4. The 2005 Bleaching Event: Coral-List Log

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Coral reef scientists and managers were fortunate to have an early warning system in place prior to the damaging events of 2005. This chapter is a log of events that occurred in the Caribbean during 2005 and is largely based on messages sent out, and submissions to, Coral-List.

CORAL LIST

'Coral-List' is a coral reef information and news email forum maintained by NOAA's Coral Health and Monitoring Program, for coral reef researchers and managers throughout the world. Since 1995, the list has broadcast announcements and discussions of various local, regional, and global topics concerning coral reefs, including coral bleaching, disease and spawning, environmental monitoring, and upcoming meetings. Coral-List currently has more than 4400 subscribers. To register go to http://coral.aoml.noaa.gov/mailman/listinfo/coral-list/.

17-Mar-05 Coral bleaching reported on 2 reefs in Southern Bahia, Brazil (Itacolomis and Abrolhos); but the temperature rise is only 0.75°C above the maximum summer average. NOAA has not detected a major HotSpot in the satellite images; maybe this is a doldrum-like event.

16-May-05 First bad news: The U.S. National Hurricane Center has predicted a 70% chance of an above-normal Atlantic hurricane season. The outlook is for 12-15 tropical storms, of which 3-5 will become major hurricanes. This could be serious for reefs in the Caribbean. Bad hurricane years are often bad bleaching years as well.

26-May-05 Satellite images show potential coral bleaching and 'HotSpots' are appearing across the Caribbean earlier than usual. Winds are generally low and a pool of unusually warm water has formed northeast of the Lesser Antilles. NOAA Coral Reef Watch has sent out an email message calling for people to start checking for coral bleaching.

THERMAL STRESS AND HOTSPOTS

NOAA Coral Reef Watch uses satellite sea surface temperature (SST) data to produce twice-weekly global estimates of thermal stress on corals (http://coralreefwatch.noaa.gov). Thermal stress depends on the capacity of corals in different locations to tolerate heat; corals near the equator are comfortable in temperatures that would be stressful for corals that are used to cooler waters.

Because stress thresholds are location-specific, the expected temperature for a normal summer is determined for each location. To measure the stress level, the current SST is compared with this normal summer temperature. The difference between these indicates the current level of stress experienced by corals and is called the 'HotSpot.'

Coral bleaching HotSpot maps illustrate the magnitude and distribution of HotSpots using different colors that correspond to the number of degrees by which the SST exceeds the normal summer temperature. Examples of the maps are on pages 8 to 11)

31-May-05 Reports are coming in from Colombia that they are seeing the highest sea surface temperature (SST) over the reefs so far this year, 29.9°C. Thankfully, there is no bleaching there … (yet).

02-Jun-05 The trade winds have begun again, mixing and cooling the waters. While this has provided some relief, there are still concerns about coral bleaching – and we're only at the start of June!

16-Jun-05 The first Coral-List report of bleached corals for the Caribbean has come from the northwest coast of Colombia at Islas del Rosario, following sustained high water temperatures.

25-Jun-05 SSTs at Culebra, Puerto Rico, have reached 30.5°C and corals are bleaching. In some areas, 50% of corals have died. On top of this, there have been outbreaks of white plague-like syndrome and black band disease. The warmest temperatures here aren't usually reached until September and October.

05-Jul-05 SSTs have started to cool on the Caribbean coast of Panama but the accumulated thermal stress shown by the coral bleaching Degree Heating Week (DHW) values are still high. Corals have bleached near Bocas del Toro; hopefully this cooling will allow them to recover.

Hurricane Dennis, 05 to 13 July 2005

Hurricane Dennis was unusually strong for a July hurricane, reaching Category 4 status. Dennis made landfall four times; in Grenada, twice in Cuba and finally in western Florida. Wind speed is used to indicate a hurricane's strength, from Category 1 (weakest) to Category 5 (strongest) on the Saffir-Simpson scale (see Hurricane Capter).

