Testimony on the

Status of Current Research on Coral Reef Ecosystems and Factors Affecting Them

Presented to the

Subcommittee on the Environment,
Committee on Science, Space, and Technology
and the
Subcommittee on Oceanography, Great Lakes, and the Outer Continental Shelf,
Committee on Merchant Marine and Fisheries

U.S. House of Representatives

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04/23/92
I would like to thank Congressmen Schueer, Lewis, Fascell, Hertel, and Brown for the opportunity to speak today at this Congressional Hearing on a subject of great interest and concern to the citizens of Florida, the United States, and the world: the current status of and research needs for coral reefs. My testimony will focus on the present status of Floridian coral reefs and offer a general list of research priorities.

Many coral reefs in Florida are declining at truly alarming rates. We have been monitoring coral reefs in Florida since 1984. The six monitored areas include two photostations in the Looe Key National Marine Sanctuary, two photostations in the Key Largo National Marine Sanctuary, and two photostations in the Biscayne National Park. Monitoring began in 1984 for photostations in the two National Marine Sanctuaries, and in 1989 in the Biscayne National Park. Each photostation consists of a plot of coral reef 10-15 m² in area, photographed at a high resolution with both black and white and color film. These six stations have in common that they are all inside protected areas.

All six regions lost coral species between the initial survey year and the most recent survey in 1991 (see Figure 1). Survey areas lost between one and four species; these losses constitute between 13% and 29% of their biodiversity. Unfortunately no reef was exempt. These extinctions are not species extinctions, that is these species still exist elsewhere in Florida and the Caribbean, they are local extinctions from the areas examined.

The amount of living coral on the reef is also declining (see Figure 1). Five of six stations showed a reduction in the percent cover of living corals.

One reef lost almost half of its coral between 1984 and 1991 (see Figure 2). Both branching corals (the elkhorn coral, Acropora palmata) and boulder corals (the greater and lesser star corals, Montastrea annularis and M. cavernosa) show declines. Normally these massive corals build the reef. For these common species, our data over the last seven years reveal that there is usually (1) a reduction in the total amount of live coral cover, (2) a reduction in the total number of individuals, and (3) a reduction in the number of the large, reproductively mature colonies in favor of much smaller individuals.

Few areas seem exempt. Coral loss is occurring in shallow water and in deep water. Coral loss is occurring in the Upper Keys and in the Lower Keys. In the one station that apparently grew, the increase in canopy branches of coral was offset by a loss of the understory branches from the same individuals for no net gain of coral.

Our data suggest that coral loss is accelerating. Losses between 1986 and 1991 were more than double the losses between 1984 and 1986. The highest rates of loss exceed 10% per year. Obviously, no reef can withstand this rate of loss for long and remain a coral reef.
Unfortunately, while we see coral dying, we do not see juvenile corals of the massive species recruiting to take their place. We have not seen recruitment of the massive coral species to any of the study sites.

The photographs reveal, in only a rudimentary fashion, the causes for decline on these reefs. Mortality of this magnitude is usually caused by hurricanes. South Florida usually receives hurricane damage every 6-7 years on average. Inexplicably, Florida has been without a direct hit from a major hurricane for the last 28 years.

"Bleaching" is an important source of coral mortality at our study sites. Coral bleaching is caused by abnormally high sea temperatures. High sea temperatures result in the loss of the beneficial symbiotic algae living within coral tissue. These algae normally provide coral with their food and oxygen, and the loss of these algae causes the coral to lose weight and eventually, under conditions of prolonged ocean warming, to starve to death. While recovery from bleaching is sometimes possible, bleached corals do not reproduce during the year they bleach. Bleached corals are also sterile for at least one year after that.

We do not know if the present trend towards higher tropical sea temperatures is caused by global warming. We can say, however, and with a high degree of certainty, that since corals already exist at or near their upper lethal temperature, any further ocean warming caused by global climate change will have an immediate and adverse effect on the survival of coral reefs. It is fully conceivable, but not proven, that we are already seeing this in current coral bleaching events. These events are global in scale, not confined to Florida or the Caribbean. The Workshop on Coral Bleaching, Coral Reef Ecosystems and Global Climate Change sponsored by the National Science Foundation, the Environmental Protection Agency, and the National Oceanic and Atmospheric Administration (1991) concluded that the possible use of coral bleaching as an early warning indicator of global warming "was seen as strong reinforcement of the need for systematic monitoring" of coral reefs.

