Monitoring Coral Bleaching Events

From Early Warnings to Building Resilience

Nestled in the world's shallow tropical waters are some of the oldest, most diverse and ecologically important ecosystems on Earth: coral reefs. While coral reefs occupy a tiny fraction of the ocean floor, they contribute billions of dollars in economic, social, and cultural benefits. Those benefits include: habitat for a wide array of marine life; food for coastal and island communities; coastline buffering against erosion, waves, storms, and floods; and jobs and income from fishing, recreation, tourism, and other reef-ecosystem based businesses.

But coral reef ecosystems around the globe are at risk from soaring ocean temperatures and changing ocean chemistry.

Changes in conditions such as temperature and light can cause stress in corals and subsequently lead them to lose their vivid colors and turn pale or white via a process called bleaching. When many corals bleach over a large area of the reef (or multiple reefs), it is referred to as mass coral bleaching.

Climate change and other human impacts are causing more frequent mass coral bleaching events and disease outbreaks. First observed in the early 1980s, mass coral bleaching is now one of the most visible consequences of steadily rising ocean temperatures.

NOAA Coral Reef Watch

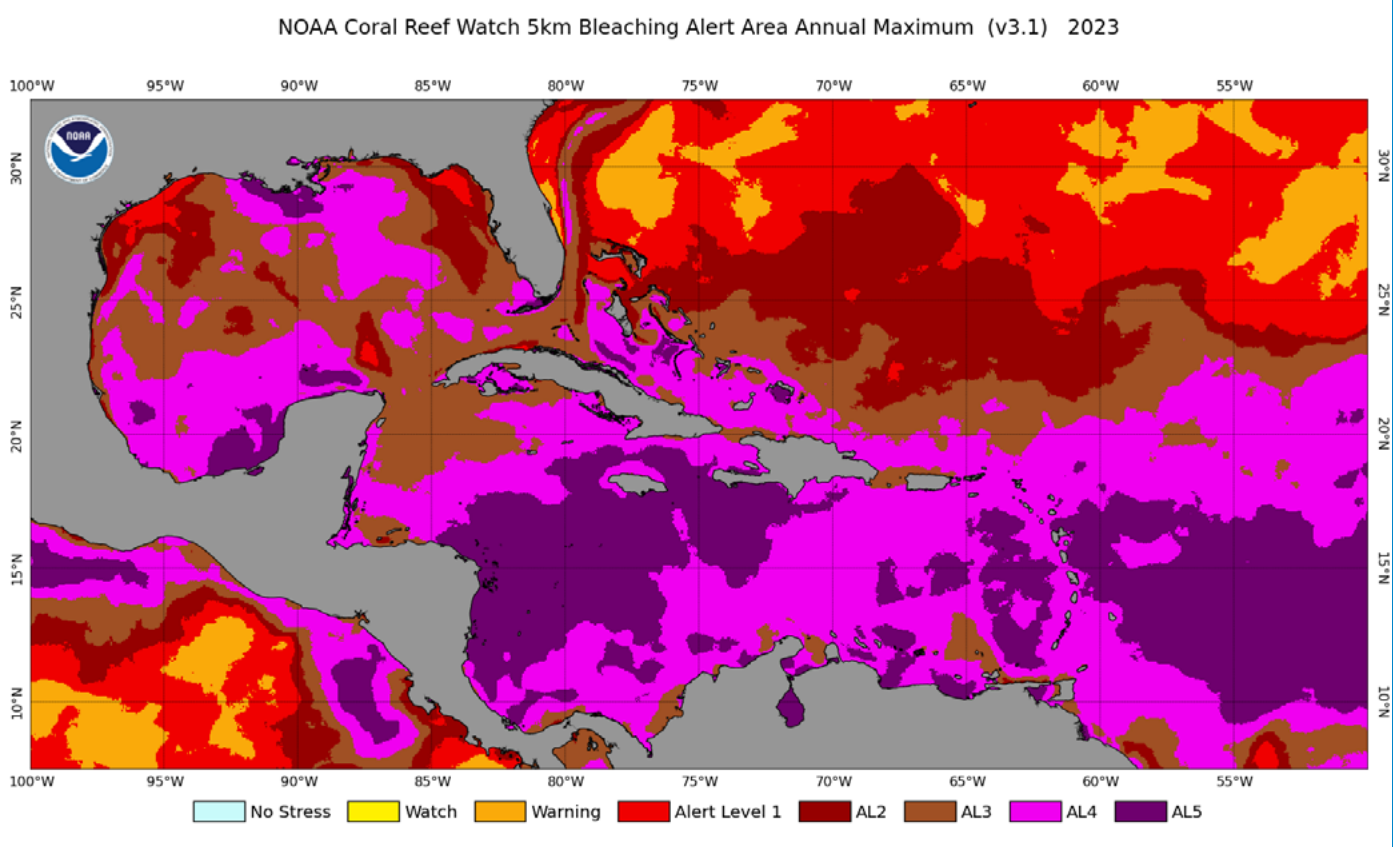
The NOAA Coral Reef Watch (CRW) program, housed in the Center for Satellite Applications and Research (STAR) within the National Environmental Satellite, Data, and Information Service (NESDIS), provides essential environmental intelligence to a diverse community of users worldwide by delivering satellite and modeled products, and alerts, to help predict and monitor changes in the coral reef environment. Since it was established in 2000, CRW has provided the world's only global early-warning system for coral reef ecosystem heat stress.

