6. Coral Reefs of the U.S. Caribbean

The History of Massive Coral Bleaching and other Perturbations in the Florida Keys

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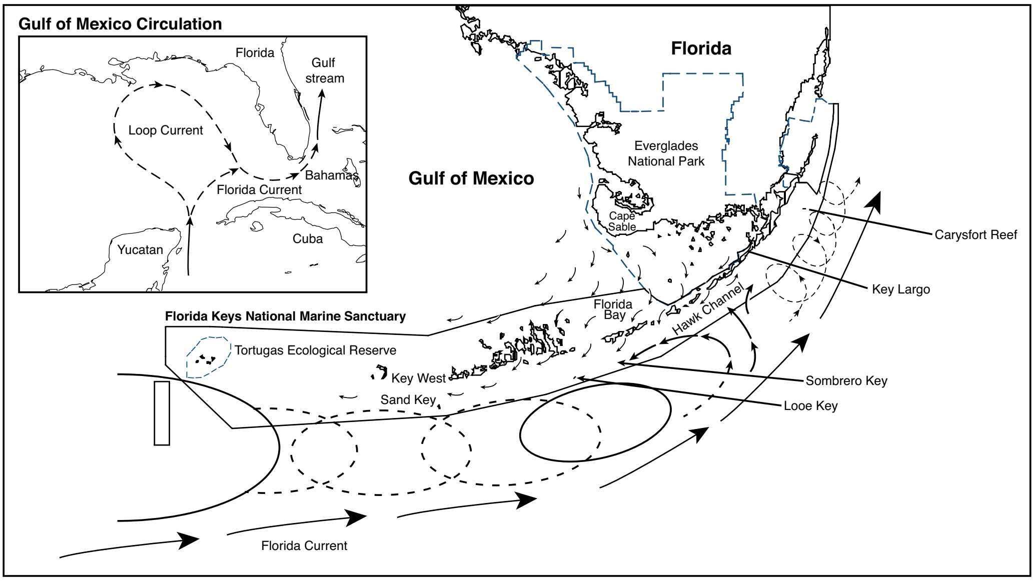
Introduction

The extensive offshore coral reefs (patch, offshore bank or bank barrier, transitional and deep reefs), fringing mangroves, seagrass meadows, and hard-bottom areas, are protected as the Florida Keys National Marine Sanctuary; the third largest marine protected area in the USA. These resources are the basis for the economically important commercial fishing and tourism located in south Florida, which attracts more than 4 million visitors who spend in excess of 14 million visitor-days per year. Most are snorkelers and scuba divers, as well as recreational fishers and water sports enthusiasts. Others come to the Keys to relax and enjoy the tropical climate of a unique destination.

The waters surrounding most of the 1700 islands of the Florida Reef Tract (here called the Florida Keys), which are arranged in a 320 km (220 mile) arc, were designated a national marine sanctuary in 1990 to stem mounting threats to the health and ecological future of the coral reef ecosystem. More than 60% of the Sanctuary (9800 km^2; 2900 square nautical miles) is in State of Florida waters, and the Sanctuary is managed through a co-trustee management agreement between the State of Florida and the national government, via the National Oceanic and Atmospheric Administration (NOAA).

The Florida Reef Tract region is warmed by the Florida Current flowing from the Caribbean and the Loop Current from the Gulf of Mexico, enabling major reef building corals and reef species to inhabit such northern latitudes. The coral reef community of the Florida Keys is vulnerable to both natural and anthropogenic impacts, including: extreme changes in sea surface temperatures; coral diseases; increased sedimentation; exposure to pollution from the land; habitat degradation and loss resulting from coastal development; over-fishing; and excessive visitor use. However, the overwhelming threats to the coral reefs have been coral diseases and increasing sea surface temperatures (SSTs) over the past 28 years. This thermal stress has been exacerbated by other anthropogenic pressures on the ecosystem.