DEGREE HEATING WEEKS

The satellite-based coral bleaching Degree Heating Week (DHW) is an accumulation of thermal stress experienced by corals within the previous 12 consecutive weeks. A DHW value of 4°C-weeks indicates that significant coral bleaching is likely; widespread coral bleaching and mortality have been associated with DHW values exceeding 8°C-weeks. For each location, DHW are calculated by adding any HotSpot values greater than 1°C and multiplying by the half-week time step of the NOAA Coral Reef Watch data. For example, if the HotSpot values for a particular location were [1.0, 2.0, 0.8, 1.2] the contribution to the DHW from these four half-week values would be (1.0+2.0+1.2)*0.5 = 2.1°C-weeks. Note that 0.8 is not included in the calculation as it is less than 1°C. Examples of maps derived illustrating the distribution of DHW values can be seen on the first page inside the front cover; the front cover is a stylized version of this map.

13-Jul-05 NOAA Coral Reef Watch launches a new operational product: the Satellite Bleaching Alert system.

15-Jul-05 More reports of bleaching have come in, including extensive paling of corals around Abacos in the Bahamas. The HotSpot image on Executive Summary page 8 illustrates the developing HotSpot.

Hurricane Emily, 11 to 26 July 2005

Hurricane Emily eclipsed the record set by Dennis, just 6 days earlier, as the strongest recorded pre-August hurricane and is the only Atlantic hurricane to have reached Category 5 status before August. Emily inflicted damage on Grenada as a tropical storm before intensifying in the western Caribbean. Emily crossed the Yucatan Peninsula (Category 4) and again made landfall in northern Mexico (Category 3).

26-Jul-05 Amazing! In the first two weeks of the Satellite Bleaching Alerts (SBA) system, emails have been sent for all 6 Caribbean/Atlantic sites. The U.S. Virgin Islands have thankfully dropped back to a condition of no thermal stress; Puerto Rico, the Bahamas, and Bermuda have gone up to Bleaching Watch, while Belize has dropped down to Bleaching Watch. There is some concern for the Florida Keys; there is a Bleaching Warning there at the moment.

02-Aug-05 Things have become worse; the National Hurricane Center has upgraded the probability of an above-normal hurricane season to 95-100%. The prediction is now for 18-21 tropical storms, including 5-7 major hurricanes.

05-Aug-05 Corals have become pale and bleached in Bermuda where calm seas and clear skies are persisting and there have been reports of unusually large numbers of nudibranchs (a type of sea slug). Reports of sponge diseases have increased in Cozumel, Mexico; requests have gone out for more sightings. It is worse around St. Croix in the U.S. Virgin Islands where sponges appear to be absent - should we send out a search party?

08-Aug-05 Elkhorn corals *(Acropora palmata)* in Biscayne Bay have lost tissue following the passage of Hurricane Dennis through the Florida Keys. With the prediction of more hurricanes, will more corals lose tissue?

SATELLITE BLEACHING ALERTS

Satellite Bleaching Alerts (SBA) notify reef managers when changes occur in the environmental conditions relevant to coral bleaching at or near their reef. NOAA Coral Reef Watch transmits emails for 24 locations around the world, including 6 strategic reef sites across the greater Caribbean region. SBAs are sent to registered users whenever HotSpot and Degree Heating Week indicators show that the thermal stress level has passed a critical threshold; either increasing or abating. Subscription is free at http://coralreefwatch-satops.noaa.gov/SBA.html; additional SBA sites are under development and further locations can be requested.

Bleaching Watch: Keep an eye out! Corals are experiencing low-level thermal stress. Temperatures have exceeded the usual summer maximum but have not yet reached the Bleaching Threshold. Degree Heating Weeks (DHWs) are not yet accumulating.

Bleaching Warning: Get prepared now. The HotSpot is now at least 1°C and corals are stressed. DHWs have begun to accumulate and are at 1°C-week.

Alert Level 1: Corals are probably bleaching or will soon! DHWs have reached 4°C-weeks, signifying that thermal stress has reached levels that cause bleaching. Generally, corals will respond to this level of thermal stress in the next 1-3 weeks, depending on the species and other local factors.

