, or right at the reef site. In this lesson, students will learn that part of the value of monitoring corals in situ is the ability to ground-truth remote satellite data and establish baselines.

In order to monitor coral bleaching and establish baseline data in situ, students need an introduction to coral biology, which includes the important process of symbiosis between corals and certain algae. Use the following information to explain to students the symbiotic relationship between corals and algae during Step 3 of the Procedure. Corals are animals that have a close relationship with plants, algae called zooxanthellae, which live within the coral polyp and give the coral its color. In this partnership, the plants (zooxanthellae) and the animals (coral polyps) rely on each other for survival. The coral polyp gets much of its food energy from the zooxanthellae, and the zooxanthellae, in turn, get a safe place to live and the nutrition they need to grow. The zooxanthellae also help recycle the coral's carbon dioxide and waste. When two species form a partnership with one another, the relationship is called symbiosis.

Because of the symbiotic relationship between coral and zooxanthellae, coral reefs, the largest skeletal structures built by animals, are very successful. But despite their success, corals are subject to environmental stresses, such as prolonged high sea surface temperatures, that can affect the symbiotic process.

Under the environmental stress of rising water temperature, coral polyps may expel the zooxanthellae from their bodies. The affected coral colony appears to whiten or lose its color. This is called coral bleaching. If the bleaching persists over a long period of time, the lack of algae and food stresses the coral, slowing growth and eventually killing the polyps.

Introduce the three activities in this lesson:

- Activity 2.1: Building a Model Coral Head
- Activity 2.2: How to Establish a Baseline and Monitor a Coral Reef Location
- Activity 2.3: Citizen Scientist Researchers Coral Reef Monitoring Simulation

Vocabulary

Algae – plant or plant like chlorophyll-containing non-vascular organisms.

Baseline Data - a quantitative level or value from which other data and observations of a comparative nature are referenced.

Climate Variability - natural ranges in climate that fall within the normal range of extremes for a particular region, as measured by temperature and the frequency of precipitation events.

Coral Bleaching - loss of zooxanthellae due to stress caused by increased sea surface temperature.

In situ - on site at an actual location.

Monitoring - sampling and measuring something in the environment (air, water, soil, vegetation, animals) over time and comparing findings with baseline samples.

Mutualism - mutually beneficial association between two species of organism.

Pin Site - coral location where scientists make repeated visits to observe coral health.

Polyp - a single coral organism that secretes calcite, which forms a corallite shell or skeleton. Many polyps together make up a coral colony.

Quadrat Sampling - a classic tool for the study of ecology; in general, a series of squares of a set size are placed in a habitat, and the species within those quadrats are identified and recorded.

Symbiosis - a relationship between two species of organisms in which both members benefit from the association (mutualism), in which only one member benefits but the other is not harmed (commensalism), or in which one member benefits at the expense of the well-being of the other (parasitism).

Temperature - important abiotic factor affecting distribution and abundance of organisms; influences metabolic rate and affects rate of growth and reproduction.

Zooxanthellae - a group of dinoflagellates living endosymbiotically in association with one or a variety of invertebrate groups (e.g., corals). In corals, they provide carbohydrates through photosynthesis, which are one source of energy for coral polyps. They also provide coloration for corals and help corals recycle waste materials.

Activity 2.1: Building a Model Coral Head

Students build model coral polyps and a coral head to learn about the structure and biological interactions of coral polyps and the ongoing symbiosis in the coral community.

Materials

- **Bulletin board**
- **White egg cartons**
- **Paper towel rolls cut into 3 sections** (1 per student)
- **Construction paper divided in half** (1/2 per student)
- **Colored pencils (green)**
- **Long balloons** (4 per student)
- **Colored and white tissue paper**
- **Scotch tape**
- **Teacher Master 2.1.1: Cross-Section of a Coral Polyp**
- **Student Master 2.2.1: Coral Reef Monitoring Sheet** (from Activity 2.2, for teacher reference only)
- **Student Master 2.1.1: Build a Model Coral Head** (1 per student)

Preparation

1. Download a copy of **Teacher Master 2.1.1: Cross-Section of a Coral Polyp** for computer projection. Alternatively, you can make a transparency of the master.

2. Build a bulletin board display of a coral reef. Before students construct their individual coral polyp models, prepare a space on a bulletin board to display built coral heads. Title the bulletin board display: What Is Coral Bleaching? Turn white egg cartons upside down with the bottom cups facing up, and cut a hole in each cup the diameter of a paper towel roll. Staple sets of egg cartons on opposite sides of the bulletin board. Label one side "Living Coral" and the other side "Bleached Coral." The egg cartons represent the skeletal structure where students will attach their coral polyp models to make coral heads. The "living" coral head will contain colored twisted tissue paper surrounding the coral polyps attached by the students. The "bleached" coral skeletal remains of the polyps will have no soft body parts, only white twisted tissue paper woven around the egg carton cups attached by students.

Note: To make different coral head shapes (branching, boulder, plate, or fleshy coral) for the insertion of student made polyps, refer to **Student Master 2.2.1: Coral Reef Monitoring Sheet** for ideas.

Procedure

1. Display **Teacher Master 2.1.1: Cross-Section of a Coral Polyp** on a computer screen and use the bulletin board display "What Is Coral Bleaching?" as a teaching tool for the model coral heads presentation.

2. Point out key features of the coral polyp using the master image:

- The coral polyp is an animal that has tentacles, mouth, gut, body cavity, interconnecting tissues, and a limestone skeleton.
- The coral polyp is mostly transparent with no pigment of its own.
- At night, tentacles come out of the polyp and capture food. During the day, the tentacles move into the body cavity.
- The inside wall of the polyp is attached to the outside wall with interconnecting tissue.
- Zooxanthellae live in the walls of the interconnecting tissue.
- Limestone builds up where the polyp secretes calcite, forming the reef skeleton.
- The skeleton houses millions of polyps on a reef system. (Point out the egg cartons representing the reef structure in the bulletin board display.)

3. Review with students the information in Teacher Background about the symbiotic relationship between coral polyps and microscopic algae called zooxanthellae. The zooxanthellae live in the polyp's interconnective tissue (point this out on the projected image) and use photosynthesis to make food from sunlight, water, and carbon dioxide, which the polyp and zooxanthellae share.

4. Tell students that they will build a model of a coral polyp. Distribute **Student Master 2.1.1: Build a Model Coral Head**. Follow the directions on the master.

5. Once students have assembled their coral polyp models, ask them to:
   - Identify the coral polyp structure.
   - Explain the process of the symbiotic relationship between corals and zooxanthellae.
   - Explain why the process of symbiosis helps keep the coral reef healthy.

6. Divide the students into teams and have each team attach their coral polyps to a coral head represented by one egg carton on the "Living

Coral" side of the bulletin board.

7. Have students recall what they learned about sea surface temperature in the satellite mapping activity. Ask:

What is the average temperature range corals need to live?

Answer: 18°C to 29°C

Make a label for the bulletin board, “Water Temperature: Range 18°C to 29°C.” Attach it to the "Living Coral" side of the board.

8. Ask students what they think would happen if the sea surface temperature rose above 29°C by 1° or more.

- For one hour?
- For 2 days?
- For 2 months?

Explain that when the water is too warm the coral polyp expels the zooxanthellae. Ask:

What happens when the zooxanthellae are no longer inside of the coral?

Possible answers:

- *They can't carry on photosynthesis to feed the coral and take away the polyp’s waste products.*
- *The color of the coral is lost and it turns white.*
- *The coral is under stress.*
- *The coral and zooxanthallae are no longer in a symbiotic relationship.*

Explain that the loss of the zooxanthallae leads to coral bleaching. The zooxanthallae are the source of the coral’s color. So when coral polyps, under environmental stress, expel the symbiotic zooxanthellae from their bodies, the affected coral colony appears to whiten. If the bleaching persists, the lack of algae and food stresses the coral, restricting growth and eventually bleaching the polyps. Point to the right side of the board that contains the bleached coral.

9. Have the students look at the model coral reef on the bulletin board. Ask:

Is there any evidence of serious coral bleaching anywhere on the display?

Possible answers:

- *On the "Bleached Coral" side, there is no color, only the polyp skeletons.*

Make another label for the bulletin board, "Water Temperature: 1°C Higher Than Highest Summer Temperature." Attach it to the "Bleached Coral" side of the board.

10. As a class, go over the Discussion Questions from Master 2.1.1.

Why are coral polyps important to coral health?

Why is the symbiotic relationship between animal and plant important to coral health?

Possible answers:

- *When two species form a partnership with one another, the relationship is called symbiosis.*
- *The coral polyp gets much of its food energy from the zooxanthellae, and the zooxanthellae, in turn, get a safe place to live and the nutrition they need to grow.*
- *The zooxanthellae help recycle the coral's carbon dioxide and waste.*

Materials

- **Teacher Master 2.2.1: Coral Quadrat Example**
- **Teacher Master 2.2.2: Unbleached and Bleached Coral Examples**
- **Student Master 2.2.1: Coral Reef Monitoring Sheet** (1 per student)
- **Student Master 2.2.2: Coral Health Key** (1 per student)

Activity 2.2: How to Establish a Baseline and Monitor a Coral Reef Location

Students learn how to examine an actual in-situ coral reef monitoring site using a coral health key needed to determine coral color and a monitoring sheet needed to record baseline information.

Preparation

Download the images of **Teacher Master 2.2.1: Coral Quadrat Example and Teacher Master 2.2.1b Bleached and Unbleached Coral Examples** to be projected from your computer.

Procedure

1. Project **Teacher Master 2.2.1b Unbleached and Bleached Coral Examples**. Point out the differences between the bleached coral example and the healthy coral example. Guide students to understand that Image 1 shows a golden color, indicating it is living, while Image 2 is white, indicating the coral is bleached. Explain that the students will be learning how to identify corals under stress of bleaching in the next activity just like researchers do.

2. Project the **Teacher Master 2.2.1: Coral Quadrat Example**. Ask students to examine the coral quadrat and describe the area. Write down all responses and add anything the students miss.

Possible descriptions:

- *There are 9 quadrats, or the image is divided into 9 sections.*
- *There are corals in all quadrats.*
- *One large coral is in quadrat #5.*
- *There are different shaped corals.*
- *There are different colored corals.*
- *Under the coral, there seems to be the same kind of material, maybe coral skeleton/polyps.*
- *Latitude and longitude are shown.*
- *The name of the coral reef site is listed.*

Ask students: Do you see any other living organisms beside corals?

Answer: Yes, algae surrounding coral

How many different colors of corals do you see?

Answer: Accept any number of colors

3. Tell students they are going to learn how to conduct a baseline study of a coral reef. Pass out the tools students will use to explore the values included in the baseline: **Student Master 2.2.1: Coral Reef Monitoring Sheet** and **Student Master 2.2.2: Coral Health Key**.

4. Explain to students that they will fill in the **Student Master 2.2.1: Coral Reef Monitoring Sheet** recording observations from the projected coral quadrat image with the data it contains.

- To begin tell students to fill in the "Site name" and "Citizen Scientists' names "that refer to their school and themselves on the Coral Monitoring sheet.
- Have students fill in the "Reef name and location" which is La Parguera, Puerto Rico at 18.05 N latitude and 67.05 W. longitude found on the projected image.
- Use the date from the image (No exact time is given).
- Add Pin # 123 on the monitoring sheet. The Pin or Tag number indicates that the coral site has been monitored in the past and has observations already recorded from a different date that can be used to compare new readings.

5. Next, tell students that they will use **Student Master 2.2.2: Coral Health Key** to monitor and log in information regarding the coral sample and color code on Student Master 2.2.1: Coral Reef Monitoring Sheet. Explain that the Coral Health Key is a four-sided card with a different color of coral on each side, either lighter or darker in color to represent degrees of coral health. Emphasize that corals with color are considered healthy.

Procedure for using the Coral Health Key:

- Choose a random coral in quadrate #5 featured on the projected coral quadrat image.
- Look at the coral and select an area.
- Hold the Coral Health Key next to the selected area and find the closet color match.
- Record the identified coral and coral color on the Student Master 2.2.1 Coral Reef Monitoring Sheet in the 3 column data box:
  - Coral Number, Quadrat 5
  - Color Code, B1 or B2
  - Coral Type: Boulder

6. Continue the monitoring activity by discussing theese questions:

Look at quadrat # 5. Is there any evidence of coral stress or bleaching? What are your observations?

Possible answers:

- *The boulder coral has a B1 reading taken with the Coral Health Key. This "light" color might indicate possible future coral stress, including bleaching.*

Do any other quadrats show colors found on the Coral Health Key?

Possible answers:

- *Quadrat #4 has a smaller boulder coral that has a reading of B1. Part of the coral in quadrat #5 has the same reading.*

Are the corals in quadrats #4 and #5 living? Declining? Dead? Do you need to conduct further monitoring to answer this question?

Possible answers:

- *We need to examine more samples at the site, at different times taking earlier quadrat readings before the image we are observing or conducting a future monitoring to see if the corals changed.*

How does in situ monitoring, or being at an actual reef site, help scientists establish a baseline to use for future comparisons?

Possible answers:

- *Scientists need to establish a baseline reading at the site, in order to assess what is going on at the time, but also to compare the baseline reading to future yearly monitoring events to see if change is taking place.*

Activity 2.3: Citizen Scientist Researchers Coral Reef Monitoring Simulation

Materials

- **Teacher Master 2.3.1: Coral Monitoring Image Sets** (1 per class)
- **Teacher Master 2.3.2: In Situ Data Log Sheet with Locations**
- **Student Master 2.2.1: Coral Health Key** (reuse from Activity 2.2, at least 1 per team)
- **Student Master 2.2.2: Coral Reef Monitoring Sheet** (copy from Activity 2.2, 3 per team, one for each dive)
- **Student Master 2.3.1: Citizen Scientist Coral Reef Mission** (1 per student)
- **Clipboards** (1 per team)
- **Safety goggles used as swim goggles** (1 pair for each student "diver")
- **Masking tape**

Students simulate a field survey in which they become Citizen Scientist Researchers, checking and monitoring the health of corals in assigned reef locations over a period of years. This interactive activity assesses students' ability to apply their knowledge of coral reef biology and coral monitoring techniques, as they record quantitative baseline data and make predictions of possible coral bleaching events.

Preparation

Note: This activity can be approached in two different ways, depending on the grade level: 1. Simulated dive to In-Situ or Pin sites as activity features, or 2. Pin sites displayed on computer for direct student observations**.**

1. Print a copy of the coral images in Teacher **Master 2.3.1: Coral Monitoring Image Sets**. The locations are:

- Set A: Stetson Bank, Pin 26
- Set B: Stetson Bank, Pin 37
- Set C: Panama, Tag 218

2. Pick three classroom quadrat locations and label them A, B, and C to correspond with the three image sets.

3. Use masking tape to tack down coral reef image #1 (for the first year) of each set in the appropriate location.

Note: Teams will monitor their assigned reef site three times during this activity. Each monitoring event represents a different year. You will need to change the reef image between each monitoring event.