Coral diseases also contribute to reef decline in the Florida Keys. Whereas no examples of white band or black band disease were present in any of our initial surveys, by 1991 all stations exhibited coral disease. White band is of unknown pathogenic origin; black band appears to be caused by an infection of the blue-green alga, Formidium. Unfortunately, we know little about the epidemiology nor anything about the physical or biological factors that promote infection and confer lethality to these diseases.

Many species of bluegreen algae are pollution indicators, and there is speculation that elevated nutrients from improper waste disposal practices in the Florida Keys may promote the growth of black-band disease. This constitutes a reasonable speculation, and one which is worthy of investigation, but at this time, we do not have proof whether observed increases in the frequency of this disease relate to human activity in the Florida Keys.
There is a developing body of evidence to prove that many nearshore environments, those areas within a 1000 meters of shore, are being seriously impacted by a variety of human activities. Unfortunately, we do not have the same kind of certainty to explain coral degradation on reefs some three to five kilometers offshore. The replacement of coral-dominated areas by algal-dominated areas is suggestive of nutrient loading in these normally low-nutrient reef waters, but we do not have adequate information to prove or disprove this contention. We cannot say with certainty whether these changes are due to mother nature or human nature.

The Workshop on Coral Bleaching, Coral Reef Ecosystems and Global Climate Change (1991) reached a similar conclusion about coral reefs world-wide: "On a global average basis, coral reefs are being lost or degraded at an alarming rate, ...but at present we lack the data needed to confirm, quantify, or explain this trend on a scientific basis." As with our own study described above, this workshop also concluded that "anthropogenic environmental alterations on global, regional, and local levels are reason for serious concern about the health and local survival of coral reef ecosystems." The group therefore strongly recommended "prompt development of a research-oriented coral reef monitoring program of global scale, a coordinated program of research at laboratory, microcosm, and field scales." Furthermore, they recommended "the development and expansion of a scientifically based, internationally coordinated long-range monitoring program oriented toward reef environments and biology." Finally, these experts emphasized in the strongest terms that "such a program would yield immediate important results in terms of major theoretical and applied scientific questions related to spatial variations, in addition to providing the longer-term data base needed for other studies." (see Appendix A for further references)

While the situation I have described is alarming, unfortunately I can neither provide you with proof as to the cause for these disturbing trends, nor offer you a specific management plan to counteract these declines. HR Bill 4537, the "Coral Reef Environmental Research Act" currently pending before Congress, would go a long way to meet the research needs that are so obviously called for by these results. The bill is a clear and forceful proposal to acquire the information needed to institute wise management practices. I personally wish to congratulate the bill's authors, Congressmen Schueier, Lewis, Fascell, Hertel, and Brown, and their respective Subcommittees, for this insightful and much-needed piece of legislation.

I wish to make an unequivocal statement on the absolute need for research in relationship to environmental management and environmental legislation. Principle 15 of the recently signed United Nations Conference on Environment and Development states the following:

In order to protect the environment, the precautionary approach shall be widely applied to states according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.
While this Principle initially sounds laudable, the way the statement is worded, it is not clear if this Principle recommends drastic remedial action before it is known what to do. For instance, in response to the Crown-of-Thorns starfish plague in the Indo-Pacific, divers were sent out to "save the reef" by cutting up the coral-eating starfish. They found out only later that, like the sorcerer's apprentice, each dismembered starfish arm grew into a whole starfish! From uninformed, but good intentions, they had actually multiplied the problem twenty fold, one time for each starfish arm. Good science in the service of management will avoid such disasters; House Bill 4537 will fund this science.

Effective environmental management requires an understanding of the dynamics of the ecosystem. Environmental management is analogous to bank management: not only do you need to know the assets in the bank at any one time, you also need to know the rate of deposits and withdrawals. Likewise, the environmental manager needs to know the condition, or inventory of the "biotic reserve," and also the natural rate of recruitment and loss. Information on change requires long-term monitoring, and I am especially pleased that the Bill highlights the need for this kind of information. As impressive as the studies that I have shown today may seem, we need longer studies, on larger spatial scales, to really understand this amazingly diverse and extraordinarily complex environment.