Alert Level 2: Double trouble. At DHW of 8°C-weeks, thermal stress is widespread and you can expect to see mass coral bleaching. Unfortunately, by this time, the thermal stress has persisted long enough that some corals will probably die soon.

No Stress: Temperatures have cooled and hopefully stressed corals will recover. At least they are no longer under thermal stress.

18-Aug-05 Extensive bleaching has been seen in the Florida Keys, right after an SBA Alert Level 1 email was sent on 13 August. SST has been around 31°C, with calm and sunny conditions. There could be more trouble in store for Florida's reefs; a strong HotSpot is developing, as shown in the image on page 9.

23-Aug-05 More bleaching has been seen in Biscayne Bay, Florida Keys, and now corals near Palominitos Island, Puerto Rico are bleaching.

Hurricane Katrina, 23 to 30 August 2005

Hurricane Katrina was one of the most devastating natural disasters in the United States history. Katrina was the most costly hurricane to strike the U.S., making landfall in Florida (Category 1) and then intensifying to Category 5 over the Gulf of Mexico before striking Louisiana/Mississippi (Category 3). Katrina was exceptionally large with hurricane-force winds extending 170 km from the centre and storm-force winds out to 370 km. The 8 m storm surge that accompanied Katrina caused major flooding in New Orleans and along the northern Gulf coast. However, Katrina also did some good in the Florida Keys, as a Category 1 hurricane, mixing up the waters and cooling overheated reefs.

27-Aug-05 Record-breaking thermal stress is affecting Sombrero Key in the Florida Keys and an SBA Alert Level 2 has been issued. Hurricane Katrina is crossing over South Florida – are we going from bad to worse?

29-Aug-05 According to an article in the Key West Citizen, Hurricane Katrina has really helped the Florida Keys, providing much-needed relief from thermal stress.

01-Sep-05 Several coral species are bleaching on the reefs of Belize, ranging in intensity from paling to bright white.

06-Sep-05 SST has dropped by more than 2°C at Sombrero Key from a week ago. The SBA level has been reduced to Bleaching Watch; hopefully these corals can recover from the thermal stress. The HotSpots are now covering extensive areas of the Caribbean, as seen on the image on page 10.

09-Sep-05 Hard corals in eastern Puerto Rico have bleached extensively, and octocorals, gorgonians, and zoanthids have also bleached. Water temperatures are around 29.5-30°C and there is barely any wind.

12-Sep-05 Things are looking bad. Corals in Biscayne Bay range from unbleached, to pale, to extensively bleached, and black band disease has been observed. The Florida Keys corals range from slight to severely bleached, and divers have reported recently-dead Elkhorn coral. Corals in southwestern Puerto Rico have started to bleach and white plague has also been seen.

14-Sep-05 The first bleaching of the flower coral *Mussa angulosa* has been recorded in northeastern Puerto Rico, as well as bleaching and mortality reports of *Palythoa caribbaeorum*. Bleaching has also been seen in northern and western Barbados and southeastern Costa Rica.

15-Sep-05 A report has come from eastern Puerto Rico of the first-ever record of a bleached colony of Elkhorn coral in the region. There has been extensive bleaching and mortality, as well as an outbreak of black band disease. Scientists have noted that for some reason there does not appear to be any cleaning gobies on the reefs - are the gobies stressed too?

17-Sep-05 Now coral bleaching has been seen in the British Virgin Islands. Are any reef areas safe?

19-Sep-05 Not only are hard corals, octocorals and zoanthids bleaching around Barbados, scientists have noted unusually high mortality of moray eels and white sea eggs (a type of sea urchin).

21-Sep-05 Thermal stress has progressed southward and eastward through Cuba, Puerto Rico and the Virgin Islands. DHW levels have exceeded 8°C-weeks, so the likelihood of coral mortality is high. It's hard to not feel helpless.