Procedure

1. Divide students into three teams and assign each team a coral reef monitoring site: A, B, or C.

2. Pass out copies of **Student Master 2.2.1: Coral Health Key**, **Student Master 2.2.2: Coral Reef Monitoring Sheet**, and **Student Master 2.3.1: Citizen Scientist Coral Reef Mission**, plus a clipboard and safety goggles (swim goggles) for the team of reef divers.

3. Have students read **Student Master 2.3.1: Citizen Scientist Coral Reef Mission** to prepare for the dive to their assigned reef survey site. Answer any questions students may have.

4. Direct each team to its reef location. Have teams record their Site Name on the monitoring sheet.

5. Have Citizen Scientists begin their dives to survey their reef sites. Remind students that each team will monitor their site for three different years. The first year, the team will collect baseline data, so they can determine if any changes are taking place in the next two dive years.

Note: To keep track of the three different monitoring years, you may wish to have students fill in Year 1, Year 2, and Year 3 for the "date of survey" on the **Coral Reef Monitoring Sheet** or provide students with the dates from **Teacher Master 2.3.2. In-Situ Data Log Sheet for their assigned site.**

6. Have teams follow the instructions under Multiple Coral Dives to Coral Location on **Student Master 2.3.1**, and complete the **Coral Reef Monitoring Sheet** for the first year.

7. Change the coral image, and have teams repeat the survey procedure, for Year 2. Change the image again, and have students complete their surveys for Year 3. Make sure students work with a new **Coral Reef Monitoring Sheet** for each dive.

8. When students have collected data for all three years, ask them to use their data to answer the questions under Putting Your Data Together on the master.

9. Discuss team findings as a class by asking the following questions:

What can you tell about the health of your reef from your baseline data? Give observations.

Possible answer:

- *You can tell what is happening at that moment in time through evidence such as coral types, coral color, location, and degree of coral color.*

What can you tell about the health of your reef each year? Present observations. .

Possible answer:

- *Because teams are looking at the same location, we will be able to detect change from year to year.*

How does using the quadrat sampling method help monitor the health of a coral reef?

Possible answer:

- *Scientists can pinpoint the same precise coral location from one monitoring time to the next.*

From your observations of each year's data, can you tell if your reef has changed over time?

Possible answer:

- *Answers will vary; it may stay the same, bleach, or return to health.*

Why is it important to have baseline data to measure if change happens?

Possible answer:

- *If there is no baseline information, you would only be guessing if change is taking place.*

10. Provide class time for teams to complete the section, Reporting Your Coral Health Findings, on the master. Then have teams report out to the class.

Student team class reports must include the following:

- What a healthy coral reef looks like
- What proof the team has that the reef is healthy
- How first year baseline data supported the following years' findings
- What evidence teams found of the consequences of rising and falling water temperature on coral health.

Note: Remind students to download and project reef images from their monitoring scenario as part of their class report.

Different outcomes will be seen for each testing site over the three-year monitoring period. For each monitoring event, the teams will select from three choices: healthy reef, declining reef, dead reef. Possible outcomes to choose from within a year are as follows:

- Year 1 : healthy reef; : declining reef; : dead reef.
- Year 2: healthy reef; : declining reef; : healthy reef.
- Year 3: healthy reef; : declining reef; : declining reef.

Teacher Master 2.1.1

Cross-Section of a Coral Polyp

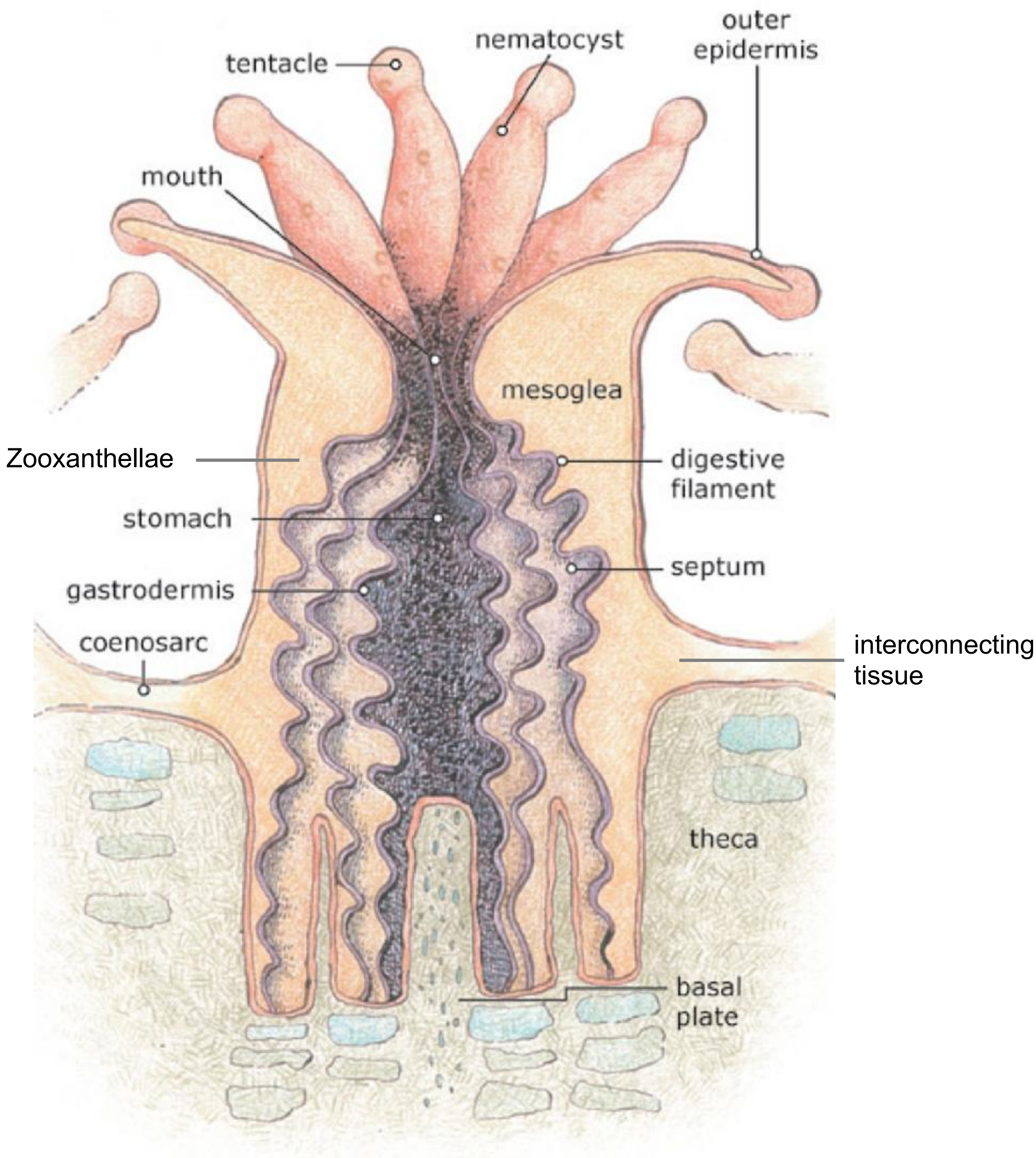
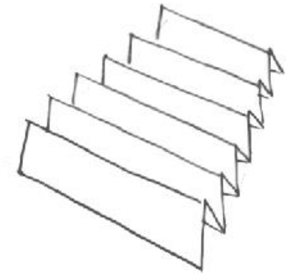


Image: NOAA

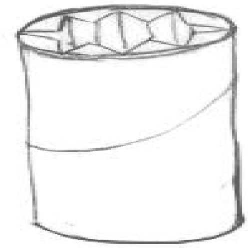
Student Master 2.1.1

Build a Model Coral Head

1. Fold a piece of construction paper in half and accordion pleat it. Use a green colored pencil to draw circles on one side of the paper. These circles represent zooxanthellae. Zooxanthellae are algae that live inside of corals. They provide carbohydrates through photosynthesis, which give energy and color to the corals.

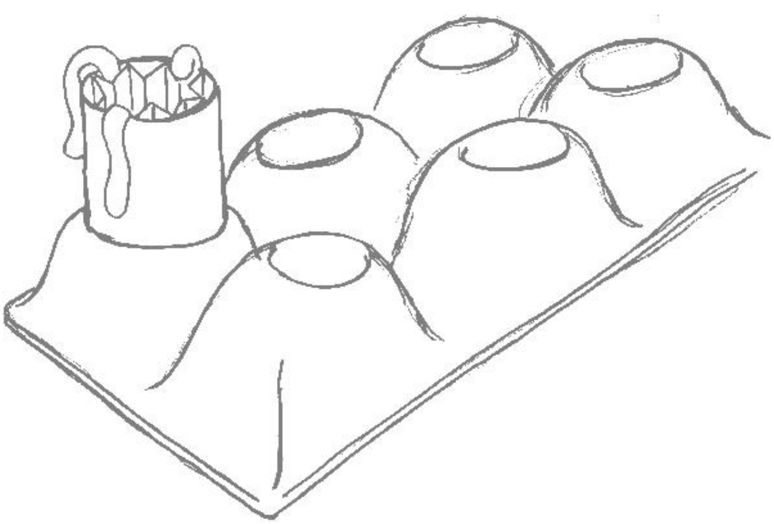


2. Hold the ends of the accordion-pleated construction paper together to form a cylinder with the zooxanthellae on the outside. Next, adjust the cylinder to fit inside of the paper towel roll. Cut off any excess paper from the top and bottom of the tube. The accordian-pleated inside of the cylinder forms the gut of the polyp.



3. Tape 4 long un-inflated balloons to the inside of the cylinder at one end. These are the tentacles. The tentacles feed the coral at night when there is no sun to allow the zooxanthellae to carry out photosynthesis.

4. To build a coral head, insert your coral polyp into the skeletal structure (egg carton) on the What Is Coral Bleaching? bulletin board display. Put tentacles inside of the polyp to signify day time when the zooxanthellae is making food. Before leaving class or school, put tentacles outside of the polyp for nighttime feeding.



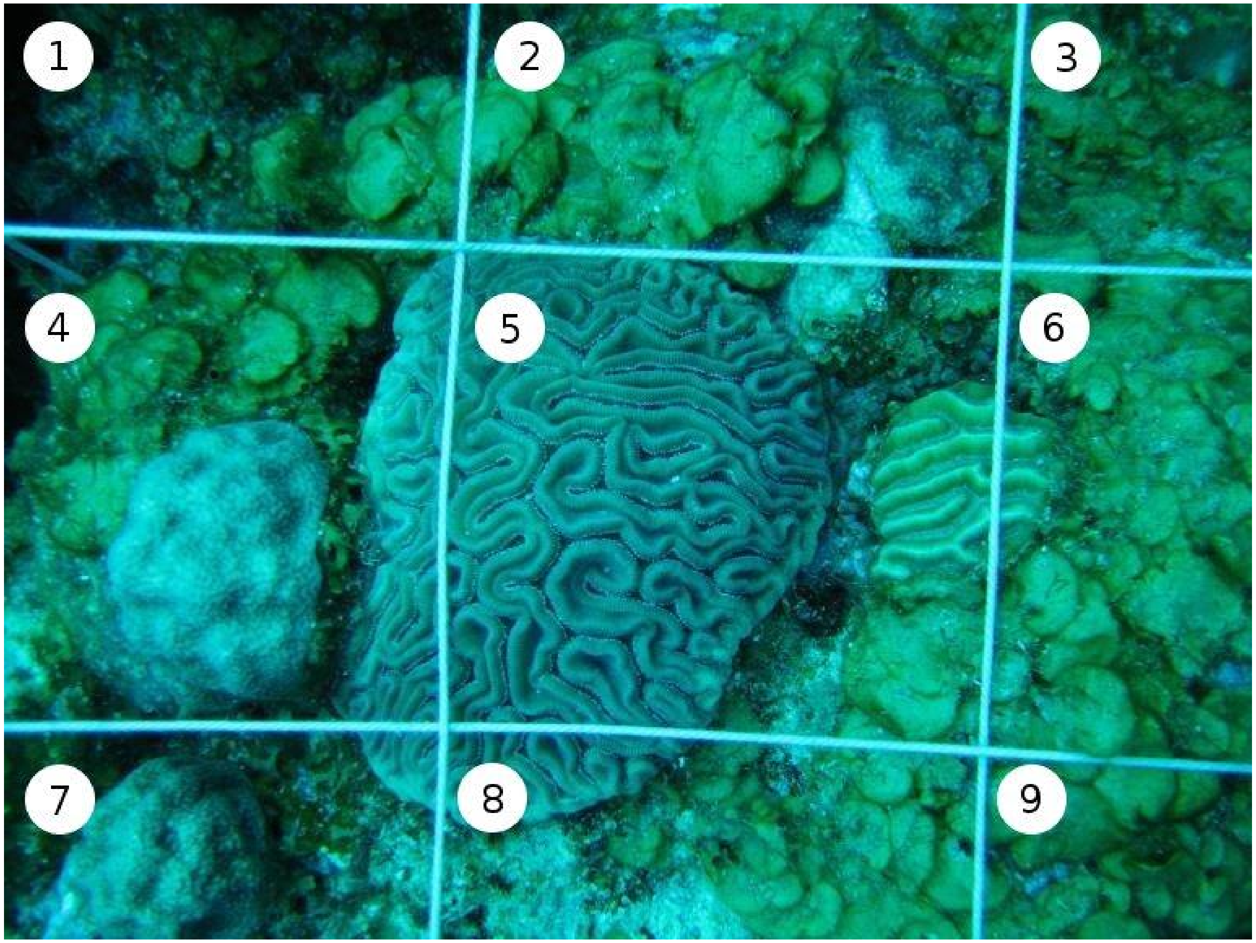
Discussion Questions

Why are coral polyps important to coral health?

Why is the symbiotic relationship between animal and plant important to coral health?