The net flow of seawater of the Florida Current is from the Gulf of Mexico and Caribbean along the Florida Keys. The progression of gyres rotating counter-clockwise entrains waters from Florida Bay and the Gulf of Mexico that influence reef areas of the Lower Keys (illustration from Tom Lee/ University of Miami, RSMAS)

History of Coral Bleaching in the Florida Keys

The first observations of massive coral bleaching in the Florida Keys were in the 1980s; these were associated with elevated SSTs. A combination of stress events, such as cold water stress from winter fronts, brief warm water events, or reduced light penetration during lengthy periods of turbid water, occurred in the 1970s. In 1977, an enormous die-off of the branching coral *Acropora* occurred as a result of a severe cold front that hit the Keys. These periodic short-term coral bleaching events reported in the 1970s were possibly preceded by similar episodes in the 1950s and 1960s. However, a pattern of intensifying coral bleaching and other marine stresses has occurred since the late 1970s.

1979: The first sign of stress on the outer coral reefs was a die-off of sponges in June-July 1979, with a massive loss of the barrel sponge, *Xestospongia muta* on Big Pine Shoal, south of Big Pine Key. Hundreds of large sponges disintegrated during a month when extraordinarily warm waters flowed from the Gulf of Mexico across the reefs.

1980: In June-July 1980, doldrum-like weather patterns replaced the normal summer trade winds; the skies remained clear and almost cloudless and the seas were very calm for 6 weeks. Within a few weeks, angelfish, surgeonfish, butterflyfish and some other reef fish showed signs of extreme stress; they were respiring heavily and could be collected by hand. Open wounds and disease were commonly seen on the fish and large numbers began dying throughout the Keys. During the fish die-off, minor coral bleaching was noted on offshore coral colonies, which appeared mottled and lighter in color than normal. There was no uniform bleaching during this episode.

1982-1983: Elevated SSTs continued in the Florida Keys and nearby reefs. In November 1982, coral reefs on the Pacific side of Panama were severely bleached, with considerable coral mortality. Record SSTs on the Pacific and Caribbean sides of Panama were thought to be the trigger for the massive die-off of the long-spined sea urchin, *Diadema antillarum* that occurred throughout the Wider Caribbean in 1983-84. About 95% of these important algal grazers died in a single year.

In July 1983, doldrum-like conditions returned to the Florida Keys at the same time the urchins *(Diadema)* were dying in what was then the Looe Key National Marine Sanctuary. The corals began turning white after only a couple of weeks of these conditions. This first mass coral bleaching spread along the seaward part of the outer coral reef tract from Big Pine Key to Sand Key Reef off Key West. Coral bleaching was most severe on the shallow fore-reef habitats, and especially on the outer shallow reefs in the lower Florida Keys where there is the greatest exposure to currents from the warmer waters of the Gulf and Florida Bay. In this area of the Keys, the net flow of water is from the Gulf, through the passes and in an offshore direction toward the reef tract. This current pattern bathes the coral reefs along the reef tract from Looe Key Reef to Sand Key with water from the Gulf and Florida Bay.

1986: In May and June 1986, there was an alarming outbreak of black-band disease on fore-reef coral colonies at Looe Key Reef. Coral colonies of all sizes were affected in an area that matched the footprint of the 1983 mass coral bleaching event. There had been very few sightings of black-band disease prior to this at Looe Key Reef. However, in 1986, this disease killed coral colonies that were more than 200 years old.

1987: Similar doldrum-like weather patterns re-occurred in the Florida Keys in June 1987. In mid-July, corals at Looe Key Reef turned mustard yellow or were mottled or pale. By mid-August, a mass coral bleaching event was occurring on the outer reefs of the entire Florida Reef Tract. In late September, there were reports of coral bleaching throughout the Caribbean. In mid-October, reports of coral bleaching in the Indo-west Pacific were coming in from coral reef managers and scientists; coral bleaching had become a global, synchronized event.

The primary significance of the 1987 bleaching event in the Florida Keys, compared with the 1983 event, was the broad extent of the coral bleaching along the seaward margin and on the outer reef tract throughout the Keys. There was also significant bleaching of corals at greater depths, but still restricted to the same area (outer reef tract). Corals from very shallow water down to depths of 30 m were almost uniformly white. This concurrence of widespread bleaching throughout the Caribbean and Indo-west Pacific in 1987 prompted the US Congress to hold a hearing in November 1987 on coral bleaching. In April 1988, a workshop on coral bleaching co-chaired by John Ogden and Bob Wicklund was held in St. Croix, U.S. Virgin Islands to advise government on potential future management action.