Hurricane Rita, 18 to 26 September 2005

Hurricane Rita took only 36 hours to strengthen from a tropical storm to a Category 5 hurricane as it passed across the central Gulf of Mexico, making it the most intense hurricane ever recorded in the Gulf; breaking the record set by Katrina just weeks earlier. While intensifying, Rita passed near Florida Keys (as Category 2), mixing the waters that had begun to warm again following the cooling by Hurricane Katrina. Rita struck the Texas-Louisiana border as a Category 3 hurricane and completely destroyed some coastal communities.

24-Sep-05 Is there a weather conspiracy against corals? There is an extended area of low pressure over the northeastern Caribbean that means light winds for the next two weeks. The northern Jamaican coast has experienced low-level bleaching, but the southern coast has areas where 80% of the corals are bleached. There is good news, with little-to-no bleaching in Bonaire and Curaçao and mass coral spawning has occurred in Curaçao as usual.

26-Sep-05 It has been the hottest August and September in 15 years of ocean temperature monitoring at St. John, U.S. Virgin Islands! Temperatures at 16 m depth have exceeded 30°C since 5 September and just peaked at 30.8°C. Most coral species are severely bleached.

30-Sep-05 The Association of Marine Laboratories of the Caribbean has called for the establishment of a long-term monitoring program for biological communities and physical environment conditions on reefs. Hopefully that will help us learn how to help corals survive through events like this.

05-Oct-05 Devastating news; a report has been received that more than 90% of corals down to 30 m are bleached in the British Virgin Islands. Bleaching has also been seen along the northern coast of Puerto Rico. DHW values have reached record highs in these areas. There is a sense of helplessness in our offices; apparently all we can do is issue more threatening reports. The image on page 11 shows the maximum extent of HotSpots across the Caribbean.

08-Oct-05 An SBA Alert Level 2 has been issued for the U.S. Virgin Islands and DHWs in the region now exceed 12°C-weeks. At least 90% of corals along the northern shore of St. Croix are white or paled. Thankfully, the sun has now moved south, so things should begin cooling off (we hope!)

11-Oct-05 DHW values have continued to escalate in the eastern Caribbean; when will it stop? Predicted cloud and rain should bring relief from thermal stress for those regions lucky enough to get them.

13-Oct-05 The Caribbean coast of Tobago has experienced its worst recorded mass coral bleaching, with around 80% of corals affected by the 31°C conditions. Near St. Croix, U.S. Virgin Islands, 50-75% of hard corals and several soft coral species have bleached.

19-Oct-05 Observations in the Flower Garden Banks National Marine Sanctuary (NMS) have shown significant mechanical damage from the passage of Hurricane Katrina. Coral boulders larger than 2 m were rolled over! In addition, at least one-third of colonies have bleached.

22-Oct-05 Temperatures are in excess of 29°C down to 20 m at Guana Key in the Bahamas and bleaching has affected 96% of *Montastraea* colonies and 50% of *Porites* colonies.

23-Oct-05 Batten down the hatches! Coral-List has to be temporarily shutdown because of the imminent arrival of Hurricane Wilma and anticipated power outages.

Hurricane Wilma, 15 to 25 October 2005

Hurricane Wilma was the most intense Atlantic basin hurricane on record, with a lowest central pressure of 882 hPa. Wilma wreaked havoc on the Yucatan Peninsula (Category 4), sitting over Cozumel for more than 36 hours, before causing extensive damage in Florida (Category 3).

25-Oct-05 Above-normal temperatures have continued across the Caribbean. The centre of the heat stress has moved south along the Lesser Antilles and NOAA reports intensified bleaching in many areas (DHW>12°C-weeks). Bonaire and Curaçao are now seeing bleaching stress (DHW>4). Major newspapers, *the Washington Post* and *Los Angeles Times,* have reported the bleaching caused by temperature stress across the Caribbean.

27-Oct-05 Reef Check has called for the mobilization of its teams throughout the Caribbean for bleaching and post-bleaching surveys. Corals along the northern coasts of Colombia and Venezuela (20% of colonies) have bleached; in the Flower Garden Banks NMS, around 40% of colonies have bleached.