Teacher Master 2.2.1

Coral Quadrat Example



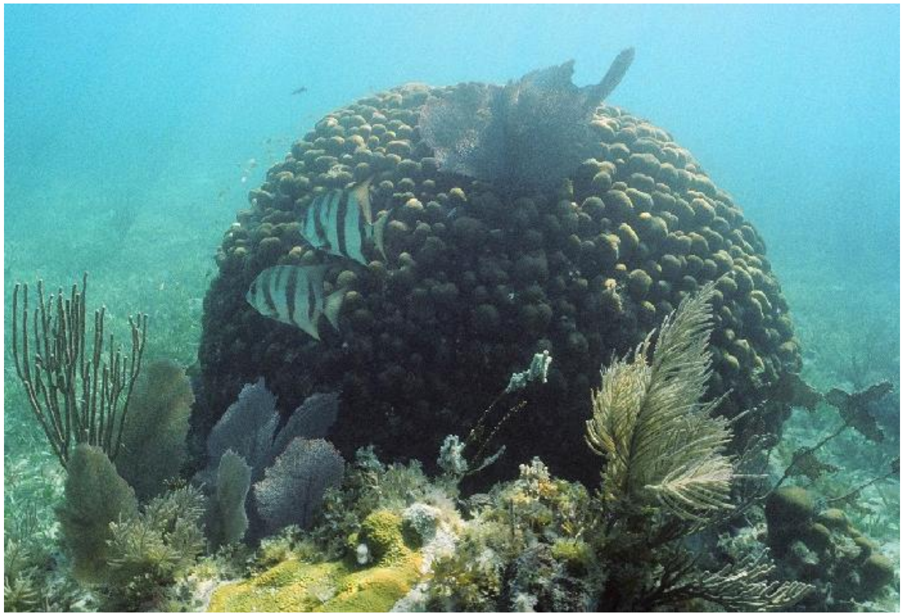
Dive date: January 2008

Survey Pin 123
La Parguera, Puerto Rico
18.05 N, 67.05 W

Image: NOAA Center for Coastal Monitoring and Assessment Biogeography Team

Teacher Master 2.2.2

Unbleached and Bleached Coral Examples



Unbleached Coral

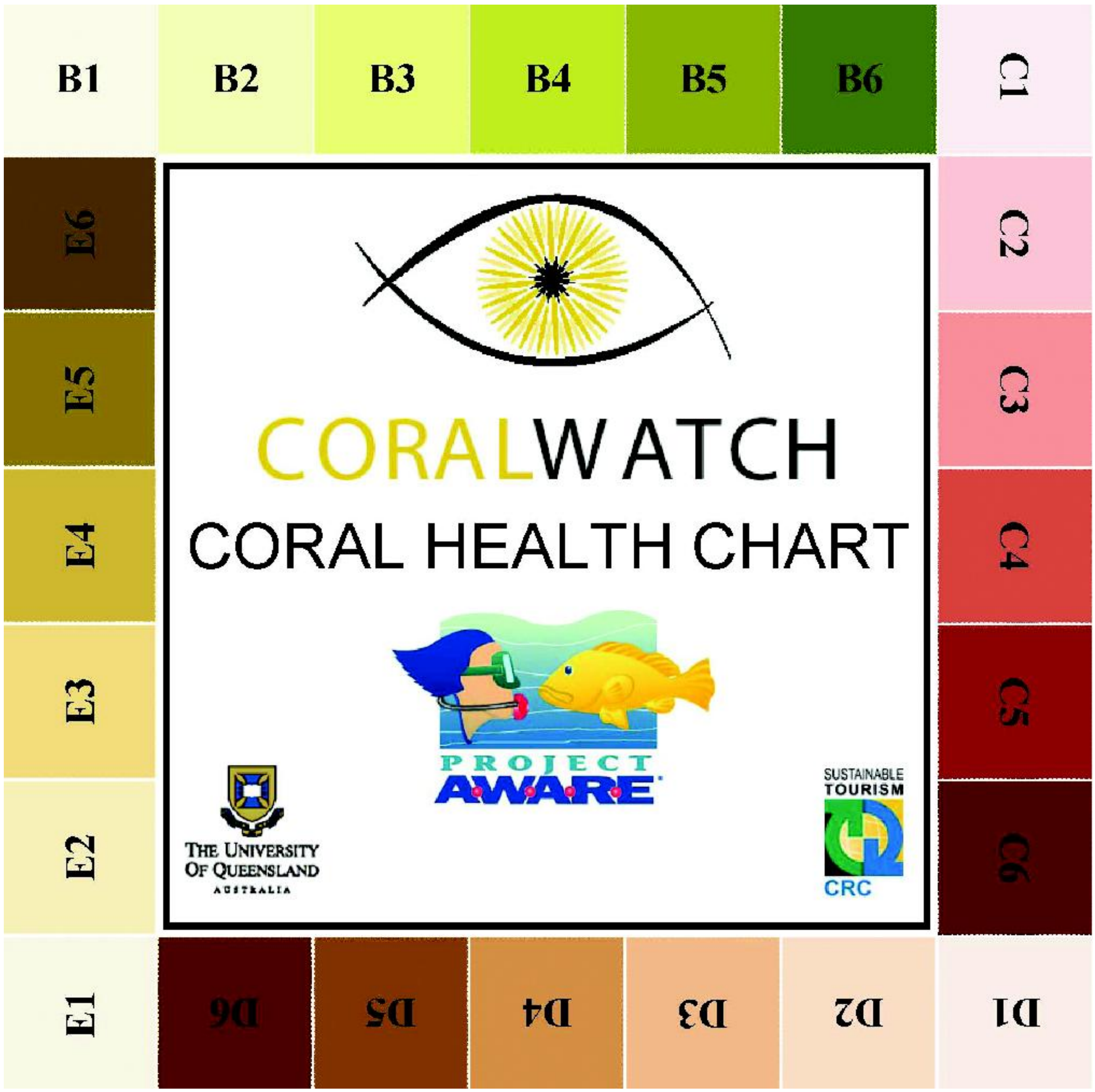
Image: Bill Precht, Florida Keys National Marine Sanctuary

Bleached Coral

Image: NOAA Center for Coastal Monitoring and Assessment Biogeography Team

Student Master 2.2.1

Coral Health Key



Coral Health Key developed by CoralWatch: www.coralwatch.org

Student Master 2.2.2

Coral Reef Monitoring Sheet

Site name: ____

Citizen Scientists' names: ____

Reef name and location: ____

Latitude: _______________________ Longitude: __________________________

Date of survey: _____/_____/__________ Time collected (i.e., 14:00 or 2pm): ________

day month year

Your activity: snorkeling________________ Weather: sunny / cloudy / raining

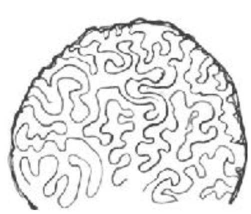
Coral Transect Tag or Pin Number: ____

Coral Number	Color Code L=Lightest; D=Darkest		Coral Type Br = branching; Bo= boulder; Pl = Plate; So = Soft			
example	*L: D2*	*D: E5*	*Br*	*Bo*	*Pl*	*So*
1	L:	D:	Br	Bo	Pl	So
2	L:	D:	Br	Bo	Pl	So
3	L:	D:	Br	Bo	Pl	So
4	L:	D:	Br	Bo	Pl	So
5	L:	D:	Br	Bo	Pl	So
6	L:	D:	Br	Bo	Pl	So
7	L:	D:	Br	Bo	Pl	So
8	L:	D:	Br	Bo	Pl	So

Coral Types

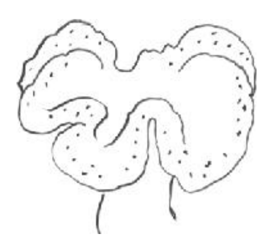
Branching

Boulder



Plate

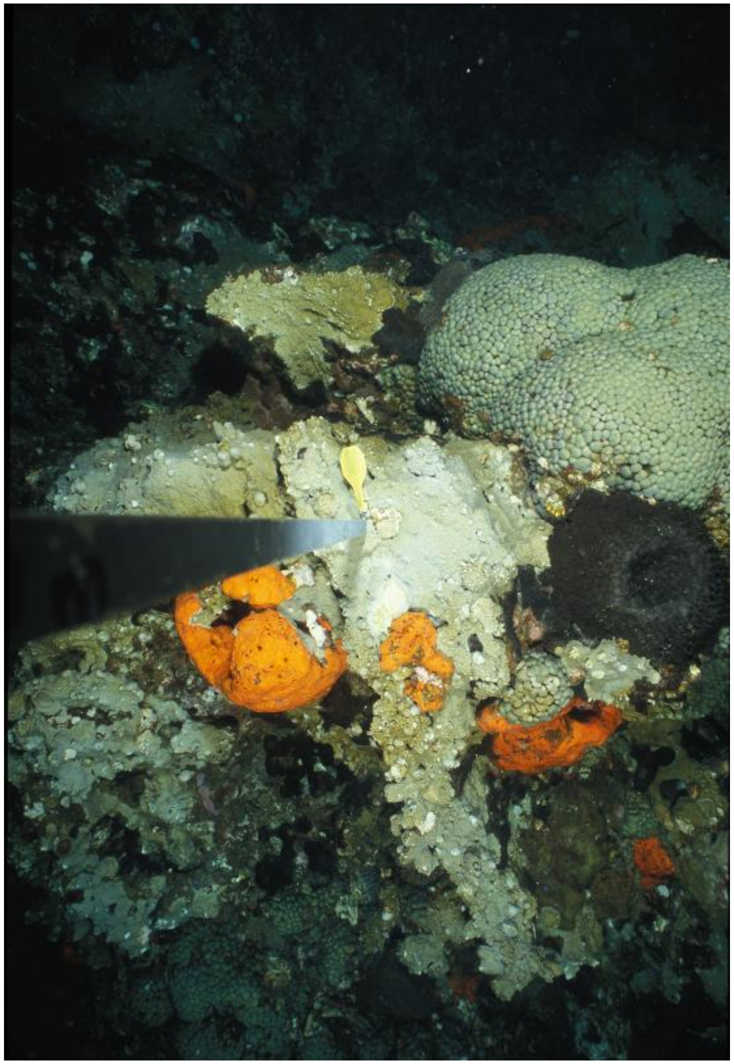
Soft / Fleshy



Coral Reef Monitoring Sheet adapted from CoralWatch: www.coralwatch.org

Teacher Master 2.3.1

Coral Monitoring Image Sets



Reef Location: A

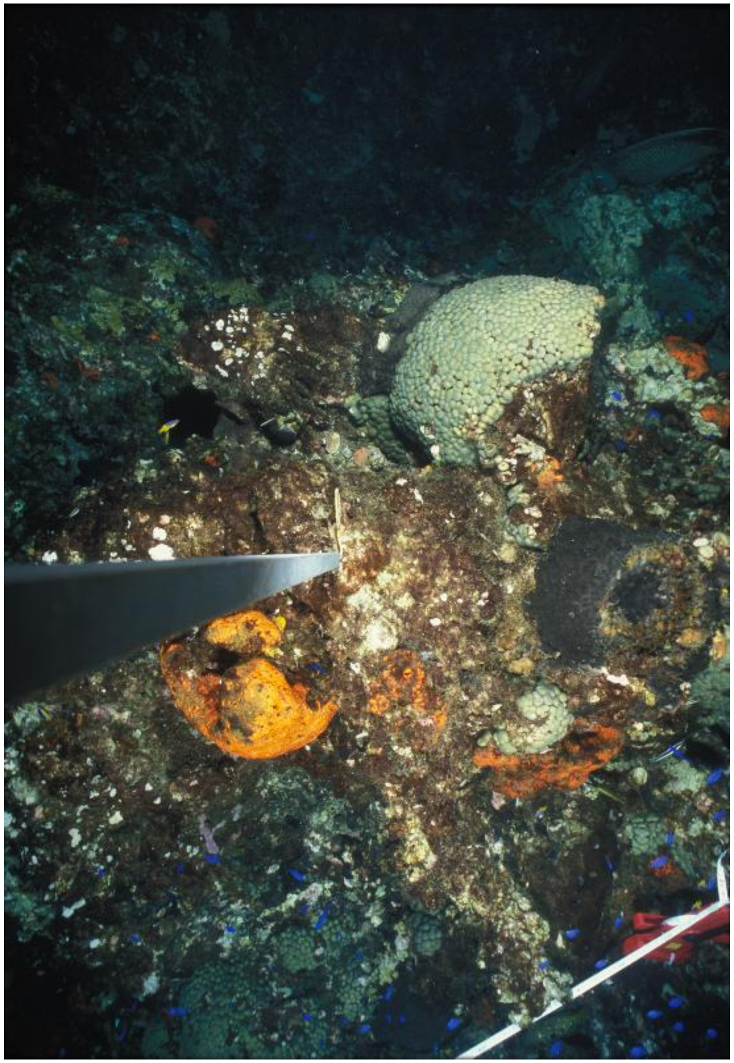
Dive date: June 2005

Survey Pin 26

Stetson Bank, Gulf of Mexico

28.0°N, 93.5°W

Image: Flower Garden Banks National Marine Sanctuary (FGBNMS)



Reef Location: A

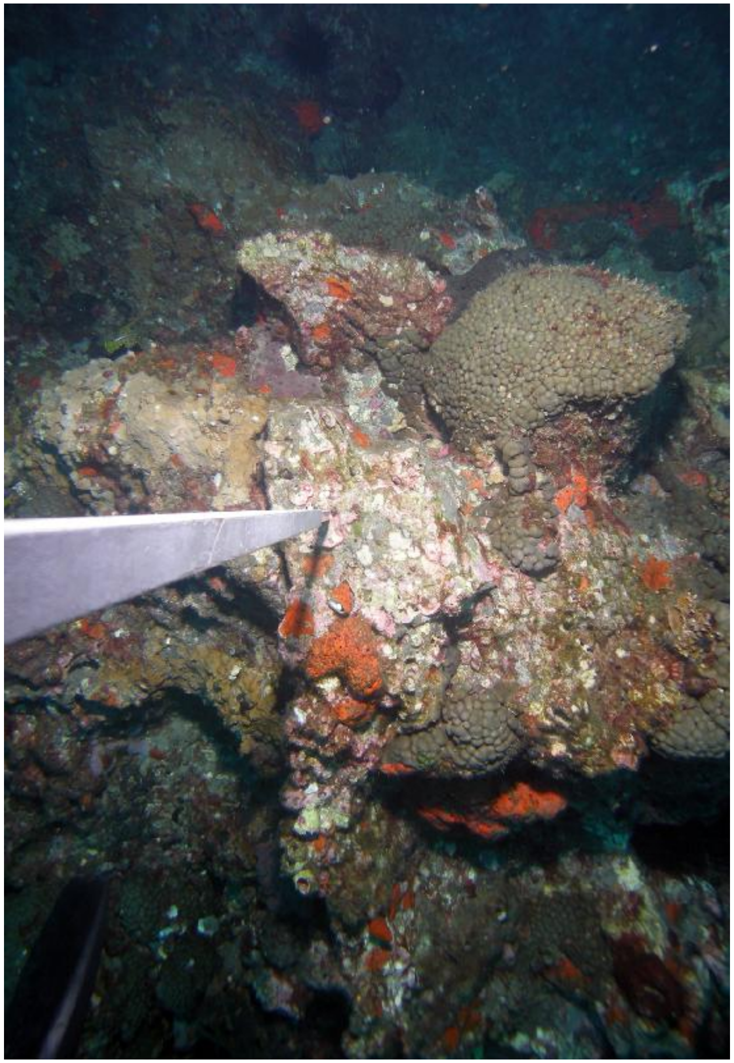
Dive date: June 2006

Survey Pin 26

Stetson Bank, Gulf of Mexico

28.0°N, 93.5°W

Image: Flower Garden Banks National Marine Sanctuary (FGBNMS)



