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The Cousteau Society

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There is only one body of water on our Planet Earth, constantly traveling from river to lake to ocean. Water frozen today into glaciers and icebergs, bathes tropical shores tomorrow. Today's tragedy lies in the contrast between the indivisibility of the ocean and the selfish way it is misused by individual countries. When the ocean is at stake, the sacrosanct principles of national sovereignty, regional independence, economic development and political expediency are irrelevant.

In an attempt to harmonize narrow viewpoints with the global character of the ocean, The Cousteau Society has taken the initiative to draft policy recommendations relating ocean protection to national needs. Global principles inspiring national ocean policies are timely and urgently needed because:

• the potential of the sea to provide for human needs is still underestimated,
• the protection of the ocean continues to be neglected,
• social needs and dilemmas grow more serious,
• the Law of the Sea remains to be fully implemented, and
• nations are struggling to meet the goals of environmentally sustainable development.

These words are from recommendations developed in May 1979 for a United States ocean policy. Nearly a quarter of a century later, they are still applicable. One of the specific recommendations, that "the President and the Congress should immediately act to confer meaningful direction and momentum to ocean affairs by enacting legislation providing for a Presidential Commission to review the nation's ocean policy," has finally come to fruition with this Commission on Ocean Policy. It is with the hope that our other recommendations will be heard that we submit this document, a compliation of comments on important issues that relate directly to the responsibilities inherent in the Commission's mandate.

The Cousteau Society
Francine Cousteau, President
January 5, 2001

The sea covers 71 percent of the Earth and constitutes more than 99 percent of the habitat for animals and plants—the largest part of the biosphere. It is home to organisms that protect shorelines, break down waste, moderate climate and generate oxygen. In addition to their planetary roles, marine species provide a livelihood for millions of people, food, medicines, raw materials and recreation for billions.

The goods and services provided by the oceans have been valued at $20.9 trillion, greater than the combined economies of the all the world's nations. They make the Earth habitable for humans as well as all the other terrestrial life. Once lost, these services could never duplicated with modern or future technologies.

Sadly, every line of evidence that has been pursued by science points to the inescapable conclusion that the health of the oceans is declining. The sea's biological diversity and ecological integrity are threatened, witness the collapse of once-bountiful New England cod fisheries, the descent toward extinction of California white abalone, the appearance of a huge "dead zone" off Louisiana, the steady decline of Florida Keys coral reefs, the North Atlantic right whales on the brink of extinction.

The impacts of human activities are most devastating at the land-sea margin where rivers and non-point source flows carry the debris of civilization: pollutants dissolved and suspended in their waters. Agriculture, urbanization and deforestation have reduced the capacity of terrestrial systems to trap and retain materials, resulting in dead zones at the mouth of most great rivers of the industrialized nations. Furthermore, the materials travel throughout the seas on global currents: in 1993, Mississippi floodwaters lowered salinity and oxygen levels in the Florida Keys. Life in the world's estuaries, coastal waters, enclosed seas and oceans is increasingly threatened by overexploitation, physical alterations, pollution, introduced species, disease, and climate change. A watershed approach to coastal land management would reduce the amount of nutrients, sediment and carbon runoff at their sources.

The challenge before the Commission on Ocean Policy is to preserve the ecological health of the seas so that the prosperity of humankind may continue. Long-term solutions must be found that allow major decisions to be taken in full awareness of both their immediate usefulness and their consequences for future generations. Our social structure is predicated on short-term concerns: businesses are pegged to quarterly gains, officials to re-elections, agencies to annual budgets, industries to seasons. The Commission will need to battle against demands for immediate profits from ocean resources in order to ensure that tomorrow's citizens can enjoy the benefits of a functioning marine system.

US ocean policy needs a foundation of knowledge. We have the technological know-how to extract resources efficiently but true understanding of natural processes requires widespread information and deep scientific research. In turn, these dictate renewed emphasis on education of citizens and decision-makers.

Moreover, when scientific evidence is inconclusive, which is the norm, the Commission must dictate a precautionary approach to management. It must require proof that a proposed activity will <u>not</u> cause environmental harm rather than await proof that a proposed activity is damaging.

Although the Commission's mandate is sweeping, we call its attention here to three particular areas that have been widely recognized as crucial to the health of marine systems: coral reefs, marine protected areas and marine mammals. All three have already built up committed constituencies among scientists and environmentalists, and have in place basic structures in the government to advise on their conservation. They need and deserve the highest priority in the Commission's policy formulation.

