PETITION TO LIST ACROPORA PALMATA (ELKHORN CORAL), ACROPORA CERVICORNIS (STAGHORN CORAL), AND ACROPORA PROLIFERA (FUSED-STAGHORN CORAL) AS ENDANGERED SPECIES UNDER THE ENDANGERED SPECIES ACT

***A. palmata* (foreground left) & *A. cervicornis* (background) at Andros Island, Bahamas [Sean Nash]**

CENTER FOR BIOLOGICAL DIVERSITY

Petitioner
March 3, 2004

NOTICE OF PETITION

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Petitioner Center for Biological Diversity ("CBD") formally requests that the National Oceanic and Atmospheric Administration Fisheries Office (NOAA Fisheries) list *Acropora palmata* (Elkhorn Coral), *Acropora cervicornis* (Staghorn Coral), and *Acropora prolifera* (Fused-Staghorn Coral) as endangered species under the federal Endangered Species Act.[1] In the alternative, petitioner formally requests that NOAA Fisheries list *Acropora palmata*, *Acropora cervicornis*, and *Acropora prolifera* as threatened species under the ESA. In either case, CBD requests that critical habitat be designated concurrent with the listing designation.

Existing measures already in place for protecting these species are both insufficient and ineffective in curbing the dramatic and disturbing losses documented herein. This petition discusses the factors contributing to the decline of these species. It also reviews the taxonomy, biology, and natural history of these coral species, as well as the factors NOAA Fisheries must consider in making a listing determination and designating critical habitat.

This petition is filed under § 553(e) of the Administrative Procedure Act,[2] § 1533(b)(3) of the ESA, and 50 C.F.R. § 424.14(b). Because *Acropora* is classified in the order Scleractinia, NOAA Fisheries has jurisdiction over this petition.[3] This petition sets in motion a specific administrative process as defined by § 1533(b)(3) and 50 C.F.R. § 424.14(b), placing mandatory response requirements on NOAA Fisheries.

The Center for Biological Diversity is a non-profit environmental organization dedicated to protecting endangered species and wild places through science, policy, education, and environmental law. CBD submits this petition on its own behalf and on behalf of its members and staff, with an interest in protecting these coral species and their habitat.

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[1] 16 U.S.C. §§1531-1544 [hereinafter ESA].

[2] 5 U.S.C. §§551-559 [hereinafter APA].

[3] Memorandum of Understanding between the USFWS & NMFS Regarding Jurisdictional Responsibilities and Listing Procedures under the ESA (1974).

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EXECUTIVE SUMMARY

This petition seeks to list *Acropora palmata* (Elkhorn Coral), *Acropora cervicornis* (Staghorn Coral), and *Acropora prolifera* (Fused-Staghorn Coral) as threatened or endangered under the Endangered Species Act (ESA). For most of the past 500,000 years, *A. palmata* and *A. cervicornis* were the dominant reef building coral species throughout Florida and the Caribbean (Jackson 1994), but since the late 1970s, 80-98% declines of these species throughout significant portions of their range have reduced coral cover and opened space on most reefs at a scale never before documented (Ginsburg 1994, Hughes 1994, McClanahan & Muthiga 1998). The ongoing pervasive mortality of these species appears to be a unique event that contrasts with long-term persistence through the Pleistocene and Holocene mass extinction periods (Greenstein et al. 1998, Aronson et al. 1998).

The *Acropora* genus is the most abundant and species rich group of corals in the world, but only *A. palmata*, *A. cervicornis*, and *A. prolifera* exist in the Caribbean region. Research on the *Acropora* genus shows that their high sensitivity to environmental stresses makes them well suited as biological indicators of the health of coral reef ecosystems and of the global environment (e.g. Glynn et al. 1992, Salvat 1992, Peters 1993, Johnstone & Kahn 1995). The dramatic losses to the Caribbean *Acropora* spp. over the past three decades are of particular concern because these species provide most of the three dimensional structure critical to the reef ecosystem, and are the only Caribbean corals with accretion rates fast enough to keep up with rising sea levels. The essential structural and ecological role of these species is irreplaceable. Their loss threatens the entire reef ecosystem and the immeasurable number of humans and marine organisms that depend upon functioning reefs.

The unprecedented decline of the Caribbean *Acropora* spp. is due to the combined effects of disease, thermally induced bleaching, physical destruction from storms, predation, competition, and anthropogenic activities that degrade habitat and water quality. Global warming is a particularly insidious threat as increasing sea surface temperatures cause a higher incidence of disease, induce repeated severe bleaching episodes, and elevate the frequency and severity of storms.

The National Oceanic and Atmospheric Administration Fisheries Office (NOAA Fisheries) first designated *A. palmata* and *A. cervicornis* as candidate species under the ESA in 1991, but removed them from the list in 1997 due to insufficient information on their biological status and threats to the species. In 1999 sufficient information was available to re-list *A. palmata* and *A. cervicornis* as candidate species of immediate concern. In April 2002, NOAA Fisheries and many of the leading experts on the Caribbean *Acropora* spp. convened a workshop in Miami to discuss the application of the ESA to the genus. The major conclusion of the NOAA Fisheries workshop was that populations of these coral species have undergone an unprecedented decline throughout their historic range, including both an 80-98% reduction in the number of individuals and a severe contraction in the species' area of distribution (Bruckner et al. 2002). NOAA

Fisheries also determined that *A. palmata* and *A. cervicornis* “warrant further listing under the Endangered Species Act” and that “Acroporids are likely to qualify for listing as threatened or endangered" (Bruckner et al. 2002). This petition requires NOAA Fisheries to act upon this conclusion within a mandated timeframe. It also provides NOAA Fisheries with new information about the Caribbean-wide status of these species, the need to address global climate change as a threat and management criterion, the insufficiency of existing regulatory mechanisms, and the wide-ranging ecological, economic, and medical importance of these species.

Pursuant to the ESA, NOAA Fisheries is required to designate critical habitat for these coral species concurrent with their listing. Critical habitat is the foundation of the ESA’s recovery system. Listing a species as endangered affords the species protections necessary for its continued survival. Recovery, on the other hand, which is defined by the ESA as conditions where de-listing would not cause further jeopardy to the species, is the purview of critical habitat. A recent report found that species that have critical habitat protection are approximately twice as likely to have improving population trends than species without critical habitat (Taylor et al. 2003). Concerning these species of coral, protection for critical habitat as a recovery mechanism is particularly important because, although current statutes prohibiting take already exist in US waters, no appreciable recovery is occurring. These species fill a critical role that cannot be filled by other species and their impending demise “will result in a major loss of reef function and structure,” (Bruckner et al. 2002). Moreover, critical habitat designations would have immediate benefits extending far beyond the reefs themselves, e.g. improved water quality throughout the coastal zone, limits on over-fishing, protections for spawning grounds, reduced impacts from development or dredging, and general benefit to innumerable species in addition to the *Acropora* spp. The ocean and land habitats that critically impact the health of these corals must be protected immediately while additional research is conducted and strategies for regeneration are developed.

Congress and the Supreme Court have obliged NOAA Fisheries to put species survival and recovery at the utmost level of importance. The ESA mandates that all Federal agencies “insure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered species or threatened species *or* result in the destruction or adverse modification of critical habitat.” [4] Furthermore, the Supreme Court has noted that, “It is clear from the Act's legislative history that Congress intended to halt and reverse the trend toward species extinction - whatever the cost.”[5] Both the Supreme Court and Congress have “spoken in the plainest words, making it clear that endangered species are to be accorded the highest priorities.”[6]

Like all species, the Caribbean *Acropora* corals are worth saving “whatever the cost,” because of their incalculable intrinsic value. Their value is apparent in terms of their ecological importance to other species, untapped medical research value, coastal protection, and very significant direct economic importance to local and regional

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[4] 16 U.S.C. §1536 [emphasis added].

[5] TVA v. Hill, 437 U.S. 153, 154 (1978).

[6] *Id*. at 194.

economies. One study in Florida evaluated the value of coral reefs to the economy of four southeastern counties, determining that reef related economic value to the counties was $7.8 billion. Worldwide, economists estimate the direct yearly economic value of coral reefs to be $375 billion.

The Caribbean *Acropora* spp. must be protected. Their value to the world is incalculable, as is the fallout price their potential eradication poses to the world. Considered under every possible light, these species are in severe peril and would benefit from critical habitat designation and listing under the ESA.

NATURAL HISTORY

Description

Acropora palmata (Elkhorn Coral)

Acropora palmata is a fast growing large branching coral (Figure 1) up to four meters in diameter and two meters in height, with thick, sturdy, antler like branches. Branches of living colonies are light brown to yellow-gold with whitish tips. For at least the last 3,000 years, this species was the dominant species on shallow, exposed reefs throughout the Caribbean and in the Florida reef tract[7]; forming dense monospecific stands (Adey & Burke 1976, Woodley 1992, Bruckner et al. 2002). This species was formerly so dominant in shallow, high-wave energy reef-crest habitats in the Caribbean that, when first describing the composition and zonation patterns of Caribbean reefs, Goreau (1959) named a significant portion of the reef ecosystem the "palmata zone." Historic success for this species stems mainly from its fast rate of growth, rapid wound healing by injured adults, high rate of survival by fragments, and ability of broken branches to continue growing (Gladfelter et al. 1978, Bak & Criens 1981, Highsmith 1982).

Figure 1: *Acropora palmata* individual colony [Sean Nash]

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[7] The Florida reef track lies mostly within the Florida Keys National Marine Sanctuary, arching southwest from south of Miami to the Dry Tortugas (Causey et. al. 2002).

Acropora cervicornis (Staghorn Coral)

Acropora cervicornis is a branching coral (Figure 2) with cylindrical branches ranging from a few centimeters to over two meters in length and height (Aronson & Precht 1997). Colonies are yellow-brown in color and have distinct protruding tubular corallites. The tip of each branch has an enlarged apical polyp, which is often pale in color and is the actively growing portion of the colony. The species often forms dense thickets (Figure 9) in fore reef and back reef habitats throughout its range. In these thickets, usually only the upper portions of the branches support living polyps; the bases of the colonies are often encrusted with algae and invertebrates and provide important habitat for innumerable fish and other species (Tunnicliffe 1981).

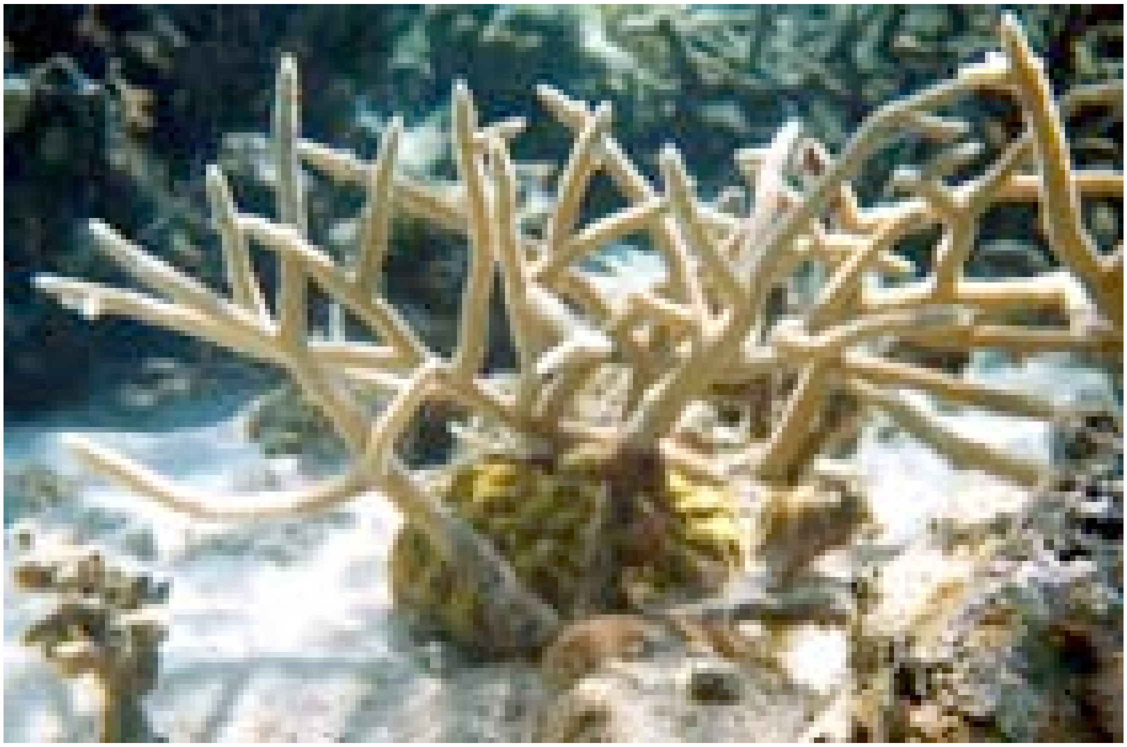

Figure 2: *Acropora cervicornis* individual colony [Sean Nash]

Acropora prolifera (Fused-Staghorn Coral)

Acropora prolifera colonies grow to about 0.5 meters and tend to be scattered. Color is usually light brown. *A. prolifera* is a hybrid of *A. palmata* and *A. cervicornis* with morphological variation in *A. prolifera* being dependent on which species provides the egg (Vollmer & Palumbi 2002). In Puerto Rico, for example, there are two discrete *A. prolifera* morphs – a thin, highly branched "bushy" morph (Figure 3), and a thicker "palmate" form with flattened branches (Figure 4). *A. prolifera* closely resembles in appearance both *A. cervicornis* and *A. palmata*.

Figure 3: ***Acropora prolifera*** **"bushy" morph [Vollmer & Polumbi]**

Figure 4: ***Acropora prolifera*** **"palmate" morph [Vollmer & Polumbi]**

Taxonomy

Kingdom Animalia
Phylum Cnidaria
Class Anthozoa (Ehrenberg 1834)
Subclass Zoantharia (deBlainville 1830)
Order Scleractinia (Bourne 1900)
Suborder Astrocoeniina (Vaughan & Wells 1943)
Family Acroporidae (Verrill 1902)
Genus *Acropora* (Oken 1815)
Species *Acropora palmata* (Lamark 1816)
Acropora cervicornis (Lamark 1816)
Acropora prolifera (Lamark 1816)

Figure 5: Taxonomy of the Caribbean *Acropora* spp.

A. palmata and *A. cervicornis* are closely related species with fossil records dating back at least 3 to 3.6 million years, and both have distinct morphologies and habitat preferences (Budd et al. 1994, Budd & Johnson 1997). *A. prolifera*, now considered a hybrid, occurs Caribbean-wide, where it varies from being locally rare to occurring in large patches. It is morphologically intermediate between *A. cervicornis* and *A. palmata* (Wallace 2000, Goreau 1959, Cairns 1982).

Coral species are notoriously difficulty to differentiate (Figure 6). The *Acropora* genus is a particularly good example of this difficulty; Vernon recognizes 165 species of *Acropora* in “Corals of the World” (2000), while Wallace only recognizes 113 species in “Staghorn Corals of the World” (1999). Recently, several researchers analyzed the DNA sequence variation of the three sympatric species of Caribbean *Acropora*. Based on those analyses, the study concluded *A. cervicornis* and *A. palmata* are distinct species, and *A. prolifera* is actually a hybrid between *A. palmata* and *A. cervicornis* (Van Oppen et al. 2000, Vollmer & Palumbi 2002). Vollmer and Palumbi further concluded that first generation hybrids of *A. palmata* and *A. cervicornis* show morphologies that depend on which species provides the egg for hybridization. The hybrid is capable of producing viable gametes and can potentially backcross with either parent, though this is rare (Volmer & Palumbi 2002, Miller & Van Oppen 2003). Vollmer and Palumbi argue that the evolutionary potential of *A. prolifera* is limited, but Miller and Van Oppen (2003) disagree, believing the phylogeny of this species remains unresolved and that the hybrid does have evolutionary potential on an ecological time scale.

Figure 6: Q: Which species is which...? A: Clockwise from top: *A. prolifera* (bushy morph), *A. cervicornis*, *A. prolifera* (palmate morph), *A. palmata*. Center: *A. prolifera* (bushy morph) [Sean Nash]

Historic Distribution

Based on status information from 60-75% of all reefs where these species occur, the historic range of these species remains the same, but localized range reductions and extirpations have occurred. Throughout their range, most populations of these species have experienced 80-98% losses of individuals (Bruckner et al. 2002).

Acropora palmata

A. palmata historically dominated the shallow fore reef zones of southern Florida and the Bahamas, the east coast of Central America, the northeast coast of South America, and reefs throughout the Caribbean. More isolated populations, but equally expansive, occurred in the southern portion of the Gulf of Mexico, near Veracruz, Mexico where the northern limit in 1992 was the Tuxpan Reef System, approx 29 ^{o} N latitude (Jordan-Dahlgreen 1992). The southern limit is Venezuela (Los Roques) and the northeastern tip of Tobago. *A. palmata* coral does not occur in Bermuda, the northern Gulf of Mexico, or the east coast of South America (Guyana, Surinam, or Brazil).

In the United States and its protectorates, *A. palmata* occurs throughout the Florida reef tract, off Puerto Rico, and offshore islands, and on fringing reefs around the U.S. Virgin Islands and Navassa Island. This species is absent from the Flower Garden Banks, Florida Middle Grounds, and the east coast of Florida north of Biscayne National Park (Triumph Reef 25 ^{o} 29’N).

Acropora cervicornis

A. cervicornis is found throughout the Florida Keys, the Bahamas, the Caribbean islands, the east coast of Central America, and the northeast coast of South America. It also occurs in the western Gulf of Mexico, but is absent from Bermuda and the east coast of South America (Guyana, Surinam, and Brazil).

In the U.S. this species occurs throughout the Florida Keys reef tract, the Dry Tortugas, Biscayne National Park, and southeast Florida reefs, extending north to Boca Raton. It also occurs in the U.S. Virgin Islands, Puerto Rico, and the associated islands of Mona, Desecheo, Culebra and Vieques. It is absent from the Flower Garden Banks and the Florida Middle Grounds.

Acropora prolifera

A. prolifera coral is found off the coast of Caribbean Islands, the Bahamas, Southern Florida, the east coast of Central America, and the northeast coast of South America. It occurs on the west coast of the Gulf of Mexico in the Veracruz reef system. It is absent from the east coast of South America (Guyana, Surinam, and Brazil), Bermuda, the west coast of Florida, and the Flower Gardens in the Gulf of Mexico.

In the United States, *A. prolifera* has been reported at Fowey Rocks, Biscayne National Park, and the Florida Keys National Marine Sanctuary from Craysfort to Molasses Reef, and from Looe Key to the Dry Tortugas. In Florida, it generally occurs as scattered or isolated colonies (Antonius 1994). It has also been reported in Puerto Rico and the U.S. Virgin Islands.

Habitat

Acropora palmata

A. palmata thrives primarily between low water level and 5-6 meters depth, in wave exposed and high surge reef zones, sometimes called the “palmata zone” (Goreau 1959). Isolated colonies can be found to depths of 18 m, primarily in areas with low rates of sedimentation and high current. *A. palmata* is sensitive to the environment, requiring clear waters with low sedimentation, high salinity, and water temperatures in the range of 25-29^{o} C (Jaap et al. 1988). It fairs poorly in areas with high sedimentation and is not found in locations with considerable runoff, river discharge, or land erosion (Lewis 1984). Populations will disappear from coral reefs exposed to sudden changes in temperature, salinity, or water quality (Davis 1982, Dustan & Halas 1987).

Acropora cervicornis

A. cervicornis occurs in back reef and fore reef environments from 0-30 m depth (Baker et al. 1997). Wave forces define the upper limit of *A. cervicornis* populations with suspended sediments and light availability controlling the lower limit (Dodge et al. 1974, Tunnicliffe 1981). Throughout its range, fore reef zones at intermediate depths (5-25 m) were typically dominated by extensive monotypic stands of *A. cervicornis* until the mid 1980s (Aronson et al 1998). Colonies are often most abundant in areas of intermediate to high water turbulence (Tunnicliffe 1981).

Acorpora prolifera

A. prolifera is found in clear water lagoon areas of offshore reefs with sub-tidal depths of up to 30 m. It also occurs with *A. palmata* and *A. cervicornis* when the water conditions are stable and clear, forming large aggregates in the back reef (Colin 1978, Bythell et al. 1989).

Species Importance

Over the past few generations, humans have accelerated the rate of species extinction in what amounts to an evolutionary instant. Congress enacted the Endangered Species Act in recognition of this phenomenon and as an acknowledgment that species preservation is inherently important. Under the ESA all species are treated with equality, and the value of any one species is considered incalculable. While these *Acropora* spp. cannot be judged to be "more important" than other species, the following is a brief summary of the critically significant role they play to the health of the world.

Ecological Importance

At a workshop held in 2002, NOAA scientist Andrew Bruckner, best states the overall ecological importance of the *Acropora* spp.:

> "The structural and ecological roles of Acroporid corals in the Caribbean are unique and cannot be filled by other coral species. Their rapid accretion rates and structural complexity are unmatched. The loss of these characteristics will likely result in a significant loss of reef function and structure. At present, there is no indication that any other Caribbean coral species can replace the important role that Acroporid corals play within reef communities of the region."

James and MacIntyre (1985) compared the accretion rates in the fossil record of several groups of corals over 1000 years; *A. palmata* and *A. cervicornis* had rates of 10.8 and 12 meters/10^3 years, respectively; *Millepora* corals accumulated at a rate of only 1.2 meters/10^3 years; mound or massive corals, such as *Montastrea annularis*, had accretion rates of 6.5 meters/10^3 years. Gladfelter (1982) found similar rates. These rates demonstrate that the *Acropora* spp. are the only corals in the Caribbean with the ability to keep up with projected sea level change (Figure 7) (Bruckner et al. 2002).[8]

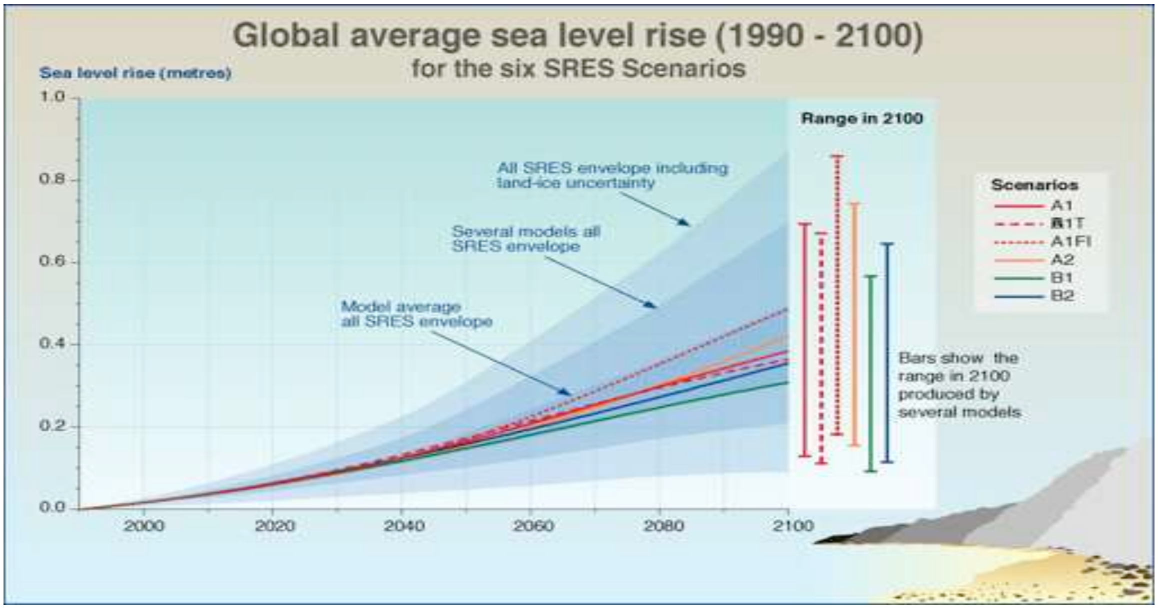

Figure 7: Six projections of expected sea level rise from the Intergovernmental Panel on Climate Change [IPCC]. The IPCC is a global organization established by the UN Environment Programme and the World Meteorological Organization to study climate change and its impacts.

