Module 5: Early Warning Systems

Section 1: Tools to Predict Mass Bleaching

Learning Objectives

By the end of this lesson you will have:

- An understanding of the importance of early warning systems in predicting mass bleaching events.
- A basic understanding of remote sensing and how satellites measure sea surface temperature (SST).
- The ability to access and interpret SST and SST anomaly data on the NOAA website.
- A knowledge of the methodology Coral Reef Watch uses to predict bleaching from satellite measurements of sea surface temperature.
- A suite of tools that will warn managers when their reefs might be at risk from elevated temperatures.

Background

A manager's response to bleaching has three major components: An early warning system for predicting and identifying mass bleaching events, an assessment and monitoring program to measure the impacts of bleaching, and a communication program. An early warning system provides information for managers to communicate to the media, government and stakeholders about the likelihood of bleaching events. Early warning systems also allow managers to identify the location and potential extent and severity of bleaching events to be able to mobilize an assessment and monitoring response.

Prediction of bleaching serves three main purposes: It allows managers to predict whether a bleaching event is likely to occur and how severe the impacts might be, it helps managers prepare for an impending bleaching event in order to monitor and manage impacts, and it also helps mangers identify where the greatest impact is likely to be and therefore where to focus management, assessment and monitoring efforts. Mass coral bleaching is preceded by environmental conditions that can be tracked to provide managers with an effective early warning system for bleaching events.

An understanding of the factors that influence sea temperature has the potential to enable managers to predict the probability of occurrence and severity of a bleaching event. In theory, the relationship between climate patterns, seawater heating, and mass bleaching should provide a mechanism for such predictions. In particular, the weather

patterns associated with phenomena such as the El Niño Southern Oscillation or the Pacific Decadal Oscillation can be associated with regional and local warming sea temperatures. Weather patterns also provide a useful indication of whether bleaching risk is increasing or decreasing. Longer-term predictions, such as seasonal forecasts, can be used to assess the probability of weather conditions that contribute to increasing sea temperatures occurring over timescales of weeks to months. For example, seasonal outlooks for the hot season that predict above-average air temperatures and decreased storm activity indicate that there is an increased probability of conditions that can lead to stressful sea temperatures.

Shorter-term predictions, such as weekly weather forecasts, indicate whether sea temperatures will increase or decrease in coming days and weeks. The risk of mass bleaching is higher when forecasts are for high air temperatures and extended periods of clear skies, low wind and neap tides. In contrast, forecasts for stormy conditions with cooler air temperatures, high cloud cover and strong winds indicate that sea temperatures may stabilize or decrease over the coming week. Once atmospheric conditions suggest the development of unusually warm conditions, measurements of sea temperatures provide a more direct indication of the potential for mass coral bleaching. Temperature stress can be monitored using satellite imagery and in-water instruments.

Sea surface temperature (SST) is known to be variable in both space and time. Fortunately, we can measure this temperature globally and in near-real-time, from the polar-orbiting satellites that NOAA deploys. This technique is known as remote sensing.