1989: There was a minor coral bleaching event in August 1989. This was restricted to the genus *Agaricia*, and only on the fore-reef at Looe Key Reef. The event lasted about 6 weeks, and there were similar reports of *Agaricia* bleaching in Puerto Rico and Lee Stocking Island in the Bahamas.

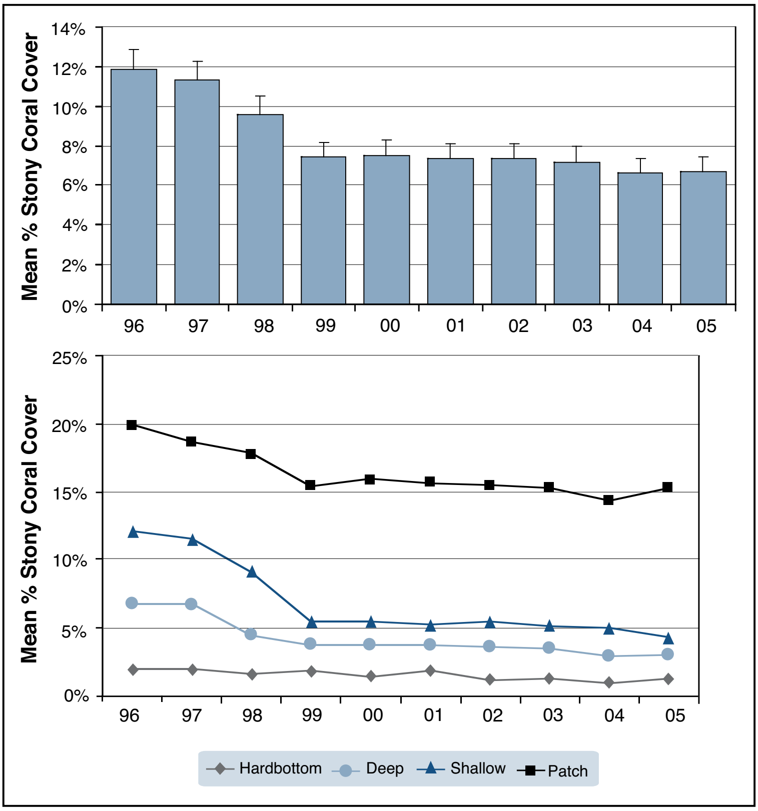
1990: More doldrum-like weather patterns with calm seas returned to the Florida Keys in July 1990. Early signs of bleaching were seen in the zoanthid, *Palythoa caribaeorum*, which turned pale white, and the polyps completely closed shortly before the stony corals bleached. In early August, corals began to bleach on the outer reef tract starting at Looe Key Reef. By mid-August, there was coral bleaching on the inshore patch reefs and in the tidal passes. This was the first time mass coral bleaching had extended to inshore waters. The shallow coral colonies at Looe Key Reef were severely bleached for 2 months; their fate was followed by monitoring. There was a substantial loss of living coral, with more than 65% mortality of fire coral *(Millepora complanta)* on the shallow reef crest. Similar anecdotal reports came from other shallow reefs, from Key Largo to Key West.

These nearshore coral reefs regularly experience higher and lower water temperatures than offshore corals and have acclimated over geological time to tolerate a broader range of temperatures. It appears that, unlike earlier mass bleaching events, SSTs during 1990 exceeded the upper temperature thresholds of acclimated inshore coral colonies. The 1990 coral bleaching event was significant because it was the first time that corals in nearshore waters had been affected by a mass bleaching episode and the first time that the large-scale loss of corals in the Florida Keys could be directly attributed to coral bleaching.