There is a need, either in future legislation or as an amendment to HR Bill 4537, to include the National Park Service as a full partner in the legislation. The reasons for this are quite simple and quite compelling: National Park Service holdings already include 25% of Florida's coral reefs. These are among the most highly developed coral reef habitats in the Florida Keys (the Biscayne National Park, the Everglades National Park, and the Dry Tortugas National Monument). Our system of National Parks also includes some of the best reef habitat anywhere in the Caribbean (the Virgin Islands National Park and the Buck Island National Monument). NPS has on its staff world-renowned coral reef scientists dedicated full time to the study and management of coral reef ecosystems. They have been doing this for more than a quarter century. The legislation which created NOAA's marine sanctuaries is identical to that which created NPS's: "to protect and preserve these environments in perpetuity for future generations." The National Park Service needs these research funds as much as any other government agency, and although not officially represented here today, is in an excellent position to contribute to the scientific research proposed by this Bill.

There is also a need to be sure that the funds proposed for research are distributed on the basis of competitive grants. Peer review is to science what freedom of speech is to democracy: it is the sine quo non of the process. It is the means by which the taxpayer will get the best results for his tax dollar. The National Park Service, the National Oceanic and Atmospheric Administration, the National Science Foundation, the Environmental Protection Agency, and the U.S. Geological Survey all have such programs, and these programs should be encouraged.

Focusing on corals, studies in the following areas should have priority because results in these categories will produce immediate benefits to both environmental management and
basic science:
1. Continuation and expansion of long term monitoring studies
2. Initiation of recruitment studies
3. Initiation of studies on the impact of visitors on the reef
4. Investigations on the effects of nutrients on the growth and survival of
   a. Corals
   b. Algae
5. Investigations of the distribution and origin of nutrients on the reef tract
6. Investigations on the consequences of current waste water disposal practices in
   the Keys to both:
   a. Nearshore mangrove, seagrass, and patch reef ecosystems
   b. Offshore coral reef ecosystems
7. Analysis of coral disease, including the
   a. Influence of nutrients on black-band disease
   b. Nature and extent of white band disease
8. Improvement of our understanding the physical oceanography of Florida Bay,
   the Florida Keys, and the outer continental margin to understand:
   a. Mechanisms of water transport between the land and the reefs
   b. Origins of water coming into the Florida marine seascape
9. The relationship between coral bleaching and global climate change

In conclusion, and as a general observation, it must be made clear to all here
assembled, that controlling the growth of human populations and reducing the amount
of pollution that humans produce to foul the earth's atmosphere and oceans will do
more to insure the survival and continuance of coral reefs than any other specific
recommendation that we might make.
Appendix A. Previous Workshop Reports


Loss of Coral Species

![Bar chart showing change in number of species (percent) at various sites from 1984-1991.]

Loss of Coral Cover

![Bar chart showing change in projected surface area (percent) at various sites from 1984-1991.]

Note: Changes at sites BP01 and BP02 are for 1989-1991.
1984

1991

Acropora palmata
Montastrea annularis
All other coral species
Mr. Scheuer. Well, Dr. Porter, I want to thank you for your remarkably interesting testimony and also for those gripping pictures that you showed us.

I am going to take advantage of the informality of the way we have structured this hearing by asking you a question out of turn.

You have discussed the damage done to coral reefs and seemingly quite recently from all the phenomenon, the destructive and negative phenomenon that you and others before you have identified. There has been some discussion recently about ecological restoration and mitigation. I think you yourself mentioned efforts to plant trees in the forests.

Over the course of human history, I suppose there has been an ebb and flow. We have lost species, we have gained new species. Maybe change is the life motif. Maybe that is what nature is trying to tell us. Change is eternal. Should we say that change is eternal and that coral reefs have sort of a God given mandate to come and go, to ebb and flow; or should we say we need to preserve these coral reefs and we should engage in restoration efforts because once they have gone they go forever and they play a very valuable part in the marine ecosystems? Do you advocate that we make significant efforts at restoration and remediation of the problems that are degrading coral reefs in Florida and around the world?

Dr. Porter. I strongly recommend that we protect and, if possible, restore these coral reefs. What is not natural about the changes that I have shown you is the absence of juvenile corals of the major reef-building species. I have similar plots in Jamaica and there we did measure recruitment of coral to those areas.

Mr. Scheuer. When you say recruitment of coral—you mean sons and daughters in those homes?

Dr. Porter. Yes, I do.

Mr. Scheuer. How does that happen?

Dr. Porter. Coral reproduction occurs in most species sexually, there is also asexual reproduction, by unioning of eggs and sperm and production of a particular larvae which settles and grows into a coral reef.