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[8] Sea level change is a symptom of global climate change. See the threats section for more information on climate change and its effects on the *Acropora* spp.

Acropora palmata

A. palmata is a major reef building species and the dominant coral on the shallow fore reef in the “palmata zone.” Few other species coexist in this environment, due to extreme fluctuation of environmental conditions. Dense thickets (Figure 8) of *A. palmata* reduce incoming wave energy, offering critical protection to coastlines. Loss of this species may result in increased coastal erosion and may negatively affect shorelines with mangrove and grass bed habitats, which rely on calm water provided by these effective coral barriers. *A. palmata* colonies contribute to the reef framework and have some of the greatest measured reef growth rates (Goureau 1959, James & MacIntyre 1985). *A. palmata* reefs have grown upward close to 15 m/10^3 years, keeping pace with rising sea level. This species produces boulder ramparts and coral cays in exposed locations in the Caribbean that are composed primarily of *A. palmata* skeletons (Williams et al 1999). High structural complexity produced by the interwoven branches of *A. palmata* colonies provide essential fish habitat, and *A. palmata* thickets often contain a higher diversity of fish species than other reefs in comparable areas (Gladfelter & Gladfelter 1978).

Figure 8: *A. palmata* thicket [Sean Nash]

Acropora cervicornis

A. cervicornis is also historically one of the most important reef building corals on western Atlantic and Caribbean reefs, often dominating fore reef and lagoonal Pleistocene and Holocene sedimentary deposits (Jackson 1992, Stemann & Johnson 1992, Greenstein et al. 1998). High population density, rapid growth rates, and high partial mortality resulting in the accumulation of large amounts of *A. cervicornis* skeletal material make *A. cervicornis* a vital component of Caribbean reef structure both when living and when dead (Gilmore & Hall 1976). Thriving thickets (Figure 9) provide critical vertical structure, including essential habitat for invertebrates and many species of reef fish. Upon death, A. *cervicornis* stands will generally collapse quickly either due to bioerosion caused by disease, e.g. white-band disease, or by breakage from hurricanes (Aronson & Precht 2001a). The dead skeletal material may remain in place, compacting to form an important component of the reef framework. It may be transported and deposited at the base of the reef, or it may be broken down into smaller fragments to contribute to clastic material that fills spaces in the rigid framework of the reef (Tunnicliffe 1983). This process facilitates the rapid accretion rates associated with *A. cervicornis*, the most rapid of which was 12 m/10^3 years on a Holocene reef at Alacran Reef, Mexico (MacIntyre et al. 1977). While dead skeletal material is vital to building the reef base, without sufficient healthy living corals, formerly dense thickets of *A. cervicornis* become flat parking lot landscapes dominated by late-successional fleshy brown algae of low net productivity or invertebrates such as sea urchins, starfish, and coral-eating snails (McClanahan et al. 2002).

Figure 9: *A. cervicornis* thicket [Sean Nash]

Acropora prolifera

A. prolifera is not a major reef building species at a Caribbean-wide scale. However, this species does form dense thickets and provides the framework for large sections of reef on a more localized scale.

Economic Importance

The economic value derived from coral reefs is enormous. Depending on the methodology used, economic valuation estimates for coral reef ecosystems range from several billion dollars a year to priceless. In the Caribbean, the *Acropora* spp. are essential to the sustained health of the reefs and thus the sustained economic value stimulated by coral reefs. Direct economic benefits from coral reefs are distributed through a wide range of industries, but primarily tourism and fishing. Worldwide, Costanza et al. (1997) estimate that reefs may contribute goods and services to the tune of $375 billion each year. One study estimated that in four Southeast Florida counties alone, the economic value associated with coral reefs was $7.8 billion (Johns et al. 2001).

However, these types of economic valuations tend to overlook additional significance of coral reefs at a local level. For the poor, coral reefs are often the last resort for survival when all other resources have been degraded (Wilkinson et al. 2002). Two-thirds of all countries with reef areas are developing countries, one quarter of which are least developed countries (Wittingham et al. 2003). In these instances, as other resources are exhausted, the more traditional economic value of coral reefs gives way to sustenance value that is vital to the survival of the poor. Unfortunately, as healthy reefs degrade they lose the ability to support an abundance and diversity of species, and their sustenance value steadily decreases, further placing the poor in jeopardy. Moreover, as the reefs are relied on more heavily for sustenance purposes, threats such as over-fishing and over-harvest are amplified.

Statistics that demonstrate the economic importance of coral reefs abound. For example, the Caribbean gives 60% of the world’s scuba-diving tours and 20 million people access its coastal areas every year (Wittingham et al. 2003). Tourism accounts for 25% of the region's foreign exchange earnings and provides one-fifth of all jobs (Zahedi et al. 1999). While whole books have been written on the importance of coral reefs to the world economy, for the purpose of this petition, suffice it to say that, if these species of *Acropora* corals disappear, there will be ramifications that reverberate throughout the world in substantial economic and human terms.

Medical Importance

Coral reefs have two common nicknames: “canaries of the sea” and “rainforests of the sea”. The first is a reference to the importance of coral reefs as an indicator of ocean health. Coal miners carried canaries to warn of unhealthy conditions. Similarly, when reefs are dying we know overall ocean health is poor. The second nickname refers in part to the famous medicinal properties hidden in the plants and animals of the rainforest ecosystem. Coral ecosystems, which are richer in marine biodiversity than any other ecosystem in the world, are the same in many respects. The medicinal resources stockpiled in coral reefs have only begun to be explored, but already to great success. The most famous of these is AZT, the anti-AIDS drug that is based on chemicals from a Caribbean reef sponge. It is now estimated that over half of all new cancer drug research focuses on marine organisms. *A. palmata* itself may have important medical properties. Fragments of other coral species have already been successfully used for facial and skull bone reconstruction, and initial analysis of *A. palmata's* mechanical and physicochemical properties suggest it could be used as an alternative xenograft for such bone reconstruction (Alvarez et al. 2002).

Behavior

Reproduction

A. palmata, *A. cervicornis*, and *A. prolifera* reproduce by both asexual and sexual means. Asexual reproduction is the most common and important mode of propagation (Aronson & Precht 2001b). These coral species exist in areas of high wave and current action, and storms frequently dislodge colonies and break branches. This process, known as fragmentation, is a crucial part of the life cycle and allows for widespread asexual reproduction. Under normal conditions without other adverse stresses, broken branches will rapidly reattach to the reef (Figure 10) and grow into a new colony, allowing populations to recover from storm damage and establish in new areas. Ecological models performed on A. *palmata* suggest that when storms occur at fifteen-year intervals, a slow increase in the abundance of colonies can take place after ten consecutive storms. When storms occur every five years, the abundance of colonies can increase five-fold after ten storms. However, when storm frequency accelerates to every two years, a steady decline in the abundance of colonies can occur (Lirman 2003).

Figure 10: New *A. cervicornis* recruits at Andros Island, Bahamas [Sean Nash]

Figure 11: *A. cervicornis* spawning in Florida [National Coral Reef Institute]

With respect to sexual reproduction, these species are hermaphroditic, with both male and female gonads developing within the same polyp, but on specific and separate mesentries. Simultaneous release of gametes is followed by external fertilization in the ocean, and is only seen in the genus *Acropora*. All three species are mass, broadcast spawners (Figure 11), releasing millions of eggs and sperm into the water for external fertilization. Egg and sperm bundles are buoyant and float to the surface, remaining viable for up to eight hours after release. Spawning occurs 4-5 days after the full moon in late August or early September. The larvae, also called planula, live in the plankton for several days until finding a suitable area to grow. Although colonies have a high investment in gamete production, few planula survive and sexual recruits are rare (Knowlton et al. 1990, Hughes et al. 1992, Dustan 1977, Bak and Engel 1979, Rylaarsdam 1983, Wallace 2000).

Growth

Acropora palmata

A. plamata is fast growing, increasing in linear dimensions by 5-10 cm every year, depending on geographical location, temperature, horizontal position on the reef, depth, and environmental conditions. The greatest rate of growth (Figure 12) occurs on the shallow fore reef during summer and early fall with reduced growth during cold water periods and in back reef environments (Gladfelter et al. 1978). In sheltered areas, and on reefs where storms disturbances are low, this species occurs in isolated colonies, primarily due to reduced likelihood of fragmentation, and low recruitment success of sexually produced larvae (Dustan 1977, Rylaarsdam 1983, Rosesmyth 1984). Under normal conditions, the high survivorship of fragmented branches after major disturbances allows *A. palmata* to spread rapidly into neighboring areas not previously occupied (Lirman & Fong 1997). However, fragmentation can also cause declines in the success of the species when severe fragmentation occurs more frequently than about every five years, when fragments settle on sand or algal encrusted substrate instead of existing coral, or when fragmentation results in a loss of colony biomass capable of reproducing sexually (Bruckner et al. 2002, Lirman 2003).

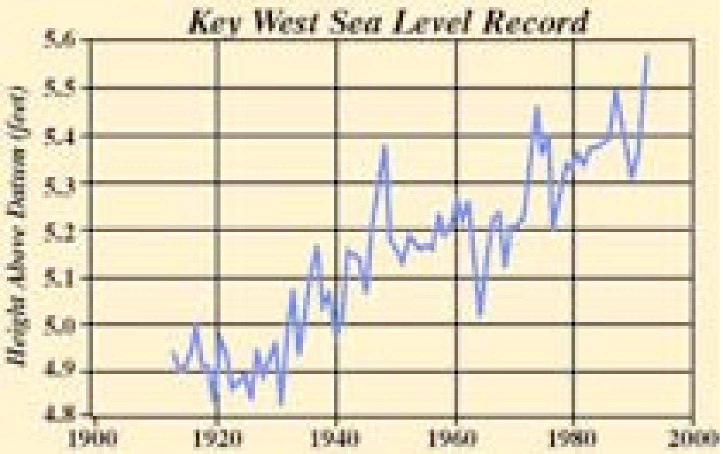

Figure 13: The high growth rate of *Acropora* corals is critical. As global warming raises sea levels, *Acropora* spp. are the only reef building Caribbean corals capable of growing fast enough to keep up. Above, data from Key West demonstrates sea level change during the 20th century [USGS]

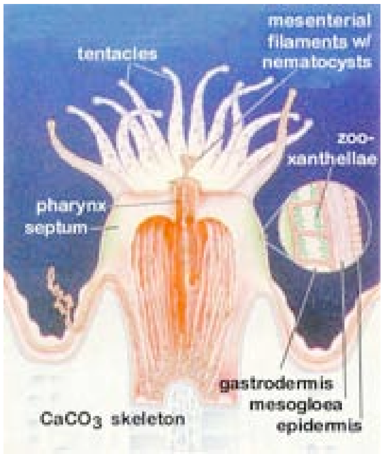

Figure 12: Diagram of an individual coral [Madl & Yip]

Acropora cervicornis

A. cervicornis has an average annual growth rate for individual branches ranging from 3-15 cm, depending on geographical location and local environmental conditions. Under optimal conditions, growth rates of 11 cm per year are reported in Florida (Shinn 1966), 7.1 cm in the U.S. Virgin Islands (Gladfelter et al. 1978), and 12 cm in Jamaica, with a maximum annual growth for individual branches over 20 cm (Tunnicliffe 1983). In St. Croix, Gladfelter (1984) did not observe any major changes in growth rates throughout the year, while in Florida Shinn (1966) reports a 30-60% decline in rates of linear extension occurring during months in which water temperatures did not exceed 26° C. Rodgers (1990) also reports a reduction in growth rates associated with turbidity and sedimentation.

Acropora prolifera

A. prolifera colonies grow to about 0.5 meters and tend to be scattered. Growth is related to water temperatures, with mean growth of 8.2 cm/year at 29.5 ° C, and 5.9 cm/year at 26° C in St. Croix, USVI (Gladfelter et al. 1978).

Feeding

A. palmata, *A. cervicornis*, and *A. prolifera* are carnivores specialized for feeding on plankton. The coral polyps (Figure 13, Figure 14, & Figure 15) are short hollow tubes with the base sitting on or in its limestone skeleton and a mouth surrounded by tentacles. The tentacles are armed with small stinging cells called nematocysts, which fire out barbed darts to paralyze and capture plankton drifting by in the currents.

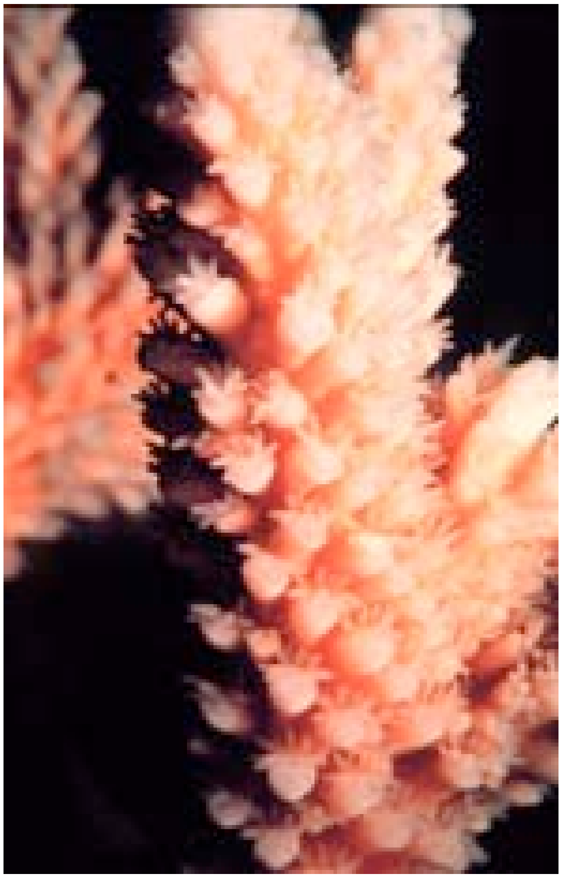

Figure 15: Extended polyps on an *A. cervicornis* branch [William Harrigan]

Figure 14: *A. palmata* polyps [Hays Cummins]

STATUS AND CHANGE IN DISTRIBUTION

Overall Losses

Coral reefs of the Caribbean region have changed markedly since the late 1970s. Over the last thirty-five years widespread *Acropora* coral mortality has reduced coral cover and opened space on most reefs at a scale without precedent (Ginsburg 1994, Hughes 1994, McClanahan & Muthiga 1998). The Caribbean-wide demise of these corals as a result of anthropogenic and natural disturbances is a unique event that contrasts with the long-term persistence of these species during the Pleistocene and Holocene mass-extinction periods (Greenstein et al. 1998, Aronson et al. 1998). Of over 100 studies performed on the status of *Acropora* corals throughout the Caribbean, virtually all document rapid declines with no significant recovery. In Florida, Jamaica, Belize, Curacao, and the US Virgin Islands greater than 80% loss (and up to 98%) has occurred (Bruckner et al. 2002). In particular, *A. cervicornis* may be experiencing an Allee effect (Knowlton 1992). The ecological significance of animal aggregations and the positive relationship between population density and the reproduction and survival of individuals is known as the "Allee effect" (Allee 1931). *A. cervicornis* is now rare and colonies may be too far apart to ensure fertilization success, preventing reduced populations from reestablishing through sexual propagation (Knowlton 1992). This species has been completely lost from many reefs and in some severe cases from entire island chains where it once dominated, thereby also prohibiting asexual reproduction via fragmentation. The very low number of surviving individuals may be insufficient to ensure re-colonization of areas that have experienced localized extinction.

The decline of Caribbean coral reefs throughout the 1980s and 1990s was primarily due to coral diseases such as white-band disease (WBD)[9], mass coral bleaching induced by rising sea surface temperatures resulting from global warming, and hurricanes that are now occurring with escalating frequency and severity. The reefs are additionally threatened by coastal development, boat and diver damage, siltation, damaging fishing practices, predation, competition, and a host of other stresses. These stresses are mounting an assault on *Acropora* corals that cannot possibly be resolved without intervention to curb the unprecedented pressures. Since the late 1990s there has been some extremely limited recovery, but not to former levels of cover, diversity, and health. Long-term recovery after this mass die-off will depend on the ability of corals to recruit, adapt, and persist in the face of increasing impending threats, and the degree to which the repeated patterns of disturbance events are alleviated.

According to a working group of coral scientists convened by NOAA Fisheries in April, 2002:

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[9] White-band disease (WBD) has been the most significant cause of mortality to *A. cervicornis*, *A. palmata*, and *A. prolifera* throughout the western Atlantic, Gulf of Mexico, and Caribbean (Gladfelter 1991). Their populations declined as much as 95% in the 1980s and early 1990s from direct mortality by WBD (Aronson and Precht 2001b). White-band disease is a type of necrosis (tissue death), which can cause extensive local mortality of coral (Gladfelter 1982).

> "An estimated 60-75% of the entire Acroporid population has been examined and enough information is available to make a determination whether these species are threatened or endangered. *A. palmata* and *A. cervicornis* have experienced an unprecedented decline throughout their historic range since the 1980s, including both a significant reduction (loss of 80-98%) in the number of individuals and an extreme reduction in area of distribution," (Bruckner et al. 2002).

The following summary of the status of *Acropora* corals listed by country illustrates the universal decline of these species throughout their ranges. Whenever possible, specific information is provided on the individual *Acropora* spp.

United States and its Territories

Florida

Florida's coral reefs are extensive. Coral reef habitat is almost continuous along the Florida reef tract (Figure 16), paralleling the Keys for 220 miles from Fowey Rocks near Miami and terminating west of the Dry Tortugas. *A. palmata* and *A. cervicornis* were primarily responsible for building most, if not all, of Florida's reefs over the past millennia. The current and predicted loss of *Acropora* corals will potentially cause Florida's entire coral reef ecosystem to disappear (Bruckner et al. 2002).

Specific data documenting losses comes primarily from research performed in the last twenty-five years, although some historic distribution accounts exist that detail the once extensive nature of healthy *Acropora* coral colonies. 96% cover of *Acropora* corals was observed in places in the Florida reef tract in 1981. This was reduced to 3% of total cover due to disease by 1986, a 93% overall loss of *Acropora* cover (Wells & Hanna 1992). Similar declines have been reported from other researchers throughout the region over the last two decades and declines continue today (Miller et al. 2002b). Although some limited recovery of *A. cervicornis* is documented in a few locations, these populations exist at the extreme margins of the species range and are highly susceptible to natural disturbances and changes in water temperature. In short, no significant recovery of *A. palmata* has been observed throughout the entire Florida reef tract (Miller et al. 2002b).

The following are individual studies performed in specific areas: Biscayne National Park, Florida Keys, and the Dry Tortugas.

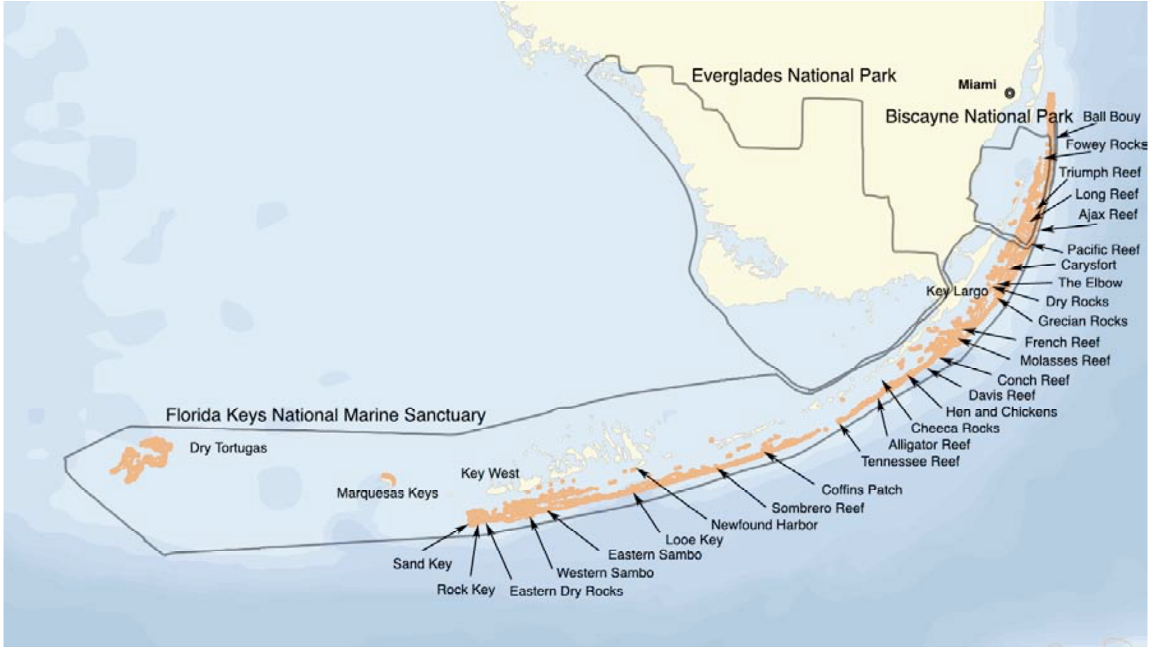

Figure 16: The Florida Reef Tract with coral reefs in orange [ReefBase]

Biscayne National Park

Overall losses of *A. palmata* are at 90% due to WBD and other factors since the late 1970s (Lirman 1998). *A. cervicornis* was completely wiped out from Triumph, Long, Ajax, and Pacific reefs before the establishment of Biscayne National Park in 1980, and outbreaks of disease have reduced *A. palmata* colonies on several reefs throughout the park (Antonius 1994). Complete extirpation of *A. palmata* occurred at Elkhorn Reef in 1998. Some limited recovery of *A. palmata* has been observed on Ball Buoy and Triumph Reef, while very limited recovery of *A. cervicornis* has occurred. The fate of these new recruits is extremely uncertain with a high likelihood of mass mortality.