Coral Reefs: Sentinels of Ocean Health

Coral reefs are the oldest, most complex, and productive ecosystems in the sea. They are equivalent to equatorial rain forests in terms of species diversity and productivity. Coral reefs are an important component of the biosphere and are critical to the economy in many regions of the US. Reef biodiversity also holds incredible potential for advancing medical science and understanding the Earth as a system. Sadly, reefs are deteriorating faster than anyone could have imagined even a short ten years ago. Conservation scientists and resource managers are scrambling to find ways to assess coral reef health, to identify the causes driving reef deterioration, and to ameliorate negative anthropogenic impacts.

Over half of the world's coral reefs are estimated to be under medium to high stress, especially in coastal areas of the Indo-Pacific and Caribbean. The health of coral reefs is linked to direct and indirect impacts from human activities that extract living resources, foul water or alter the climate beyond tolerable ranges. Reef systems are more sensitive to a changing environment than are our finest oceanographic instruments and their condition can be considered an indicator of the health of the oceans. As such, coral reefs are the harbingers of the declining health of the seas.

The reefs of the Florida Keys have lost 38% of their living coral cover since 1996 and over 92% since 1975. Mortality factors include disease, nutrification, and physical destruction. The important shallow water framework-building corals, *Acropora palmata*, (elkhorn coral) and *Montastrea annularis* (star coral), are among the hardest hit species in the Florida Keys and elsewhere in the Caribbean. Their loss severely curtails the biological process of reef construction.

Reefs do not produce large amounts of extractable resources, and are not able to withstand the stress of over-harvesting. The Keys are at the downstream end of the hydrology of South Florida, a system with explosive human population and agricultural growth in the last 50 years. The Gulf Stream, which flows past the Keys, may also be a source of stress as it carries materials from elsewhere in the Caribbean and Gulf of Mexico. Additionally, in 1984, there was a dramatic reduction in grazing pressure due to the mass mortality of the spiny sea urchin, *Diadema antillarum,* which resulted in dramatic increases in macroalgae cover. More recently, African dust has been implicated in the spread of pathogens and nutrient enrichment throughout the Caribbean.

The Coral Reef Task Force, comprised of scientists, administrators and stakeholders, was established in 1998 to address this dire situation. The Task Force squeezed a range of productive activity into two years of dedicated work, culminating in the creation of a National Action Plan to Conserve Coral Reefs.

The Plan adopts a science-based, adaptive management approach that recognizes two important principles: we need to learn more about how these complex ecosystems work and we must act quickly to minimize humanity's impacts on reefs at all scales. It points out that land-based threats can be reduced by strengthening the permitting and management of coastal development and by reducing pollution. It calls for the adoption of a science-based, precautionary, ecosystem approach which will unify the action of all US agencies to understand the ecology of coral reefs and humanity's impact on them.

The Action Plan calls for including the human dimension in reef conservation because, pragmatically, coral reefs cannot be managed, only people can. The Task Force's working group on education encapsulated this truth in its central theme: “People must care about reefs for successful long term reef conservation." This means carefully incorporating local people and traditional community-based practices in formulating management policies. It means well-informed, scientifically literate decision-makers, increased public awareness and compiled information available to all.

Still, the best action plan in the world is useless without appropriate funding to federal agencies, academia and non-governmental organizations. Since the adoption of the Action Plan in early March, 2000, there have been no significant funds allocated by Congress specifically for implementation. The Cousteau Society believes that coral reef conservation is an issue so important that short-sighted politics must be set aside. The Society, with broad public support for coral reefs, urges the Commission on Ocean Policy to press for immediate actions lest the good work of the Task Force be doomed to obscurity.

Recommendations for Reef Conservation

1. Adopt the precautionary approach to managing the human relationship with the sea to account for the uncertainty of knowledge of coral reef ecosystems.
2. Work closely with the US Coral Reef Task Force to formulat policy for the preservation of coral reefs.
3. Seek to engage the independent scientific community for creative input to management decisions.
4. Identify geographic areas where baseline data on the distribution and health of coral reef ecosystems is lacking.
5. Focus attention on preserving the ecological integrity of reef ecosystems and their watersheds, not simply the physical reef structure.
6. Assure that economic policy and trade do not result in further harm to reefs.
7. Continue and strengthen US support for the International Coral Reef Initiative. Support full implementation of the Biodiversity Convention, the Jakarta Mandate on Marine and Coastal Biodiversity, and other international agreements on marine conservation.
8. Urge Congress to create and pass more comprehensive legislation building on the Coral Reef Conservation Act of 2000 to address the root causes of coral reef decline.
9. Establish effective oversight procedures whereby citizens can call for open meetings when and where warranted. Such a process should include provisions for an official response from federal agencies or expert groups such as the Coral Reef Task Force
10. Recognize that coral reefs are indicators of overall oceanic health and changing climate.

