

ScienceNews

IN HIGH SCHOOLS | EDUCATOR GUIDE



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**Rebuilding
Reefs**



SOCIETY FOR
SCIENCE & THE PUBLIC

About this Issue

The cover story of this issue, “[Rebuilding reefs](#),” explores how scientists are working to save coral reefs. Researchers agree that reefs are under threat because of human activity, including climate change, but different research teams are finding their own unique ways to help reefs recover. In reading this article, students can explore ways scientists share information and build on each other’s work, as well as how scientists design experiments and collect evidence to test specific ideas. Whether thinking about how the symbiotic relationship between coral and live-in algae relates to bleaching or about how the ocean’s acidity affects the solubility of corals’ calcium carbonate exoskeletons, students can focus on a particular area of science mentioned in the article while appreciating the cross-curricular nature of rebuilding coral reefs.

Connections to Your Curriculum

- Natural selection
- Symbiotic relationships
- Sexual vs. asexual reproduction
- Photosynthesis and cellular respiration
- Effects of climate change and greenhouse gases on oceans
- Experimental design
- Light absorption in seawater
- Structure and properties of CaCO_3

What's in this Guide?

- [Article-Based Observation:](#) These questions focus on reading and content comprehension by drawing on information found in the article “Rebuilding reefs.” Students will explore how scientists are trying to save the world’s coral reefs.
- [Quest Through the Archives:](#) With Internet access and your school’s digital access to *Science News*, your students can use this short section to explore the history of coral reef science and coral bleaching as reported by *Science News* since 1922.
- [Cross-Curricular Discussion:](#) These questions and extension prompts encourage students to think about the different approaches scientists take to a problem and how coral science connects to student learning across the science disciplines, as well as the ethical considerations associated with the approaches discussed in the article. This section culminates with Engineering and Experimental Design questions and prompts to help further define the research covered in the article.
- [Data Analysis Activities:](#) Three activities give students the opportunity to use and interpret data to look for patterns in bleaching alerts. These activities flow together but can be used independently.

Standards Alignment

Next Generation Science

Matter and its Interactions: [HS-PS1-2](#)

Waves and their Applications in Technologies for Information Transfer: [HS-PS4-1](#)

Ecosystems: Interactions, Energy, and Dynamics: [HS-LS2-2](#), [HS-LS2-6](#), [HS-LS2-7](#), [HS-LS2-8](#)

Heredity: Inheritance and Variation of Traits: [HS-LS3-1](#)

Earth and Human Activity: [HS-ESS3-6](#)

Engineering Design: [HS-ETS1-4](#)

Common Core

ELA Standards: [Reading Informational Text \(RI\)](#): 1, 4, 7

ELA Standards: [Writing \(W\)](#): 2, 4, 6

ELA Standards: [Speaking and Listening \(SL\)](#): 2, 4, 5

ELA Standards: [Reading for Literacy in Science and Technical Subjects \(RST\)](#): 1, 2, 4, 7, 9

ELA Standards: [Writing Literacy in History/Social Studies and Science and Technical Subjects \(WHST\)](#): 2, 4, 6, 7, 8

Article-Based Observation

Directions: After reading the article “Rebuilding reefs,” answer these questions:

1. The author begins the article by comparing a coral reef to a metropolis with “high-rise apartments.” Explain this metaphor and identify the point where the metaphor breaks down.
2. Explain the role and importance of algae to the survival of coral.
3. According to the article, how is the ocean changing? How do these changes affect the algae living within the coral and, ultimately, the coral reef itself?
4. What happens during a bleaching event and why is this a concern to scientists?
5. What strategies are the scientists in Florida, Hawaii and Australia using to rebuild coral reefs?
6. A friend asks what you’re reading. Tweet (in 140 characters or less) what this article is about.

Responses to Article-Based Observation

1. The author begins the article by comparing a coral reef to a metropolis with “high-rise apartments.” Explain this metaphor and identify the point where the metaphor breaks down.

Possible student response: A metropolis is a large urban setting, a bustling city. The structure of a coral reef reminds the author of a large city, with the coral polyps living on the corals’ hard skeletons and many other organisms living around the coral. The corals are dependent on their symbiotic algae for survival. The reefs, like a city, have built structures. However, in our cities, animals do not grow the buildings and typically don’t eat them. Those living within the buildings can interact in ways corals cannot. Also, human buildings don’t get bigger with each new tenant.