Although there was no mass coral bleaching in the Florida Keys between 1990 and 1997, there were wide-spread outbreaks of various diseases that affected both branching corals *(Acropora)* and boulder corals *(Diploria, Montastraea,* etc.*)*. The *Acropora* species, especially elkhorn coral *(Acropora palmata)*, were most affected by the outbreaks, with large amounts of living coral tissue killed by various diseases (e.g. white-band, white plague, white plague type II, etc.). There were also fish disease outbreaks in the Florida Keys and other parts of the Caribbean. The symptoms and species affected closely resembled the 1980 fish die-off; the disease agent was a fungus, *Brookynella*, which affects tropical reef fish during environmental stress.

1997-1998: Doldrum-like weather conditions returned to the Florida Keys in July 1997 and by mid-August, a mass coral bleaching event was underway. Once again, the bleaching event was widespread and heavily damaged the inshore corals. Third generation residents raised the alarm and reported to Sanctuary managers that such bleaching was unknown in the Florida Keys in recent history. The 1997 coral bleaching event was extensive and long-lasting, and affected both offshore and inshore corals, with many remaining bleached or mottled well into 1998. Previous bleaching events had subsided by November. However, waters of the Florida Reef Tract did not cool much during the winter of 1997-98 and the unseasonably warm water of 1997 continued into early 1998. The doldrum-like weather patterns started early in 1998, and the warm water persisted even when the wind blew, unlike previous years.

Coral bleaching in the Florida Keys and other parts of the tropical world during 1997-98 was the first ever back-to-back event, with local, regional and global scale damage similar to the 1987 and 1990 episodes. Bleaching on remote Pacific islands coincided with devastating bleaching in the Florida Keys and the tropical North Atlantic (Wider Caribbean). The Florida Keys were then hit by Hurricane Georges in September 1998 and Tropical Storm Mitch, just as the bleaching was being assessed. In addition, there were outbreaks of the fish disease *Brookynella*, similar to 1980, killing angelfish, butterflyfish and other reef species. Similar reports came in from other areas of the Wider Caribbean.

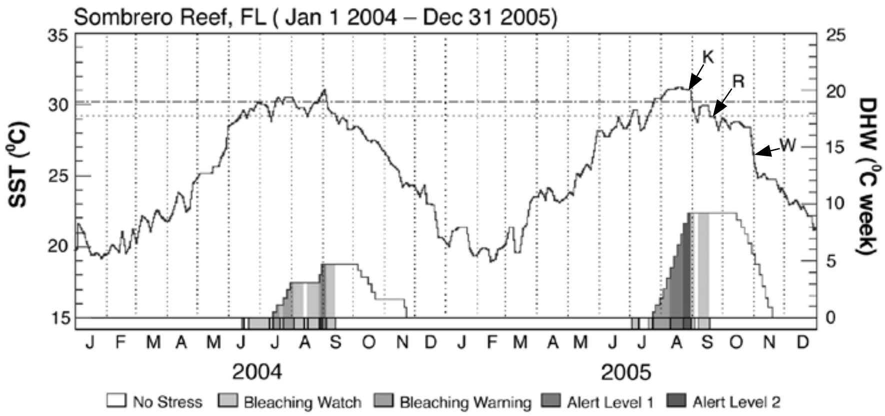


There has been an almost continual decline in coral cover in the Florida Keys in all habitats since 1996, with a mean decrease from 11.9% cover in 1996 to 6.7% in 2005. The hard-bottom habitat usually has a low cover of isolated, small coral colonies alongside gorgonians (octocorals), sponges and other organisms; but this habitat makes up the largest proportion of rocky substrata within the Sanctuary. These data have been collected at multiple stations with 43 fixed sites along the Florida Keys, by the Florida Keys National Marine Sanctuary, US Environmental Protection Agency and NOAA since 1996, via the Coral Reef Evaluation and Monitoring Project (CREMP), which also involves the Florida Fish and Wildlife Research Institute and the University of Georgia. The top figure shows a precipitous decline in bleaching years with a leveling-off of coral cover since the 1997-98 bleaching events and the hurricanes of 1998, 2004 and 2005. The lower graph shows the same precipitous decline in all coral habitat types between 1996 and following the 1997-98 bleaching events and subsequent coral disease outbreaks. Coral cover is higher in the patch reef areas compared with offshore reefs. The patch reefs have been exposed to broader ranges of sea surface temperatures, sediments and nutrients over a much longer timeframe i.e. centuries compared with decades (data from www.floridamarine.org).