Marine Protected Areas: Bastions of Conservation

Submerged lands under US jurisdiction occupy more than 4.4 million square miles, an area much larger than the entire US land area. Moreover, the United States—from Guam and Alaska to California, from Maine and Texas to Puerto Rico—has the highest marine ecosystem diversity of any nation in the world. Yet, the US has no comprehensive system to protect this unequaled national treasure.

When President Clinton issued an Executive Order in 2000, decreeing the development of a formal network of Marine Protected Areas (MPAs), the US lagged well behind countries like New Zealand and Australia in establishing marine reserves. Heretofore, the ocean has basically been another resource to be mined, and marine reserves just a resource-development device. Backed by recent scientific reports confirming the value of reserves, the Executive Order moved MPAs to a new, broader footing, more like that of national parks that preserve a habitat for its own sake.

The future urgently needs a strong defense of MPAs. Fishing industries, for example, use scientific uncertainty to argue against no-take zones. Broadly, they contend that an MPA should not be established until there are absolute rules for defining which sites would benefit which stocks most efficiently. There is also reluctance to accept no-take zones until all other contributory factors in the decline of marine life are excluded, to include sand or gravel mining, oil or gas exploration, ocean dumping, dredge-spoils disposal, introduced species, other fisheries, climate change and air or water pollution. Fishing industries put their faith in the ultimate resilience of Nature without allowing Nature the opportunity to rebound.

But MPAs must be for more than fish stocks. They are essential for protecting and restoring ecological integrity, and ensuring that use of marine life is ecologically sustainable. They protect natural and cultural marine resources from beaches to shipwrecks to biodiversity and representative ecosystems. This integrated habitat approach of MPAs relies not on proof that a problem exists but on proof that an activity causes no harm.

Modeling studies indicate that the quality of an MPA, not its size, matters more. None of the standard measures of success—biomass (amount of fish and shellfish), density (number of creatures), average size (maturity) and diversity (number of species)—improve with increasing the size of one given area, but they do improve with increasing the number and total area. Multiple assorted reserves (following a metapopulation approach) also offer added insurance against natural or human catastrophes (disease, oil spill) or simply changing circumstances (currents shifting, temperatures rising). To maximize the quality of protected habitat and minimize the no-take area, the challenge is to establish such facts as how hard a stock can be fished, how do its larvae disperse, what kind of food and shelter are necessary. Risk assessment must also include a thorough analysis of the consequences of loss.

A model of Chesapeake Bay blue crabs found that females and their offspring need more than a safe spawning area; they also need migration corridors and seagrass nurseries along the path of currents. Such findings underline the importance of setting aside a diversity of habitats—marine, estuarine, benthic, rocky, grassy, etc. In the absence of perfect knowledge, an MPA network must include all kinds of habitats, especially the rare ones.

Once an MPA is decided, it must be enforced, evaluated, adjusted and defended. Well-designed and managed marine protected areas provide a variety of benefits, including some that complement other marine management tools and some that are unique to MPAs. They maintain functioning natural ecosystems and processes. They protect biodiversity, endangered or rare species, important habitats (including spawning and nursery areas) and marine wilderness. MPAs reduce overexploitation by providing refuge from fishing pressure and thereby enhance fisheries in surrounding areas; this sets up an "insurance policy" against uncertainty and errors in fishery management as well as natural calamities.

Recommendations for Marine Protected Areas

1. Continue evaluation of all marine regions of the US as to MPA candidacy.
2. Work closely with regional councils, scientists and local stakeholders in participatory planning of protected areas.
3. Use science-based selection and design of sites, including size, shape, management, and evaluation processes.
4. Optimize the biological, economic and social value domestically and contribute meaningfully to a global system of MPAs.
5. Represent all major ecosystem types in each biogeographic region, based on the best available information.
6. Support unique ecosystems or natural features, including areas that are important to rare or endangered species or ecological processes, life-support systems, and life history stages, including areas of upwelling, spawning or nursery areas, feeding and breeding areas, resting areas and migratory stopover areas.
7. Have special cultural or historical values
8. Educate stakeholders, resource-managers and the general public about the long-term economic benefits that will help offset short-term costs of MPAs.
9. Provide protection to adjacent terrestrial areas.
10. Replicate habitat and species protections and encompass a wide range of places and conditions as a hedge against predicted climate change and catastrophic events.

