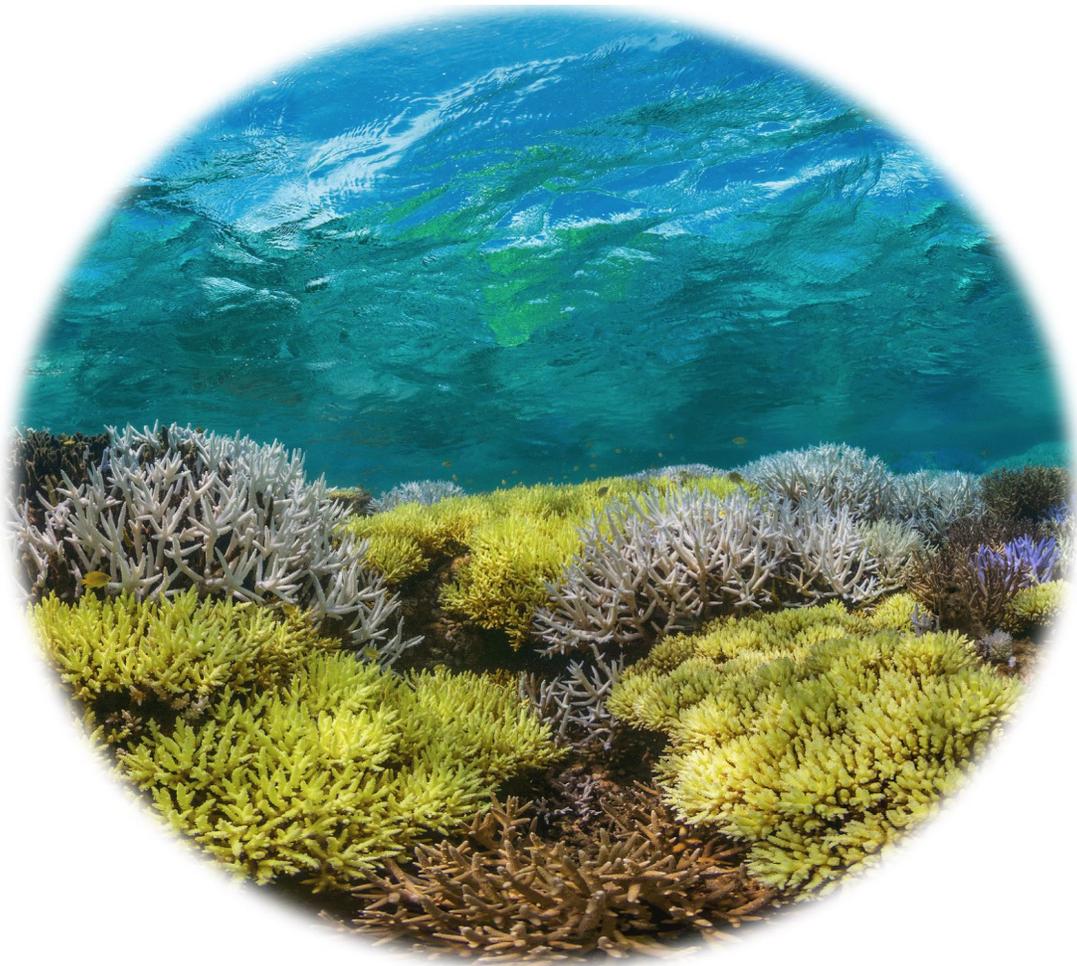


DATA IN THE CLASSROOM

# INVESTIGATING CORAL BLEACHING USING REAL DATA

---



2nd Edition (2017)

This curriculum module was originally developed for the NOAA Ocean Data Education (NODE) Project. This 2nd edition (2017) was completed under contract by Amy Dean. Data in the Classroom is a collaboration of many NOAA programs and offices including: National Environmental Satellite, Data, and Information Service (NESDIS), National Estuarine Research Reserve System, National Oceanographic Data Center and the Office of National Marine Sanctuaries.

Permission is hereby granted for the reproduction of these lessons without alteration and on the condition that the acknowledgment above is cited.

---

---

## TABLE OF CONTENTS

Introduction.....	3
Coral Bleaching Basics.....	3
Curriculum Overview .....	4
Science Standards and Climate Literacy.....	5
Level 1.....	6
Level 2.....	14
Level 3.....	23
Supplemental Student Activity–Building a Model Coral Head.....	37
Level 4.....	43
Level 5.....	50

---

## INTRODUCTION

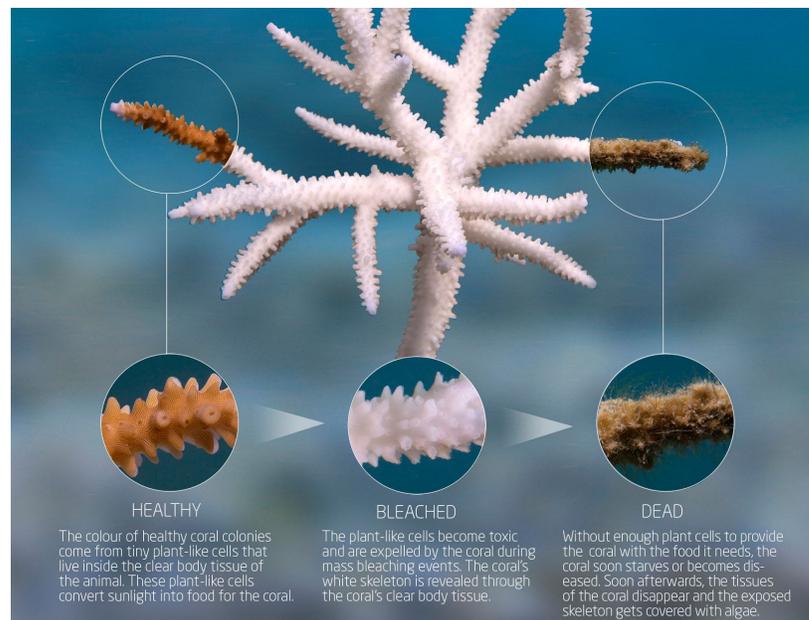
Coral reefs are one of the most diverse ecosystems on the planet. Found throughout tropical regions, they support an estimated 500 million people (one in every 15 people) in terms of food, livelihoods and other benefits.<sup>1</sup> Unfortunately, and despite being vitally important to humanity, half of the coral reefs in most regions have been lost over the last 30 years.<sup>2</sup> Climate change is one of their greatest threats. In this module, students will use real data to investigate the consequences of rising sea surface temperature on coral reefs. They will also consider the importance of coral reefs in their own lives.

### Coral Reef 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."

## Curriculum Overview

This curriculum module offers activities at five different levels of student interaction, sometimes referred to as Entry, Adoption, Adaptation, Interactivity and Invention. Levels 1 and 2 are very directed and teacher driven. Levels 3-5 of Adaptation through Invention are more student directed and open up opportunities to design lessons featuring student inquiry. This chart illustrates the five levels of this module, *Investigating Coral Bleaching Using Real Data*.

			5	<b>INVENTION: Designing Your Own Investigation</b> – Students will design their own plan to answer a research question. They will describe how they will use data and consider the limitations of the data.
			4	<b>INTERACTIVITY: Identifying a Bleaching Event</b> – Students evaluate the latest, real-time bleaching predictions and in-the-field monitoring observations to determine how sea surface temperature is affecting the health of Florida's coral reefs.
		3		<b>ADAPTATION: Monitoring the Health of Coral Reefs</b> – Students will learn how to identify coral bleaching and understand how scientists measure bleaching at reefs around the world.
	2			<b>ADOPTION: Measuring Coral Heat Stress</b> – Students will examine data from sea surface temperature graphs and maps to assess the extent to which corals on the Great Barrier Reef were at risk of bleaching due to heat stress.
1				<b>ENTRY: Identifying and Mapping Coral Reef Locations</b> – Students will learn how to read and interpret sea surface temperature (SST) maps. This is a teacher-led discussion and activity.