The greatest loss of coral cover has been on the shallow, spur and groove bank-reefs, where most diving occurs. One could speculate that the diving was the cause of this loss, but the largest decline has been on Carysfort Reef in the Upper Keys where dive pressure is low. However, diving remains on the list of cumulative stresses to coral reefs.

The shallow offshore reefs have existed for decades within a narrow range of seasonal temperatures, salinity, and sedimentation. Recently, the maximum SST has often exceeded 31°C during July and August when doldrum weather patterns set in for long periods. The shallow reefs bleached first and remained bleached for longer, thus excessively stressing the coral colonies. The largest decline in coral cover occurred following 1997 and 1998; since then coral cover has remained low and relatively constant.

While there has been relatively little decline in coral cover since 1999, there has been little new coral recruitment. Thus, it appears that the same environmental and water quality problems that contributed as secondary stresses causing the loss of coral have also prevented recovery by new coral recruits. Another factor was the loss of algal grazing *Diadema antillarum* in 1983; macro-algae now cover much of the reefs preventing the settlement of new coral recruits, and increasing competition for space amongst various reef organisms. While there has been some coral recruitment, it has been insufficient to prevent the reefs from becoming increasingly barren of living corals.



Three hurricanes passed near the Florida Keys in 2005. SSTs (recorded at a SeaKeys C-Man station on Sombrero Reef) rose to more than 31°C in July, but the passage of Hurricanes Katrina (K), Rita (R) and Wilma (W) reduced elevated SSTs, alleviating the stressful conditions and resulting in minimal coral bleaching (image from Mark Eakin NOAA/NESDIS).

There are more than 9000 patch reefs in the Upper Keys; these have shown the least decline in coral cover and are still the most extensive coral communities. The patch reefs occur in very turbid, shallow inshore waters of the Keys, through Hawk Channel and to the outer reefs. They grow in waters with the highest levels of nutrients in the Sanctuary and are seasonally exposed to the warm waters of the Gulf of Mexico. These waters get very cold in winter and very warm in summer, but the patch reefs have acclimated to the widest range of environmental conditions in the Florida Keys. There are 200 - 300 year old coral colonies that are unblemished from diseases. These are the only reefs that have shown any increase in coral cover during the last 10 years.

Other reef animals are also disappearing in the Florida Keys; for example, the corallimorph, *Ricordea florida*, (also known as false coral) was abundant on shallow reefs such as Looe Key Reef in the 1960s and 1970s, but began to disappear from Looe Key Reef in the early 1980s. Most of the populations had vanished from the shallow reefs by the time monitoring started in 1996. There are anecdotal reports that crinoids have also disappeared from the reefs. These were frequently seen on shallow reefs like Looe Key Reef in the 1960s and 1970s and were common at 20 to 40 m on deep reefs. A survey in September 2001 between 20 and 30 m found none during 6 hours in areas where crinoids were previously abundant. However, crinoids are still seen on the reefs in the Tortugas Ecological Reserve, to the far west of the Sanctuary, in waters that have been less influenced by elevated SSTs and land-based sources of pollution, indicating that crinoids are another group affected by higher SSTs and pollution.

2004-2005: Although elevated SSTs occurred in the Florida Keys in 2004 and 2005, there was only minor to patchy coral bleaching. The corals escaped the severe coral bleaching that was recorded throughout much of the Wider Caribbean. Both 2004 and 2005 were active hurricane seasons; each tropical storm reduced SSTs, by mixing the surface waters with deeper, cooler waters.

Conclusions

Coral bleaching has been intensifying over the past 25 years at the local scale in the Florida Keys; this is consistent with other observations at regional and global scales. The pattern and intensity of coral bleaching events has shown a spatial and temporal expansion during this time, with concurrent increases in secondary impacts, such as coral diseases, loss of living tissue and low recruitment on the coral reefs of the Florida Keys. The shallow bank-reef habitats have been most severely affected, probably because they have historically existed in a narrower range of environmental conditions. In contrast, patch reefs, which are regularly exposed to elevated nutrient and sediment levels and broad seasonal fluctuations in water temperature, have been least affected and have retained the highest living coral cover. These corals have probably survived the bleaching episodes because they are better adapted to a broad range of physical conditions, similar to those that occur during doldrum-like weather. The mechanism is unclear; it is possible that natural selection has influenced their genetic composition so that they are able to tolerate greater fluctuations of temperature and nutrient levels, and lower light conditions.

