Coral Reefs in Hot Water

Coral reef ecosystems are in trouble. About 20 percent of the world's coral reefs have already been lost, and that number may climb to 50 percent in the next 20 to 40 years. The main culprits are pollution, overfishing, and climate change. In this activity, you will use satellite data to determine threats to coral reef ecosystems from warming ocean water.

What are corals?

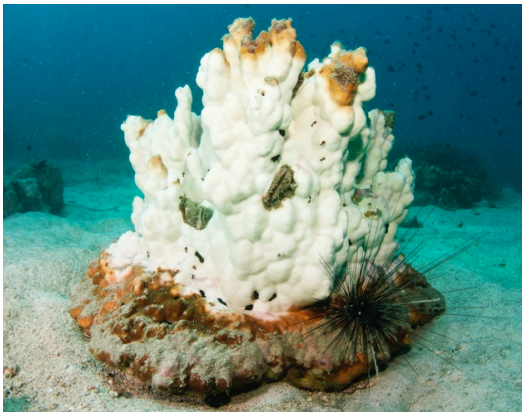
Although they may look like plants or rocks at first glance, corals are animals related to jellyfish and anemones. Individual corals are called polyps and, in many species, form colonies of identical clones. Polyps secrete a hard calcium-based skeleton that creates the physical structure of coral reefs. Reef-building corals have a limited ability to acquire food and nutrients on their own, so they rely on intracellular symbiotic algae (symbiont) that supply sugars and oxygen produced via photosynthesis.

Why study corals?

Coral reefs are a critical marine habitat, accounting for 25 percent of marine biodiversity even though they only occupy 0.015 percent of the ocean. Five hundred million people depend on coral reefs for food sources, coastal protection, building materials, and income from tourism. The net value of coral reef ecosystems has been estimated to be almost $30 billion per year.

What is coral bleaching?

Elevated temperatures can damage the photosynthetic system of the symbiont, causing them to create reactive oxygen molecules that can damage the coral cells. Corals respond by ejecting the symbionts, without which the polyps are colorless and the coral reef appears white. This is called bleaching and is a serious threat to the health of the coral reefs. Corals can survive without symbionts for short periods of time and can reacquire symbionts when heat stress subsides. However, if the bleaching is prolonged, the coral will likely die.



When does bleaching occur?

Heat stress makes corals vulnerable to bleaching. Generalizing about the amount of heat stress that corals can withstand is complicated because they are adapted to local environments and are somewhat able to acclimate to changing environments. One method to determine whether a coral is at risk of bleaching is to record when temperatures rise 1°C or more above the normal maximum for a given location. For purposes of tracking coral health, normal temperatures are determined by averaging monthly temperatures for 1985 to 1993. The warmest normal temperature is the month with the highest average temperature, called the **maximum monthly mean** (MMM). The temperatures are measured by satellites using an infrared radiation sensor and represent **sea surface temperature** (SST). Only nighttime data are used to avoid overestimating heat due to solar heating of a thin layer at the sea surface.

Heat stress is assessed by a measure called **degree heating weeks** (DHW). It is a cumulative measurement of the intensity and duration of heat stress that a coral reef experiences over a period of 12 weeks, equivalent to a season. Empirical observations suggest that bleaching occurs when four DHW accumulate within a 12-week window, and coral death occurs when DHW values are greater than 8. Because heat tolerance can vary within and between different coral species, these DHW thresholds are merely guidelines: some corals may survive in areas with high heat stress, while others may perish with relatively mild stress. Further, the temperature data is averaged over relatively large areas of 5 km^2, but actual temperatures experienced by corals may vary greatly due to local conditions. Finally, corals can recover after the stress disappears, and the 12-week window accounts for this.

PROCEDURE

We have summarized temperature data for 28 different locations. Your teacher will assign which location you should use for the procedure below.

1) **Access** the data for your location from:

   http://www.biointeractive.org/coral-temperature-data

   and download the data file associated with your location (e.g., Fiji.xls is the file for the Fiji location).

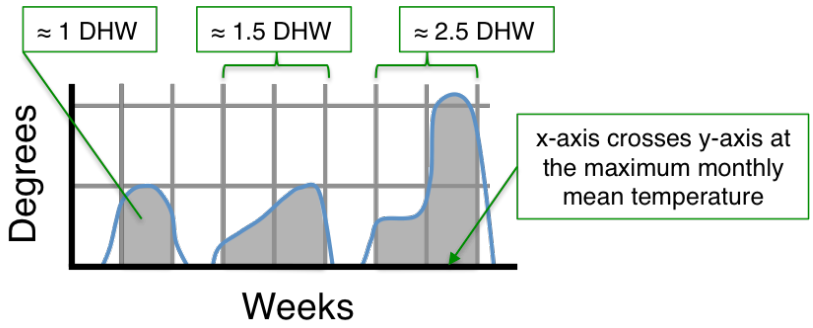
2) **Graph** the data using a spreadsheet program. You will make three graphs, each covering two years of data. Graphing instructions for Excel and OpenOffice are provided at the end of this packet.