---

## Next Generation Science Standards (NGSS)

This module was developed to build data literacy, engaging students in increasingly sophisticated modes of understanding and manipulation of data. In 2017, the module was updated and adapted to incorporate the innovations described in the NGSS<sup>1</sup> where possible. An alignment document has been developed to help teachers and educators understand how the activities in this module align with the new standards. You can learn more about how this module relates to specific NGSS components by visiting the [Data in the Classroom website](#).

## 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 *Investigating Coral Bleaching Using Real Data* module examines coral health over a long period of time. The module integrates *Climate Literacy, The Essential Principles of Climate Sciences*<sup>2</sup> 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.

- 1 NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington D.C.: 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.
- 2 Climate Literacy, The Essential Principles of Climate Sciences; March 2009, A Climate-Oriented Approach for Learners of All Ages, US Global Change Research Program.

# LEVEL 1: ENTRY

## IDENTIFYING AND MAPPING CORAL REEF LOCATIONS

Investigating Coral Bleaching Using Data in the Classroom

NOAA Data in the Classroom 

Introduction Level 1 Level 2 Level 3 Level 4 Level 5 Get Data Teacher's Guide

### Coral Reef Locations and Temperature

#### Introduction

**Objectives**

- Students will use maps to identify the locations of coral reef ecosystems around the world.
- Students will interpret sea surface temperature maps to understand the range and habit of coral reefs.

**Activities:**

- Examine coral reef locations around the world
- Understand how to interpret maps of sea surface temperature



### SUMMARY

- Grade Level: 6-8
- Teaching time: Two 45-minute periods
- Activities: a) Examine coral reef locations around the world, b) understand how to interpret maps of sea surface temperature and c) make connections between coral locations and ocean temperature.
- 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.
  - 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.
  - 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.

---

## LESSON PLAN – LEVEL 1

### Objectives

Students will use maps to identify the locations of coral reef ecosystems around the world. Students will interpret sea surface temperature maps to understand the range and habit of coral reefs.

### Background

Coral reefs have a very limited distribution around the planet. Reef-building corals are typically located in tropical and subtropical waters between 30° N and 30° S latitudes. Generally, corals need shallow, sunlit and clear water to survive. They also need warm water. Though different species of coral can withstand different amounts of temperature fluctuations, most corals survive in temperatures ranging from 18°C to 29°C.

Corals are very sensitive to changes in ocean temperature. Small increases in temperature can cause corals to expel their symbiotic algae, called zooxanthellae, responsible for both their coloration and nutrition. This process is called coral bleaching and when frequent or severe enough, it causes coral mortality and an overall decrease coral abundance.

Due to changes in climate, ocean temperatures have been increasing over time. As a result, coral bleaching has become a significant threat to coral ecosystems worldwide. To carefully monitor the ocean temperatures that coral reefs are exposed to, scientists use highly detailed maps of sea surface temperature (SST). SST is continuously recorded using instruments on satellites that measure heat from the surface of the ocean. By plotting the data values as colors on a map, called a false-colored map, it is easy to spot patterns of temperature.

In Level 1, students learn to read and interpret satellite-generated maps of SST. This will enable them, in Levels 2-5, to use sea surface temperature (SST) data to answer this question:

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

---

## Materials

- Projector
- Computers and internet access

## Teacher Prep

There are a variety of ways to implement this activity. Decide which works best for your classroom, and prepare as appropriate.

- Go to the Data in the Classroom website and familiarize yourself with the [Level 1](#) activities.
- If your students have computers and internet access, you may choose to have them complete the online student activities during this lesson.
- If you do not have internet access in your classroom, you can alternatively download the PowerPoint (PPT) slides from the [Teachers Guide page](#) of the online activity. The PPT contains some of the same color maps and images from the online activities.

## Procedure

### Introduction:

Engage students in this module by explaining that they will be looking at an important problem – how rising ocean temperatures affect coral reefs.

1. Navigate to the [Investigating Coral Bleaching](#) online activities. Click on the Introduction tab.
2. Scroll down to the section titled 'The Threat to Coral Reefs.' Play the short 4-minute video.

### Part 1: Where in the World?

Students will begin their study of corals and coral bleaching by identifying the locations of coral reefs around the world. Note, you may use the worksheets at the end of this lesson plan to help guide the students through this task, if desired.

- 
3. Navigate to Level 1 of the Investigating Coral Bleaching online activities. Project [Level 1](#) onto a screen to help guide students through the activity.
  4. Scroll down to the section titled 'Background.' Here, you'll find a map displaying the locations of coral reef communities around the world. In addition to reef locations, the map also shows ocean depth (dark gray colors are very deep and light gray are shallow.)
  5. Point out that coral reefs are distributed around the planet, but only in limited locations. Zoom in and out on the map, as desired, as you explore the following questions with your students.
  6. Ask: where do coral reefs seem to be located?  
**Possible answer:** Waters near the shore or on either side of the equator.
  7. Ask: 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 parts of the North American continent, Greenland, Asia, and to the south near Antarctica.
  8. Give students time to answer the question at the end of the online activity.  
**Answer - Question 1:** Water near the shore and on either side of the equator

## Part 2: Reading Sea Surface Temperature Maps

Before students can start using data to understand coral bleaching events, they need to learn how to read sea surface temperature (SST) maps.

1. Scroll down to the next section. Here, you'll find a map displaying sea surface temperature measurements (SST) from space. This type of map, called a false color map, uses a variety of colors to represent different temperature measurements across the ocean's surface.
2. Using the projected image, discuss the key features of the map:
  - The map displays information about sea surface temperature taken from instruments onboard satellites orbiting the earth.

- 
- The geographic area of the map is defined using lines of latitude and longitude.
    - X axis = longitude, degrees east and west.
    - Y axis = latitude, degrees north and south of the Equator.
  - The land areas on the map are colored gray.
  - The Pacific Ocean is colored various shades of red and blue. The colors represent temperature at the ocean's surface.
  - Locate the color legend on the map by clicking the information icon on the map. This legend indicates the surface water temperature in degrees Celsius. Note: if the legend covers an area of the map you are viewing, you can alternatively use the legend embedded in the left sidebar.
  - Ask students what color indicates the warmest water (dark red) and the coldest water (dark blue) on the map.
5. Ask: How can using satellite data help researchers to study water conditions over time? Why is it important for researchers to look at data for more than one year to determine sea surface temperature changes?
- Possible answers:** Researchers can track changes in SST from one year to another and look for patterns. Using SST satellite data from different time periods can show trends and how the climate changes over time.
6. Give students time to answer the question at the end of the online activity.
- Answer - Question 2:** 26 °C
- Answer - Question 3:** 30°S to 30°N

### Part 3: Coral Reef Habitat and Range

Now that students can read a sea surface temperature (SST) map, they can analyze a more complex, layered map that combines coral reef locations, average SST, and ocean depth. The goal here is for students to use the data to predict *why* corals have such a limited distribution around the planet.

- 
1. Scroll down to the next section. Here, you'll find a map that contains four layers of data: coral reef locations, latitude and longitude, sea surface temperature and ocean depth.
  2. Find the 'Layers' box in the upper right corner. Demonstrate how to turn layers on and off. Click > next to each layer and demonstrate how to change the transparency of each layer.
  3. Zoom in and out on the map, as desired, as you explore the following question with your students: 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
4. 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.
  5. Give students time to answer the question at the end of the online activity.