2. Explain the role and importance of algae to the survival of coral.

Possible student response: Algae live within the corals. They photosynthesize, capturing the sun’s energy and turning it into sugar, which they share with the coral. The corals provide the algae with a home and protection from predation. Without the algae, the coral cannot get enough nutrients. This is known as a symbiotic relationship because the organisms live together and benefit.

3. According to the article, how is the ocean changing? How do these changes affect the algae living within the coral and, ultimately, the coral reef itself?

Possible student response: Earth’s oceans are warming and becoming more acidic (decreasing in pH). Because algae are very sensitive to the physical conditions in which they live, these changes can lead to a breakdown of the algae-coral relationship. But corals cannot survive for long without the algae. If corals and their algae cannot adapt, the corals may die and the health of the reef ecosystem could suffer.

4. What happens during a bleaching event and why is this a concern to scientists?

Possible student response: A bleaching event occurs when the temperature of the water increases 1 to 2 degrees Celsius for a prolonged period of time. The algae that live within the corals become toxic and are expelled. Without their algae, the corals might not be able to continue building the reef. As bleaching events become more common and more severe, there is concern that organisms that depend on the reef ecosystem, humans included, may no longer find what they need.

5. What strategies are the scientists in Florida, Hawaii and Australia using to rebuild coral reefs?

Possible student response: In Florida, reef fragments are being grown to repopulate larger reef systems. In Hawaii, scientists are breeding corals to be tolerant of conditions expected in the future. In Australia, fertilized coral embryos are being released systematically with the hope that they will take hold in areas that need to be repopulated.

6. A friend asks what you’re reading. Tweet (in 140 characters or less) what this article is about.

Possible student response: Coral reefs are under threat due to climate change and human activity. These scientists are finding ways to help.

Quest Through the Archives

Directions: Use the archives at www.sciencenews.org to answer these questions:

1. What is the date of the earliest article you can find that focuses on coral reefs? What is the focus of this article?
2. What is the date of the earliest article you can find that names coral bleaching as a potential problem? Does the research presented in the archived article align with what's reported in the current article?
3. How has coral reef coverage in the news changed over time? Support your statement with accompanying *Science News* articles.

Responses to Quest Through the Archives

1. What is the date of the earliest article you can find that focuses on coral reefs? What is the focus of this article?

Possible Student Response: www.sciencenews.org/archive/study-coral-reef-origin. This article from 1949 focuses on the origin of coral reefs.

2. What is the date of the earliest article you can find that names coral bleaching as a potential problem? Does the research presented in the archived article align with what's reported in the current article?

Possible Student Response: www.sciencenews.org/archive/bleached-reefs. This article from 1990 presents research that questions whether warmer ocean temperatures promote coral bleaching.

3. How has coral reef coverage in the news changed over time? Support your statement with accompanying *Science News* articles.

Answers may vary for this prompt, but look for supporting evidence from specific articles.

Cross-Curricular Discussion

After students have had a chance to review the article “Rebuilding reefs,” lead a classroom discussion based on the questions that follow. The discussion is subdivided roughly by topic in case you would like to focus on one particular content area. The Extension Prompts are more topic-specific or conceptually advanced. Use [Blackline Master 3](#) to accompany the discussion.

BIOLOGICAL SCIENCES

Discussion Questions:

- 1a. The article talks about different strategies for coral reproduction. Ask students to review the strategies mentioned. Ask them to brainstorm the pros and cons of each. Discuss how Dave Vaughan, at the Mote Tropical Research Laboratory, got his idea to raise coral microfragments. What do students think are the benefits of farming coral under controlled conditions? Do students think it is OK to mix farmed coral with wild coral? What if Vaughan’s technique was mixed with the selective breeding strategy of Ruth Gates, of the Hawaii Institute of Marine Biology? Are there ethical considerations to creating “super corals”?