Florida Keys

Once dominated by the *Acropora* spp., reefs throughout the Florida Keys have suffered some of the worst declines ever recorded (Figure 17 & Figure 18) despite both state and federal protective status for virtually the entire area. Upper Key losses to *A. palmata* began during the 1980s when 50-80% losses were attributed primarily to white-band disease. During the same period, a 96% decline of *A. cervicornis* populations took place on Molasses Reef, Key Largo National Marine Sanctuary (Jaap et al. 1988). Analysis of coral losses at Looe Key reef reveal a decline of 93% for *A. palmata* and 98% for *A. cervicornis* over the 17 year interval from 1983 to 2000. *Acropora* coral populations had already undergone a substantial decline prior to the initial census in 1983 (Miller et al. 2002a). Total cover of *A. palmata* on Carysfort Reef was reduced from 60% in 1984 to 10% by 1998 (Causey et al. 1998). Some of this loss was due to boat groundings, which resulted in reducing colonies to rubble (Dustan & Halas 1987). Major bleaching events in 1997 and Hurricane Georges (Figure 19) in 1998 destroyed 90% of the remaining populations from some lower key locations (Figure 20) (Causey et al. 1998). Overall declines continue for the *Acropora* and other coral species. The Coral Reef Monitoring project reports that the most striking changes in the years 1996-2000 was the continued decline in coral cover for *A. palmata* and *A. cervicornis*. At shallow stations, the mean percent cover of *A. palmata* dropped from 3.01% (1996) to 0.35% (2000). FKNMS-wide, percent cover of *A. cervicornis* dropped from 0.20% (1996) to a barely detectable 0.006% (2000).

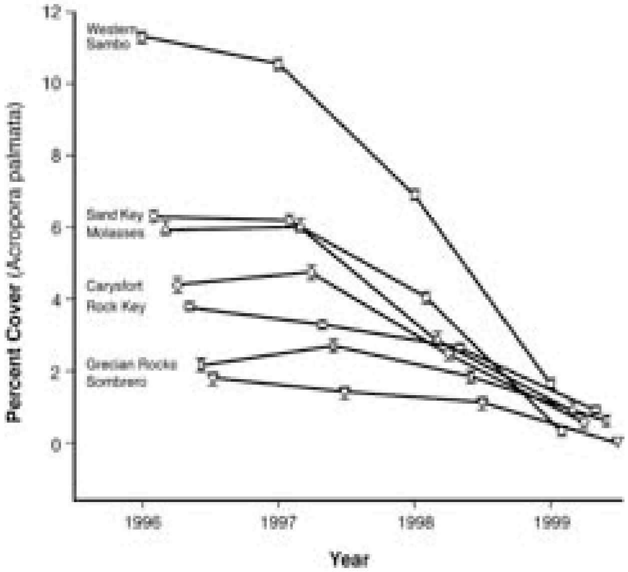

Figure 17: Percent cover of *A. palmata* at seven reef sites in the FKNMS 1996–1999. By 1999, percent cover of this species had decreased at each of the sites: Carysfort Reef (diamond), 85%; Grecian Rocks Reef (rectangle), 71%; Molasses Reef (upward triangle), 84%; Rock Key Reef (oval), 77%; Sand Key Reef (circle), 95%; Sombrero Reef (downward triangle), 100%; Western Sambo Reef (square), 84%. Data are presented as mean ± SD. [Patterson et al. 2002]

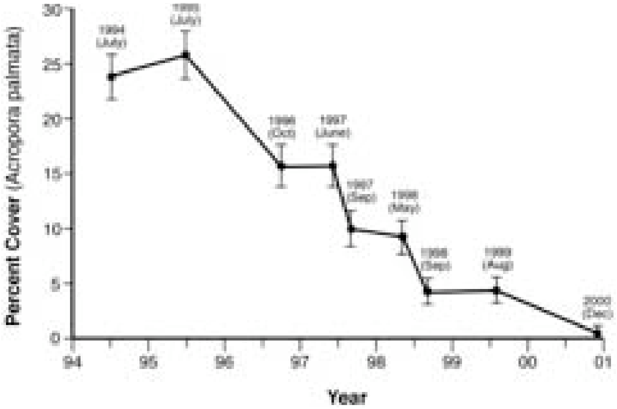

Figure 18: Percent cover of *A. palmata* at Eastern Dry Rocks Reef, Key West, FL, 1994–2000. The effects of seasonal seawater temperatures on rate of tissue loss are evidenced by the stair-step pattern of the graph. Between July 1994 and December 2000, 98% of the *A. palmata* cover on this reef was lost. Data are presented as mean ± SD. [Patterson et al. 2002]

Figure 19: Left - Rock Key before Hurricane Georges. Right - the same location the following year [Steve Quirolo]

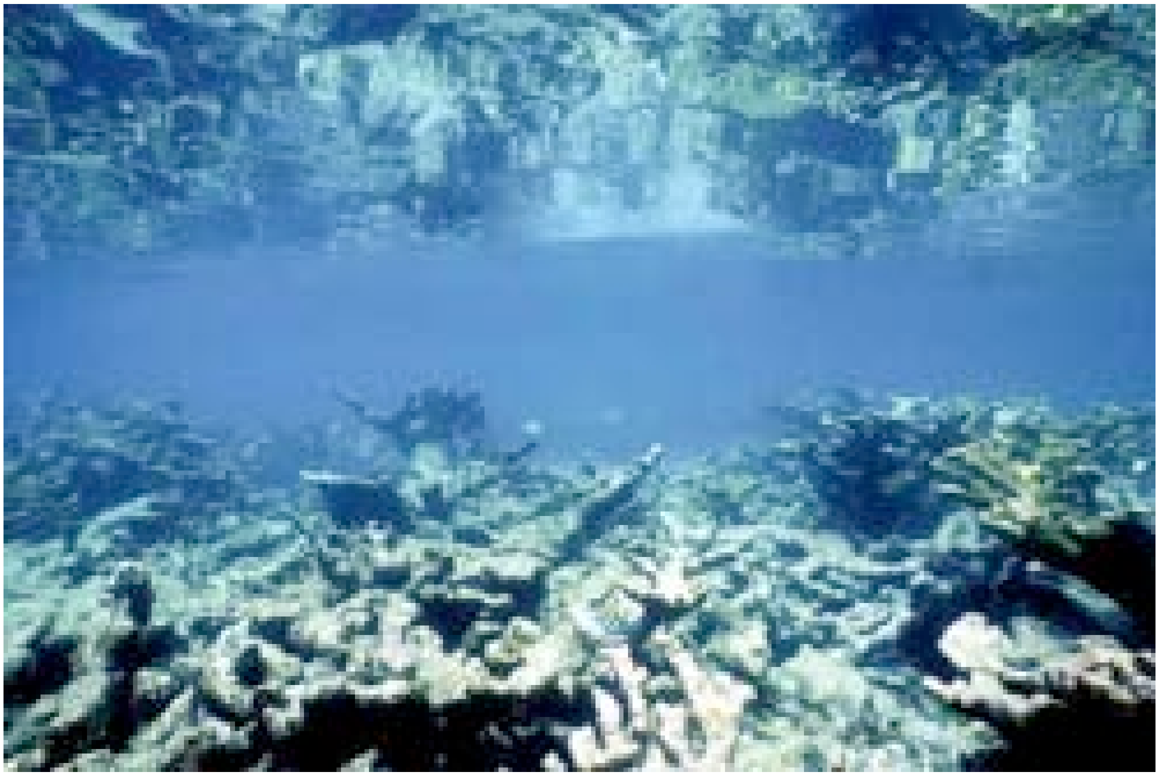

Figure 20: Dead reef in Key West [Wolcott Henry]

Dry Tortugas

Jaap and Sargent (1993) report an overall loss of *A. palmata* cover in the Dry Tortugas from 440,000 m^2 in 1881 (Agassiz 1882) to a low of about 200 m^2 in 1977 to an area of 1400 m^2 by 1993, in total a decrease greater than 99%. The species disappeared from Long Key Reef before 1932 and from Bird Key Reef between 1932 and 1960. Less information is available on the historic status of *A. cervicornis*, however, Davis (1982) and Porter et al. (1982) reported greater than 90% loss of *A. cervicornis* in the Dry Tortugas following a cold front during the winter of 1976-77. An *A. cervicornis* die off occurred at Little Africa reef between 1995 and 1997, leaving cover at less than 1%. No subsequent recovery has been observed as recently as 2002 (Bruckner et al. 2002). Currently, White Shoal is the only place in the Dry Tortugas that has any stable *A. cervicornis*, with cover totaling just 2-3% (Bruckner et al. 2002). Due to adverse water quality, disease, the possibility of destructive storms, and other factors, Jaap and Sargent (1993) state that most habitats in the Dry Tortugas are unsuitable for *Acropora* corals and that full-scale recovery is unlikely (Figure 21).

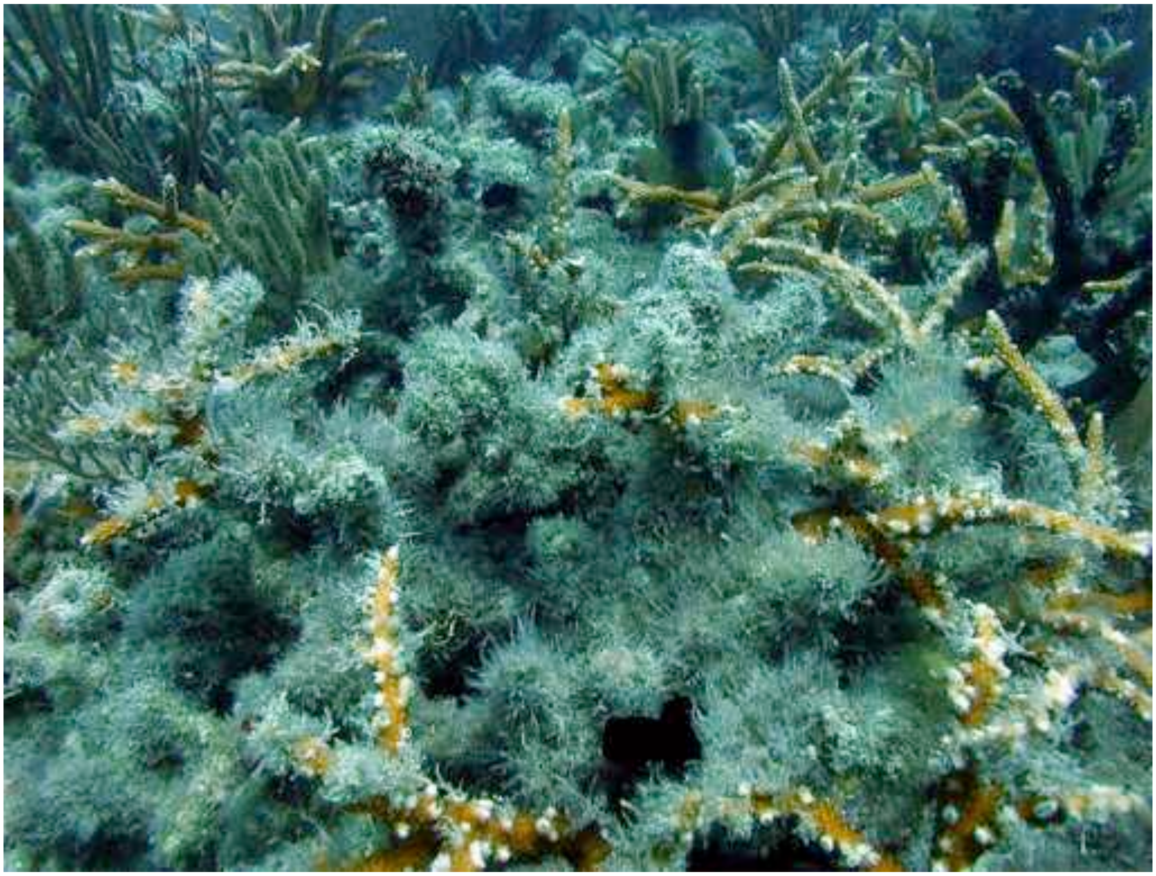

Figure 21: Algae engulfs this *A. cervicornis* colony at Bird Key Reef, Dry Tortugas National Park. Threespot Damselfish (visible top center of photo) damage is also extensive [M. Chiappone]

Navassa Island Wildlife Refuge

Navassa Island is a small, 2 mi^2 U.S. protectorate located between Jamaica and Haiti in the Caribbean Sea. In 1999, the Secretary of the Interior transferred full administration of Navassa to the U.S. Fish and Wildlife Service. The Navassa Island Wildlife Refuge is managed as a remote unit of the Caribbean Islands National Wildlife Refuge, including the island and sub-merged lands out 12 miles offshore. The island is uninhabited with no development nearby, therefore the water is clean and the reefs are not heavily exploited. Very little quantitative information exists regarding the *Acropora* spp. at Navassa as there is no regular reef monitoring or ongoing research, but the reefs were assessed in 2000 (Causey et al. 2002). Average live coral cover ranged from 20-26% at 11-23 m. Other major cover consisted of sponges (7-27%) and fleshy brown algae (10-23%) (Causey et al. 2002). *A. palmata* appeared healthy with no white-band disease or predation scars, and *A. cervicornis* was healthy but less abundant. No historic trend data is available for *Acropora* spp. at Navassa and therefore it is difficult to know their historic distribution (Causey et al. 2002).

Puerto Rico

Puerto Rican coral reef habitat exists primarily on the northeast, east, south, and southwestern coasts, and on the offshore islands (Figure 22). *Acropora* corals were major components of all reef systems prior to mass die-offs due to bleaching in the 1980s (Weil et al. 2002). Goenaga and Cintron (1979) conducted island-wide surveys of 35 localities in 1978-79 and found 88% of all locations colonized by *A. palmata* and 52% by *A. cervicornis* colonies. At that time, most *Acropora* colonies were healthy and thriving, although a few already showed signs of anthropogenic impacts of sedimentation and pollution. Since then *Acropora* coral colonies have declined 90-95% over the last 25 years in almost all locations where they were formerly abundant and it is now clear that the reefs surrounding the main island are degraded (Causey et al. 2002, Weil et al. 2002). The dense *Acropora* thickets that once existed have all but disappeared with the exception of a few reefs in the southwest and isolated offshore locations (Weil et al. 2002).

Figure 22: Puerto Rico with coral reefs highlighted in orange [ReefBase]

Over 90 localities on the eastern coast of Puerto Rico have been surveyed in the last decade. All surveys indicate extensive declines and many localized extinctions (Weil et al. 2002). In a comparison of surveys performed in the 1970s to the late 1990s at 85 individual sites, *A. palmata* was completely lost from 29 of these sites, *A. cervicornis* disappeared from 11 sites, and *A. prolifera* was extirpated from 7 sites (Hernandez-Delgado 2000, Weil et al. 2002). Those sites with *Acropora* colonies remaining have all been degraded and have experienced a significant reduction in live coral cover (Hernandez-Delgado 2000, Weil et al. 2002). There is a low abundance of large mature colonies and a low abundance or lack of new sexual recruits and reattached fragments throughout the eastern reefs (Weil et al. 2002). With continued mortality and overall losses there is a clear indication that recovery is not occurring (Weil et al. 2002).

Like the eastern coast, reefs along the southwestern coast and offshore islands have suffered parallel losses to once extensive *Acropora* stands. For example, between 1975 and 1992, total volume of *A. palmata* at Media Luna and Turrumotte cays near La

Parguera fell from 11,000 $m^3$and 34,900 m^3 to 7 m^3 and 14 m^3, a nearly complete loss of 100% (Williams et al. 1999). Similarly large numbers of *A. cervicornis* were lost during the same time period (Williams et al. 2000) and populations have continued to decline over the last decade (Bruckner et al. 1997, Morelock et al. 2001).

U.S. Virgin Islands

Smith et al. (1998) report that the biggest change to reefs in the US Virgin Islands (USVI) over the past two decades has been the virtual loss of extensive stands of *A. palmata* and *A. cervicornis* from every major reef system. Populations have shown little recovery. The demise of the *Acropora* spp. in the USVI has prompted coral researchers to predict the disappearance of numerous coral cays and small islands in the near future (Williams et al. 1999). White-band disease has been more responsible for mortality of the *Acropora* spp. than any other factor, and recovery has been jeopardized by physical damage from hurricanes (Bruckner et al. 2002). Current status for each of the three major USVI islands is below.

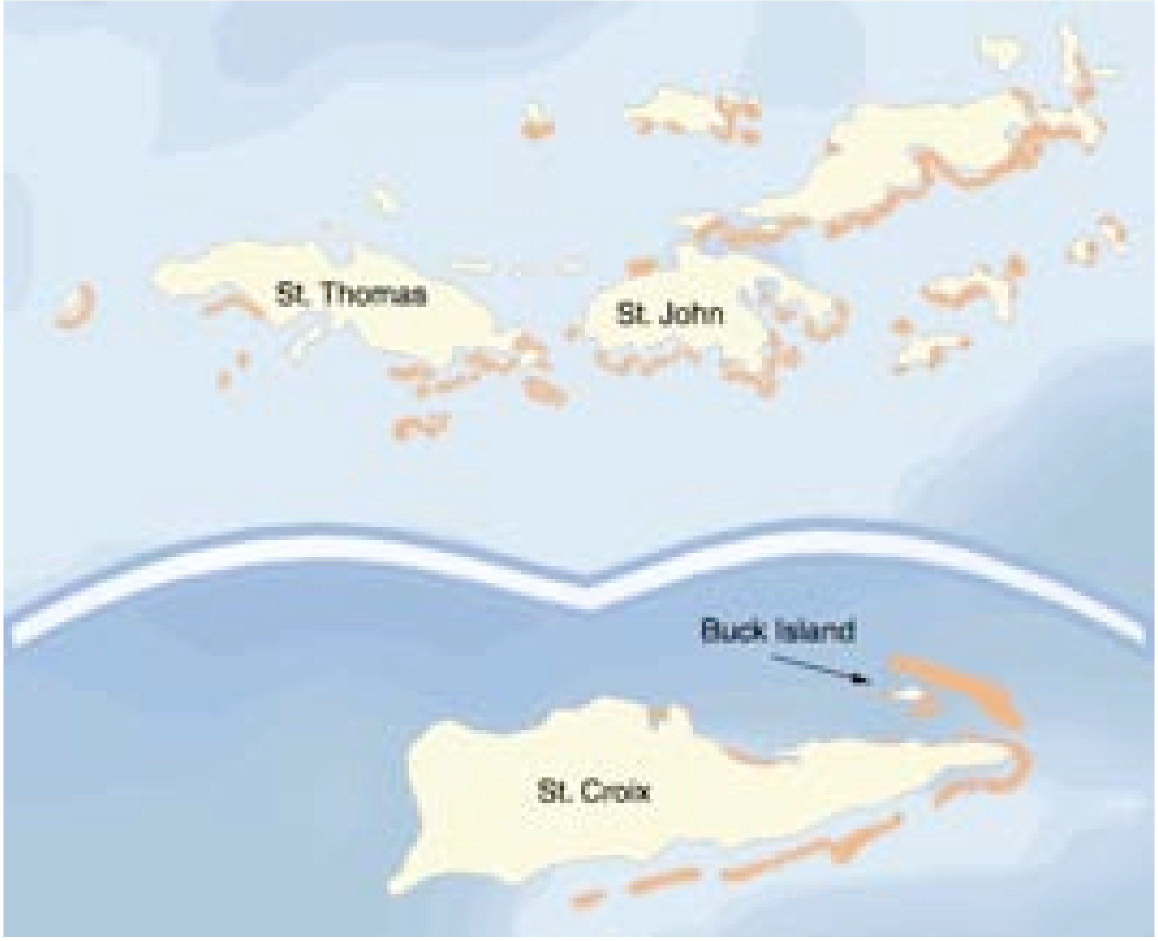

Figure 23: USVI with coral reefs highlighted in orange [ReefBase]

St. Croix

In the US Virgin Islands at St. Croix, localized disappearance of *A. palmata* barrier reef community was first reported by Adey in the 1970s. During the last two decades, storm damage, disease, and bleaching have reduced populations of *A. palmata* by up to 95% throughout the island (Davis et al. 1986, Peters 1997). Consistent long-term data for St. Croix exists only from Buck Island Reef National Monument, just offshore of the main island. The park is comprised of the 176-acre Buck Island and its surrounding coral reef ecosystem. At Buck Island, 80% losses of *A. palmata* due primarily to white-band disease occurred between 1976 and 1985, reducing overall *A. plamata* cover to just 5% (Gladfelter 1982, Bythell et al. 1993). In 1989 hurricane Hugo leveled the remaining *A. palmata* colonies on Buck Island, reducing *A. palmata* to just 0.8% cover after the hurricane (Rogers 1992, Gladfelter et al. 1991).

Similarly, *A. cervicornis* has faired equally poorly. In 1976, 27% total live cover throughout all reefs declined to 2% total cover by 1985, and by 1991 this species was no longer found on the northern reefs (Bythell et al. 1992). On the south side of Buck Island, *A. cervicornis* had been reduced in range by an order of magnitude from 1976 to 1991 and is now rare (Bythell et al. 1989, 1993). In 1976, one well-developed area off Buck Island was estimated to contain 60% live cover of *A. prolifera*. Since 1985 this population has declined because of white-band disease, and in 1992 it was reported to be mostly dead. *A. prolifera* has been reduced to 10% of the total live coral, which is only 5% of the total bottom cover (Bythell et al. 1989, 1992). Structural recovery at Buck Island from Hurricane Hugo has been very slow due to several subsequent hurricanes in 1995, 1998, and 1999 (Turgeon et al. 2002).

St. John

Reefs off St. John were once dominated by *A. palmata* but have been greatly affected by white-band disease and hurricanes (Burckner et al. 2002). In 1987, individual *A. palmata* colonies in Hawksnest Bay on the north of St. John were reduced by 80% over seven months because of heavy seas and damage from snorkellers and boats (Smith et al. 1998). Following Hurricane Hugo in 1989, total coral cover around St. John dropped to between 8-18%, down from 30%. (Smith et al. 1998). In a long-term study (1987-1998) located in a marine protected area, Edmunds (2002) reported serious reef degradation (56% reduction of live coral cover) on at least one St. John reef. In comparison with other long-term studies of Caribbean coral reefs, the degradation of this coral reef is noteworthy as there are few local anthropogenic disturbances that can be held responsible for the decline (Edmunds 2002). The strong possibility that large-scale events such as hurricanes and global warming have played a pivotal role in the decline of at least this reef in St. John emphasizes the need to embrace landscape and regional scale phenomena in order to understand and manage local coral reef dynamics (Edmunds 2002).

St. Thomas

The existence of large dead stands of *Acropora* indicates that the *Acorpora* spp. were once the dominant reef-building corals and space occupier around St. Thomas. Currently, only scattered and diseased colonies remain, apparently succumbing to white-band disease and hurricanes (Antonius & Weiner 1982, Bruckner et al. 2002).

Other Countries

Acropora corals have declined dramatically throughout their range in the Caribbean Sea. Reports from 28 countries documented below show consistent declines with an overall reduction rate of at least 80%. The drastic decrease in their populations over their entire range during a short time period (20 years) signals the alarm that they are critically endangered and headed for extinction. Coral reefs in easily accessible areas continue to decline, although the rate of decline may have slowed. The reefs of the Dominican Republic, Haiti, and Jamaica are in particularly terrible condition, with low coral cover and few fish. The deterioration of these reefs is due to nutrient and sediment pollution, coral disease, over-fishing, anchor damage, destructive fishing, and tourism pressures. Coral reef tourism, a critical component of Caribbean economies, is severely threatened by these losses. Many countries have Marine Protected Areas but these typically remain as "paper parks" where little to no enforcement of regulations occurs (Wilkinson et al. 2002). All areas are increasingly threatened by the borderless effects of global climate change.

Summaries of the status of the *Acropora* spp. for 28 countries throughout the species range are presented below.