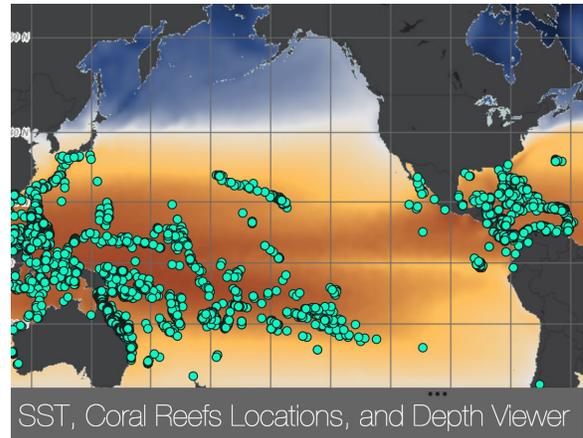
**Answer - Question 4:** Coral reefs occur in shallow waters between 30° N and 30° S latitudes

**Answer - Question 5:** All of the above

**Answer - Question 6:** 18 - 29 degrees C

# CORAL REEFS: WHERE IN THE WORLD?

**Dear Student,** Are you fascinated by coral reefs where every surface, nook, and cranny is bursting with life? These oases of life are found around the tropics, where sunlight and sea surface temperature are fairly even throughout the year. But there's a problem - rising ocean temperatures are seriously affecting the health of coral reefs. Your job will be to investigate the consequences of rising temperature on reefs around the planet. Let's begin by investigating the locations of coral reefs around the world and the temperature range in which they can survive.



*A map of coral reef locations around the world.*

## Instructions:

Go to the Coral Bleaching activity on the website. Click on Level 1, complete the activities and answer the questions below.

1. Generally, coral reefs are found in shallow waters between \_\_\_\_\_ degrees N latitude and \_\_\_\_\_ degrees S latitude.
2. In the United States, coral reefs are located off the coasts of which state(s)?  
\_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_.
3. Corals have a limited temperature range within which they can live. Most corals survive in temperatures ranging from \_\_\_\_\_ to \_\_\_\_\_ degrees Celsius.

# LEVEL 2: ADOPTION

## MEASURING CORAL HEAT STRESS

Investigating Coral Bleaching Using Data in the Classroom

NOAA Data in the Classroom 

Introduction Level 1 Level 2 Level 3 Level 4 Level 5 Get Data Teacher's Guide

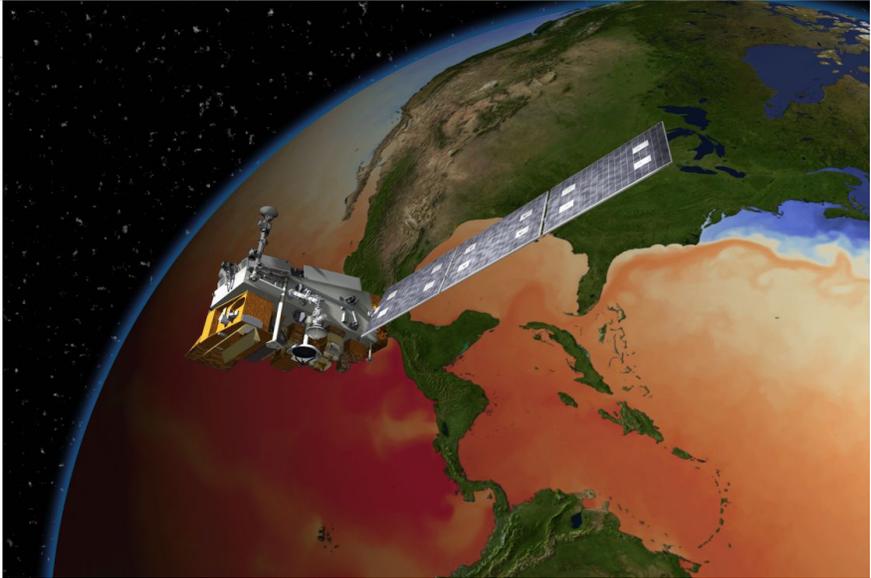
### Measuring Coral Heat Stress

#### Introduction

**Objectives**  
Students will learn how prolonged, warmer than usual ocean temperature can contribute to coral bleaching.

**Activities:**

- Learn how to calculate accumulated heat stress from sea surface temperature data
- Use Degree Heating Week data to understand patterns of coral bleaching



## SUMMARY

- Grade Level: 6-8
- Teaching time: Three 45-minute periods
- Activities: Use temperature data to assess the extent to which corals on the Great Barrier Reef are at risk of bleaching due to heat stress.
- Vocabulary:
  - 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 ( $^{\circ}\text{C}$ -weeks), where 1 DHW is equivalent to 1 week of SST  $1^{\circ}\text{C}$  above the expected summer maximum.
  - Heat Stress – For corals, heat stress is caused by ‘higher than normal’ ocean temperatures that increase the susceptibility of corals to bleach.

---

## LESSON PLAN – LEVEL 2

### Objectives

Students will examine data from sea surface temperature (SST) graphs and maps to assess the extent to which corals on the Great Barrier Reef were at risk of bleaching due to heat stress.

### Background

Lots of living things, including us, can get stressed out when exposed to ‘higher than normal’ temperatures. Imagine getting into a bathtub filled with water that is too hot for your comfort. If the water is only slightly warmer than you normally like it, you may be able to tolerate it for a minute or two before getting out. If the water is really hot, you may not be able to tolerate it for long at all. Both of these situations cause heat stress. Heat stress can come from prolonged exposure to water that is only a bit warmer than ideal, or shorter, more intense periods of extreme heat (almost like a heatwave).

Remember from Level 1, that corals have a limited temperature range within which they can live. When it gets too warm, they get stressed out. In other words, corals are extremely sensitive to heat stress. When corals experience warmer than usual ocean temperatures, they expel the symbiotic algae living in their tissues, causing them to ‘bleach’ or turn completely white. When corals bleach, they are not dead. But if ‘warmer than usual’ conditions persist, corals can die. Other threats, like disease and pollution, can cause bleaching; however, the leading cause of coral bleaching worldwide is heat stress. As surface ocean temperatures have already increased and are projected to continue increasing by at least another 2 °C under a business as usual scenario by the year 2100, coral bleaching events are expected to increase in frequency and intensity over the coming decades.<sup>3</sup>

We’ll examine the biology behind coral bleaching in Level 3. In this level, students learn to

<sup>3</sup> Schoepf, V et al. 2015. Limits to the thermal tolerance of corals adapted to a highly fluctuating, naturally extreme temperature environment. *Scientific Reports* (5) 17639.

---

assess coral bleaching risk by measuring the extent to which corals are exposed to abnormally warm conditions, or heat stress. Scientists use ocean temperature data to estimate how much heat stress corals have been exposed to over a period of time. Because many coral reefs are in very remote areas, temperature data provided by satellites provide a much easier way to collect this data.

Reefs around the world experience their warmest conditions at different parts of the year. For example, in the southern hemisphere, the ocean heats up the most in January-March, in the northern hemisphere its July-September. In the tropics, the warmest temperatures may occur at any time during the year.

Coral polyps become stressed once they experience ocean temperatures that exceed 1°C above the warmest average summertime temperature. For example, if a reef in Australia experiences its warmest summer season in January, and that mean monthly temperature is 28°C, we can expect the coral in that area to become stressed and possibly bleach once temperatures are above 29°C. In this activity, we call this temperature the *bleaching limit*.

Between December 2015 through 2017 (when this lesson was written), the Great Barrier Reef was exposed to temperatures above the *bleaching limit*, due to the combined effects of climate change and a strong El Niño. Record high temperatures occurred not just around the Great Barrier Reef, but globally, and triggered an episode of coral bleaching that was the third global-scale event since mass bleaching was first documented in the 1980s while also the longest and most widespread episode on record.

Prolonged and severe heat stress, like the kind that corals from the Great Barrier Reef have experienced, can add up. This accumulation of stress makes significant bleaching more likely and recovery more difficult, and on the Great Barrier Reef it has led to widespread bleaching, coral decline and habitat loss. In this activity, students examine NOAA satellite data and products in order to predict and analyze the severity of coral bleaching on the Great Barrier Reef during this third global-scale mass bleaching event.

---

## Materials

- Projector
- Computers and internet access
- Photocopies of student worksheets

## Teacher Prep

There are a variety of ways to implement this activity. Decide which works best for your classroom, and prepare as appropriate.