Extension Prompts:

- 1b. What are the pros and cons for corals of reproducing sexually versus asexually (cloning)? Why would it be best to have more genetic variation in the population? [Sexual reproduction allows for genetic variation and, when done by researchers, can be designed to select for preferred characteristics in hopes of helping coral survive. Cloning allows for quick reproduction and can replicate an organism with existing traits. However, cloning doesn’t introduce genetic diversity. If ocean conditions kill some cloned corals, it is possible that all other cloned, and thus genetically identical, corals may die.]
- 1c. Write the general chemical equation for photosynthesis and cellular respiration. Use this information to explain the symbiotic relationship between algae and coral. [Photosynthesis is represented by the chemical reaction: $H_2O + CO_2 \rightarrow C_6H_{12}O_6 + O_2$ (with sunlight/energy required). Cellular respiration is represented by the opposite reaction: $C_6H_{12}O_6 + O_2 \rightarrow H_2O + CO_2$ (with energy produced). Students should explain that the algae use water and carbon dioxide to create glucose and oxygen. The corals use the oxygen and glucose produced by the algae for cellular respiration.]

EARTH SCIENCE AND PHYSICAL OCEANOGRAPHY

Discussion Questions:

- 2a. The article talks about the effect of greenhouse gases on coral reefs. What are some greenhouse gases? Ask students to list a few and give their chemical formulas [For example: Water vapor, H_2O . Carbon dioxide, CO_2 . Methane, CH_4 . Nitrous Oxide, N_2O . Ozone, O_3 .]

2b. Ask why these gases are referred to as “greenhouse gases” and what effect they are having on Earth.

[These gases absorb and emit infrared radiation, trapping heat in the atmosphere the way heat is trapped in a greenhouse. This trapped heat warms the Earth’s atmosphere.]

2c. Corals live underwater, so they are dealing with the effects of increased absorption of carbon dioxide in seawater. How does carbon dioxide, a common greenhouse gas, react with water? [In a water (aqueous) state, carbon dioxide forms carbonic acid (H_2CO_3), which loses a proton (H^+) to form bicarbonate (HCO_3^-).]

Have students examine the chemical reaction and explain how this reaction affects the pH of ocean water. [The result of the lost proton is to increase the hydrogen ion or hydronium ion concentration in the water, decreasing the pH of the water.] Ask students to use information in the article to develop an explanation for how the change in pH affects coral. [As levels of carbon dioxide in the ocean increase, the pH of the ocean decreases, creating a more acidic condition – known as ocean acidification. As acidity increases, coral skeletons are weakened and skeleton growth might slow. The reef might become less healthy.]

Extension Prompts:

2d. Coral exoskeletons are made from calcium carbonate. Discuss how the presence of an acid affects the solubility of calcium carbonate. Students studying chemical reactions can write the equilibrium solubility expression for calcium carbonate [$CaCO_3(s) \longleftrightarrow Ca^{2+}(aq) + CO_3^{2-}(aq)$] and use it as evidence to support their answer. [As hydrogen ion concentrations increase, CO_3^{2-} is consumed (producing bicarbonate, HCO_3^-). As CO_3^{2-} is consumed, more calcium carbonate will dissolve, increasing the solubility of calcium carbonate.]

PHYSICAL SCIENCE AND EARTH AND SPACE

Discussion Questions:

3a. Algae that live within coral colonies need light in order to photosynthesize. The coral colonies use the products of this photosynthesis as food. Brainstorm factors that influence the concentration of light reaching the coral reefs. [Because of the curvature of the Earth, latitude affects the angle that light hits the water and thus the light that reaches a particular location. Sea state – big waves, for example – can affect the scattering of light and thus how much light is reflected or absorbed into the water column. Water clarity (quantity of particulates, for example) affects the quantity and quality of light reaching corals. Water depth influences the wavelengths of light that can reach corals.] Ask students which of these factors might be affected by human activity?

Extension Prompts:

3b. What happens to light as it enters the water? [Light travels faster in air than in water. Therefore, when light penetrates the surface of the water, it is refracted, or bends.]

3c. Explain fluorescence. [The ability of atoms or molecules to absorb specific wavelengths of light and emit different wavelengths of light as they return to their initial state.] From an evolutionary perspective, why might fluorescent proteins exist in corals? [Scientists in the article suggest that fluorescent proteins might act as a sunscreen to protect photosynthetic algae from solar radiation, for example.] Can students think of

other organisms that fluoresce? [A few examples include arthropods, deep sea fish, fireflies and glowworms.]