From the vantage point of space, satellites can monitor coral reefs and their surroundings frequently and broadly. In the most remote regions on the Earth's surface, satellite data are key to ensuring that coastal and island communities around the world receive near real-time updates on changing reef conditions. This allows stakeholders to quickly and effectively implement actions to protect their reefs before and during periods of severe stress. CRW also uses in situ (or in place) data provided by local partners working on these reefs to help develop, calibrate, and validate its satellite-based products.

NOAA CRW offers a variety of satellite products, most of which are based on sea surface temperature (SST) measurements and are updated in near real-time. Examples include a suite of operational coral bleaching heat stress products; a daily global 5km Marine Heatwave Watch (MHW); Regional Virtual Stations; historical 5km Thermal History; Coral Disease Outbreak Risk (for Hawaii and the Great Barrier Reef, Australia); and Ocean Color Monitoring (for Puerto Rico and Hawaii coral reefs), among others. With their focus on current conditions, this satellite data helps users assess whether coral reefs are currently at risk for bleaching. With a near-future focus, NOAA CRW also provides modeled predictions, which incorporate satellite data as the observational feed, of potential heat stress up to four months in the future via the Four-Month Coral Bleaching Heat Stress Outlook. The Outlook is based on the second generation NOAA Climate Forecast System.

Coral Bleaching Alert Area Product

NOAA CRW's Satellite Coral Bleaching Alert Area product uses satellite-based data on accumulated ocean heat stress to provide alerts for coral reef areas globally that may be experiencing high enough heat stress to cause coral bleaching and death. NOTE: on December 15, 2023, CRW implemented a revised coral bleaching heat stress category system for its Bleaching Alert Area product. Extreme accumulations of marine heat stress in 2023, in multiple regions of the world, necessitated the introduction of additional Bleaching Alert Levels. This development is a refinement of the original system that only used Bleaching Alert Levels 1 and 2. The new Alert Levels 3-5 provide important, added detail, for when the magnitude of extreme heat stress exceeds the threshold of Bleaching Alert Level 2 conditions.



The dark red/brown areas on this map, which is focused on the Northwest Atlantic Ocean, Caribbean, and eastern tropical Pacific Ocean, show the heat stress capable of causing reef-wide bleaching with mortality of heat-sensitive corals. The light brown (Alert Level 3), pink (Alert Level 4), and dark purple (Alert Level 5) areas on the map indicate locations where the magnitude of extreme heat stress exceeds the Bleaching Alert Level 2 threshold and can lead to multi-species or near complete mortality on a coral reef.

