




National Aeronautics and
Space Administration



ARSET

Applied Remote Sensing Training

<http://arset.gsfc.nasa.gov>

 @NASAARSET

Introduction to Remote Sensing for Ocean and Coastal Applications

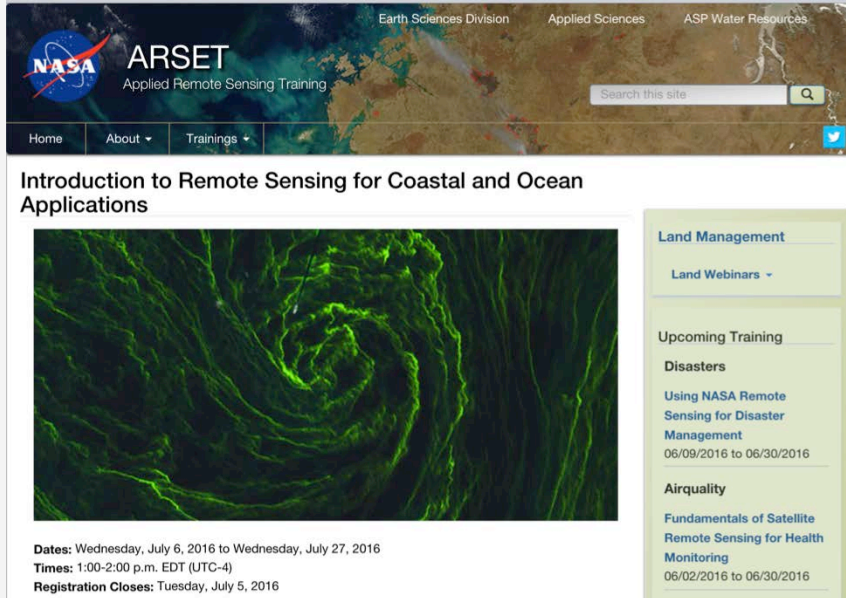
Week 4: Coral Reefs

Course Structure

- One lecture per week – every Wednesday July 6 – July 27
- 1:00 – 2:00 PM EDT (UTC-4)
 - Lectures
 - In-class demonstration
 - Homework exercises, due August 10th
- Webinar recordings, presentations, and homework assignments can be found after each session at:
 - <http://arset.gsfc.nasa.gov/land/webinars/coastal-oceans-2016>
- Q/A: Following each lecture and/or by email (sherry.l.palacios@nasa.gov)

Accessing Course Materials

<http://arset.gsfc.nasa.gov/land/webinars/coastal-oceans-2016>



The screenshot shows the ARSET (Applied Remote Sensing Training) website. The header includes the NASA logo, the text "ARSET Applied Remote Sensing Training", and navigation links for "Earth Sciences Division", "Applied Sciences", and "ASP Water Resources". A search bar is present. Below the header, there are navigation tabs for "Home", "About", and "Trainings". The main content area features the title "Introduction to Remote Sensing for Coastal and Ocean Applications" and a large satellite image of a coastal area with green and blue patterns. To the right of the image is a sidebar with sections for "Land Management", "Land Webinars", "Upcoming Training", "Disasters", "Using NASA Remote Sensing for Disaster Management", "Airquality", and "Fundamentals of Satellite Remote Sensing for Health Monitoring".

Introduction to Remote Sensing for Coastal and Ocean Applications

Dates: Wednesday, July 6, 2016 to Wednesday, July 27, 2016
Times: 1:00-2:00 p.m. EDT (UTC-4)
Registration Closes: Tuesday, July 5, 2016

Land Management

Land Webinars

Upcoming Training

Disasters

Using NASA Remote Sensing for Disaster Management
06/09/2016 to 06/30/2016

Airquality

Fundamentals of Satellite Remote Sensing for Health Monitoring
06/02/2016 to 06/30/2016

Course Agenda:

[Agenda.pdf](#)

Session One: Overview of Satellite Remote Sensing of Aquatic Environments

July 6, 2016

An overview of themes in coastal and ocean applied science, how remote sensing is used for coastal and ocean applied science, fundamentals of remote sensing (spatial, temporal, spectral resolutions), and the advantages and limitations of remote sensing in aquatic environments. [View the recording »](#)

- [Presentation Slides »](#)

Session Two: Platforms and Sensors for Ocean Observations, Data Access, and Processing Tools

July 13, 2016

Satellites and sensors for coastal and ocean applications, satellite data processing levels, NASA satellite data access tools and data processing tools. [View the recording »](#)

- [Presentation Slides »](#)

Your Course Instructors

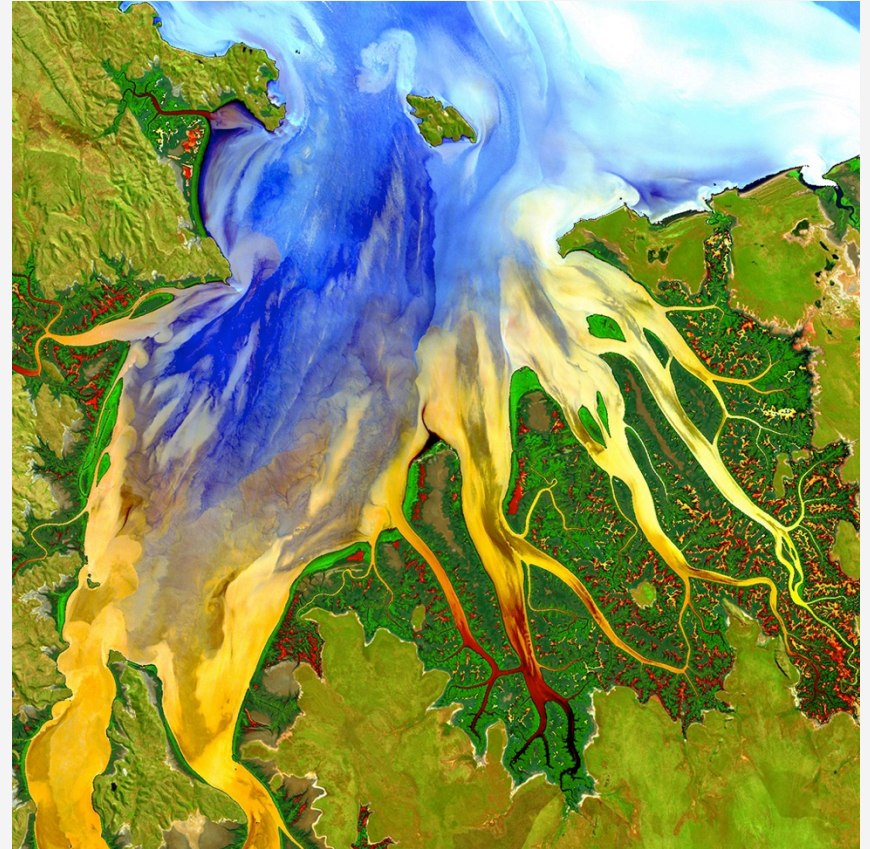
- Sherry Palacios: sherry.l.palacios@nasa.gov
- Amber McCullum: amberjean.mccullum@nasa.gov
- Cindy Schmidt: cynthia.l.schmidt@nasa.gov

- Guest Speakers:
 - Mitchell Roffer, Roffer's Ocean Fishing Forecast Service (Week 3)
 - Mark Eakin, NOAA Coral Reef Watch (Week 4)

- General ARSET Inquiries
 - Ana Prados: aprados@umbc.edu

Course Objectives

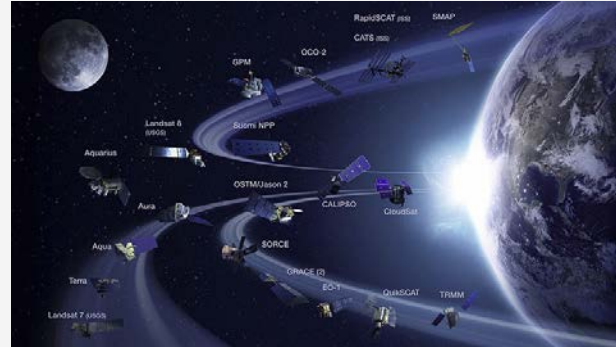
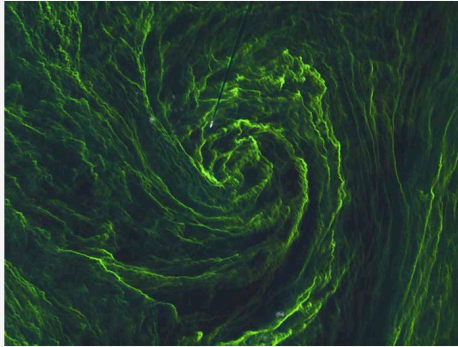
- Overview of NASA Earth Observation resources available for open ocean and coastal applications including:
 - A basic understanding of remote sensing of aquatic systems
 - How to access and visualize NASA Earth science data
 - How to use NASA Earth science data, tools, and products for ocean and coastal applied science issues
- Conduct live demonstrations of useful ocean and coastal applied science tools



Credit: NASA/USGS Landsat; Geoscience Australia

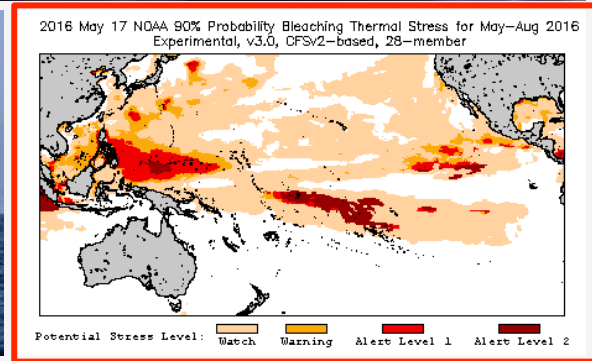
Course Outline

Week 1
Overview of
Satellite
Remote Sensing



Week 2
Platforms
and Sensors
for Ocean
Observations

Week 3
Animal
Movement



Week 4
Coral Reefs

Week 4 Agenda

- Overview of coral biology
- Threats to coral reefs
 - Local
 - Global
- Remote sensing of coral reefs
- Examples of remote sensing tools for understanding coral reef systems
- Live Demo:
 - Dr. Mark Eakin: NOAA Coral Reef Watch



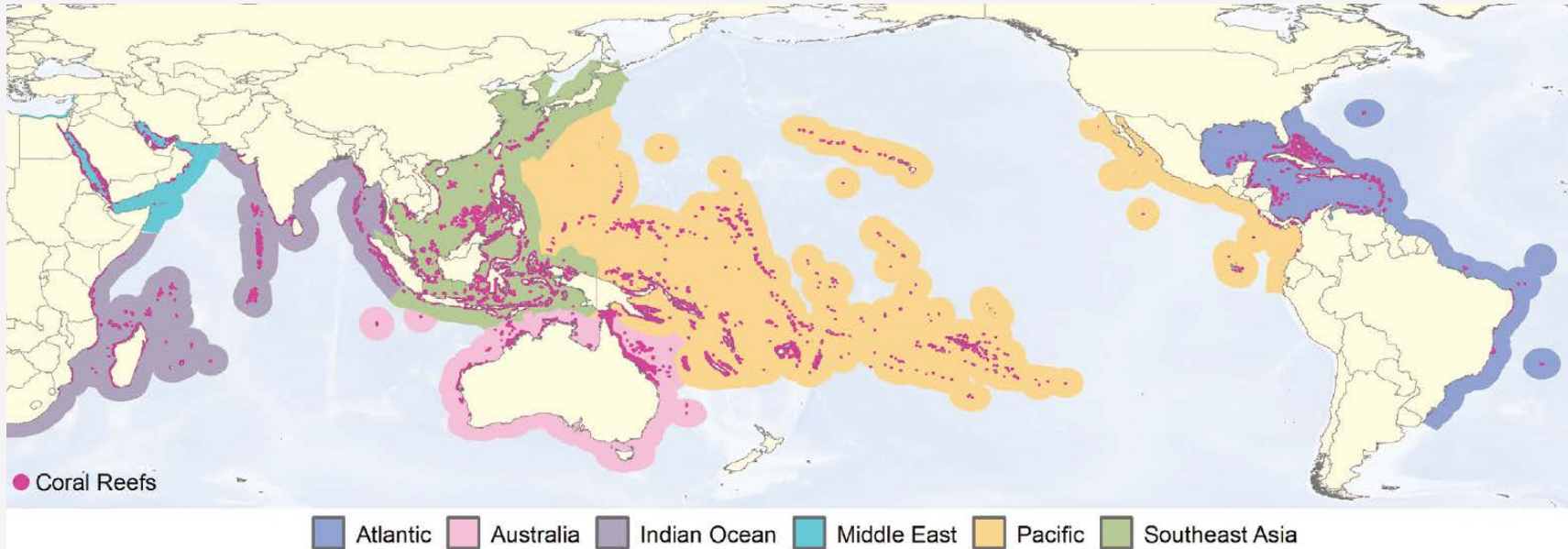
Credit: XL Catlin Seaview Survey, Osprey Reef, Great Barrier Reef

An aerial photograph of a tropical coastline. A river with a complex delta system flows from the top left towards the center. The river is surrounded by lush green vegetation. The river meets the ocean, where a sandy beach and a shallow lagoon are visible. The ocean water transitions from a light turquoise near the shore to a deep blue further out. A semi-transparent white rectangular box is overlaid on the right side of the image, containing the title text.

Overview of Coral Biology

Worldwide Distribution of Coral Reefs

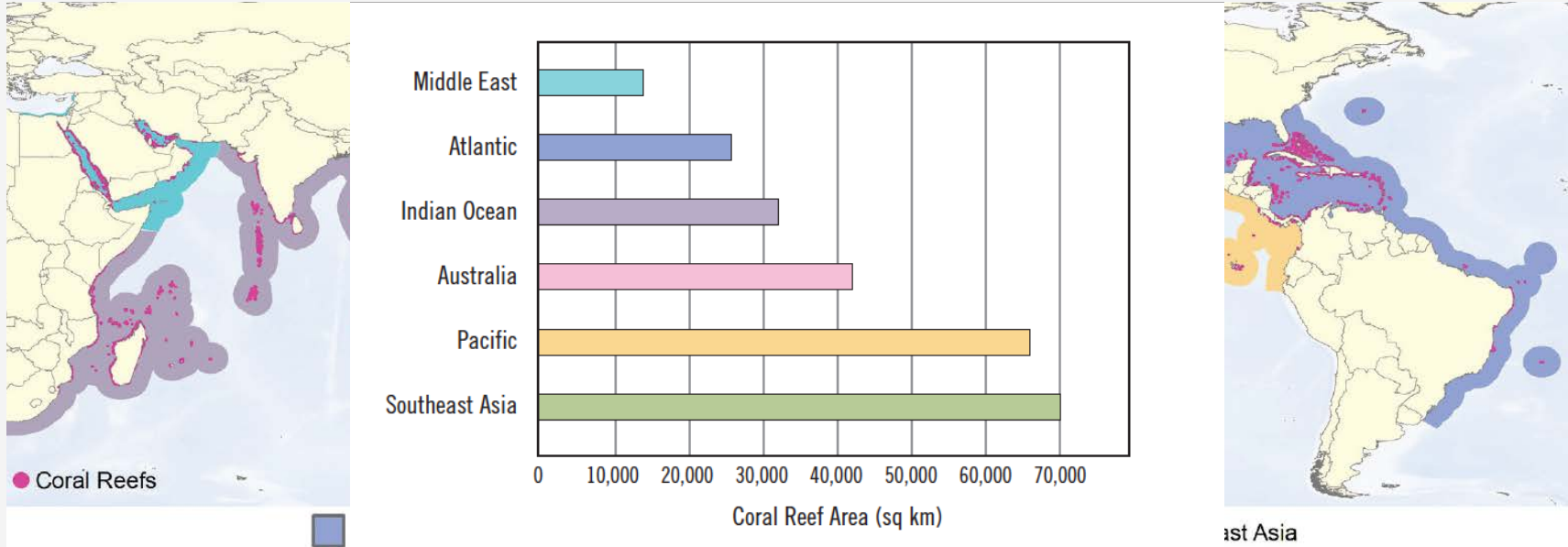
Reefs at Risk Revisited (2011)



Credit: Reefs at Risk Revisited

Worldwide Distribution of Coral Reefs

Reefs at Risk Revisited (2011)



Credit: Reefs at Risk Revisited

The Tropical Coral Reef and its Allies

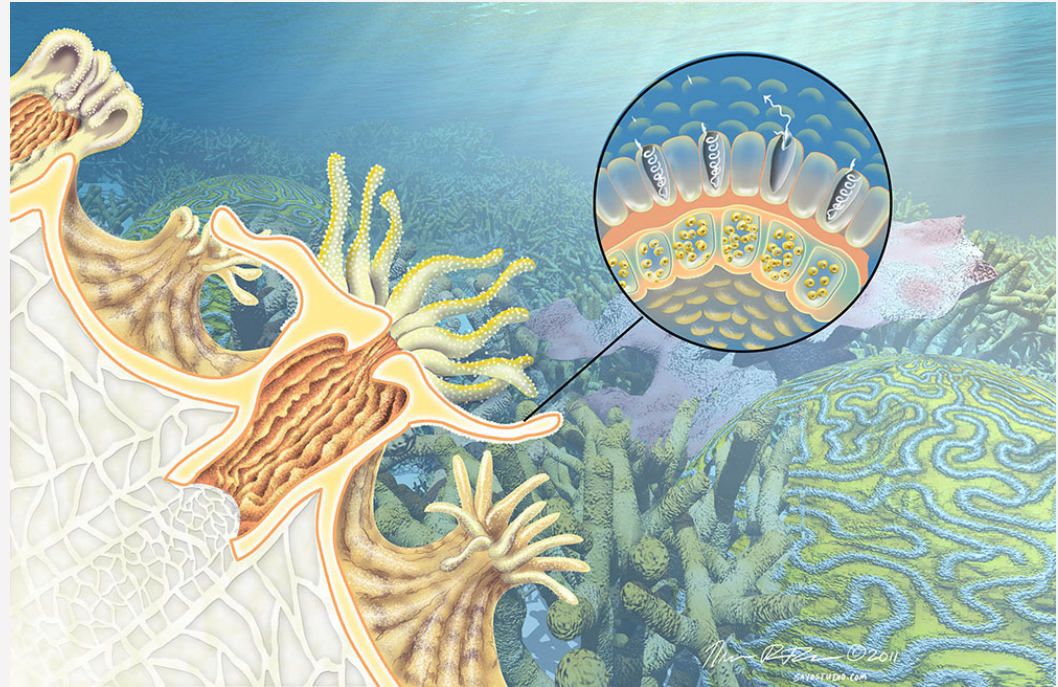
- Scleractinian “stony” corals
- Mangroves
- Seagrasses
- Upland watersheds
- Open ocean



Credits: The Bahamas Trust, P. Selvaggio, B. Ross

Scleractinian Coral Biology

- Hundreds of thousands of tiny (1-3mm diameter) polyps make up a coral colony
- Secretes calcium carbonate skeleton that makes the coral “stony”
- Stings prey with tiny stinging cells called nematocysts
- Part of a mutually symbiotic relationship with dinoflagellate (commonly known as zooxanthellae)



Credit: NR Fuller, Sayo Studio

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Coral Reef Systems

- Ecosystem engineers
- Oases of biodiversity in the tropical ocean
- Nursery grounds for many animal species
- Hotspots of productivity



Credit: Reefs at Risk Revisited

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Biome	Productivity (kg C/ m ² /yr)
Average Oceanic Areas	0.1
Temperate Grassland	1
Rainforest	1 - 2
Kelp Forest	2
Intensive Alfalfa Crop	1 - 2
Coral Reef	1.5 - 5

An aerial photograph of a coastal region. In the upper left, a river with a complex delta system flows into the sea. The land is green with some brown patches. The water transitions from shallow turquoise near the coast to deep blue further out. A semi-transparent white rectangular box is overlaid on the right side of the image, containing the title text.