Reef Location: A

Dive date: March 2009

Survey Pin 26

Stetson Bank, Gulf of Mexico

28.0°N, 93.5°W

Image: Flower Garden Banks National Marine Sanctuary (FGBNMS)

Reef Location: B

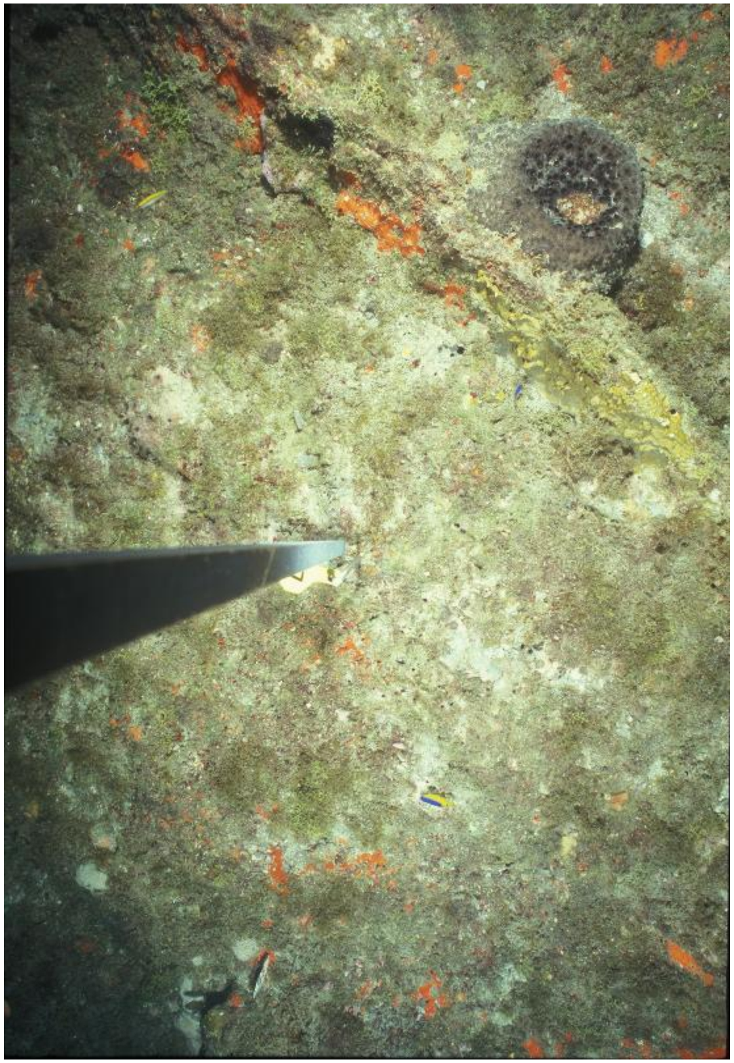
Dive date: September 2003

Survey Pin 37

Stetson Bank, Gulf of Mexico

28.0°N, 93.5°W

Image: Flower Garden Banks National Marine Sanctuary (FGBNMS)



Reef Location: B

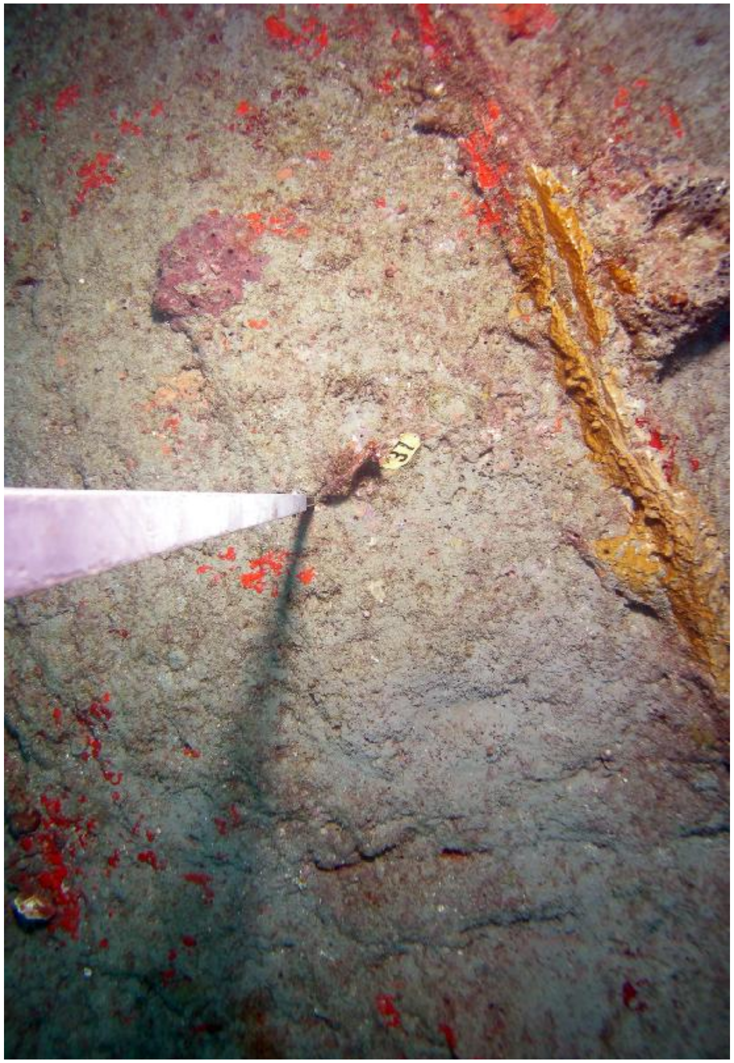
Dive date: July 2007

Survey Pin 37

Stetson Bank, Gulf of Mexico

28.0°N, 93.5°W

Image: Flower Garden Banks National Marine Sanctuary (FGBNMS)



Reef Location: B

Dive date: March 2009

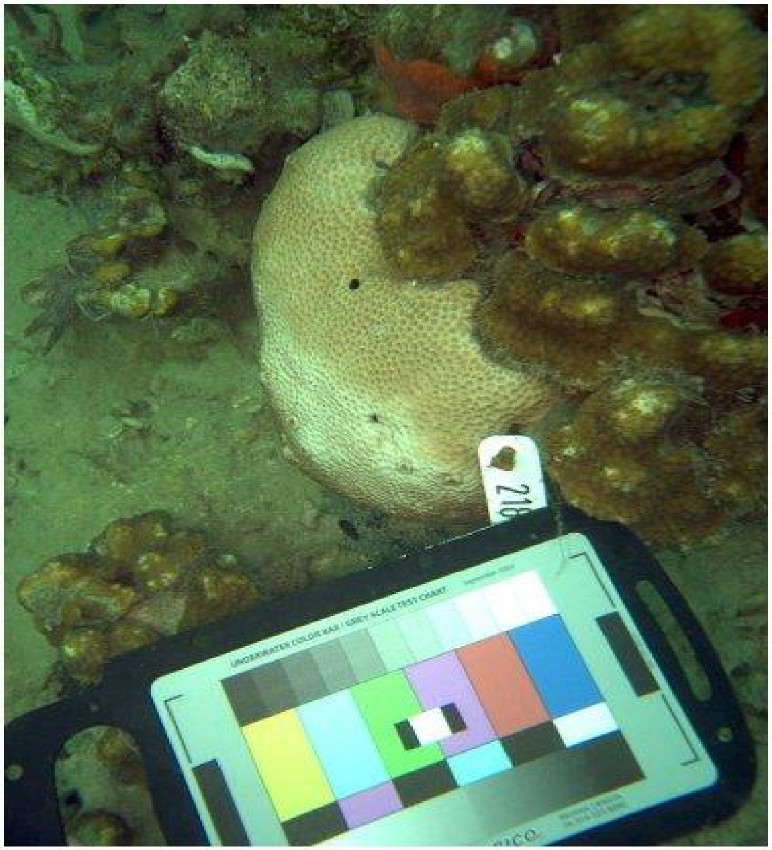
Survey Pin 37

Stetson Bank, Gulf of Mexico

28.0°N, 93.5°W

Image: Flower Garden Banks National Marine Sanctuary (FGBNMS)

Reef Location: C



Dive date: 2005

Survey Tag 218

Panama

9.3°N, 82.2°W

Image: Benjamin P Neal, Catlin Seaview Survey

Reef Location: C

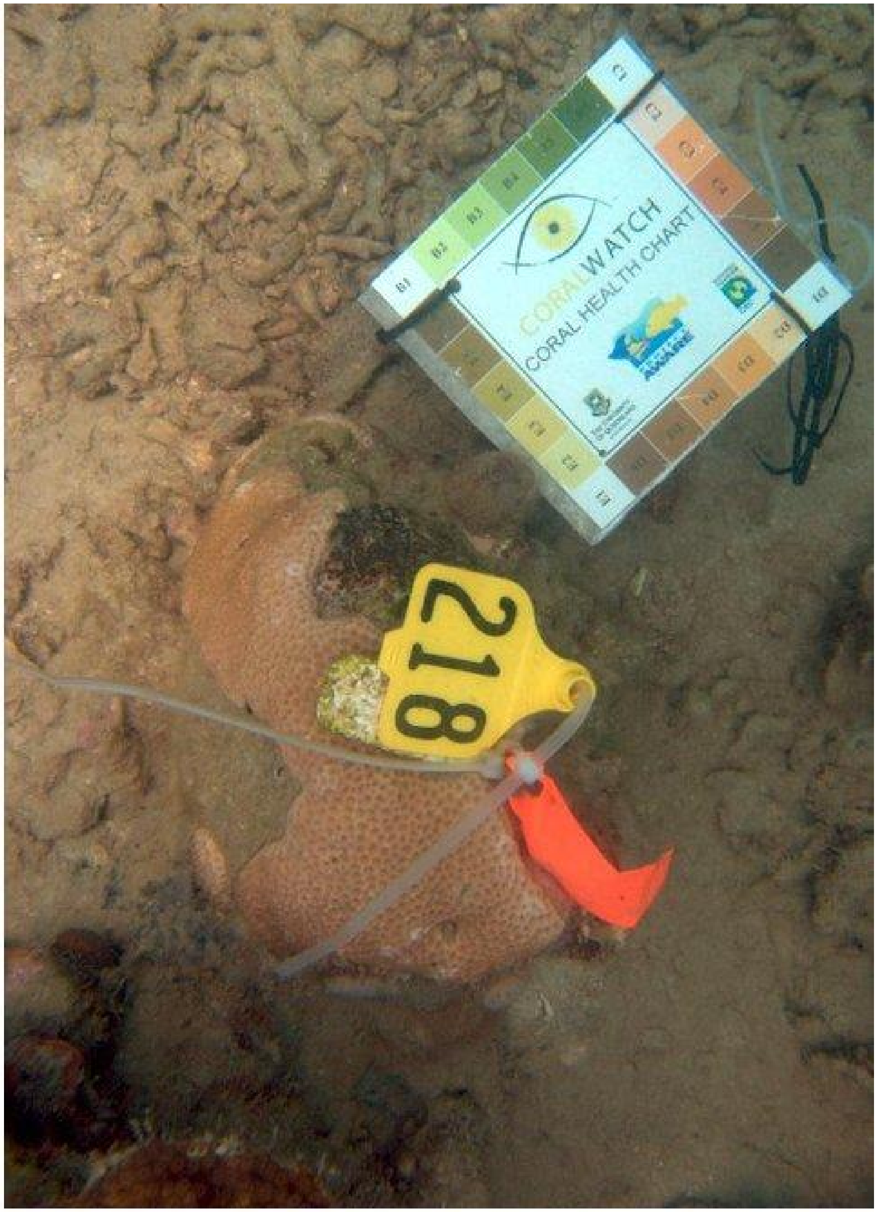
Dive date: 2006

Survey Tag 218

Panama

9.3°N, 82.2°W

Image: Benjamin P Neal, Catlin Seaview Survey



Reef Location: C

Dive date: 2008

Survey Tag 218

Panama

9.3°N, 82.2°W

Image: Benjamin P Neal, Catlin Seaview Survey

Teacher Master 2.3.2

In Situ Data Log Sheet with Locations

Coral Reef Site A	Year/Month	Coral Reef Description (circle one)		
Stetson Bank, Pin 26 28.0°N, 93.5°W	June 2005 (Baseline)	Healthy Reef	Declining Reef	Dead Reef
	June 2006	Healthy Reef	Declining Reef	Dead Reef
	March 2009	Healthy Reef	Declining Reef	Dead Reef

Coral Reef Site B	Year/Month	Coral Reef Description (circle one)		
Stetson Bank, Pin 37 28.0°N, 93.5°W	Sept 2003 (Baseline)	Healthy Reef	Declining Reef	Dead Reef
	July 2007	Healthy Reef	Declining Reef	Dead Reef
	March 2009	Healthy Reef	Declining Reef	Dead Reef

Coral Reef Site C	Year/Month	Coral Reef Description (circle one)		
Panama, Tag 218 9.3°N, 82.2°W	2005 (Baseline)	Healthy Reef	Declining Reef	Dead Reef
	2006	Healthy Reef	Declining Reef	Dead Reef
	2008	Healthy Reef	Declining Reef	Dead Reef

Student Master 2.3.1

Citizen Scientist Coral Reef Mission

Congratulations! You have been chosen as a Citizen Scientist to join a team to monitor the health of coral reefs. You and your team will assume the role of Citizen Scientist coral reef biologists monitoring corals in selected ocean locations. Put on your goggles and get ready to take the plunge to observe coral health over time. Your mission is to monitor the same reef location over three different years to look for changes in coral heath.

Your question is, "Is there evidence of coral bleaching at my coral reef pin site?" Attach your **Coral Health Key** and three **Coral Reef Monitoring Sheets** to a clipboard. Fill in the information at the top of each monitoring sheet about your team and site location. Read over the procedures below and ask your teacher any questions you may have. Now you're ready to begin your dives.

