

## Coral Reefs and Global Warming

#### **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 over previous decades. 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 km², 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**

In 2005, Eakin *et al.* (2010) directly assessed coral bleaching in the Caribbean. This study enables us to compare actual bleaching events in 2004-2005 to predicted bleaching events, which were based on sea surface temperature (SST) and estimated degree heating weeks (DHW). In this exercise you will assess accuracy of bleaching predictions to actual bleaching data and draw conclusions about the utility of using SST to predict bleaching events. To explore datasets and the different metrics of temperature stress to corals beyond this activity go to NOAA's Coral Reef Watch and monitoring stations here: http://coralreefwatch.noaa.gov/satellite/vs/

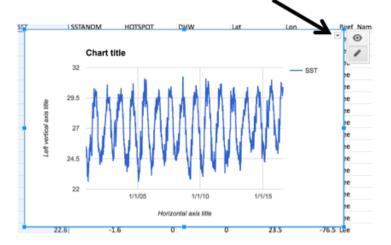
- 1. Your group will be assigned to examine one of four coral reef regions:
  - Bermuda
  - U.S. Virgin Islands
  - Puerto Rico
  - Bahamas

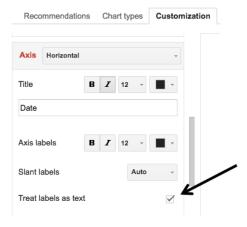
To analyze the data and draw conclusions you will work in pairs, and then you will compare your results with other group members prior to creating your final figure to share with the class.

- 2. Go to the Google Sheet provided by your instructor on Blackboard. Your data has already been extracted from NOAA from: http://coralreefwatch.noaa.gov/satellite/vs/caribbean.php
  - Click on the tab for your specific group
    - Since you will be working in pairs (if there are 4 at your table) choose one of the two tabs with your location (i.e. choose "Bermuda\_1" or "Bermuda\_2"). Make sure that you are only making edits to your tab.
- 3. Get oriented with your table. What do my column labels mean? The time series data are extracted in four-day composites from the monitoring stations. The beginning and end times for each measurement are represented in the first eight columns:
  - BYYY, BM, BD, BH = year, month, day, and hour of the beginning time point
  - EYYY, EM, ED, EH = year, month, day, and hour of the ending time point
  - SST: Twice-weekly sea surface temperature composite value
  - SSTANOM: The difference between the SST and the daily climatological SST
  - HOTSPOT: HotSpots values are greater than zero when bleaching thermal stress is present DHW:
     Bleaching Degree Heating Weeks (DHW) value in the units of degree Celsius-weeks. The DHW is a measure of thermal stress accumulated over a 12-week period.
  - Lat and Lon: Latitude and longitude of the center of the pixel with the monitoring station Reef\_Name:
     The name of the reef site to which the virtual station is associated.
- 4. You'll need to create a Date column for better visualization of the data. To do this you will need to combine the beginning date data into a single column that can be the X-axis.
  - Create a new column at the end of the dataset, all the way to the right of the dataset. Title the new column "B-Date".
  - To easily create this data write the formula "=Date(A2, B2, C2)", where BYYY is located in cell A2, BM is located in cell B2, and BD is located in cell C2 (remember that starting a cell entry with "=" tells Google sheets to read it as a formula).
  - Copy the formula down to the last data row by clicking on the cell, move the cursor to the bottom right of the cell (small blue box), cross hairs will appear in place of your cursor, click and drag the your cursor all the way to the bottom of the dataset. This will autofill the entire column using the formula.
- 5. Plot the data for your site by selecting B-Date and SST columns and Insert Chart.
  - Select both by first clicking on the column B-Date (click on the letter above to highlight the entire column) hold the control key and click on SST (again, click on the letter above to highlight the entire column).
  - Once both columns are highlighted click on the "Insert" heading above and select "Chart" from the pull-down menu.
    - Select "Line" from the Chart Types. Click Insert (bottom left blue button).