Marine Mammals: Major, Mysterious Factors

Although marine mammals are among the most studied, most charismatic and most protected of the ocean's denizens, their role in the global ocean ecosystem remains poorly understood and their status precarious. The Marine Mammal Protection Act, the Endangered Species Act and adherence to the moratorium on commercial whaling have provided a patchwork of protective measures that has proved insufficient.

Recent status reports that indicate failures in current policy include the faltering recovery of West Indian manatees in Florida, the catastrophic decline in Steller sea lion populations in Alaska, the relentless depression of monk seal numbers in Hawaii, the unheard-of predation on otters by orcas in the Aleutian Islands, the fall toward extinction of the North Atlantic right whale, the unaccountable swings in "recovered" gray whales. On a political level, threats include the growth industry of breeding dolphins for display and export, weak opposition to the resumption of whaling at the International Whaling Commission, scape-goating marine mammals for fisheries declines, attempts to slacken standards for dolphin-safe tuna labels, financial support for widening US aboriginal whaling and pressure to reduce protection for the sake of military expediency or oil exploration in the name of national security.

Marine mammals, like humans, sit atop the food chain, where they are exposed to the accumulated pollutants and pressures of "progress." Like us, they spend much time in coastal regions where they must contend with traffic, industry, contaminated water and climate change. Unlike us, they have no control over the levels or location of disturbances. The Commission on Ocean Policy must work to consolidate and strengthen measures to protect marine mammals.

As much as humans have learned about this large group of animals, every year brings new surprises about their behavior and ecology. We remain ignorant of their role in the global ocean ecosystem even while recognizing instinctively that creatures so huge and so numerous must provide a key function. Whales travel hemispheric migratory paths from pole to equator, transporting enormous amounts of carbon. They eat primarily non-commercial marine life but in such quantities that they must directly affect the prey-predator balance. We caught a glimpse of this complexity with the decimation of sea otters in California's kelp forests. The loss of otters resulted in an exponential over-growth of sea urchins, which led to the deforestation of kelp beds, which entailed the decline of species like rockfishes and sculpins. The losses reversed when the otters were sufficiently protected to rebound. The lesson: we must not allow harm to top-level marine life, particularly when we do not know the outcome of our negligence and greed.

Recommendations for Marine Mammals

1. In the face of deep ignorance about marine mammals, exercise a precautionary approach to management.
2. Strengthen support for independent research and, in particular, the stranding network of responders.
3. Expand designation of critical habitat.
4. Bolster international opposition to the resumption of commercial whaling through the International Whaling Commission.

5. Resist permitting the use of deadly Low Frequency Active Sonar and other destructive acoustic technologies.
6. Deny short-term industrial invasion of protected areas that threatens the long-term health of marine mammals, e.g. arctic oil exploration.
7. Expand public education to counter recreational abuses such as dolphin-feeding.
8. Abandon extreme fishery-directed measures such as otter-free zones and sea lion removals as failures.
9. Highlight the importance of the Marine Mammal Commission in formulating policy.
10. Encourage research into the ecological dynamics of marine mammals and marine ecosystems.

CALYPSO
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Ecological Decline of Coral Reefs in the Florida Keys, 1974-2000

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"Evolution produces a very few new species every million years. If we are to assume that nature can cope with our feverish developments, it is probable that mankind would be submitted to the fate of the dinosaurs. Destruction is quick and easy. Construction is slow and difficult."

J.Y. Cousteau, 1973.

Introduction

The Florida Keys are positioned at the northern extent of the tropical Western Atlantic and are home to the only living coral reefs in the continental United States. Temperature appears to be the principal controlling variable with the suggestion that farther north, polar cold fronts lowered the water temperature below the threshold necessary for reef development (Mayer (1916). The Keys are separated from the mainland by shallow bays: Biscayne Bay, Barnes Sound, Blackwater Sound and Florida Bay. A lagoon, populated with seagrass beds, parch reefs, and banks of carbonate sand,. separates the outer reefs from the islands (Shinn et. al.,1989, Jaap, 1984, Jaap and Hallock,1990. The islands of the Dry Tortugas are more isolated, lying approximately 65 miles to the west of Key West.

The reefs are most abundant in the upper and lower regions of the island chain which are separated by the large tidal passes that connect Florida Bay with the Atlantic Ocean. Outwelling cold water from Florida Bay appears to limit the distribution of reefs within the Keys (Gingsburg and Shinn 1964). This Florida Bay Hypothesis has been expanded to suggest that both the physical and chemical characteristics of Florida Bay strongly influence the health and vitality of reef-building corals in the Keys (cf. LaPointe, 1999 and Porter et. al., 1999.).