- Go to the Data in the Classroom website and familiarize yourself with the [Level 2](#) activities.
- If your students have computers and internet access, you may choose to have them complete the online student activities during this lesson.
- If you do not have internet access in your classroom, you can alternatively download the PowerPoint (PPT) slides from the [Teachers Guide page](#) of the online activity. The PPT contains the same color maps and images from the online activities in [Level 2](#).

## Procedure

### Part 1: Background

1. Navigate to Level 2 of the Investigating Coral Bleaching online activities. Project [Level 2](#) onto a screen to help guide students through the activity.
2. Scroll down to the section titled 'Background.' Give students time to read the information and watch the video.
3. Ask: Do you remember the temperature range within which corals are typically found?  
**Answer:** Corals live in a tropical climate where the SST can range from 18°C to 29°C.
4. Ask: If you were a coral living down in Florida, at what time of the year might you experience the warmest ocean temperatures?  
**Possible answer:** During summer months.

- 
5. Ask: How long could a summer 'heat wave' last (days, weeks, months)? And how could the duration of a heat wave 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.

6. 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.

## Part 2: Measuring Water That Is Warmer Than Normal

Satellite data has become an essential tool for scientists who study coral bleaching caused by heat stress. Here, students will become scientists who are using sea surface temperature data to determine the extent to which corals on the Great Barrier Reef are at risk of bleaching.

1. Scroll down to the next section and give students time to read the text. Ask: How warm does the ocean temperature need to be before corals might bleach?

**Answer:** Bleaching may occur if temperatures exceed 1°C above the warmest average summertime temperature (for that specific location).

2. The graph in this section shows summertime sea surface temperature (SST) data for a location on the Great Barrier Reef (Jan-Mar 2017). If needed, explain how to read the graph (the axes, the legend, etc).

3. In groups or together as a class, complete the activity. Use photocopies of the worksheets to help guide the students through this task, if desired.

4. Review the answers to the questions.

**Answer - Question 1:** 12

**Answer - Question 2:** 0.6 °C

5. Discuss: Are the corals on the Great Barrier Reef at high risk, moderate risk or low risk of bleaching due to heat stress?

---

**Possible Answer:** In Jan-Mar 2017, corals were at high risk of bleaching because they were exposed to prolonged 'higher than normal' sea surface temperatures that were above the bleaching limit every week over the three month period. They were also exposed to a short, but more intense spike in temperature at the end of January, when temperatures were 1.3°C higher than the bleaching limit.

6. If desired, allow students time to start a list of questions they have about coral bleaching on their worksheet.

### Part 3: Calculating Heat Stress From Satellite Data

Next, students will learn that heat stress 'adds up' or accumulates over time and how this accumulation of stress is measured. For more information about this topic, visit the [NOAA Coral Reef Watch online tutorial](#).

1. Scroll down to the next section and give students time to read the text. Ask: why would it be important to make these calculations? What might the data be used for?

**Possible answers:**

- The calculations measure not only how far the temperature is above the *bleaching limit* but how long it has stayed above that point. This enables scientists to consistently measure bleaching risk and compare risk over time.
- The calculations can be used to better understand and predict coral bleaching events around the world. *Note:* NOAA uses these calculations to assess risk and alert scientists and reef managers when the thermal stress rises to dangerous levels.

### Part 4: Understanding Maps of Degree Heating Weeks

Scientists assign a value, or a number, to bleaching risk - called *Degree Heating Weeks*. We know, from looking at the temperature data from the Great Barrier Reef, that corals were at risk of bleaching in the summer of 2017. Now, students will learn to assess the extent to which corals on the Great Barrier Reef were at risk of bleaching by analyzing maps of *Degree Heating Weeks*.

1. Scroll down to the next section. Here, you'll find a map displaying Degree Heating Weeks (DHW).
2. Using the projected image, discuss the key features of the map:

- 
- a. Much like the SST maps in Level 1, this map uses a variety of colors to represent different DHW values that correlate to coral bleaching risk.
  - b. The different colors represent how much thermal stress has 'added up' over the previous 12 weeks (3 months). Because this is a data map from April 2017, it is showing accumulated heat stress from the previous 12 weeks, Jan-Mar 2017.
  - c. Display the legend by clicking on the information icon on the bottom of the map.
  - d. Ask students what color indicates no thermal stress, DHW = 0 (blue). Have students find a blue area on the map. In these areas, corals have not accumulated thermal stress over the 3 months prior to April 1; in other words, the temperature did not cross the local bleaching limit.
  - e. Ask students when they might expect to see significant coral bleaching, especially in more sensitive species.  
**Answer:** When thermal stress reaches 4 DHW or higher (yellow and light orange regions of the map).
  - f. Ask students when they might expect to see widespread bleaching and mortality from the thermal stress.  
**Answer:** When thermal stress reaches 8 DHW or higher (dark orange, red or purple regions of the map).
3. Give students time to answer the questions at the end of this section.  
**Answer - Question 4:** 10
  4. If desired, encourage students to explore the map and compare the bleaching risk at the Great Barrier Reef with other regions. What do they notice?
  5. Ask: What questions could you ask (and answer) using the types of data you explored in Level 2? Give students time to record their questions on the worksheet.

# MEASURING WATER THAT IS WARMER THAN NORMAL

Your mission: An oceanic heat wave is causing severe coral bleaching at reefs across the globe. It's the worst bleaching event in history. To what extent are the corals on the Great Barrier Reef at risk? You have been selected to join a team of scientists who will analyze temperature data to find out.



*Can you locate the Great Barrier Reef from space?*

Instructions:

1. Go to the Coral Bleaching activity on the website. Click on [Level 2](#) and scroll down to the activity titled *'Measuring Water That Is Warmer Than Normal.'*
2. The graph shows real temperature data (collected by satellites) along the Great Barrier Reef during Summer 2017. Use the graph to answer the questions below:
  - a. On the Great Barrier Reef, how warm does the water need to be for corals to bleach? \_\_\_\_\_
  - b. How many weeks did the temperatures exceed the 'bleaching limit'?  
\_\_\_\_\_
  - c. How many degrees above the bleaching limit did the sea surface temperature rise during the week of Feb 18th, 2017? \_\_\_\_\_

- 
3. Are the corals on the Great Barrier Reef at high risk, moderate risk or low risk of bleaching due to heat stress? Use the temperature data to explain your answer.

---

---

---

---

4. As you work through Level 2, keep a list of questions that you have about coral bleaching in the table below.

What GENERAL questions do you have about coral bleaching?	What questions could you ask (and answer) using the types of data you explored in Level 2?

# LEVEL 3: ADAPTATION

## MONITORING THE HEALTH OF CORAL REEFS

Investigating Coral Bleaching Using Data in the Classroom

NOAA Data in the Classroom

Introduction Level 1 Level 2 **Level 3** Level 4 Level 5 Get Data Teacher's Guide

### Monitoring Coral Reefs in the Field

#### Introduction

**Objectives**  
Students will learn how to identify coral bleaching and understand how scientists measure bleaching at reefs around the world.

**Summary**  
Grade Level: 6-8  
Teaching time: 45 minutes

**Activities:**

- Learn how to identify healthy vs. bleached corals

A diver in a black wetsuit and mask is underwater, holding a white quadrat frame over a coral reef. The coral within the frame is mostly white, indicating bleaching. The diver is wearing orange fins and a blue buoyancy compensator. The background shows a clear blue ocean with more coral reefs.

### SUMMARY

- Grade Level: 6-8
- Teaching time: Three 45-minute periods
- Activities: a) Learn how to identify healthy vs. bleached corals, b) use quadrat sampling to estimate the extent of bleaching events, and c) conduct surveys of reefs around the world
- Vocabulary:
  - Coral Bleaching - loss of zooxanthellae due to stress caused by increased sea surface temperature.
  - Indicator: an organism so intimately associated with particular environmental conditions that its presence indicates the existence of those conditions.