Multiple Dives to Coral Location

1. Swim to your assigned coral reef site. Remember, you are underwater and can't speak. Use hand signals to communicate.
2. Observe your coral colony on site or from your computer and begin filling in your **Coral Reef Monitoring Sheet** for the first dive with information about the reef. Do you see any other living organisms beside corals? How many different colors of corals do you see?
3. Use your **Coral Health Key** to measure the health at your assigned coral site. Pick corals that will be easy to identify when you return to monitor the dive site again. Remember, you are looking for changes in specific colonies or coral heads over different years.
4. When you finish surveying, swim out of the quadrat area and return to your lab. Discuss your findings with your team. Record all data on your monitoring sheet. Your first data sheet is your baseline and represents Year 1. You will compare the data you collect from subsequent dives with this baseline data.
5. Repeat steps 1 through 4 two more times. Wait for a signal from your teacher to begin each new dive. Bring a new **Coral Reef Monitoring Sheet** to each dive to record observations. Each monitoring of the coral site represents a different year.

Putting Your Data Together

Organize and examine the three data sheets, one for each year. Use the questions below to guide your work:

- What can you tell about the health of your reef from your baseline data?
- How does using the quadrat sampling method help you monitor the health of a coral reef over time?
- From your observations of each year's data, can you tell if your reef has changed over time?
- Why is it important to have baseline data to observe if change is taking place?

Reporting Your Coral Health Findings

Your final step is to publish and present your team's findings for your peers.

1. First, analyze the data you collected to see if it tells the story of your coral reef's health. Use the Presentation Discussion Questions below to plan your presentation.
2. Next, share your data with your classmates. Use your collected data, vocabulary words, and your reef images as part of your presentation.
3. Complete the Data Log below, and present it as part of your report to highlight key information for each year and compare data from one year to another.

Data Log

Coral Reef Site	Year/Month	Coral Reef Description (circle one)		
Lat: , Lon:	(Baseline)	Healthy Reef	Declining Reef	Dead Reef
		Healthy Reef	Declining Reef	Dead Reef
		Healthy Reef	Declining Reef	Dead Reef

Presentation Discussion Questions

Looking at all of the collected data, what can you tell about the health of the coral at this reef over time? What stays the same? What changes?

Can your team detect any consequences of rising or falling sea surface temperature on your monitored coral reef? Give evidence.

Is there evidence of coral bleaching taking place? Give evidence.

If coral bleaching is taking place, does it always mean the corals will die?

Why is coral research important?

How was your experience as a Citizen Scientist on this project valuable to you?

Level 3: Adaptation

Degree Heating Weeks - Duration and Intensity Matter

Summary

Grade Level: 6-8

Teaching Time: Three 45-minute periods

This teacher-led lesson examines how stress on corals depends not only on temperature rise, but also on how long the coral is subjected to temperature anomalies.

Objectives

- Students will develop a working definition of rising temperature “anomalies” and understand their importance relative to evaluating coral reef health.
- Students will develop a working definition of "degree heating week," and discover why this concept is important in predicting coral reef health over time.
- Students will use satellite false-color data maps and time series graphs as tools to identify areas where corals are at risk for bleaching.
- Students will use a degree heating week calculator to help them visualize how to measure accumulated thermal stress to evaluate coral reef health.

Focus Questions

- What are temperature anomalies and how are they identified?
- Why are degree heating weeks useful in assessing temperature stress on coral reefs?
- How can you use degree heating weeks time series graphs and maps to find evidence of coral bleaching?

Climate Literacy

Individual organisms survive within specific ranges of temperature, precipitation, humidity, and sunlight. Organisms exposed to climate conditions outside their normal range must adapt or migrate, or they will perish. (CL3a)[6]

Background (Teacher)

Students have explored coral reef health using remote sensing data on a global scale and in situ monitoring of reef transects on a local scale. From these two vantage points, students examined coral's sensitivity to water temperature and the sea surface temperature (SST) ranges corals need to survive.

In this lesson, students learn how to assess coral bleaching risk by measuring accumulated thermal stress. Abnormally warm conditions can lead to coral stress over time, so scientists use data from satellites to compute the mean sea surface temperature each month for a given region. The highest monthly mean represents the maximum temperature that corals in the region would typically experience. This is called the MMM or Maximum Monthly Mean sea surface temperature, and it's different in different places. When temperatures rise above the maximum monthly mean, scientists refer to the resulting temperature difference as a “HotSpot.” Sea surface temperature that exceeds the maximum monthly mean by at least one degree Celsius is considered above the “bleaching threshold” for corals.

Degree heating weeks values are calculated by adding up the HotSpots that are above the bleaching threshold over the previous twelve weeks. Satellite measurements of SST occur twice each week, so dividing the sum of the previous twenty-four observations by two yields a result in degree-Celsius-weeks.

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6 *Climate Literacy: The Essential Principles of Climate Science*, Second Version: March 2009. http://www.globalchange.gov/browse/educators

Corals are sensitive to temperatures above the bleaching threshold, but the heat stress becomes worse the longer high temperatures persist. That's why degree heating weeks were designed to capture both how far the temperature rose above the bleaching threshold and how long it stayed above. Even after temperatures drop below the bleaching threshold, the computed DHW can remain high for many weeks.

When DHW reaches 4 degree-Celsius-weeks, corals will have high thermal stress. When DHW reaches 8 degree-Celsius-weeks or more, widespread bleaching and mortality will likely occur.

This lesson contains two activities to help students understand how to use DHW to monitor coral bleaching:

- Activity 3.1: Using a DHW Calculator to Compute Thermal Stress
- Activity 3.2: Generating DHW False-Color Maps and Time Series Graphs

Vocabulary

Anomaly - the deviation of a particular variable (e.g., temperature) from the mean or norm over a specified time.

Bleaching Index - indicator based on the strength and duration of local anomalies, used to monitor bleaching events.

Bleaching Threshold - the typical maximum temperature, generally occurring in late summer, to which corals in a particular location are accustomed. When the sea surface temperature (SST) exceeds this temperature by some threshold (typically 1°C) corals are in danger of bleaching.

Coral Reef Bleaching Monitoring - the collection of near real-time data either from satellite images or in situ monitoring stations for the purpose of improving and sustaining coral reef health throughout the world.

Degree Heating Week (DHW) - a data collection system derived by NOAA to indicate the accumulated thermal stress experienced by coral reefs. DHW is measured in degree Celsius weeks (°C-weeks), where 1 DHW is equivalent to 1 week of SST 1°C above the expected summer maximum.

Degree Heating Week Accumulation - accumulated thermal stress that coral reefs experience over a typical 12-week period.

HotSpot – temperature anomaly where sea surface temperature is greater than the maximum of the monthly mean for a given region.

Maximum of the Monthly Mean Sea Surface Temperature (MMM SST) - the highest monthly mean computed in a given year. Scientists can compute a mean sea surface temperature (SST) each month, the highest of which is the maximum of the monthly mean (MMM). The MMM represents the highest SST that corals would typically experience in a given location.

Mean - the quotient of the sum of several quantities and their number; the average or the measure of central tendency.

Sea Surface Temperature (SST) – Sea surface temperature is the average temperature in the uppermost layer of the ocean, only a few millimeters deep. Sea surface temperature, often referred to as SST, can be globally monitored through satellite remote sensing.

Thermal Stress Anomaly (TSA) - an area of the ocean surface experiencing warmer SSTs than the typical maximum temperature reached at that location.

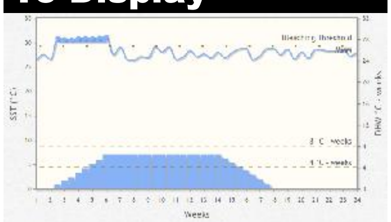
Time Series Graph - a way to measure, at periodic intervals, the effect of the introduction of an experimental variable (X), by the change or gain immediately before and after its introduction.

Activity 3.1: Using a DHW Calculator to Compute Thermal Stress

Materials

- Computer with Internet access
- Degree Heating Weeks Calculator
- Teacher Master 3.1.1: Computing Degree Heating Weeks
- Teacher Master 3.1.2: SST and DHW Time Series Graphs

To Display



Find the Degree Heating Weeks Calculator on dataintheclassroom.noaa.gov

Students learn to use a degree heating weeks (DHW) calculator in order to measure maximum of the monthly mean sea surface temperature (MMM SST) anomalies.

Preparation

Familiarize yourself with the degree heating weeks (DHW) calculator, so that you can demonstrate how it works to the class. The purpose of this interactive calculator is to help students see the effects of changing sea surface temperature (SST) over time. It is a simple model that can be programmed with values derived from real data to help students visualize how different factors influence coral health.

Follow these steps to use the DHW calculator:

1. Visit dataintheclassroom.noaa.gov, and find the Coral Bleaching module.

2. Follow the link to "Calculator."

3. Look below the graph to find the maximum monthly mean (MMM). Choose any of the example MMM values.

4. Enter a maximum value for sea surface temperature in the box labeled Max SST. The calculator will use this value to calculate degree heating weeks (DHW).

5. Enter a number of weeks in the duration field provided. This will be the length of time over which the maximum SST value is recorded. DHW combines the intensity with the duration of high temperature events in order to determine thermal stress on corals.

6. Press the "Play" button to run the calculation. To make a new calculation with different values, use the "Reset" button.

Procedure

1. Project the online DHW calculator found on dataintheclassroom.noaa.gov. Tell students they will use this calculator to help them understand and monitor thermal (temperature) stress in corals, using a measure called degree heating weeks, or DHW. Explain that DHW is not something they can measure directly, like temperature or rainfall. Instead, DHW is calculated using sea surface temperature data measured with satellite instruments. Scientists developed DHW in order to keep track of important factors related to thermal stress in corals. Tell students that before they use actual satellite data, they will practice using the calculator to study thermal stress related to the intensity and duration of temperature anomalies.

2. Define the term "temperature anomalies" for students. Sea surface temperature, or SST, has a normal seasonal range. Sometimes, however, there is a sharp temperature increase, where the water temperature heats up over the highest normal. When temperatures rise above the maximum monthly mean, scientists refer to the resulting temperature difference as a "HotSpot." The anomalies have a beginning and an end. Scientists have figured out a way to measure when the temperature spike starts, when it ends, and how many degrees it changed over time.

Help students understand temperature anomalies by guiding them through the following questions.

What is a "HotSpot"?

Answer:

- *A HotSpot is a temperature anomaly in which sea surface temperature exceeds the maximum temperature that is typical for a region.*

Do you remember the SST range where corals are typically found?

Answer:

- *Corals live in a tropical climate where the SST can range from 18°C to 29°C.*

How long can an anomaly last?

Answer:

- *An anomaly can last a few hours or as long as months.*

Why does anomaly duration matter to corals?

Possible answers:

- *Accept any answer. If it lasts a few hours, it most likely won't hurt the corals, but if it lasts for weeks or months, the corals are in danger of bleaching.*

Ask students to think about and share their own experiences with extreme temperatures. Tell them to imagine working outside on a hot day. Then ask:

Does the stress you feel working in hot conditions get worse with time? What can you do to bring yourself into a comfortable temperature range?

Possible answers:

- *turn on the air conditioner*
- *go swimming*
- *hope the weather changes to cooler temperatures*

3. As a demonstration using the calculator, select a maximum of the monthly mean (MMM) value of 27°C (Oahu, Hawaii), and enter values for a maximum SST of 28.0°C and a duration of 5 weeks. Click play to run the calculator. The calculator will display two graphs near the top and bottom of the display. Both are time series graphs covering a hypothetical 24-week period.

Note

If you do not have Internet access, have students refer to Teacher Master 3.1.1: Computing Degree Heating Weeks as you discuss calculator features.

Use the generated graphs to explain calculator features and computations:

- x axis = time in weeks
- y axis (left) = SST in °C (15°C to 35°C)
- y axis (right) = DHW in °C-weeks
- The top graph represents sea surface temperature (SST) data over time. It rises to the maximum value entered for SST, in this case 28.0°C. Note the two horizontal lines. MMM is defined as the maximum of the monthly mean SST in a given region. By measuring against MMM, scientists are looking for temperature conditions that are higher than normal for a given region. In particular, scientists are interested in temperature conditions that exceed MMM by 1°C. This level is referred to as the bleaching threshold.
- Degree heating weeks are computed by adding up temperature anomalies – or HotSpots – greater than the bleaching threshold over a period of 12 weeks. Point out areas where the wavy line rises above the bleaching threshold. These temperature values will contribute to DHW.
- The bottom of the screen displays a graph of DHW for the site. DHW values are recorded when SST rises above the bleaching threshold. These DHW values persist for 12 weeks after SST falls below the bleaching threshold.
- Point out the two horizontal lines. These lines denote SST levels at 4° and 8°C-weeks. When DHW reaches 4°C-weeks, the corals will have high thermal stress. When DHW reaches 8°C-weeks or more, widespread bleaching and mortality will likely occur.

4. Enter into the calculator other maximum SST numbers and different durations to show students the resulting DHW values. Discuss the probable effects on coral health.

5. Display **Teacher Master 3.1.2: SST and DHW Times Series Graphs**

using a whiteboard or computer screen. Explain to students that now that they have used the DHW calculator, they are ready to examine time series graphs to determine when an anomaly starts and stops.

Remind students that when they used the DHW calculator, they were looking at the SST in °C and the DHW in °C-weeks all on one screen. Tell them that now they will be generating two different types of time series graphs: one showing SST in °C and another showing coral bleaching DHW in °C-weeks.

6. Direct students to the top graph, which shows night time SST in °C. Ask:

What is the range on the x axis?

- *Answer: 15.0 - 35.0°C.*

What is the range on the y axis?

- *Answer: 2 years; 2006 and 2007.*

Point out the wavy line showing SST. Ask:

What is the maximum SST measured during this two-year time period?

- *Answer: about 29.1°C*

7. Direct students to the bottom graph. Ask:

What is the maximum DHW computed in this time period?

- *Answer: about 15°C-weeks*

Remind students of the coral bleaching thresholds shown by the calculator. When the thermal stress reaches 4°C-weeks, the corals will have high stress. When the thermal stress is 8°C-weeks or higher, widespread bleaching and mortality is likely to occur. Ask:

Keeping this information in mind, are the corals under stress?

Possible answer:

- *DHW rose well over 8°C-weeks. Therefore, the corals are under stress, and bleaching is expected.*

8. Now have students study both graphs. Ask the following question:

Did the peak DHW occur at the same time as the peak SST? Why or why not? Explain the relationship between the SST and DHW graphs.

Possible answers:

- *No, the peak DHW occurred slightly after the peak SST. Because DHW calculations look at 12 weeks of data, DHW values may persist even after anomalously high temperatures have declined. For this reason, when plotting a time series graph of SST and DHW, one should expect to see an offset between peaks in SST and DHW.*

Discuss with students what the persistence of DHW values might mean for coral health. Help them understand that the effects of high temperatures on coral health may persist even after temperatures drop.