Coral Vitality Time Series: Long-term study of Carysfort Reef

Coral populations in the Florida Keys have declined precipitously since 1974 when quantitative monitoring began (Dustan 1977a, Dustan, 1985, Dustan and Halas, 1987, Dustan 1999, Porter and Meier, 1992, Porter et. al. 2001). Between 1974 and1982 living coral cover and diversity on Carysfort Reef increased in the shallow areas of the reef while there was significant decline on the deeper fore-reef terrace. Change in shallow water seemed driven by the physical destruction of the dominant stands of *Acropora palmata*, elkhorn coral. Cover increased because the lush, three-dimensional habitat had been reduced to planar rubble by groundings and storms. Smaller colonizing species were settling on open substrate. On deeper portions of the reef, colonies were dying from disease and sediment damage, but were not being replaced by recruitment (Dustan and Halas, 1987).

Observations on the phenotypic condition of over 9800 corals on 19 different reefs in the Key Largo region in 1984 revealed that sixty percent of the corals showed signs of physical or biological stress, 5-10 percent were infected with disease (Black Band and White Plague) and about one third appeared healthy. Surprisingly, virtually all the reefs had approximately the same level of unhealthy corals. This argued for widespread stress factor such as water quality rather than stressors that are localized to specific reefs. (Dustan, 1993). High rates of mortality were documented by other researchers in the Florida Keys between 1984 and 1991 (Porter and Meier, 1992) .

Carysfort Reef continued to decline and by June 1996, coral cover in the shallows had decreased to approximately 10%, and 14% in the deeper habitat zones. During a dive on Carysfort Reef in July 1998, virtually every colony of *Montastrea annularis* species complex was infected with the White Plague. Large colonies (in excess of 1 meter in diameter) were rapidly being overtaken by White Plague. Since the skeletal growth rate of *M. annularis* has been measured at 5 to 10 mm/year, these colonies were over 100 years old. In 2000, coral cover on the reef had dropped below 5% and corals have ceased providing any significant contribution to reef framework construction (Table 1).

Reef zone	1974-5	1982-3	1996	2000	Change
Shallow	42%	53%	10.6%	4.1%	-90%
Deep	62%	50%	13.5%	4.7%	-92%

Table 1. Change in percent cover of living coral on Carysfort Reef between 1974 and 2000.
Data from Dustan and Halas, 1987, Porter et. al, 2001)

Carysfort Reef has entered a state of ecological collapse. Similar ecological degradation has occurred on many reefs throughout the Florida Keys; the USEPA Coral Reef Monitoring Project measured a Keys-wide loss of 38% between 1996 and 2000 (Porter et. al. 2001a). Carysfort Reef, however, is the only reef where monitoring was been documented with quantitative monitoring dating to the mid 1970's (Dustan and Halas, 1987, Porter and Meier, 1992).

Quantitative long-term monitoring in the Dry Tortugas at the "other end" of the Keys, revealed that coral cover on Bird Key had decreased an estimated 20-25% between 1975 and 2000. It would appear that corals in the Dry Tortugas are not stressed to the same degree as in the "mainland" Florida Keys. These reefs are buffered from Key West by 65 miles of ocean which may help to explain why these reefs are somewhat healthier than the Keys reefs.
In 1990, the Florida Keys National Marine Sanctuary Act established the Florida Keys National Marine Sanctuary. The U.S. Environmental Protection Agency (USEPA) instituted a water quality assurance and protection plan for the Florida Keys which initiated the Coral Reef Monitoring Project. From 1996 to 2000, there was a significant increase in the geographical distribution of coral diseases and a significant increase in the number of species with diseases (Table 1 and 2, Porter et al, 2001, Richardson, 1998). Coral bleaching also became more common throughout the Keys. Similar trends in diseases are appearing in other marine organisms, most notably in the Florida Keys where gorgonians, soft corals, have been infected with a pathogen identified as *Aspergillus sydowii*, an opportunistic terrestrial soil fungus (Smith et. al. 1996).

Number of Stations with Disease					
				Diseased	**Percent**
	WH	**BB**	**OD**	**Stations**	**Diseased**
1996	7	7	16	26	16%
1997	61	11	66	95	59%
1998	97	28	92	131	82%
Increase n (96-98)	90	21	76	105	
Increase % (96-98)	1285%	300%	475%	404%	

Table 1. Distribution of coral diseases by station 1996-1998 . Data from USEPA Coral Reef Monitoring Project (Porter et.al., 2001b)

Number of Coral Species with Disease					
				Diseased	**Percent**
	WH	**BB**	**OD**	**Species**	**Diseased**
1996	3	2	8	11	27%
1997	22	4	22	28	68%
1998	28	7	28	35	85%
Increase n (96-98)	25	5	20	24	
Increase % (96-98)	833%	250%	188%	218%	