Coral reefs of the Florida Keys are affected by the same stresses damaging reefs worldwide: climate change; diseases; land-based sources of pollution; habitat loss and degradation; and over-fishing. There is no longer a debate that coral bleaching is linked to global climate change; and a few people debate the causes of global climate change. Irrespective, coral reef scientists and managers need to take every possible immediate action to preserve and conserve the coral reef resources of the world. While such scientific debate is healthy and part of the scientific process, there comes a time when debate seeking second opinion distracts from the obvious, and provides decision-makers with a no-decision option. The suspected causes for the coral loss in the Florida Keys have varied enormously over the years; now there is recognition that elevated SSTs are the primary cause of coral bleaching. A minority viewpoint has focused on land-based sources of pollution as the cause of coral decline. Clearly, both have played a major role in the decline of coral reefs on a global scale; research should be focused on unraveling the causes of coral decline at scales from microbial to the ecosystem.

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Coral Bleaching in the U.S. Virgin Islands in 2005 and 2006

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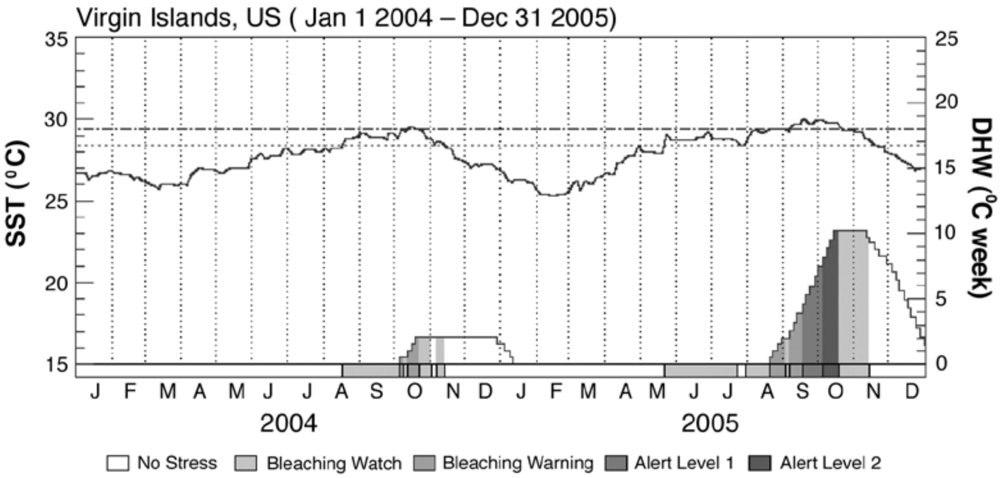
Summary

- Severe coral mortality occurred in the U.S. Virgin Islands (USVI) between July and November, 2005 because of bleaching and disease; the average decline in hard coral cover was 51.5%;
- Sea surface temperatures exceeded the 29.5°C coral bleaching threshold for 12 weeks in 2005; maximum temperatures exceeded 30°C. The reefs suffered more thermal stress during this period than during the previous 20 years combined;
- Coral bleaching was observed between July and November, 2005; on average it affected more than 90% of the coral cover;
- Bleaching occurred in 22 coral species over a wide range of depths;
- The greatest bleaching-related mortality occurred in the genus *Agaricia*; bleaching also severely affected *Montastraea, Colpophyllia, Diploria* and *Porites*, but mortality in these species was usually the result of subsequent infection by white plague or white syndrome;
- Coral losses in late summer 2005 were more severe than any time in the last 40 years.