Materials

- **Teacher Master 3.2.1: DHW False-Color Map and Time Series Graph**
- **Student Master 3.2.1: Practice Generating DHW Maps and Graphs (1 per student)**

Activity 3.2: Generating DHW False-Color Maps and Time Series Graphs

Students just saw how time series graphs of DHW illustrate thermal stress for a given location. In this activity, students will examine two ways to look at real DHW values. False-color maps show degree heating week conditions over a large geographic area, but at a snapshot in time. Time series graphs plot DHW data from a single location to enable scientists to see changes over time.

Preparation

Practice following the step-by-step instructions below to generate false-color maps and time series graphs to show DHW derived from real satellite data. In this lesson, you will assist students in learning how to generate maps and save them.

1. Visit dataintheclassroom.noaa.gov, and find the Coral Bleaching module.

2. Follow the link to "Get Data."

3. Using the controls on the left side of the map, pan and zoom out until the map displays the region around the Bahamas, between Florida and Cuba.

4. Select "Degree Heating Weeks" under "Which dataset?"

5. Select “Time series graph” on the menu labeled "Which view?"

6. Using the form, specify a start date of 01-Jan-2004 and an end date of 31-Dec-2005.

7. Click the "Get Data" button.

8. Save the graph to your computer. On a PC, right click with the mouse and select "Save as...." On a Mac, hold down the Ctrl key and click with

the mouse.

9. Now select “Map” on the menu labeled “Which view?”

10. Specify a date of 01-Sep-2005.

11. Confirm that the map still shows the same region you selected earlier.

12. Click the “Get Data” button, and save the resulting map to your computer.

Procedure

1. Display **Teacher Master 3.2.1: DHW False-Color Map and Time Series Graph** on a computer screen.

Note: If you do not have Internet access, copy **Teacher Master 3.2.1** and distribute a copy to each student before introducing map features.

Explain the key features of the false-color map at the top of the master.

- The map shows the region around the Bahamas.
- The latitude range is approximately 18° N to 27° N, and the longitude range is approximately 86° W to 70° W.
- This map scale shows DHW in °C-weeks.
- The units of measure for DHW (°C-weeks) combine the intensity and duration of thermal stress into a single number.
- Point out the color scale to the right of the map. Purple areas are 0°C-weeks. Have students find the purple areas on the map. In these areas, corals have not accumulated thermal stress over the 3 months prior to September 1; in other words, the temperature has not crossed the local bleaching threshold.
- Colors with higher numbers on the color scale may indicate thermal stress to corals. Scientists have determined that when the thermal stress reaches 4°C-weeks, corals will have high stress, and one would expect to see significant coral bleaching, especially in more sensitive coral species. When thermal stress is

8°C-weeks or higher, one would likely see widespread bleaching and mortality.

Ask students:

Which areas have high DHW values? What DHW values do you see represented on the map?

Possible answers:

- *Areas to the west and east of south Florida show DHW values in the range of 8° to 9°C-weeks.*

2. Direct students to the time series graph at the bottom of the master. Ask:

What does the graph show?

Answer:

- *DHW data from a single location over a period of time*

In contrast, what does the false-color map show?

Answer:

- *DHW conditions over a large geographic area at a single point in time.*

Discuss the relative advantages of the two different data displays. The false-color map allows scientists to assess coral bleaching risk over a large geographic area, whereas the time series graph helps scientists track the history of threats to coral health in a particular location over a period of time.

3. Distribute **Student Master 3.2.1: Practice Generating DHW Maps and Graphs**. Have students follow the instruction on the master to practice generating their own maps and graphs, and answer the questions in step 5.

4. Review with students their answers to the questions on **Student Master 3.2.1: Practice Generating DHW Maps and Graphs**:

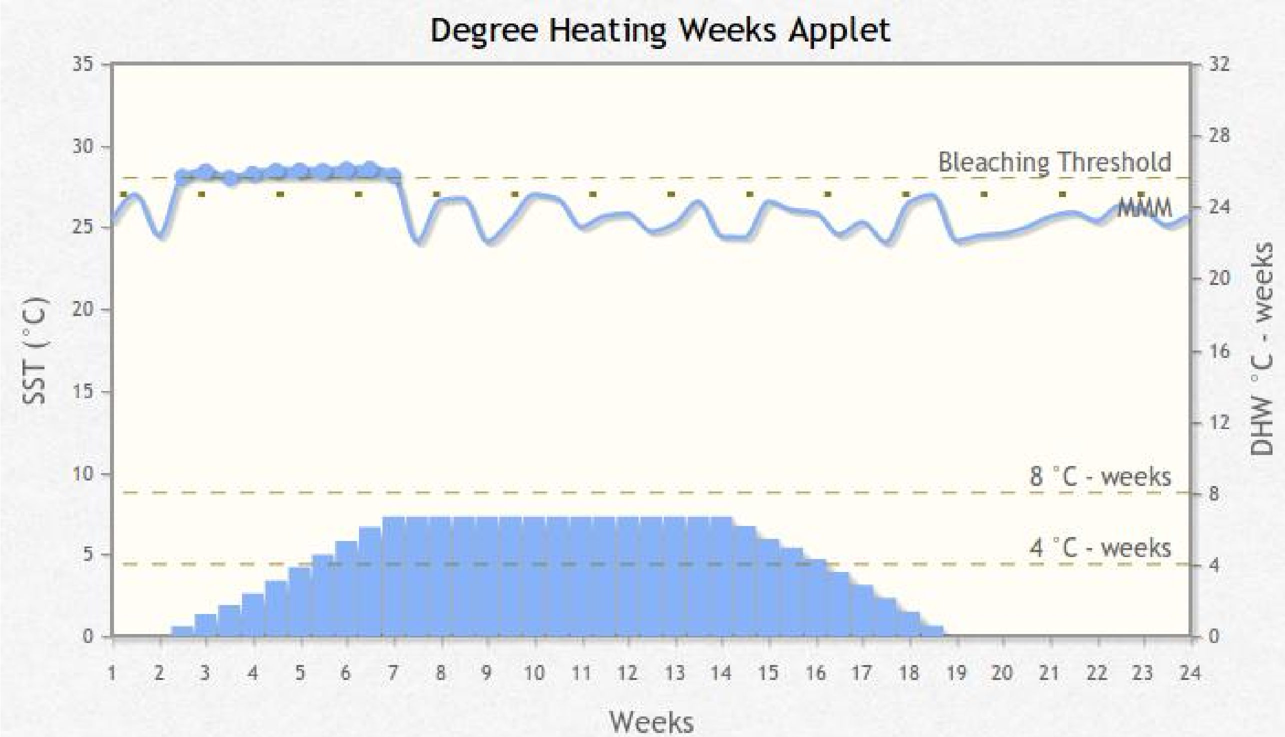
When you generated your maps, how high did the DHWs get?

What do you think this measurement indicates for the health of corals in the area?

Consider how you might use this tool to learn more about coral reefs in different parts of the world.

Teacher Master 3.1.1

Computing Degree Heating Weeks



Select a value for the maximum monthly mean SST. Temperatures greater than 1°C above that maximum are added together to calculate degree heating weeks. To run your calculation, select a maximum temperature and the duration for that temperature to occur, and press Calculate.

Maximum monthly mean SST (varies regionally):

27.0 deg C - Oahu, Hawaii ▼

Program a temperature anomaly to use for this calculation:

Select Maximum SST: 28.0 (°C)

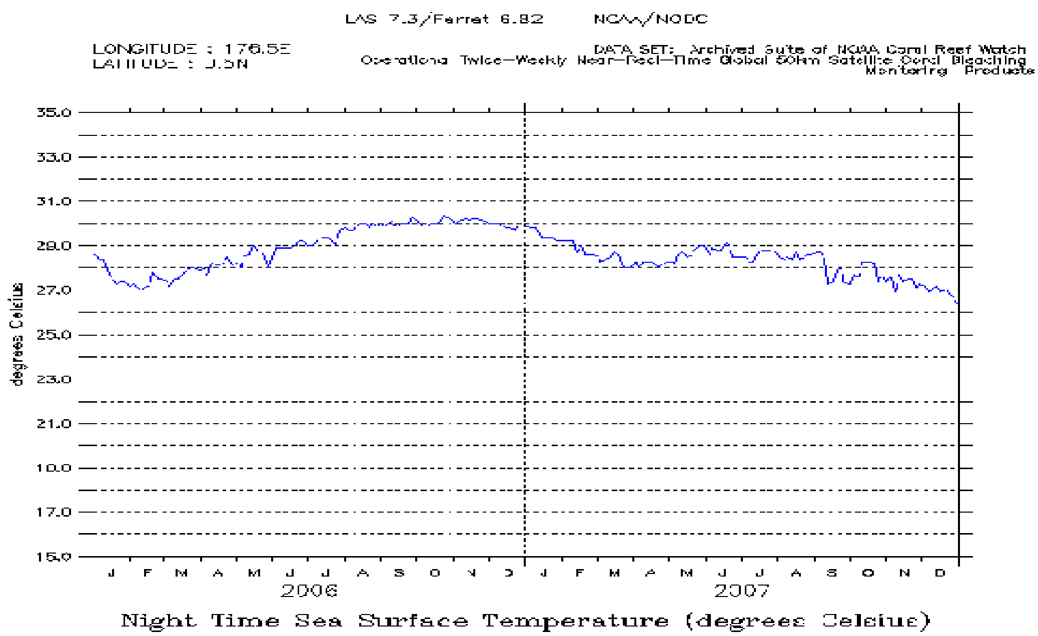
Specify Duration: 5 weeks

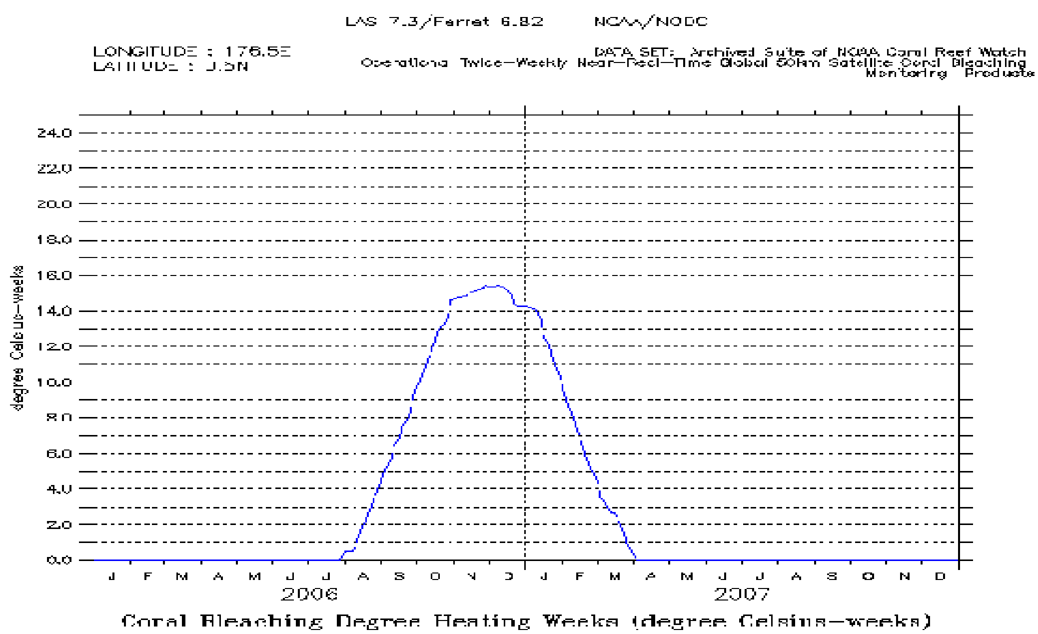
Play Reset

Teacher Master 3.1.2

SST and DHW Time Series Graphs

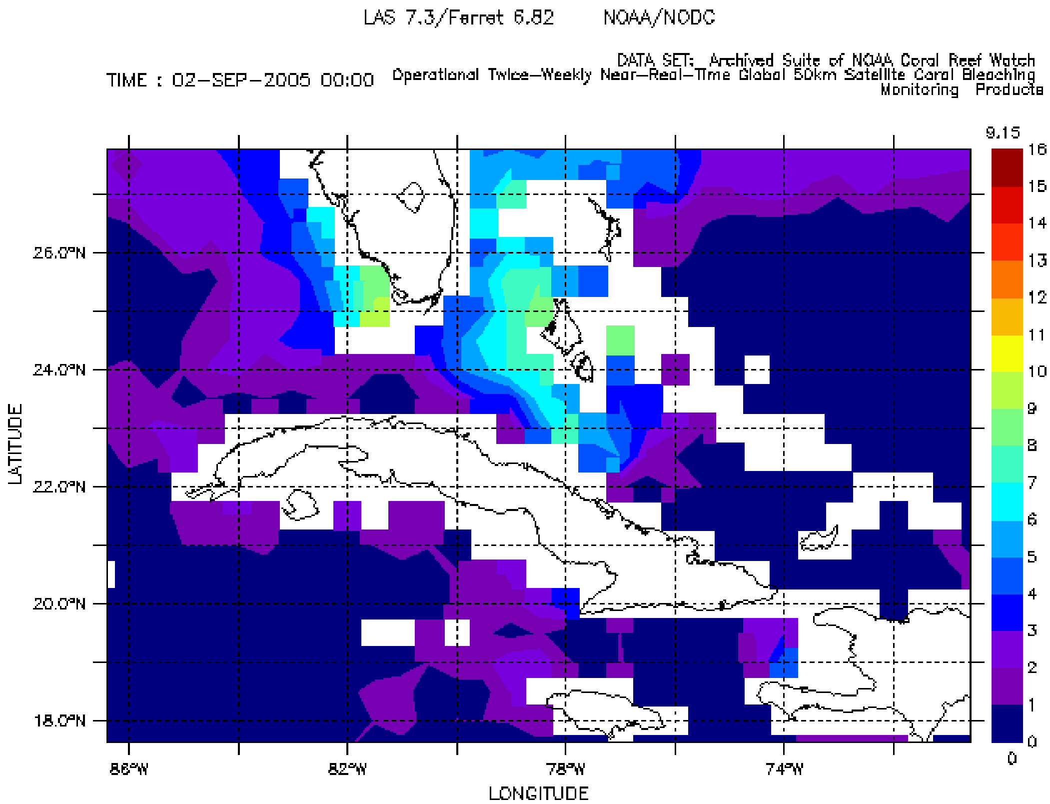
Howland and Baker islands are two nearby uninhabited U.S. atolls in the Equatorial Pacific. Below are examples of SST and DHW time series graphs for an area near Howland and Baker islands, generated from real data available from NOAA.