Corals which reach 1cm or larger are visible to the camera system we are using. We have not seen corals of that size recruiting to our stations.

Mr. Scheuer. Through your station in Florida?

Dr. Porter. We have not seen them in our stations in Florida, that is correct. This also complements the work that Dr. Jaap described on the settling plates as well. We know we can see juvenile corals using the system that we have because using an identical system in Jamaica we saw recruitment.

Mr. Scheuer. Recruitment means multiplying?

Dr. Porter. Multiplying, yes, a rival of new colonization of coral.

Now, asexual—

Mr. Scheuer. Is recruitment, either sexual or asexually—is it economically viable? In times of strained resources and limitations on what we really can do, is it a cost-effective process to try and stimulate?

Dr. Porter. We don't know enough about the processes of coral recruitment for me to answer that. The studies need to be initiated
to determine the things which will promote coral reef health and preserve the environments we have.

After that, nature must be allowed to take its course.

Mr. NOWAK. Jim?

Mr. SCHEUER. Go ahead, Congressman Nowak.

Mr. NOWAK. On your findings, you had a relatively short period here where you have identified the decline, at least in the Florida situation.

Dr. PORTER. Yes, sir.

Mr. NOWAK. You have identified a decline. Have you identified the cause of any particular decline in any of those areas that you showed with the pictures?

Dr. PORTER. The photographs reveal—

Mr. NOWAK. Global warming didn't cause that in seven years.

Dr. PORTER. Bleaching did, as well as a higher incidence of black-band disease. Black-band disease, coral diseases were completely absent from these stations when they were set up. Every station had diseases at the end.

Why? We do not know that.

Mr. NOWAK. You have no idea what could have caused that black-band or any other diseases that you showed?

Dr. PORTER. A working hypothesis is that elevated nutrients may promote growth of that blue-green algae disease but that is only a hypothesis, and requires research.

Mr. NOWAK. Wouldn't that level of nutrients have had to have come from someplace?

Dr. PORTER. Yes, sir it would.

Mr. NOWAK. It didn't come all over, it came in that particular area.

Dr. PORTER. At this point in time, this is still a speculation and it is worthy of investigation, but it is not something that we can formulate a policy on.

Mr. NOWAK. What I am saying is, if you could identify the source of that nutrient, you are going to identify what caused your problem?

Dr. PORTER. Yes.

Mr. NOWAK. If you don't identify the problem, you can go monitor 400 more stations and find the same thing happening, and you can report back to this committee. We won't be here in 2020, but you could tell us this is happening all over the place.

Dr. PORTER. There are very good research programs which could investigate and determine the answer to that question. They have not yet been funded. I would agree with Dr. Rosendahl that coral reef research funding has been sporadic and totally inadequate.

Mr. NOWAK. My point is simply that unless we take that next step, do that, and try to identify where that nutrient is coming from, whether it is off a land-based farm or whether it is washing in through a sewage treatment plant or whatever, you are never going to stop the destruction from happening. If it is happening that fast, and that is seven years, it is substantial.

Dr. PORTER. Absolutely.

Mr. NOWAK. Isn't that true in the growth, in the length of these coral life cycles?
Dr. Porter. Absolutely. We set stations up to measure corals grow and that is not what we saw.

It is critical to get the information to answer those questions specifically, and as my colleague to my left, Dr. Ogden, will describe, a broad-scale ecosystem program does exist to address issues of where materials are coming from, where they are going to, but those studies are not yet complete.

Mr. Scheuer. That was very interesting, Dr. Porter.

Dr. Porter. Thank you, Mr. Chairman.

Mr. Scheuer. John Ogden, Director of the Florida Institute of Oceanography, St. Petersburg.

Dr. Ogden. Distinguished Members of the House, Members and staff, ladies and gentlemen, I am honored to be here to comment on the current efforts of the Congress to support research related to the long-term protection and sustainable use of coral reef ecosystems. I speak on behalf of the Florida Institute of Oceanography, a consortium of the State university system, including the University of Miami and Department of Natural Resources, as well as the American Institute of Biological Sciences and International Society for Reef Studies.

Why coral reefs? Here in the developed world we place a high value on them, as we have seen so far this morning. Certainly for natural resources and tourism but perhaps we value them more as distant, exotic systems of prolific natural world.