These products and alerts enable coastal and island communities to:

1. Prepare for coral bleaching and disease outbreak events that may have significant, long-term impacts on coral reef ecosystem health and functioning,
2. Take actions (e.g., closing areas to fishing or scuba diving) to reduce additional, local stresses on the reef ecosystem,
3. Prioritize resources to protect key corals and reefs, especially during periods of high or prolonged heat stress (e.g., by rescuing native or rare corals to preserve genetic diversity and/or by shading/cooling key nursery reefs), and
4. Conduct restoration activities in times of no heat stress.

In addition to enabling resource managers and coastal/island communities to effectively monitor all the reefs in their jurisdiction and implement targeted conservation actions to help reduce stressors on and protect their coral reef ecosystems, CRW's satellite-based information allows NOAA to meet its users' needs and its missions, goals, and objectives.

> ***"The importance of this effort relies on us being able to monitor the evolution of the heat stress in near real-time and to inform the ongoing impacts from the severe, prolonged marine heatwave. These efforts are key for decision-making processes as we continue coral recovery and conservation efforts during the current and future marine heatwave events."***
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> *—Maria Vega-Rodriguez, Departamento Recursos Naturales Y Ambientades, Gobierno de Puerto Rico*

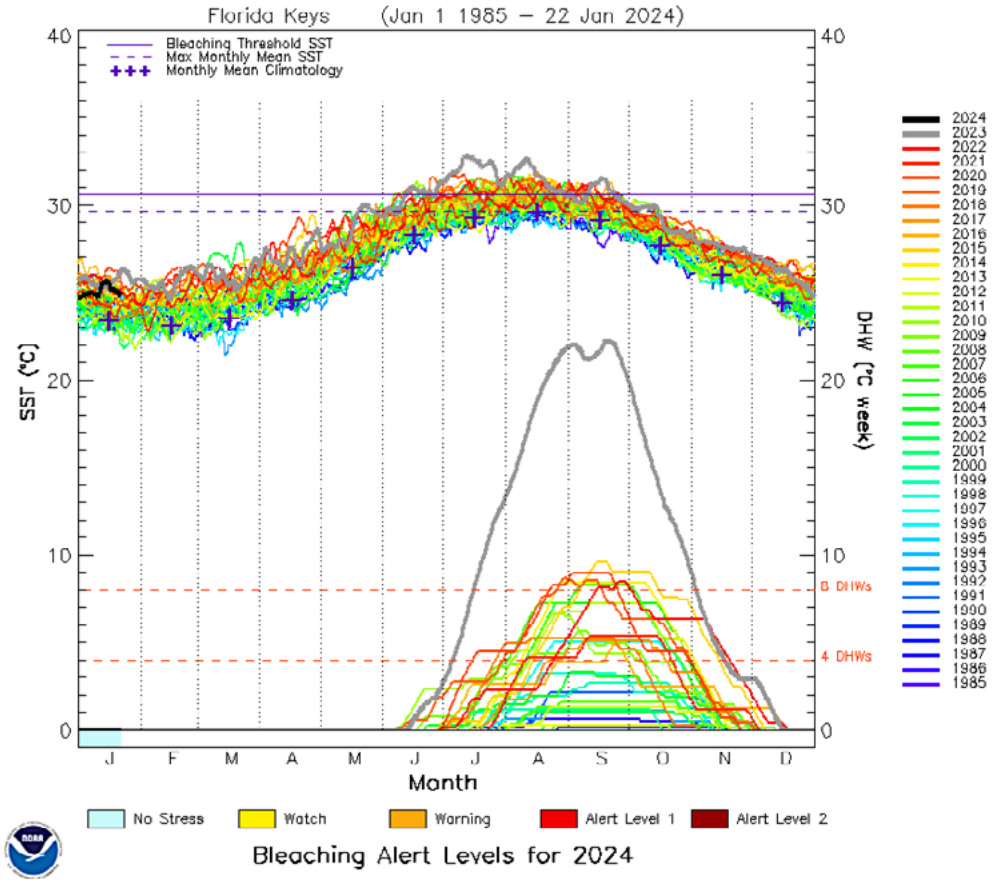
In response to the critical, user-defined need for remote prediction, monitoring, and assessment of the coral reef environment and coral health globally, CRW also engages heavily with its users and partners in research, development, and operations, and conducts extensive communication and outreach. As with previous major heat stress events in the region, CRW recently provided advance warning and near real-time satellite monitoring of the 2022 heat stress and subsequent mass coral bleaching event on the Great Barrier Reef in Australia. CRW collaborated directly with the Australian Government and other local stakeholders to coordinate information sharing and messaging to global media outlets.