Threats to Coral Reefs

Threats to Coral Reefs

Reefs at Risk – Revisited (2011)

Local Threats

- Coastal Development
- Watershed-Based Pollution
- Marine-Based Pollution and Damage
- Overfishing and Destructive Fishing

Global Threats

- Past Thermal Stress
- Future Thermal Stress
- Ocean Acidification

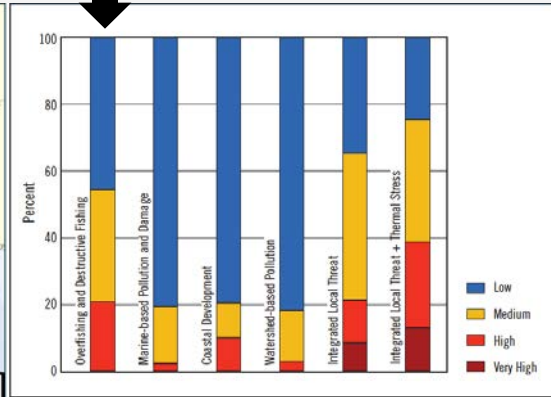
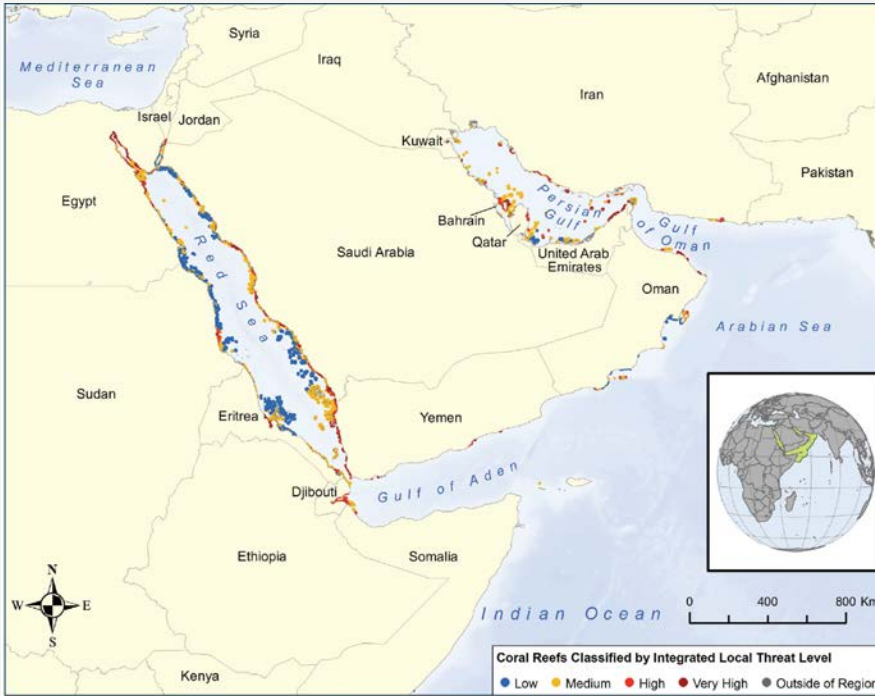


Credit: Reefs at Risk Revisited (<http://www.wri.org/publication/reefs-risk-revisited>), NASA JPL

Local Threats by Region

Middle East

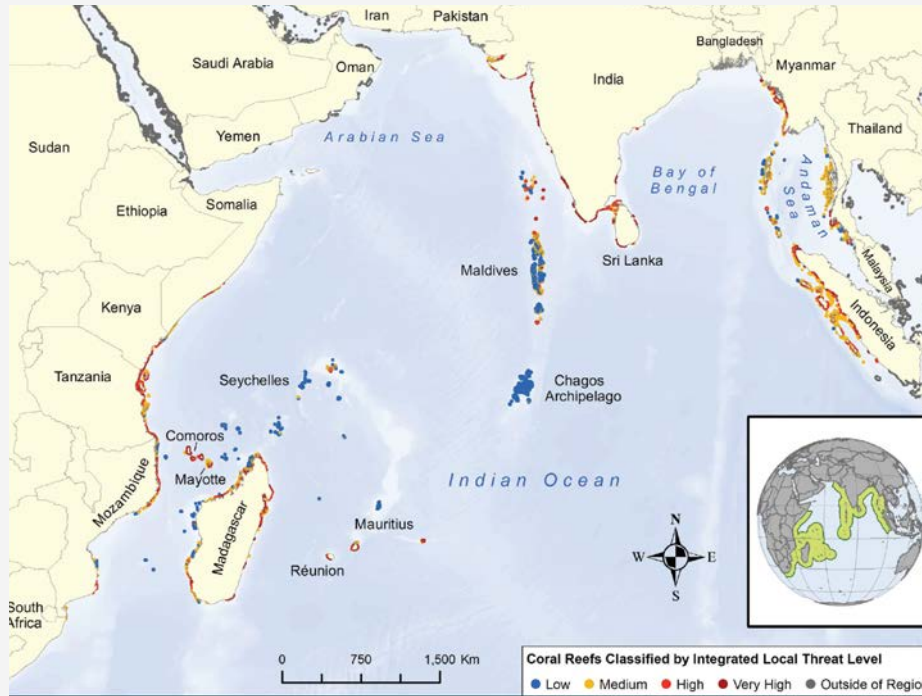
Overfishing & Coastal Development



Credit: Reefs at Risk Revisited

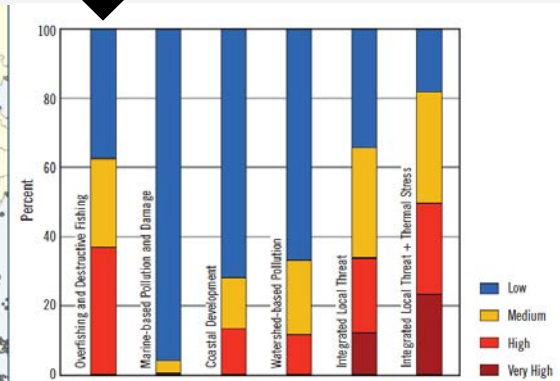
Local Threats by Region

Indian Ocean



Credit: Reefs at Risk Revisited

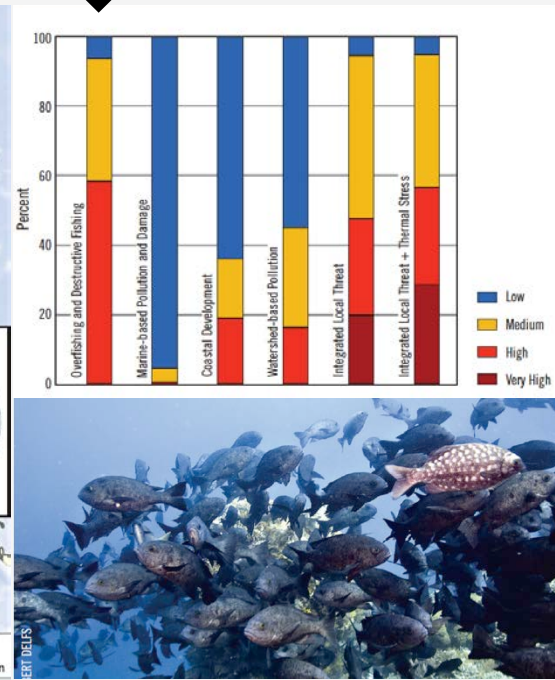
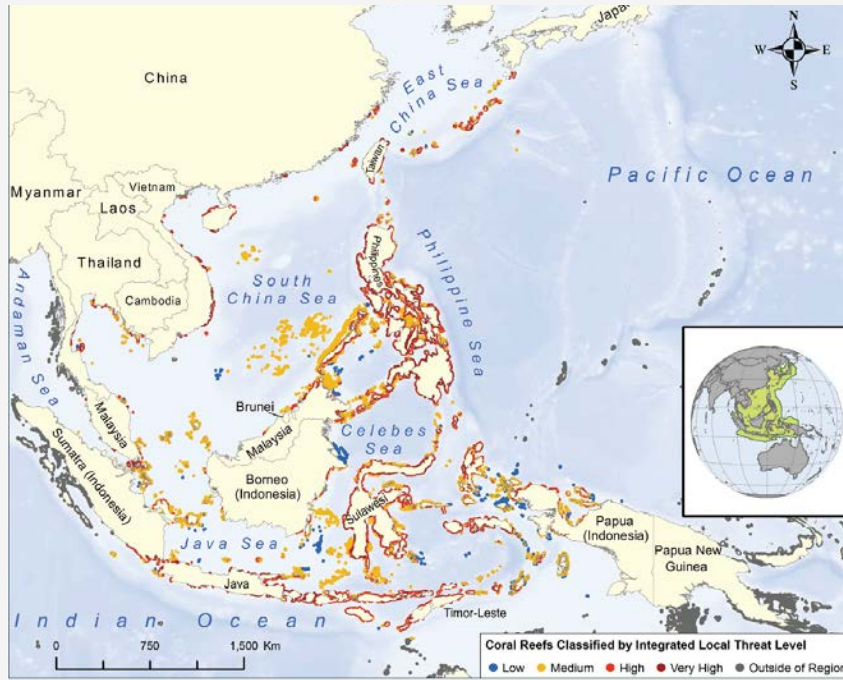
Overfishing



Local Threats by Region

Southeast Asia

Overfishing

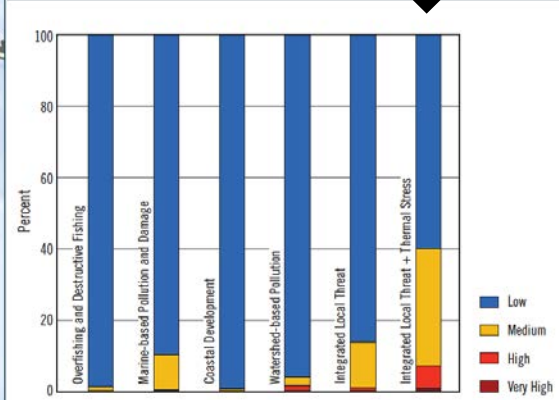
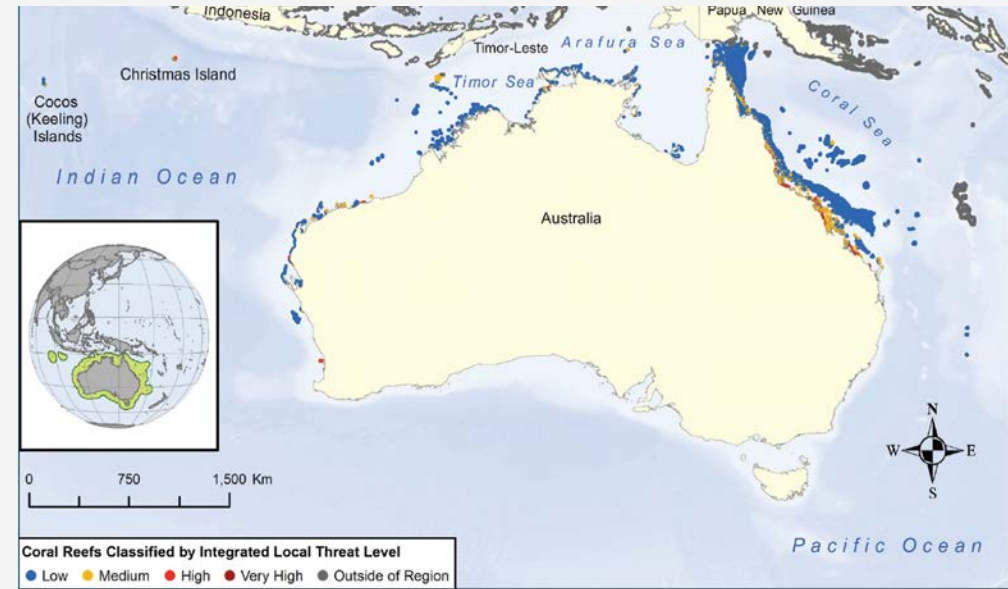


Credit: Reefs at Risk Revisited

Local Threats by Region

Australia

Integrated
Global Threats:
Climate Change

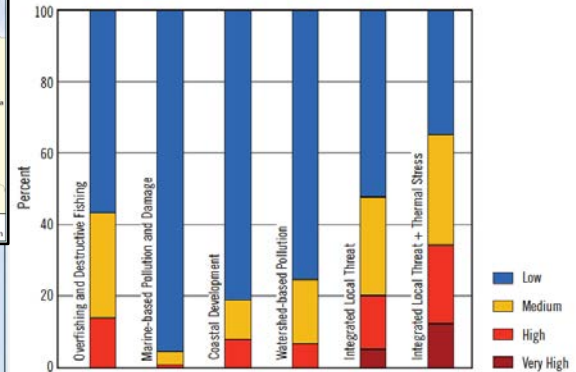
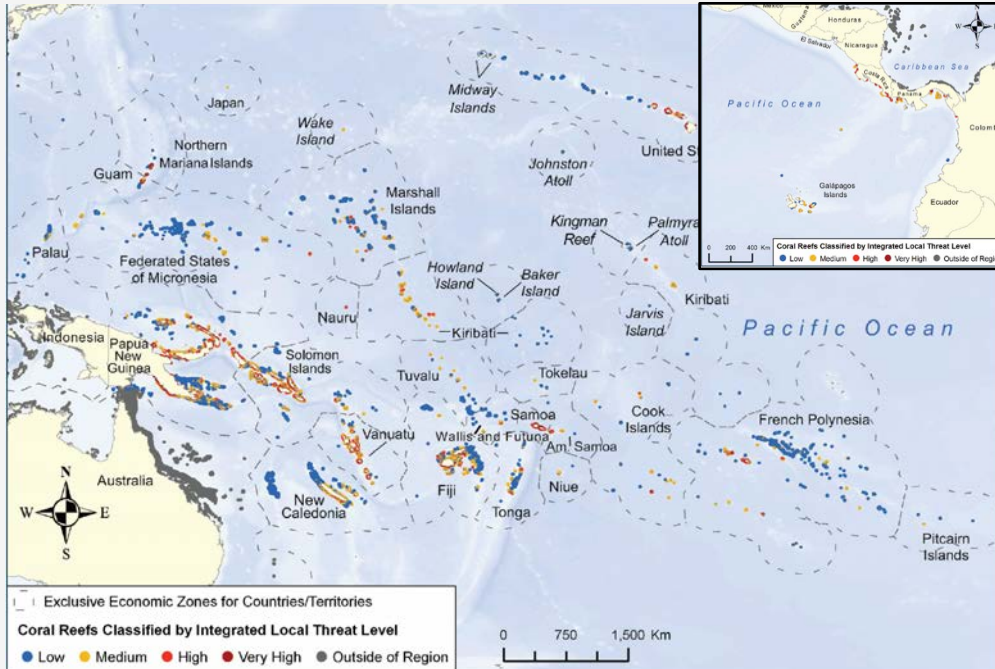


Credit: Reefs at Risk Revisited

Local Threats by Region

Pacific Ocean

Overfishing

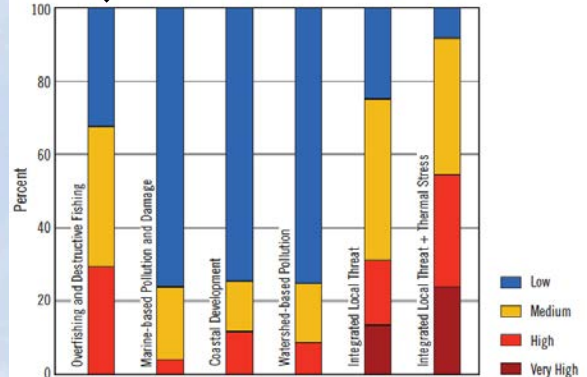


Credit: Reefs at Risk Revisited

Local Threats by Region

Caribbean Sea/Atlantic Ocean

Overfishing & Mechanical Destruction

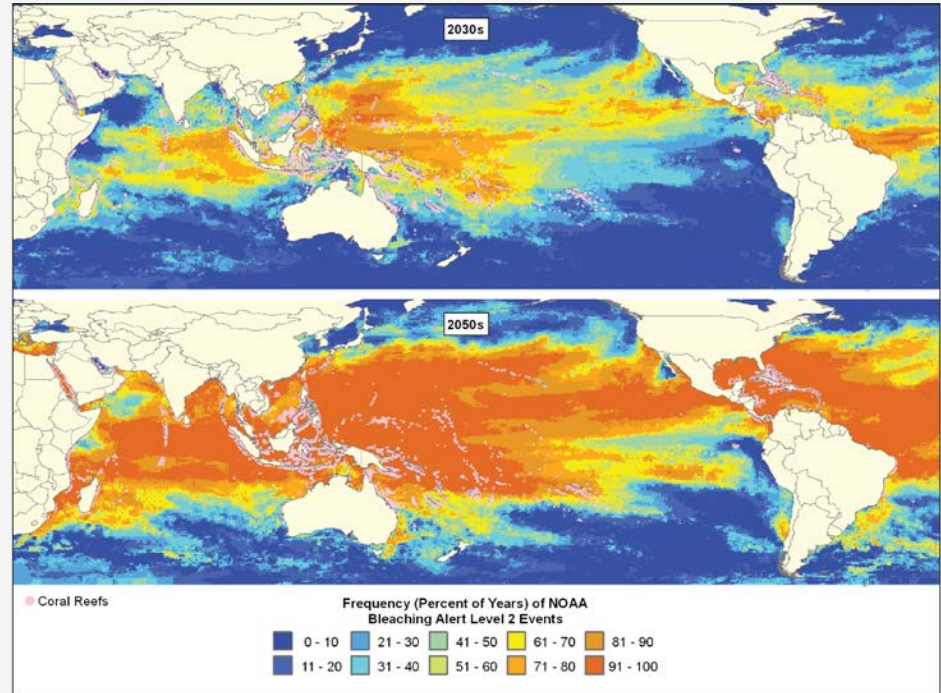


Credit: Reefs at Risk Revisited

Global Threats

Rising Ocean Temperature

- Ocean temperatures are rising with climate change
- Extended periods of above normal temperatures result in coral expelling zooxanthellae, pigment loss, or both. Also called coral bleaching
- 2014 – 2016 has been an unprecedented bleaching event
- Elevated temperature makes corals susceptible to disease

