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Printed by IGS Printing and Laminating, Ottawa, Ontario, Canada
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 600 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. Exposure to temperatures 1 degree C above average for the warm season, 2 degree C above average for the warm season, and 3 degree C above average for the warm season, significantly reduce coral health.](image)

Most threatened of all are the atoll island nations of the Pacific and Indian Oceans, which will disappear entirely if healthy reefs are not preserved. Reefs have undergone decades of accelerating degradation wherever humans are present due to local impacts (like anchors, mining, dredging, tourism, and destructive fishing practices such as dynamite and pole-beam), and from regional impacts (like inadequate 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 stress 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 Oceans.

The Framework Convention on Climate Change states that its 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. Nor has the uniquely threatened situation of the world's coral reefs been adequately highlighted by IPCC. Coral reefs are being forced below their maximum temperature limits and have been repeatedly pushed above them on a large scale for the first time in the 1998s and 1999s, indicating that they are they will be the first ecosystems to suffer widespread 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 associated organisms from warmer zones.

![Fig. 2. Sea surface temperature data for the first six months of 1998. Dotted line indicates temperatures 1 degree C above average; dark line indicates temperatures 2 degrees C above average.](image)

Large scale coral bleaching has taken place repeatedly since the 1990s. 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 color 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 month. 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...
During the first half of 1998 the global extent of water temperatures measured by NASA satellites were too hot for coral reefs extending over any of the 367 locations 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 started research across the Southern Indian Ocean, Australia, and Brazil that bleaching conditions were starting, and as a result of early warning research teams were able to get into the field unusually early and with extensive coverage. The impacts were severe in the Indian Ocean, where every part was affected. Some parts of the Indian Ocean were nearly 2 degrees above average for five months and coral death rates were very high, with over 90% of reefs being killed in many places. The majority of all corals died in 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 recently impacted this year.

Detailed analysis of the temperature records from all coral reef sites shows that coral reef bleaching is occurring at a rate faster than the global warming average, but that 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 the 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 warming rates do not reduce global warming rates, but because the heat remains in the system, moved down into deeper waters will eventually return to the surface. In addition, we have identified large regions where the upwelling of cold deep waters has failed completely since 1982, with consequent occurrences in fish and catch. Examination of temperature records suggests that the majority of bleaching events were not reported because there are no diving ability affected sites at the time, because it was not recognized, or because it was not reported.

Bleaching of coral reefs also shows a sharply accelerating trend, with several thousand of all first reports of bleaching at all reef locations worldwide being made in 1997 and 1998. While this pattern in part reflects intensified field studies made in this period and increasing skill in disease identification, the majority of over 150 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 the region are already dying from disease. Coral reef diseases are also found on all sites investigated across the Pacific and Indian Oceans, but generally at lower levels. The majority of the identified disease syndromes cause characteristic patterns of tissue death which appear to be caused by infection by different types of bacteria, but in the majority of cases the pathogenic organisms have not yet been identified. Consequently, the history can be said about the mechanisms of attack, cause of virulence, or survival, and some areas until these are greatly expanded funding for field identification and trapping of disease and for novel advanced laboratory research. In almost all cases the new diseases were thoroughly investigated by the time their symptoms were recognized that bleaching in these 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, crops, 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 disease is likely to be very prolonged, but happens at all. Coral reefs damaged by severe local stresses such as ship grounding, 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 unusually low levels of the most abundant and rapidly growing branching and plate corals in the Indian Ocean and parts of the Pacific. As a result there will be very few corals of these species reproducing in coming years, and hence very little supply of new coral larvae. In the Caribbean many species have virtually entire single colony affected by disease, and there are viability problems due to disease. Even if there were an adequate supply of coral larvae, reef recovery is biologically impossible in polluted areas unless pollution from sewage, run-off, fertilizers, and physical damage is halted. Recovery will be impossible even in areas which are totally unaffected by such stresses if it goes hot again in the future.

The importance of controlled ecosystem services in providing the bulk of the marine fish diversity, terrestrial tourism, white sand supply, and disease protection for over 100 countries is difficult to estimate accurately. Because we do not pay fees for these free services we tend not to value them, but nevertheless they are the most environmentally valuable coastal ecosystem present. When reefs are lost and we must import fish to feed our people, when we

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Coral reefs are not just essential to the people of over 100 countries, they are the heart of our commitment to sustainable development because they are already at the limits of what they can take from human beings and are very close to total collapse. Unless we stop destructive practices in reefs, we risk losing the marine life that makes them valuable and important to our well-being. Overfishing, excessive tourism, and pollution have reduced the productivity of reefs. We will see serious degradation or total loss of many of the benefits we derive from coral reefs.

With increasing sea levels and increasing intensity of hurricanes, cyclones, floods, and cyclones, damage to reefs will greatly accelerate the existing erosion of the coastal island nations. Serious and urgent action is needed from the world's governments to live up to their promises to protect the most vulnerable ecosystems, coral reefs. This will need to include all the steps required for sustainable development including protecting the fishing, controlling erosion, managing sewage, protection of the diverse habitats, research and monitoring of threats from global change, climate change, increased tourism and the coral reefs and the organisms and people who depend on them.

The Women’s Fisheries Development Section of the Secretariat of the Pacific Community

INDRODUCTION

Most people in the Pacific are aware of the large role that women play in harvesting, processing, and marketing marine resources. A look at many islands and coastal areas will show that most visible people on the reef are often women. Women do much of the processing of marine species harvested by both men and women. Many of the market and roadside sellers of marine produce are women.

Nevertheless, when people talk of fishing, they usually think of fishermen and the fish-dominated commercial fisheries. In development and management programmes priority is often given to assisting large-scale operations and production areas dominated by men - in order to encourage activities that will bring in an income for the country. The role of subsistence fisheries in ensuring the well-being and health of their families and communities is often overlooked.

Fig. 1: Women harvest, process and market marine resources. This contributes to effective utilization of marine resources, nutrition and economy of rural communities in a way that needs to be given greater importance in education and development programs. (Drawing by Aide Farquhar)