In developing countries, their impact is much more immediate. In a recent speech, the president of Mexico, for example, tied the economic future of his country to the genetic patrimony contained within the immense diversity of its land plants and its coral reefs.

Yet, also, as we have seen, there is a worldwide perception that coral reefs are in decline and the causes are related to the accumulating stresses from steadily increasing coastal human populations.

It is fitting, as we have heard, that these hearings are taking place here, the site of the nicest, newest, and largest marine sanctuary and one among three with significant coral resources. The effort to develop the management plan, which incidentally is attempting to bring together this information that Congressman Fas- cell asked about earlier, will guide the protection of coral reefs in the United States and serve as an example to the world.

I have three brief points to make. First, coral reefs are only one element of a complex mosaic of ecosystems, including forested land margins, coastal mangroves, and seagrass beds that interact in an interdependent tropical seascape. Research is needed that focuses on this seascape as a whole. We cannot manage coral reefs in isolation anywhere in the world.

Coral reefs exist in dynamic equilibrium, and with mangroves and seagrasses, are influenced by contact with land. Sediments and nutrients carried by freshwater runoff are filtered off by forests, mangrove wetlands and finally seagrass beds. The existence of coral reefs is directly dependent on the buffering capacity of these shoreward coastal ecosystems.

Coral reefs, in turn, buffer the influence of the open ocean on the land. In addition to these physical interactions, the systems have numerous biological linkages. Mangroves and seagrasses, for example, are nurseries for coral-dwelling organisms such as lobsters.
My second general point, coral reef ecosystem research and monitoring programs should be international, long-term, and regional in geographic scale in order to discriminate between natural cycles of change upon which human impacts are superimposed.

Your very perceptive questions are already beginning to bring this out. Research should be based at existing institutions, the marine laboratories, and apply the best available technology, which we are not doing yet, in automated environmental monitoring and remote sensing to detect long-term trends.

Subregions of the global ocean, such as the Caribbean Sea seen in the bottom part of my overhead, are interconnected by ocean currents, and have a relatively uniform marine biota living on reefs and associated systems under a variety of environmental conditions.

Research should be aimed at regional comparative studies of a wide variety of coral reef sites within these subregions where their structure differs and magnitude of human impact varies.

In this way, it should be possible to identify general principles of the function of coral reefs, their interaction with other systems, and make predictions about other coastal areas and institute scientifically-based management plans.

The Caribbean Coastal Marine Productivity or CARICOM program was established at a growing network of research sites in the Caribbean, shown on that map as dots, in 13 countries. In spite of cultural differences between the nations of the Caribbean, the research institutions have a common culture based on scientific traditions, which greatly facilitates the development of a complex international program and technology transfer which is critical to its success.

Discussions have taken place all over the world in recent years on the creation of similar marine laboratory-based networks in Micronesia, Southeast Asia, as well as even global networks for the purpose of climate change research. The coordination of regional coral reef monitoring programs will be featured in discussions at the 7th International Coral Reef Symposium in Guam this June and a lot of this information we hope to bring together.

My final point is not biological but economic.

In many parts of the world, the conservation of coral reefs does not require further research but rather economic schemes that serve the needs of nations while linking them in concerted efforts to promote sustainable use of coral reef ecosystems.

Guidelines should be established for the multilateral development bank loans for projects with potential impact on coral reefs. This strategy has aided research on tropical forests and in conservation of tropical forests.

International development projects currently fail to take into account the trade-offs and long-term impacts on the marine environment—which is as devastating to coral reefs as road development is in the Amazon Basin.

Some of the voting country members of the multilateral development banks are presently reviewing their loan policies with respect to the preservation of general biological diversity. For example, the U.S. Treasury Department with a voting share of 20 percent in the
World Bank has produced a memorandum titled "Tropical Forest and Wetland Voting Standards."

Similar guidelines for projects affecting the marine environment, particularly coral reefs, were drafted but never implemented. This should be done and it should serve as an example for other countries who are voting significant shares of the multilateral development banks.

In summary, coral reef research, as has been stated by all of you on the panel and my colleagues more eloquently than I, should be supported because of the need for management and conservation of these fragile systems, but most of all perhaps because they can help us to understand the dynamic functioning of the natural world upon which we as human society depend.

It is fitting that the U.S. should lead this effort, but it is critical that our plans be international in scope and involve research, management and economics.

Thank you very much.

[The prepared statement of Dr. Ogden follows:]