- 
- 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.
  - 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).
  - Variable - a component of the ecosystem, physical or biological, that has an effect on other components of the ecosystem.
  - 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.

---

## LESSON PLAN – LEVEL 3

### Objectives

Students will learn how to identify coral bleaching and understand how scientists measure bleaching at reefs around the world.

### Background

This teacher-led lesson invites students to become scientists and scuba divers who will monitor bleaching at coral reef locations around the world. 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.

As highlighted in the previous lesson, scientists use sea surface temperature data to determine the extent to which corals are stressed and at risk of bleaching. However, how do scientists know exactly how corals respond to changes in sea surface temperature? And how the entire coral reef system responds to bleaching? In-the-field research and monitoring are needed in order to systematically measure a variety of variables (such as bleaching).

Coral reef monitoring is the gathering of data and information on coral reef ecosystems. An important aspect of monitoring is that it should be repeated on a regular basis, preferably over an extended period of time. In this activity, students will be learning to collect data on one variable - percent bleaching. A variable is a component of the ecosystem, physical or biological, that has an effect on other components of the ecosystem. For monitoring, the variables are the components or species that we collect data on, e.g. percentage cover of hard coral. It is impossible to measure every variable on a coral reef, therefore 'indicators' are used to detect change or impacts, or show reef 'health'. Indicators are either ecologically or economically important. Examples of ecological indicators include percent hard coral cover, which is an indicator of coral reef health because many other organisms rely on hard coral for their survival.

---

Corals are made up of a symbiosis between an animal (the coral polyp) and a plant-like organism called zooxanthellae (pronounced zoh-xan-thell-ee, often called “zooks”). In this symbiosis, the coral receives food from the zooks, and the zooks receive protection and nutrients from the coral. Since both organisms benefit from this symbiosis, its called a “mutualism.”

However, when conditions are not ideal, this mutualism breaks down, and the zooks are expelled by the coral. The result is a much weaker coral since it does not have its usual food supply. This process of expelling the zooks and weakening is called “bleaching” since without the zooks, the coral turns a bright white color, compared to the brown, green, red, etc when it is healthy.

If the coral stays bleached for too long, it may actually die, just like a human would of starvation. When that happens, the coral skeleton breaks down and other creatures begin to grow on it, leaving a encrusted rubble of a reef.

## Materials

- Projector
- Computers and internet access
- Photocopies of Student Worksheets #1 and #2

## Teacher Prep

- Go the the Data in the Classroom website and familiarize yourself with the [Level 3](#) activities.
- If your students have computers and internet access, you may choose to have them complete the online student activities during this lesson. Use the worksheets at the end of this lesson with Parts 2 and 3 of the online activities.
- If you do not have internet access in your classroom, you can alternatively download the PowerPoint (PPT) slides from the [Teachers Guide page](#) of the online activity. Students can use the electronic images from this PPT to complete the activity. *Note:* Part 4 of this lesson can only be completed with internet access.

---

## Procedure

### Part 1: Background

In order to monitor coral bleaching, students need an introduction to coral biology, which includes the important process of symbiosis between corals and certain algae.

1. Navigate to Level 3 of the Investigating Coral Bleaching online activities. Project [Level 3](#) onto a screen to help guide students through the activity.
2. Scroll down to the section titled 'Background.' Here, you'll find an image showing the differences between healthy, bleached and dead coral.
3. Give students time to read the information in this section.
4. Ask: What are zooxanthellae? What do they do for corals? And what do corals do for zooxanthellae?

**Possible answer:** Zooxanthellae are tiny algae that live within the tissues of corals. The most important thing that the algae do is provide food, in the form of carbohydrates, to the corals through photosynthesis. The corals provide protection and nutrients for the zooxanthellae.

5. Ask: What is coral bleaching? Are bleached corals dead?

**Possible answers:** When water temperatures become warmer than normal, corals can become stressed out. Stressed corals expel the algae (zooxanthellae) living in their tissues causing the coral to turn completely white, thus the term 'bleached.' When a coral bleaches, it is not dead. Corals can survive a bleaching event, but they are under more stress and are subject to mortality.

6. Ask: How can you tell the difference between a healthy coral, a bleached coral and a dead coral?

**Possible answers:** Healthy corals comes in shades of olive green, brown, tan and pale yellow; bleached corals appear white; dead coral often becomes covered in algae.

### Part 2: Identifying the Effects of Bleaching on Coral Reefs

In this section, students make broad-scale observations to better understand and define the problem of bleaching. Explain to students that they will be joining a team of scientists who are looking for evidence of coral bleaching at four reefs in the Pacific Ocean. Students

---

will need to make careful observations to determine if there has been bleaching or mortality.

1. Scroll down to the next section. Here, you'll find a map showing the locations of four coral reefs in the western Pacific Ocean.
2. At each of these reefs, students will compare two photos taken at different times at the exact same location on each reef.
  - Project Level 3 and show students how to use the map tool to 'visit' each of the four coral reefs. You can zoom in and out on the map, click on images to expand, etc.
  - Pair up students into teams and give each team a copy of Student Worksheet #1 (at the end of this lesson). Give the teams time to review the mission and demonstrate how to complete the table, using the example.
3. Discuss their findings and give students time to answer the questions at the end of the worksheet.
4. Observations about each of the coral reef sites may include the following:
  - Phoenix Islands: In 2004, the reef was healthy. In 2016, the reef was mostly dead. *Note: this occurred after a several bleaching event.*
  - Pago Pago, American Samoa: In December 2015, the reef was healthy. In February 2016, the reef was bleached. *Note: these photos were taken before and after an intense bleaching event. Notice how much can change in only two months.*
  - Great Barrier Reef, Australia: In March 2016, the coral head is bleached. In May 2016, the coral has died and is covered in algae. *Note: The Great Barrier Reef suffered the worst bleaching on record in 2016. One of the worst-hit areas was around Lizard Island, where around 90% of the coral died.*

- 
- Maui, Hawaii: In August 2015, the reef was healthy and in November 2105, the reef was bleached. *Note: these photos were taken before and after an intense bleaching event, one of the first to ever hit the Hawaiian Islands.*

5. Review and give students time to answer 'Question 1' at the end of this section.

**Answer:** B and C

### Part 3: Calculating Percent Bleaching Using Quadrat Sampling

In this section, students will learn how to use a common monitoring technique called a quadrat to measure how much of a reef is healthy, bleached or dead. This interactive activity challenges students to apply the broad-scale observational skills practiced in Part 2, as they learn how to collect the quantitative data that is needed to track bleaching over time.

1. Project the photo (of the diver and the square, white quadrat) at the beginning of Level 3. Explain that scientists monitor coral reefs using a number of different tools and methods. Scientists sometimes use a tool called called a quadrat inside which they can count and measure things. In this virtual activity, students will be using quadrats to estimate how much of an area is affected by bleaching. Note, scientists use quadrats that are big enough to get a good estimate of 'density' or 'cover' yet small enough so that they can collect data in a reasonable amount of time.
2. Scroll down to the section titled 'Calculating Percent Bleaching Using Quadrat Sampling.' Select (click) Reef #1. The photo shows a white quadrat placed on top of a coral reef. The quadrat is divided into 100 small squares of equal size. Note that each square is numbered. Student will monitor a random subset of 10 squares, outlined in yellow.
3. Give each student team a copy of worksheet #2. Demonstrate how to complete the table, using the example. And give student teams time to virtually monitor one of the reefs.
4. The expected results for each of the reef locations can be found on the *Answer Key* at the end of this section.

---

#### Part 4: Optional - Surveying Coral Reefs

The type of monitoring activities that students learned to conduct in Part 3 can be expensive and time consuming. Many countries do not have the resources required to regularly conduct scuba surveys that monitor the health of their coral reef ecosystems. As a result, there is often limited data across entire regions of the world.