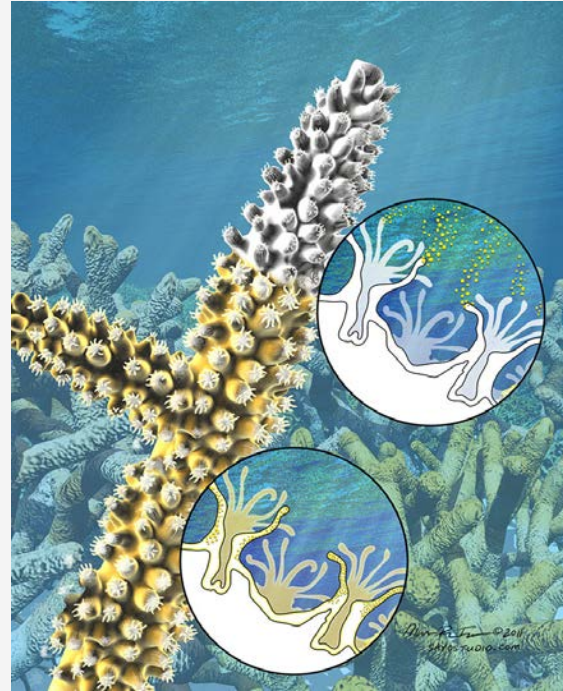


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Credit: XL Catlin Seaview Survey/Underwater Earth

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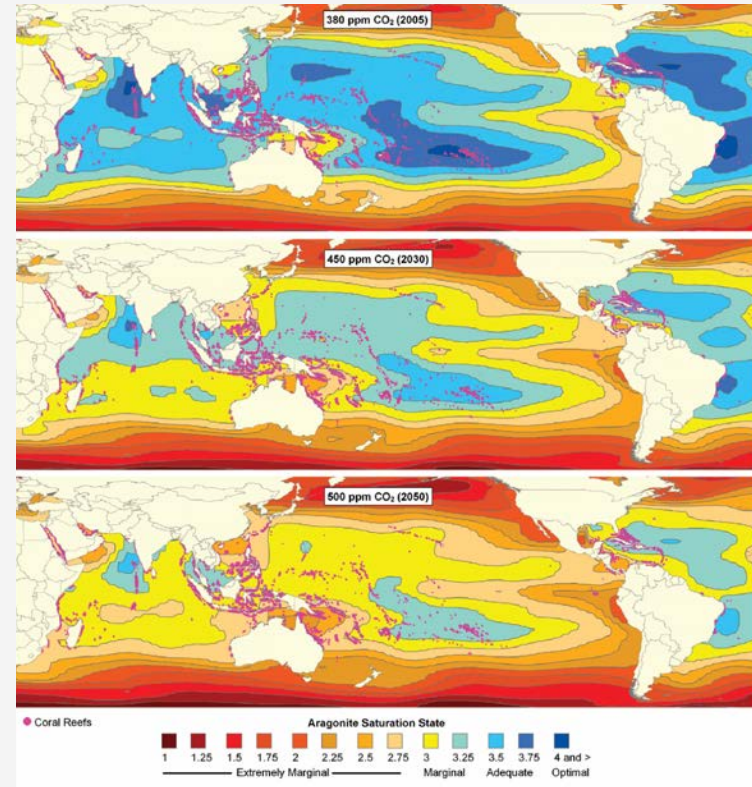


Credit: Reefs at Risk Revisited

Global Threats

Ocean Acidification

- Atmospheric CO₂ equilibrates with seawater resulting in rising ocean pCO₂
- CO₂ reacts with seawater causing a decrease in pH: it becomes more acidic
- Low pH water 'dissolves' calcium carbonate
- Coral skeletons are made of a particularly vulnerable crystal form of calcium carbonate known as aragonite
- Ocean acidification threatens the growth and sustainability of coral reef systems

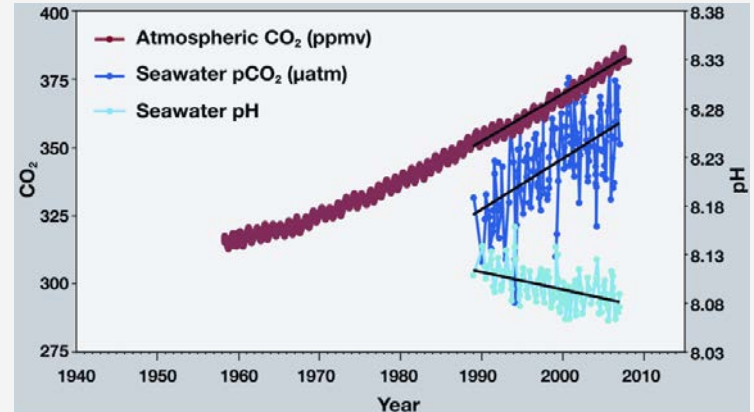


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Credit: Modified from Feeley 2008

Characteristics of Degraded Coral Reefs

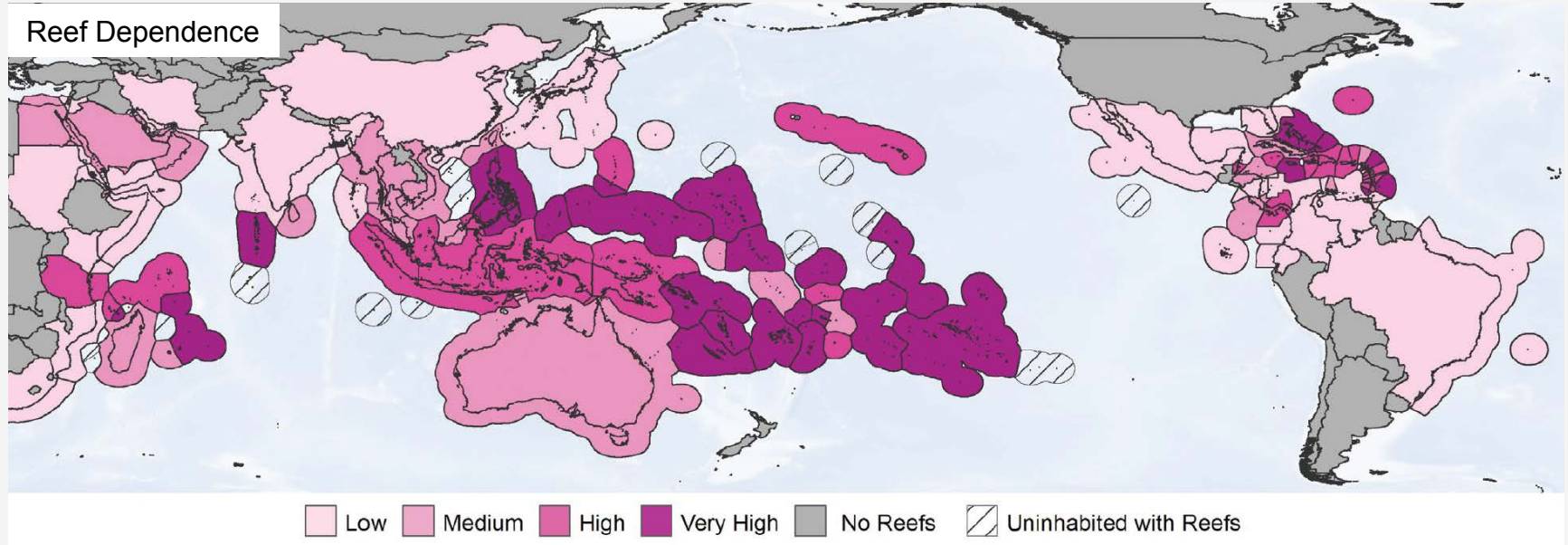
- Reduced habitat complexity
- Phase shifts from stony corals to fleshy macroalgae, soft corals, and sponges
- Reduced numbers of grazing fish
- Coral bleaching
- Physical destruction (e.g., from blast fishing)



Credit: XL Catlin Seaview Survey

Socio-Economic Consequences of Degraded Coral Reefs

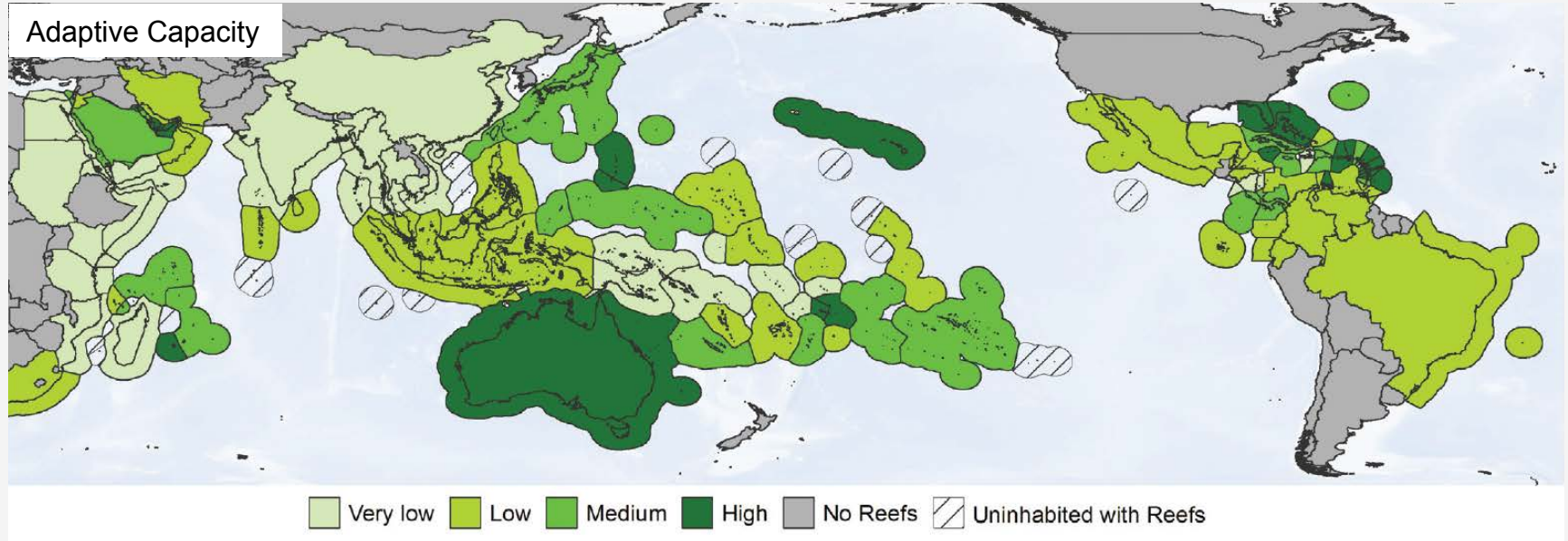
Reef Dependence & Adaptive Capacity Govern Vulnerability



Credit: Reefs at Risk Revisited

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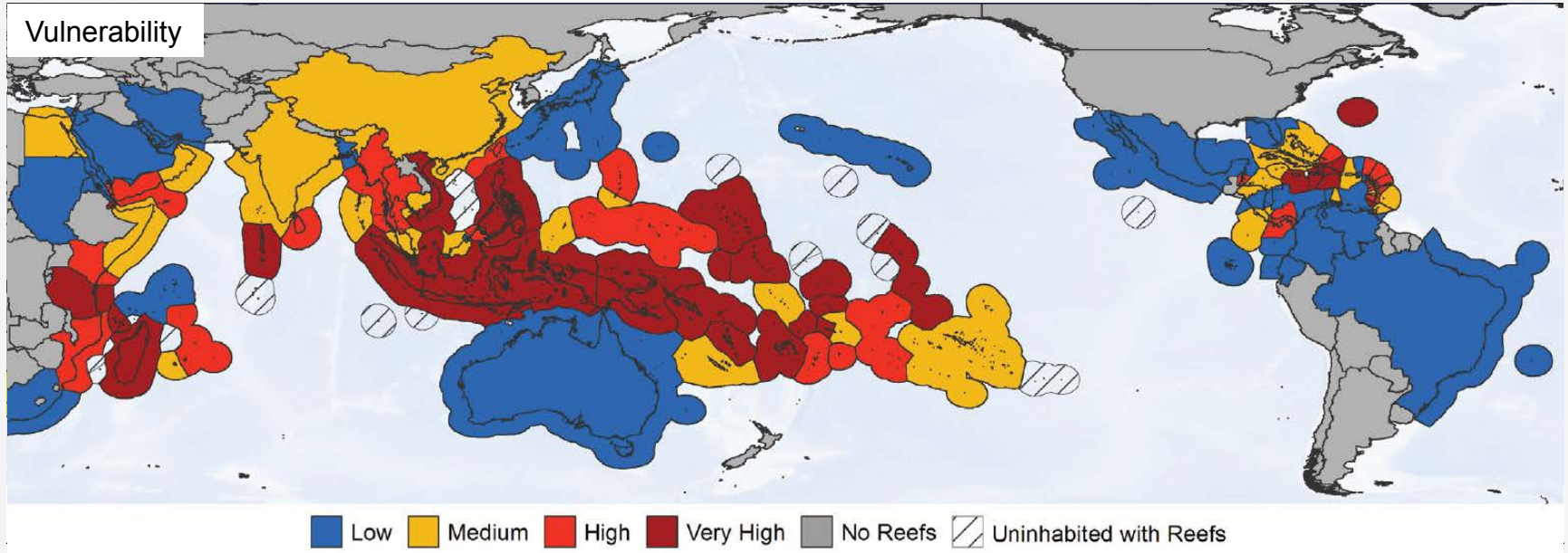
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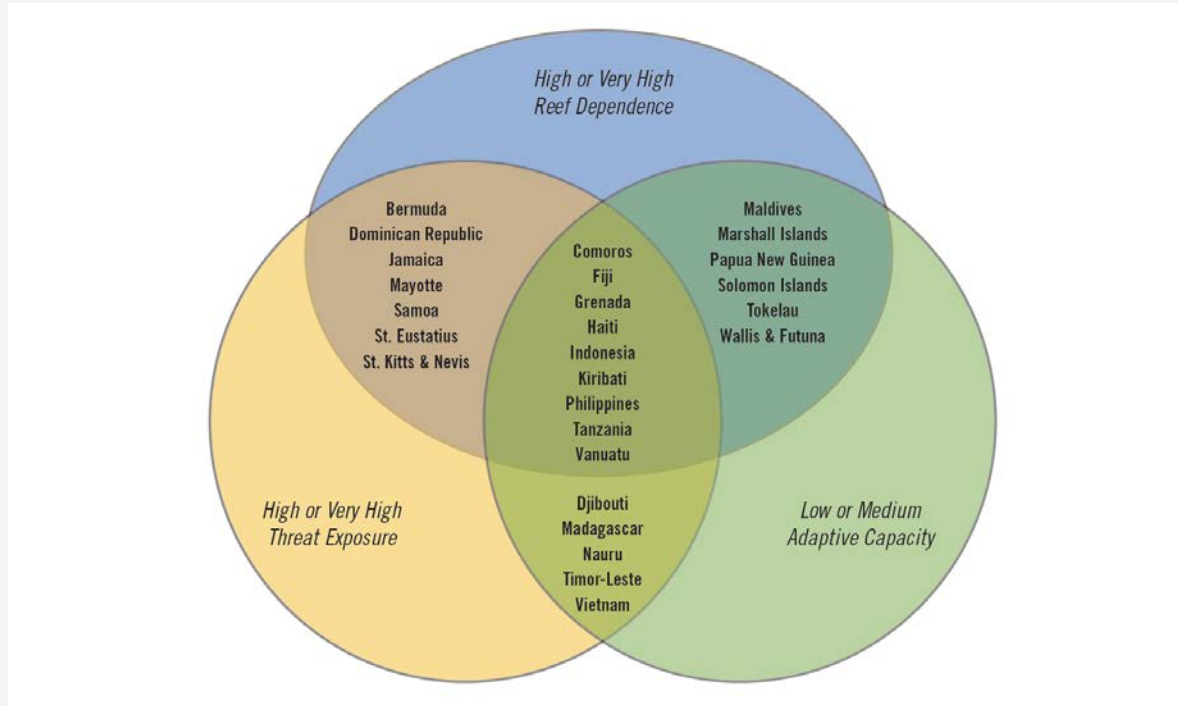
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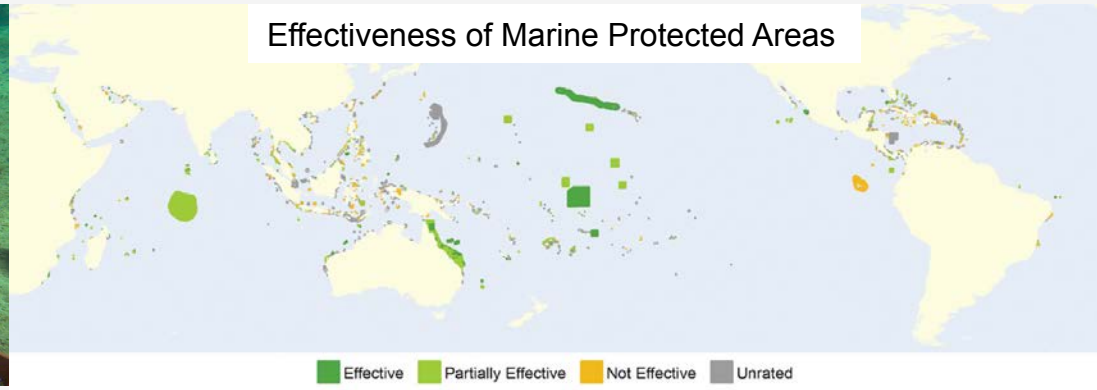
Credit: Reefs at Risk Revisited


Conservation

- Efforts are underway to 're-seed' reefs after major bleaching events
- Marine protected areas (MPAs) and locally managed marine fisheries are being used to lessen the impact on top predators or grazers
- Remote sensing can be used to monitor reef condition



credit: Reefs at Risk Revisited



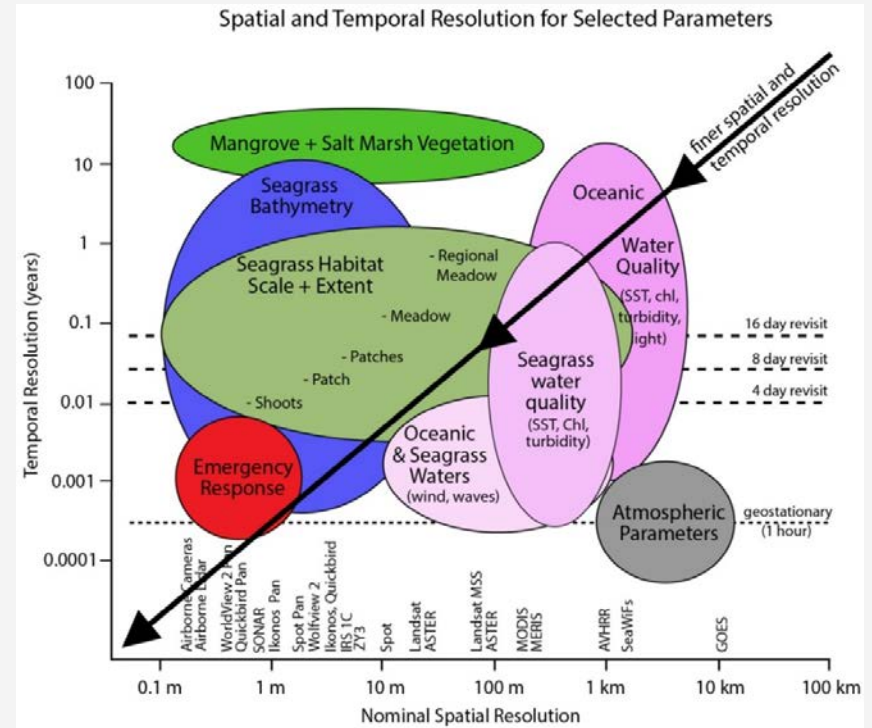
An aerial photograph of a coastal region. In the upper left, a river with a complex delta system flows into the sea. The land is green and brown, indicating vegetation and bare earth. The coastline is irregular with small islands and peninsulas. The water transitions from shallow turquoise near the shore to deep blue further out. A semi-transparent white rectangular box is overlaid on the right side of the image, containing the title text.