Introduction

The first indications of potential thermal stress to the corals of the USVI occurred in July 2005 with observations of bleached corals, and in August when satellite information provided by the National Environmental Satellite, Data, and Information Service (NESDIS) Coral Reef Watch indicated that sea surface temperatures (SSTs) in the north-eastern Caribbean were higher than normal. Temperatures continued to rise, producing more thermal stress during this single period than during the previous 20 years combined (Coral Reef Watch 2005, accessed 19 November 2007). The bleaching threshold of 29.5°C (83.3°F) was exceeded for about 12 weeks prior to 12 November 2005, with SSTs reaching just over 30°C; a full degree warmer than the previous year. This chapter discusses how monitoring efforts in the USVI captured the bleaching event of 2005 and demonstrates that several methods used to monitor the health of the reefs arrived at the same conclusion: coral cover on USVI reefs is declining.



Sea surface temperatures (SSTs) in 2005 exceeded those of 2004, especially between August and November (solid line) when they exceeded the coral bleaching threshold of 29.5°C in the USVI (dashed line). The accumulation of 'Degree Heating Weeks' (DHW) is shown along the X-axis in red along with the timing of bleaching watches and warnings issued in 2004 and the major alerts in 2005 from August to November. The thermal condition is categorized according to the five bleaching alert levels defined by Coral Reef Watch's Satellite Bleaching Alert. Source: http://coralreefwatch.noaa.gov/satellite/current/sst_dhw_series_usvirgin_cur.html

Effects of the 2005 Bleaching Event

Declines in coral cover and increases in macroalgae resulting from a variety of stresses including hurricanes and coral disease have been reported previously in the USVI. For example, major coral losses occurred in the 1970s and 1980s as a result of white band disease, killing more than 90% of *Acropora cervicornis* and *A. palmata* colonies, the primary shallow water reef building corals. However, the 51.5% decline in mean coral cover during the 12 months following the major 2005/06 bleaching and disease event was unprecedented. These losses occurred on well developed 'high' coral cover, high coral diversity reefs being monitored by the National Parks Service. Even deep reefs with high coral cover (>30% cover, >30 m) were affected by bleaching and disease.

National Park Service Inventory and Monitoring (NPS I&M) and US Geological Survey (USGS) scientists documented the effects of the 2005 bleaching and subsequent coral disease at long-term monitoring sites around St. John and St. Croix. An average of 90% of the coral cover bleached at 5 permanent sites (100 transects at depths between 4 m and 19 m) in St. John and St. Croix, including Virgin Islands National Park (VINP) and Buck Island Reef National Monument (BIRMN). By late 2005, many of the corals began to regain color; but then became infected by the white plague coral disease. In just one year, the average decline in coral cover at these sites was 51.5% (range 34.1% - 61.8%). There were massive declines in the major reef building coral species: the *Montastraea annularis* (complex) once comprised 80% of the total coral cover, but suffered a 51% decline compared with pre-2005 levels; the cover of *Agaricia agaricites, Colpophyllia natans* and *Porites porites* declined by 87%, 78%, and 48% respectively. However, there was no change in cover of *M. cavernosa*. While mortality of *A. agaricites* was directly attributable to bleaching, mortality in nearly all other coral species resulted from subsequent infection of white plague disease. The average number of species per transect also declined by 21%.

Agency	Region	Category	% Bleaching	% Mortality
NPS I&M / USGS	St. Croix, St. John	Overall	90	51.5
		A. agaricites		87
		C. natans		78
		M. annularis (complex)		51
		P. porites		48
NPS / USGS	St. Croix, St. John	*Agaricia* spp.		87*
		C. natans		35*
		Diploria spp.		17*
		M. annularis (complex)		12/55*
		P. porites		15*
UVI	Region-wide	Overall	57	40
		Montastraea reef - total loss		70-90
		Montastraea reef – *Montastraea* loss		83-95
BB / NPS	St. Croix	October	53	
		December	28	
USGS	VINP	*A. palmata*		15/36
NPS	BIRNM	*A. palmata*	79.8	58.1

Summary of results of surveys conducted by several agencies (explained in the text) to determine the impacts of the 2005 bleaching / disease event in USVI. * indicates that percentages have been calculated as the proportion of the total number of colonies of each coral species surveyed. All other percentages have been calculated from coral cover data. Where two values are separated by /, the first value reports the percentage cover or proportion of colonies that suffered complete mortality, and the second reports the percentage of partial mortality.