Disease Types: WH = white plague **BB** = black band disease **OD** = other diseases

Table 2. Distribution of coral diseases by species 1996-1998 . Data from USEPA Coral Reef Monitoring Project (Porter et.al., 2001b)

STRESSES:

The stress to Florida Keys coral reefs resides within a series of nested scales and it is extremely difficult to partition the individual contribution of each stressor. Growing at the northern limits of reef development implies high levels of naturally occurring stress. And, since many corals live a long time, reef populations are now exposed to amplifications of naturally occurring stress, as well as stresses that are new within their lives. The impact of stress accumulates and is probably synergistic. In the Florida Keys, disease is a significant source of colony mortality. Already stressed corals may have weakened immune systems that makes them even more susceptible to disease. Coral recruitment and regeneration rates are low.

Urbanization:

Urbanization in the Florida Keys has been intense with most of the development has centered around Key Largo, in the Northern Keys, Marathon in the Middle Keys, and Key West in the South. The human population of the Florida Keys grew tenfold from 1870 1990, with about 30% of the residents living in Key West. Tourism doubles the population during peak times with two thirds of the visitors participating in water related activities. There are over 24,000 boats registered in Monroe County and approximately fourteen percent of the visitors (roughly 365,000 people) bring with them when they visit the Keys.

Hydroscape Manipulation

Human manipulation of South Florida surface hydrology began shortly after Florida became a state in 1855. Large-scale drainage and flood control programs drained of thousands of acres of swampland for agriculture and constructed hundreds of miles of canals to control the surface flow of water from Lake Okeechobee southward to Biscayne Bay. The massive efforts to channel the water flow have resulted in the flow of excess freshwater, nutrients, and sediments into the coastal waters, including Florida Bay (cf. Davis and Ogden, 1994). The addition of fertilizers, organic carbon, and urban and commercial dumping further enrich the watershed's effluent as it flows into the sea. Although concentrations may be diluted, these agents may still affect reef health. Coral reef ecosystems have evolved to be very efficient in trapping and retaining nutrients even in concentrations that, though technically might be beyond the level of detection, may still be ecologically significant.

Upstream of the Keys, the effluent of cities, towns, and farms slowly bleeds into the sea through canals, rivers, and coastal bays. While the distribution of point sources, such as sewage outfalls, deep injection well package plants or agricultural irrigation canals, are controlled through permitting processes, their effluents are not easily traceable once they enter the tropical shallow water ecosystems. For example, in Key Largo, the effluent from Class 5 shallow-well injection package plants migrates through the Key Largo limestone at rates of 3 to 30 meters per day, depending on tides, weather condition, etc. Since this is the preferred method for waste disposal by developments and hotels it presents a known significant pollution threat for the near shore coastal environment (Reich et. al.1999.).

Physical damage:

Boat groundings and anchor damage have been widespread and severe throughout the Florida Keys (Dustan, 1977a, Davis, 1977). The installation of hundreds of mooring buoys throughout the Keys has greatly reduced anchor damage on reefs and may one day serve as a means to regulating access to reef areas. Boat grounding can cause catastrophic damage to shallow reefs and in 1999, there were 540 small boat grounding documented in the Florida Keys National Marine Sanctuary. There have been 5 major ship groundings on reefs since 1985, (ie. Hudson and Diaz, 1988).

Regional and Global Stresses

The Keys are downstream from almost every source of sediment or nutrient in the Caribbean basin and Gulf of Mexico. Materials wash into the sea from the west and east coasts of the Florida peninsula and through the Everglades. The area of sediment influx extends to the watershed of the Mississippi River and continues throughout the Caribbean Sea. Sediments from as distant as the Orinoco and Amazon Rivers have been identified on Carysfort Reef (Dustan, unpublished). In 1993, the floodwaters from the U.S. Midwest combined with the Loop Current, which flows into the Florida Current, and reduced salinity and oxygen concentrations along the reefs of the Keys. On September 14, the SeaKeys Station, off Key Largo, recorded a decrease in salinity, from 36 to below 32ppt., and oxygen, from 7.1 to 5.2 on Molasses Reef (Porter, per comm.). This signal was unusually large due to the magnitude of the floods but clearly demonstrated the connectivity between interior watersheds of North America and the Florida Keys.