In this section, students can explore high-resolution, 360 degree images that are part of a vast collection of coral reef visuals and data from the Catlin Global Reef Record (2012-present). Computers, rather than people, analyze these images quickly. As a result, a lot more data can be gathered to increase our understanding of the health of corals around the world. For more information about this project, visit [globalreefrecord.org](http://globalreefrecord.org).

1. Give students time to take a virtual dive at one or more of the reef locations.
2. Discuss: Are there any disadvantages to using computers to analyze coral health?
3. If desired, students can select one reef location of interest and write an essay or poem using observations from the virtual dive and/or additional online research.

# IDENTIFYING THE EFFECTS OF BLEACHING ON CORAL REEFS AROUND THE WORLD

Your mission: Congratulations! You have been selected to join a team of scientists who will be investigating the health of coral reefs around the world. Your current mission is to look for evidence of coral bleaching and mortality at four reefs in the Pacific Ocean. Put on your goggles and get ready to take the plunge.



Visit the reefs (above) using the map in Level 3.

Making Observations: Go to the [Coral Bleaching activity](#) on the website, click on Level 3, and scroll down to the activity titled 'Identifying the Effect of Bleaching on Coral Reefs.' Use the map tool to visit each of the four coral reefs in the western Pacific. Examine the photos and complete the table below. As an example, Reef #1 is partly completed for you.

Coral Reef #	Reef Name and Location	Date	Observations:
1	Phoenix islands, Republic of Kirabati	2004	<p><u>healthy</u>      bleached      dead</p> <p><i>Other observations: coral is bright green and yellow. Lots of colorful fish are present.</i></p>
1	Phoenix islands, Republic of Kirabati	2016	<p>healthy      bleached      dead</p> <p><i>Other observations:</i></p>

---

Coral Reef #	Reef Name and Location	Date	Observations:
2			<p>healthy      bleached      dead</p> <p><i>Other observations:</i></p>
2			<p>healthy      bleached      dead</p> <p><i>Other observations:</i></p>

Coral Reef #	Reef Name and Location	Date	Observations:
3			<p>healthy      bleached      dead</p> <p><i>Other observations:</i></p>
3			<p>healthy      bleached      dead</p> <p><i>Other observations:</i></p>

Coral Reef #	Reef Name and Location	Date	Observations:
4			<p>healthy      bleached      dead</p> <p><i>Other observations:</i></p>
4			<p>healthy      bleached      dead</p> <p><i>Other observations:</i></p>

---

Making Sense of Your Observations: Answer the questions below.

1. How many of the reefs you visited showed signs of bleaching? \_\_\_\_\_

2. Has the health of these coral reefs changed over time? If yes, describe the changes you observed.

---

---

3. If you were a scientist, what more would you want to know to better understand coral bleaching?

---

---

---

---

4. What is one way that you could more accurately measure the amount of coral bleaching taking place at these locations?

---

---

---

---

# MONITORING CORAL REEFS IN THE FIELD

Your mission: You and a team of scientists are setting out to monitor coral health at different locations in the Pacific Ocean. The data that you collect will be used by managers and government officials who protect these coral reefs. Put on your scuba gear and dive in with a clipboard, data sheet and a tool called a quadrat in order to collect data that will help to begin to track the health of corals at these locations.



Question: How much coral is dead? How much is bleached?

Monitoring Methods - follow these instructions: To answer the question above, go to the [Coral Bleaching module](#) on the website. Click on Level 3 and scroll down to the activity titled 'Monitoring Coral Health Using Quadrat Sampling.'

- Select (click) a reef to monitor.
- Follow the online instructions, and record your data in the table on the next page.
- When you are done collecting data, calculate the percent dead and bleached.

**Example:** Using the photo from Reef #1

Square #	Is Coral Dead? 0=coral is alive, 1=coral is dead	Is Coral Bleached? 0=unbleached, 10=completely bleached
4	1	
16	0	3

← Leave blank since coral inside this square is dead



# ANSWER KEY

## REEF #1

Square #	Dead	Bleached
4	1	n/a
16	0	3
20	1	2
22	0	1
32	0	2
44	0	3
45	0	3
74	0	1
93	0	1
94	0	3
	Total Sum = 2	Average = 2.1
	% dead = 20%	% bleached = 21%

## REEF #2

Square #	Dead	Bleached
1	1	n/a
3	1	n/a
20	1	n/a
27	1	n/a
44	0	4
48	0	0
49	0	2
61	0	5
62	0	4
89	0	3
	Total Sum = 4	Average = 3
	% dead = 40%	% bleached = 30%

## REEF #3

Square #	Dead	Bleached
4	1	n/a
5	1	n/a
8	n/a	n/a
12	1	n/a
37	0	1
42	1	n/a
49	1	n/a
55	0	3
78	1	n/a
95	0	8
	Total Sum = 6	Average = 4
	% dead = 60%	% bleached = 40%

## REEF #4

Square #	Dead	Bleached
4	0	1
16	0	1
20	0	1
22	0	1
32	0	4
44	0	1
45	0	2
74	0	0
93	0	2
94	0	0
	Total Sum = 0	Average = 1.3
	% dead = 0%	% bleached = 13%

---

## Supplemental Student Activity – *Building a Model Coral Head*

The following hands-on activity could optionally be used to support the online activities in Levels 1-3. In this activity, 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: Cross-Section of a Coral Polyp
- Photocopies of Student Worksheet: Build a Model Coral Head (1 per student)

### Preparation

1. 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?*
2. 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:* Reef-building corals exhibit a wide range of shapes. To make different coral head shapes (branching, foliase, etc.) for the insertion of student made polyps, refer to [NOAA's National Ocean Service Education webpage, 'How Do Stony Corals Grow?'](#)

## Procedure

1. Display Teacher Master: 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:
  - 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. Discuss 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 the student worksheet and materials for building a coral polyp.
  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 (Level 1).
  8. Ask: What is the average temperature range corals need to live?  
**Answer:** 18°C to 29°C
  9. 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.
  10. 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?
  11. 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.

- 
12. Explain that the loss of the zooxanthellae leads to coral bleaching. The zooxanthellae 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.
13. 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.
14. 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.
15. As a class, go over the discussion questions at the end of the student worksheet. *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.