The fate of 4153 coral colonies on the 100 transects was tracked by NPS and USGS. Colonies of *Agaricia spp*. were the most severely affected by bleaching with 87% mortality, and 35% of *C. natans,* 17% of *Diploria spp*. and 15% of *P. porites* colonies had died within 6 months of the peak bleaching in September 2005. The *M. annularis* (complex) initially exhibited substantial recovery from bleaching, but subsequently, there was high mortality as a result of white plague coral disease, with 12% of colonies dying completely and about 55% showing partial colony mortality.

Bleaching and mortality in territorial waters followed a similar pattern to that observed within the national parks. Researchers from the University of the Virgin Islands reported an average of 57% of the coral cover bleaching (74% of individual colonies) at a range of depths, which resulted in only a 4% decline in coral cover. However, there was a subsequent increase in tissue-eroding white syndrome, from 0.5% of colonies infected prior to and during bleaching, to 4% after the bleaching. This was probably responsible for a 40% decline in coral cover across the territory. In two deep (20-30 m) areas that formerly had high *Montastraea* cover (~36%), there was a 70-90% decline in total coral cover, resulting predominantly from the loss of *Montastraea* (83-95% cover loss).

At 30 m depth along this *Montastraea* reef system, NCCOS/Biogeography Branch (BB) and NPS recorded a significant decrease in average coral cover between 2005 and 2006, from 8.69% (± 1.6) in 2005 to 6.60% (± 1.3) in 2006, representing a 24% decline in coral cover. The difference between this estimate and the 70-90% decline described above is most likely explained by the patchy spatial distribution of corals along this reef system and differences in sampling techniques. The overall conclusion is that coral cover declined significantly between 2005 and 2006.

In October 2005, the BB and NPS BIRMN observed bleaching in 22 scleractinian coral species in north-eastern St. Croix, with nearly 53% of the coral cover bleached at 91 of 94 randomly selected sites (depth range 3-28 m). The average coral cover at these sites was 5.6%. Bleaching was widespread, with no obvious spatial pattern. Coral species most affected by the bleaching event included *D. labyrinthiformis, Agaricia* spp., *Mycetophyllia* spp., and *M. annularis.* By December 2005, bleaching was still evident, with colonies at 15 of 18 randomly selected sites still bleached. Only 28% of the 3.9% total coral cover was bleached, and an additional 4% colonized by cyanobacteria or other algae (i.e. recently dead), but there was evidence of corals recovering from bleaching.

The first time that bleached *A. palmata* colonies had been observed in the USVI was in July 2005, with 50% of 460 colonies in VINP, St. John showing some bleaching. This eventually resulted in 36% (± 7.4) of colonies suffering partial mortality and 15% (± 8.5) dying completely. Mortality of *A. palmata* rose during 2005, but was not always directly related to bleaching. Isolated incidences of disease and bleaching contributed to the rise in mortality. Bleaching was not followed by severe outbreaks of disease except at one site, Hawksnest Bay, where a combination of disease and bleaching caused greater mortality within 3 months than other stresses (e.g. predation, physical damage) had caused during the previous 2.5 years. All surviving colonies regained normal coloration by February 2006.

There was also extensive bleaching of *A. palmata* in 2005 at BIRMN, St. Croix. Bleaching was observed between August 2005 and January 2006, with greatest bleaching recorded at South Forereef in November 2005, where 79.8% (± 9.1) tissue bleached, followed by 58.1% (± 9.8) tissue mortality. The greatest tissue mortality (66.4% (± 8.7)), occurred at the Underwater Trail. There was 36.4% (± 12.5) tissue mortality at the North Bar. Colonies on the back-reef appeared to be more affected than colonies elsewhere, raising the possibility that reduced water flow and calmer conditions exacerbated the bleaching and resulted in greater mortality.

Conclusion

The coral bleaching/disease event of 2005 added to the historical impacts of other stresses (pollution, over-fishing, physical damage), resulting in major damage to the reefs of the USVI. Management actions to improve water quality, prevent over-fishing and reduce physical damage and overuse may create a foundation for better reef recovery and long-term survival.

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