- 3d. Allow your students to draw relationships and make distinctions between the use of light energy in fluorescence and photosynthesis in algae. [*Light energy is absorbed to initiate both processes. In photosynthetic organisms, energy is absorbed from incident photons. This absorbed energy is either used as heat to drive the chemical reactions of photosynthesis or is re-emitted as radiation. Fluorescence is often used as an indicator of the initial events of photosynthesis.*]

ENGINEERING AND EXPERIMENTAL DESIGN

Discussion Questions (open-ended):

- 4a. The article talks about some threats to corals being global in nature and some being local. Ask students to brainstorm the nature of local threats to corals.
- 4b. Students can research what specific communities are doing to minimize their direct negative impact on the reefs.
- 4c. Are all reef-adjacent communities facing similar challenges?
- 4d. Students may want to look at what organizations foundations, such as [Reef Check](#), are doing to help educate local populations and support them in finding solutions that protect local reefs from anthropogenic impacts.
- 4e. Students may be able to find out whether these same communities are implementing specific and similar measures to protect the reefs. Students might want to research how communities can develop a [coral bleaching response plan](#).

Extension Prompts (open-ended):

- 4f. Peter Harrison of Southern Cross University created floorless mesh tents as part of his work to reseed the reefs. Have students discuss some of the variables they'd have to consider when designing such a structure. What oceanic conditions would it have to withstand? How would it be transported to the desired location and then secured? What challenges could students anticipate when designing a structure with the same goal? Students might want to draw out their plans and present them to the class.
- 4g. Identify an experiment that was described in this article. What hypothesis was tested? Can students identify the variables and whether they are dependent, independent or extraneous? Was the hypothesis validated or disproved? Students can find original research papers by following the links to "Citations" at the bottom of the [online version of "Rebuilding reefs."](#)
- 4h. How did the scientists use their results to continue their research or experimentation?
- 4i. Ask students to think of another hypothesis that could be tested to add information to support reef-rebuilding efforts. Ask them to identify the variables (dependent, independent or extraneous) of a proposed experiment and explain how these variables might be measured. If time permits, students could work alone or in teams to design an experiment to test the variables they identified.

Cross-Curricular Discussion

Directions: The following list of discussion questions is provided to help you take notes, brainstorm ideas and test your thinking in order to be more actively engaged in class discussions related to this article.

BIOLOGICAL SCIENCES

- 1a. What are some strategies for coral reproduction listed in the article? List those you find and include the pros and cons for each. Think about the potential results of combining the microfragment technique and the selective breeding strategies mentioned in the article. Would the results be beneficial? Are there ethical considerations to creating “super coral”?
- 1b. What are the pros and cons of corals reproducing sexually versus asexually (cloning)? Why would it be best to have more genetic variation in the population?
- 1c. Write the general chemical equation for photosynthesis and cellular respiration. Use this information to explain the symbiotic relationship between algae and coral.

EARTH SCIENCE AND PHYSICAL OCEANOGRAPHY

- 2a. List some greenhouse gases (including the names and any chemical formulas you know).
- 2b. Why are some gases named “greenhouse gases”? What effect are they having on the Earth?
- 2c. How does carbon dioxide, a common greenhouse gas, react with water? Try to write out the chemical reaction of carbon dioxide and water. Explain how this reaction affects the pH of ocean water.
- 2d. How does the presence of an acid affect the solubility of calcium carbonate? Write the equilibrium expression and use it as evidence to support your answer.

PHYSICAL SCIENCE AND EARTH AND SPACE

- 3a. What factors influence the concentration of light reaching the coral reefs? Which of those might be affected by human activity?
- 3b. What happens to light as it enters water?
- 3c. What is fluorescence? Why might fluorescent proteins exist in coral? What other animals can you think of that fluoresce?
- 3d. In terms of light energy, compare fluorescence and photosynthesis.

ENGINEERING AND EXPERIMENTAL DESIGN

- 4a. What are some local threats to corals?
- 4b. What are specific communities doing to minimize their negative impact on the reefs?

- 4c. Are all reef-adjacent communities facing similar challenges?
- 4d. What are foundations and organizations, such as Reef Check, doing to help educate local populations and support them in finding solutions that protect local reefs?
- 4e. How can communities develop a coral bleaching response plan?
- 4f. What oceanic conditions would the tent structure developed by Peter Harrison have to withstand? How would it be transported to the desired location and then secured in place? What challenges could you anticipate when designing a structure with the same goal?
- 4g. Find an experiment that was described in this article. What hypothesis was tested? Can you identify the variables (dependent, independent or extraneous)? Was the hypothesis validated or disproved?
- 4h. How did the scientists use their results to continue their research or experimentation?
- 4i. Can you think of another hypothesis that could be tested to add information to reef-rebuilding efforts? Identify the variables (dependent, independent or extraneous) and explain how you might measure them.