Central and South America

Figure 24: Central America with coral reefs highlighted in orange [ReefBase]

Belize

Extending for a distance of 250 km, the Belizean Barrier Reef Complex is the largest continuous reef system in the western Atlantic. Some of the first reported disturbances to *Acropora* corals were severe storms and hurricanes, such as Hurricane Hattie in 1961 which reduced living coral cover by 80% (Kramer et al. 2000). *A. cervicornis* was the dominant reef-builder on Belizean reefs until populations were devastated by disease in the mid-1980s. These losses were followed by increases in macroalgal cover of up to 60% that displaced new coral recruits (Kramer et al. 2000). Another coral species, *Agaricia tenuifolia* (Figure 48), colonized dead *A. cervicornis* rubble and replaced it as the dominant coral species (Aronson et al. 1998). The algal competition coupled with *Agaricia* recruitment combined to prevent the *Acropora* spp. from successfully re-colonizing the reefs. Similar transitions between coral and algal communities have been seen in other areas of the Belize barrier reef, including the patch reefs on remote Glovers Reef where during the last 25 years there has been a 75% loss of coral cover, including 99% loss of *A. palmata* and *A. cervicornis*, and an over 300% increase in macroalgae (McClanahan et al. 1998, Kramer et al. 2000).

Colombia

Colombia has over 1,000 km^2 of Caribbean reefs scattered over 21 areas in 3 groupings: fringing reefs on rocky shores of the mainland coast (e.g. Santa Marta and Urabá), continental shelf reefs around offshore islands (e.g. Rosario and San Bernardo archipelagos), and the San Andrés Archipelago oceanic reef complexes in the Western Caribbean. On the Caribbean coasts of Colombia, there is evidence that coral reefs have suffered considerable mortality during the last 20 years. This mortality has primarily resulted from increased sedimentation, sewage pollution, hurricanes, bleaching events, and diseases (Garzón-Ferreira & Kielman 1993, Garzón-Ferreira 1997).

The only long-term monitoring site in Colombia is Tayrona Natural Park, Chengue Bay. Data since 1993 shows no clear signs of either decline or recovery following major degradation attributed mostly to white-band disease during the 1980s, which caused a 90% decline in *Acropora* corals (Garzón-Ferreira et al. 2000, 2002). The reefs of San Andres were healthy from 1968-1973, but were found to be in poor condition in 1992, with about 52% of the coral recently dead and *A. cervicornis* virtually gone from San Andres (Garzón-Ferreira et al. 2000). At Islas del Rosario, live coral cover loss was about 20% between 1983-1990 (Garzón-Ferreira et al. 2000).

Costa Rica

There is less than 50 km^2 of coral reef on the Caribbean side of Costa Rica mostly along the high wave-energy, sandy beaches. There has been major damage to coral reefs of this region in the last thirty-five years and the appearance of some reefs has changed considerably. Evidence of this dramatic reef decline comes from Cahuita Natural Park, which is the only site with long-term data. Live coral cover at the park decreased from 40% in the early 1980s to 10% in the mid 1990s to just 3% by 1999 (Garzón-Ferreira et al. 2000).

Guatemala

There have been no surveys of the distribution and condition of coral communities in Guatemala. Based on the information gathered from nearby study sites, *Acropora* corals were probably heavily impacted by Hurricane Mitch, especially from storm run-off and the 1998-bleaching event. Hurricane Iris in 2001 also caused major flooding and sedimentation (Kramer et al. 2000, Almada-Villela et al. 2002).

Honduras

Hurricanes, bleaching, coral diseases, over-fishing, and coastal development have caused extensive disturbance to reefs in Honduras with widespread losses to *Acropora* corals in the past two decades (Kramer et al. 2000). Overall live coral cover varies from 5-28%. There are large thickets of standing dead *A. cervicornis*. The *Acropora* spp. now make up a small percentage of coral cover (<5%), while macroalgae cover continues to increase on at least 82% of the reefs (Kramer et al. 2000). Most reefs surveyed in Honduras (38 of 44) were damaged from the 1998 disturbance events that included bleaching and hurricanes; 25 had moderate disturbance, 13 had severe disturbance, and 6 had low disturbance. The impacts of Hurricane Iris in 2001 on the reefs of Honduras were not as severe as those in Belize; however, there was major damage to corals near river areas due to increased flooding and sediment release (Almada-Villela et al. 2002).

Mexico

The southwestern Gulf of Mexico contains about 20 reefs off Veracruz, some of which are the best studied in the world. These are influenced by high turbidity from coastal runoff. There is an extensive fringing reef along the Yucatan Peninsula from Isla Contoy south to Xcalak, including offshore islands and the Banco Chinchorro atoll. These reefs continue as the Belize barrier reef.

The coral reefs of Mexico are among the most stressed by both natural and human disturbances in the entire Caribbean (Lang et al. 1998). Anthropogenic increases in sediments and nutrients, plus agricultural and industrial chemical pollution have contributed to the disappearance of many corals within the last 20–30 years, and to their replacement by fleshy algae, particularly in the shallow near-shore reefs of southern Veracruz. Corals on reefs near the coast are sometimes killed by low winter temperatures or by runoff during the rainy season. Reef coral skeletons were extensively used in the construction of public buildings and a fort during the 17th and 18th centuries resulting in localized destruction of reef habitats (Lang et al. 1998). Large-scale physical damage includes boat groundings, military maneuvers, and the construction of the Veracruz harbor (Lang et al. 1998). Coral skeletons, particularly on reefs near the port of Veracruz, contain relatively high concentrations of heavy metals (Lang et al. 1998).

Extensive *A. palmata* ramparts once dominated the coastline. These almost completely died off in the early 1980s due to white-band disease and have not recovered (Kramer et al. 2000). Extensive mortality of *Acropora* has been documented at Isla de Sacrificios and other Mexican reefs (Kramer et al. 2000). Reefs on the Atlantic side were battered by hurricanes in 2000, 2001, and 2002, which struck from the Yucatan Peninsula to Honduras, destroying corals with some losses up to 75%. These impacts followed closely on the heels of the extreme coral bleaching event and Hurricane Mitch in 1998, which also caused widespread damage to the region's reefs (Almada-Villela et al. 2002). Coral diseases continue to be present in the Yucatan area, including some of the highest infection rates found in the region (Almada-Villela et al. 2002). Coral cover ranged from 2-28% in 1981, but was just 1-6% in 1993 at the CARICOMP monitoring site of Puerto Morelos. Much of the loss was due to Hurricane Gilbert in 1988 and the mass coal bleaching in 1995. The largest decline in coral cover was on the back reef, from 28% down to 5%, and on the reef crest where 27% cover dropped to 6% (Kramer et al. 2000).

Nicaragua

Very little information exists regarding the status and change in distribution of *Acropora* corals in Nicaraguan waters. Transects performed in 1994-96 on five reefs indicated that bottom cover was dominated by algae (44%) and live coral cover was around 25%, most of which consisted of *Montastrea, Agaricia, Porites, and Millepora* coral species. Dead stands of *Acropora* corals (Figure 25) were present from the Caribbean-wide mass mortality in the early 1980s, but little recovery has occurred and *Acropora* spp. did not comprise any significant live coral cover (Kramer et al. 2000). Overall, the reefs of Nicaragua have probably lost about 10% of coral cover over the last 10 years. The total losses are not known for sure, but are considered substantial; similar to the mass *Acropora* mortality observed elsewhere in the Caribbean (Almada-Villela et al. 2002).

Figure 25: Damaged coral at Nasa reef in Nicaragua [Lamarr Trott]

Panama

Most reefs in the San Blas Islands formerly had extensive thickets of *A. cervicornis*. By 1991, *A. cervicornis* was found in the San Blas Islands occurring primarily in debris fields with only a few small living colonies. Most *A. palmata* was also dead. Overall coral cover in the San Blas Islands has dramatically declined from 40% down to below 15% (Ogden & Ogden 1994). Caribbean reefs in Panama are now primarily composed of *Agarica* spp. and *Millepora* spp. Evidence of continued degradation and lack of recovery of *Acropora* corals is documented by a recent survey performed by an Atlantic and Gulf Rapid Reef Assessment (AGRRA) expedition in June 2002 to the Archipelago de Bocas del Toro in northwestern Panama. Bleached stony corals were noted in shallow reefs near Islas Aqua, Bastimentos and Popa, Cayo Coral, Cayos Zapatilla, and most dramatically at Tobobo on the eastern side of the Peninsula Valiente. At Cayos Zapatilla, pale to complete bleaching of A. *palmata* was noted at one site, while at a second site no bleaching was noted, but approximately half the colonies were “old standing dead”. At Tobobo, partial to complete bleaching affected about 50% of the corals larger than 10 cm, primarily *A. palmata* and *M. complanata*. Bleaching was particularly conspicuous at depths less than 2 m.

Venezuela

In Venezuela, the best reef development occurs around the oceanic islands, specifically at Archipelago de Aves, Archipelago Los Roques, La Orchila, and La Blanquilla. Coral communities are common on the Venezuelan continental shelf, but major changes in coral reef structure have been reported along the continental shelf, where coral reefs have declined in the last decade (e.g. Morrocoy National Park). Threats include high sedimentation, terrestrial runoff, and upwelling (Garzón-Ferreira et al. 2002).

There has been much industrial, urban, and tourist development on the coast, with consequent sediment, human, and industrial pollution. There is intensive fishing on the fringing continental reefs and at Los Roques (lobster, conch, and fish). The island reefs are less exploited for tourism, but there is no control. Hurricanes are relatively rare. There was mass mortality of *Diadema* in 1983, and large-scale bleaching of corals in 1987, and much more in 1995–1996 (Woodley et al. 1998). The only reef being monitored regularly on the continental coast is Sombrero Key (Morrocoy Natural Park) where coral reef health collapsed during the five years leading up to 1996, with coral cover reducing from 43% to less than 5% (Garzón-Ferreira et al. 2000). This mass mortality was related to a climatic and oceanographic anomaly that resulted in a severe phytoplankton bloom followed by sudden oxygen depletion. Chemical pollution is also blamed (Garzón-Ferreira et al. 2000).

There have been new efforts during 2000–2002 to assess the status of coral reefs, with most surveys conducted in the Los Roques National Park. These reefs are almost pristine compared with other Caribbean reefs with live coral cover ranges from 18-44%, dead coral cover from 31-64%, and algal cover between 0.1-11%. Coral diseases (yellow blotch, dark spots, white plague and white-band) are rare (below 6%), although in some places, white plague disease has affected up to 24% of the major reef builders (Garzón-Ferreira et al. 2002).

Islands of the wider Caribbean Sea

Figure 26: Wider Caribbean Sea with coral reefs highlighted in orange [ReefBase]

Anguilla

Little information exists about the *Acropora* spp. in Anguilla. Hurricane Luis in 1995 caused extensive damage to *A. palmata* in shallow water (Smith et al. 1998). In late 2002, Reef Check surveys of an exposed reef 5 m deep and 100 m off of Blackgarden showed 15% live coral cover, 4% macroalgal cover, 46% rock, and low numbers of key fish species and the *Diadema* sea urchin (Hoetjes et al. 2002).

Antigua and Barbuda

The reefs of Antigua and Barbuda cover about 25 km^2. Reefs surround Antigua except on parts of the west and south coasts. Reefs are found along most of the coast of Barbuda, with an extensive algal ridge on the east coast. The reefs are under sedimentation stress from shoreline tourism development and destruction of wetlands. Hurricane Hugo in 1989 and Hurricanes Luis and Marilyn in 1995 caused extensive damage to reefs on the south and southeast coasts of Antigua, particularly to *Acropora* spp. on shallow reefs. (Smith et al. 1998)

Bahamas

The Bahamas are comprised of about 700 islands along with several thousands cays and rocks. This system sits on two large shallow bank systems extending 970 km southeast towards Haiti from about 80 km off Florida. The Little Bahama Bank is in the northern Bahamas and the Great Bahama Bank extends from central to southwestern Bahamas.

Reefs cover 1,832 km^2 of the Great Bahama Bank and 324 km^2 of the Little Bahama Bank. Living coral reefs fringe most of the northern and eastern windward coasts and the bank edges.

More than four million tourists visited the Bahamas in 2000, providing an estimated 60% of GDP and employing approximately 50% of the Bahamian workforce. This has resulted in rapid degradation of coastal waters and coastal habitat destruction (Linton et al. 2002). Comparison of aerial photographs of the north coast of New Providence island showed that 60% of the coral reef habitat has been lost from dredge and fill, construction of the cruise ship port, and sedimentation since 1943 (Woodley et al. 2000). There is also over-exploitation of fishes, lobsters, conch, and other target species (Linton et al. 2002).

Coral reefs have declined in waters of the more developed and populated islands. Some areas to the south show high algal cover, a likely result of inadequate waste treatment and fertilizer runoff, and lower fish abundance and diversity, probably due to fishing pressure. Coral disease, particularly white-band disease of the main *Acropora* species, has been widespread (Linton et al. 2002). Photographs and transects taken in 1983 and 1992 at Telephone Pole Reef on San Salvador show formerly dense thickets of *A. cervicornis* have died and collapsed to form layers that now are being covered by rapidly growing heads of *Porites porites* (Figure 49). Abundant *M. annularis* at the same site remains unchanged (Curran et al. 1993). Monitoring in San Salvador by the Caribbean Coastal Marine Productivity Program (CARICOMP) since 1994 shows a change in coral cover at 10 m depth of 9.6% to 4% in 2001, while macroalgae (~40%) predominates (Woodley et al. 2000, Linton et al. 2002). There was extensive bleaching in 1998 and some mortality in the Exuma Cays. Hurricanes Andrew (1992), Bertha & Lili (1996), and Floyd (1999) all passed through the Bahamas causing widespread damage (Figure 27 & Figure 31).

Figure 27: *A. palmata* overturned by Hurricane Lili off San Salvador [John Garver]

The relatively isolated reefs of the less developed islands (Abacos, Andros, Bimini, Eleuthera, Cat Island, Long Island, the Exumas etc.) are some of the few places still considered to be healthy, with high percent cover by hard corals as well as high densities of fish. Andros Island, the source of many of the photos in this petition, is the largest but one of the least populated islands of the Bahamas, and boasts the third largest barrier reef system in the world (229 km). Sites in North and Central Andros seem to be healthiest based on lower coral mortality, lower abundance of macroalgae, and higher abundance and diversity of fish. These reefs, removed from human impacts, are considered to be in good condition overall (Linton et al. 2002).

Barbados

The Barbados coral reefs cover 16.4 km^2 with an additional 7.2 km^2 of coral rubble, which is being consolidated by encrusting algae. The west and south coast has an almost continuous bank reef that has deteriorated significantly over the last 20 years, while the northeast and southeast coasts have the most reefs and are in better condition, with high diversity but low coral cover due to exposure to oceanic waves (Hoetjes et al. 2002).

A. palmata provided the framework for the Barbados reefs for tens of thousands of years, but in the last 100 years *A. palmata* has virtually disappeared from Barbados. Large tracts existed as recently as 1918, but these no longer live. *A. palmata* remains a part of the Barbados reefs as rubble; in some places covering as much as 45% of the sandy bottom (Lewis 1984).

The last extensive surveys were in 1997-98 on the east, southeast, and north coasts. On the offshore reefs coral diversity dropped by 24% between 1982 and 1992, along with a 34% drop in abundance and an increase of dead coral surface from 22% to 43% over 20 years. 65–90% bleaching was recorded in 1998. At one site, monitoring showed that approximately 20% of bleached corals did not survive, but this site was also impacted by effluent from the rum refinery. Reef Check surveys in April 2001 showed 10-42.5% (mean 28%) hard coral cover, and fleshy algal cover of 0-20% (mean 6.3%) along the west and southwest coast (Smith et al. 1998, Hoetjes et al. 2002).

British Virgin Islands

The 60 small islands and rocks of the British Virgin Islands occupy just over 150 km^2 of land on a shelf of over 3,000 km^2. This archipelago sits on the eastern part of the Puerto Rican Bank. Most of the bank consists of sand and numerous rock outcrops covered by coral reefs. These vary from small isolated patches of a few square meters to the extensive Horseshoe Reef of Anegada covering approximately 77 km^2 (Smith et al 2000).

Currently, overall reef condition is relatively good, with localized deterioration associated with areas of high population, shoreline development, and rapid growth of marine activities such as yachting, snorkeling, and diving. The number one threat to the coral reefs of the BVI is almost certainly sedimentation from coastal developments (Petrovic et al. 2002). Tourism has expanded considerably in the BVI, particularly yacht charter and recreational boating, cruise ships, and diving tourism. Development for this has resulted in coastal degradation, increased sedimentation, land reclamation, dredging and construction, and sewage pollution (Smith et al. 1998). There has been damage to corals at dive sites from anchors, and from the large numbers of novice divers. Hurricanes Hugo (1989), Luis (1995), and Marilyn (1995) badly damaged corals, particularly shallow-water *A. palmata* (Smith et al. 1998). The passage of numerous storms since 1995, most recently Hurricanes Jose and Lenny in late 1999, caused severe damage to dive sites at Norman Island, Peter Island, Salt Island, Cooper Island, Ginger Island and Virgin Gorda (Smith et al. 2000). Damage to many reefs was extensive and sometimes repeated two or more times in a single season (Petrovic et al. 2002).

Bleaching has not been a major problem in BVI. However, the reefs and near-shore marine habitats surrounding the principal island of Tortola continue to deteriorate. The exploitation of the marine resources in the BVI continues virtually unabated. All species of economic importance are harvested at levels that are almost certainly not sustainable, and populations of many species, including important herbivores, are declining. Lobster and conch have been over-fished to the extent that both must be imported to meet the tourist demand (Petrovic et al. 2002).

Cayman Islands

These consist of 3 islands: Grand Cayman (197 km^2), Little Cayman (25 km^2), and Cayman Brac (32 km^2). The islands are composed of porous limestone rock with no rivers or streams, which results in exceptional water visibility around the islands. The islands have well-developed fringing reefs on the narrow shelves around them, which end as steep walls dropping to great depths (Woodley et al. 1998).

The resident population of the Cayman Islands is about 37,000, but total tourist arrivals exceed 1.4 million each year, accounting for about 70% of GDP. Rapid tourism growth is resulting in dredging of wetlands, but the two outer islands have escaped much of this, due to their remote location. Tourism related developments have resulted in damage to the reefs including habitat destruction, increased suspended sediment loads from dredging and mangrove removal, sewage, oil pollution, and destruction by cruise ship anchors and anchor chains (Linton et al. 2002). Additionally, tourism demand for seafood has placed considerable pressure on stocks of conch, lobster, and fish (Woodley et al. 1998).

Conditions on the reefs of Little Cayman and Grand Cayman vary considerably, but overall cover is declining consistently. Data from the Department of Environment, Protection and Conservation Unit show coral cover on six reefs in Little Cayman declining from an average of 22.2% in 1997 to an average of 19% in 1999 and 16% in 2001. On Grand Cayman, average coral cover declined from 25.6% at nine sites in 1997 to 15.7% in 2001. Lower cover in Grand Cayman is possibly due to increased impact from coastal development and water pollution. Little Cayman is more remote and relatively undeveloped and less likely to be impacted by such pressures. Coral cover on Cayman Brac averaged 15.6% in 2000 (Linton et al. 2002). The deeper reefs off George Town have been destroyed by the continual anchoring of cruise ships, and nearby shallow reefs have been damaged by the resulting sedimentation (Woodley et al. 1998).

Acropora spp. have been severely damaged by white-band disease, although isolated healthy stands exist (Linton et al. 2002). There was large-scale bleaching of corals in 1987, and even worse bleaching in 1995–1996 and 1997–1998 (Woodley et al. 1998). Most reefs have recovered from the 1998 bleaching event, with corals that had partial mortality growing back over the dead surfaces, but in some cases corals have not recovered (Linton et al. 2002).

Cuba

The Cuban archipelago is made up of the Island of Cuba, the Isle of Youth, and over 4,000 keys and islets totaling 110,860 km^2. Coral reefs grow along virtually the entire border of the Cuban shelf (>98%) and extend inshore across broad areas of the shelf. The shelf edge is 2150 km long on the north coast and 1816 km on the south. Inshore patch reefs are dispersed in the western Gulf of Guanahacabibes and Gulf of Batabanó, and the eastern Gulf of Ana María-Guacanayabo (Linton et al. 2002).

These reefs are among the best in the Caribbean, probably due to minimal coastal development on the north and south coasts and the fact that many reefs are offshore and outside the influence of land based sources of pollution. In Cuba, about half of the shelf edge reefs are separated from the land by broad shallow lagoons and this protects the reefs and cays from most of the anthropogenic pressures. Southern Cuba's coral archipelagos including Los Canarreos Archipelago through Punta Guanahacabibes, and Archipélago Jardines de la Reina ('Gardens of the Queen') are healthy and considered among the least damaged areas of the Caribbean. This area has high biodiversity and the largest and most diverse shelf habitats in the insular Caribbean (barrier and patch reefs, islands, mangroves forests, and extensive sea grass beds) (Linton et al. 2002).

Coral cover data is sketchy, however signs of decline are evident near large population centers such as Havana where highly polluted waters are damaging about 3% of the shelf edge reefs. For example, the CARICOMP sites at 10 m depth on Cayo Coco averages 6% coral cover. Reefs at Herradura (31% coral cover), west of Havana, and in the Archipelago de los Canarreos appear to be in good condition. Nutrient enrichment has caused overgrowth by algae and blue green (cyanobacterial) mats, and coral diseases (white-band, yellow band, and aspergillosis) have caused some coral mortality (Woodley et al. 2000). In late 2000 and early 2001, there was a massive outbreak of white plague disease on corals near Havana. In 1998, there was intense coral bleaching, but recovery was widespread. Reefs of the southwest are more impacted but live coral cover is still moderate (Linton et al. 2002). Threats to reefs of the southern archipelagos are currently low, however, tourism is growing rapidly with 1.8 million visitors in 2001, generating $US1.9 billion in gross revenues. The associated development is causing environmental damage along the coast, including prime habitats for endangered species. In addition to habitat destruction, there is increased pollution from sewage, agricultural run-off, and chemical contamination of reefs near high population centers (Cuba's resident population is approximately 11.2 million). There is also relatively high fishing pressure on fish resources in most areas. Unregulated fishing has reduced reef fish populations, and illegal harvesting of black corals continues. Reef dive tourism is not well managed with considerable anchor and diver damage in the intensely visited locations (Linton et al. 2002).

Dominica

Reef development is limited on the narrow coastal shelf. But on the south, west, and northwest coasts, corals grow on rocks and on the steep slopes and walls, making spectacular dive sites for the increasing numbers of diving tourists. The small population and minimal coastal development means that the corals are not severely impacted by human activities. No hurricanes have hit since Hurricane David in 1979, however, Hurricane Luis in 1995 caused heavy sedimentation and wave destruction of *Porites* sp. along the southwest coast (Smith et al. 1998). Most of the reefs are considered very healthy (Hoetjes et al. 2002).

Dominican Republic

The Dominican Republic has approximately 1,576 km of coast including the islands of Saona, Catalina, Beata, and the Cayos Siete Hermanos. Reefs border approximately 166 km of the coast and mangroves 268 km. The largest expanse of reef (64.2 km) is along the north coast in the Montecristi region to the northwest. Most of the coral reefs are fringing reefs, but there are also two barrier reefs, numerous patch reefs, and four large offshore banks. In the eastern and northwestern coasts, broad coastal shallow platforms with barrier reefs are found, while in other places terrigeneous sediments produce high turbidity that prevents reefs from forming (Linton et al. 2002).