# CROSS-SECTION OF A CORAL POLYP

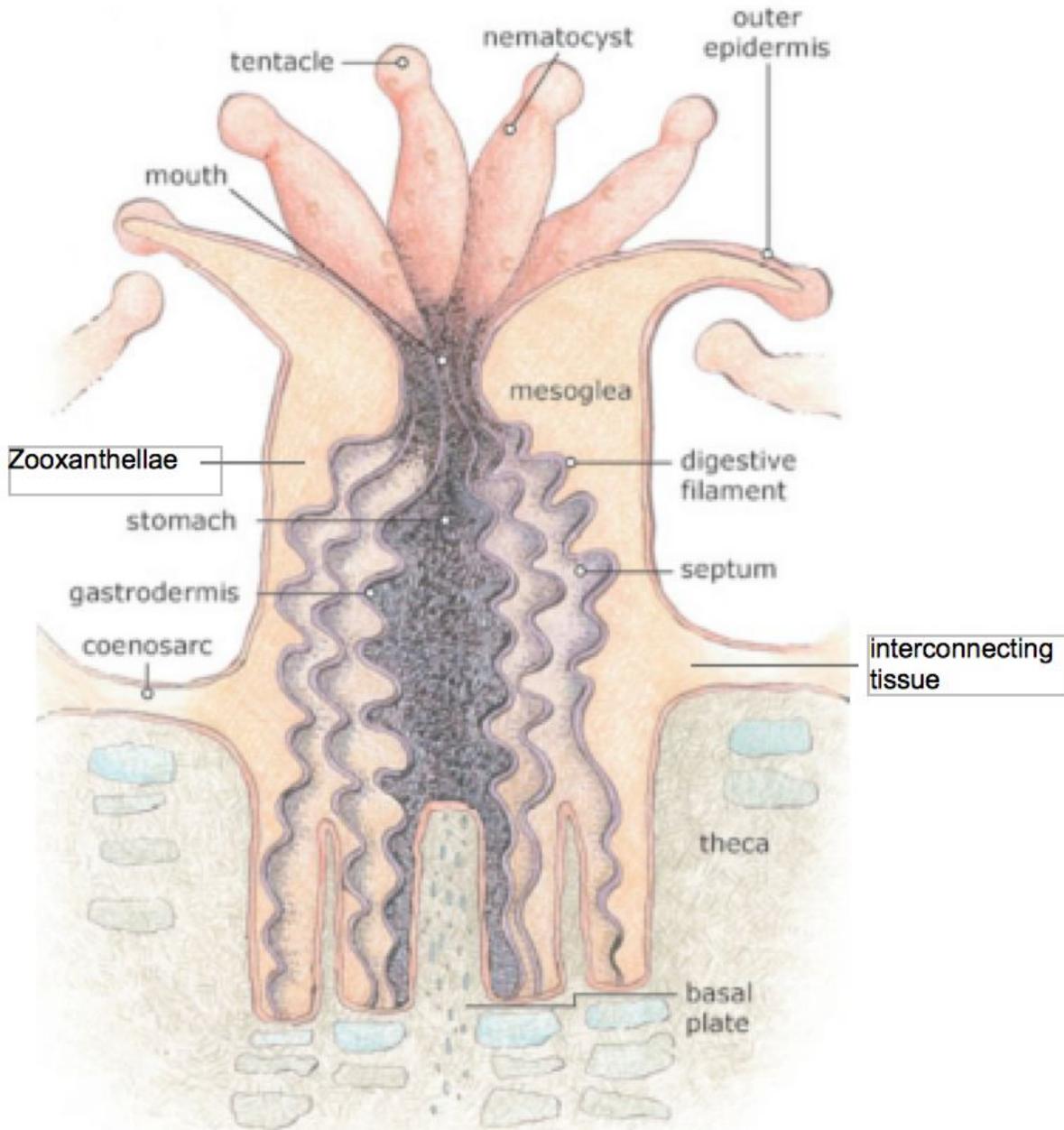
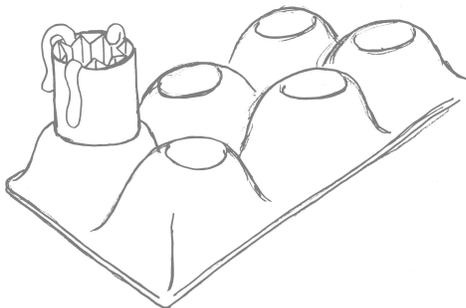
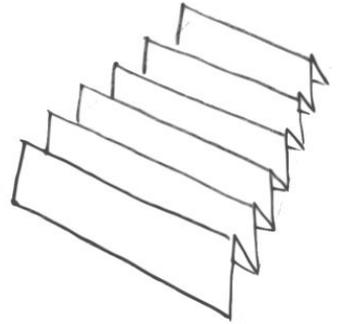


Image: NOAA

# BUILD A MODEL CORAL HEAD

## Instructions:

- 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.
- 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 accordion-pleated inside of the cylinder forms the gut of the polyp.
- Tape four 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.
- 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:

1. Why are coral polyps important to coral health?
2. Why is the symbiotic relationship between animal and plant important to coral health?

# LEVEL 4: INTERACTIVITY

## IDENTIFYING A BLEACHING EVENT

Investigating Coral Bleaching Using Data in the Classroom

NOAA Data in the Classroom

Introduction Level 1 Level 2 Level 3 **Level 4** Level 5 Get Data Teacher's Guide

### Identifying a Bleaching Event

#### Introduction

**Objective**  
By using real-time and historical coral bleaching data, students will be able to analyze the presence and intensity of bleaching events and corroborate that with stories from the news.

**Background**  
Not all coral reefs go through bleaching events with the same frequency or intensity - some may go years without a significant bleaching event, while some locations go through multiple years of



### SUMMARY

- Grade Level: 6-8
- Teaching time: One 45-minute period
- Activities: a) analyze a graph to predict the occurrence, timing and severity of coral bleaching in the Florida Keys and b) determine the relationship between the predictions and how much bleaching was actually observed on the reef.

---

## LESSON PLAN – LEVEL 4

### Objectives

Students will evaluate the latest, real-time bleaching predictions and in-the-field monitoring observations to determine how sea surface temperature is affecting the health of Florida’s coral reefs.

### Background

Throughout this Coral Bleaching module, students have been exploring the question *‘What are the consequences of rising sea surface temperature on coral reefs, and why should we care?’* Oceanographers, marine biologists, scuba divers and all those who enjoy 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 we care? Students need to understand that a study of coral reef health, comparing the past to the present, can help them think what actions can be taken to better protect coral reefs on a warming planet.

So far, students have learned to generate, read, and interpret different kinds of data related to coral bleaching. Now, they will apply what they have learned in order to examine the relationship between bleaching predictions (from Level 2) and how much bleaching is actually observed on a reef (from Level 3).

Evidence-based predictions are useful IF they are accurate. So how good is NOAA’s *Degree Heating Weeks* product at predicting bleaching events? Students will evaluate the latest, real-time bleaching predictions from the Florida Keys, home of one of the largest reef communities in the world. They will use these data to make predictions about the timing and intensity of the bleaching. And finally, students will determine if their predictions were accurate by examining scientific reports and media accounts of bleaching observations during the time that bleaching was predicted.

---

## Teacher Prep

There are a variety of ways to implement this activity. Decide which works best for your classroom, and prepare as appropriate.

- Go to the Data in the Classroom website and familiarize yourself with the [Level 4](#) activities.
- Familiarize yourself with the data products used in this activity.
- Research a few recent news articles about coral bleaching in the Florida Keys, if desired. These can be used to help link their data explorations to broader, global issues.

## Procedure

### Part 1: Background

1. On an overhead projector, display a news report from a coral bleaching event in the Florida Keys, optionally from the mass bleaching episodes during the summers of 2014 and 2015.
2. Explain that students will continue their investigations of coral bleaching by evaluating the latest, real-time bleaching predictions from the Florida Keys.

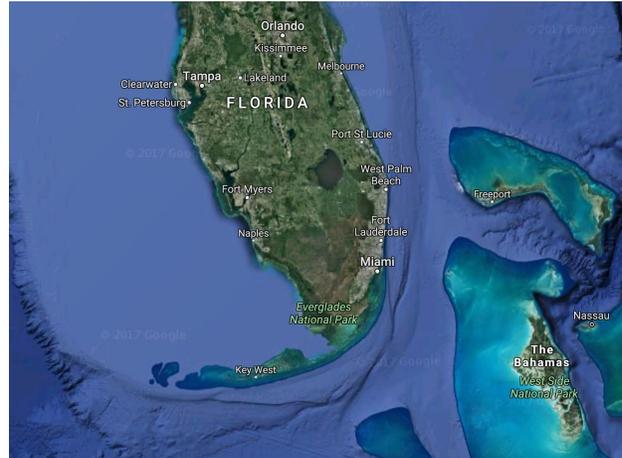
### Part 2: Analyzing Bleaching in the Florida Keys

1. Assign students to work in teams of two and give each team a copy of the student worksheet, *Coral Bleaching in the Florida Keys*.
2. Project the online activity in [Level 4](#) and demonstrate how to access the Coral Bleaching graph using the map tool, if necessary.
3. In Part 1 of their worksheets, students will be challenged to interpret a time series graph of Degree Heating Weeks (DHW), explored in Level 2. Here are a few features and reminders to help students interpret the graph:
  - a. Degree Heating Weeks (DHW) values are plotted along the y-axis, time along the x-axis.

