Coral reefs and global change: Impacts of temperature, bleaching, & emerging diseases

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Coral reefs are the ecosystem most threatened by global change. Over 100 countries now face potentially crippling losses from deterioration of coral reef-generated natural services to marine biodiversity, fisheries, tourism, beach sand supplies, and shore protection from coastal erosion accentuated by rising sea levels and increased tropical storm strength.

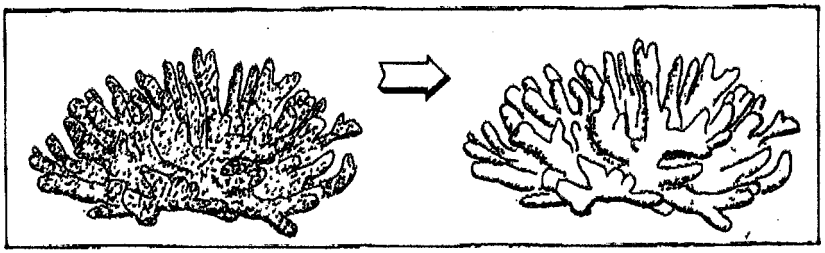

Fig. 1. Exposed to temperatures 1 degree C above average for the warm season, symbiotic algae leave the coral, which loses the source of much of its energy, and grows more slowly. If the temperature remains 1 degree above for two months, or reaches 2 degrees above average warm season temperatures, significant coral death follows.

Most threatened of all are the atoll island nations of the Pacific and Indian Ocean, which will disappear entirely if healthy reefs are not preserved. Reefs have undergone decades of accelerating degradation wherever humans are near, due to local impacts (like anchors, mining, dredging, tourists, and destructive fishing practices such as dynamite and poisons), and from regional impacts (like inadequately treated sewage, fertilizers, and soil erosion due to deforestation and poor agricultural practices). In the last two years coral reef health worldwide has entered a catastrophic decline due to global threats to their survival which are affecting even the most remote and previously untouched reefs. Most coral in the Indian Ocean died from heat stroke this year, and the impact of abnormally hot water is now spreading throughout the Western Pacific and Caribbean. Most corals around the

Caribbean are slowly dying from new emerging diseases whose causes are largely unknown, and new coral reef diseases are also being found all over the Pacific and Indian Ocean.

The Framework Convention on Climate Change states that it's purpose includes protection of critical climatically-sensitive ecosystems, but its protocols do not identify these ecosystems, require their monitoring for climatically-induced damage, or require abatement of specific threats to them. Not has the uniquely threatened situation of the world's coral reefs been adequately highlighted by IPCC. Coral reefs are living just below their maximum temperature limits and have been repeatedly pushed above them on a large scale for the first time in the 1980s and 1990s, indicating that they are they will be the first ecosystem to suffer wide-scale damage from climate warming. The warmest ecosystems, like coral reefs, are uniquely threatened by global warming, because unlike cooler ecosystems, they cannot be replaced by immigrant organisms from warmer zones.

Fig. 2. Sea surface temperature data for the first six months of 1998. Diagonal slashes indicate temperatures 1 degree or more above warm season normals, capable of causing bleaching or mortality of corals. Analysis from NOAA satellite data by Alan Strong.

Large-scale coral bleaching has taken place repeatedly since the 1980s. All previous bleaching events prior to this period were of purely local extent and due to small-scale local stresses. Since 1990 we have successfully predicted the location and timing of all large-scale coral bleaching events from satellite temperature data alone. Bleached corals lose their healthy colors and become transparent. They are starving and unable to grow or reproduce. Like humans in a famine, they may survive if the stress is brief, but will die if it is too prolonged. Our detailed analysis of sea surface temperatures show that every large scale bleaching event follows warming of only 1 degree C above the average for the warmest months. These conditions cause most corals to bleach but not to die, and less evident paling of corals can take place for smaller excess temperatures. If water temperatures get more than 2 degrees above average in the warmest month, or if they remain 1 degree above for two months or more, significant coral

death follows.

During the first half of 1998 the global extent of water temperatures measured by NOAA satellites that were too hot for corals exceeded that of any full year previously measured since 1982 (Figure 1). Over half of the 207 localities whose detailed temperature history we have measured since 1982, which cover every major reef area in the world, bleached in 1998.

This was the worst year ever reported for bleaching in terms of the number of places where it took place. Bleaching began in 1997 following very high water temperatures in the eastern Pacific. In early 1998, we alerted researchers across the Southern Indian Ocean, Australia, and Brazil that bleaching conditions were starting. As a result of early warning, research teams were able to get into the field in the beginning of the event and examine more extensive areas of the reefs. The impacts were worse in the Indian ocean, where every part was affected. In some parts of the Indian ocean, water temperatures were nearly 2˚ C above average for five months and coral deaths were very high, with over 90% of corals being killed in many places. The majority of all corals died at most sites around the Indian Ocean. As maximum temperatures moved into the Northern Hemisphere summer, severe bleaching set in across the Western Pacific and Caribbean. The majority of all reefs in the world have already been severely impacted this year.