Numerous surveys since 1992 all document the progressive degradation of Dominican coral reefs and other coastal environments (Woodley et al. 2000). Near-shore reefs are severely impacted by anthropogenic activities that include sedimentation from deforestation, coastal development and dredging, pollution from agricultural and industrial development and untreated wastewater discharge, and over-fishing. These problems stem primarily from increasing human populations (estimated >9 million) and tourism. Large areas of the coast have been destroyed, including reconditioning of beaches that causes additional sediment damage. The development of transshipment ports will result in yet more reef destruction (Linton et al. 2002).

Shallow reefs near rivers on the central and south coast consist of mostly dead colonies, covered by turf algae, detritus, and garbage (Aronson & Precht 1998). Recent studies on shallow (3-10 m) reefs of the north coast (Puerto Plata and Las Terrenas) show 80% coral mortality and 92% cover by algae. The poor status of reefs is partly due to the diseases affecting *Acropora*, *Diadema* (the absence of which enhances the spread of algae), and *Gorgonia* in the last 20 years. Still erect stands of dead *A. palmata* were seen from Bávaro and Boca Chica, with signs of white-band disease in *A. cervicornis* at Bahía de Las Aguilas in the southwest (Woodley et al. 2000). Data from the CARICOMP site at El Penõn in the Parque del Este (an MPA) at 10 m depth indicate a decline from 20% average coral cover in 1996, to 11% in 2001 (Linton et al. 2002). Generally, higher coral cover is found only on deep or offshore reefs that are less impacted by anthropogenic effects (Linton et al. 2002). These include the Montecristi barrier reef and the Silver Banks with mean coral cover approximating 40-50% (Linton et al. 2002).

French West Indies

The French West Indies are the islands of Martinique, the Guadeloupe Archipelago (with Guadeloupe, La Désirade, Marie-Galante, and the Les Saintes islands), St. Barthélémy, and part of St. Martin. Reefs are absent on the leeward side (northwest and west) of Martinique because the shelf is narrow and there is sediment from the erosion of Montagne Pelée. The northern coast has little coral growth because of its steepness and high sedimentation. Further south, fringing reefs have developed along the coast protected by a barrier reef (Smith et al. 1998).

Corals and fishes have been monitored on permanent transects in seven stations on the coral reefs in Martinique, Guadeloupe, and Saint-Barthelemy. Coral cover varies between 22-43%, and the density of juvenile corals is 2-9 individuals per m^2. The level of coral disease is alarmingly high in some places with 9-62% of corals showing disease, the amount being related to the degree of human impacts. Brown algae *(Dictyota, Sargassum)* are the main coral competitors and algal cover varies between 2.4-31%. The reefs are stressed by eutrophication and overgrowth by macroalgae, which result in reductions in juvenile coral recruitment and injury to adult coral tissues. The level of stress is more marked closer to cities or bays receiving significant pollution runoff. Coral communities on Saint-Barthélémy have remained in good health as human pressures are less pronounced (Hoetjes et al. 2002).

Massive coral bleaching has never been seen in the French West Indies, but there is chronic bleaching every year in September, when water temperatures reach 29^{o} C. The Pigeon Islets (leeward side of Guadeloupe) are one of the most famous SCUBA diving spots, but there is evident physical damage from 80,000 divers per year. There is some protection with a ban on most fishing activities and the installation of permanent moorings (Smith et al. 1998).

Hurricanes have frequent impact in the French West Indies. The coral reefs of Martinique were damaged by swells from Hurricanes David (1979) and Allen (1980), with large losses to *A. palmata* and *A. cervicornis* communities on shallow outer reef slopes. Hurricane Hugo hit Guadeloupe in 1989, damaging branching corals of the shallow fore-reef zone (e.g. *Acropora* spp.). Hurricanes Luis and Marilyn (1995) smashed corals, sponges, and gorgonians down to 25 m, resulting in heavy sedimentation composed of fine calcareous sand that was suspended for months and killed many animals that had initially survived the hurricane. Reefs were battered again when Hurricane Georges passed directly over Guadeloupe in September 1998 (Smith et al. 1998).

Haiti

Like the reefs of the Dominican Republic, Haitian reefs are suffering far-reaching destruction. Soil erosion and wetland removal are particularly severe (perhaps less than 1% of the native vegetation remains intact). There are no sewage treatment plants, nor sanitary landfills in this nation of eight million people (Lang et al. 1998).

Reefs have suffered from the recent Caribbean-wide mortalities in *Acropora* and *Diadema*, as well as the effects of extreme deforestation, over-fishing, and local pollution (Woodley et al. 2000). There is virtually no monitoring due to ongoing civil war and a political impasse between the Haitian government and the international community about funding environmental activities. Over-fishing continues unchecked and the lack of herbivores means macro algal growth is not controlled and smothers corals. There is obvious damage from urban runoff from Port-au-Prince, which is severely polluted with oil, industrial chemicals, and trash (Figure 50). There are increasing threats from road construction, sedimentation from deforestation and soil erosion, pollution, and overfishing, especially near Port-au-Prince. Illegal exploitation of corals for export under the guise of 'harvesting live rock' is increasing, with apparent indifference by government officials. Similarly officials ignore destruction of coral reefs by private boats (Linton et al. 2002, Lang et al. 1998).

Jamaica

The large island of Jamaica is in the center of the Caribbean Sea. It historically had well-developed fringing reefs on the north coast and patchy reef formations on the south coast that are compromised by rivers laden with sediment. Corals also grow on neighboring banks at the Pedro Cays, 70 km south, and the Morant Cays, 50 km southwest.

In 1951, Thomas F. Goreau began research on Jamaican reefs, possibly making Jamaican reefs the longest directly observed submarine ecosystem. During the 1950s and 1960s reefs all around Jamaica were photographed, mapped, bathymetrically profiled, and their species and ecology described by Goreau. After almost 50 years of study, it is clear that coral reefs have deteriorated due to a variety of causes. Degradation factors include overgrowth by algae, sponges, and soft corals; eutrophication by sewage nutrients, reduced numbers of herbivores due to over fishing and natural causes, hurricanes, sedimentation, diver and boat damage, and coral bleaching. Mass coral bleaching is apparently a novel phenomenon beginning in 1980. Continuous analysis of relative stresses at eleven sites shows that its pattern in space and time is unrelated to previously existing stresses (Goreau 1992).

Once dominated by corals, algae now dominates Jamaican reefs, and the thickets of *A. palmata* and *A. cervicornis* corals along the north coast reefs are virtually gone (Figure 28). Jamaican reefs suffered little storm damage for more than 30 years, until they were severely impacted by Hurricane Allen in 1980 and Gilbert in 1988. In 1980, there was some white-band disease in *A. cervicornis*, while in 1983 the abundant sea urchin *Diadema antillarum* died off. These combined impacts marked the beginning of a major deterioration of Jamaican coral reefs. In the late 1970s, nine reefs on the north coast had coral cover averaging 52% at 10 m depth, but this declined to 3% in the 1990s, in parallel with an increase in fleshy macroalgae from 4% to 92% (Woodley et al. 1998, Woodley et al. 2000).

Figure 28: Damaged reef in Jamaica [Terry Hughes]

Mass bleaching with considerable mortality took place in Jamaica during 1987, 1989, 1990, and 1998 (Woodley et al. 1998). Since then, studies at 27 sites along 10 km of the north coast around Discovery Bay show that coral cover has increased slightly. In 1997, at 5 m it was 15% (algae 35%), at 10 m it was 16% (algae 56%), and at 15 m it was 11%, up from 2%, although algal cover was 63%. However, this increase was mainly due to recruitment by opportunistic species such as *Porites astreoides*, *P. porites,* and *Agaricia agaricites* (Figure 48 & Figure 49), rather than by the original frame-builders such as the *Acropora* spp. and massive corals (Wilkinson et al. 2000).

In August 2000, a survey conducted by the Atlantic and Gulf Rapid Reef Assessment (AGRRA) program on stretches of reef along Jamaica's northern and western coasts revealed that live hard coral cover remains low along the north and west coasts, averaging 5% on shallow reefs, and 12% on deeper reefs. Coral mortality was moderately high (mean 42%), with 52% mortality observed at shallow sites, and 41% at deeper sites. The highest levels of mortality occurred in the reef-building corals, *Acropora* spp. and *Montastrea* spp. Macroalgae was abundant throughout the study area, composed predominately of fleshy varieties, but calcareous algae (e.g. *Halimeda spp.*) were common at all sites. Coral recruitment was low at an average 3.6 individuals per m^2, with only 1.8 individuals per m^2 on the east coast. Bleaching was noted in 2.3% of the living colonies, and diseases were detected in less than 2% of living colonies. High levels of coral mortality, high macroalgal coverage (Figure 29), and low levels of coral recruitment reported along the entire stretch of coast surveyed, suggests that the condition of reefs on Jamaica's north and west coasts remain in a degraded state, including areas not heavily impacted by human development (e.g. east coast) (AGRRA 2000).

South coast reefs remain stressed, particularly those near high population centers. For example, coral cover near Kingston Harbour varied from 7.3% at South East Cay to 21.4% at Rackhams Cay (average 15%). The density of coral recruits ranged from 1 to 6.4 individuals per m^2, and the incidence of coral bleaching was 1.9 to 16.7%. There are, however, some reefs outside most of the coastal stresses that are in reasonably good condition. Reef Check surveys in Bloody Bay Negril suggest 30-40% coral cover, with many healthy gorgonians, but very few fish were seen confirming that over-fishing continues to be a major problem. Beach erosion in Negril continues without any immediate solution, and in future, the rapid deterioration of the reefs in the Negril Marine Park may reduce their ability to protect the shoreline from erosion. Reefs around the offshore islands in the Portland Bight Protected Area are also in better condition, though impacted by siltation and some algal overgrowth. Visual estimates of coral cover at Pigeon Island in 2001 and 2002 were >20% and coral recruits of different species e.g. *Agaricia*, *Siderastrea*, and *A. cervicornis* were observed. There were low levels of disease (1.4%) and bleaching (1.4%). Again, fishes were small and scarce with no large predators. The offshore reefs at the Morant and Pedro Cays are relatively inaccessible and less impacted than inshore reefs, but there is no recent data (Linton et al. 2002).

Figure 29: Algae covered *A. cervicornis* in Jamaica [Terry Hughes]

Montserrat

Corals occur as scattered patch reefs from 2 m to 40 m off the west and north coasts of Montserrat. Runoff and steep slopes limit the distribution of reefs around the island, particularly near ravines that carry sediments. Large-scale ongoing volcanic eruptions are damaging reefs on the south and southwest coasts. Additionally, there has been damage from Hurricanes Hugo (1989) and Luis (1995). There are low human impacts from pollution and diving tourism, and the reefs are relatively pristine, with high diversity. A survey of species richness conducted in 1995 and 1996 identified 37 hard coral species, 17 octocorals, 87 other invertebrates, 3 seagrasses, 67 fish and 37 algae. Live coral cover ranged from 20 to 45%. Trap and spear fishing are potentially destructive, given the limited amount of reef. No marine protection can be contemplated as the volcanic activity has disrupted government (Smith et al. 1998, Smith et al. 2000).

Netherlands Antilles (Aruba, Bonaire, & Curaçao)

Aruba, Bonaire, and Curaçao are small oceanic islands about 70 km north of Venezuela. Aruba has considerable tourism development based on the reefs, particularly for SCUBA divers. From 1980 to 1982, white-band disease killed over 90% of *A. cervicornis* in shallow waters, and decreased the coral's ability to regenerate after physical damage. Wells (1988) reports greater than 90% losses of *A. palmata* also due to white-band disease. Reefs on the southern and western coasts have been severely degraded by recreational uses, and by various kinds of pollution, including pollution from an oil refinery that closed in 1985 but re-opened in 1992 (Woodley et al. 1998).

A long tradition of coral reef research on Curaçao shows a dramatic lowering of coral recruitment. Rolf Bak assessed coral settlement and growth on permanent quadrants with photographs in the early 1970s. This was repeated and the results show that coral cover has changed little over the past 20 years, but the amount of coral settlement in 1999-2001 is now about one tenth that of 20 years ago. Also the amount of variation between years is 3.7 times smaller, meaning that the trend looks consistent. The massive reductions are linked to a loss of crustose coralline algae, which is where many new coral larvae are attracted to settle, and large increases in macroalgae (mainly *Lobophora* and *Dictyota*) and sediment trapping turf algae. It is unlikely that the production of gametes and larvae by adult colonies has dropped as coral cover has hardly changed over the 20 years. These results show that determining coral reef health by observing coral cover is not enough for MPA management, as it appears that other factors are preventing the arrival of new corals (Wilkinson 2002).

In the past, *Acropora* corals formed dominant constituents of the shallow (<10 m) reef fauna and were found along the entire southwest coast of both Curaçao and Bonaire. In 1981, mass mortality occurred throughout the region (Roos 1971, Bak & Criens 1981, Van Duyl 1985). Van Duyl (1985) inventoried the shallow benthic communities (0-10 m depth) along the south coast of both islands in 1980-81 at a small spatial resolution (<1 m^2), and determined that live *Acropora* corals covered about 8 km^2 of the reef bottom or about 15% of the shallow reef terrace. Observations made by Vermeij and Bak from 1998-2002 indicate that there has been a 98% decline of *Acropora* coral cover over the same area in the past two decades. There appears to be no sign of significant recovery, although some individual *Acropora* colonies on northern coasts seem to have survived the mass mortality and may contain some adaptive genetic variation that has allowed them to persist (Bruckner et al. 2002).

St. Kitts and Nevis

The reefs now have lower species diversity than similar areas in the region, probably because of sedimentation, but are becoming increasingly important for diving tourists.

Marine conservation is focused on the low and dry Southeast Peninsula of St. Kitts, and on deeper reefs off the west coast, which have higher diversity and cover of coral than other reefs. However, there is no current monitoring of the reefs.

St. Lucia

There are narrow fringing reefs and coral veneers all along the volcanic island coast of St. Lucia, with some small patch reefs in the southeast. Data from west coast reefs indicate live coral cover frequently greater than 50% prior to a series of storms, beginning with Tropical Storm Debbie in 1994. In November 1999, the unusual track of Hurricane Lenny resulted in severe wave action on the leeward coast of the island, heavily damaging coastal infrastructure. Sedimentation from that storm reduced coral cover by 50% at some sites, particularly near large river mouths. Reef Check surveys in St. Lucia in 2001 show that the shallow reefs continue to be under stress with further declines since 1999 surveys. Live coral cover in 1999 ranged from 30-50% at four Reef Check sites, dropping to an average 6.9% in 2001. The shallow sites were dominated by standing dead *A. palmata*, which contributed to more than 50% of the total benthic cover. The deeper reefs appeared healthier than the shallow reefs with 17% cover, although this is still a decline from 1999. Bleaching was common in 1998 but did not result in high levels of mortality. In 1999-2000 there was an unusually high incidence of white band disease on reefs in the Soufriere Marine Management Area (Hoetjes et al. 2000, 2002).

St. Vincent and the Grenadines

The shelf around St. Vincent is narrow, with few reefs on the north and east coasts, but good coral grows on the rocks around headlands on the west coast, and there are some fringing reefs on the south and southeast coasts. Reef growth is much better on the shelves around the Grenadine Islands to the south. The condition of the Tobago reefs has deteriorated over the past 15 years due to storm damage, white-band and other diseases, physical damage from fishing gear and boat anchors, and localized pollution from visiting yachts (Smith et al. 1998). Live colonies of A. palmata that once flourished at Horseshoe Reef in the high-energy shallow-reef zones have virtually disappeared (Deschamps et al. 2003)

Trinidad and Tobago

Trinidad and Tobago are on the edge of the South American continental shelf, under the direct influence of the Orinoco River. Thus, there are comparatively fewer coral reefs in Trinidad than Tobago due to its proximity to the river delta. There is a single fringing reef on the northeast coast of Trinidad, and many patch reefs near the offshore islands, and particularly around Tobago. These reefs are heavily used for fishing and tourism with up to 200 tourists visiting Buccoo reef per day. In southwest Tobago, there are 1,654 hotels and another 1,372 rooms are approved for construction (Hoetjes et al. 2002).

CARICOMP data for Eastern Buccoo Reef, Tobago shows virtually unchanged cover of hard and soft corals or algae over five years. There are occasional elevated values of ammonia nitrates and petroleum hydrocarbons on some of the reefs, with discharges from land being the likely cause. The most common problems are coral bleaching and diseases, but these have generally been much less than elsewhere in the Caribbean. There was a major fish kill on Trinidad and Tobago reefs in 1999 that correlated with flooding of the major South American rivers (Hoetjes et al. 2002).

At the southwestern end of the island of Tobago, the Buccoo Reef and Bon Accord Lagoon system has reef habitat covering an area of 7 km^2. This system is the best example of contiguous reef, seagrass, and mangrove wetland in Trinidad and Tobago, and it is unique to the southern Caribbean due to its size, attractiveness, and easy accessibility (Goreau 1967). Such attributes have led to its development as a major tourist attraction, with guided tours to the reef first initiated in the 1930s (Laydoo et al. 1998).

The western areas of Buccoo Reef are composed of thickets of *A. cervicornis*, while those in the eastern area are composed of both *A. cervicornis* and *Millepora* spp. There are five emergent reef flats, generally characterized by a narrow seaward reef crest and a more extensive back reef. The reef crests are limited to wave-resistant corals such as *M. annularis*, and *A. palmata*, and the back reef areas are composed mostly of coral rubble. In the shallow fore reef zone (2-6 m depth) *A. palmata* is common. The substrate of the shallow fore reef is mainly composed of rubble and dead standing remains of *A. palmata* (Laydoo 1985). In October of 2001, surveys were done on three of the Buccoo reefs, finding about 10% of colonies were diseased, with bleaching on about 1-3% of colonies. The rate of disease at is higher than in other locations in the Caribbean, which may be attributable to the nearby Orinoco River, which carries large sediment and fresh water loads during the rainy season (Hoetjes et al. 2002).

The promotion of the Buccoo Reef area as a major tourist attraction, combined with hotel and residential development in adjacent coastal areas, has caused physical damage over an extensive area of the Outer Reef flat; corals have been broken or crushed by trampling feet, falling anchors, and intermittent boat groundings. Indirect impacts are more insidious and are linked to the discharge of untreated sewage and to increased surface run-off (Laydoo and Heileman, 1987). Pollution threatens the viability of the reef through nutrient enrichment of the seawater and increased algal growth. This, combined with the effects of reef walking, potentially reduces the possibility of coral regeneration in damaged areas. Sewage pollution at some localities presents a serious hazard. Buccoo Reef system was designated in 1973 as the country's only marine protected area under the Marine Areas (Preservation and Enhancement) Act of 1970. However, no effective management has been implemented since its designation as a protected area (Laydoo et al. 1998).

Turks and Caicos Islands

These reefs are similar to those of the Bahamas with a deep fore-reef dominated by gorgonians and boulder coral *Montastrea annularis*. Green algae are abundant on the fore reef, especially *Laurencia, Microdictyon* and *Lobophora*. The reefs have changed little since AGRRA surveys in 1999 and levels of coral mortality remain low, while coral diversity and cover remain relatively high (>30% at several locations). Coral disease and bleaching are rare, and a wide variety of target fish species such as groupers are evident. There are low levels of bleaching in South Caicos (Linton et al. 2002).

However, tourism development on the Turks and Caicos Islands is rapidly threatening the relatively healthy reef system, particularly the remote cays where tourists dive. The major threats to the reefs around Providenciales are pollution from sewage and anti-fouling paints in marinas, coastal development, fish processing plants, conch aquaculture, coral breakage by divers and anchors, boat groundings, and construction of tourism infrastructure. Several large developments and the likely introduction of cruise ships to Providenciales, Grand Turk, West Caicos, East Caicos, and South Caicos threaten the viability of the National Parks, Nature Reserves, and Sanctuaries adjacent to these areas. Fishing pressures are substantial, in particular in the South Caicos, Grand Turk, and Providenciales region. It is unlikely that conservation measures and enforcement will be able to keep up with the likely negative impacts of these activities, unless additional resources are diverted to the protection and enhancement of the marine resources (Linton et al. 2002, Homer & Shim 2000).

AGRRA surveys in 1999 at Grand Turk, Providenciales, West Caicos, South Caicos, Ambergris Cay, and the Mouchoir Bank found coral mortality was low (<1%), diversity was high (37 coral species), and coral cover was as high as 30% at several locations. Almost no macroalgae were found except in the Mouchoir Bank, Ambergris Cay, and in the shallow palmata zone. On the east-facing banks, dead *A. palmata* stands were more abundant than live ones and *A. cervicornis* was rare. The level of active coral diseases was low, but many different diseases were seen, especially on the north side of Providenciales where tourism activities are intense, and at other heavily dived sites (Woodley et al. 2000).

In 2000, the Coastal Resources Management Project (CRMP) also assessed reefs around Providenciales and West Caicos. Live *A. palmata* which was noted to be a dominant component from previous reports has been significantly reduced to 0-2% in most areas and up to 5-15% in the best sites, most likely the result of disease (Homer & Shim 2000). At Northwest Point and West Caicos, coral cover on the flat at the top of the wall was relatively low (<20%) and algae (*Dictyota* and *Lobophora* spp) were abundant. On the reef face at 15-25 m hard coral cover ranged from 20-50%; generally with 30-60% algal cover (*Lobophora*). Deeper on the reef wall there was higher hard coral cover of 30-60%, and lower *Lobophora* (20-50%). In the most popular near shore patch reef in Providenciales (1-3 m depth on Bight Reef), there is repeated damage by snorkelers trampling and breaking coral, especially at low tide (Woodley et al. 2000). Hard coral cover was generally of the order of 2-5% and 10-30% at a few sites (Homer & Shim 2000).

Acropora palmata, *Acropora cervicornis*, and *Acropora prolifera* are "Species" under the ESA

The ESA provides for the listing of all species warranting the protections afforded by the Act. The term "species" is defined broadly under the act to include "any subspecies of fish or wildlife or plants and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature," 16 U.S.C. § 1532 (16).

This petition requests listing of *Acropora palmata*, *Acropora cervicornis*, and *Acropora prolifera* because all three are clearly endangered. *A. palmata* and *A. prolifera* are without a doubt distinct species that individually deserve listing. Current taxonomic literature also identifies *A. prolifera* as a separate species, although its phylogenetic classification remains unresolved. *A. prolifera* is also extremely rare, so even if all three species were evaluated as a single entity listing would still be warranted. Furthermore, given the difficulty in visually differentiating between the Caribbean *Acropora* spp., *A. prolifera* merits ESA protection under the similarity of appearance provision of the Act. 16 U.S.C. § 1533(e).

Acropora palmata, *Acropora cervicornis,* and *Acropora prolifera* are "Threatened" or "Endangered" under the ESA

NOAA Fisheries is required to determine, based solely on the basis of the best scientific and commercial data available, whether a species is endangered or threatened because of **any** of the following factors[10]:

1. The present or threatened destruction, modification, or curtailment of its habitat or range.
2. Over utilization for commercial, recreational, scientific or educational purposes.
3. Disease or predation.
4. Other natural or manmade factors affecting its continued existence.
5. The inadequacy of existing regulatory mechanisms.