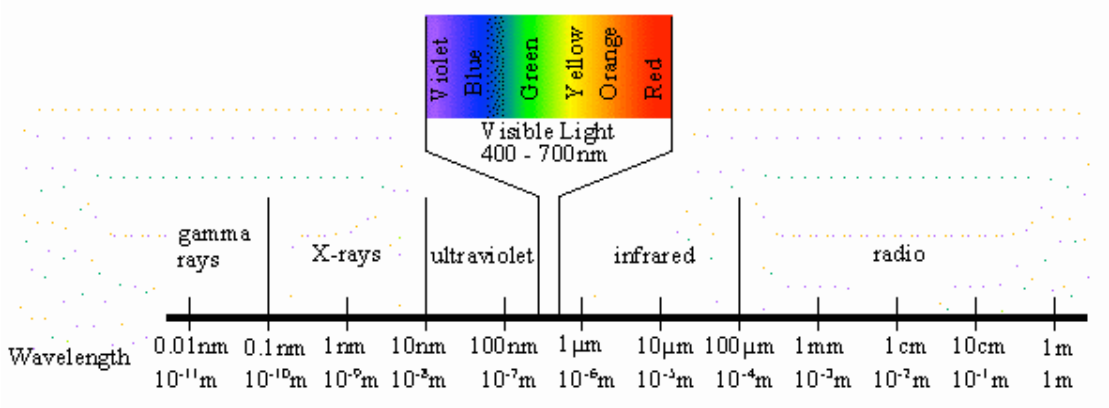
<u>What is remote sensing?</u>

Basically, remote sensing means measuring some property of an object without actually touching it. Usually, we add some interpretation to this measurement to draw conclusions about the object we are sensing.

For example, our eyes and ears are remote sensing instruments, and in fact humans are all skilled remote sensors. Let's take an example. How can you tell if the burner on an electric stove is hot, without touching the surface and burning your hand? There are actually two ways that you use remote sensing to tell whether the burner is cool or hot. The first way is to look at the color of the burner. If it is red, you can interpret that color to mean that the burner is very hot. But if the color is black, the stove still may be quite hot. What other sense can you use to detect if the burner is warm?

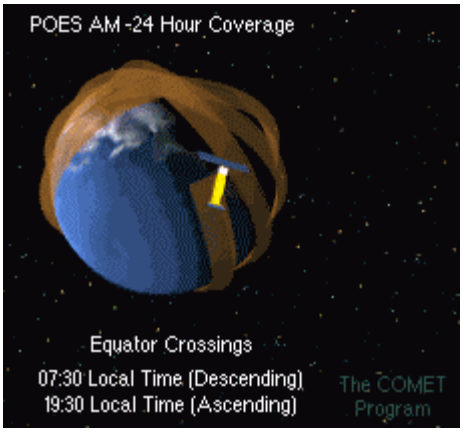
Answer: If you put your hand close to the burner, you can feel the heat without touching the surface. Your skin is actually sensing the infrared radiation from the stove. As you will see, this is similar to the way satellites measure the temperature of the ocean's surface.

Remote sensing uses sensors that measure parts of the electromagnetic spectrum. This "spectrum" is a way of talking about natural energy: from x-rays and ultra-violet light (UV), through visible light, to infrared (IR) and microwaves. At the right are high-energy waves like gamma rays, which pass right through physical matter. In the center is a narrow band of energy that our eyes are tuned to detect—visible light, from higher-energy blue light to the lower-energy red. The next section of this spectrum is called infrared. This is energy that we can feel as heat, like what comes off the hot burner on your stove. All the way at the lower (left) end are radio waves, which have low energy and long wavelengths. Many of these forms of energy are used in remote sensing.



Satellite remote sensing

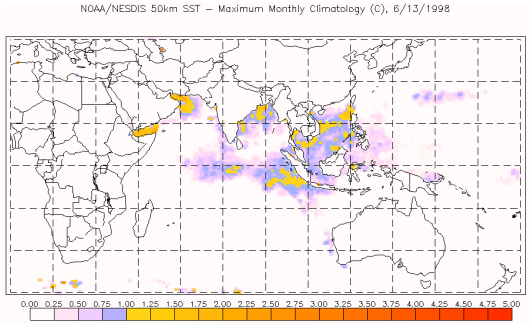
NOAA operates two different types of satellites that carry remote sensing instruments. Geostationary satellites stay in the same position relative to Earth, so they can take frequent measurements of an area throughout the day and night. However, each satellite can only see a fraction of the Earth's surface. Because coral reefs are located all around the world, the Coral Reef Watch program uses NOAA's polar-orbiting satellites. Although they can only measure a given area once or twice a day, they have the advantage of getting measurements around the entire planet.



There are only 4 properties of the ocean that a satellite can directly measure:

- How far away is the water surface?
- How rough is the surface?
- What color is the water?
- What is the temperature of the water?

It is this last property that can be directly used in monitoring for bleaching conditions.