Detailed analysis of the temperature records from all coral-reef sites shows that coral-reef areas are warming up faster than the global warming average, but there are strong regional differences in warming rates, frequency of bleaching, and potential ecosystem impacts. Reefs in the Caribbean, Red Sea, and Persian Gulf are warming up fastest, while some South Pacific reefs actually show a cooling trend. Global warming can cause local cooling in areas where stronger winds cause more deep water to be pulled up. Such variations in local rates do not reduce global temperature rise because the excess heat remains in the system mixed down into deep waters that will eventually return to the surface. In addition, we have identified large regions where the upwelling of cold, deep waters has failed completely since 1988, with consequent reductions in fishery catches. Examination of temperature records suggests that the majority of bleaching events are not reported because there was no diving activity at affected sites at the time, because it was not recognized, or because it was not reported.

Tabulation of coral disease reports also shows a sharply accelerating trend, with around three fourths of all first reports of diseases at all reef locations worldwide being made in 1997 and 1998. While this pattern in

part reflects intensive field studies made in this period and increasing skill in disease identification, the majority of over 15 known coral diseases were not seen in large numbers of photographs made before 1990. The impact of coral-reef diseases is worse in the Caribbean, and the majority of all corals at sites around this region are slowly dying from diseases. Coral-reef diseases are also found at all sites investigated across the Indian and Pacific oceans, but generally at lower levels. The majority of the identified disease syndromes cause characteristic patterns of tissue death that appear to be caused by infectious disease agents, but in the majority of cases the pathogenic organisms have not yet been identified. Consequently little can be said about the mechanisms of attack, cause of virulence, or source areas until there is a greatly expanded funding for field identification and mapping of diseases and for much more advanced laboratory research. In almost all cases the new diseases were so widespread by the time their signs were recognized that locating their source regions was impossible. However, the lack of correlation of disease abundance in time and space with the patterns seen for coral bleaching, pollution, and all other known causes of stress to corals suggest that these are independently emerging threats akin to the emerging diseases affecting humans, crop plants, and livestock.

Bleaching and diseases have certainly killed more corals in the last two years than all previous human damage. Unless they are controlled, all efforts at reef protection will be futile. Recovery of coral reefs from mortality caused by severe bleaching and diseases is likely to be very prolonged, if it happens at all. Coral reefs damaged by severe local stresses, such as ship groundings, hurricanes, or pest outbreaks can recover in a few decades as long as surrounding reefs are healthy. However, in the last year, we have seen virtually all colonies of the most abundant and rapidly growing branching and plate corals in the Indian Ocean and parts of the Pacific die. As a result, there will be very few corals of these species reproducing in the coming years, and hence, very little supply of new coral larvae. In the Caribbean, many species have virtually every single colony affected by disease, and these are unlikely to reproduce while dying. Even if there were an adequate supply of coral larvae, reef recovery will be impossible near populated shores unless pollution from sewage, soil erosion, fertilizers, and physical damage are halted. Recovery will be impossible even in areas that are totally unaffected by such stresses if it gets hot again in the future.

The importance of coral-reef ecosystem services in providing the bulk of the marine biodiversity, fisheries, tourism, white sand supply, and shore protection for over 100 countries is difficult to estimate accurately. Because we do not pay reefs for these free services, we tend not to value them, but nevertheless they are the most economically valuable ecosystem we possess. When reefs are lost and we must import fishes to feed our people, when we

must dredge sand to replace eroded beaches, when tourists stop coming back and jobs evaporate, when we must build seawalls along thousands of kilometers of coastline that reefs formerly protected, the cost will come to many tens of millions of dollars per kilometer.

Coral reefs are not just essential to the people of over 100 countries; they are the truest test of our commitment to sustainable development because they are already right at the limit of what they can take from human beings and are very close to total collapse. Unless we stop destructive practices in reefs, treat our sewage to prevent the nutrients getting into the sea, reforest our degraded watersheds, mandate agricultural practices that conserve soil and soil fertility, and halt global warming simultaneously, we will see serious degradation or total loss of the many benefits we derive from coral reefs. With increasing sea levels and increasing intensity of hurricanes, typhoons, and cyclones, damage to reefs will greatly accelerate the existing erosion of the atoll island nations. Serious and urgent action is needed from the world's governments to live up to their promises to protect the most climatically-sensitive ecosystems known, coral reefs. This will need to encompass all of the steps required for sustainable development including protecting fisheries, controlling erosion, treating sewage, protecting bio-diverse habitats, researching and monitoring threats from global change, large-scale funding for reef restoration and shore protection, and especially halting global warming by ending the build up of greenhouse gases. If world leaders do not take these steps, they will sooner or later condemn all coral reefs and the organisms and people who depend on them.