All five of these factors apply to the decline of *Acropora palmata*, *Acropora cervicornis,* and *Acropora prolifera*. The *Acropora* spp. meet the definition of species which are endangered or threatened "throughout all or a significant portion of its range."[11]

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[10] 16 U.S.C. §1533(a)(1) and (b).

[11] 16 U.S.C. §1532(6) and §1532(20)

Current or Threatened Habitat Destruction or Modification or Curtailment of Habitat or Range

Hurricanes

The catastrophic effects of hurricanes and tropical storms on coral reefs have contributed significantly to the decline of the *Acropora* spp. Climate models indicate that the frequency and severity of these storms will increase in the future as a result of human induced global warming (Figure 30). Several NOAA simulations have concluded that a CO_2 induced warming of about 2° C will result in increased surface wind intensities of roughly 3-10%, with some studies predicting as much as a 20% increase in storm intensity (Knutson et al. 1998, 2001, Knutson & Tuleya 1999, Henderson-Sellers et al. 1998, Walsh & Ryan 2000). Hurricanes and tropical storms physically damage coral reefs by breaking off colonies (Figure 31) and polluting the waters with sediment and runoff from flooded coastlines and rivers. Although the *Acropora* spp. have adaptations allowing them to inhabit high-energy reefs, including using breakage caused by physical forces associated with storms and hurricanes as a mechanism for reproducing clonally, fragmentation is harmful when it occurs too frequently. Previously, fragmentation was thought to be adaptive, with high survivorship of hurricane generated fragments and a rapid recovery of affected zones (Glynn et al. 1964, Highsmith 1982). However, recent observations indicate that initial mortality to colonies and fragments may be quite high, with injured colonies and fragments exhibiting reduced growth rates and declines in reproductive output. Additionally, damaged populations are susceptible to subsequent disturbances (Lirman 1998). In Puerto Rico, populations damaged by storms have continued to decline, with high incidence (40-60%) of fragment mortality within the first 90 days (Bruckner et al. 1997). Evidence in a study of *A. palmata* found that when storm frequency approaches every two years a steady decline in abundance of colonies may occur (Lirman 2002).

The detrimental effect of frequent hurricanes to the *Acropora* spp. is evidenced in the U.S. Virgin Islands. After white-band disease reduced *A. palmata* populations from 85% cover to 5% cover during the 1980s, Hurricane Hugo (1989) hit Buck Island Reef National Monument (St. Croix) with winds approaching 259 kph. In the shallow fore reef zone where *A. palmata* historically dominated, the remaining population was leveled to less than 1% (Gladfelter 1991a, 1991b). Recovery has been very slow due to frequent passage of additional hurricanes in 1995, 1998, and 1999 (Turgeon et at. 2002).

In the Florida reef tract, Hurricane Andrew (August 1992, with winds in excess of 230 kph) and Tropical Storm Gordon (November 1994, with winds up to 70 kph) likewise caused multiple disturbances to the *Acropora* spp. Andrew caused extensive colony fragmentation in shallow reefs (Tilmant et al. 1994). Tropical Storm Gordon reversed the damage pattern, affecting the deeper reefs this time. The fragments created by the first storm were subsequently covered in dead *A. palmata* rubble transported by Gordon. The final result was a net loss of coral cover attributable to the frequency of the storms (Lirman & Fong 1995).

In 1980, Hurricane Allen followed an incredibly destructive path near Discovery Bay, Jamaica. It was the strongest storm recorded at the time, hitting populations of *Acropora cervicornis* particularly hard (Woodley et al. 1981, Knowlton et al. 1981). The devastation was an important precondition for the phenomenal level of macroalgal overgrowth that occurred over the following decade (Liddell & Ohlhorst 1992). Direct mortality of the *Acropora* spp. from the storm combined with collateral mortality from predatory fish and invertebrates, reduced herbivorefeeding from a long history of over fishing, and the Caribbean-wide mass mortality of the echinoid *Diadema antillarum* in 1983–84 to set the stage for Jamaica's dramatic loss of its once extensive coral reefs (Hughes et al. 1987, Knowlton et al. 1990, Knowlton 1992). Today, the reefs once dominated by coral are covered in algae and the thickets of *Acropora* spp. are virtually gone.

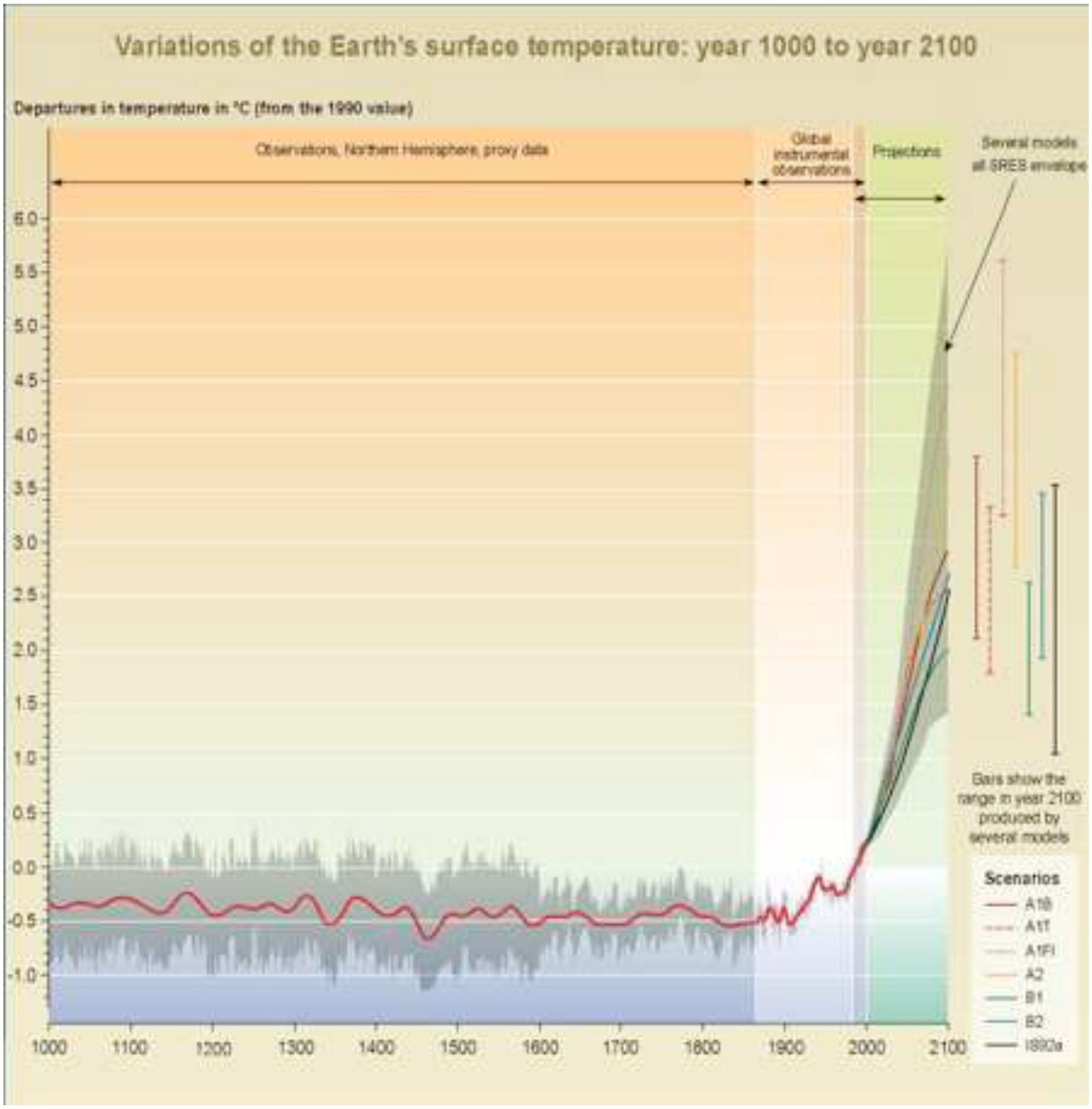

Figure 30: CO_2 induced warming increases hurricane frequency and severity, induces bleaching, and raises sea levels. The graph above shows six simulations that predict future warming [IPCC]

Figure 31: Overturned *A. palmata* on Andros Island, Bahamas [Sean Nash]

Physical Damage by Boats and Anchors

Boat traffic is a major threat wherever humans come in contact with coral reefs. Propellers speeding through shallow waterways break corals, scar seagrass beds, and kill endangered marine mammals. Groundings and anchor damage are considered some of the most destructive chronic human factors causing significant localized damage to shallow-water coral reefs (Turgeon et al. 2002). Coral reef damage associated with ship groundings includes the direct loss of corals and other benthic invertebrates when they are dislodged, fractured, and crushed. Groundings also increase the risk of contamination from oil and toxic chemical spills. Large ports located near shallow water reefs such as those in Palm Beach, Florida, San Juan, Puerto Rico, and virtually any island port in the Caribbean, increase the probability of vessel collisions with reefs. Over the past decade, moderate to severe large vessel groundings have damaged reef structures in the US a number of times, including those in southeastern Florida, Puerto Rico, and the USVI (Turgeon et al. 2002). In 2002, a cargo ship dropped anchor in the Florida Keys National Marine Sanctuary near the Dry Tortugas. The anchor smashed more than 1,000 rare corals in a 6,600-square-foot area of one of Florida’s most pristine dive sites. (SF Chronicle, Nov 2002).

Dredging

The continuous dredging of harbors and lagoons for shipping and anchorage directly impacts coral reefs with sediment and pollution. The subsequent loss of reef structure removes protection from ocean waves and storms, exposes shorelines to increased tidal action, and facilitates coastal erosion and degradation. Dredging sand to replenish beaches degrades water quality during the operation, causes silt that buries corals, removes protection from storms, and requires frequent reapplication every 5-10 years. Reef managers in every US Atlantic-Caribbean jurisdiction rate dredging related activities at the highest level of concern (Turgeon et al. 2002).

Coastal Development

Coastal development causes both short and long term damage to corals. During initial development, construction can physically damage reefs though dredging to create and maintain shipping channels, building of marinas and docks, and disturbance of the shoreline causing erosion, sedimentation, and increasing water turbidity. After construction, long-term chronic impacts include pollution from sewage and chemicals associated with the increased human presence and storm run-off from roads (Turgeon et al. 2002). Throughout the range of the Caribbean *Acropora* spp., reefs close to population centers, ports, and tourism are either of lower quality than reefs removed from such activities or they have simply disappeared. In countries such as the Dominican Republic, Haiti, and Jamaica, where economic development is heavily dependent on the marine environment, the deterioration of the reef system is particularly conspicuous (Linton et al. 2002). In the United States, specific polluted “hot spots” have been identified near reefs in Florida, Puerto Rico, and the USVI (Turgeon et al. 2002). Some areas on the Yucatan Peninsula, Florida, and some Caribbean islands have up to 40% of the coastline developed, and much of the shoreline of other countries is now artificial. (Turgeon et al. 2002)

One particularly egregious example is Puerto Rico, where the status of the coral reefs is amongst the most critical in the Caribbean as a consequence of accelerated urban and industrial coastal development during the last 40 years, combined with a lack of effective management of these resources. Massive clearing of mangroves, dredging of rivers for sand and harbors, runoff from large-scale agricultural developments, deforestation in large watersheds, and raw sewage disposal, are all major stress to the reefs (Causey et al. 2002). Where dense *Acropora* thickets once existed, virtually none remain (Bruckner et al. 2002).

Unlike Puerto Rico, Cuba’s reefs are considered some of the best in the Caribbean. Typically the reason given is minimal coastal development on the north and south coasts and the fact that many reefs are offshore and outside the influence of land-based sources of pollution (Linton et al. 2002).

Agricultural and Land Use Practices

Of increasing concern is degradation of the coral reefs caused by agricultural and other activities inland, sometimes far from the coast. Sediment from agricultural and land use practices results in increased nutrient levels of near-shore waters. High nutrient levels promote the growth of algae over coral and eventually can transform coral reefs into algal fields devoid of hard coral cover (Turgeon et al. 2002). In Haiti for instance, heavy logging, fires, and overgrazing have resulted in sediment-laden watersheds silting the coastal reefs and promoting heavy algal growth (Lang et al. 1998). In Central and South America, the most serious threat to coral reefs is from increased sediment runoff from logging, land clearing, and agriculture, particularly in the inland forests and on mountain slopes. This has resulted in losses in coral cover, and reduced reproduction and growth on the Caribbean and Pacific coasts of Costa Rica, in the Santa Marta area in Colombia, and Morrocoy Natural Park in Venezuela. These threats to reefs are predicted to continue (Garzón-Ferreira et al. 2002).

The poor condition of reefs in Jamaica's Negril Marine Park is also attributed to eutrophication. Data from the Negril Coral Reef Preservation Society (NCRPS) confirms that macroalgal biomass on the reefs in Negril is at critical levels, particularly on reefs near the mouth of the South Negril River. Sewage and land run-off carrying agricultural fertilizers are the primary contributors to the high nutrient loadings around Negril (Linton et al. 2002, Causey et al. 2002).

Rum Distilleries

Rum distilleries discharge toxic pollutants directly into the ocean and coastal zone in many areas throughout the Caribbean. The U.S. EPA cited the Bacardi Corporation for Clean Water Act Violations in Puerto Rico in 2001 stemming from waste discharges at a distillery that were toxic to mangroves and coral reefs (EPA PR# 01053 2001). Untreated rum-effluent from a distillery in St. Croix, USVI results in an 8 km benthic 'dead zone' caused by the high toxin levels and raised temperatures, but the U.S. EPA still grants an exemption to the distillery each year (Causey et al. 2002).

Damaging Fishing Practices

In Nicaragua, Honduras, Mexico, Haiti, Cuba and other nations that contain poor or depressed coastal communities there are problems with excessive and damaging fishing practices. Many subsistence fishers continue to employ fishing practices that are destructive to corals such as the use of dynamite or other explosives that stun fish and destroy the reef corals in the process. Fishers also sometimes drag or scour nets across reefs causing physical damage to colonies (Kramer et al. 2000).

Over Utilization for Commercial, Recreational, Scientific or Educational Purposes

Divers

While hurricanes break the most corals, chronic coral damage also occurs at areas of high recreational use by snorkellers and divers (Causey et al. 2002). Divers and snorkelers can cause damage quite easily by touching live corals or by selectively exterminating certain species by collecting. In addition to physically destroying corals, divers stir up sediments, possibly act as vectors for disease, and can cause considerable harm by visiting overhanging crevices and exposing corals to trapped exhaust air. Divers also increase boat traffic to reefs, which opens the reefs to the harms associated with boat traffic, e.g. groundings, collisions and anchoring causing scarring or breakage, chemical pollution, and disturbance of the sea floor in shallow waters. Many popular snorkel and dive sites experience heavy visitor use, for example on St Croix in the USVI and at Buccoo reef off Tobago, more than 200 visitors a day is not uncommon (Causey et al. 2002, Hoetjes et al. 2002).

Commercial Aquarium Trade and Illegal Harvest

The United States is by far the world's largest importer of coral reef organisms for curios, jewelry, and the marine aquarium industry. Paradoxically, the U.S. either prohibits or strictly limits the extraction of stony corals in its own federal, state, and territorial waters because of widespread concerns that the organisms are vulnerable. Nonetheless, 70-80% of the live coral, 95% of the live rock, and 50% of the dead in international trade is imported into the U.S. each year, and the global trade in corals is increasing at a rate of 10-20% per year. In 1997 over 500,000 items and 15,000 kg of stony corals, and 410,000 items and 600,000 kg of reef substrate (live rock) were imported into the U.S. In 1998 the U.S. imported 550,000 items and 94,000 kg of stony corals and 570,000 items and 890,000 kg of reef substrate. Corals extracted for curios are primarily fast-growing branching species (e.g. *Acropora* spp.). Large size specimens are more valued and the trade targets reproductively mature colonies. In some instances, harvesting for the souvenir and aquarium trade has introduced the use of chemical substances such as bleach that affect corals and other non-target species (Bruckner et al. 2002, NOAA http://www.nmfs.noaa.gov/prot_res/PR/tradeincorals.html).

Recreation and Tourism

Degradation of coral reefs from heavy collecting and other recreational and tourism uses is becoming more widespread, particularly in the Caribbean Sea. The lagoons of fringing reefs usually form a shallow natural pool, which is very popular among tourists and locals, resulting in a steep gradient of coral destruction in the shallow water zones of impacted reefs. It can range from 100% mortality in lagoons, to roughly 60-70% mortality in highly structured back reefs. More trouble arises when tourism takes off at a big scale. Infrastructure is a main source polluter and creates a lot of silt while in the construction phase. Pollution continues after completion when sewage treatment plants dump their contents into the ocean causing nutrient overloading and promoting algal growth. Economic activities like container ports, ferry terminals, boat traffic, and uncontrolled anchoring further increase the degradation of reef ecosystems.

Disease or Predation

Disease

Western Atlantic reefs have become a “hot spot” for diseases as a consequence of increased virulence, spread, and host range of coral diseases, a recent emergence of new diseases, and the relatively small, enclosed, and interconnected nature of the Caribbean basin (Bruckner et al. 2002). Coral diseases are inadequately understood and often misidentified both in the field and in scientific literature. Moreover, while hundreds of studies have been published on coral diseases since Antonius first reported coral disease in 1973, the causative agent has been confirmed for only three diseases (Bruckner 2003). In the *Acropora* spp., white-band disease is the most significant cause of mortality throughout the Caribbean (Turgeon et al. 2002).

The increase in numbers and severity of coral diseases (Cervino et al. 1998, Richardson 1998) suggests that reef corals, especially in the Caribbean, may be more physiologically stressed now than they have been in the past 5,000 years or more (Aronson & Precht 1997, Greenstein et al. 1998).

White-band Disease

White-band disease (WBD) (Figure 32, Figure 33, & Figure 34) has been the most significant cause of mortality to *A. cervicornis, A. palmata,* and *A. prolifera* throughout the western Atlantic, Gulf of Mexico and Caribbean (Gladfelter 1991). Their populations declined as much as 95% in the 1980s and early 1990s from direct mortality by WBD (Aronson & Precht 2001b). White-band disease is a type of necrosis, which can cause extensive local mortality of coral (Gladfelter 1982). It is of uncertain pathogenic origin, causing the coral's tissues to die and slough away in white-bands and patches. It has been reported in epidemic proportions in populations of *Acropora* corals throughout the Caribbean. The etiology of WBD and the causes of outbreaks are poorly understood and recent reports suggest that there are several varieties of the disease. Two forms are currently recognized.

WBD-I: Cases of WBD-I are recognizable as segments of bare skeleton, sometimes bordered by narrow bands of disintegrating necrotic tissue on otherwise healthy looking *Acropora* branches. The bands of disease spread along the branches from base to tip, eventually killing entire colonies. a rod-shaped bacteria has been found in the tissues of affected corals, but the role of this microorganism in the development of disease has not yet been determined.

WBD-II: WBD-II has been reported among *A. cervicornis* species, in which affected colonies bleach in a band that advances up the branch followed by progressive tissue necrosis (Ritchie & Smith 1998). Bacteria of the genus *Vibrio* have been found in the surface mucous of the bleached margin. The advance of white-band disease dramatically exceeds the growth of regenerating branches resulting in decline of the population (Davis et al. 1986).

WBD is strongly affected by abiotic conditions such as increased sea surface temperature. Stressed colonies are more easily susceptible. Reef structures affected by WBD can lead to a massive die-off, always accompanied by biotic activity of epizoic parasites such as Gram^{NEG} rod-shaped bacteria, ciliates, protozoans, acoel turbellarians, nematodes, tiny copepods, and/or amphipods. The forming algal overgrowth subsequently results in the death of the coral colony through colonization by bioeroding endolithic invertebrates, gastropods, and boring cloinid sponges that render the remaining "healthy" structure more susceptible to breakage during storms. WBD outbreaks are sometimes triggered by the settlement of blue-green algae (Madl & Yip 2002).

Figure 32: WBD on *A. palmata* [Andrew Bruckner]

Figure 33: WBD on *A. cervicornis* [Andrew Bruckner]

Figure 34: Another example of WBD on *A. palmata* [Andrew Bruckner]

White Pox Disease (Acroporid serratiosis) / Patchy Necrosis

Populations of *A. palmata* have been decimated by white pox disease, also known as patchy necrosis (Figure 36) with losses of living cover in the Florida Keys typically in excess of 70% (Patterson et al. 2002). The catastrophic declines of *A. palmata* documented thus far are comparable to the losses documented for this same species in St. Croix due to white-band disease (Gladfelter 1982). Patterson et al. (2002) identified a common fecal enterobacterium, *Serratia marcescens,* as the causal agent of white pox. This is the first time that a bacterial species associated with the human sewage has been implicated as a marine invertebrate pathogen (Patterson et al. 2002). White pox disease is highly contagious. First observed in 1996 effecting *A. palmata* in Florida, by 1997 white pox was found at all surveyed reefs in Florida that had *A. palmata* (Porter et al. 2002). It has since spread throughout the Caribbean region. The rate of tissue loss is rapid, averaging 2.5 cm^2/day (Harvell et al. 1999), and is greatest during periods of seasonally elevated temperature (Figure 35) associated with global warming (Patterson et al. 2002).

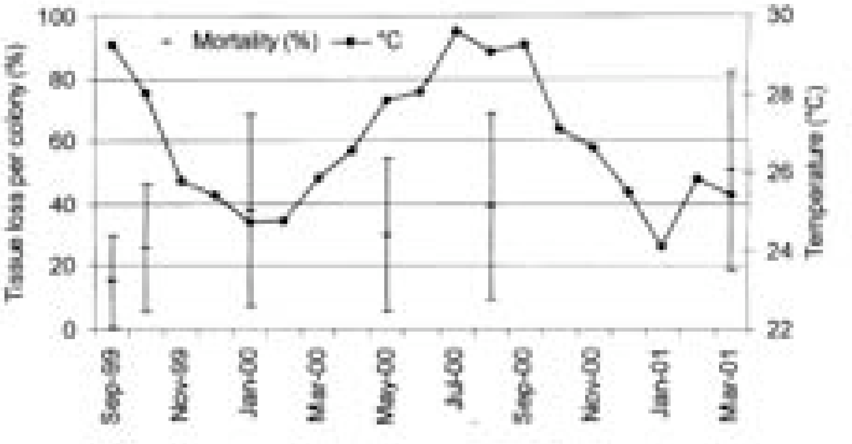

Figure 35: *A. palmata* mean tissue loss as a percentage of total colony area of *A. palmata* colonies (± SD) and monthly average SST sampled daily at the Research Station dock in Puerto Morelos, Mexico. CARICOMP. [Rodriguez et al. 2001]

A recent event of patchy necrosis in southwest Puerto Rican reefs produced moderate levels of partial tissue mortality in a high proportion of colonies in a relatively short period of time (November 13-18, 2002). On average, 35-74 % of all colonies of *A. palmata* in six reef areas were affected by this syndrome. Average tissue loss varied between 14% and 17% of the colony surface area. While most of the tissue recovered, in some areas a layer of turf algae and sediment seemed to slow down the advance of the new growth (Weil et al. 2002). On Puero Morelos reef, in the Mexican Caribbean, patchy necrosis was identified in both *A. palmata* and *A. prolifera*. Although *A. palmata* colonies with necrotic patches have been observed on this reef in the past 20 years, the density and widespread distribution observed in 1999 was unprecedented (Rodríquez-Martínez et al. 2001).