Remote Sensing of Coral Reefs

Remote Sensing for Coral Reef Monitoring

S. Phinn & C. Roelfsema, Editors

- Used to measure benthic type, reef structure, water quality, sea surface temperature
- Spatial, temporal, and spectral scale have large impact on the types of questions that can be asked
- Deriving coral productivity from imagery is in its early stages of development

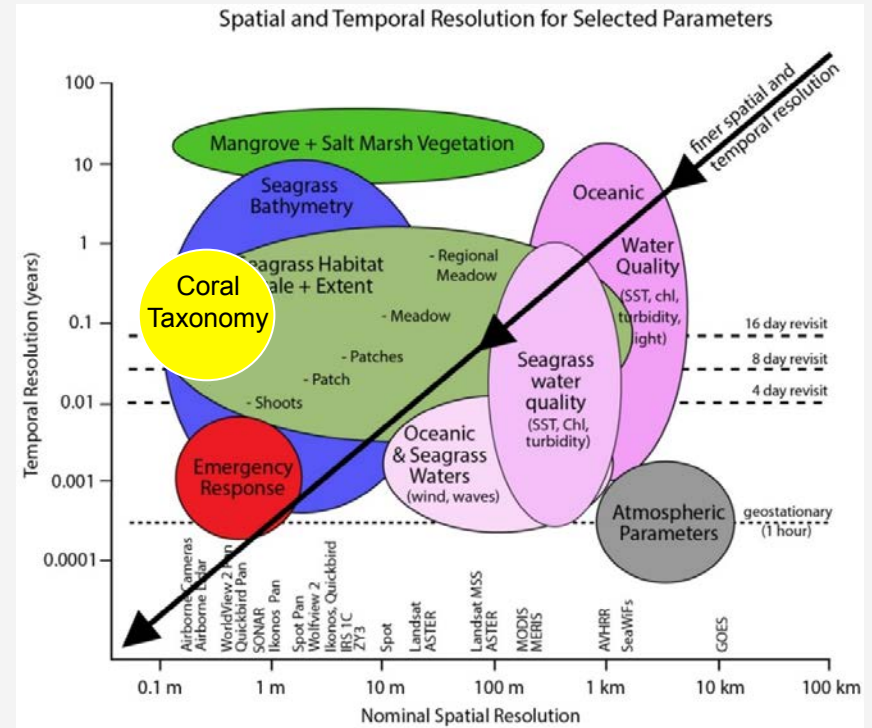


Hedley et al. 2016

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Hedley et al. 2016

Observing Environmental Factors with Remote Sensing

Hedley et al. 2016

Environmental Factor	Proxy/Measurement	Association	Sensor or Technology	Considerations
Photic Depth	light attenuation in water	high	moderate and high resolution satellites	Newer methods improve on limitations of standard ocean color algorithms in shallow coastal waters
Sedimentation	turbidity	medium	moderate and high resolution satellites	Sea floor reflectance in shallow waters limits the quantification of in-water constituents
Pollution	turbidity, algal blooms	low, low	moderate and high resolution satellites	Turbidity is proxy for pollution, algal blooms can help pin-point polluted areas
Exposure	wind energy and bathymetry	medium	satellite scatterometers for wind	Calculation of wave energy
Coastal Development	changes in land use	high	moderate and high spatial resolution multi-spectral satellites	Changes in land use can be proxy for coastal development
Overfishing	distance to reef-fishing from human settlement	low	airborne remote sensors, multi-spectral high resolution satellites	Settlements near reefs are more likely to exploit resources
Thermal Stress	SST	High	low spatial resolution radiometers	Direct measure of stress variable affecting corals
Ocean Acidification	SST, Sea Surface Salinity	Low	low spatial resolution radiometers	Can be used with other in situ and remote sensing data to derive seawater CO ₂ concentrations

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Remote Sensing Technologies for Coral Reef Mapping

Hedley et al. 2016

Objective	Sensor Technology	Feasibility	Considerations
Reef Extent	High and moderate resolution satellites, airborne sensors	Routinely possible	Spatial heterogeneity at the location determines the spatial resolution of the sensor to use
Rugosity	Boat and airborne active remote sensors	Routinely possible	Depth, turbidity and spatial heterogeneity at the location determine the acoustic method to use
Coral vs. Macroalgae	Hyperspectral airborne sensors	Demonstrated in limited cases only	Water column attenuation, presence of spectrally similar components and spatial heterogeneity at the location determine feasibility
Coral Mortality	Hyperspectral airborne sensors	Demonstrated in limited cases only	Water column attenuation, presence of spectrally similar components and spatial heterogeneity at the location determine feasibility
Coral Bleaching	Multispectral and hyperspectral airborne and satellite sensors	Demonstrated in limited cases only	Water column attenuation, presence of spectrally similar components and spatial heterogeneity at the location determine feasibility. Spectral confusion with sand to be avoided by comparison with imagery from earlier date
Bathymetry	Hyperspectral airborne and high resolution satellite sensors, acoustic and LIDAR	Routinely possible	Image processing effort is extensive

Remote Sensing Technologies for Coral Reef Mapping

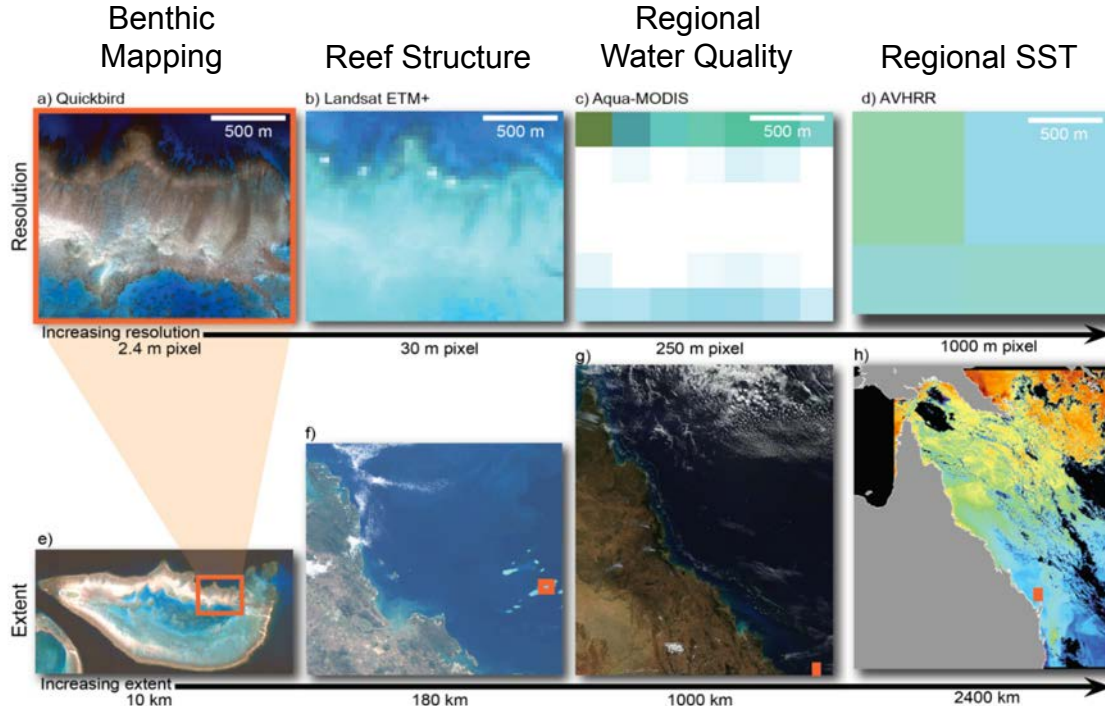
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Spatial Scale Needed for Imagery Varies by Question

Example: Heron Island, Australia

Example Question:



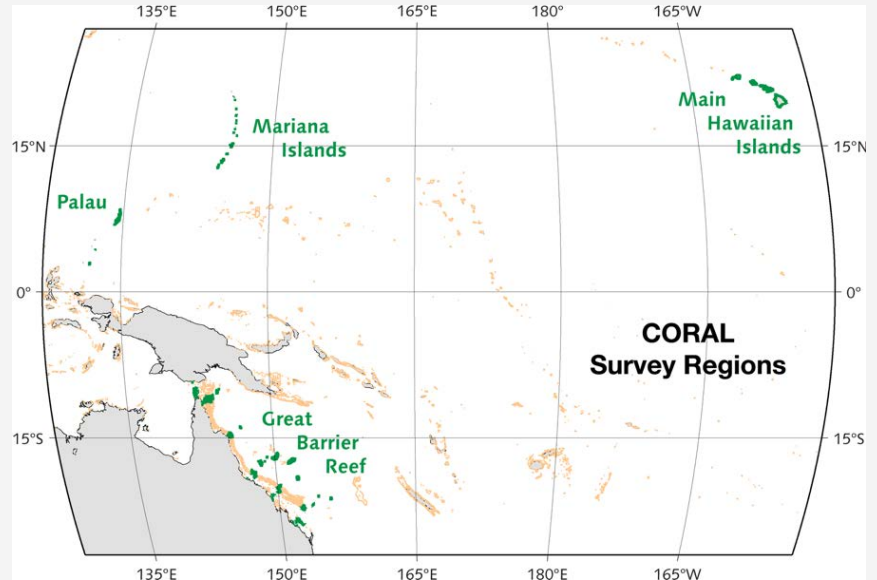
Hedley et al. 2016

NASA CORAL Earth Venture

<https://coral.jpl.nasa.gov/>; <http://coral.bios.edu/>



- Coral Reef Airborne Laboratory (CORAL)
- Question: What is the relationship between coral reef condition and biogeophysical forcing parameters?
 - Measure condition of corals: proportion of coral, algae, and sand, calcification, and primary productivity
 - Establish empirical models (some using remote sensing inputs) to assess coral condition
- Sensor: Portable Remote Imaging SpectroMeter (PRISM)



credit: E. Hochberg

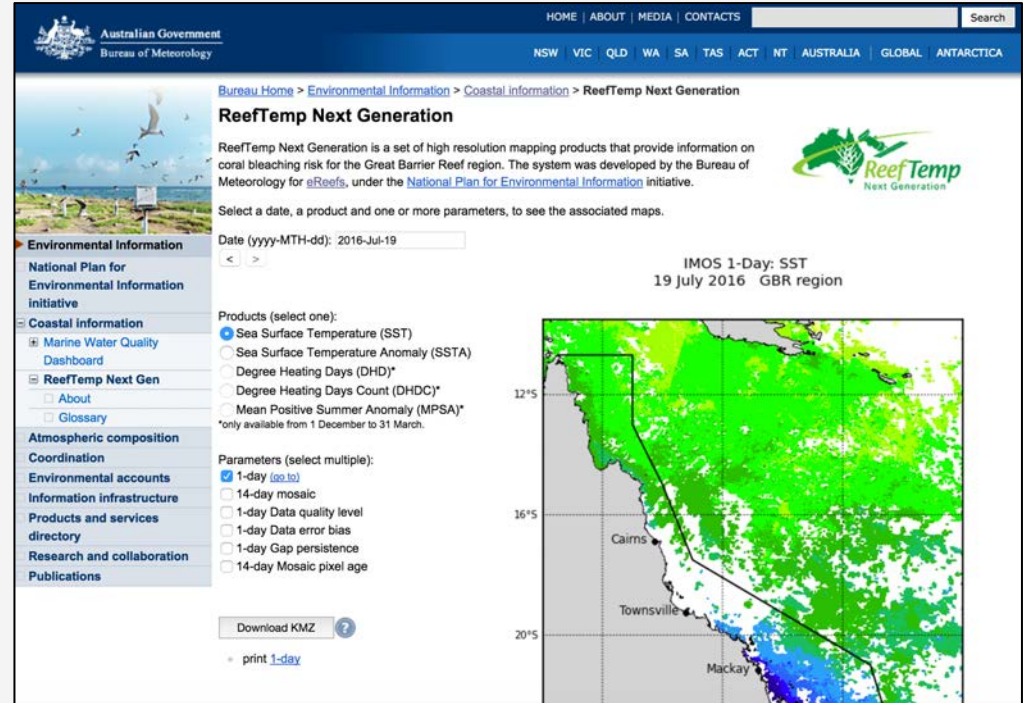
An aerial photograph showing a coastal landscape. On the left, a river flows through green fields and vegetation towards the ocean. The ocean is a vibrant turquoise color, transitioning to a deep blue further out. A coral reef system is visible, with various shades of blue and green indicating different reef structures. A semi-transparent white rectangular box is overlaid on the right side of the image, containing the title text.

Examples of Remote Sensing Tools for Understanding Coral Reef Systems

Australia's eReefs

ReefTemp

- ReefTemp is a web interface to view sea surface temperature data for the Great Barrier Reef
- It is a data portal that provides near real-time access to water temperature data
- It is freely available



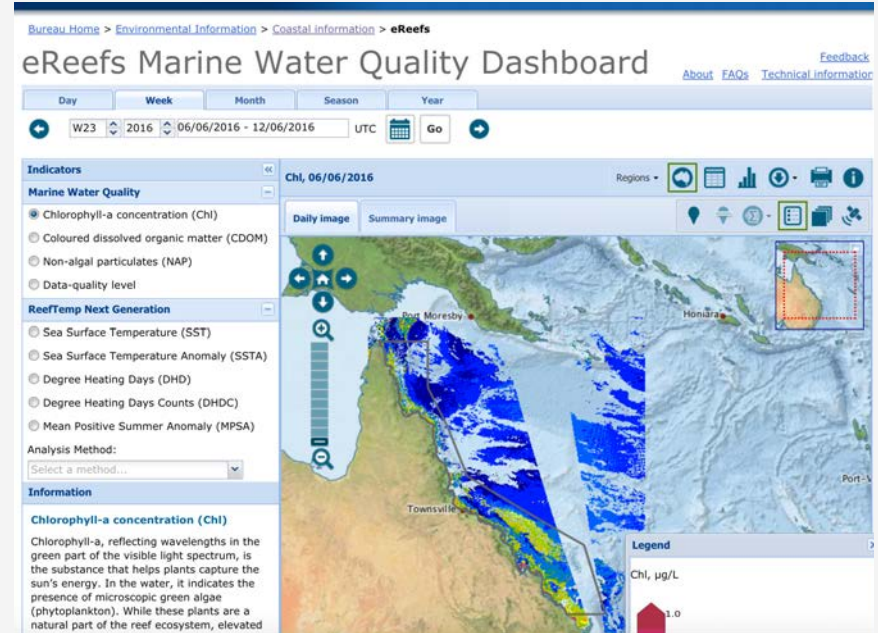
The screenshot displays the ReefTemp Next Generation web interface. The page header includes the Australian Government Bureau of Meteorology logo and navigation links for HOME, ABOUT, MEDIA, CONTACTS, and a search bar. Below the header, the breadcrumb trail reads: Bureau Home > Environmental Information > Coastal information > ReefTemp Next Generation. The main heading is "ReefTemp Next Generation". A descriptive paragraph states: "ReefTemp Next Generation is a set of high resolution mapping products that provide information on coral bleaching risk for the Great Barrier Reef region. The system was developed by the Bureau of Meteorology for eReefs, under the National Plan for Environmental Information initiative." A "ReefTemp Next Generation" logo is visible on the right. Below the description, there is a date selection field set to "2016-Jul-19" and navigation arrows. A "Products (select one):" section includes radio buttons for "Sea Surface Temperature (SST)", "Sea Surface Temperature Anomaly (SSTA)", "Degree Heating Days (DHD)*", "Degree Heating Days Count (DHDC)*", and "Mean Positive Summer Anomaly (MPSA)*". A note indicates "*only available from 1 December to 31 March." A "Parameters (select multiple):" section includes checkboxes for "1-day (go to)", "14-day mosaic", "1-day Data quality level", "1-day Data error bias", "1-day Gap persistence", and "14-day Mosaic pixel age". A "Download KMZ" button with a help icon and a "print 1-day" link are at the bottom left. On the right, a map titled "IMOS 1-Day: SST 19 July 2016 GBR region" shows a satellite-style map of the Great Barrier Reef area with a color scale from blue (cooler) to red (warmer). The map includes latitude and longitude markers (12°S, 16°S, 20°S) and labels for Cairns, Townsville, and Mackay.