3) **Estimate the number of degree heating weeks (DHW).**

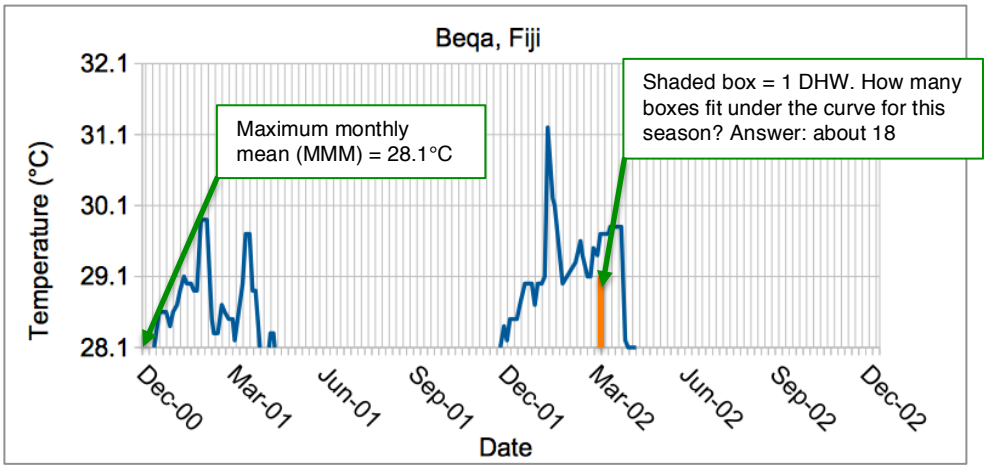
   Your graphs show two years of data to illustrate the cyclic nature of temperature, but you will estimate the DHWs only for the years **2002**, **2010**, and **2014**.

   To calculate the number of DHWs, count the boxes under every curve above the MMM that appears during that year. For instance, 1°C above the MMM for 1 week = 1 DHW, 2°C above the MMM for 1 week = 2 DHW, and so on.

Schematic example for estimating DHWs. The shaded areas represent the DHWs.



Below is an example of a temperature graph for Beqa, Fiji. In this example, the cumulative DHW is greater than 8 for 2002, so it is likely that corals at this location experienced bleaching severe enough to kill them.



4) Using the examples above as a guide, add up the DHW values for your location for the years **2002**, **2010**, and **2014**. Count all the DHWs within a 12-week window (calendar dates will vary from site to site). Tip: If the season spans January 1, then assign it to the year in which most of the heat stress occurs. For example, the 2002 hot season may actually start in December of 2001.

   a) Use the following table to assign the risk level for your location for 2002, 2010, and 2014. As shown in the table, when DHW is greater than 8, coral mortality is likely and you can stop counting.

Location:				
Latitude:				
Longitude:				
Year	**DHW = 0 No Bleaching**	**0 < DHW < 4 Bleaching Possible**	**4 < DHW < 8 Bleaching Likely**	**8 ≤ DHW Mortality Likely**
2002				
2010				
2014				

b) Find your location on the world maps provided by your teacher and mark the DHW for the corresponding years (using stickers or colored pencils as directed by the teacher). Use the completed maps to answer the following questions.

Discussion Questions

1. After analyzing the world maps, what patterns, differences, or similarities do you notice between the different years represented?

2. What geographic patterns do you notice? Are there regions of the globe that are more prone to bleaching than others?

3. Is there a global trend from 2002 to 2014? Explain:

For more information and references, check out:

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

You can also view real-time maps of threats to coral reefs in Google Earth:

http://coralreefwatch.noaa.gov/satellite/ge/index.php

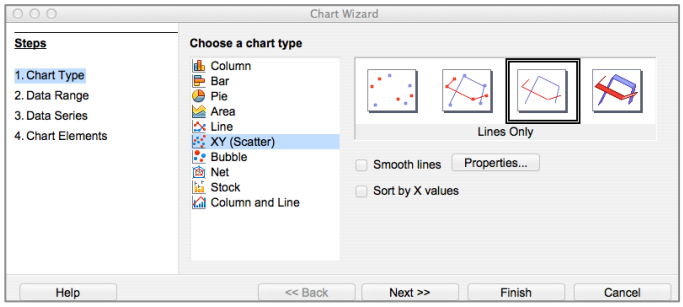
Graphing Instructions for OpenOffice

OpenOffice is free software that you can download from www.openoffice.org.