01-Nov-05 Scientists in Mexico are assessing the damage to corals from Hurricane Wilma. In the Lesser Antilles, the centre of the heat stress has expanded southward and has affected even more coral regions.

02-Nov-05 The International Coral Reef Initiative has passed a Statement of Concern encouraging countries in the region to take immediate action to document the extent of bleaching, mortality, and recovery; and to target surviving coral reefs for protection.

04-Nov-05 Good and bad: corals have started to recover their color over the past 10-14 days in the U.S. Virgin Islands and Puerto Rico. Many Elkhorn and Staghorn *(Acropora palmata* and *A. cervicornis)* corals have been killed during the thermal event and disease outbreaks and lesions have hit bleaching-affected corals.

Coral disease appears to be spreading! *Outbreaks of coral disease have been linked to periods of thermal stress. As such, the prevalence of disease often increases following bleaching events, as already stressed corals are more susceptible to infections. As temperatures return below stressful levels, disease progression frequently slows.*

07-Nov-05 The U.S. Coral Reef Task Force has passed a resolution for its members to lead a coordinated interagency response to monitor the ecological and sociological impacts of the Caribbean bleaching; already one of the worst regional-scale events on record. The resolution also called for improved forecasting of thermal stress and its impacts on coral reef ecosystems.

11-Nov-05 In northern Colombia, bleaching ranges from partial to severe across several species, with water temperatures at 29°C. At Cayo Sombrero, Venezuela, the whiteness of corals has generally increased.

22-Nov-05 The SBA alert level for the U.S. Virgin Islands and Puerto Rico has been reduced to No Stress. It seems the bleaching here is finally over. The big question is whether the corals can recover.

28-Nov-05 Is this a case of 'hit them while they're down'? Outbreaks of white plague have been recorded in a variety of species in both the U.S. Virgin Islands and the southwest of Puerto Rico. The outbreaks are most intense in offshore waters where the depth is 15 m or more. Though the progress of the disease has slowed as temperatures have dropped, some coral deaths have been attributed to the disease. Black band disease has been seen in the British Virgin Islands.

01-Dec-05 The 2005 Hurricane season officially ended, with a record 26 named storms, including a record 13 hurricanes (5 of which were severe). This was the first time in history that the seasonal list of names was exhausted and the back-up Greek letter system had to be used.

16-Dec-05 Mixed reports; no sightings of bleaching in Bermuda; some totally bleached colonies at Grand Cayman Island but no mortality. At La Parguera, Puerto Rico, while most corals have begun to recover their color, some remain completely white and there has been high mortality among Elkhorn, Staghorn and *Millepora* corals.

21-Dec-05 Most nearshore corals in Colombia are dead, while corals 100 m offshore have experienced outbreaks of various diseases.

30-Dec-05 Tropical Storm Zeta has formed, missing the record of the latest ever to form by 6 hours. It finally dissipated on 6 January 2006.

03-Jan-06 Bleaching in the Flower Garden Banks NMS is down to 10% of colonies; however, white plague symptoms have been observed in more than 2%.

31-Jan-06 Coral mortality levels in Martinique have hit 18%. The mortality is likely to be the result of an outbreak of white plague.

03-Mar-06 One up, one down. Bleaching now only affects 5% of colonies in the Flower Garden Banks NMS, but the incidence of white plague has risen to around 7%, with up to 20% of colonies infected in localized areas.

08-May-06 Are Caribbean reefs disappearing? Elkhorn *(Acropora palmata)* and Staghorn *(A. cervicornis)* corals will be listed as threatened species under the U.S. Endangered Species Act. This is the first time any coral species have been officially classed as endangered. Let's hope we don't see another year like this anytime soon.

16-Oct-06 Corals at some locations are still bleached. Most researchers have ended monitoring of mortality from 2005, as it has become too difficult to distinguish damage from the 2005 warming from later stress.

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