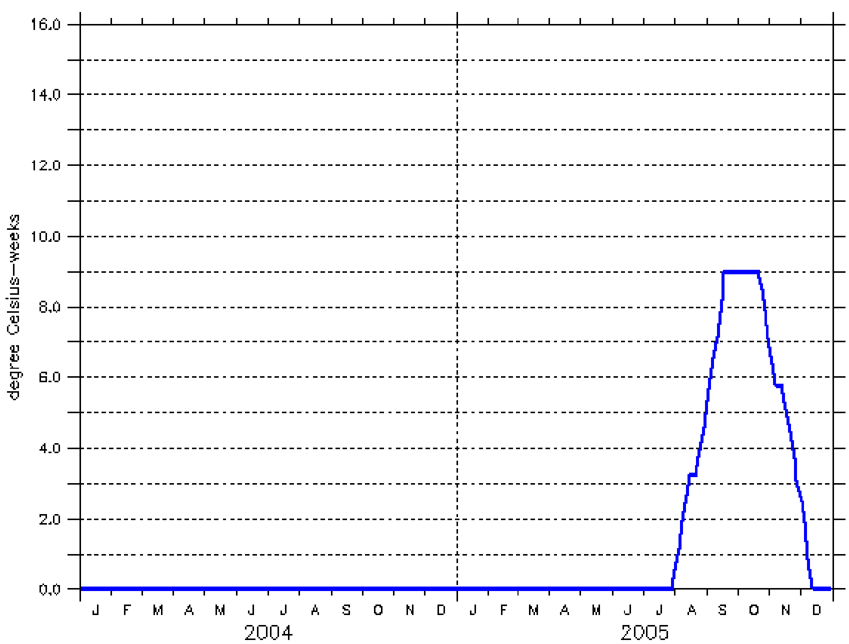


Teacher Master 3.2.1

DHW False-Color Map and Time Series Graphs



Coral Bleaching Degree Heating Weeks (degree Celsius—weeks)



Coral Bleaching Degree Heating Weeks (degree Celsius—weeks)

Student Master 3.2.1

Practice Generating DHW Maps and Graphs

You will now access real data from NOAA to generate graphs of degree heating weeks over time.

1. Go online and get the data!

    a. Visit www.dataintheclassroom.noaa.gov, and find the Coral Bleaching module.

    b. Follow the link to "Get Data."

    c. Using the controls on the left side of the map, pan and zoom out until the map displays the region you are studying.

    d. Select "Degree Heating Weeks" under "Which dataset?"

    e. Select either “Map” or “Time series graph” on the menu labeled "Which view?"

    f. Using the form, specify a date or date range.

    g. Click the "Get Data" button.

    h. Save the graph to your computer. On a PC, right click with the mouse and select "Save as...." On a Mac, hold down the Ctrl key and click with the mouse.

2. Use the Data Log below to keep a record of the data you select and practice saving graphs so you can refer to them later.

3. Print out one of your graphs. Use a straightedge to draw horizontal lines on the graph at 4° and 8°C-weeks. When the value rises above 4°C-weeks, you should expect to see significant coral bleaching. At values above 8°C-weeks, you can expect severe coral bleaching mortality.

4. Try making a time series graph that displays data from several years. Keep track of all the graphs you produce in your Data Log.

Data Log

As you use the online data access form to select data about coral reef health and possible coral bleaching, keep a record of the parameters you select on this Data Log. Your Data Log will help you remember and keep track of the data you have looked at. The first filled-in row is presented as an example.

	Region	Date(s)	Max DHW	Notes
1	18-28° N Latitude 80-73° W Longitude	Jan 1, 2004 - Dec 31, 2005	9°C-weeks	Saved to disk as DHW_graph
2				
3				
4				

5. Examine your data and answer the following questions:

How high did the DHWs get?

What would this measurement indicate for the health of corals in the area?

Consider how you might use this tool to learn more about coral reefs in different parts of the world.

Level 4: Interactivity

Citizen Scientists Mission - In Search of Evidence

Summary

Grade Level: 6-8

Teaching Time: Two 45-minute periods

In this teacher/student-led level, students will use the knowledge and satellite data skills gained in the first three levels to identify data needed to support a simple hypothesis about a coral bleaching event.

Objective

- Students will present data in support of a research question.

Focus Questions

- Can you find evidence for coral bleaching events based on satellite data?
- Why is coral research important?

Climate Literacy

Scientific observations indicate that global climate has changed in the past, is changing now, and will change in the future. The magnitude and direction of this change is not the same at all locations on Earth (CL 4d)[7].

Background (Teacher)

The main research question for students' work on coral bleaching in this module asks: What are the consequences of rising sea surface temperature on coral reefs, and why should we care? Oceanographers, marine biologists, Citizen Scientist Researchers, and all those who have enjoyed the experience of tropical coral reefs have become increasingly concerned with the health of these biologically rich, but delicately balanced, regions in the ocean. Your students have become aware that coral bleaching is one of the many threats to coral reefs and their associated fragile ecosystems. What if they do not recover? Why should

7 *Climate Literacy: The Essential Principles of Climate Science*, Second Version: March 2009. http://www.globalchange.gov/browse/educators

we care? Students need to understand that a study of coral reef health, comparing the past to the present, can help them think about future climate change and how to prepare for it.

So far, students have learned to generate, read, and interpret different kinds of data related to coral bleaching. At this level, students will apply what they have learned to answering a prepared research question. Students will compare collected satellite data against their in situ field surveys from Level 2 to see if there is a significant predictive relationship between accumulated heat stress (measured using NOAA Coral Reef Watch's degree heating weeks product) and bleaching intensity. After their study, students can join climate researchers in considering if severe, widespread coral bleaching and mortality will have long-term consequences for reef ecosystems, which may suggest a troubled future for tropical marine ecosystems under a warming climate.

Vocabulary

Students are encouraged to use vocabulary words presented in previous levels of this coral reef module as they write and discuss their coral bleaching research findings.

Activity 4: Answering and Supporting a Research Question

This activity challenges students to think like Citizen Scientist Researchers by designing a scientific investigation in which data collection and analysis are integral to identifying coral bleaching events. Students are asked to use real data to solve a problem, as they look for degree heating weeks for a specific coral region.

Materials

- **Teacher Master 4.1: In Situ Data Log Sheet with Locations (same as Teacher Master 2.3.1 from Level 2, Activity 2.3)** (1 per team)
- **Student Master 4.1: Citizen Scientists Coral Reef Bleaching Mission - In Search of Evidence** (1 per student)
- **Student Master 4.2: Data Log Sheet** (1 per student)

Preparation

1. It is recommended that you not show students any of the SST DHW maps or graphs before beginning this activity. A goal of this investigation is to encourage students to apply data gathering skills and techniques learned earlier in the module to examine unknown data. Specifically, students will read and interpret data and apply their knowledge to their observations from the in situ study in Level 2.

2. Reassign students as Citizen Scientist Researchers to their teams from Level 2 for the three coral reef monitoring sites: A. Stetson Bank, Pin 26; B. Stetson Bank, Pin 37; or C. Panama, Pin 208 (see **Teacher Master 4.1 In Situ Data Log Sheet with Locations**). Have each team divide data search responsibilities according to the following table.

Note: You may want to assign tasks for different monitoring years to different students if there are more than four students on a team.

Monitoring Year	Student #1	Student #2	Student #3	Student#4
Monitoring Year 1	SST Map	Coral Bleaching DHW Map	Time Series Graph Coral Bleaching DHW	Manager of Data Entry on Data Log Sheet
Monitoring Year 2	SST Map	Coral Bleaching DHW Map	Time Series Graph Coral Bleaching DHW	Manager of Data Entry on Data Log Sheet
Monitoring Year 3	SST Map	Coral Bleaching DHW Map	Time Series Graph Coral Bleaching DHW	Manager of Data Entry on Data Log Sheet

Procedure

1. Pass out the following materials to each team:

- Completed student team in situ reports and data sheets from **Level 2: Monitoring Coral Reefs—Establishing a Baseline**
- **Teacher Master 4.1: In Situ Data Log Sheet with Locations** – to remind students of the latitude and longitude of their assigned in situ locations and the dates of their three site monitoring visits
- **Student Master 4.1: Citizen Scientists Coral Reef Bleaching Mission - In Search of Evidence** (provide a copy for each student)
- **Student Master 4.2: Data Log Sheet** – to help students identify and organize the data they will need to collect to study the research question (provide a copy for each student)

2. Review with students the steps on **Student Master 4.1: Citizen Scientists Coral Reef Bleaching Mission - In Search of Evidence.** Answer any questions students may have.

Ask teams to follow the prompts on the worksheet to:

- Identify the kinds of data they want to look at, in what region, and over what time period.
- Go online and generate their own time series graphs of degree heating weeks for the region they examined in Level 2 to complete their virtual in situ monitoring.
- Analyze the resulting data graphs and maps to identify periods of thermal stress.
- Based on this new information, have teams refine their presentations about coral reef conditions at their in situ site. Their revised presentations should include the data products they generated in this activity and incorporate information about DHW.

3. Have teams present their revised coral health findings to their

classmates.

4. Ask teams to use their collected in situ data together with newly collected satellite data and their knowledge of corals to answer the questions under Discuss Conclusions below:

Discuss Conclusions

- Do you think the susceptibility of corals to temperature changes may result in coral bleaching or a decrease in coral health?
- Why is it important to examine coral reefs for bleaching events both locally in situ and globally using satellite SST data?
- Why is it important to study coral reef health by comparing past reef with present reef conditions?
- As a Citizen Scientist Researcher, why is it important for you to care about rising sea surface temperature, and the health of coral reefs related to a changing climate?

Teacher Master 4.1

In Situ Data Log Sheet with Locations

Coral Reef Site A	Year/Month	Coral Reef Description (circle one)		
Stetson Bank, Pin 26 28.0°N, 93.5°W	June 2005 (Baseline)	**Healthy Reef**	Declining Reef	Dead Reef
	June 2006	Healthy Reef	**Declining Reef**	Dead Reef
	March 2009	Healthy Reef	Declining Reef	**Dead Reef**

Coral Reef Site B	Year/Month	Coral Reef Description (circle one)		
Stetson Bank, Pin 37 28.0°N, 93.5°W	Sept 2003 (Baseline)	**Healthy Reef**	Declining Reef	Dead Reef
	July 2007	Healthy Reef	**Declining Reef**	Dead Reef
	March 2009	Healthy Reef	Declining Reef	**Dead Reef**

Coral Reef Site C	Year/Month	Coral Reef Description (circle one)		
Panama, Tag 218 9.3°N, 82.2°W	2005 (Baseline)	**Healthy Reef**	Declining Reef	Dead Reef
	2006	Healthy Reef	**Declining Reef**	Dead Reef
	2008	Healthy Reef	**Declining Reef**	Dead Reef

Student Master 4.1

Citizen Scientists Coral Bleaching Mission - In Search of Evidence

Corals are facing bleaching events related to changing sea surface temperature (SST). Rejoin your Citizen Scientist Researcher team and recheck your in situ field data. Now you will use satellite degree heating weeks (DHW) maps and graphs to find more evidence regarding a possible large-scale coral bleaching event at your monitoring site. Your mission is to determine if coral bleaching is part of your site's past, present, and/or future. Let's get started!

Plan Your Investigation

Your Assignment: Collect and use satellite data to investigate whether high SSTs occurred at your site to cause coral bleaching or stress. Take out your previous Data Log Sheet (**Student Master 2.3.1**).

Where was your in situ site located? Latitude: Longitude:

What was the day, month, and year of each data collection?

Year 1: _____________ Year 2: _____________ Year 3: _____________

Your Research Question: Did the duration and intensity of changing water temperature affect coral health at your site?

Your Hypothesis: When there is accumulated thermal stress, with water temperature rising above the maximum of the monthly mean sea surface temperature (MMM SST), it will cause coral reef stress at the monitoring location.

Conduct Your Investigation

1. Design a plan to test your hypothesis and answer the research question.

What do you need to get started?

a. More information: Do you need more information about changes in temperature over time and how long the temperature stayed at a high level?

b. Specific data: When you go online to collect data, how many of the following maps and graphs will you generate?

- SST map
- Coral bleaching DHW maps
- Coral bleaching DHW time series graphs

Hint: You should download three time series maps, one for each date you observed at your in situ site.

2. Go online and get the data using the following steps:

a. Visit www.dataintheclassroom.noaa.gov, and find the Coral Bleaching module.

b. Follow the link to "Get Data."

c. Using the controls on the left side of the map, pan and zoom out until the map displays the area immediately around the site you are studying.

d. Select the dataset you wish to access under "Which dataset?"

e. Select either “Map” or “Time series graph” on the menu labeled "Which view?"

f. Using the form, specify a date or date range.

g. Click the "Get Data" button.

h. Save the graph to your computer. On a PC, right click with the mouse and select "Save as...." On a Mac, hold down the Ctrl key and click with the mouse.

3. Record the data you select and/or save it on **Student Master 4.2: Data Log Sheet,** and save images to your computer so you can refer to them later for data analysis and to show your classmates when you present your findings.

4. Analyze the data by answering the following questions:

What are the local conditions at your reef site for each year observed?

Hint: Look at time series graphs of SST to get a sense of the temperature range at this site.

Were corals at risk for thermal stress?

Look at false-color maps of DHW. Look for areas with DHW values above zero.

Hint: Check the DHW number at the top right of the map for a data point.

How high did the DHWs get?

Hint: Look at a time series graph of DHW for the area. If the DHW value gets above 4°C, you should expect to see significant coral bleaching. Values above 8°C indicate that you can expect coral mortality.

5. From your observations of each year's data, can you tell if your reef was at risk for bleaching? Give evidence.

6. Draw conclusions about your data.

Comparing all three years of data sets, would you conclude your reef was under stress?

Hint: Look at your maximum DHW figures/maps. DHWs measure the accumulated thermal stress on the reef. The maps/figures show the maximum DHW values experienced during each year of your in situ *monitoring.*

How did thermal stress compare at each year's monitoring?

How did the severity of coral stress or bleaching compare at each year's monitoring?

Write down what you learned from your investigation of coral health. Use your data to help you decide if your hypothesis is supported. If your hypothesis is not supported, think about other data you might need to collect.

Report Your Coral Health Findings

All researchers need to publish and present their findings to their peers.

1. Your first step is to combine the data you collected to see if it tells the story of your coral reef's health.

2. The next step is to share it with your classmates. Use your collected data, vocabulary words, and reef images as part of your report.

3. Include the maps and graphs that you generated as part of your report, and highlight key information for each year so you can easily compare one year to another.