Data Analysis Activities: Coral Bleaching

These activities are based on ones found at:

flowergarden.noaa.gov/document_library/eddocs/reefmonitoringlesson.pdf

Purpose: This series of activities focuses on observing change over time. In the first part, students observe photographs of a coral reef. The second activity asks students to look for patterns in data of sea surface temperatures. In the third part, students use the skills practiced to analyze a location of their choosing. These activities flow together but can be used independently.

Notes to the teacher: The National Oceanic and Atmospheric Administration maintains a robust database of weather information. Recently, NOAA has compiled interactive tools to help the public understand how weather and physical oceanography data can be used to understand local and global phenomena, such as coral bleaching. The style of the graphs that NOAA has made available may be unfamiliar, but by breaking them down into each element, students can soon see how interacting variables tell a story about the coral reef environment.

Background: When temperatures spike 1 to 2 degrees Celsius above normal for a prolonged period of time, a bleaching event can occur. These bleaching events appear to be becoming more common, threatening the health of the reef and all the organisms that depend on it. By having data on water temperature trends over time, scientists and the public can begin to find patterns and learn more about bleaching events. Such data is more than a series of numbers. When put together in a compelling manner, this data has the power not only to inform the public about a situation, but also to spark public response. There are a lot of data available through www.coralreefwatch.noaa.gov.

PART 1: OBSERVING CHANGE OVER TIME

Approximately 30 minutes

Preparation: Find a set of images that show a coral reef changing over time. The Flower Garden Banks National Marine Sanctuary has a set of monitoring images. From the sanctuary's [Image Library page](#), click on the section titled "Monitoring" and choose the location you'd like students to observe. Print the images in color (or have students examine the images online to save paper and ink).

Materials:

- Computers with Internet access OR
- Prepared images of coral reefs (printed in color)

Directions:

1. The article discusses how scientists noticed that there was a problem emerging for coral reefs. Explain that scientists will sometimes monitor a site over time and record observations in order to determine if and how a location is changing.
2. Photography is a powerful tool for recording how an environment changes. Direct students to the reef monitoring images you selected (electronic or printed). Decide if you want students to work alone or in small groups. Small groups have the benefit of increasing dialog.
3. Have students observe the images and describe changes that occurred from one year to the next. For example, a piece of coral is no longer visible or there appears to be something blocking a portion of the reef.
 - a. Have students make a grid to record their observations.
 - b. Have teams share their observations with the other groups and compare their observations.
4. Locate the Flower Garden Banks on a map (students might be exploring the eastern or western area) and have students determine the approximate geographical location of their coral reef. Ask students to research events that occurred in the region they are observing during the time of the reef photographs. What could have caused the changes that students observed? Would the changes have been natural or anthropogenic?
5. Discuss the power of using images to show the impact of natural and human-caused events. Students might brainstorm how these images could be used to inform policy makers or the general public about the impact of various events in order to raise awareness.

Optional Extension:

- Students can make a short public service announcement or flier showing what has happened to the reef and what they think caused it.

PART 2: USING DATA

Approximately 30 minutes

Materials:

- [Blackline Master 4](#) to project or pass out for students to examine

Directions:

1. Show this [NOAA animation](#) of coral bleaching events. Explain that these animations come from a series of data that are banded and colorized to help identify trends over time. This animation shows bleaching alerts over the past six months. Tell students they are going to look at a part of the Gulf of Mexico, just off the coast of Houston, Texas, known as the Flower Garden Banks National Marine Sanctuary using the given graphs.
2. Display the first graph of the Flower Garden Banks area ([Blackline Master 4](#)), covering 2013 to 2014.

3. Explain how to read the graph:

Bleaching represented on SST (focus on the purple and blue lines and text):

SST = Average Sea Surface Temperature (in purple). If the SST is greater than the temperature experienced in the hottest month (Max Monthly Mean SST, indicated by the dotted blue line), then the corals are susceptible to bleaching (indicated by the solid blue line).