The Coral Reef Watch program has customized NOAA's satellite SST measurements into trusted data products that highlight areas that are currently at risk for coral bleaching. HotSpot maps (Strong et al. 1997) show SSTs that are currently above the monthly mean temperature we expect to see in the hottest month. The mapped HotSpots are updated twice each week, and have proven to be a very reliable indicator of current temperature stress in coral reef areas. However, we also know that the duration of the heat stress is also important in predicting the severity of coral bleaching. Coral Reef Watch therefore also produce Degree Heating Week (DHW) maps that combine the HotSpot intensity of the temperature anomaly with the duration of exposure, providing a composite picture of cumulative thermal stress over the last 12 weeks. One DHW is equivalent to one week of SST at 1 °C greater than the expected summertime maximum. Two DHWs are equivalent to two weeks at 1 °C above the expected maximum or one week of 2 °C above the expected maximum. At DHWs over 4, the Coral Reef Watch program issues a Coral Bleaching Alert that mass bleaching is likely to be occurring.

Worksheet or Activity

Activity: "You Make the Call"

Purpose: The purpose of the "You Make the Call" exercise is to integrate information from many different sources to determine if the reef you are managing is at risk for bleaching. The exercise spans three weeks, and participants will consider how changing weather, sea surface temperature, and local conditions might change the threat of bleaching.

Instructions: Instructor will divide participants up into four groups based on their location in the room. Your group will receive a piece of paper with a type of reef and basic information about the reef. The information will include:

- Reef type
- Tidal range
- Important information about adjacent landscape features, uses, etc.
- Current Conditions

- Recent Weather
- Satellite Bleaching Alert Status
- Bleaching Observations
- Other Relevant Events

Based on current conditions for this first week including recent weather, satellite bleaching alert status, bleaching observations and other events you will be asked to determine how great a threat your reef is for widespread coral bleaching. Once the threat level is determined for week 1, updated information for week 2 and then week 3 will be passed out. Based on changes in weather, satellite bleaching alert status, etc. participants will be asked to revise their threat level over time.

On-the-Web

NOAA Coral Reef Watch:

Homepage: http://coralreefwatch.noaa.gov/satellite

Tutorial on our data products:
http://coralreefwatch.noaa.gov/satellite/education/tutorial/welcome.html

Sign up for free Satellite Bleaching Alert e-mails: http://coralreefwatch-satops.noaa.gov/SBA.html

Florida Keys BleachWatch program:
http://isurus.mote.org/Keys/bleaching.phtml

Florida Keys Current Conditions Reports:
http://isurus.mote.org/Keys/current_conditions.phtml

Great Barrier Reef Current Conditions Reports:
http://www.gbrmpa.gov.au/corp_site/info_services/science/climate_change/management_responses/current_condition_reports/

GBRMPA Bleachwatch Program:
http://www.gbrmpa.gov.au/corp_site/info_services/science/climate_change/management_responses/bleach_watch2.html

ReefTemp: (Australian high-resolution satellite bleaching tools)
http://www.cmar.csiro.au/remotesensing/gbrmpa/ReefTemp.htm

Mesoamerican Coral Reef Watch Program:

http://mesoamericanreefwatch.net/en/bleachwatch/bleachwatch.php

Other key links:
NOAA Coral Reef Conservation Program, with info on all of NOAA's coral reef activities:
http://www.coralreef.noaa.gov/

Submit a bleaching report to ReefBase:
http://www.reefbase.org/contribute/bleachingreport.aspx

Publications and References

Brown, B.E. (1997). Coral bleaching: Causes and consequences. *Coral Reefs* 16: S129-S138.

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Glynn PW, D'Croz L (1990) Experimental evidence for high temperature stress as the cause of El Niño- coincident coral mortality. Coral Reefs 8: 181-191.

Goreau, T. J. and R. Hayes, 1994. Coral Bleaching and Ocean "Hot Spots." *Ambio*, 23:176-180.

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IPCC (2001). *Climate Change 2001: The Scientific Basis.* Published for the Intergovernmental Panel on Climate Change by the Cambridge University Press, Cambridge, United Kingdom.