2023: A Historically Hot Year for Reefs in the Florida Keys

In April 2023, CRW scientists observed and began communicating with local stakeholders about multiple marine heatwaves that were developing in the eastern tropical Pacific and in the Atlantic/Caribbean that had the potential to negatively impact corals in both regions. By July, in Florida, heat stress conditions had become so severe that Dr. Derek Manzello, the NOAA CRW Federal Coordinator, who had previously, for two decades, researched the impacts of ocean warming on reefs in the Florida Keys, dubbed the heat stress event "historically horrific." Using SST measurements from a satellite record dating back to 1985, Manzello pointed out that water temperatures were much higher and came much earlier in 2023 than any prior year.

During Florida's severe marine heatwave and prolonged mass bleaching event, CRW products were critical to a wide array of efforts including in-water monitoring, conservation, and rescue/relocation of coral colonies, as well as communication with decision makers, the press, and the public.

Single-pixel satellite Virtual Stations—a new addition to the NOAA CRW product portfolio—were created in response to an emergency need by coral reef stakeholders in Florida. The product enables users to compare current heat stress levels across sites, to assist with: prioritization of current efforts by location, communication among stakeholders, and subsequent relocation of coral colonies back into the water, once the heat stress subsides, for monitoring and restoration activities.



In the figure, the thick gray line represents 2023. Heat stress capable of causing coral bleaching, including mass bleaching and subsequent mortality, starts once the SSTs surpass the solid bluish-purple horizontal line.

NOAA/OAR/Atlantic Oceanographic & Meteorological Laboratory coral reef ecologist, Dr. Ian Enochs, surveys coral bleaching at Cheeca Rocks, Florida Keys in July 2023.

A piece of brain coral completely bleached.

The comments that follow help demonstrate how meaningful the Single-pixel satellite Virtual Stations were in understanding and meeting the needs of different stakeholders in different situations.

> ***"The NOAA Coral Reef Watch single-pixel satellite virtual stations have been remarkably well received, and are actively being used by coral reef stakeholders all over the state, to help monitor environmental changes in near real-time and triage ongoing impacts from the severe, prolonged marine heatwave. These data will be of great use in the future, as we learn and adapt FKNMS's conservation and management efforts with ocean warming."***
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> *—Katey Lesneski, Mission: Iconic Reefs, Research and Monitoring Coordinator, Florida Keys National Marine Sanctuary*

Working with local management partners, CRW also developed single-pixel satellite Virtual Stations for key restoration and nursery reef sites in Puerto Rico and the US Virgin Islands.

Anthropogenic climate change and human-induced hazards are putting the health of coral reef ecosystems in jeopardy globally. However, even as these ecosystems face mounting and severe threats, NOAA's satellite and modeled products continue helping user communities worldwide to prepare for coral bleaching and disease outbreak events; take action to limit stressors to coral reef ecosystems; and shape conservation, rescue, restoration, resilience, and communication efforts. Through the CRW program, ecosystem managers, scientific researchers, in-water monitoring networks, elected officials, and coastal/island communities in the US and around the world have critical tools to help them effectively manage, monitor, research, and protect coral reef ecosystems in a rapidly warming world.

> ***"Florida's coral reef community now has an enhanced decision-support-tool that provides data on which sites are experiencing the highest heat stress and require urgent intervention, such as coral rescue and relocation efforts aimed to preserve the genetic diversity of threatened staghorn and elkhorn corals. These data are still being used for prioritization of in-water efforts and resources, as well as a communication tool among Florida's coral reef stakeholders, the public, and the press."***
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> *—Jennifer Moore, Co-Lead, Mission: Iconic Reefs, National Marine Fisheries Service (NOAA)*