Bleaching represented by DHW (focus on the orange text and figures at the bottom of the graph):

DHW = Degree Heating Weeks is the cumulative measurement of intensity and duration of thermal stress on the coral (DHW represents how many degrees greater the current average SST is from the maximum average SST for the hottest month). Significant bleaching occurs when DHW values reach 4 (indicated by the bottom dotted orange line). When the DHW is equal to 8, widespread bleaching is likely (indicated by the top dotted orange line). The level of stress is also indicated by the color-coding (light blue is no stress and dark red is Alert Level 2 Stress).

4. Ask students what the area along the bottom of the graph represents. [Months of the year.] Ask students to identify when there is a bleaching watch [July and September 2013; July, August and September 2014] and when there is a bleaching warning [August 2013; July, August and September 2014]. What about bleaching alerts? [None.]
5. Show students the next graph, from 2014 to 2015. Have them compare the data to the first graph. Do they notice any differences? If so, what?
6. What about the graphs covering 2015 to 2016? Have students look over the three graphs for similarities. Do there seem to be any patterns or trends?

PART 3: ANALYZE A REEF

Approximately 30 minutes

Materials:

- [Blackline Master 5](#) for each student
- Computers with Internet access

Directions:

1. Direct students to [NOAA's regional virtual stations](#) interactive website. Have each team explore the main page. By clicking on a pin, students can get information on current coral bleaching alerts. Have them select a location where coral reefs can be found. They can click on the "Alert Gauges & Outlook" for short- and long-term data on bleaching alerts at this location. The "Time Series Graphs & Data" link will take them to a series of data graphs from the chosen location and those surrounding it. Give students time to explore the data that is available using [Blackline Master 5](#).
2. Ask students to use the available data to tell a story about the location they selected. What do they know about the level of threat to that reef? Can students predict when the next bleaching alert is

likely to occur based on the data they have available? Can they anticipate how long the alert might last? [Blackline Master 5](#) can help guide their research.

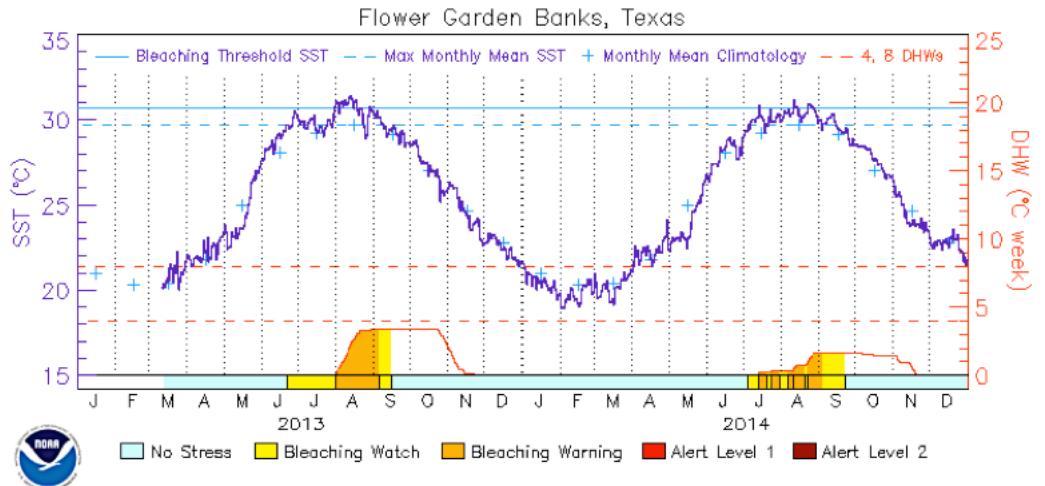
Optional Extensions:

- Students can compare data from a region to find the location that is at greatest threat.
- Students can prepare information to tell the public about the threat to the reef they are studying. Who should they share this information with? Who is the most appropriate audience? What do students want the public to do? Students might decide to write an open letter to a news outlet or an international body. They might want to create an informational video to post online.
- Many scientists use climate models to better understand phenomena like climate change. Scientists adjust the model to test ideas and see how the model is affected. Could students design an experiment using the data available through NOAA's site? What would the experiment look like? What ideas could students explore? Is there any data they wish the site provided to help create a more complete picture of the bleaching situation?