<http://www.bom.gov.au/environment/activities/reeftemp/reeftemp.shtml>

Australia's eReefs

eReefs Marine Water Quality Dashboard

- The transparency of the water column has a big impact on coral health
- The dashboard is a data portal that provides near real-time access to water quality data for different reef regions of Australia
- The tool permits viewing, statistics, and the download of data
- It is freely available

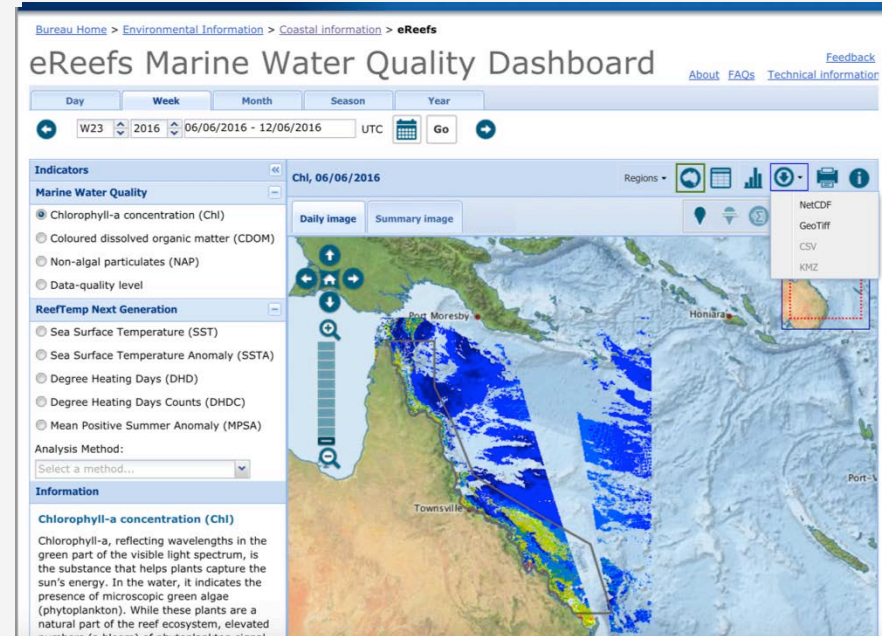


<http://www.bom.gov.au/marinewaterquality/>

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<http://www.bom.gov.au/marinewaterquality/>

Special Guest: Dr. Mark Eakin

NOAA Coral Reef Watch <http://coralreefwatch.noaa.gov/satellite/index.php>

NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)

DOC > NOAA > NESDIS > STAR > CRW

Coral Reef Watch
CRTF | CRCP | CREIOS | CoRIS

Coral Reef Watch Satellite Monitoring

Click on buttons below image to change parameter; click on image to navigate to parameter's web page.

NOAA Coral Reef Watch Daily 5-km Geo-Polar Blended Night-Only Bleaching Alert Area 7d Max 19 Jul 2016

Switch to 50-km products

CO₂
406.81

Alerts HotSpot DHW SST Anomaly SST Trend Outlook Doldrums Virtual Stations

2014-Present: Status of the Ongoing Global Coral Bleaching Event

The NOAA Coral Reef Watch program's satellite data provide current reef environmental conditions to quickly identify areas at risk for [coral bleaching](#), where corals lose the symbiotic algae that give them their distinctive colors. If a coral is severely bleached, disease and partial mortality become likely, and the entire colony may die.

Continuous monitoring of sea surface temperature at global scales provides researchers and stakeholders with tools to understand and better manage the complex interactions leading to coral bleaching. When bleaching conditions occur, these tools can be used to trigger bleaching response plans and support appropriate management decisions.

Announcements

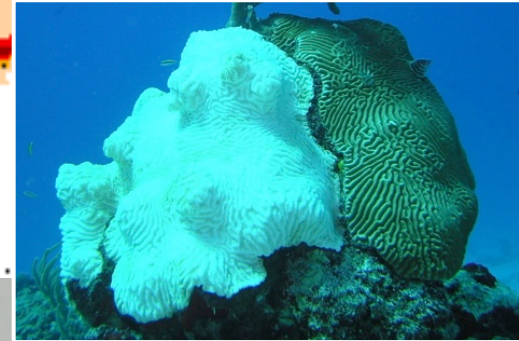
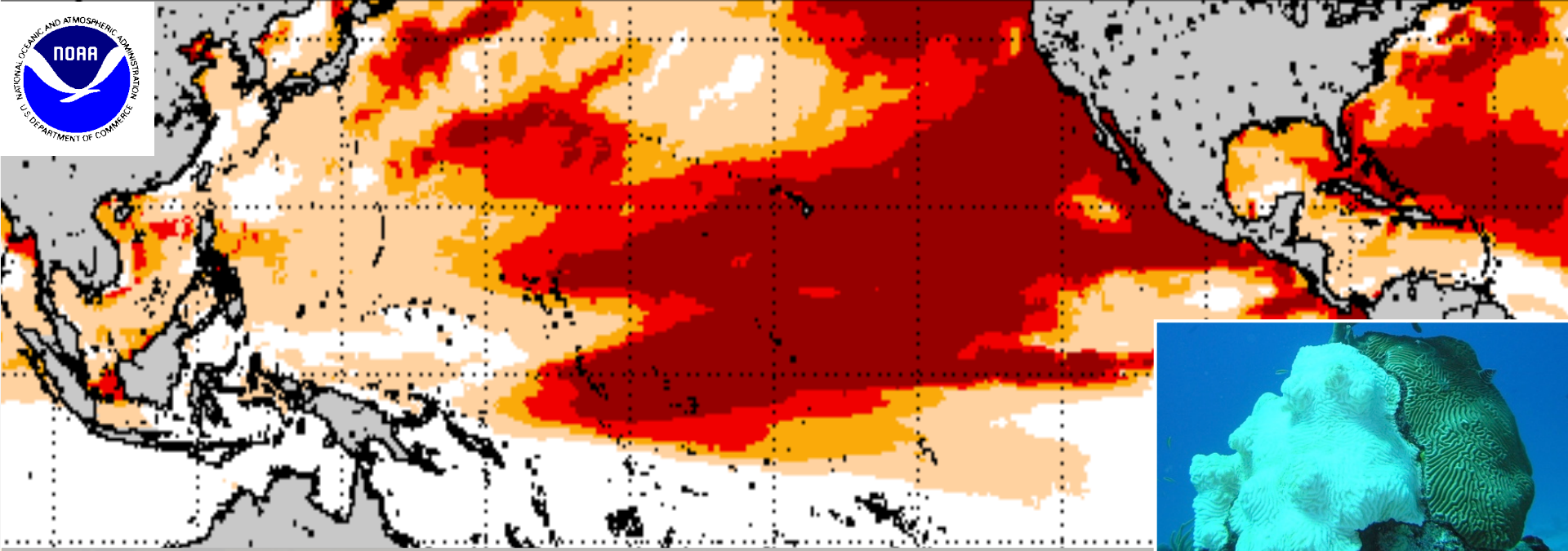
June 30, 2016:
CRW releases new [Reef Larval Connectivity](#) product for Hawaii.

April 30, 2016:
New CRW paper in [Reef Encounter](#) updates status of ongoing global coral bleaching event and

http://coralreefwatch.noaa.gov/satellite/education/tutorial/crw29_exercises.php

An aerial photograph of a coastal region. In the upper left, a river with a complex delta system flows into the ocean. The land is green and hilly. The ocean is a vibrant turquoise color near the shore, transitioning to a deep blue further out. A semi-transparent white rectangular box is overlaid on the right side of the image, containing the title text.

Live Demo: NOAA Coral Reef Watch

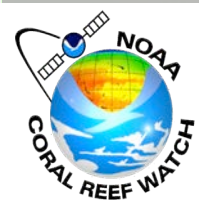


NOAA Coral Reef Watch: Coral Bleaching Products and the Biggest Bleaching Event in History

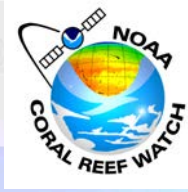
Dr. C. Mark Eakin

NOAA Coral Reef Watch

<http://coralreefwatch.noaa.gov>



2015 Coral Bleaching: American Samoa



December 2014

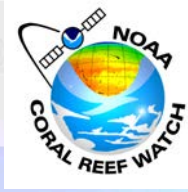


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<http://coralreefwatch.noaa.gov>



2015 Coral Bleaching: American Samoa



February 2015

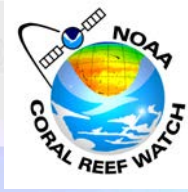


XL CATLIN
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SURVEY

<http://coralreefwatch.noaa.gov>



2015 Coral Bleaching: American Samoa



August 2015

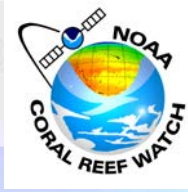


XL CATLIN
SEAVIEW™
SURVEY

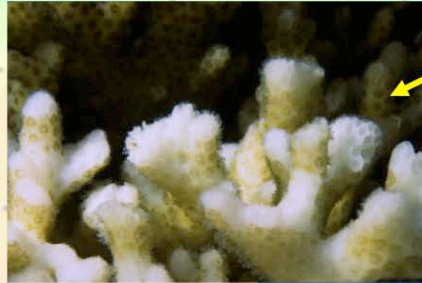
<http://coralreefwatch.noaa.gov>



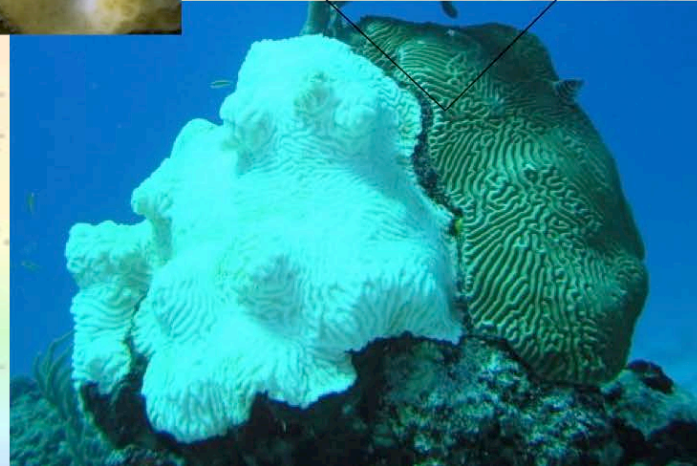
What is Coral Bleaching?



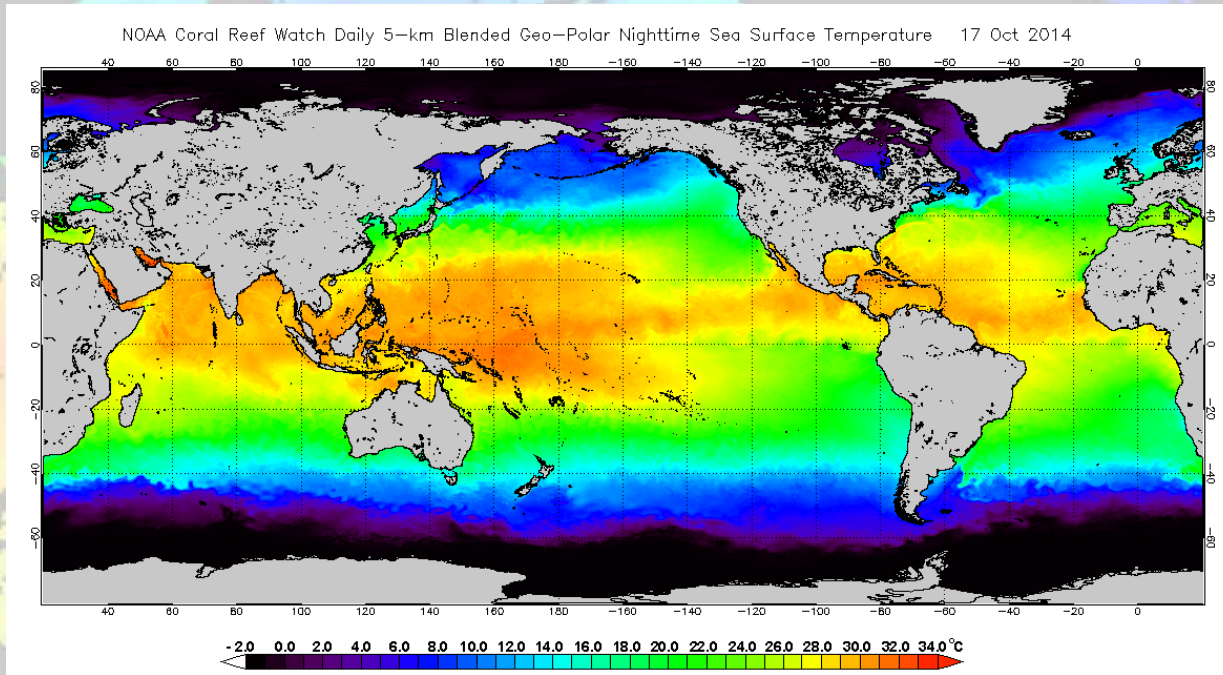
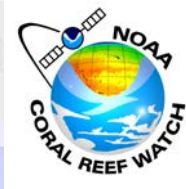
- Most of corals' food comes from photosynthesis
- Corals can “bleach” due to stress
- Corals exposed to high temperatures and/or high light become stressed
- Corals eject their algae; coral appears “bleached”
 - If stress is mild or brief, corals recover, otherwise they die



Symbiotic algae



Coral Reef Watch 5-km Satellite-Based Products



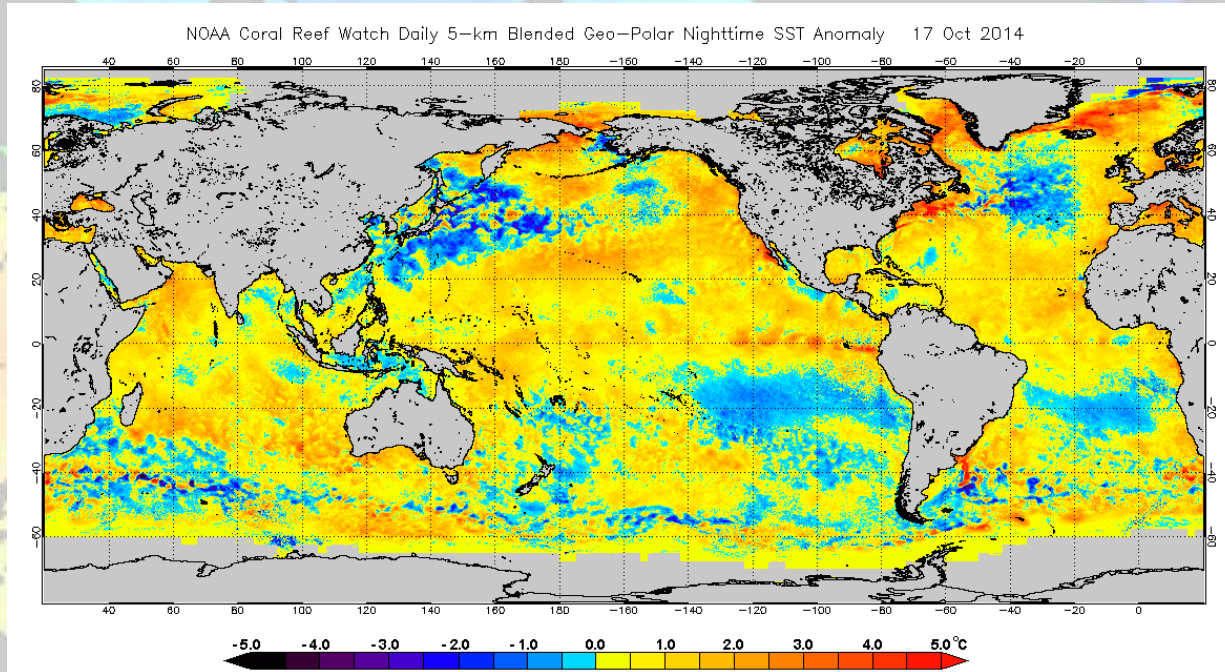
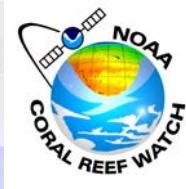
Sea Surface Temperature