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Strong, A. E., F. Arzayus, W. Skirving, and S. F. Heron. Identifying coral bleaching remotely via Coral Reef Watch – improved integration and implications for climate change. Chapter 9 in *Coral Reefs and Climate Change: Science and Management*, J. T. Phinney, O. Hoegh-Guldberg, J. Kleypas, W. Skirving, and A. E. Strong (Co-Eds), American Geophysical Union, 2006.

Slides

Section 2 Community-based Monitoring

Learning Objectives

By the end of this lesson you will:

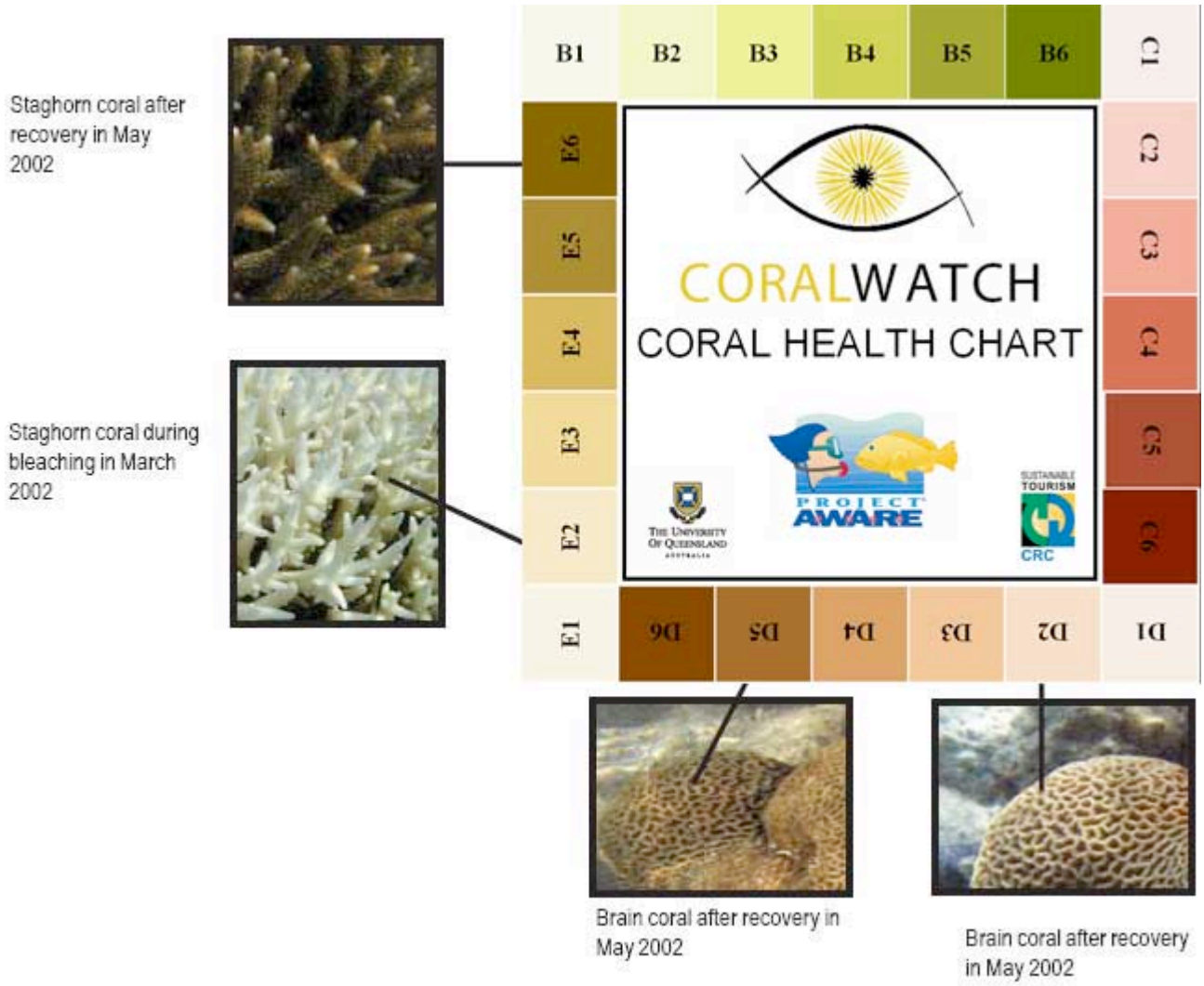
- Understand the role of community or citizen monitoring in an Early Warning System and as a component of a management response to a mass coral bleaching event, disease outbreak, etc.
- Understand the components of community-based monitoring and its strengths and weaknesses.
- See examples of a number of community-based monitoring programs.
- Understand the role of ReefBase.