•	Why is a line graph the most appropriate choice to visually depict this data?				
•	What should be on the x-axis? (circle one)  • Explain:	Date	SST		
•	What should be on the y-axis? (circle one)  • Explain:	Date	SST		

 Label your axes and format the x-axis by clicking on the graph and placing cursor in the upper right corner. A triangle will appear. Click on the triangle and choose "Advanced edit..." When labeling the x-axis check the box "Treat data as text"





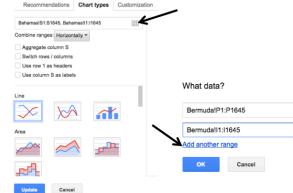
• Examine the resulting figure. What trends are immediately obvious? Do you think these trends are normal? What might explain the patterns you are observing?


6. Add a solid line to indicate the Threshold Temperature for bleaching concern (Maximum Monthly Mean or MMM SST). Recall that a Hot Spot is defined as MMM  $+ 1^{\circ}$ C, and use the temperatures that register as Hot Spots to determine the MMM value.

• Find your minimum value greater than 0 in the Hot Spot column (usually 0.1) by scrolling through your data and then look at the SST for that row. Add 1°C to that SST get your MMM + 1°C.

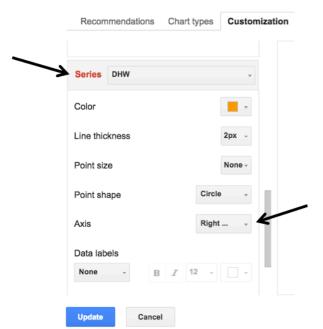
• Enter this value in a new column and copy it down the entire length of the dataset (same way that you did for the formula autofill). Title the column "MMM".

- Add a second series to your graph to visualize this line in relation to the variation in SST.
  - To add a second data series to your figure. Again, click on the triangle and chose "Advanced edit...".
     Go to Chart Types and click on the graph squares (Select Chart Series). Then click the blue "Add another range". Click the new empty box, then highlight the "MMM" column from your datasheet. Click Ok (blue button, bottom left).
  - This line should appear as a different color.



 Are there any years in which the risk was especially high? Recall that high risk is associated with years in which the SST is above the MMM.


- 7. Add a third series to your graph for Degree Heating Weeks (DHW).
  - Following the instructions above add Degree Heating Weeks (DHW) to your figure.
    - To add a third series to your figure. Again, click on the triangle and chose "Advanced edit...".
       Go to Chart Types and click on the graph squares (Select Chart Series). Then click the blue "Add another range" with your cursor in the new empty box highlight the "DHW" column from your datasheet. Then click Ok (blue button, bottom left).
    - o Again, this line should appear as a different color.
    - You will need to adjust the axes after adding the "DHW" data. Again, click on the triangle and chose "Advanced edit...". Under the Customization tab scroll down to the Series tab, click the pull-down menu to "DHW". Then click the axis pull-down menu just below and select "right axis". This will put the SST and DHW on two different axes.
    - Label the right axis by clicking on the pull-down horizontal axis.
  - What do you notice about the DHW and SST variation and patterns?



Recall the relationship between Degree Heating Weeks
 (DHW) and bleaching risk. Consider the following standards when looking at your figure.

○ No bleaching: DHW=0

Bleaching possible: 0<DHW<4</li>
 Bleaching likely: 4<DHW<8</li>
 Mortality likely: 8≤DHW

Look specifically at the Degree Heating Weeks <u>over the two-year period of 2004-2005</u>. How much bleaching risk do you expect for your site? Justify your answer.

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8. Copy one representative final figure from your group onto the summary Tab on the Google Sheet. Look at the other figures generated for the 3 other locations in the Caribbean and answer the questions below.

How do your results compare to other sites in the Caribbean? Is the bleaching risk between 2004-2005 higher or lower at your site compared to other sites?

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