Coral Bleaching In The Seychelles
Impacts and Recommendations

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SUMMARY

Coral bleaching was assessed by underwater digital video in reefs at 14 locations around the Seychelles in late May 1998 as part of a continuing assessment of reef health with the Seychelles Marine Park Authority. Preliminary estimates are that around three quarters of all corals were recently dead, ranging from around 50% to over 90% at different sites. More precise measurements of mortality will be available later from detailed quantitative analysis of video records, but these will be underestimates of final mortality because many corals that were still partially alive at the time were still dying. The catastrophic mortality was due to excessively high sea surface temperatures, whose effect exceeds all previous threats to reefs to date. Strong international action to halt global warming is essential to prevent further recurrences of high temperature mortality in the future. Reef restoration efforts using mineral accretion technology to grow breakwaters and speed up the growth of corals will be essential to accelerate the recovery of lost environmental services such as reef fisheries, sand generation, tourism, and shore protection.

BACKGROUND

Coral reefs of the Seychelles contain the bulk of the nation's marine biodiversity, provide the white sand and snorkeling on which the tourist industry is based, and supply the bulk of the inshore fish catch. These reefs are under threat from a variety of causes including sedimentation of soils eroded from deforested hill slopes, overgrowth by algae fertilized by sewage runoff, physical damage from dredging, boats, anchors, and tourists, and over fishing of selected species (N. J. Shah, 1995). A system of marine parks has been set up to protect these economically valuable ecosystems, and the Marine Park Authority has established a set of permanent sites to monitor long term change in reef health. In 1997 these monitoring sites were filmed by Dr. Thomas Goreau, President of the Global Coral Reef Alliance, in order to provide a high-resolution digital image record for identification of coral species and abundance and as a baseline against which to compare subsequent changes.

Until this year climate change was a very minor factor affecting coral reefs in Seychelles. This report shows it is now the major factor. At the start of February Goreau, as part of a long term programme monitoring global satellite sea surface temperature impacts on coral reefs, emailed the Marine Park Authority, along with groups across the Indian Ocean, Australia, and Brazil, that the January temperatures in those areas were so high that severe coral bleaching should be starting. This was immediately confirmed by the MPA, and at all other locations subsequently.

METHODS

In mid 1997 MPA transect sites around Mahe and nearby islands were filmed with high resolution digital video. Nine sites around the Mahe group were refilmed one year later, and 5 additional sites added around the Praslin - La Digue group. Visual estimates of coral cover and recently dead corals reported here were made to a precision of around 10%. Detailed quantitative analysis with much higher precision is being conducted by detailed frame by frame analysis of the videos. This will take several more months to prepare, and the results presented here should be understood as preliminary. Although the final report will add numerous details of coral abundance, bleaching, and mortality on a species by species basis, information on coral diseases, abundance of algae and other marine organisms, with quantitative data that will be far more precise and perhaps slightly different in detail, it will not change any of the conclusions reached in this preliminary report.

Temperature data was derived from NOAA satellite radiometers, and is presented as monthly average sea surface temperature since 1982. Spot temperature measurements were made at many of the sites, and were mostly close to or above 31 degrees Celsius, around two degrees above normal maximum average temperatures.

Recently dead coral was distinguished from older dead coral by its appearance. Almost all corals bleached to an intense white colour, but a few colonies of certain species bleached to unusual pastel colours, largely blue, but also including pink, yellow, and peach colours. Although it was widely believed that white corals were dead and brown corals were alive because many corals normally have a brown colour when alive, in fact the opposite was the case. Tissue which had recently been killed was rapidly covered by microscopic algae filaments with a brown colour. White tissue on corals was in still alive but had turned transparent due to loss of the microscopic algae which provide corals with their colour and much of their food. A large fraction of corals which were white over portions of their surface were largely covered with expanding dead brown areas. Therefore the amount of corals estimated here as recently dead is an underestimate of the total mortality since many of those counted as alive were in fact largely dead and steadily dying (the final report will separate these into different fractional mortality classes). Corals which had been killed by other factors before the bleaching event (such as excess sediment from land or dredging, algae overgrowth, tourist and anchor damage, storm waves, or coral-eating crown of thorns starfish, were easily distinguished from recently dead corals because they were not covered with thin brown films. Instead they were covered with much larger mats of algae, of types which varied according to the local nutrient supply. In low nutrient areas corals were covered with pink encrusting limestone-producing algae crusts, in moderate nutrient areas they were covered with a fine greenish brown algal turf, and in high nutrient areas they were covered with large fleshy algae (mostly Sargassum) or with slimy mats of cyanobacteria (blue-green algae). In most areas recently dead corals outnumbered older dead corals by more than ten times.

BRIEF SITE ASSESSMENTS

This section briefly summarizes observations at each of 14 sites, in a southeast-northwest order. Much more detailed observations will be included in the final report with the quantitative data. Overall results, conclusions, and recommendations are in following sections.

1) Baie Ternay, Mahe

In 1997 this reef was in nearly perfect condition. There are no local sources of stress to this reef. Healthy corals covered well over 90% of hard bottom (i.e. not including sandy or muddy areas). Corals were brightly coloured, their forms suggested rapid growth rates, and their very large sizes suggested that many colonies were several centuries old. The only problem seen was that a few percent of the corals had been killed by crown of thorns starfish, which were moderately abundant. In 1998 approximately 80% of all the corals were freshly dead, and more were dying, but it appeared that around half or more of the large head corals might be able to survive. In 1997 Baie Ternay ranked with the most beautiful reefs I have seen anywhere in the world. A year later it was a graveyard.

2) North of Victoria Harbour, Mahe

This reef is located near to the radio towers, and is expected to be severely affected by future dredging and land reclamation activities. Although sediment damage was common, in 1997 the live coral cover was surprisingly high despite proximity to mud from rivers on Mahe, except on top of the reef flat where they had been subjected to physical damage, probably from storms. Several coral species seen here were not found at any other site. In 1998 around 80% or more of corals were intact and recently dead.

3) Victoria Harbour mouth, Mahe

The reef east of the lighthouse is probably the most polluted in Seychelles because it lies right next to the major shipping channels, is subjected to pollution from the Port of Victoria including sewage, leakage of marine fuels, and tuna cannery wastes, and is covered with muddy freshwater from rivers and drains from the capital city and steep hinterlands in the rainy season. The species composition is markedly different from other reef sites, being dominated by more stress-tolerant species. Signs of damage from mud were very common. Surprisingly this site had the lowest proportion of recently dead corals at any site, around 50%. This contradicts the widespread dogma that stressed corals are more likely to be killed by additional stresses due to weakened resistance. The explanation is that such sites are in fact dominated by coral species with higher stress tolerance, and so are less affected by stress that kills the more sensitive species which dominate other sites.

4) South of Victoria Harbour, Mahe

This site lies north of the reclaimed land at the airport and east of landfill areas south of Victoria, and has been subjected to high sediments first from rivers on Mahe and then from dredging operations. Although sediment covered corals were fairly abundant, the bulk of the corals, around 70%, died between the 1997 and 1998 filming.

5)Southeast Cerf

This site is on the opposite side of Cerf Passage. In 1997 the coral cover was high and dominated by fragile branching corals. In 1998 around 80% of all corals were recently dead, including almost all of the branching species.

6) West Sainte Anne

This reef was one of the most diverse in terms of coral species, being dominated by large, old, head corals. In 1998 around 70% of the corals were recently dead, but some large coral heads were not bleached, and others appeared to be starting to recover.

7) Southeast Sainte Anne

Most of this reef had around 90% live coral cover in 1997, being dominated by rapidly growing branching corals and plate corals, with few large head corals. The major stresses were two opposing gradients: physical damage from storms increasing to the east, and overgrowth by large fleshy Sargassum algae from the surface down to a depth which increased in the direction of Mahe. In 1998 over 80% of corals were recently dead, including almost all the branching and plate species, and including many of the head corals.

8) Marine Trail, between Ronde and Moyenne

In 1997 the deeper portions of the trail were covered with lush live corals, but the shallower areas were completely overgrown by Sargassum. In 1998 over 80% of the corals were recently dead.

9) North Moyenne

In 1997 this site had much lower algae cover than the site on the Mahe side of the island, apparently due to exposure to clean open ocean water, but had signs of storm damage in shallow areas. Live coral cover was high. Roughly 80% were recently dead in 1998.

10) East Cousin

Despite absence of local sources of stress, live coral cover was extremely low around Cousin. While there was considerably more recently dead coral than live coral, the overwhelming bulk of dead coral was old. This included loose coral rubble, largely of species which were rare alive, and dead standing coral which was overgrown by encrusting red algae, indicating good water quality. When and why most of the reef fringing Cousin died is unknown. One possibility is severe storm damage and another is large swarms of crown of thorns starfish, but it is surprising that similar damage was not seen on other islands in the Praslin - La Digue group. Even though there was large amounts of the clean hard dead coral and red calcareous algae surfaces on which young corals prefer to settle and grow, there was almost no sign of new coral settlement in recent years.

11) South Curieuse

Live coral cover was low, with isolated corals on hard rock surfaces surrounded by sand. About 70% were recently dead.

12) Coral Gardens, Southeast Curieuse

Reefs in this area were a favored site for Scuba diving because of high coral diversity. Around 60 to 70 percent were recently dead, with a fair amount of variability from place to place, being lower where head corals dominated and higher where branching corals were most common.

13) Southwest La Digue

Reefs at this site appeared to be subjected to strong influence from waves and swells from the southwest monsoon, because this was the only site in which corals grew to form ridges oriented into the waves separated by sand channels. Coral cover was low to moderate with considerable amounts of coral rubble in shallower areas, likely due to wave damage. Intact, recently dead coral was around two to three times more abundant than live coral.

14) Coco, between Felicite and Les Souers

This reef was widely regarded as the most beautiful in Seychelles because of magnificent growth of brightly coloured branching corals covering all the shallow slopes. In May 1998 almost all of them were dead, with recent mortality of around 90%. Although a few branches of a few large branching coral colonies were still alive, these appeared to be remnant portions which were the last to die. In deeper water corals sparsely covered granite rock outcrops, and mortality was lower, around 70%, because head corals were more common.

PRELIMINARY RESULTS

Overall around 70 to 80% of corals in the Seychelles had died between the start of bleaching in January and the observations in May. This is an underestimate of the final mortality, because many of those corals with live but bleached tissue were in the process of dying. Mortality was highest in the healthiest reefs, and lowest in the most highly stressed reefs. According to David Rowat and Glynis Sanders bleaching was at least as severe in the Beau Vallon area, and anecdotal reports from divers visiting the Amirantes and Aldabra indicate that the same situation prevailed there as well. It is therefore unlikely that any Seychelles reefs, even in the most remote coral atolls, escaped severe bleaching.

CONCLUSIONS

Monthly average sea surface temperatures in the Seychelles normally do not get much over 29 degrees C, but in 1998 they stayed over 30 or 31 degrees for at least five months. This is the hottest period ever measured in the satellite record going back to 1982. According to studies of global patterns of coral bleaching and temperature mass coral bleaching, when the majority of all corals in a reef are bleached, results whenever monthly average temperatures in the warmest season of the year reach around 0.9 degrees C or more above the long term average for that month (Goreau & Hayes, 1994). If these conditions last only one month and it then cools down, almost all corals will gradually recover after a period depending on how hot it got, how long conditions stayed excessively warm, and on the species of coral. While bleached and recovering, corals do not grow or reproduce. If excessively hot conditions persist for two to three months, or if temperatures reach 2 or 3 degrees above average for one month, coral mortality becomes significant. In 1998 the unusually hot conditions persisted for most of the year across most of the Indian Ocean, and severe coral mortality, ranging from 50% to around 90% took place in Seychelles, Comoros, Kenya, Maldives, Sri Lanka, and India, with serious bleaching (but as yet unrecorded mortality) in other areas including Madagascar, Reunion, Mauritius, Tanzania, Mozambique, Oman, Somalia, Thailand, and Indonesia.

Although some persons who do not wish to accept that high temperatures cause bleaching attempt to blame freshwater runoff or pollution as the cause instead, these cannot explain the phenomenon seen because bleaching and mortality were lowest in the most polluted reefs, and no bleaching was seen after the record rains, flooding, and landslides which affected the Seychelles in August 1997 (J. Souyave, personal communication). High temperature coral bleaching and mortality during 1998 also affected the Great Barrier Reef, the eastern

Pacific, Brazil, and the Caribbean, and all these events were also predicted in real time from the satellite temperature records.

It has also been popular to blame this event on El Nino. This is misleading for several reasons. First this implies that this is a unique event that occurred for unpredictable reasons and will not repeat, and about which we can do nothing. The fact is that high temperatures are the direct cause of large scale bleaching, and their excessive magnitude and duration are the cause of the severe mortality seen in 1998, and whenever they rise to such levels again bleaching will recur whether or not there is an El Nino. No such event of such severity has been known to happen in the Seychelles or elsewhere in the Indian Ocean before, although much milder bleaching events with low mortality affected much smaller areas since the 1980s. No such large scale bleaching events are known anywhere in the world before the 1980s, when all recorded bleaching was due to purely local stresses such as lagoon waters heated under stagnant conditions during exceptionally low tides, industrial hot water effluents, or extreme cyclone flooding.

El Nino is a natural event that has been going on for thousands of years, but this year very large and very old coral colonies, hundreds of years old, were killed, although they had survived dozens to hundreds of previous El Nino events (which take place every 3 to 7 years on the average). El Nino produces irregular oscillations in local temperatures, with some parts of the world getting hotter and some areas getting colder, but this year bleaching occurred in regions which should have gotten colder as well as areas which normally heat up during El Nino events. While El Nino may be a proximate cause of high temperatures in areas which were unusually warm during El Nino, it is probably not the ultimate cause. This is because the irregular and small temperature oscillations which El Nino produces in some locations are superimposed on the rising baseline caused by global warming, which is making successive El Ninos more and more severe even if they produce the same absolute warming.

If corals cannot take temperatures more than 1 degree C above normal maximum temperatures, they will all be imperiled by global warming of one degree. The Kyoto agreements commit the world to a warming of several times this amount in coming generations because it sets the "acceptable" level of warming at a politically convenient and arbitrary level that far exceeds the tolerance level of corals. In other words, it is a death warrant for the world’s coral reefs, sooner or later.

Recovery of the corals is likely to be extremely slow. First it will require that it does not get hot again, and secondly that reefs are free of other stresses which kill corals, especially the algae overgrowth that is spreading outward from population centers such as Victoria as population rises and more sewage discharge results in higher nutrient inputs to the coastal zone, thereby fertilizing rapid algae proliferation. Even if conditions remain perfect for corals in the future, recovery is likely to be very slow because the most abundant branching and plate species have been almost totally wiped out, and these are the fastest growing and most rapidly reproducing species. If not actually killed, these have stopped growing and reproducing while affected, so there will be no local source of baby corals to settle for most species in the near future. Nor are new corals likely to be transported to the Seychelles by ocean currents because all potential sources of coral larvae also suffered the same catastrophic mortality as the Seychelles. As the dead coral framework becomes broken up by waves and by boring organisms, the food supply and habitat of almost all other reef creatures will disappear, and these species will vanish, leaving only a handful of "weedy" species. Colourful fish still swim through the dead corals, but eventually almost all of them will disappear, at a rate and in an order which we cannot yet predict. Lack of a growing reef framework to protect the coastline will at first provide a new supply of dead coral rubble, but much of the new sand supply for beaches will eventually vanish, and reduced sand replenishment and the higher wave energies reaching the shore line (which would have been absorbed by growing coral) will result in greatly accelerated beach erosion.

<u>In summary, high temperatures in 1998 have produced a catastrophe in Indian Ocean coral reefs of a magnitude which has never been seen before, which has killed more coral than all direct human damage from all causes to date, which will have very long lasting and expensive impacts, and which is likely to recur in the future.</u>

RECOMMENDATIONS

1) It is important that affected countries do not mistakenly attribute the 1998 coral bleaching event to the wrong causes, and do not attempt to downplay or conceal its impacts, as denial or obfuscation will prevent any clear assessment of the policy steps needed now and in the future.

2) It is crucial that over 100 coral reef countries recognize that their economies are severely threatened by current and future high temperatures, and demand that global temperature rise be reduced to levels which are below the tolerance limits of corals, through a combination of adopting environmentally-sound "acceptable" limits for global climate change, sharp reductions in net greenhouse gas emissions through large scale increases in reforestation to provide carbon dioxide sinks and a rapid transition away from fossil fuels like oil, coal, and natural gas (which pollute the atmosphere with greenhouse gases) and towards renewable non-polluting energy sources (like solar panels and tidal turbines). In view of the extreme damage caused by high temperature this year, the Seychelles should be one of the countries in the moral lead in pushing for environmentally sustainable global energy policies.

3) Reef restoration methods like Mineral Accretion, which use solar power or tidal current energy to speed up coral growth and settlement, and which have been

shown to be highly effective in the Seychelles in a short term pilot project by Wolf Hilbertz and Tom Goreau in cooperation with the Ste. Anne Marine Park, should be greatly expanded to contribute to restocking reefs with corals. However this will also require simultaneous control of global warming and land based sources of nutrients and soil as well as dredged sediments, which can kill corals.

4)The major Seychelles islands are uniquely free from costal erosion because of its massive granite rock, but all of its sand beaches, tourist industry, the residential, industrial, and transportation areas on coastal landfill, and outlying coral islands will be threatened by coastal erosion once the reef barriers which protect them are breached and as global sea level rise (now 2 millimetres per year worldwide) accelerates. The use of Mineral Accretion technology can literally grow limestone breakwaters in the sea which get stronger with age and are self-repairing at a cost at least ten times below that of conventional seawalls. If global warming is not controlled, this will be the only cost-effective way to protect beaches and coastal infrastructure, since high temperatures make mineral accretion more rapid. Pilot projects analogous to the large projects in the Maldives by Hilbertz and Goreau should be developed to at least pilot stage in critical areas. Information on these new technologies has already been provided, and is included here as appended material. Such reef restoration and shore protection projects are already included in the Seychelles Biodiversity Strategy submitted to the Global Environmental Facility of the World Bank, but no funding has been identified for their implementation. Finding funding to initiate these programs should be a priority, linked to an expanded coastal zone management programme.

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