A. Open OpenOffice and then open the data file for your location (downloaded from the Dropbox folder).

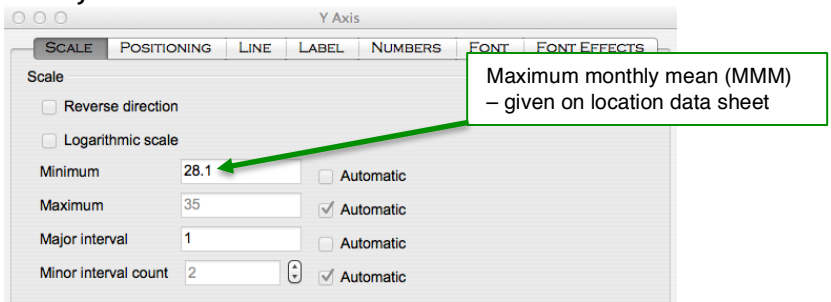
B. Select the date and sea surface temperature (SST) columns that you wish to graph and click on the graph icon on the menu bar. 

C. Choose "XY (scatter)" as the chart type and then "Lines Only."



D. The *x*-axis should be "time" and the *y*-axis should be "temperature."

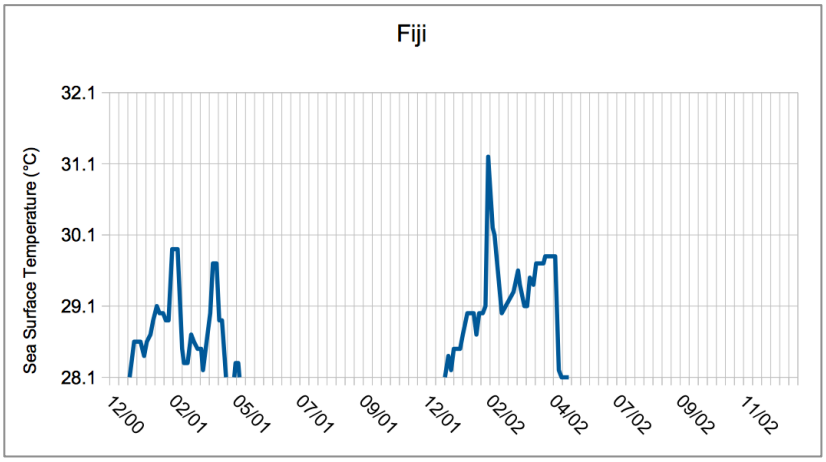
E. Double-click on the *y*-axis and set the axis minimum to the MMM for your location and set the major interval to 1.



F. Double-click on the *x*-axis and set the major interval to 7 days (i.e., 1 week). You may wish to rotate the axis labels by selecting "Label" on the axis formatting pane.

G. Show the major *x*-axis gridlines by selecting "Insert" and then "Grids" from the top menu.

H. See example below.



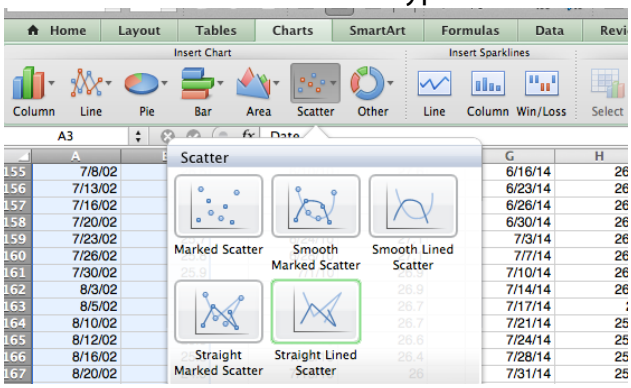
Graphing Directions for Excel

These directions are for Excel for Mac 2011. Other versions of Excel will work fine, but the menus might appear slightly different.

A. Open Excel and then open the data file for your location (downloaded from the Dropbox folder).

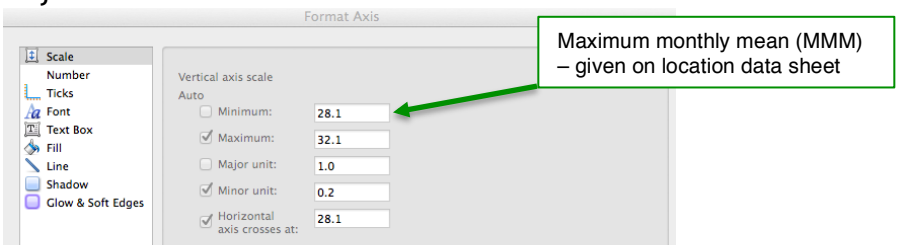
B. Select the date and sea surface temperature (SST) columns that you wish to graph and click on "Charts" on the menu bar.

C. Choose "Scatter" as the chart type and then "Straight Lined Scatter."



D. The *x*-axis should be "time" and the *y*-axis should be "temperature."

E. Double-click on the *y*-axis and set the axis minimum to the MMM for your location and set the major unit to 1.



F. Double-click on the *x*-axis and set the major interval to 7 days (i.e., 1 week). You may wish to rotate the axis labels by selecting "Label" on the axis formatting pane.

G. Show the major *x*-axis gridlines by selecting "Chart Layout" and then "Gridlines" from the menu.

H. See example below.