<http://coralreefwatch.noaa.gov>



Coral Reef Watch 5-km Satellite-Based Products



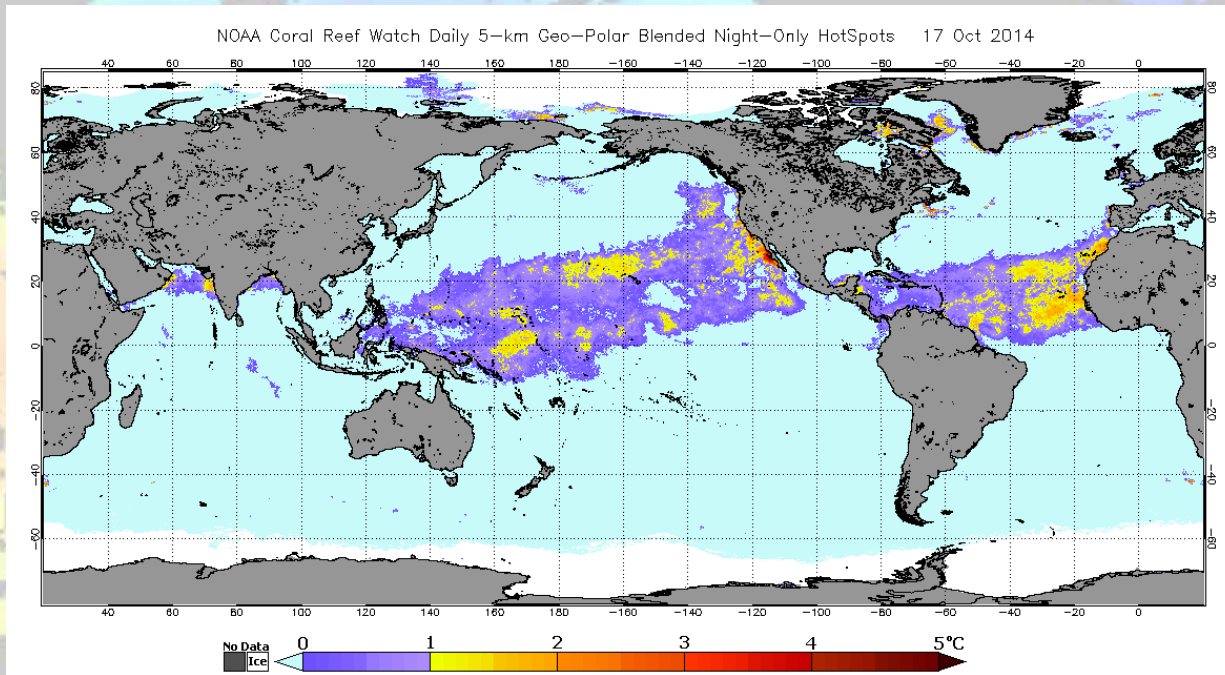
SST Anomaly



<http://coralreefwatch.noaa.gov>



Coral Reef Watch 5-km Satellite-Based Products



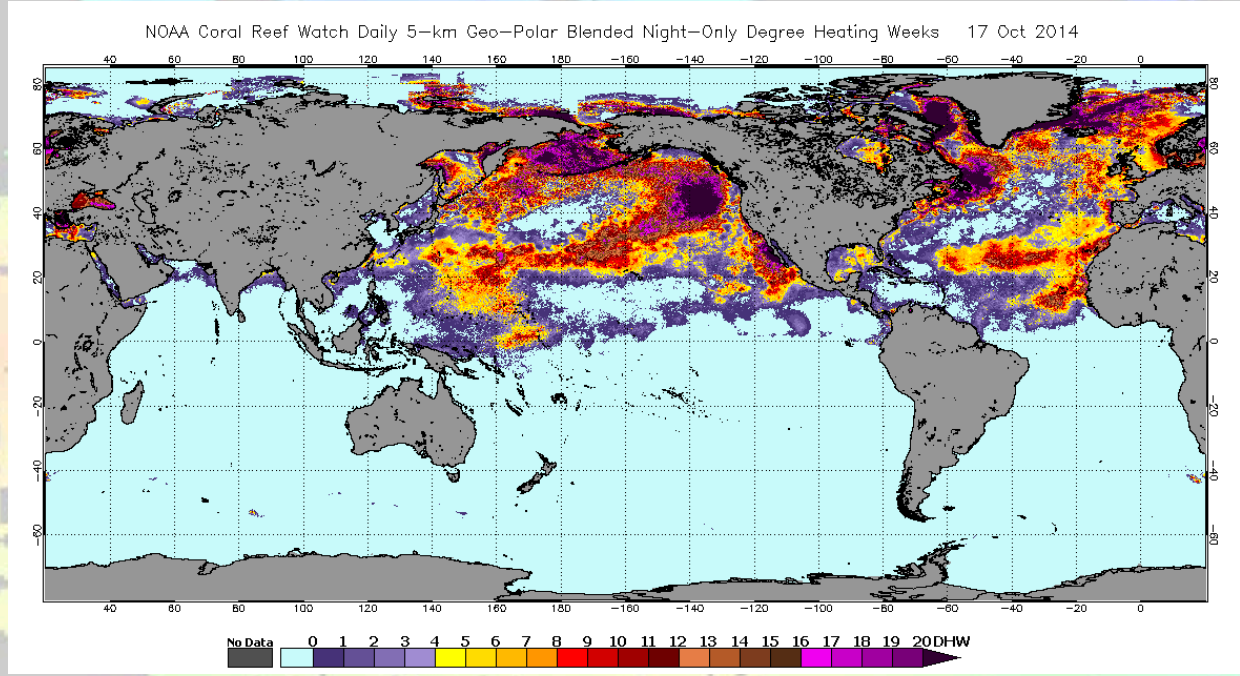
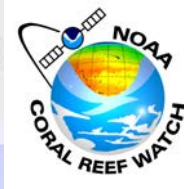
HotSpot



<http://coralreefwatch.noaa.gov>



Coral Reef Watch 5-km Satellite-Based Products

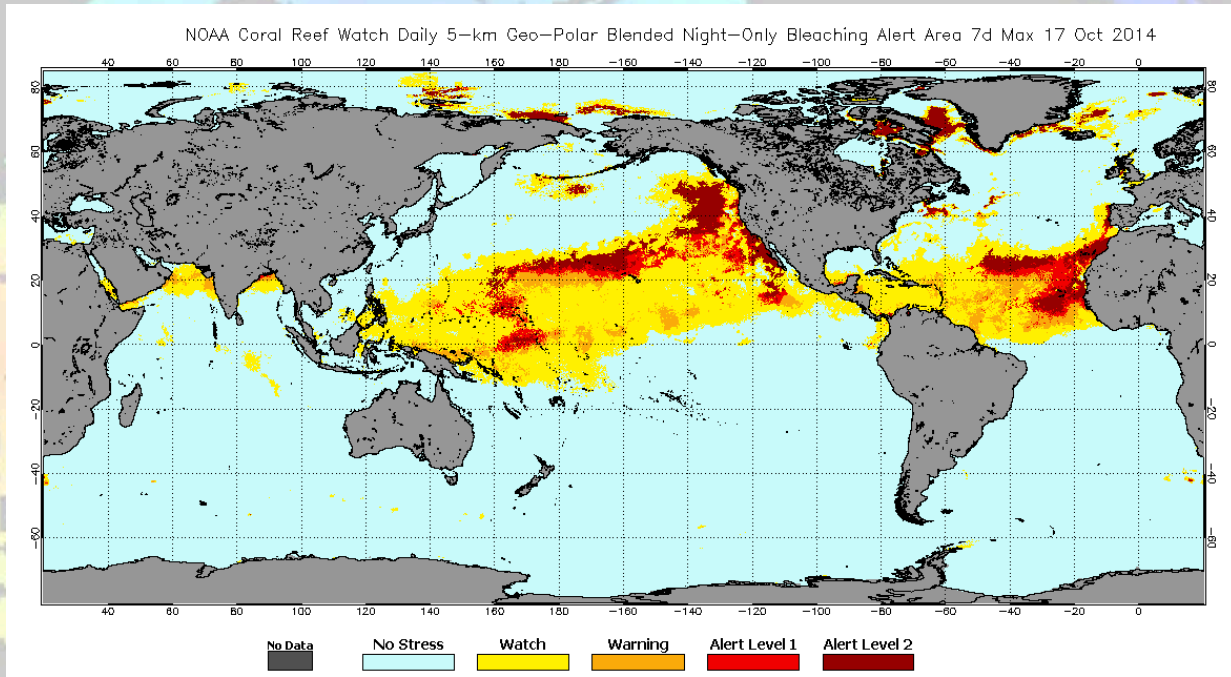
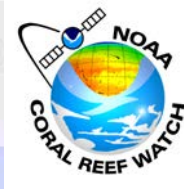


Degree Heating Week

<http://coralreefwatch.noaa.gov>



Coral Reef Watch 5-km Satellite-Based Products

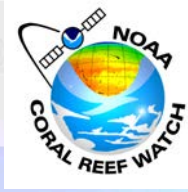


Bleaching Alert Area

<http://coralreefwatch.noaa.gov>



Coral Reef Watch: Product Comparison



5 km Geostationary-Polar Blend

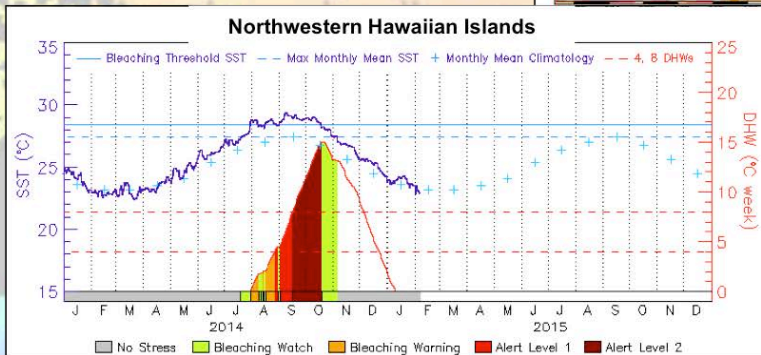
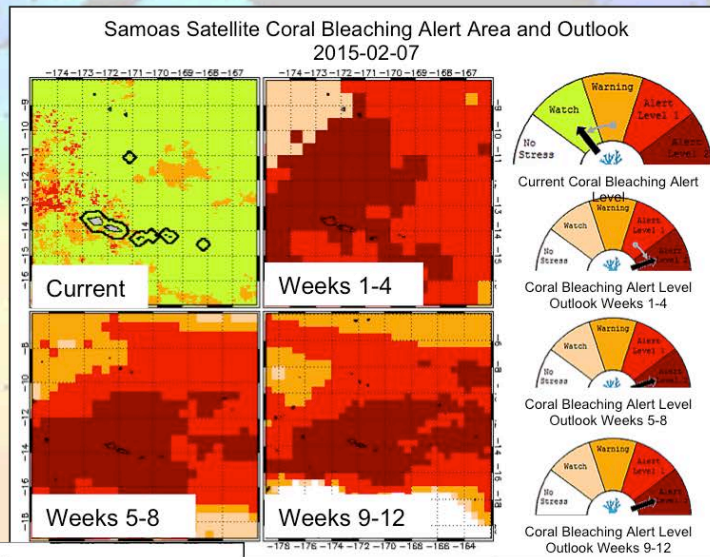
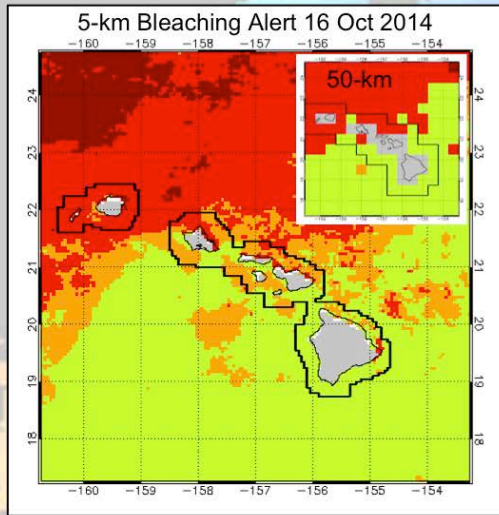
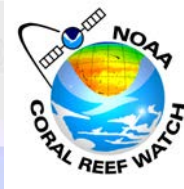
- **Climatology:** 22 year, 4 km (Pathfinder AVHRR)
- **Data:**
 - 5 km Operational Blended, night only
 - Polar-orbiters (2) + Geostationary (4)
 - Up to 50 scenes/day

50 km Polar-only (Operational)

- **Climatology:** 7 year, 50 km (AVHRR)
- **Data:**
 - 50 km Operational, night only
 - Polar-orbiter (1)
 - Max 1 scene/day



2014-5: New Coral Reef Watch 5-km Product Suite for Coral Bleaching



<http://coralreefwatch.noaa.gov>



Local Use of 5-km products



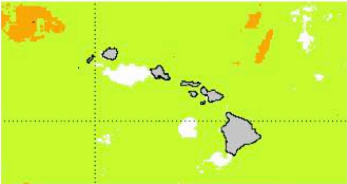
**Reef Response
Current Conditions
June/July 2014**

Report SUMMARY: June/July 2014 EOR Report Summary

Coral Bleaching

One coral bleaching report was received through the Eyes of the Reef Network in June and July 2014. There was Bleaching "Watch" alert issued for Oahu through NOAA Coral Reef Watch. No Rapid Responses were initiated.

In June and July 2014, 27 reports were received through the Eyes of the Reef Network. Three Rapid Assessments were initiated. A coral disease outbreak continues to affect the north shore of Kauai. DAR is awaiting results from samples taken after a die-off of flying gurnards on Oahu.



NOAA Potential Bleaching Intensity Levels	
 No Stress	No bleaching
 Bleaching Watch	Possible bleaching
 Bleaching Warning	Possible bleaching
 Alert Level 1	Bleaching Likely
 Alert Level 2	Coral Mortality Likely

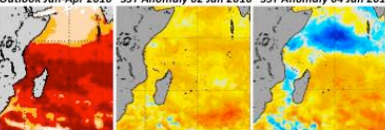
Figure 1. Current NOAA CRW Bleaching Alert Area, Exp. 5 km 8/13/2014 (<http://coralreefwatch.noaa.gov/satellite/bleaching5km/>)

WESTERN INDIAN OCEAN – Regional coral bleaching alert

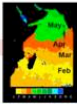
DATE OF THIS ALERT: 4 January 2016

<http://www.cordioea.net/bleachingalert/>
Contact: bleaching@cordioea.net

NOAA Products – 2 January
Outlook Jan-Apr 2016 SST Anomaly 02 Jan 2016 SST Anomaly 04 Jan 2015





Left: the bleaching warning throughout the WIO is already at moderate to high levels. Middle: the entire WIO is warmer than normal starting the season, compared to the same time in 2015 (right) where large pockets of cool water are evident, and which spread to a larger extent through to the end of January 2015.




Bleaching Alert level is high across all virtual NOAA stations, with only the 3 coolest locations showing no stress (Somalia, Maputo and South Africa), 11 at Bleaching Watch and 7 at Bleaching Warning level.

Tropical Cyclones
None.

Bleaching observations
Grande Comoros:
Initial observations indicate bleaching is already starting on Grande Comore, at a 'moderate' level. *Said Ahamada/AIDE Comoros*




Florida Department of Environmental Protection
Coral Reef Conservation Program

SEAFAN BleachWatch Program

Current Conditions Report #20140902

September 2, 2014



Summary: Based on climate predictions and field observations, the threat for mass coral bleaching in southeast Florida, between Miami-Dade and Martin counties is currently **HIGH**.

Environmental Monitoring

The latest CRW experimental 5 kilometer (km) Daily Coral Bleaching Alert Area (Figure 1) indicates that southeast Florida is presently experiencing a moderate to high level of thermal stress, with an Alert Level 1 or Bleaching Warning present throughout the region. This indicates that bleaching is likely in southeast Florida and additional alerts are possible if current conditions continue or worsen.

NOAA's Bleaching Hotspot Map compares current SST to the maximum monthly mean, which is the average temperature during the

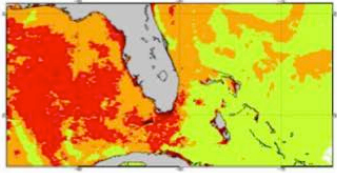




Figure 1. NOAA CRW Experimental Daily 5 km Blended Geo-Polar Nighttime Blended Bleaching Alert Area; August 31, 2014
<http://coralreefwatch.noaa.gov/satellite/bleaching5km/index.php>

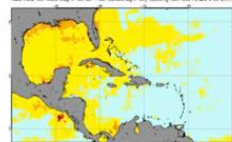


**CARIBBEAN
CORAL REEF WATCH**



Notable Observations

- Sea surface temperature (SST) anomalies have decreased noticeably across most of the equatorial Pacific. La Niña is favoured to develop during the Northern Hemisphere summer with a high chance that it will remain through fall and winter 2016-7. [Read more.....](#)
- Warm SSTs observed in the Caribbean but no significant thermal stress expected outside the southwestern Caribbean at this time.
- Bleaching warnings issued for the Florida keys, N Bahamas, NW & SW Cuba. Bleaching watches in TCI, Belize, Cayman Isl., Jamaica & Hispaniola.



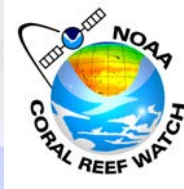
Click here to track current conditions



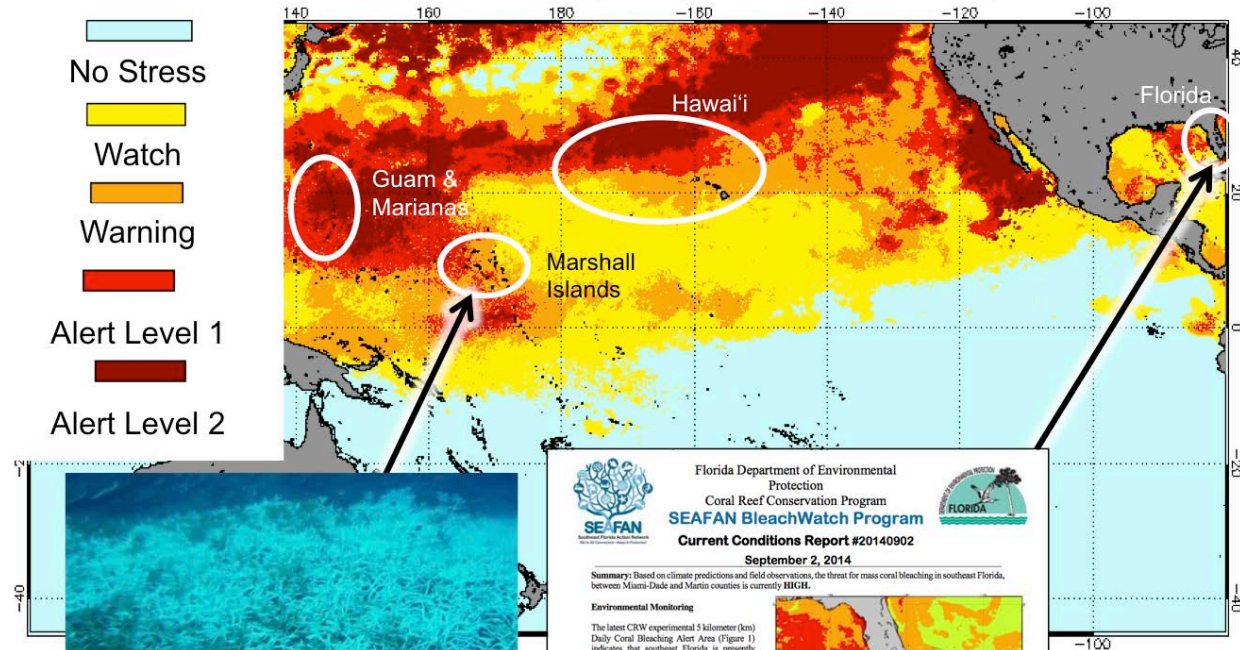
<http://coralreefwatch.noaa.gov>



Global Bleaching: Last Half of 2014



NOAA Coral Reef Watch Annual Maximum Satellite Coral Bleaching Alert Area 2014



Florida Department of Environmental Protection
 Coral Reef Conservation Program
SEAFAN BleachWatch Program
 Current Conditions Report #20140902
 September 2, 2014

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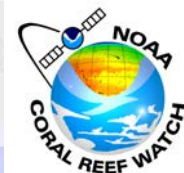
NOAA's Bleaching Hotspot Map compares current SST to the maximum monthly mean, which is the average temperature during the

Figure 1. NOAA CRW Experimental Daily 5 km Blended Sea Surface Temperature Blended Bleaching Alert Area, August 31, 2014
http://coralreefwatch.noaa.gov/satellite/bleaching/alert_areas.php