- 
- b. Remind students, from Level 2, that DHW values are calculated using sea surface temperature data to predict the timing and intensity of coral bleaching.
    - c. When DHW is 4 or higher: bleaching is expected.
    - d. When DHW is 8 or higher: widespread bleaching and mortality is expected.
    - e. When DHW is 12 or higher: mass mortality is expected.
  4. In Part 2 of their worksheets, students will use online accounts (photos, media, scientific reports) to determine the extent to which their bleaching predictions were accurate. The simplest way to do this will be to access [Mote Marine Lab's Condition Reports](#), published online every two weeks throughout the summer. The worksheet contains a link to these reports. Make sure to scroll all of the way down the page to find the reports. After accessing and evaluating their data, students should work together to answer the questions and complete the conclusion section at the end of the worksheet.
  5. A sample conclusion may include the following: Sea surface temperatures were higher than normal last summer (2016), and exceeded a Degree Heating Week value of 4 during Aug and Sept 2016. Coral bleaching is therefore likely during this period, but given that the 'oceanic heat waves' did not last very long (~2-4 weeks in total), I predict that bleaching would not be severe. In-the-field observations from Mote Marine Lab report that 'partial bleaching' or 'no bleaching' occurred throughout the Florida Keys during this same time period. In conclusion, sea surface temperature was higher than normal for short periods during the summer of 2016, and caused partial bleaching at some reefs throughout the Florida Keys.

# RESEARCH PROJECT: CORAL BLEACHING IN THE FLORIDA KEYS

Your mission: Florida's coral reefs make up the third largest barrier reef ecosystem in the world. These reefs protect the shore and bring in billions of tourist dollars every year. How is sea surface temperature affecting the health of Florida's coral reefs? You are joining a team of scientists who are using data to find out.



## Part 1 - Has the water been warm enough to put Florida's corals at risk?

1. Go to the Coral Bleaching activity on the website. Click on [Level 4](#) and scroll down to the activity titled '*Analyzing Bleaching in the Florida Keys.*'
2. On the map, select the light green circle that marks the location of the Florida Keys. Click '*Graph Link.*' The graph shows the latest *Degree Heating Week (DHW)* data for this region. Analyze the graph and answer the questions below:
  - a. What does the y-axis on the left represent? \_\_\_\_\_
  - b. What time period is represented on this graph? \_\_\_\_\_
3. Record the date(s), if any, when coral bleaching was expected (above 4 DHW):  
\_\_\_\_\_

- 
4. Make a prediction: How severe was the risk of bleaching during the time period described above? *Support your prediction by including information about 'how long' and 'how much' DHW values were over 4.*

---



---



---

Part 2 – How much bleaching was actually observed?

5. Was your prediction accurate? Did corals bleach? Did they survive and recover? To find out, you'll need real data and observations from people who monitor coral reef conditions in the Florida Keys. Use the two options below, to begin your search:
- Florida's *Mote Marine Lab* publishes coral [Condition Reports on their website](#). These reports will show you when and where bleaching occurred in the Florida Keys during a given time period. **\*See page 2 of the reports.**
  - Search for news articles about bleaching in the Florida Keys by using search terms such as: coral bleaching, Florida Keys, 2015.
6. Record information and specific evidence about bleaching from at least 2 sources.

Source	Date	Bleaching data and observations
Example: Mote Marine Lab, Current Conditions Report #20160601	June 1, 2016	No bleaching was observed during this time period.

---

Part 3 – Draw a Conclusion: How is sea surface temperature affecting the health of Florida’s coral reefs? Use evidence and data from Parts 1 and 2 to support your conclusion.

---

---

---

---

---

---

---

---

---

---

# LEVEL 5: INVENTION

## DESIGN YOUR OWN INVESTIGATION

Investigating Coral Bleaching Using Data in the Classroom

NOAA Data in the Classroom 

Introduction Level 1 Level 2 Level 3 Level 4 Level 5 Get Data Teacher's Guide

### Designing Your Own Investigation

#### Introduction

**Objective**  
Students will apply what they have learned to consider the issue of coral bleaching on a larger scale. To do this, students will ask questions, collect and analyze data and construct an argument that shows how data supports their conclusions.



### SUMMARY

- Grade Level: 6-8
- Teaching time: Two 45-minute periods
- Activities: Design an investigation using real data to examine a research question

---

## LESSON PLAN – LEVEL 5

### Objectives

Students will apply what they have learned to consider the issue of coral bleaching on a larger scale. To do this, students will ask questions, collect and analyze data and construct an argument that shows how data supports their conclusions.

### Background

Students have used real data to begin to understand how warmer than normal sea surface temperature affects the health of coral reefs at specific locations around the world. Now, it is time to examine this issue on a global scale. How does the health of coral reefs compare from one location to another? And how is changing sea surface temperature affecting the health of coral reefs over time?

Students should be encouraged to develop their own research questions for this activity. In general, questions that lead them to considering changes in the frequency or intensity of coral bleaching over time will provide a good starting point.

Sample research questions with links to data tools are available in the online Level 5 activity. Students can be challenged to apply what they have learned about reading and understanding data to interpret a variety of data products.

### Materials

- Projector
- Computers and internet access
- Photocopies of student worksheets

### Teacher Prep

- Go to the Data in the Classroom website and familiarize yourself with the [Level 5](#) activities, sample questions and data tools.

- 
- Explore and practice using the data tools in Level 5. Be prepared to demonstrate the tools for students.

## Procedure

This activity challenges students to think like scientists by designing a scientific investigation in which data collection and analyses are important parts of the process. Students are challenged to engage in a number of scientific practices, including asking questions, analyzing data and constructing explanations using data.

1. Assign students to work in teams of two and give each team a copy of the student worksheet, *Design Your Own Investigation*.
2. Project [Level 5](#) onto a screen and scroll down to the section titled 'Plan Your Investigation.' Locate the data tools: Degree Heating Weeks maps and Coral Reef Station data.
3. Prior to developing a question, students will need to understand what types of data are available to them. The data tools and visualizations that are available in Level 5 are described below. Instructions to use the tools can be found by clicking the 'Get Data' tab in the upper navigation bar. With students, discuss these data and demonstrate how to use the data tools, if needed.
  - a. Degree Heating Weeks - Map Viewer: This tool can be used to identify where coral heat stress is highest around the globe as well as short and long-term changes in heat stress over time.
  - b. Coral Reef Station data tool (2013 - present): This data tool will enable students to explore bleaching risk (Degree Heating Weeks values) at five different locations since 2013. Locations includes the Great Barrier Reef, Fiji, Hawaii, the Galapagos and the Florida Keys.
4. Guide students through the selection of a research question (or have them make up their own) that is appropriate to their academic experience. Sample questions are highlighted in the online Level 5 activities. If your students completed the activities and worksheet in Level 2, ask them to review their answers to worksheet question 4,

---

“What questions could you ask (and answer) using the types of data you explored in Level 2?”

5. Next, in their small groups, students should determine what data are needed to answer their question, making a list on their worksheet.
6. Using the data tools on the website, students can then access, save and/or print the graphical displays of data. If necessary, help students determine if they have enough data to answer their question and identify areas where they may need to seek out additional sources of information.
7. After accessing and reviewing their data, students should work together to write a detailed interpretation of what their data shows and complete the conclusion section at the end of the worksheet.
8. After students complete their research, provide time for them to present their findings to the class.
9. Use student presentations as an opportunity to relate their investigations to the current news and debate about coral bleaching and global climate change.

# DESIGN YOUR OWN INVESTIGATION

Develop Your Question:

---

---

---

---



Make a Plan: Make a list below of the specific data you will need to answer the question.

Data Set	Date	Map or Graph?
Example: Degree Heating Weeks, Florida Keys	August 2015	map

Other than the data listed above, what other information (if any) will you need to answer your question?

---

---

---

Get the data: Use the website to get the data you will need.

Interpret the data: What does your data show? Be specific and descriptive.

---

---

---

---

---

---

---

---

---

---

---

Draw a Conclusion: What is the answer to your question? Use evidence and data to support your conclusion.

---

---

---

---

---

---

---