Coral populations of the Florida Keys, like reefs everywhere, are also subject to global scale stresses such as global warming and increased ultraviolet due to ozone thinning. Coral bleaching has been correlated to increased water temperatures in the late summer and early fall. Particularly serious mass bleachings occurred in the last 20 years. Most of these events were recorded in many areas of the wider Caribbean and thus have been linked to warming seas. However, recent work points to another, previously unsuspected ecological stressor which parallel the impact of global warming, transatlantic African dustfall (Shinn et. al., 2000). Their most recent work has uncovered a soil fungus, *Aspergillus sydowii,* that causes the Caribbean-wide disease that occurs in sea fans. Isolated African dust collected in the Caribbean contains species of Aspergillus and there is an apparent correlation between increased amounts of dust and various disease outbreaks. The atmospheric distribution of African dust is a potential cause of other synchronous Caribbean-wide coral diseases, including those that have killed the staghorn coral *Acropora cervicornis* and the sea urchin *Diadema.* The near extinction of these organisms in 1983 correlates with the period of highest annual dust transport to the Caribbean since measurements began in 1965. In addition to Aspergillus spores, African dust is composed of the major crustal elements including iron, phosphorus, sulfate, aluminum, and silica, which may enhance the growth of tropical marine algae.

The reefs of the Florida Keys are facing an accumulation of nested stresses which range from local fishing and diving to regional (cities, agriculture, and industry); and global (ozone thinning, and warming). The over-addition of nutrients, organic carbon, and sediments from substandard sewage disposal land use practices in the Keys and upstream in South Florida also contributes to reef decline as does coastal hypoxia near river mouths and deltas.

Localized Ecological Reef Stress

Starting in 1982, there was a mass mortality of Diademia antiullarun throughout the Caribbean Sea. Populations of *Diadema antillarum* have still not recovered from this event to anywhere near their pre-mortality days (Lessios 1988). Urchins are still rare on Keys reefs, 16 years later. Following the mass mortality, macro algal populations throughout the Caribbean soared as they were released from herbivory. Thus while nutrient levels were apparently rising due to increased urbanization, human population growth, levels of herbivory on the reef plummeted. At present, these two scenarios cannot be uncoupled and there remains a hot debate on which stressor is ecologically important (see Lapointe 1999 and Hughes et al, 1999).

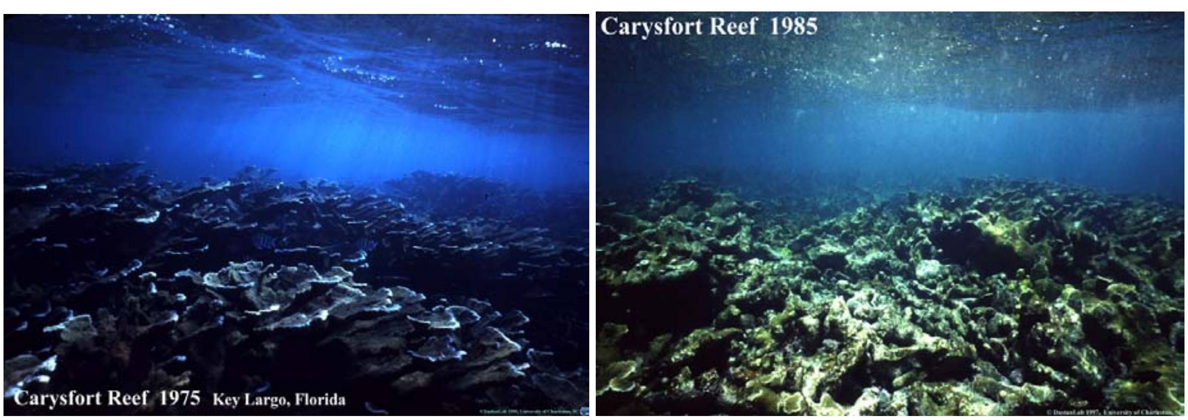

Figure 1, Carysfort Reef, Key Largo, FL. Between 1975 and 2000 Carysfort Reef lost over 90% of its living coral cover.. The shallow water *A. palmata* zone can be seen underwater in Plate B, a pair of photographs taken from the same vantage point ten years apart.

Increased sedimentation smothers coral tissue, increased nutrients and a dramatic reduction in herbivory has resulted in algal overgrowth and elevated temperatures promote bleaching. Reefs near population centers have the increased pressures from sewage, runoff, garbage dumping, and greatly increased levels of harvesting. Coral diseases, first discovered in the Keys in the 1970's, have increased over 400% since 1996 throughout the Keys. Global change has elevated ocean temperatures and increased ultraviolet light flux that are believed to increase the frequency and severity of coral bleaching.

