WRITTEN TESTIMONY OF

Alan E. Strong

Team Leader and Project Manager

Coral Reef Watch Program

National Environmental Satellite, Data, and Information Service

National Oceanic and Atmospheric Administration

U.S. Department of Commerce

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Chairman Gilchrest and members of the Subcommittee, thank you for the opportunity to appear before you today. It is my privilege to spend a few minutes with you this morning to share what we have been learning at NOAA about recent climate events over the tropics and how they apply to our coral reefs. Our operational satellite data now make it possible to measure short-term trends, or tendencies, of sea surface temperatures (SST) at global scales since the mid-1980s.

Coral reefs flourish mainly in the tropical latitudes, extending beyond 30° north or south of the Equator in only a few cases. Every coral species, as well as numerous other reef inhabitants, maintains a special symbiotic relationship with a microscopic algae called zooxanthellae. These algae provide their hosts with oxygen and a portion of the food they produce through photosynthesis. When stressed, many reef inhabitants have been observed to expel their zooxanthellae en masse. Without the characteristic color the of the algae, the coral appear as a nearly transparent layer over their white skeleton. This phenomenon is referred to as coral bleaching. The ability of the coral to feed itself in the absence of zooxanthellae may be very important to its survival during and after a bleaching event. Recovery rates appear to differ, however, by species and even by colony, and the time required to attain full recovery of symbiotic algae may vary from as little as two months to as much as one year. If the level of environmental stress is high and sustained the coral may die.

Although recently noted as occurring during El Niño or La Niña events, bleaching cannot be explained by localized stressors, natural variability, or El Niño alone. Nonetheless, mass bleaching is likely accentuated by an underlying rising baseline of global marine temperatures, and exacerbated by human-based activities such as overfishing, localized pollution and coastal land development. As oceanographers, we need to address other less known and poorly understood natural oceanic variations when attempting to understand our changing climate.

As you have heard, coral bleaching, and high SSTs, have been observed with increasing frequency in the

last twenty years - the period of time recorded in NOAA's satellite data. Over most of the 20th Century, coral bleaching was an infrequent event, and certainly nothing had been witnessed as large as the recent worldwide bleaching event of 1998, or the unprecedented bleaching across the Great Barrier Reef earlier this year.

It should be noted that the coral bleaching events we have been witnessing with increased frequency during the past two decades are caused by weather events - clear skies and light winds occurring roughly at the time of highest overhead solar angle, causing anomalous increases in SST. Although bleaching has been around as long as corals themselves, the paleo-climate record (shown in coral cores) shows that corals have adapted surprisingly well to these infrequent events in the past. Climate change acts as a modulator of these weather events. Virtually all the climate models predict that if warming trends continue or increase these bleaching events will continue to increase in frequency, as well as severity.

The Pacific Decadal Oscillation (PDO) is a long-lived El Niño-like pattern of Pacific climate variability, whose fluctuations are generally believed most energetic in two general periods, one from 15-to-25 years, and the other from 50-to-70 years. The North Atlantic Oscillation (NAO) is the dominant mode of winter climate variability in the North Atlantic region ranging from central North America to Europe and much into Northern Asia. The NAO is a large-scale seesaw in atmospheric mass between the subtropical high and the polar low. The corresponding index varies from year to year, but also exhibits a tendency to remain in one phase for intervals lasting several years. The "Ocean Conveyor Belt" transports warm ocean water from the Pacific Ocean through the Indian Ocean and into the Atlantic Ocean. In the North Atlantic, the warm water, which turns very salty due to evaporation during the journey, runs into cold water coming down from the north. The warm water cools quickly, and sinks due to greater density. This creates a sub-surface countercurrent which carries the cool water back to the Indian and Pacific oceans.

To address coral bleaching we need to separate out, not only the shorter term variability of El Niño, but also the PDO, especially as it relates to Conveyor Belt variability of the global ocean and interactions between the tropics and the Southern Ocean. Our knowledge of these linkages to the tropics and potential involvement with coral reefs is still limited. Yet, it is critical that we enhance our knowledge of these links and put this recent upsurge of increased bleaching into proper perspective.