Background

One the first community-based monitoring programs was established on the Great Barrier Reef by the University of Queensland. The following information was taken from their website (http://www.coralwatch.org/ProjectDetails/default.aspx).

Current attempts to monitor coral bleaching often involve costly satellite-born technologies, are restricted to locations researcher are working in and often require sampling of live tissue for physiological analysis. Our coral reef monitoring approach using color charts is the first attempt to provide useful data on a relatively large scale with the help of an inexpensive, 'user friendly' and non-invasive device. At the University of Queensland, Australia we have developed a method of coral health monitoring which uses simple color charts, like paint color matching charts. This is a result of the unusual union between world leading vision and color experts at VTHRC (Vision, Touch and Hearing Research Centre) and world leading coral experts at CMS (Centre for Marine Studies). The color charts can be used by anyone, scientists, school children, tourists and politicians. Perhaps most importantly, the opportunity for everyone to participate in a global reef-monitoring project removes the sense of hopelessness felt by many in the face of outcomes predicted from global warming. With this monitoring program we also aim to educate the public about coral bleaching and its devastating effect on coral reefs.

This is how it works: The color charts are based on the actual colors of bleached and healthy corals. Each color square corresponds to a concentration of symbionts contained in the coral tissue. The concentration of symbionts is directly linked to the health of the coral. All you have to do is match the color of the coral with one of the colors in the coral health monitoring chart. You then record the matching color codes, along with coral type (species if possible), on the website data sheet (***www.coralwatch.org***).



Why we need your help: Little is known about trends of coral bleaching on a global scale, though as these bleaching episodes increase in frequency we are learning more. Currently coral health monitoring mainly occurs around a few reefs that are regularly visited by scientists. There are many questions that will have to be answered in order to try and save the reefs. This is where you can help! If many people around the world, like you, participate in the monitoring program we will be able to answer questions such as:

1. Large and small-scale pattern of coral bleaching: Based on water temperature measurements and knowledge of currents, it is possible to predict which areas will be affected by bleaching. We hope to answer several questions within this. Do all reefs bleach during every El Niño event, or are there some reefs/zones of reef that never bleach? Does the same reef bleach every time?
2. Duration and severity of coral bleaching: How long are different reefs affected by bleaching events? How severely are different reefs around the world affected? Is the severity and duration dependent on whether or not a reef has bleached before? Does the overall health of the reef get worse from one bleaching event to another?

3. Large and small scale pattern of recovery: To date most research has concentrated on the onset of bleaching rather than recovery. With your help it will be possible to measure recovery - how long after the drop in water temperature do different reefs recover? How long does recovery take? Is it variable between different reefs and different coral types?

With your help it will be possible to monitor coral health throughout the year, not just during bleaching events. It is important to measure the small natural fluctuations in the coloration of healthy corals, which do happen seasonally, so that we can immediately identify if there is a color change outside the normal range. In this way it will be possible to find out if there are other factors that may influence coral health throughout the year. (Source http://www.coralwatch.org)

Using this sentinel community-based monitoring program as a template, many other such programs have been developed around the world. We will discuss some of those projects as well as their many levels of usefulness to scientists and managers.

Worksheet or Activity

Activity: Take your Coral Watch kit out to the reef and practice being part of a citizen monitoring program.

Activity: Explore the ReefBase website on your own (www.reefbase.org).