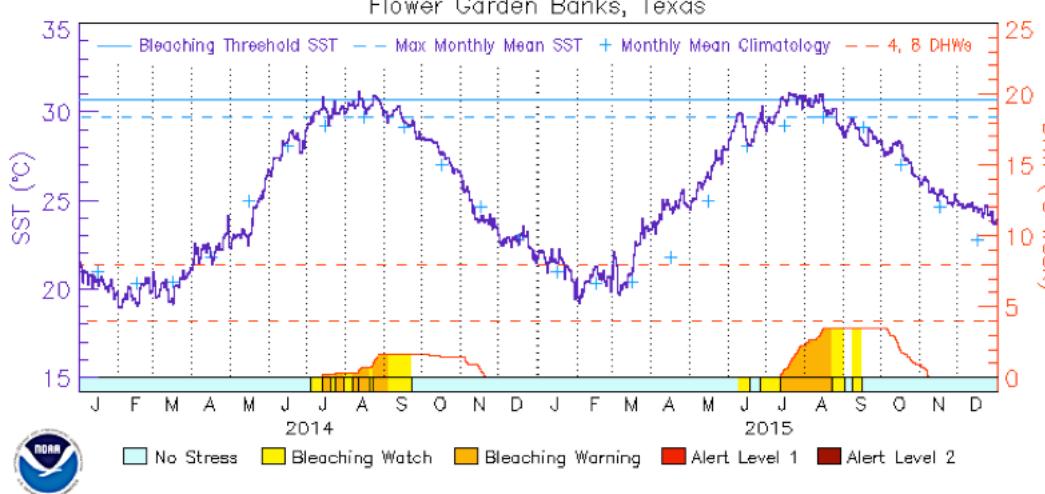
Data Analysis Activities: Part 2

Graphs from Flower Garden Banks National Marine Sanctuary

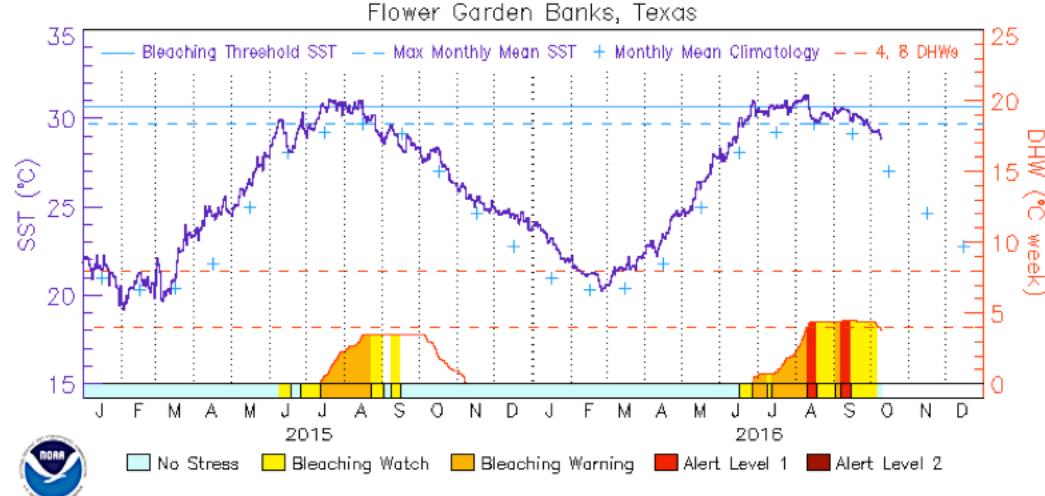
2013-2014



2014-2015



2015-2016



Data Analysis Activities: Part 3**Directions:**

1. Go to the NOAA Virtual Stations website: coralreefwatch.noaa.gov/vs/map.php. Take a look around. You can select map or satellite view. Notice the color scale along the bottom of the map and the date on the bottom left. Click on some of the pins around the world and see what information comes up. What information is provided about each location?

2. Along the top of the initial page, there are boxes with information. Click on the ones below and see if you can determine what information is given:

SST:

DHW:

BAA (Bleach Alerting Area), Give a general description of what you see:

Outlook: What happens to each of the above when you switch this to a different year?

3. Select a location and click on it. Notice that there are additional links. What information is provided from each link?

Location:

Alert Gauges & Outlook:

Time Series Graphs & Data:

