NPR

6/6
S. HRG. 100-499

BLEACHING OF CORAL REEFS IN THE CARIBBEAN

HEARING

BEFORE A

SUBCOMMITTEE OF THE
COMMITTEE ON APPROPRIATIONS
UNITED STATES SENATE

ONE HUNDREDTH CONGRESS

FIRST SESSION

SPECIAL HEARING

Printed for the use of the Committee on Appropriations

LANG

U.S. GOVERNMENT PRINTING OFFICE
79-795 O WASHINGTON : 1988

For sale by the Superintendent of Documents, Congressional Sales Office
U.S. Government Printing Office, Washington, DC 20402

STATUS OF DIADEMA

Senator WEICKER. The coral is? What has happened—and again, others can answer the question when your turn comes to testify—what has happened to the Diadema? From my own observation, there has been some return of Diadema, at least around the Island of St. Croix.

Dr. LANG. Very much.

Senator WEICKER. I see more of them there. Really, as far as I am concerned, God can do us a favor and get rid of them. But, seriously, I have had to become cautious again. There was about a year there where I walked around with impunity and did whatever I wanted to do. Not any longer.

My question is really twofold. Number one, is the Diadema coming back, and number two, has it been replaced with anything else? We have seen, and I speak strictly as a layman, where on land certain species of animals and certain species of plant life become extinct yet are replaced by others that have adapted to the new environment, whatever it is.

What do you see happening here? Has this happened to coral in the past? Are there species of coral no longer existent, and new species of coral that we see in more recent times?

Mr. WICKLUND. I want to just answer the first part of your question. They are definitely coming back in the Bahamas. We have seen an increase in numbers, but it is very slow; nothing like the way it was before 1983. But they are coming back.

When you lose one animal it can be replaced by another, as far as the Diadema is concerned, its loss was replaced by grazing fish and we don't see a real effect of the loss of Diadema, at least in our area. The fish, in other words, have taken over the job of the Diadema.

But in other places of the Caribbean, which have been fished out, and indeed a lot of the Caribbean has been fished out, there are problems in these areas of abundant corals and it could be because there is no grazing fish or few of them left to take over the grazing job that the Diadema covers.

The Diadema keep the algae down on the reefs so that they don't compete with the corals. So in this case, after we lost the Diadema in at least the Bahamas, this problem would not exist.

FEDERAL AGENCY RESPONSIBILITY FOR INVESTIGATION

Senator WEICKER. Let me just ask one last question. Obviously, we want to do something in a coordinated way here. How is this best approached, in other words? Who is going to do this? NOAA?

Mr. WICKLUND. I think certainly NOAA would be the perfect vehicle for looking and coordinating the problem, particularly since a lot of us here are involved in one NOAA program or another. Of course, a lot of people on the outside could also contribute.

Senator WEICKER. Where did you get your cost estimate? It sounds awfully low.

Dr. DILL. This is for the study that could prepare a proposal that could go in for a bigger study. What we need to do is get the people who have already seen this together, and a lot of us are poor, and we are being funded by the abject poverty foundation that is money normally for food, clothing and shelter and our own housing, and so the thing that we need to do is have a workshop, and that $60,000 would be to have the workshop; allow people to go around and make telephone calls; go out and look at these areas; pull the people together; and then, with this group, I would say we are talking about 15 to 18 people who have been working on this.

These are just rough numbers. Have these people, then, determine what really needs to be done; write a proposal; and then submit it to the proper agency and NOAA could very well be that agency. The U.S. Geological Survey could be it. NSF could be it, and then have appropriations to fund a well-coordinated program that had some thought ahead of time so that we have been a coordinated program bringing in the people that can really do this.

The last thing we want to do is run out everywhere and say, "Let's get all this other information." I think we need to sit back, but hurry, and say, "What do we need to do, and when do we need to do it to find out what is causing it? How widespread is it, and the progress, and what are the implications?"

This would be my recommendation. That is mine; that is not anybody else's.

Senator WEICKER. All right. I thank you. Your statements in their entirety have been placed in the record, and we will proceed with the other witnesses. If there are further questions, they will be submitted to you for response for the record.

Panel 2

TEXAS MEMORIAL MUSEUM

STATEMENT OF JUDITH C. LANG, PH.D., CURATOR OF INVERTEBRATE ZOOLOGY, TEXAS MEMORIAL MUSEUM, UNIVERSITY OF TEXAS, AUSTIN, TX

ECOLOGICAL AND ECONOMIC IMPORTANCE OF CORAL REEFS

Senator WEICKER. Our next witnesses are Dr. Judith Lang, Curator of Invertebrate Zoology, Texas Memorial Museum, University of Texas at Austin; then Walter Jaap, Biological Scientist, Bureau of Marine Research, Florida Department of Natural Resources.

Go ahead.

Dr. LANG. Senator Weicker, thank you for the opportunity of appearing before this subcommittee today. For brevity and because the ecological and economic importance of coral reefs are inextricably intertwined, I shall address both of these topics simultaneously.

Coral reefs are mostly restricted to warm, shallow, clear blue oceanic waters. They are composed largely of calcareous skeletons of reef corals, animals whose soft tissues contains populations of symbiotic algae called zooxanthellae. The pigment of these algal symbionts give reef corals much of their color and, somehow, their presence allows them to grow with unusual rapidity.

Being a major site of calcium carbonate deposition, coral reefs form an important buffer in the global carbon dioxide cycle. Consolidation of corals and of other calcareous organisms create the framework of a reef. During storms, this framework serves as a breakwater, greatly reducing erosion and attendant losses, both ecological and economic, in tropical lagoons and along shorelines. Throughout the tropics, the skeletons of dead corals are also used commercially for use as a building material or crushed to make gravel or to manufacture cement.

Some of the skeletons of these corals and of other calcareous organisms become fragmented and end up forming the white coral sand which so enhances the recreational and commercial value of many tropical beaches. Coral sands are also mined for use in beach replenishment and for other constructional activities.

Despite their location in a virtual oceanic desert—blue water is very poor in nutrients—coral reefs are among the most productive of all natural ecosystems. The fast growth rates of reef corals apparently are facilitated by close cycling of nutrients between the animal hosts and their symbiotic zooxanthellae.

OTHER LIFE FORMS ON CORAL REEFS

In addition, many kinds of free-living algae inhabit reefs. Some of the non-calcareous algae can grow even faster than reef corals do. Fortunately, on reefs which have not been overfished, the normal feeding activities of herbivorous fishes and sea urchins such as Diadema usually prevent these algae from overgrowing and smothering the corals.

Many other fishes, crustaceans, molluscs also live on reefs, although some make regular excursions into surrounding lagoonal ecosystems in order to feed. Hence, coral reefs are a critical component of many coastal fisheries. Worldwide, average reef fisheries' yields are estimated at nearly 43 tons of biomass per square mile per year. In 1982, the value of just the commercial spiny lobster catch in Monroe County, FL, was approximately $15 million. At present, however, most commercial fisheries in the western tropical Atlantic have been overfished and are highly vulnerable to disruption.

In numbers of contained species, coral reefs are among the world's richest ecosystems. The intricately-formed coral skeletons provide attachment sites for many sedentary organisms and shelter for numerous motile animals. Some of the more visually attractive of these organisms are harvested for the aquarium trade or as decorative objects and jewelry.

Many reef organisms are known to contain unusual and even toxic chemicals. Although only a few medically-important compounds have had their origins here, the medical and commercial potential of this species-rich reservoir is, as yet, relatively untested.

AESTHETIC AND RECREATIONAL VALUE OF REEFS

Without question, however, the greatest economic contribution of tropical beaches and coral reefs is in their aesthetic and recreational value. Tourism, which is largely concentrated in coastal areas, presently accounts for about 40 percent of the gross domestic income of the Caribbean Island nations. In addition, the minimum, non-market use value of the coral reefs in Key Largo State Park in Florida is nearly $3,900 per square meter, which means that a single reef here, Molasses Reef, is worth about $500,000,000.

HIGH VULNERABILITY OF CORAL REEFS

Despite their high productivity and diversity, coral reef ecosystems are easily disturbed. Once perturbed, their rates of recovery can be fairly slow. Unfortunately, reefs are proving to be particularly vulnerable to a variety of perturbations associated with habitat degradation or with development in nearby coastal areas.

For example, many reef corals are killed or show reduced rates of growth when sediment levels are increased, as when land is cleared or when channels are dredged. Increased nutrient levels, commonly associated with sewage outfalls, allow fleshy algae gee to bloom and displace reef coral.

In general, the combined effects of such stresses are probably most severe when reef corals are close to their physiological tolerance limits for some environmental factor.

Many coral reefs and associated commercial fisheries in the western Atlantic have deteriorated within the last several decades. Indeed, the oldest marine park in the United States, John Pennecamp, is now ranked as one of the world's ten most threatened protected areas.

Limited experience indicates that reefs can recover once artificial stresses are reduced but, to date, there have been few such improvements in this geographic area.

In summary, the ecological and economic value of coral reefs is considerable but can only be realized when reef ecosystems are managed as fragile but renewable resources and when they are exposed to a minimum of artificial stresses.

Thank you.

[The prepared statement of Dr. Judith C. Lang follows:]

Prepared Statement of Judith C. Lang

Texas Memorial Museum, University of Texas, Austin, TX 78705 and Department of Zoology, University of Texas, Austin, TX 78712

Ecological Importance of Coral Reefs

Reef corals (scleractinians and Millepora) are sessile, marine animals which secrete a skeleton of calcium carbonate as they grow. Their soft tissues contain populations of symbiotic zooxanthellae (Symbiodinium--a photosynthetic alga). One result of this mutually-beneficial association is that the extension rates of the zooxanthellate reef corals are relatively rapid, usually 1-20 cm/year. Large coral colonies may contain many thousands of individual polyps, and be hundreds or even thousands of years old.

Compaction and consolidation of the skeletons of reef corals and of other calcareous reef inhabitants create the frameworks of coral reefs--massive structures with high accumulation rates (up to 12 meters/1000 years) which significantly alter the relief of surrounding sea floors. Globally, coral reefs cover at least 600,00 square km, or about 0.1% of the planet's surface. Most reefs are located in clear, shallow, oceanic waters of the tropics and subtropics. As a major site of calcium carbonate deposition, they form an important buffer in the global CO_2 cycle.

Broken-down skeletal fragments of carbonate-producing reef organisms are major constituents of "coral sands". These fine-grained particles (really a mixture of silts, sands and gravels) are transported by waves and currents away from reefs, providing sediment for the lagoons, beaches and islands which develop in their lee. By dissipating the energy of waves and currents, reefs also serve as breakwaters, thereby reducing erosion in such lagoonal and nearshore ecosystems as seagrasses, mangroves and sandy beaches.

Coral reefs are among the most productive of natural

ecosystems. Despite their location in blue waters which are poor in nutrients, estimates of gross primary production range between about 300 and 5,000 gm carbon/square meter/year. Important primary producers on reefs are the zooxanthellate corals, other algal-aminal and algal-protozoan symbioses, free-living filamentous, fleshy and calcareous algae and phytoplankton. High productivity is presumably maintained in part by close cycling of nutrients between reef corals and their zooxanthellae, and among other producers and consumers. The contributions of free-living, photosynthetic cyanobacteria (blue-green algae) which are capable of fixing dissolved gaseous nitrogen may be especially important in some reef habitats.

Trophic relationships are particularly complicated on reefs, as illustrated by the reef corals themselves. Organic photosynthates which they receive from zooxanthellae apparently facilitate the production of mucus and the growth of their soft and skeletal tisses. In addition, reef corals actively feed on free-living zooplankton and, perhaps, other exogenous foods, at least in part to obtain essential mineral nutrients for their algal symbionts. Similar nutritional relationships exist between many other reef animals and their zooxanthellar symbionts, regardless of whether or not the former deposit calcareous skeletons.

In turn, the soft tissues of reef corals are eaten by certain specialized predators. Some fishes and invertebrate animals consume mucus (produced by corals to clear sediment and capture small plankton) which they have gentled sucked or scratched from the surfaces of live corals. In addition, strands of mucus which have been released by corals are eaten by benthic scavengers or, as currents waft them away, are snapped up by pelagic zooplankton and fishes.

The movements of motile animals form important trophic links between coral reefs and other ecosystems. Demersal zooplankton, which hide in crevices of the reef by day and emerge in the evening to feed in the water column above, are themselves preyed upon by reef corals and other sedentary invertebrates as they pass to and fro. By foraging in nearby seagrass beds at night, diverse fishes, sea urchins and other invertebrates import significant quantities of nutrients into reefs from surrounding ecosystems. The wastes which they subsequently eliminate contain nutrients which measurably increase growth rates of the corals under which they shelter by day.

Coral reefs are among the richest ecosystems in the world in terms of the number of species of living organisms which they contain. The skeletons of reef corals create topographically complex structures, thereby providing attachment sites for numerous sedentary organisms (including other corals) and shelter for motile fauna. Among the sessile flora and fauna are many species which compete with each other for space and, presumably, for access to nutritional resources. Complicated variations in competitive outcomes, both within and among species, apparently enhance the coexistence of these competitors, even on reefs which are structurally dominated by a few species of large, "canopy-forming' reef corals.

Other species are borers which excavate cavities in coral skeletons to provide space for their own tissues. Certain fish and sea urchin grazers scrape off surficial skeketal layers as they feed. Collectively these bioeroders weaken the surface frameworks of reefs, and create many of the fine-grained particles which end up in nearby lagoons and on sandy beaches and islands.

Crustose coralline algae and foraminifera, however, bind coral skeletons to the substratum, hence contributing to the formation of reef frameworks. Moreover, in return for food, small crustacean symbionts deliberately protect certain species of host corals from predatory starfish. Some large scavengers inadvertently may prevent rapidly-extending branching corals from

expanding over the more slowly-growing, mound-shaped species at whose bases they find shelter.

Complicated indirect relationships also exist between corals and other reef organisms. For example, herbivorous fishes and invertebrates crop the fleshy, benthic algae whose abilities to grow rapidly in shallow reef habitats are often so great that, uncontrolled, they easily would overgrow and smother many reef corals.

The Economic Importance of Coral Reefs

Economically, coral reefs represent one of the most important marine resources of the tropics. Reefs dissipate waves, minimizing the impact of storms on commercially-important lagoonal ecosystems and on port facilities, houses and other coastal installations. By serving as sources of food, shelter or as nursery grounds for fishes, crustaceans, molluscs and echinoderms, coral reefs also form the basis of many coastal fisheries. Traditionally these resources provided much of the consumed protein in the diet of tropical islanders. Even to-day, about 180 species of reef fishes are harvested for human consumption in Puerto Rico. The value of all reef-related, commercially-edible organisms in Monroe County, Florida, was estimated at approximately $19,000,000 in 1982 (spiny lobsters accounted for $15,000,000 of this total). Worldwide, average yields of reef fisheries are estimated at nearly 43 tons of biomass/square mile/year in depths of less than 100 feet. Although aquaculture of reef organsims has been little developed to date, the Caribbean King Crab is a promising candidate for such activities.

Reefs contain numerous non-edible resources of considerable commercial importance. Throughout the tropics, the skeletons of reef animals are major sources of sand and gravel. Both modern and fossil corals are quarried for limestone to use for construction and in the manufacture of cement. Some of the more visually attractive live algae, fishes and invertebrates fetch high prices in the aquarium trade. In addition, the skeletons of reef corals, precious corals, soft corals, molluscs and other dead reef organisms are sold as decorative objects or for jewelry by entrepreneurs around the world.

Medically-important chemicals which have been extracted from reef organisms include prostaglandins, an anticancer agent, and an ultraviolet blocker recently synthesized for use as a sun cream. Given the high species diversity of these communities, that many sedentary reef organisms contain unusual chemical compounds, and the known toxicity of numerous reef inhabitants, reefs represent a vast and, as-yet largely untapped, reservoir of chemicals which potentially are of both medical and commercial value.

In many tropical and subtropical areas, vital parts of the tourist industry are concentrated in coastal areas. Here, reef-derived sandy beaches make an important contribution to the recreational value of the coastlines. The livelihood of operators of glass-bottom and sports-fishing boats, snorkeling and SCUBA-diving facilities, and numerous coastal merchants, are further dependent upon the clear blue waters and the intrinsic beauty for which coral reefs are renowned. Tourism presently accounts for about 40% of the gross domestic income of Caribbean Island nations. The minimum, non-market use value of the coral reefs in Key Largo State Park has been estimated at nearly $3,900/square meter. By this criterion, Mollasses Reef alone is worth $500,000,000.

Vulnerability of Reef Ecosystems

Their high productivity and diversity notwithstanding, coral reef ecosystems are easily perturbed by external disturbances, and their rates of recovery can be fairly slow. For example, most reef corals live near their upper thermal limits and those growing at high latitudes (e.g., Florida, northern Bahamas, Bermuda) may also be killed by cold temperatures in winter.

Deviations of salinity or light from optimal values appear to further narrow the range of tolerable temperatures in reef corals. On many reefs, extreme levels of mechanical damage are associated with the periodic passage of hurricanes. In addition, reefs can be devastated by population explosions of predators (especially the Crown-of-Thorns starfish in the Indo-Pacific), or diseases, and by altered predator-prey ratios following disturbances that disproportionately affect reef corals. Natural disturbances do, however, open patches on coral reefs which, if colonized by surviving reef organisms and new recruits, contribute to the high species diversity of these communities.

Unfortunately, reefs are particularly susceptible to pertubations associated with habitat degradation or development in nearby coastal areas. For example, excessive levels of sediment, nutrients and other pollutants decrease the growth rates of established corals, and probably limit their sexual reproductive activities and the ability of juveniles to settle in open patches. Large increases in bioeroding organisms (which potentially could shift the carbonate balances of reefs) have been noted under conditions of sewage stress. In general, eutrophication allows fleshy algae to bloom, grow above, and eventually smother reef corals and other sedentary animals. Although reefs which are chronically perturbed by high levels of artificial stresses may not recover, limited experience to date suggests that reef corals and their associated populations can return if artificial stresses are reduced.

In many areas of the western Atlantic, reef corals are routinely stressed by sediment, industrial or agricultural chemicals, sewage, and eutrophication. Not surprisingly, many of its coral reefs and associated commercial fisheries have deteriorated within the last several decades. The John Pennecamp Coral Reef State Park (the oldest marine park in the U.S) is ranked as one of the world's ten most threatened protected areas. On many central Caribbean reefs, where stocks of herbivores have been depleted by the combined effects of chronic overfishing and disease, unchecked algal growth presently is occurring at the expense of reef corals.

Conservation Measures

In 1980, coral reefs were identified as one of the world's "essential ecological processes and life-support systems" by the International Union for the Conservation of Nature. Although reefs are still poorly represented among the world's protected areas, worldwide there are, at present, in excess of 200 reserves which offer at least theoretical protection for the reef communities contained within their boundaries. Given the importance of the physical and nutritional linkages which exist among coastal ecosystems, to be effective protection should also be extended to any adjacent lagoons and coastlines and, if possible, any watersheds. Properly managed, such reserves can help to sustain renewable marine resources and provide educational and recreational facilities to the general public. In addition, they are suitable sites for the basic research efforts and long-term monitoring studies which are essential for delimiting the capacity of reef ecosystems either to resist or recover from natural and artificial pertubations.

Bleaching

It has long been recognized that reef corals which are under stress are likely to loose their symbiotic zooxanthellae. When this algal loss is sufficiently great that the underlying coral skeletons are visible below their cover of soft tissues, corals are commonly said to have "bleached". Natural sources of external stress include temperature extremes, subaerial exposure, reduced salinity, increased sedimentation and altered levels of illumination. Bleaching is also observed when reef corals artifically are perturbed by starvation, exposure to certain particulates, oil and to fish collecting chemicals. In general,

synergistic effects among several factors are likely to occur when corals bleach in the field.

Although the underlying biochemical and physiological mechanisms are unclear, the cytoplasm of the affected corals may show reduced lipid levels, degenerate zooxanthellae, abnormal mitochondria, mucoid polysaccharide materials and varying degrees of tissue atrophy and necrosis. Apparently depending on the severity of the stress(es), affected corals gradually either recover a "normal" complement of zooxanthellae or die.

Previously-recorded bleaching episodes in the western Atlantic have been attributed primarily to the effects of high water temperatures, to lowered salinities and, possibly, to increased levels of suspended sediment. Prior to 1987, the only bleaching event which is known to have extended over a fairly wide geographic area (a few sites in Colombia, Panama, Costa Rica, San Andres, Florida and the Bahamas) occurred in 1983 and was possibly correlated with the unusually large, 1982-1983 El Nino Southern Oscillation. Mortality rates appear to have been low at most of these locations. During the same year, however, extensive bleaching and subsequent death of reef corals was widespread across the Pacific and even in the western Indian Ocean.

Present Bleaching Event

A brief summary of my personal observations of the present bleaching phenomenon in Colombia and the Bahamas is followed by a preliminary assessment of this event.

<u>Colombia</u>:

Bleaching of some corals was first observed in mid July at the Islas del Rosario. At this time, water temperatures were about 30°C at 0-3 meters depth and, on at least one day, the water was turbid (indicates the presence of sediment and possibly of exogenous nutrients or other pollutants, its salinity could also have been lowered). By mid-August, loss of zooxanthellae was noted in 14 species of scleractinian reef corals in

Millepora and in several species of soft-bodied cnidarians. Zooxanthellate sponges were not affected. Overall, the patterns and extent of bleaching were highly variable, both among species and among locations (Tables 1-3), but were confined to shallow (6 meters) habitats. At that time the event was judged to be less severe than the bleaching episode of 1983.

I have since heard that in early August some reef corals were also observed to have bleached at the Islas de San Bernardo.

Bahamas:

Slightly higher than average water temperatures may have occurred in the late summer-early autumn at Lee Stocking Island. Winds may have been more from the south, southwest and west than usual. Bleaching, which was first noted at the end of September, extends to depths of at least ~~60~~ 55 meters. By early October, about 18 species of scleractinians, Millepora, many gorgonians, several other groups of soft-bodied cnidarians, and possibly some sponges had been affected to some degree. In several species, up to 96-98% of the specimens examined were either pale (i.e., containing few zooxanthellae or reduced amounts of accessory photosynthetic pigments), partly bleached (some soft tissues are white) or completely bleached. Patterns and extent of bleaching varied with species and habitat and, in some groups, (e.g., Millepora, gorgonians) increased with depth (Figs. in prep.). At one location one/third (22/67) of the staghorn corals seen had died within the previous week or two, but the reason for their demise is not known. Shallow populations of the related elkhorn coral, however, were relatively unaffected at this time.

Provisional Assessment:

Overall, the near-simultaneous appearance of bleaching in Colombia and Florida in mid-July, and its current widespread distribution (Colombia to ?Bermuda and Virgin Islands to Florida or Cozumel) by late September suggests that some large-scale physical factor(s) is involved. Presumably any pathogens or

pollutants as might be released at a point source could not have dispersed over such a wide geographic area within such a short time frame. Until we know what percentage of the corals which have bleached ultimately will recover, it is not possible to evaluate the ecological or economic severity of this phenomenon.

Should a region-wide, natural physical explanation prove to be the proximate cause of this event, its appearance in such continental shelf areas as Florida and Colombia several weeks to months before the insular locations still needs to be explained. The regional stress(es) could have been experienced first or most acutely here; alternatively, chronic exposures of reef corals to artificial stresses (excessive nutrients, sediment, etc.) could heighten their sensitivities to additional pertubations. Distinguishing between these alternate possibilities would appear to be an important goal, as the answer would, in turn, clarify what intervention, if any, is appropriate from a reef management perspective.

Recommendations

Recommendations 1 to 5 are intended to provide data on the extent and duration of the present bleaching. If available, this information could be compared directly with that gathered in the eastern Pacific since 1983. An important goal is to ascertain whether or not human activities have contributed to its early appearance in Florida and Colombia. Short-term emergency appropriations should be solicited to allow these studies to begin immediately, before the conditions of the affected corals change. (Only rarely after corals have died is it possible to determine the reasons for their demise.)

Recommendations 6 to 11 are for longer-term ecological and physiological studies aimed at determining the cause(s) and consequences of these kinds of events, and at providing environmental data which are essential to document any future natural disturbances. Emergency funds could be used to initiate these researches, but funds for their continuation should then be solicited from regular granting agencies.

Our ability to understand the potential impact of pertubations like the present bleaching event in reef ecosystems will be greatly enhanced if recommendations 2-10 are replicated at least in one relatively-polluted and in one comparatively-unpolluted reef area.

1. Try to establish a reliable chronologly for the present event, with particular attention to relative timing, wind speed and direction, ambient temperature, salinity, cloud cover and suspended sediment load wherever such information is available. Comparative information on the species which are and (just as important) are not affected, and the habitats in which they occur, would allow certain limits to be placed on the factor(s) which may have initiated this phenomenon.
(In progress at the University of Puerto Rico).

2. In areas for which massive bleaching has occurred in the shallower reef habitats and is visible in plan view, use aerial reconnaisance flights or satellites to obtain false color IR and other photographic information. Digitization of these data would provide large-scale quantification of the effects of bleaching on reef communities.

3. Try to determine if there are any unusual histological features or any microbial infestations present in the soft tissues of the bleached corals relative to controls.
(In progress in Florida at least.)

4. Measure lipid levels (an important measure of nutritional state) in bleached and unbleached corals.

5. Particularly if chronological data suggest that the corals in continental areas such as Florida and Colombia might be chronically stressed, analyze tissue samples and ambient sea water for terrigenous sediment, heavy metals, pesticide and

herbicide residues, etc., and for elevated levels of fulvic acid (an indicator of increased runoff from land).

6. Establish and maintain automated weather stations adjacent to sites for which a good ecological data base of its reef communities either exists at present or will be forthcoming in the near future.

7. Monitor marked, bleached corals and controls at regular intervals until the former either recover or die from the effects of this pertubation.

8. Sample bleached and unbleached specimens of at least several species to determine the effects of this stress upon their sexual reproductive activities.

9. Several years from now, core some surviving massive corals (both unbleached and ones which recover from the bleaching) and use established X-radiographic methods to determine any effects of bleaching on annual rates of skeletal growth.

10. Quantitatively document any changes in the ecological structure of affected reef communities with standardized, time-series transect measurements or photography.

11. Experimentally establish thermal limits for reef corals collected from different habitats as a function of illumination, salinity and water motion. The classical tolerance studies of Mayer (1914, 1918) and of Vaughan (1911) were excellent for their time, but limited to corals collected in very shallow water. They are not an appropriate data base to-day. Subsequent studies of western Atlantic reef corals are of limited scope.

If the chronology of the present bleaching suggests that artificially stressed reef corals are particularly sensitive to the effects of the present pertubation(s), these experiments should be expanded to consider the effects of suspended sediment load, increased nutrient supply and diverse industrial and agricultural pollutants. Particular attention should be given to synergistic effects which are perhaps of greatest importance near a reef coral's physiological limits of tolerance for any given physical factor.

Table 1

Bleaching Conditions on the Southern Side of Isla Tesoro, Colombia, at Depths of 0-5 m, on August 15, 1987.

Species	Condition: All Bleached	Partly Bleached	Pale	Fine
Scleractinians:				
Acropora palmata		x	x	
A. cervicornis				x
Agaricia agaricites	x	x		xx
A. tenuifolia	x		x	xxx
Siderastrea siderea		x		xxx
Porites astreoides	x	x		xxx
P. porites	x		xxxx	
Favia fragum	x	x		xx
Diploria labyrinthiformis	x	xx		xxx
D. strigosa		xx		xx
Montastraea annularis		xx	x	xxxx
Meandrina meandrites		x		x
Other Cnidarians:				
Millepora	x	x		xxx
Erythropodium caribaeorum	x	x		xx

Table 2

Bleaching Conditions on the Southern Side of Isla Rosario, Colombia, at Depths of 0-5 m, on August 16, 1987.

Species	Condition: All Bleached	Partly Bleached	Pale	Fine
Scleractinians:				
Acropora palmata		xx		
A. cervicornis				x
Agaricia agaricites		x		x
A. tenuifolia	xxx	xxxxx		
Porites astreoides		xx		xx
P. porites		x		x
Favia fragum		xx		xx
Diploria clivosa		x		x
D. labyrinthiformis		x		x
D. strigosa		x		x
Colpophyllia natans		x		x
Montastraea annularis		xxx	xx	xxxx
Other Cnidarians:				
Millepora		xxx		x
Erythropodium caribaeorum	xx	xx		x
Palythoa		xx		

Table 3

Bleaching Conditions on the Eastern Side of the Islas Pajarales complex, Colombia, at Depths of 0-6m, on August 16, 1987.

Species	Condition: All Bleached	Partly Bleached	Pale	Fine
Scleractinians:				
A. cervicornis		x		xx
Agaricia agaricites	xx			
A. tenuifolia	x	xxxx		xxxx
Porites astreoides		xxx		xx
P. porites	xx	xxxx	xx	x
Favia fragum	xx			
D. labyrinthiformis				x
D. strigosa		x	x	
Montastraea annularis		xx		xxxx
Other Cnidarians:				
Millepora		xx		xx
Erythropodium caribaeorum		x		xx
Stoichactis helianthus			x	
Palythoa		xx		x
Zoanthus				x

Florida Department of Natural Resources

Bureau of Marine Research

STATEMENT OF WALTER C. JAAP, BIOLOGICAL SCIENTIST III, FLORIDA DEPARTMENT OF NATURAL RESOURCES, BUREAU OF MARINE RESEARCH

REASONS FOR MASSIVE CORAL BLEACHING

Senator Weicker. Thank you, go right ahead.

Mr. Jaap. Senator Weicker, I would also like to thank you on behalf of the State of Florida for this opportunity to present this information. I would like to also give credit to Billy Causey, who is the manager of the Looe Key National Marine Sanctuary, and John Halas, the manager of Key Largo National Marine Sanctuary, as much of the things that I will discuss today came about as a result of their observations.

Massive coral bleaching is an unusual event. It is usually triggered by a major change in some physical or chemical factor that stresses the reef. Coral bleaching has been caused by drastic alterations in salinity, temperature, both heat and cold, light and food deprivation, siltation and when extreme low tides expose reef corals above the surface.

The 1983 El Niño Southern oscillation [ENSO] event was a major cause of coral bleaching throughout the tropical Pacific, and others have already mentioned this: major coral mortality occurred with the 1983 ENSO event.

Bleaching in 1987 has already been reported as having occurred from Bermuda, Bahamas, Southeast Florida, the Florida Keys, the Greater Antilles Island groups; Puerto Rico; St. John, U.S. Virgin Islands and St. Croix, U.S. Virgin Islands; Jamaica; the Cayman Islands; Cartagena, Colombia; Cozumel, Mexico; and the Flower Garden Banks, off the coast of Texas.

Reefs in Caribbean Panama, to our knowledge, were not affected. We are not certain about other areas such as the Bay Islands of Honduras, Aruba, Venezuela, Haiti, Cuba and Trinidad.

The bleached animals include anemones, sponges, stony corals, soft corals, fire corals and zooanthids. The bleaching was observed as deep as 180 to 240 feet in some areas. The earliest reports that we have were in June, and the latest occurred in October.

My written testimony does not indicate the actual date that the bleaching started, but it is an indication of the geographic distribution. As early as July 12, the Florida Keys corals began discoloring. The epicenter of that event was Looe Key National Marine Sanctuary.

Billy Causey, the manager at Looe Key, reported that corals in shallow water were first to discolor, and then over time, the discoloring moved deeper and the discoloring intensified. The animals turned bone white. Fire coral and golden sea mat were heavily impacted. Some elkhorn coral actually died, but we don't know if this is coincidental. A disease may have killed it.