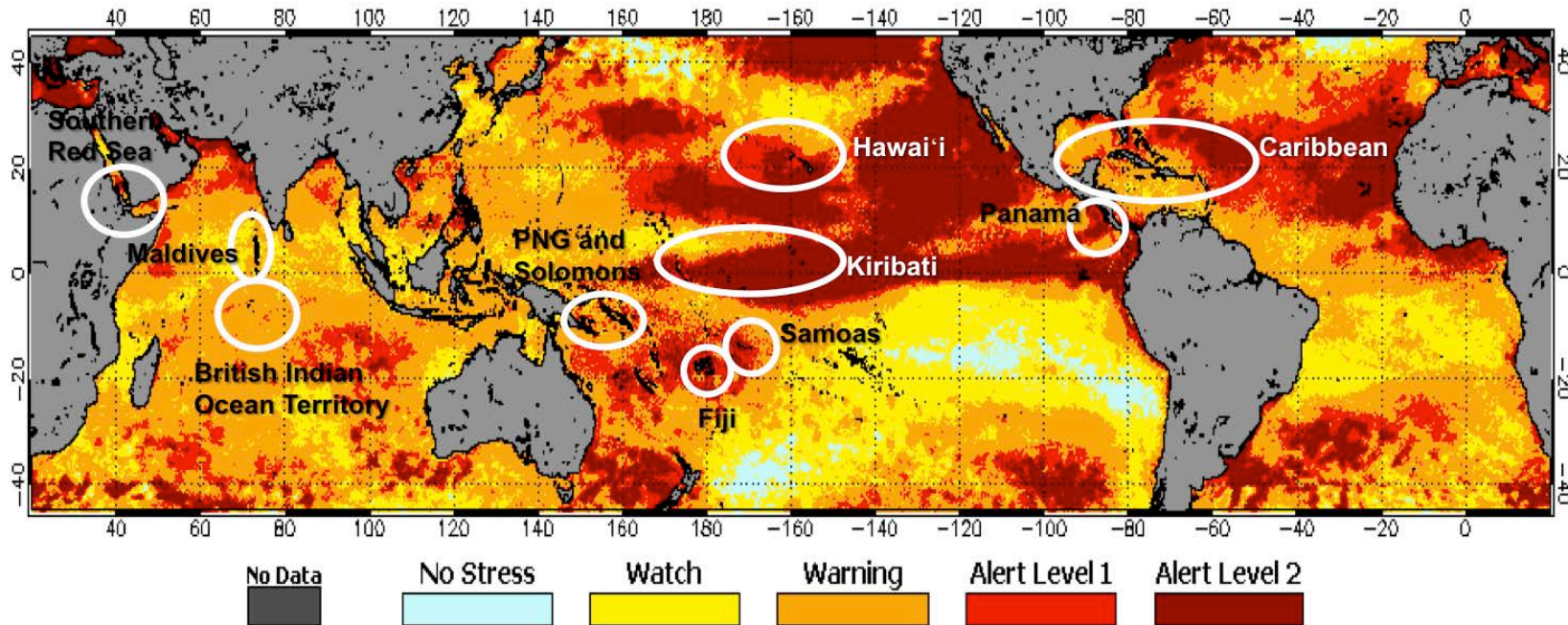


<http://coralreefwatch.noaa.gov>

Global Bleaching: 2015



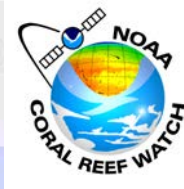
NOAA Coral Reef Watch Annual Maximum Satellite Coral Bleaching Alert Area 2015



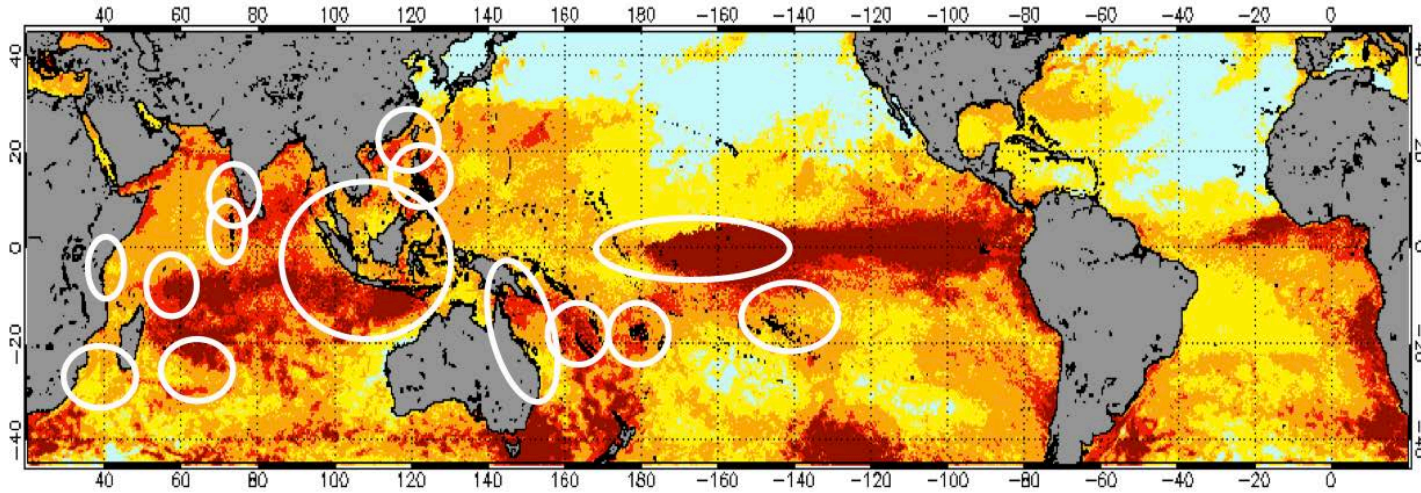
<http://coralreefwatch.noaa.gov>



Global Bleaching: First Half of 2016



NOAA Coral Reef Watch Maximum Satellite Coral Bleaching Alert Area 1 Jan – 19 July 2016



Western India
Seychelles
Kenya/Tanzania
Mozambique

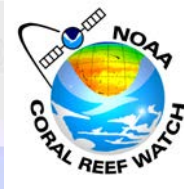
Maldives
Réunion
Mauritius
Madagascar

Taiwan
Philippines
Thailand
Indonesia
E. Australia

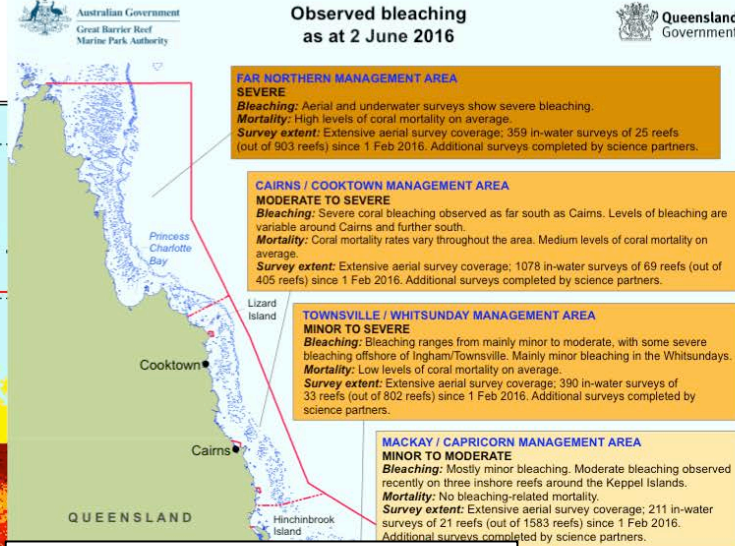
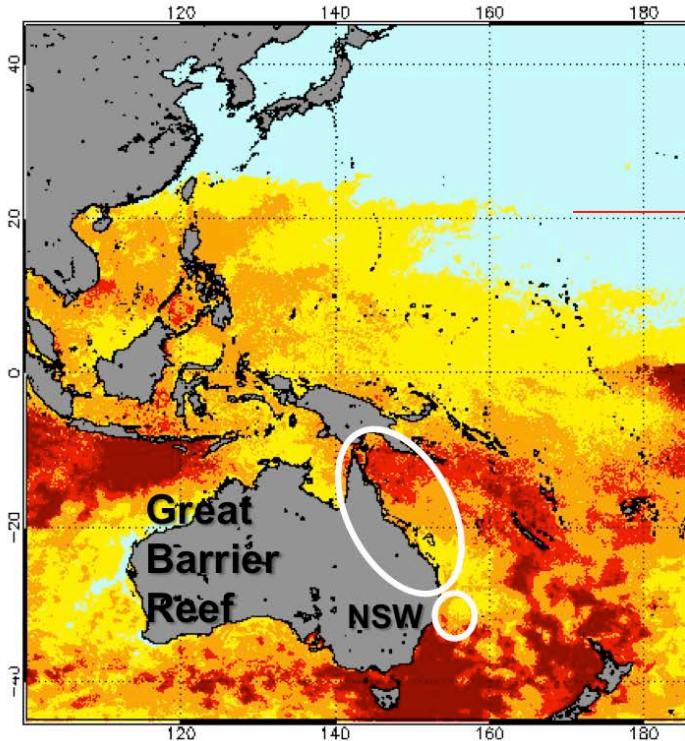
New Caledonia
Fiji
Kiribati
French Polynesia



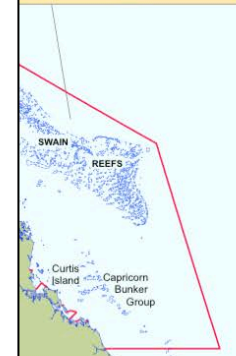
Global Bleaching: First Half of 2016



NOAA Coral Reef Watch Maximum Satellite Coral Bleaching Alert Area YTD 7 June 2016



- 93% of reefs with bleaching
- Far Northern GBR with 95% severe bleaching & 50% dead



Great Barrier Reef Bleaching: 2016



Justin Marshall, Coral Watch



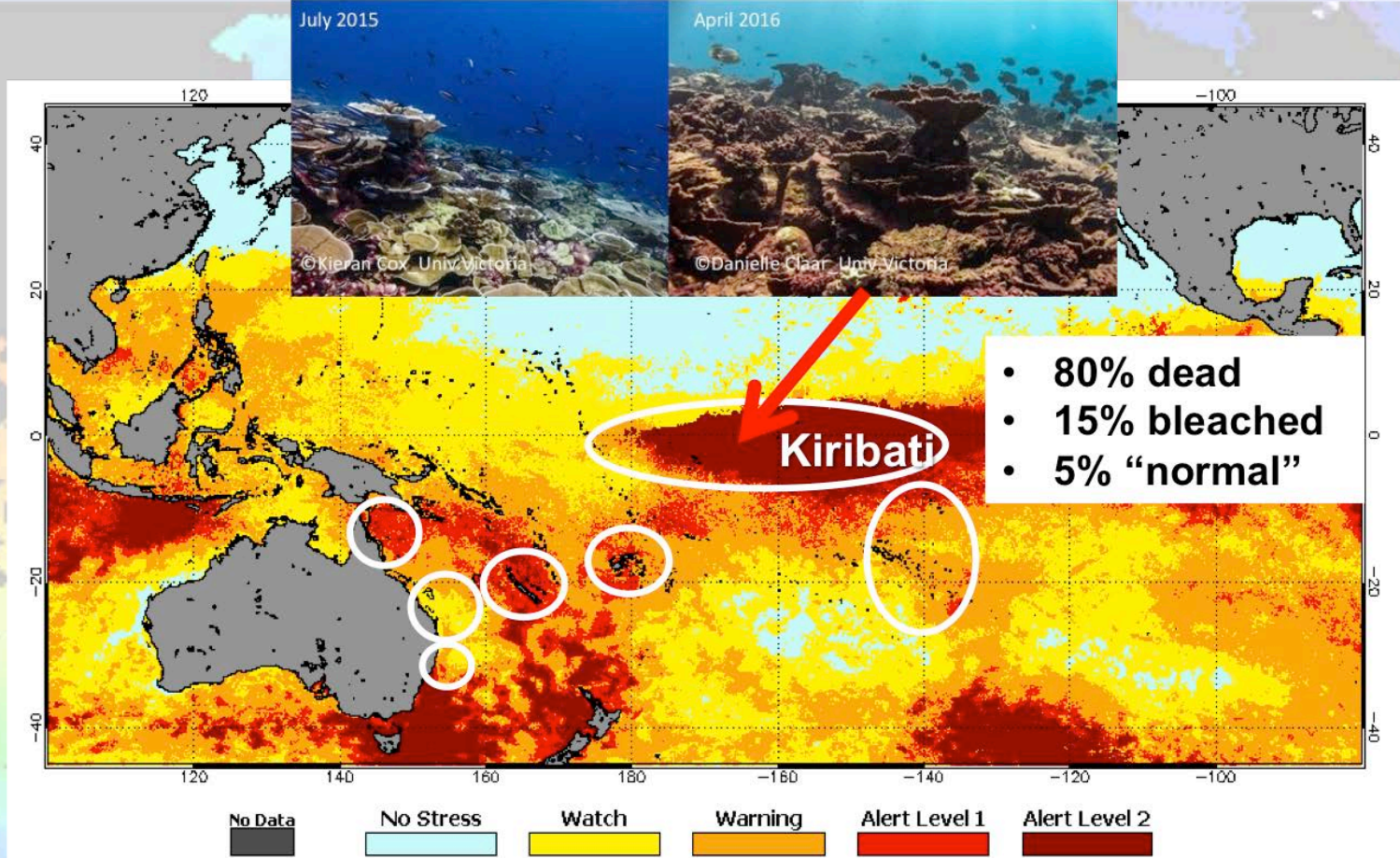
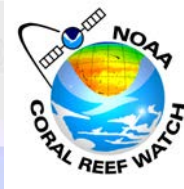
Lizard Island Mortality: 2016

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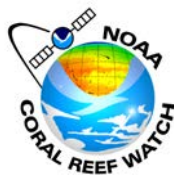


The lack of fish was an indication that there was “complete ecosystem collapse”
Justin Marshall, Univ. of Queensland
The Guardian 21 July 2016

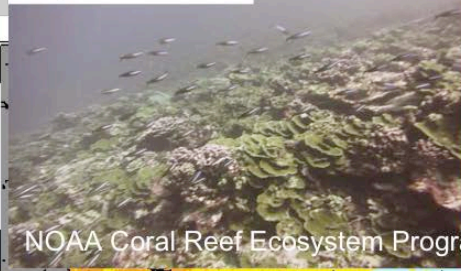
Global Bleaching: Early 2016



Global Bleaching: Early 2016



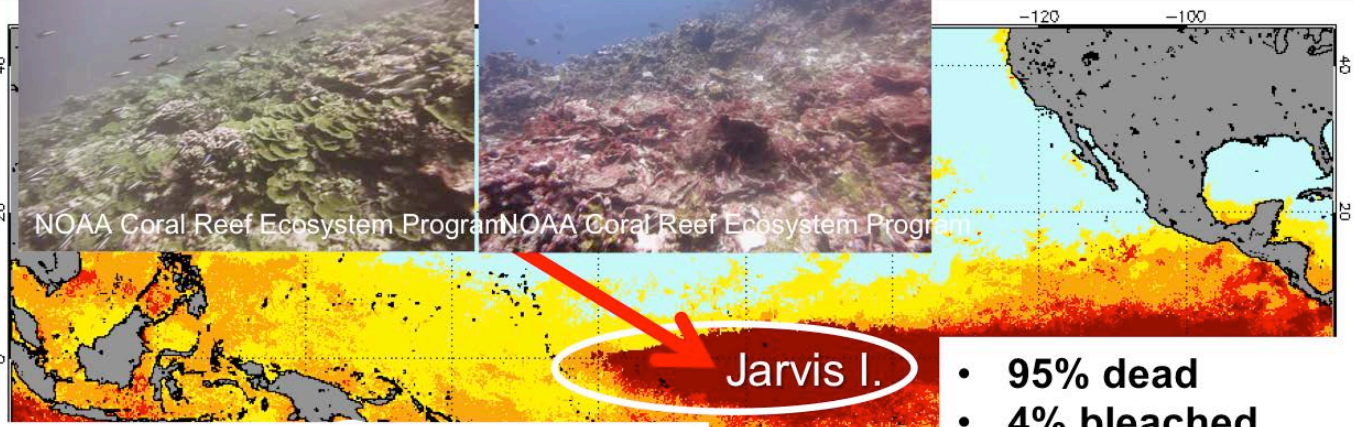
April 2015



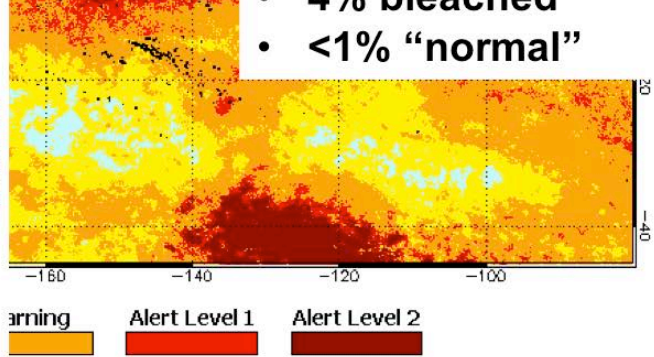
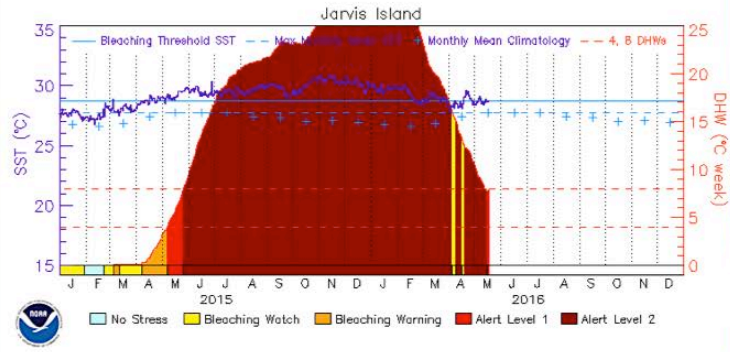
May 2016



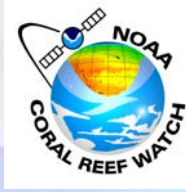
NOAA Coral Reef Ecosystem Program NOAA Coral Reef Ecosystem Program



- 95% dead
- 4% bleached
- <1% "normal"