In an additional attempt to understand the linkages of bleaching, SST anomalies and short term variability, we have recently reprocessed all of NOAA's operational satellite SST data from 1985 through 2000. These data are the most complete and accurate means for assessing short term global SST trends. Viewed globally, the trends show some noteworthy regions of SST increases and decreases over the 16-year interval. Of concern for coral reefs, notable rises in SST (in excess of +0.2 deg C/decade - noted in red in Figure) are seen in the ocean area off the southern Caribbean and off SE Asia-Japan. Significant decreases in SST are being seen by satellite (in excess of -0.2 deg C/decade - noted in blue in Figure), over this time period, covering large portions of the central Pacific from Hawaii to American Samoa; falling SSTs are also shown over some of the more biologically diverse coral reefs of the southern Indian Ocean.

When these most recent satellite SST trends (1985 through 2000) are compared with a sub-set of the SST data from the 10 years just prior to the 1997/98 El Niño, what appears to be a late-1990s reversal in trend is suggested over large regions of the Pacific Ocean. This change in trend is most dramatic over the North Pacific, where many regions that prior to the 1997/98 El Niño had been (1985-1996) exhibiting increasing trends (red) have now (1985-2000) become regions where decreasing trends (blue) are seen, and *vice versa*. This may be an early indication of a reversal underway in the PDO - only time will tell. (The last PDO reversal took place in the 1970s before satellite SSTs were available.) If this is a PDO reversal, it will only

remain in this phase for a few decades (20-35 years) before flipping again. So, for many of those regions that are now experiencing a cooling trend, or a decreased warming trend, this must be viewed as only temporary.

An overview of the tropics (30N to 30S), based on our satellite SSTs, shows that northern hemisphere tropical SSTs, on average, are increasing at a rate of +0.16 deg C/decade (+0.016 deg C/yr). Over the southern hemisphere tropics, the rate of increase is gradually increasing, but presently this upward rise is merely a third of the rate in the northern hemisphere.

The best way to examine and understand these phenomena is to continually monitor the environment. NOAA's "Coral Reef Watch" program is a joint effort between the National Environmental Satellite, Data, and Information Service (NESDIS) and the Office of Oceanic and Atmospheric Research (OAR). Coral Reef Watch plans to install approximately 20 *in situ* Coral Reef Early Warning System (CREWS) towers to cover most domestic coral reef regions over the next five years (see Figure). Five of these systems will be located in regions where SSTs have been exhibiting notable (red) upward tendencies, namely the Commonwealth of the Northern Mariana Islands, US Virgin Islands, and Puerto Rico, and two will be located in the central Pacific, a region presently demonstrating a cooling (blue) trend (Palmyra/Kingman & Howland/Baker). These stations continuously monitor key environmental parameters such as SST, UV, wind speed, salinity, and turbidity and provide "anchor points" to maintain satellite calibration throughout our domestic coral reefs. During FY02, NESDIS and OAR received $1.25M ($ 0.75M for NESDIS; $0.5M for OAR), via the NOAA coral reef program, to fund Coral Reef Watch and CREWS. Funding to continue these efforts are also included in the FY03 budget request.

Based on these reprocessed and globally complete SSTs along with other observations, it is my conclusion that:

- •The first impacts of anomalous SSTs have already been seen in the 1998 bleaching and are likely to be more severe in the coming decade - only lessened in some regions (during the next two or three decades) by PDO;
- •There is a need to monitor environmental indices, ecosystems, impacts, recovery, and adaptation;
- •There are practical steps that reef managers can take, but to truly be effective they need timely information;
- •Reef managers with timely and accurate information ("early warnings") gain credibility with their constituents enabling them to reduce ecosystem stress brought on by human pressures.
- •Remote Sensing Products Answers
- •Knowledge Credibility Empowerment

Once again, Chairman Gilchrest, thank you for the opportunity to testify before you today. As my testimony indicates, using NOAA's environmental satellites to observe and monitor climate trends in the world's oceans has yielded significant information on the health of our coral reefs on a global scale. We hope to continue these efforts, and enhance our ability to provide useful, timely and accurate information to coral reef managers, to assist them in maintaining the health of these vital ecosystems. I would be happy to respond to any questions the Committee may have.

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Exhibits:

1. Annual Bleaching HotSpot Composites: 1985-2000
2. Coral Reef Watch - 2002
3. 2002 Great Barrier Reef Bleaching Event