Worksheet: "Monitoring and Reporting Bleaching Conditions" in your Bleaching Response Plan

MONITORING AND REPORTING BLEACHING CONDITIONS

The activities in the right-hand column are examples of activities related to monitoring and reporting bleaching
modify these as is appropriate for your site. It is important to identify these activities and who will be responsib
Choose a back-up who is not likely to be on travel or vacation at the same time as the primary person. Deterr
activities. The Great Barrier Reef Marine Park Authority table of activities is provided on the back of this shee

Frequency (e.g. weekly)	Timing (e.g. every Monday)	Person Responsible (also provide back-up)	Activity (modify and fill in other activities as needed)
Routine tasks:			
			Check the NOAA Seasonal Bleaching Outlook
			Check NOAA HotSpot & DHW maps on web
			Receive and review Coral Reef Watch Satellite Bleaching Aler
			Review weekly weather summary (e.g., air temp, cloud cover a
			Review Coral Reef Watch reports and update maps
			Make use of traditional Hawaiian seasonal prediction tools
			Brief senior management team on weather and heating condit
			(optional: if you publish bleaching conditions on your website) and coral conditions and draft bleaching risk current conditions recent images. Announce web update and send brief report.
			Monitor extent of bleaching using existing information channel
			Advise senior management if dramatic worsening of condition
			Others:
Responsive tasks:			
			Actively solicit confirmatory bleaching reports from reliable sou monitoring participants, field scientists, tourist/dive operators,
			Alert relevant project coordinators and managers
			Brief senior management
			Brief elected officials
			Prepare media position, draft statement and consult with medi
			Brief all staff, stakeholders and collaborators
			Release media statement
			Actively promote and solicit submissions to online bleaching re spatial coverage
			Implement Bleaching Assessment and Monitoring component
			Others:

MONITORING AND REPORTING BLEACHING CONDITIONS
EXAMPLE: From GBRMPA Bleaching Response Plan

Frequency	Timing	Person Responsible (back-up)	Activity
weekly	Monday		Check GBRMPA ReefTemp and NOAA HotSpot maps on web
			Receive updated Great Barrier Reef sea temperature graphs from AIMS
			Review weekly weather summary, for example air temp, cloud cover and wind from Bureau of Meteorology
			Review BleachWatch (including BleachWatch Aerial) reports and update maps
			Print out ReefTemp and NOAA HotSpot maps for GBRMPA Climate Change Group Director to brief senior management team
Weekly/ fortnightly	Tuesday		Summarise weather, sea and coral conditions and draft bleaching risk current conditions report for website. Include recent images.
Weekly/ fortnightly	Wednes-day		Have updated current conditions report reviewed, approved and published on external web
			Announce web update and send brief report
Weekly/ fortnightly	Constant		Monitor extent of bleaching using existing information channels and evaluate for trends (ie change in bleaching extent)
			Advise GBRMPA senior management team and the Minister for the Environment, Heritage and the Arts if dramatic worsening of conditions is evident
Event-based	High bleaching risk		Actively solicit confirmatory bleaching reports from reliable sources, including BleachWatch participants, Day-to-Day Management field officers, AIMS, other researchers, etc.
			Alert relevant project coordinators and managers
			Brief GBRMPA senior management team
Event-based	Moderate bleaching event detected		Brief GBRMPA executive and the Minister for the Environment, Heritage and the Arts
			Prepare media position, draft statement and consult with GBRMPA media coordinator and executive
			Brief all GBRMPA staff, stakeholders and collaborators
			Release media statement
			Actively promote and solicit submissions to online bleaching reports to provide wide spatial coverage
			Implement Bleaching Assessment and Monitoring component

On-the-Web

Coral Watch (University of Queensland):
www.coralwatch.org

Bleach Watch (Great Barrier Reef Marine Park Authority):
http://www.gbrmpa.gov.au/corp_site/key_issues/climate_change/management_responses/bleach_watch2.html

Eyes on the Reef, Reef Check Hawaii:
http://www.reefcheckhawaii.org/eyesofthereef.htm

Florida Keys Bleach Watch:
http://isurus.mote.org/Keys/bleaching.phtml

MesoAmerican Coral Reef Watch Program:
http://www.marcoralwatch.net/

Slides