June 2014-June 2016 Thermal Stress



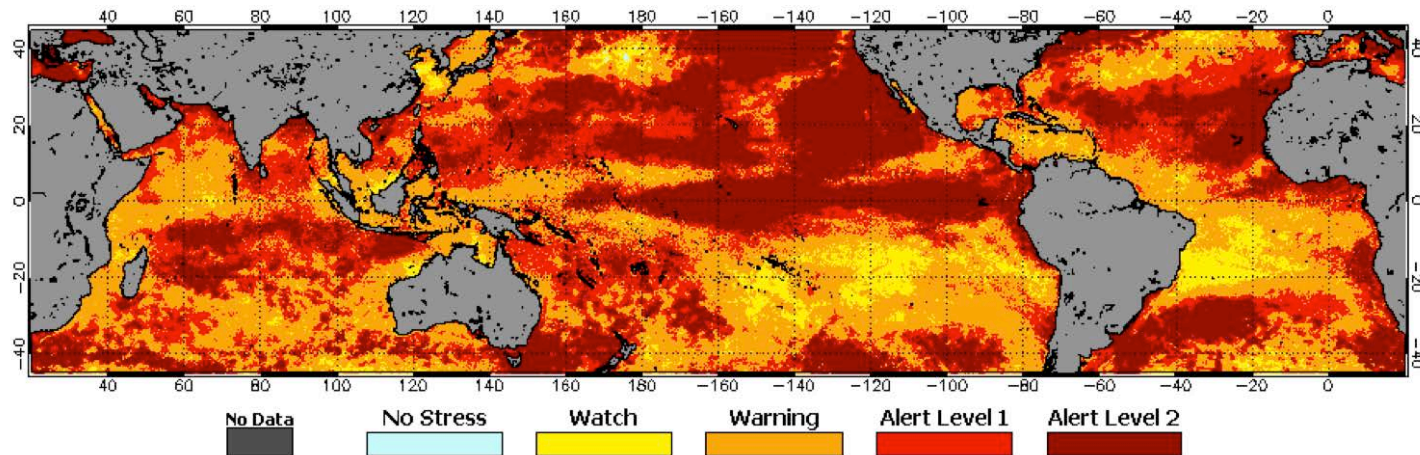
Global Reefs:

- > 40% @ Alert Level 1 or 2
- Level 2 Area > Massachusetts
- Over 1/2 exposed twice
- ~100% stressed

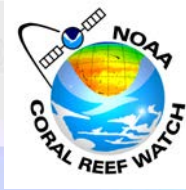
US Reefs:

- 72% Alert Level 1 or 2
- Over 1/2 exposed twice
- 100% stressed

NOAA CRW 5-km Night-Only Bleaching Alert Area Maximum 2014/01/01-2016/06/30

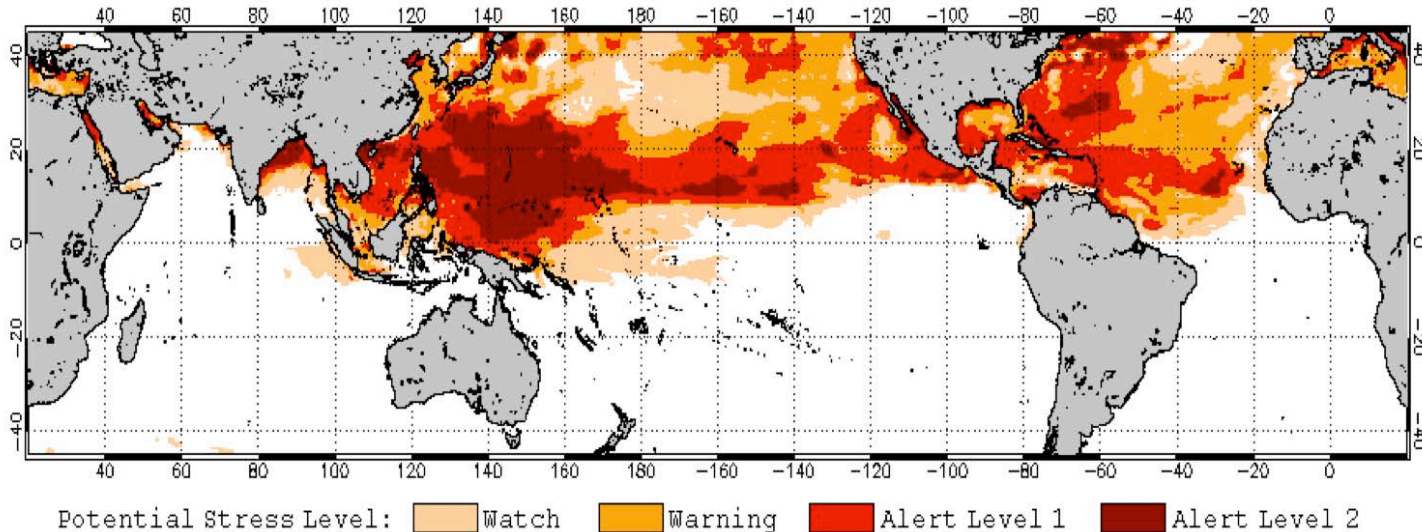


Bleaching Risk Through October 2016

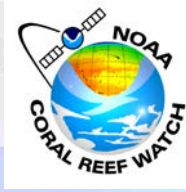


- Severe bleaching likely in NE Philippines, Micronesia, Guam/CNMI, Marshall Islands
- Bleaching likely in Hawai'i, Caribbean

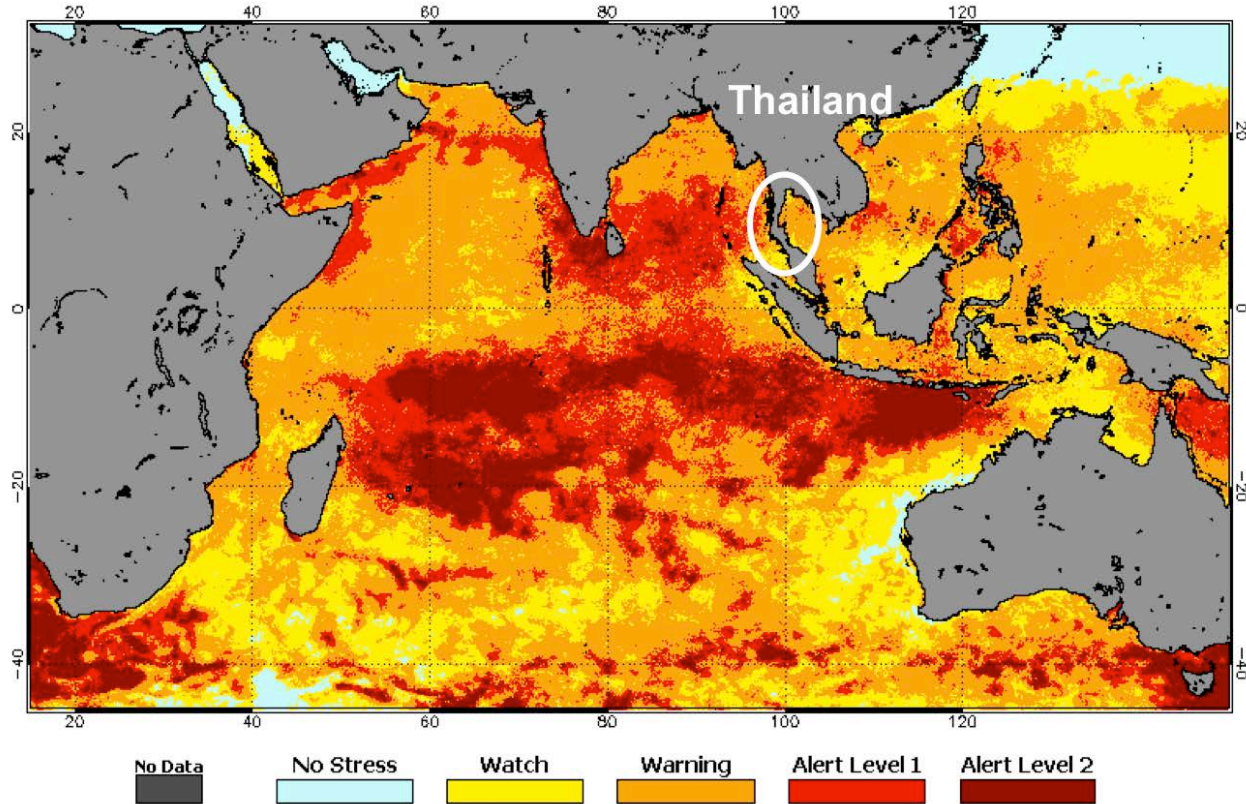
2016 July 19 NOAA Coral Reef Watch 60% Probability Coral Bleaching Thermal Stress for July - Oct 2016



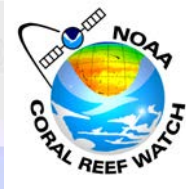
Management Responses: Thailand Reef Closures



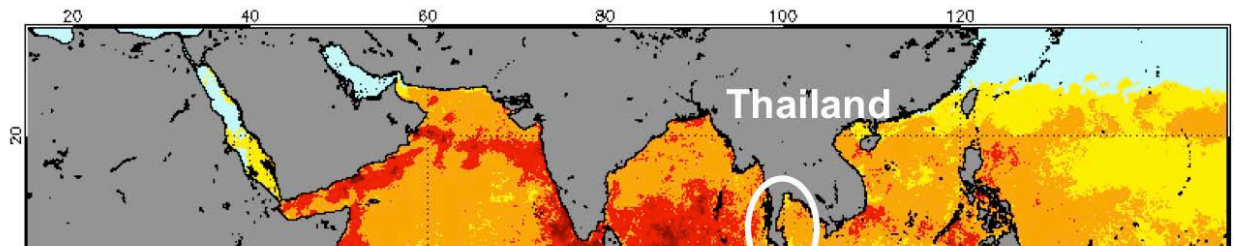
NOAA Coral Reef Watch Maximum Satellite Coral Bleaching Alert Area YTD
18 June 2016



Management Responses: Thailand Reef Closures



NOAA Coral Reef Watch Maximum Satellite Coral Bleaching Alert Area YTD 18 June 2016



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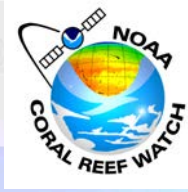
Coral

Thailand closes dive sites over coral bleaching crisis

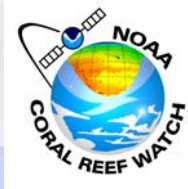
In a rare move to shun tourism profits for environmental protection, 10 popular dive sites have been shut down in a bid to slow a coral bleaching crisis



Management Responses: 2015 Hawai'i Bleaching – DAR “Ark”



Key Messages



New 5-km product suite

- **Just in time for 2014 bleaching**
- **Higher resolution, better regional products**
- **Excellent use by community**

2014-17? Bleaching:

- **Longest, most widespread, often repeated bleaching**
- **> 40% of global reefs affected**
- **72% of U.S. reefs affected**



[@CoralReefWatch](#)



[CoralReefWatch](#)

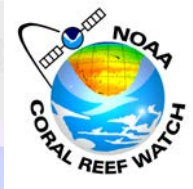
CoralReefWatch.NOAA.Gov



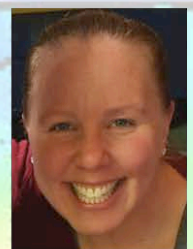


NOAA Coral Reef Watch Team

<http://coralreefwatch.noaa.gov>



Mark Eakin



Jacqueline De La Cour (GST)



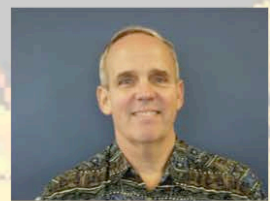
Gang Liu (GST)



Kyle Tirak (GST)



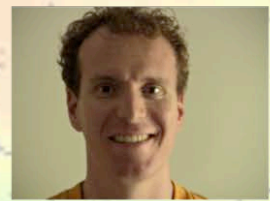
Erick Geiger (GST)



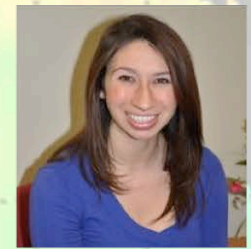
Alan Strong (GST & SRI)



William Skirving (GST & ReefSense)

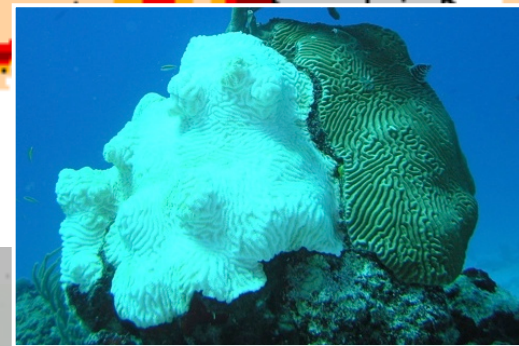
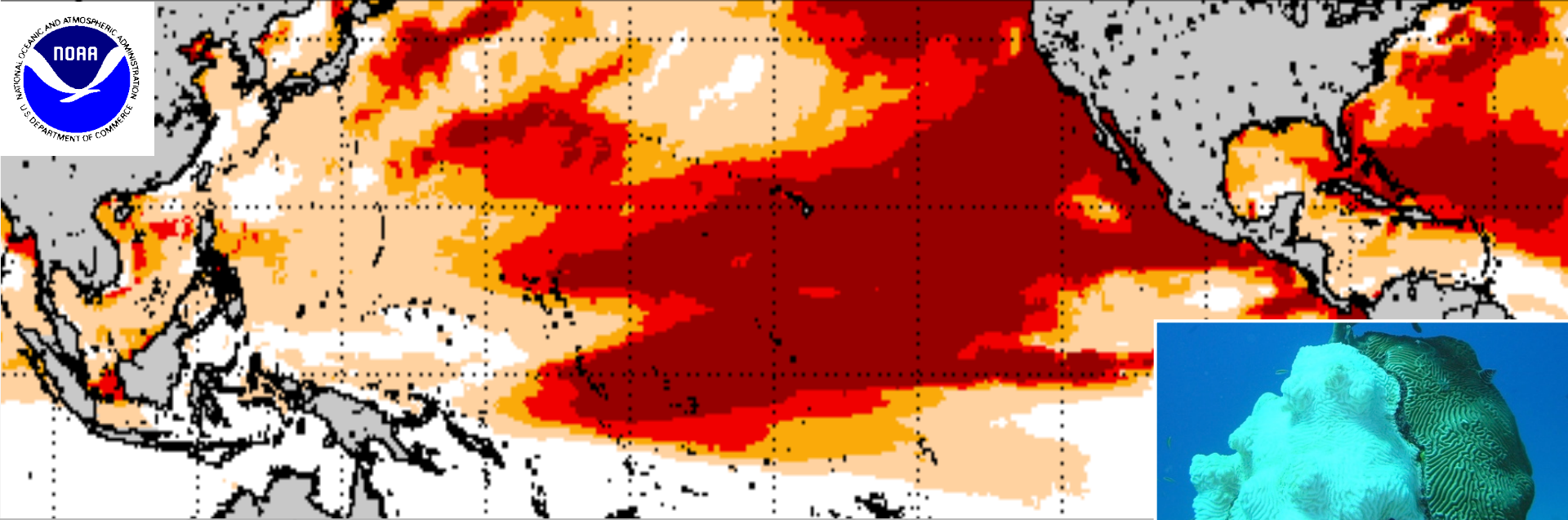


Scott Heron (GST & ReefSense)



Andrea Gomez (CCNY & NOAA-CREST)





Questions?

Dr. C. Mark Eakin
NOAA Coral Reef Watch

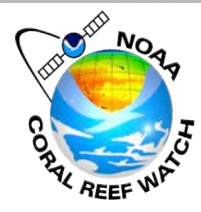
<http://coralreefwatch.noaa.gov>




Coral Reef Watch



@CoralReefWatch



An aerial photograph of a coastal region. A river with a complex delta system flows from the top left towards the center. The water transitions from a light turquoise near the shore to a deep blue further out. The land is green with some brown patches, possibly indicating a wetland or marsh area. A semi-transparent white rectangular box is overlaid on the right side of the image, containing the text 'Week 4 Summary' and a horizontal line.

Week 4 Summary

Week 4 Agenda

- Overview of coral biology
- Threats to coral reefs
 - Local
 - Global
- Remote sensing of coral reefs
- Examples of remote sensing tools for understanding coral reef systems
- Live Demo:
 - Dr. Mark Eakin: NOAA Coral Reef Watch

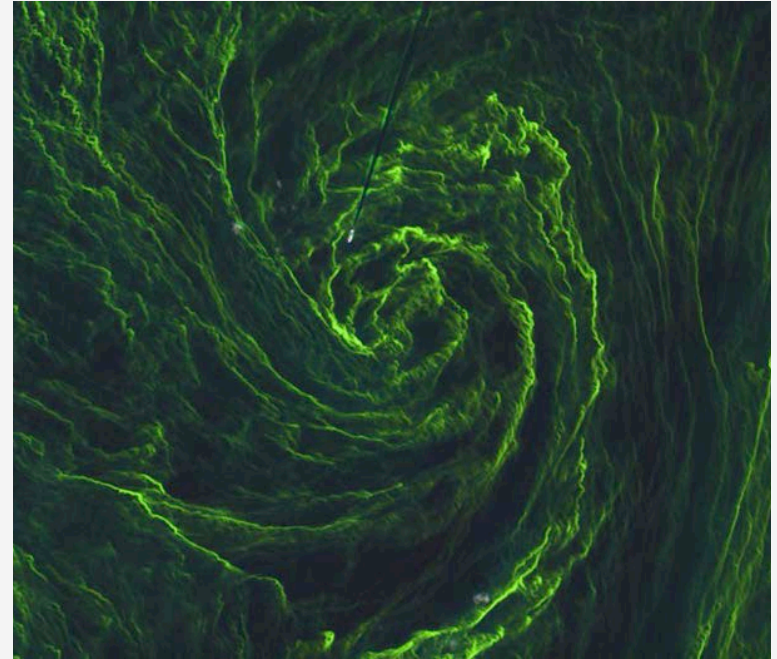


Credit: XL Catlin Seaview Survey, Osprey Reef, Great Barrier Reef

Course Summary

- A basic understanding of remote sensing of aquatic systems
- How to access and use NASA Earth science data, tools, and products for ocean and coastal applied science issues
- Demonstrations of Applied Science tools developed in partnership with NASA
 - animal movement
 - coral reefs

Eye of an Algal Storm Cyanobacteria Bloom in the Baltic Sea



http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-2/Sentinel-2_catches_eye_of_algal_storm

Course Contacts

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National Aeronautics and
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ARSET

Applied Remote Sensing Training

<http://arset.gsfc.nasa.gov>

 @NASAARSET

Thank you!

Please submit your Course Survey!