Figure 36: Patchy necrosis effecting *A. palmata* [Andrew Bruckner]

Shut-down Reaction

Antonius (1977) first reported this condition in Florida and Belize, and it affects *Acropora* spp. and massive corals by inducing the polyp to cease all vital functions and die. This disease is often referred to as Rapid Wasting, Rapid or Stress Related Tissue Necrosis, White Plague, or White Death. Observations in laboratory experiments and field observations of corals under sublethal (abiotic) stress such as elevated temperature, sedimentation, and chemical pollution have revealed that specimens can die from a simple scratch. Sudden disintegration of the coral tissue starts at the margins of the injury and is characterized by sloughing off of tissue in thick strands from the coenosarc, leaving behind a completely denuded coral skeleton. From the initial interface, the phenomenon proceeds in an enlarging circle on massive corals, or moves along the branches in ramose forms, spreading to all side-branches upon reaching a junction. SDR is especially dangerous as it can spread with an average speed of 10 cm/hour - fast enough to be visually observed. Being contagious, a floating strand of contaminated tissue can transmit SDR to produce an onset in a neighboring stressed colony, thus triggering a catastrophic chain reaction which may occur several times during the course of a season (Madl & Yip 2002).

Calicoblastic Neoplasm

Tumors of calicoblastic neoplasms are raised, whitened, abnormal lumps on coral colony surfaces with distorted polipary structure. It is a pathologic process that results in the formation and proliferation of an undifferentiated mass of cells. These cells grow and multiply more rapidly than normal and lack the structural organization and function of normal tissue. First noted by Squires in 1965, their effect on growth and regeneration was examined in Curaçao (Bak 1983). Neoplasms are thought to reduce the reproductive potential of coral, and they are susceptible to ulceration and invasion by filamentous algae. Affected areas lack mucous secretory cells and are very porous, increasing vulnerability to sedimentation and wave stress (Peters et al. 1986). Instances of Calicoplastic neoplasms were reported from Carysfort Reef, Florida in 1975 and Grecian Rocks, Florida in 1982. They are known to occur sporadically at low levels throughout the Caribbean (Peters et al. 1986).

Predation

Predation of corals is a natural part of the reef ecosystem. However, as the reefs are continually facing increasing stress, predation can have unnaturally strong detrimental effects. In cases such as the damselfish and the corallivorous snail, the incidence of predators is increasing even as the number of corals is decreasing. The following is a summary of five species that prey directly on corals throughout the Caribbean.

Fireworm (Hermodice carunculata)

A major coral predator is the fireworm, which eats *A. cervicornis* and denudes the branch tips of their living tissue. The predation marks show up as scars several centimeters long. The fireworm also digests tissue of *A. palmata* and the predation scars appear as white patches (Glynn 1963, Antonius 1977, Bruckner et al. 2002).

Figure 37: Fireworm [Sean Nash]

Corallivorous Gastropod (Coralliophila abbreviata)

The Corallivorous gastropod (Figure 37) is a type of snail that is also a major predator of *Acropora* corals (Rylaarsdam 1983). Both the fireworm and gastropod have become more prevalent and cause more damage to *Acropora* coral populations in Puerto Rico and the Florida Reef Tract in part as a result of over-fishing of their predators, the octopus, and spiny lobster (Bruckner et al. 1997b, Szmant 1997). In addition to an increased number of individuals, as a consequence of reduced *Acropora* populations these predators have become more concentrated (Knowlton et al. 1990). In a Florida Keys study, sites with low density *A. palmata* had consistently more snails than sites with higher density thickets (Miller et al. 2002b).

The gastropod is an excellent example of the interaction and subsequent magnification of coral stresses. After Hurricane Allen heavily damaged *Acropora* populations, *Acropora* colonies that could formerly sustain a low level of predation by the snail could no longer cope with the same predation level after the storm. After the storm caused initial damage, the snail was subsequently responsible for the demise of the few remaining colonies (Knowlton et al. 1981).

Figure 38: These snails leave white trails of exposed skeleton where they've eaten the coral [Craig Quirolo]

Long-spined Sea Urchin (Diadema antillarum)

Although not widely documented, the long-spined sea urchin (Figure 39) is known to eat *Acropora* (Bak & Van Eys 1975, Sammarco 1980, 1985). It does so actively when starved, but may also do so opportunistically while feeding on algae growing next to coral tissue. It should be noted, however, that the dramatic loss of this urchin to 3% of its original size in the early 1980's has been cited as a catalyst for the increases in fleshy algae that currently plague coral reefs. In many cases urchin numbers remain as low as 1% of their pre-1983 levels (Turgeon et al. 2002).

Figure 39: Spiny Urchin [Sean Nash]

Stoplight parrotfish (Sparisoma viride)

Parrotfish (Figure 40) bite at coral branches, removing tissue and the underlying skeleton (Bruckner and Bruckner 1998). Parrotfish feed on the endosymbiont zooxanthallae of the coral tissue, producing extensive scrape marks and destruction of tissue and skeleton. In stressed colonies, filamentous algae often colonize the patches, whereas under normal conditions the coral tissue and skeleton recovers. The constant scraping of parrotfish is an element in transmitting diseases from one colony to the next.

Figure 40: This little Parrotfish is busy eating his coral lunch [Sean Nash]

Damselfish

Damselfish (Figure 41) bite repeatedly at the same location on *A. palmata* branches creating conspicuous lesions that are then colonized by macroalgae. Regeneration of these lesions is continually interrupted and, as a result, the surrounding polyp secretes a wall of tissue and skeleton around the lesion and encloses the macroalgae. The loss of herbivores and large predatory fish has stimulated the proliferation of small fish like the damselfish, thereby multiplying their damaging effect on reefs (Causey et al. 2002, Bruckner et al. 2002).

Figure 41: Threespot Damselfish [Sean Nash]

Other Factors

Global Warming and Coral Bleaching

Coral reefs share a symbiotic relationship with dinoflagellate microalgae called zooxanthellae. Zooxanthellae photosynthesize while residing in coral and provide their hosts with almost 95% of their resulting energy and nutrients (Muscatine 1990). Corals receive amino acids, sugars, complex carbohydrates, and small peptides and in return provide their zooxanthellae with necessary plant nutrients, such as ammonia and phosphate from their waste metabolism (Trench 1979). These are especially crucial since the water column usually lacks such inorganic nutrients (Hoegh-Guldberg 1999). Coral reefs are very sensitive to temperature change and can tolerate only a few degrees above normal high temperatures (Berntson & Mathews-Amos 1999). Sea surface temperatures of even one degree Celsius above normal summer highs and lasting for at least 48 hours are useful predictors of later bleaching (Strong et al. 1999). Once temperatures rise, corals will expel their zooxanthellae, resulting in a loss of pigmentation (thus the term "bleaching"; Figure 42, Figure 43, & Figure 44) and nutrition (Williams 2000). If temperatures remain unchanged, the exposed coral tissue will eventually die (Williams 2000). Seaweed and other organisms will probably colonize the coral skeleton (Hayes & Goreau 1998). If the skeleton remains intact, sea life may erode the reef and make it easily destroyable by storms (Hayes & Goreau 1998). Once coral reefs become rubble, shoreline erosion increases, fish and other organisms cannot be supported, fisheries stocks greatly decrease, and the tourist industry suffers (Hayes & Goreau 1998).

Figure 42: Partially bleached *A. palmata*, Andros Island, Bahamas [Sean Nash]

Figure 43: Fully bleached *A. plamata* colony [Andrew Bruckner]

Coral may have a chance for survival after bleaching if the temperature cools. However, corals require at least four to five years to fully recover their zooxanthellae, and bleaching episodes are now occurring at least every two to three years (Williams 2000). Within this period of recovery, corals can be more susceptible to injury and diseases (Williams 2000). Six widespread bleaching events lasting between one to three years and increasing in severity have occurred since 1979 (Williams 2000). While the connection between high water temperatures and coral bleaching is no longer disputed, the scientific community did not fullyaccept this causal relationship in the early 1990's despite field and aquarium experimental proof (Williams 2000). However, this relationship is now incontrovertible (Strong et al. 2000, Wilkinson et al.1999, Hoegh-Guldberg 1999, Hughes et al. 2003).

Figure 44: Bleaching on *A. cervicornis* [Andrew Bruckner]

Coral Species in Particular Danger

A. palmata, *A. cervicornis*, and *A. prolifera* have suffered higher mortality rates than other coral species because of bleaching. Before 1980 (the last year of the first widespread bleaching event recorded in history), *A. palmata* was the dominant species in the Caribbean and the Florida Reef Tract (Bruckner et al. 2002). Over the last ten thousand years, this species has been one of the three most important Caribbean coral in terms of reef development and fish habitat (Williams 2000). *A. palmata* now exists sparsely in southern Florida, the Bahamas, and throughout the Caribbean (Williams 2000).

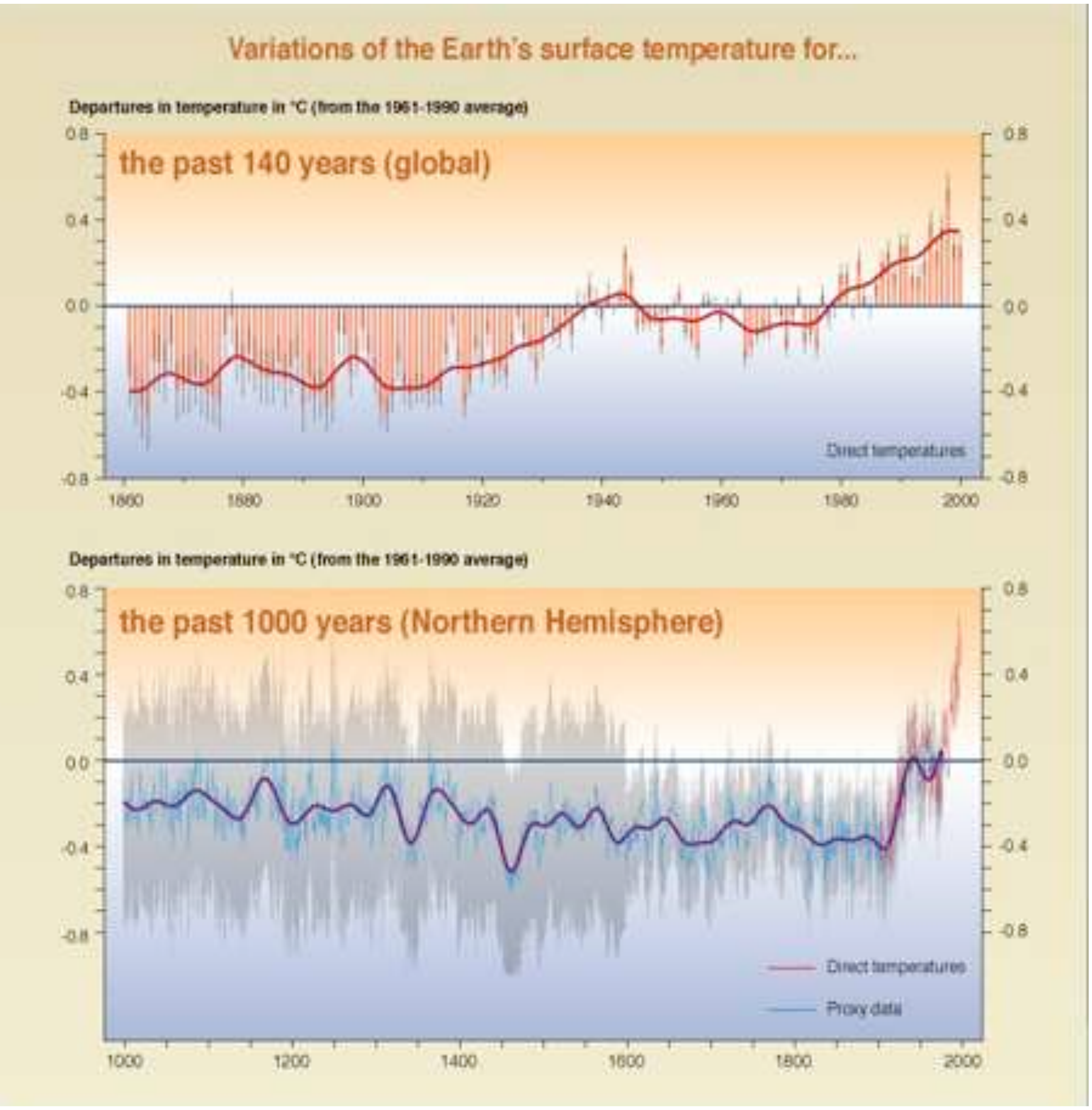

Figure 45: Humans have dramatically affected global temperature change over the last 100 years [IPCC]

In 1998, the year the World Meteorological Association has declared the warmest year on record (Figure 45), the most severe coral bleaching event ever occurred worldwide. Bleaching affected the *Acropora* spp. throughout their range, showing a clear relationship to exceptionally high sea surface temperatures (Figure 46). For example, in July, August, and September of 1998 bleaching was reported throughout the Florida Keys. At Coffins Patch Light bleaching correlated with water temperatures of 30-31^{o} C. In the Western Sambo Ecological Reserve, bleaching was seen in up to 90% of *A. palmata*, with some mortality, 50-80% of *A. cervicornis*, and 40-60% of other corals. There was moderate bleaching between 10 and 30 m in Dry Tortugas National Park and on the Tortugas Banks. Approximately 15-25% of colonies were affected with water temperatures around 30^{o}C. There was also evidence of bleaching at Ft. Jefferson. Similar extensive bleaching effected *Acropora* populations throughout the Caribbean (Wilkinson et al. 1998).

Figure 46: This a sea surface temperature anomaly, or 'hot spot' map derived from NOAA AVHRR (Advanced Very High Resolution Radiometer) satellite data showing elevated sea surface temperatures on September 29, 1998 [Zahedi et al. 1999]

Coral reef species differ in their sensitivities to bleaching. Some species have deep tissues and are more resistant, while some, especially the *Acropora* spp. have veneer tissue configurations that are easily susceptible to bleaching (Hoegh-Guldberg 1999). *Acropora* corals show such sensitivity to warmer waters that up to 95% of colonies can bleach and die in the three to six months after temperature stress (Hoegh-Guldberg 1999). Besides being extremely susceptible to bleaching, the *Acropora* spp. are particularly in danger because they take around four to five years to mature while present bleaching events occur as frequently as every two to three years (Williams 2000). This means the corals suffer from bleaching before they recover from prior events or become stronger and sturdier upon reaching the adult phase. Furthermore, coral species are not likely to adapt or acclimatize to warmer temperatures, because bleaching concerns the expulsion of zooxanthellae and there is no evidence that corals bleach to exchange one type of zooxanthellae for another (Gates et al. 1992). It is also unlikely that corals can acclimatize since there is no pattern suggesting that corals are getting better at dealing with temperatures exceeding their thermal limits. Corals seem to be just as near their thermal limits as they were when major bleaching events began in the late 1970s and early 1980s (Hoegh-Guldberg 1999). In fact, during the six major bleaching events some coral regions have bleached every time (Hoegh-Guldberg 1999).

The frequency of bleaching is expected to rise quickly (Linton et al. 2002, Turgeon et al. 2002), especially in the Caribbean, and most regions will experience bleaching every year within thirty to fifty years (Hoegh-Guldberg 1999). In 2000, the United States Department of State acknowledged the severe effects of global warming and bleaching on coral reefs, stating:

> *"The mass coral bleaching and mortality events of 1998 may not be accounted for by localized stressors or natural variability alone. Rather, the effects of these factors were likely accentuated by an underlying global cause. It is probably that anthropogenic global warming has contributed to the extensive coral bleaching that has occurred simultaneously throughout the disparate reef regions of the world. Thus, the geographic extent, increasing frequency, and regional severity of mass bleaching events are an apparent result of decades of rising marine temperatures and strong regional climate events."* (US Dept of State 1999).

Relation to Hurricanes and Coral Disease

Virtually every scientific report concerning the status of the Caribbean *Acropora* spp. notes that the two primary threats to the species are hurricanes and disease. Global warming has a direct effect on the frequency and intensity of both these threats. Simulations of hurricanes based on expected increases in atmospheric CO_2 predict as much as a 20% increase in hurricane frequency and intensity (Henderson-Seller et al. 1998, Knutson et al. 2001).

At the same time, rising sea surface temperatures (SST) (Figure 47) are closely correlated with coral health. Elevated temperatures cause a thermally induced breakdown in the coral-zooxanthellae host-symbiont relationship (Brown 1997), promoting accelerated growth of pathogens (Kushmaro et al. 1996, 1998), and reducing the potency of the host's immune system (Toren et al. 1998, Alker et al. 2001). Harvell et al. (1999) also note that climate and environmentally mediated physiological stresses may compromise host resistance and increase frequency of opportunistic diseases. Many coral diseases peak in severity and incidence at the end of the warmest season (Edmunds 1991, Kuta & Richardson 1996, Richardson et al. 1998), corresponding with the time when coral tissues are thinnest and symbiont densities lowest (Fitt et al. 2000). For example, Patterson et al. (2002) and Rodríquez-Martínez et al. (2001) provide evidence that the rate of tissue loss due to white pox/patchy necrosis correlates with seasonal conditions of elevated SST. Under normal conditions, SST increases each year in late summer and decreases thereafter in a cyclical manner, but all current models of global climate change suggest that, on average, SST will rise significantly over the next century (Kleypas et al. 1999).

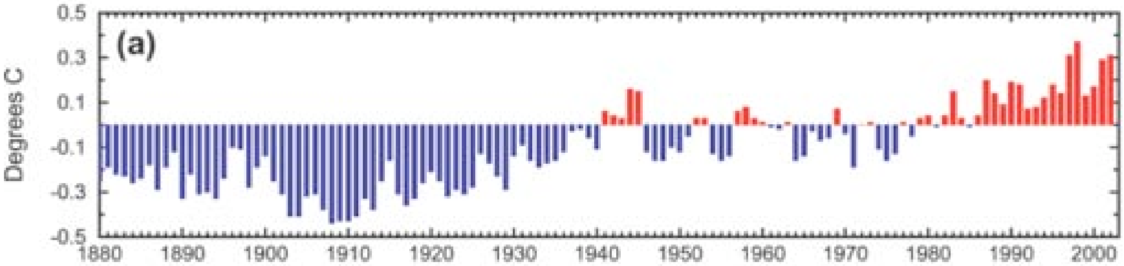

Figure 47: Timeline of Global Sea Surface Temperatures [Waple & Lawrimore]

Localized Bleaching

As more and more instances of coral bleaching are being examined, there is some evidence that coral bleaching can also be caused by environmental factors other than increased sea temperatures. These incidences are now being classified as local bleaching events (as opposed to global). Localized events have been recorded after chemical spills, sedimentation, and decreases in ocean salinity after heavy rains or flooding.

Competition

Macroalgae

The observed decline in the *Acropora* spp. throughout the Caribbean has been accompanied by a significant increase in the total cover of fleshy macroalgae by as much as 80-90%. Macroalgae colonizes spaces opened by coral mortality or injury (Figure 21, Figure 29, & Figure 49) and prevents settlement of coral larvae. Macroalgal growth has accelerated in the past twenty years, in part due to an epidemic in 1983-1984 that decimated the long-spined sea urchin (*Diadema*), reducing populations as much as 99% around the Caribbean. Loss of this herbivore is significant because it feeds on macroscopic algae, thereby playing a major role in reef ecology by keeping algal abundance in check. They are recovering slowly, but in many cases abundance remains at 3% or less of their pre-1983 populations (Turgeon et al. 2002). At least two additional factors contribute to increased algal growth. First, anthropogenic pollution associated with sewage and land-based runoff nutrient loads the water, providing conditions advantageous to macroalgae and detrimental to the *Acropora* spp. which require clean clear water (Scheffer et al. 2001). Secondly, the *Diadema* sea urchin is not macroalgae’s only competitor; there are also many species of herbivorous fish that cleanse the reefs of macroalgae. The reduction of fish stocks due to over-fishing leaves an insufficient number of herbivores to combat algal growth, thus allowing macroalgae to dominate reefs once lush with *Acropora* corals (Scheffer et al. 2001).

Agaricia tenuifolia

Agaricia tenuifolia is a lettuce coral that recruits to dead *A. cervicornis* skeletons. A mass mortality of *A. cervicornis* populations in the late 1980s that resulted from the Caribbean-wide epizootic of white-band disease, initiated a transition from *A. cervicornis* to *A. tenuifolia* in the Belizean Barrier Reef (Aronson et al. 1998). Intense feeding by the herbivore echinoid *Echinometra viridis* prevented algal recruitment and growth on the dead *Acropora* skeletons. This enabled *Agaricia tenuifolia* to recruit opportunistically to the *Acropora* rubble and grow to dominance (Aronson et al. 1998).

Figure 48: *Agaricia tenuifolia* [Brian Helmuth]

Porite porites

Porite porites competes with the *Acropora* spp. for substrate space (Figure 49). A case of an *A. cervicornis* dominated assemblage changing to *P. porites* dominated occurred on Telephone Pole Reef at Fernandez Bay (Greenstein et al. 1998). Since the change, the *P. porites* has declined and is now being replaced by fleshy macroalgae (Curran et al. 2002).

Figure 49: Algal overgrowing *P. porites*. Note the A. *cervicornis* rubble under the *P. porites* [Source Unknown]

Clionid Sponges

A recent problem in the mortality of *A. palmata* colonies in Puerto Rico is the intrusive colonization and fast advance of a brown endolytic clionid sponge (*Cliona langae*). This sponge monopolizes much of the exposed reef substrate that was formerly occupied by live *A. palmata,* rapidly overgrowing standing colonies and fragments. In 1999, the sponge attacked an average 16% of all colonies of A. *palmata* from three reefs in La Parguera. Average coral tissue mortality rate was 9 cm/year, which is faster than the coral's growth rate. The sponge is resilient and in almost all cases it kills the colony within a short period of time (Bruckner et al. 2002).

Cliona tenuis is another sponge dominant in branches and pavement of dead and collapsed *A. palmata* in many localities throughout the Caribbean. It is abundant in deep windward terraces of SW Puerto Rico. It is also widespread in windward fore-reef terraces of SW Caribbean islands, atolls, and banks, but absent at similar sites in Serrana Bank (San Andre´s Archipelago, Colombia) and Los Roques Archipelago (Venezuela). The sponge is now found amidst *A. palmata* rubble in Jamaica where it was not reported in the late 1960's (Pang 1973) when *A. palmata* was healthy and dominant (Zea & Weil 2003).

Pollution

Optimum coral reef development is strongly correlated with clean clear waters (Turgeon et al. 2002). Throughout the Caribbean, reefs influenced by human activities are less healthy than remoter reefs that have less human influence, particularly coastal development and its accompanying pollution (Figure 50). Every coral reef ecosystem under U.S. jurisdiction has suffered from human disturbances to some degree (Turgeon et al. 2002). In the Atlantic and Caribbean regions, portions of reefs off Florida, Puerto Rico, and the USVI have all been degraded by multiple environmental and human-induced stresses. In contrast, the Flower Garden Banks National Marine Sanctuary and Navassa Island have few human induced pressures and remain relatively pristine (Turgeon et al. 2002).