Coral Reef Site	Year/Month	Coral Reef Description (circle one)		
Lat: , Lon:	(Baseline)	Healthy Reef	Declining Reef	Dead Reef
		Healthy Reef	Declining Reef	Dead Reef
		Healthy Reef	Declining Reef	Dead Reef

Discuss Conclusions

- Do you think the susceptibility of corals to temperature changes may result in coral bleaching or a decrease in coral health? Give examples for why or why not.
- Why is it important to examine coral reefs for bleaching events both locally in situ and globally using satellite SST data?
- Why is it important to study coral reef health by comparing past reef with present reef conditions?
- As a Citizen Scientist Researcher, why is it important for you to care about rising sea surface temperature, and the health of coral reefs related to a changing climate?

Student Master 4.2

Data Log Sheet

As you use the online data access form to select data about coral reef health and possible coral bleaching, keep a record of the parameters you select on this data log sheet. Your data log will help you remember and keep track of the data you have looked at. Remember to save the maps and graphs to your computer so that you can access or print them later. The first row is presented as an example.

	Data Set	Map or Graph?	Region	Date (s)	Notes
1	DHW	Map	18-28° N Latitude 80-73° W Longitude	Sep 2, 2005	Max DHW = 9°C-weeks

Level 5: Invention

Design Your Own Investigation

Summary

Grade Level: 6-8

Teaching Time: Two 45-minute periods

Level 5 is an important student-driven interactive learning experience that can be used to measure student progress. This last level provides an opportunity for students to apply their acquired monitoring and mapping skills, and their coral content knowledge, to a real coral bleaching identification project. Students will pick a coral reef location on the planet, list the time frame in which they will examine coral health, and make a prediction based on SST time series observations as to whether their chosen location is experiencing coral bleaching over time.

Objective

- Students will design their own investigation using real data to try to answer a research question of their choosing. Their research question will serve as the Focus Question for this level. Their study will be based in one of several suggested coral reef locations.

Climate Literacy

Scientific observations indicate that global climate has changed in the past, is changing now, and will change in the future. The magnitude and direction of this change is not the same at all locations on Earth (CL 4d)[8].

Background (Teacher)

At this level middle school students are ready to use the authentic learning environment of coral reefs and real data to monitor actual coral bleaching events as indicators of what is happening to the health of coral reefs in the world's oceans. They will also be challenged to think about the importance of coral reefs to them personally.

8 *Climate Literacy: The Essential Principles of Climate Science*, Second Version: March 2009. http://www.globalchange.gov/browse/educators

Students are ready to move beyond interpreting a single selected coral bleaching site to examining coral reefs as an interactive system on the planet. Students many times do not recognize the differences between parts of an individual coral reef and coral reefs as a total system. Individual students will access and manipulate data regarding a coral reef site of their choosing, and then all students will join their coral reef studies together to look at coral reefs as a system within the world's oceans.

Activity 5: Designing Your Own Investigation

Materials

- **Student Master 5.1: Citizen Scientist Researchers - Design Your Own Investigation** (1 per student)
- **Student Master 5.2: Data Log Sheet** (1 per student)
- **Computer with an Internet connection**
- **NOAA Coral Reef Watch Virtual Stations website**

Students will design and conduct a scientific investigation using real data to answer a research question of their choosing. They will use appropriate tools and techniques to gather, analyze, and interpret data. Based on their experience, students will then communicate their scientific procedures and findings.

Preparation

This activity can be assigned to individuals or to teams of two students. To assist students, focus their investigation on one of the suggested student projects below.

- Determine whether there is evidence of coral bleaching at a location of the student's choice; or
- Determine whether there is evidence of coral bleaching near the Hawaiian Islands.

Note: Examine the NOAA Coral Reef Watch Virtual Stations website, which links to graphs and monitoring stations before students use this tool to pick a coral reef site. A link to the NOAA Coral Reef Watch Virtual Stations website can be found in Level 5 of the Coal Bleaching module at dataintheclassroom.noaa.gov.

The Virtual Stations map shows coral reef locations worldwide. When you click on a station site, an information box will display a summary of conditions in that area. This tool will help students make a free choice of reef locations for their research.

Procedure

1. Distribute **Student Master 5.1: Citizen Scientist Researchers - Design Your Own Investigation** and **Student Master 5.2: Data Log Sheet**.

Review with students **Student Master 5.1: Citizen Scientist Researchers – Design Your Own Investigation** and tell students they are going to design and carry out their own individual research project on coral reef health. First, they will need to pick a coral reef site to research. Project the NOAA Coral Reef Watch Virtual Stations website and show students how the website can be used to select coral locations and other information around the planet.

2. Meet with students to assist them in developing a good research question that can be tested using available data. The questions below can help students formulate their question.

- Is there evidence for a coral bleaching event or stress at your chosen location this year?
- Has there been evidence for coral bleaching or stress at your chosen location in the past?

Note: If students are having trouble formulating a research question, you may wish to refer them back to the research question they used in Activity 4: Did the duration and intensity of changing water temperature affect coral health at your site?

3. Guide and approve the student selection of a coral reef location using the online NOAA Coral Reef Watch Virtual Stations map or a listed Hawaii location. Help students use the tool to answer the following questions.

- Where is your selected site or location?
- Over what time period will you observe the selected coral reef?
- What is your predicted answer to your research question? Your predicted answer to your research question is your hypothesis.

4. Have each student or team follow the steps under Plan Your Investigation and Conduct Your Investigation on **Student Master 5.1** to develop a plan for a research project that will answer their research question. The plan should include:

- A research question (developed in step 2)
- A testable hypothesis that addresses the research question (developed in step 3)
- A list of additional information needed
- A list of data that will be collected to provide evidence for their hypothesis

5. Have students follow the steps on **Student Master 5.1** to go online and get their data.

6. Remind students to use **Student Master 5.2: Data Log Sheet** to record the data products they select and examine.

7. Have students choose a method to analyze their data. (Some possibilities are organize a table, generate maps or graphs, or answer questions.)

8. Have each individual or team draw conclusions from their investigation.

9. After students complete their research, have them follow the steps under Report Your Coral Health Findings on the master to organize, prepare, and present their findings to the class. Their use of the NOAA Coral Reef Watch Virtual Stations site, showing their individual coral site, should be part of their presentations.

Note: Project the Virtual Stations website image as a background to the student presentations (see top of **Student Master 5.1**). The goal is for students to see their selected coral sites as part of a total coral reef system, the health of which is being affected by rising sea surface temperatures.

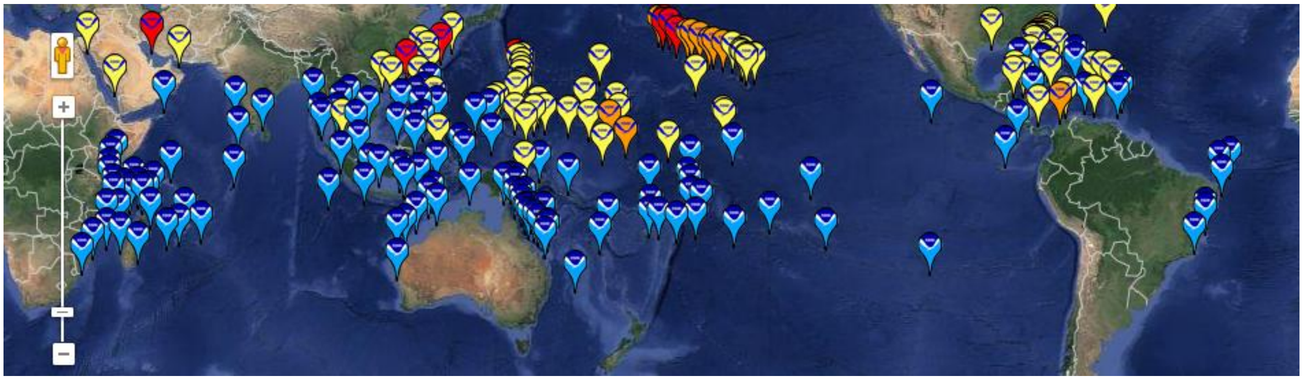
10. Encourage students to understand the importance of coral reefs around the world. Have individuals or teams compare and contrast their coral reef observations and data with other teams' findings from different locations. Remind them to include examples of maps, graphs, and other data.

11. Use student presentations as an opportunity to relate student investigations about coral bleaching to the debate about global climate change. Conduct a discussion around the questions at the bottom of **Student Master 5.1**:

- Do you think the susceptibility of corals to temperature changes may result in coral bleaching or a decrease in coral health at your location? Give examples.
- Why is it important to study coral reef health by comparing past reef with present reef conditions?
- Is your coral reef location part of a total system of corals? How do you think rising sea surface temperature is changing the coral reef system?
- As a Citizen Scientist Researcher, why is it important for you to care about rising sea surface temperature globally, and the health of coral reefs related to a changing climate?
- Answer the Big Question for your study of coral reefs: What are the consequences of rising sea surface temperature, and why should you care?

Student Master 5.1

Citizen Scientist Researchers - Design Your Own Investigation



Hello Citizen Scientist Researchers:

Join oceanographers, marine biologists, climatologists, and all of those who have enjoyed the experience of coral reefs in understanding why they are important to our future lives on the planet.

NOAA's Coral Reef Watch notes that, in many ways, coral reefs directly benefit the nations where they occur. They provide a huge economic benefit: recreation and commercial fishing on coral reefs generate billions of dollars each year for local economies. Reefs also act as a natural barrier, a first line of defense in protecting tropical coasts from storms and floods. Scientists are only beginning to explore the range of potential medicines that reef organisms can provide, including cancer treatments, painkillers, sunscreen, and antivirals. But even more importantly, coral reefs host some of the greatest biodiversity on the planet. Coral reefs are a vital and threatened natural resource.

You have explored the need to compare past coral health with present coral health to measure if changes are taking place related to rising sea surface temperature (SST). Why is this important? Researchers believe that coral reefs are sensitive to changes in ecosystems and can show some of the first signs of how rising SST is affecting our planet's future.

The Big Question for your study of coral reefs is: What are the consequences of rising sea surface temperature, and why should you care?

Now it's your turn to help investigate the health of coral reefs worldwide. Choose a coral reef to study, looking at coral health past and present in order to predict the future. Let's get started!

Pick a Coral Reef Location

Travel online to NOAA's Coral Reef Watch Virtual Stations website. Follow the directions below:

1. What reef site would you like to study? ___________________________

2. Where is this coral reef site located? Latitude: Longitude:

3. You will collect data for at least three years, using your first year as a baseline. What are the day, month, and year of each data collection?

Year 1: _____________ Year 2: _____________ Year 3: _____________

List any additional years: ____

Plan Your Investigation

Develop a research question you would like to explore about the past and present health of the coral reef you selected. Then form a hypothesis that helps answer that research question. Check with your teacher to approve your question.

Research Question: ____

Hypothesis: ____

Conduct Your Investigation

1. Design a plan to test your hypothesis and answer the research question.

What do you need to get started?

a. More information: Do you need more information about changes in temperature over time and how long the temperature stayed at a high level?

b. Specific data: When you go online to collect data, how many of the following maps and graphs will you generate?

- SST map
- Coral bleaching DHW map
- Coral bleaching DHW time series graphs

Hint: You should download one time series graph for each date you observe at your coral reef site.

2. Go online and get the data using the following steps:

a. Visit www.dataintheclassroom.noaa.gov, and find the Coral Bleaching module.

b. Follow the link to "Get Data."

c. Using the controls on the left side of the map, pan and zoom out until the map displays the area immediately around the site you are studying.

d. Select the dataset you wish to access under "Which dataset?"

e. Select either “Map” or “Time series graph” on the menu labeled "Which view?"

f. Using the form, specify a date or date range.

g. Click the "Get Data" button.

h. Save the graph to your computer. On a PC, right click with the mouse and select "Save as...." On a Mac, hold down the Ctrl key and click with the mouse.

3. Record the data you select and/or save it on the **Student Master 5.2: Data Log Sheet,** and save images to your computer so you can refer to them later for data analysis and to show your classmates when you present your findings.

4. Analyze the data by answering the following questions:

What are the conditions at your reef site for each year observed?

Hint: Look at time series graphs of SST to get a sense of the temperature range at this site.

Were corals at risk for thermal stress?

Look at false-color maps of degree heating weeks. Look for areas with DHW values above zero.

Hint: Check the DHW number at the top right of the map for a data point.

How high did the DHWs get?

Hint: Look at time series graphs of DHW for the area. If the DHW value gets above 4°C, you should expect to see significant coral bleaching. Values above 8°C indicate that you can expect severe coral bleaching mortality.

5. From your observations of each year's data, can you tell if your reef is/was at risk for coral bleaching? Give evidence.

6. Draw conclusions about your data.

Comparing data sets for each year you observed, would you conclude that your reef is/was under stress?

Hint: Look at your maximum DHW figures/maps. DHWs measure the accumulated thermal stress on the reef. The maps/figures show the maximum DHW values experienced during each year of your in situ monitoring.

How did thermal stress compare at each year's monitoring?

How did the severity of coral stress or bleaching compare at each year's monitoring?

Write down what you learned from your investigation of coral reef health. Use your data to help you decide if your hypothesis is supported. If your hypothesis is not supported, think about other data you might need to collect.

Report Your Coral Health Findings

All researchers need to publish and present their findings to their peers.

1. Your first step is to combine the data you collected to see if it tells the story of your coral reef's health.

2. The next step is to share your findings with your classmates. Use your collected data, vocabulary words, reef images, and the NOAA Coral Reef Virtual Stations website as part of your report.

3. Include the maps and graphs that you generated as part of your report, and highlight key information for each year so you can easily compare one year to another.

Discuss Conclusions

Discuss the following questions with your team partner or team up with students who investigated different locations:

- Do you think the susceptibility of corals to temperature changes may result in coral bleaching or a decrease in coral health at your location? Give examples.
- Why is it important to study coral reef health by comparing past reef with present reef conditions?
- Is your coral reef location a part of a total system of corals? How do you think rising sea surface temperature is changing the coral reef system?
- As a Citizen Scientist Researcher, why is it important for you to care about rising sea surface temperature globally, and the health of coral reefs related to a changing climate?
- Answer the Big Question for your study of coral reefs: What are the consequences of rising sea surface temperature, and why should you care?

Student Master 5.2

Data Log Sheet

As you use the online data access form to select data about coral reef health and possible coral bleaching, keep a record of the parameters you select on this data log sheet. Your data log will help you remember and keep track of the data you have looked at. Remember to save the maps and graphs to your computer so that you can access or print them later. The first row is presented as an example.

	Data Set	Map or Graph?	Region	Date (s)	Notes
1	DHW	Map	18-28° N Latitude 80-73° W Longitude	Sep 2, 2005	Max DHW = 9°C-weeks