Protective measures:

The Florida Keys were placed under state and federal protection beginning with the creation of the Dry Tortugas National Monument in 1935 by President Franklin Roosevelt. The first underwater park, John Pennekamp Coral Reef State Park was established in 1960. Biscayne National Park was established in 1968. The Marine Protection, Research and Sanctuaries Act set forth the guidelines for establishing the Key Largo National Marine Sanctuary in 1975. The protected area was expanded in 1981 with the formation of Looe Key National Marine Sanctuary. The Florida Keys National Marine Sanctuary and Protection Act 1990 brought the entire Florida Keys under federal protection. In 1992 the Dry Tortugas National Monument was redesignated as Dry Tortugas National Park in 1992 to protect both the historical and natural features. Sanctuary designation for a larger portion of the Dry Tortugas banks and surrounding occurred with the Tortugas 2000.

Presently, the FKNMS utilizes the concept of multi-use zoning to generate varying levels of resource protection. Mooring buoys to protect reefs from anchor damage have been installed throughout the Keys and sanctuary officers patrol the waters. In an effort to reduce large vessel groundings, a series of radar beacons have been placed on outer reef lighthouse to help warn commercial shipping traffic of the reefs. Appropriate treatment of sewage and issues surrounding non-point pollution have not been adequately addressed.

Florida Keys Coral Reef Ecosystem: Timeline

1935	Dry Tortugas National Monument by President Roosevelt
1960	John Pennekamp Coral Reef State Park established December 10, 1960
1968	Biscayne National Park established
1969	Skin Diver Magazine sounds alarm on reef degradation (Barada, 1975)
1972	Marine Protection, Research and Sanctuaries Act
1973	Coral Diseases discovered in Key Largo (Antonius, 1974
1974	Beginning of long term reef monitoring at Carysfort Reef
1975	Key Largo National Marine Sanctuary established
1981	Looe Key National Marine Sanctuary established
1983	Significant reduction of corals at Carysfort Reef since 1974
1984	Key Largo Coral Vitality Study 60% corals stressed (Dustan, 1993)
1987	Severe coral bleaching throughout Caribbean
1991	Florida Keys National Marine Sanctuary and Protection Act 1990
1992	Reef coral degradation estimated at 5% loss per year (Porter and Meier, 1992)
1995	USEPA Water Quality Protection Plan Coral Reef Monitoring project,
1997	Outbreak of White Band Disease 2. pathogen identified (Richardson, 1998)
1998	President Clinton issued Executive Order 13089 on Coral Reef Protection
	First US Coral Reef Task Force Meeting at Biscayne National Park
1999	Carysfort Reef coral coverage below 5%
2000	Proposed Tortugas 2000 National Marine Sanctuary
2001	USEPA Coral Monitoring reports 38% loss of living coral 1996-2000

Forcasting:

Signs of degradation have been expressed in the popular literature since 1969 and clearly expressed in the scientific literature since 1977 (Dustan, 1977, Dustan and Halas, 1987, LaPointe , Porter and Meier 1992, Porter et al. 2001. But because there are multiple stressors and they are nested, managers have been at loose ends and reluctant to apply conservation measures beyond fisheries regulations, enforcement, and permitting. To this day, the Florida Keys does not have an tertiary sewage treatment, and much of the region is without sewage treatment beyond septic tanks which leak into the water. The Water Quality Assurrance Program is an attempt to collect long term ecosystem data on the water quality, seagrass beds, and coral reefs which will be used to drive ecosystem management. Since its inception in 1995, the reefs have lost at least 38% of their living coral cover and little has been done to ameliorate the situation. The US Coral Reef Task Force, originated by Presidential Order 13089, has produced an Action Plan for Coral Reef Conservation, but the plan has not been implemented.

The reefs of the Florida Keys will take hundreds of years to regrow, once their environment has been restored. Reefs have evolved to be highly conservation symbioses and detailed trophic interactions because they evolved in energy-rich, nutrient-poor waters. These very same adaptations have made reefs vulnerable to anthropogenicic degradation, particularly temperature, sedimentation, increased nutrient concentrations, and over-harvesting. Ironically, the many values of coral reefs -- as a fisheries resource, for coastal protection and building materials, and as tourist attractions -- now are contributing to now are contributing to their steady and rapid decline in the Florida Keys. As clear as observational science has demonstrated this, we still lack specific knowledge concerning the identification of the specific factors and the magnitude of their relative contributions. Future research needs to be targeted at nested scale process studies.. But at the same time, we cannot delay the application of conservation methods that do work. Measures such as marine protected no-take zones, tertiary sewage, and aspects of watershed conservation can and should be implemented immediately, or it will be said that the coral reefs of the Florida Keys disappeared on our watch, while we were watching.

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