Patterson et al. (2002) recently established *S. marcescens* as the causal agent of white pox disease in *A. palmata*; the first time that a bacterial species associated with the human sewage has been shown to be a marine invertebrate pathogen. *S. marcescens* (proteobacteria) is a fecal enteric bacterium in humans. It is a ubiquitous and opportunistic pathogen that can cause a variety of disease conditions in humans (Grimont & Grimont 1994). This species can also be found as part of the intestinal microbiota of other animal species and as a free-living microbe in both water and soil (Grimont & Grimont 1994). These enteric bacteria have recently been shown to be concentrated in the surface layers of corals in the Florida Keys (Lipp et al. 2002).

Figure 50: Poverty contributes heavily to pollution problems. This canal in Port-au-Prince, Haiti will drain into Caribbean waters untreated [www.cbuhaiti.org]

Domestic, urban, and industrial pollutants in wastewater are a problem in many areas, notably in the Gulf of Mexico and the wider Caribbean. Overt effects include local eutrophication and algal blooms. Although some data are available on concentrations of pollutants (e.g. petroleum hydrocarbons and heavy metals) in water, sediments, and biota, their effects on ecosystem structure and function are generally not well known. Through much of the tropical regions, the coastal zone is fast becoming the repository of solid wastes.

Around all reefs off the southern coast of Puerto Rico there has been degradation of water quality due to high sediment inputs and increased turbidity from clear cutting of the hillsides, sewage discharged into the sea, and rivers pouring excessive pollutants from agriculture and tuna canneries onto the near-shore reefs in the west (Causey et al. 2002). Likewise, in Nicaragua there are problems with excessive and damaging fishing and pollution from untreated sewage. Most shallow reefs around the populated Corn Islands are degraded due to discharge of untreated sewage (Kramer et al. 2000). Further examples of harmful effects caused by pollution exist in varying degrees of severity everywhere humans exist throughout the Caribbean.

Sedimentation

All corals are vulnerable to sedimentation associated with increased runoff and river discharge, especially in areas with minimal wave action. Sedimentation also occurs due to disturbance by snorkelers, divers, boats, dredging, and coastal erosion. The *Acropora* spp. are particularly sensitive to poor water quality as they have a poorly developed mechanism to remove sediment from their branch surfaces and they require high light levels for photosynthesis (Bruckner et al. 2002). *A. palmata* corals under low light conditions modify their growth, forming broad flat branches that are very fragile and ill suited to shallow, high-energy reef zones (Bruckner et al. 2002). Rogers (1983) found that even low doses of sediment accumulating on the flattened branch surfaces can result in rapid tissue necrosis. In addition, injuries regenerate more slowly at elevated sediment levels (Meesters & Bak 1995).

Nutrient overloading

High nutrient levels increase the presence of macroalgae and degrade water quality. *A. palmata* is particularly sensitive to these types of stressors (Bruckner et al. 2002). These problems are endemic to the entire Caribbean. For example:

In the United Sates, there is considerable concern about water quality, with continued pollution by agricultural chemicals, sediments, and nutrients from agriculture and industry throughout Southeast Florida and the Keys. Total phosphorus concentrations are increasing as far as the Dry Tortugas, and increases in nitrates appear to close to shore on the shelf of the Lower and Upper Keys (Causey et al. 2002).

In Costa Rica, Panama, Colombia, Venezuela, and Brazil, most of the reefs are strongly influenced by continental runoff, with large amounts of sediments and often high concentrations of nutrients flowing out of some of the largest rivers in the world - the Amazon, Orinoco, and Magdalena rivers. This high turbidity and sedimentation reduces coral growth in most coastal areas and also occasionally impacts reefs further offshore (Garzón-Ferreira et al. 2002).

In Bermuda, which has one of the highest population densities in the world, virtually all available land has been developed and the coral reefs are under heavy threat. The inshore lagoons receive nutrients from agriculture and sewage run-off and groundwater seepage (Linton et al. 2002).

Hypothermia

Because corals have specific requirements for water temperatures, a reduction in normal sea surface temperatures by only a few degrees Celsius can result in mortality. Death to large stands of *A. palmata* by hypothermia has been significant in the Dry Tortugas and areas along the Florida Reef Tract with direct connections to Florida Bay (Jaap & Sargent 1993). Mortality to the *Acropora* spp. due to hypothermia has also occurred on the northern most reefs of Mexico (Lang et al. 1998).

Mass Die-Off of the Sea Urchin

The long-spined sea urchin (*Diadema antillarum)* grazes macroalgae, which is a primary competitor of *Acropora* corals for space on the reef. In 1983-84 up to 90% of all sea urchins throughout the Caribbean died off resulting in an explosion in macroalgal growth that prevented coral larvae from recruiting onto reefs (Carpenter 1990). Sea urchins have not recovered from this mass mortality and appear to be at levels around 10% of the pre-1983 abundance (Causey et al. 2002, Edmunds & Carpenter 2001). In some cases, abundance remains at 1% or less of their pre-1983 populations (Turgeon et al. 2002).

Over-harvest and Over-fishing

The severe over-harvest of many reef fishes may have a detrimental affect on the continued supply of sufficient nutrients for *Acropora* corals. Removing fish stocks at unsustainable levels can have a detrimental effect on the overall food supply and plankton of the ocean and possibly result in the starvation of coral polyps. Furthermore, the loss of herbivores and large predatory fish has stimulated the proliferation of small fish like the damselfish, thereby multiplying their damaging effect on reefs (Causey et al. 2002, Bruckner et al. 2002). Decreased fish stocks also stimulate macroalgae, which benefits from the lack of herbivore competition (Scheffer et al. 2001).

In Puerto Rico and throughout the Caribbean, spiny lobster (Figure 51) populations are declining due to persistent and increasing fishing pressure. A side effect of this over-fishing has been an explosion in populations of coral-eating mollusks, a favorite food of the lobsters, which have subsequently increased predation on the *Acropora* spp. (Causey et al. 2002).

Figure 51: Spiny Lobster at Andros Island, Bahamas [Sean Nash]

Inadequacy of Existing Regulatory Mechanisms

Coral reefs are generally multinational, with most reefs occurring in lesser developed nations, and major stresses acting on reefs worldwide being comparable among nations.

Current governmental protections of coral reef species and coral reef ecosystems fall into three categories. The first category includes laws and protections that do not address bleaching or global warming. These usually concern the prohibition of direct human contact of coral, such as take or physical destruction. The second category includes protections that address bleaching or global warming through research. These include the creation of research programs and the funding of research projects to better understand these phenomena. The third category includes laws and protections that address the lowering of greenhouse gases emissions through *voluntary efforts* by government agencies, officials, and businesses, which may also be facing budgetary constraints or the need to produce profits. The following is an analysis of state, federal, and international protections of coral reefs and their ability or inability to adequately address the bleaching and global warming issues.

State Protections

Florida Law

While the State of Florida recognizes *A. palmata* and *A. cervicornis* as endangered species, this designation carries no management implications (Deyrup & Franz 1994).

Florida laws protecting coral reefs and species focus mainly on the prevention of human contact, such as direct destruction or take of coral. The state has no protections that address coral bleaching or global warming. Florida prohibits the take, the destruction, the sale and any attempts to commit these actions against hard corals such as the *Acropora* spp.[12] Florida statute further forbids the destruction, damage, removal, and take of coral from occurring in the John Pennekamp Coral Reef State Park.[13] The state has also enacted penalty statutes for parties responsible for coral damage. The legislature has authorized the Department of Environmental Protection to develop civil penalties for coral damage not to exceed $1,000 per square meter of coral.[14] Florida also fines parties responsible for pollution damage ten dollars per square foot of coral reef impacted. The state created an Ecosystem Management and Restoration Trust Fund within the Department of Environmental Protection to place all coral damage penalty funds.[15] Statutory law has also designated the Florida Keys region an area of critical state concern and has directed the creation of a land use management system that protects its natural environment.[16]

While these laws prevent direct damage to coral reefs and species through take, destruction, pollution damage, and land use, the laws do not tackle the devastating instances of coral bleaching in the Florida Keys and the increasing occurrence of global warming. Furthermore, it is clear that insufficient action has been taken as evidenced by the continuing decline of the *Acropora* spp. In part, the problem is insufficient penalties and a low incidence of citation. Providing protection under the ESA would afford the *Acropora* spp. significantly greater protections and therefore present greater deterrence to parties that undertake harmful activities.

Federal Protections

Designation as Candidate Species Under the Endangered Species Act

NOAA Fisheries designated *A. palmata* and *A. cervicornis* as candidate species under the Endangered Species Act (ESA) first in 1991.[17] After almost a decade of inactivity, NOAA Fisheries again designated the species as candidate species in 1999.[18] Candidate species do not gain any form of protection under the ESA. Instead, the purposes of the designation are: 1) to increase public awareness of the species, 2) to identify those species that may need protection under the ESA and, if possible, to recover them before ESA listing is necessary, 3) to stimulate voluntary conservation efforts by federal

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[12] Florida Administrative Code § 68B-42.009.

[13] F.S.A. § 258.083.

[14] F.S.A. § 253.04.

[15] F.S.A. § 403.1651; F.S.A. § 380.0558.

[16] F.S.A. § 380.0552.

[17] 56 FR 2679.

[18] 64 FR 33466.

agencies and other parties, and 4) to identify uncertainties associated with the status of the species.[19]

The *Acropora* spp. continue to occupy the candidate species list today and, thus, receive no federal protections.

The United States Coral Reef Task Force (Executive Order 13089)

In 1998, former president Bill Clinton signed Executive Order 13089 for the protection of U.S. coral reef ecosystems.[20] The order, based on ecosystem protection and recovery, does not address the special needs of the disappearing *Acropora* spp. or the issues of coral bleaching and global warming. The order, instead calls for 1) federal agency cooperation and 2) the creation of the United States Coral Reef Task Force (Task Force).

Section Two of the order states:

> All Federal agencies whose actions may affect U.S. coral reef ecosystems shall: (a) identify their actions that may affect U.S. coral reef ecosystems; (b) utilize their programs and authorities to protect and enhance the conditions of such ecosystems; and (c) *to the extent permitted by law*, ensure that any actions they authorize, fund, or carry out will not degrade the conditions of such ecosystems.[21]

This section, however, does not mandate any federal agency action because the section is designated by the order as policy, which is simply a guiding principle or procedure.[22] The order also does not override any existing laws that would prevent the agencies from ensuring that their actions will not degrade ecosystem conditions.

Section three of the order states:

> In furtherance of section 2 of this order, Federal agencies whose actions affect U.S. coral reef ecosystems, shall, *subject to the availability of appropriations*, provide for the implementation of measures needed to research, monitor, and restore affected ecosystems.[23]

This section sets another limitation to federal agency action because it allows agencies without available appropriations to negatively affect coral reef ecosystems without researching, monitoring, or restoring the sites. The order does not direct mandatory recovery. Instead, it depends on the existence of agency budget surpluses, which are a rarity. The order does not ameliorate the situation by providing funds to agencies for these processes; nor does the order direct agencies to cut, reorganize, or apply for additional funding. The order serves merely as a guiding principle for agencies to follow

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[19] 64 FR 2629.

[20] Exec. Ord. 13089.

[21] *Id*. at §2 (emphasis added).

[22] *See id.*

[23] Exec. Ord. 13089 at § 3 (emphasis added).

to the extent permitted by law and to the extent that agencies have additional funding to spend.

Executive Order 13089 also explicitly denies the creation of any right, substantive or procedural, enforceable in law or equity by a party against the U.S., its agencies, and its officers.[24] Thus, no citizens or environmental groups can sue to compel agency action regarding the protection of coral reef ecosystems. The failure of the order to influence federal agency action has been recognized by the United States Coral Reef Task Force. In 2000, the Task Force stated, "at present, however, there exists no infrastructure to facilitate the implementation of Executive Order 13089 by federal agencies or their state and territorial conservation partners."[25]

The order created the Task Force, a body co-chaired by the Secretary of the Interior and the Secretary of Commerce, through the Administrator of the National Oceanic and Atmospheric Administration (NOAA), and whose members include, but are not limited to, the Administrator of the Environmental Protection Agency, the Attorney General, the Secretary of Agriculture, the Secretary of Defense, the Secretary of State, the Secretary of Transportation, the Director of the National Science Foundation, the Administrator of the Agency of International Development, and the Administrator of the National Aeronautics and Space Administration.[26] The Task Force oversees the implementation of policy and federal agency responsibilities and guides activities under the U.S. Coral Reef Initiative.[27] Besides those functions, the Task Force has four major duties: 1) coordinating a comprehensive plan to map and monitor the nation's reefs, 2) researching to identity the causes and effects of coral reef degradation, 3) developing, recommending, or implementing the reduction, mitigation, and restoration of coral reef degradation, and 4) assessing the nation's role in the protection of coral reefs and implementing conservation strategies worldwide.[28]

The Task Force has acknowledged the severity of bleaching and global warming issues. It has not, however, been able to enforce positive change in those areas. A paper presented by the Department of States in 1999 to the second meeting of the Task Force stated:

In 1998 coral reefs around the world suffered the most extensive and severe bleaching and subsequent mortality in modern record. In the same year, tropical sea surface temperatures were the highest in modern record, topping off a fifty-year trend for some tropical oceans. Localized stressors or natural variability cannot account for these events alone. Nor can El Niño by itself explain the patterns observed worldwide. At this time, it appears that only anthropogenic global warming could have induced such extensive coral bleaching simultaneously throughout the disparate reef regions of the world. Thus the

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[24] *Id*. at § 6.

[25] United States Coral Reef Task Force, "The National Action Plan to Conserve Coral Reefs" (Washington D.C., 2000) ("National Action Plan") at 32.

[26] Exec. Ord. 13089 at § 4.

[27] *Id*.

[28] *Id*. at § 5.

geographic extent, increasing frequency, and regional severity of mass bleaching events are likely a consequence of a steadily rising baseline of marine temperatures.[29]

The Department of State, a statement to the Task Force, directly attributed coral bleaching to global warming. The department then stated:

> Significant attention needs to be given to the monitoring of coral reef ecosystems, research on the projected and realized impacts of global climate change, and *measures to curtail greenhouse gas emissions*.[30]

In response to these dire predictions and clear calls for immediate action, the Task Force issued a resolution stating, "Agencies must consider their role in drawing attention to the predicted impacts of global scale climate change on the resources they manage. We believe conservation goals can no longer be achieved without taking into account global climate change."[31] The Task Force acknowledged the cause of coral bleaching, its severity, and the impossibility of meeting conservation goals without taking global warming into account in 1999.

In 2000, however, it described the various threats to coral reefs by stating, "The origin and impact of these threats range from very localized and potentially manageable events, such as resource extraction or coastal development, to *poorly understood global phenomena* affecting entire oceans (e.g., *climate change, bleaching* , and disease)."[32] Localized and easily manageable threats can be dealt with quite successfully by legislation such as the Florida laws covered above. Global phenomena, on the other hand, must be dealt with on international, national, and local levels. The Task Force does not have the authority over federal agencies to mandate any national change concerning greenhouse gas emissions. The Task Force has called Executive Order 13089 a "formidable call to action" and under a section entitled "Constraints on Federal Agency Action," has cited resource, legal, and policy restraints in its abilities to create change. It has also stated that because of the changing nature of the problem and of agency resources to meet the problem, the Task Force cannot specify agency priorities beyond the next fiscal year.[33] This translates into agency inability to plan, conduct, and fund long-term projects, such as those needed to address critical issues and difficult issues such as bleaching and global warming.

The Task Force has instead categorized bleaching and global warming as "poorly understood" issues and has planned two forms of action for the future: 1) the creation of an interagency Coral Reef Disease Consortium to determine the causes and consequences of diseases, and 2) the highlighting of coral reef issues in international bodies dealing

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[29] U.S. Department of State, "Coral Bleaching, Coral Mortality, and Global Climate Change" (Hawaii, 1999) (paper presented at the second meeting of the U.S. Coral Reef Task Force).

[30] *Id*. (emphasis added).

[31] Rubin, J.P. [spokesman for U.S. Department of State], "NOAA, ICLARM meet to strengthen ways to manage coral reefs" (Washington D.C., 1999), at http://usinfo.gov/topical/global/environ/latest/99071301.htm (emphasis added).

[32] National Action Plan at 10 (emphasis added).

[33] *Id*. at 8.

with climate change including the Kyoto Protocol.[34] The first plan of action deals with research and the second plan of actions concerns attempts to change global policy. While necessary, neither goal meets the call to action posed by the Department of State. In its most recent meeting, the Task Force further addressed the global climate issue. The Task Force plans to develop an interagency, public and private partnership to study coral reef responses to climatic change and to apply this knowledge to short and long term reef management.[35] This plan also focuses almost solely on global warming research and application of this research to management. The Task Force does not have the ability to mandate or seriously influence a decrease in greenhouse gases emissions.

National Marine Protected Sanctuaries

In 1972, Congress passed the National Marine Protection, Research, and Sanctuaries Act to prevent unregulated dumping of radioactive, chemical, or biological substances into the oceans.[36] Title III of the Act, later called the National Marine Sanctuaries Act (NMSA), charged the Secretary of the Department of Commerce to identify, designate, and manage marine sites based on conservational, ecological, recreational, historical, aesthetic, scientific, and educational value.[37] The present NMSA also forbids the destruction, injury, or loss of any sanctuary resource managed under sanctuary law and prohibits the possession, sale, import, and export of any sanctuary resource taken in violation of sanctuary law.[38]

In 1975, the United States designated its first marine sanctuary to protect the wreckage of the U.S.S. Monitor, a Civil War ironclad. In 1990, Congress designated the Florida Keys National Marine Sanctuary, which affords protection to the waters and inhabitants surrounding most of the 1,700 islands that comprise the Florida Keys.[39] The sanctuary includes the *Acropora* spp.[40] This area extends 220 miles in a northeast to southwest arc between the southern tip of Key Biscayne, south of Miami, to beyond but not including the Dry Tortugas Islands.[41] The Florida Keys National Marine Sanctuary and Protection Act places strict limitations on the operation of vessels and prohibits the leasing, exploration, development, or production of minerals or hydrocarbons within the sanctuary.[42] The Act also charges the Secretary of Commerce along with other government entities to develop a comprehensive management program and a water quality protection program for the sanctuary.[43]

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[34] U.S. Coral Reef Task Force, "FY2000 Accomplishments and Future Activities" (Washington D.C., 2000) ("FY2000 Accomplishments") at 5, 11.

[35] U.S. Coral Reef Task Force, "Decisions from the Eighth Meeting of U.S. Coral Reef Task Force – Resolution 5: Coral Reefs and Climate Change" (San Juan, Oct. 2002) at http://coralreef.gov/res5.cfm.

[36] P.L. 92-532.

[37] *Id*. at Title III, § 301.

[38] 16 U.S.C. 1436.

[39] P.L. 101-605.

[40] Florida Keys National Marine Sanctuary Species List at 4, at http://www.fknms.nos.noaa.gov/sanctuary_resources/specieslist.pdf.

[41] NOAA National Marine Sanctuaries: The Florida Keys, at http://www.sanctuaries.nos.noaa.gov/oms/omsflorida/omsflorida.html.

[42] P.L. 101-605 at § 6.

[43] *Id*. at §§ 7-8.

Since the designation of the Florida Keys National Marine Sanctuary, the number of prohibited activities has risen. These currently include: 1) mineral and hydrocarbon exploration, development, and production, 2) removal of, injury to, or possession of coral or live rock, 3) alteration of, or construction on, the seabed, 4) discharge or deposit of materials or other matter, 5) operating a vessel in such a manner as to strike or otherwise injure coral, 6) conduct of diving/snorkeling without flag, 7) release of exotic species, 8) damage or removal of markers, 9) movement of, removal of, injury to, or possession of sanctuary historical resources, 10) take or possession of protected wildlife, 11) possession or use of explosives or electrical charges, 12) harvest or possession of marine life species, and 13) interference with law.[44]

The designation of the Tortugas Ecological Reserve in 2001 has further increased the protection of waters and its inhabitants around the Florida Keys.[45] The reserve consists of two parts: Tortugas North and Tortugas South. In Tortugas North, regulations prohibit all taking of marine life, restrict vessel discharges to cooling water and engine exhaust, prohibit anchoring, and prohibit use of mooring buoys by vessels more than 100 feet in combined length.[46] Tortugas South also forbids the taking of marine life and places limitations on vessel discharge.[47] In addition to these rules, Tortugas South also prohibits diving and requires vessels to be in continuous transit through the areas with fishing gear stowed.[48]

The Florida Keys National Marine Sanctuary and the Tortugas Ecological Reserve successfully protect its coral species from human take, immediate destruction, and injury from vessels. The Task Force hopes to achieve similar success by establishing additional no-take reserves that will encompass at least twenty percent of U.S. coral reefs by 2010.[49] However, the designation of marine protected areas, like Florida's statutes concerning coral reefs, does not address the issues of bleaching and global warming or disease. Also, the continued loss of these corals indicates that the designations alone are not sufficient to arrest the decline and encourage the recovery of these species. The designation of a sanctuary and its boundaries does not lessen the threat of these phenomena. Global warming of the seas does not respect imaginary boundaries. Bleaching will occur regardless of whether certain coral species reside in a sanctuary. In fact, the Department of State, in its presentation at the second meeting of the U.S. Coral Reef Task Force, has acknowledged and warned that "even those reefs granted well-enforced legal protection as marine sanctuaries, or as areas managed for sustainable use, are threatened by global climate change."[50] Thus, while the designation of marine protected areas is crucial to prevent some forms of direct human damage to the *Acropora spp.*, the designation cannot protect them from larger long-term global threats.

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[44] 15 C.F.R. 922.163.

[45] *See* 66 FR 16120-02; 66 FR 33462-01.

[46] Florida Keys National Marine Sanctuary Press Release, "Florida's Tortugas becomes nation's largest marine reserve," at http://www.fknms.nos.noaa.gov/news/press_release/tortugaser.html.

[47] *Id*.

[48] *Id*.

[49] National Action Plan at 20.

[50] U.S. Department of State, "Coral Bleaching, Coral Mortality, and Global Climate Change" (Hawaii, 1999) (paper presented at the second meeting of the U.S. Coral Reef Task Force).

The U.S. Coral Reef Initiative (USCRI) and The U.S. All-Islands Coral Reef Initiative (USAICRI)

In 1996, the United States launched the United States Coral Reef Initiative (USCRI).[51] Created as a platform for U.S. support of national and international coral reef conservation efforts, the USCRI's goal "is to strengthen and fill the gaps in existing efforts to conserve and sustainably manage coral reefs and related ecosystems (sea grass beds and mangrove forests) in U.S. waters."[52] The USCRI consists of federal, state, territorial and commonwealth governments, the nation's scientific community, the private sector, and other organizations.[53] The National Oceanic and Atmospheric Administration (NOAA), one of the prime federal agency contributors to the USCRI, has devoted its efforts to achieving results in three priority areas: 1) solutions for conservation and sustainable development, 2) information for decision-makers and the public, and 3) science for improved local and regional management.[54] To promote conservation and sustainable development, NOAA has worked to reduce the impacts of pollution from agricultural and urban sources in the Caribbean, developed and used technology to restore coral reefs in the Florida Keys, helped create, along with other partners, marine protected areas, and transferred information technology to local communities to promote sustainable use.[55] To inform decision-makers and the public, NOAA has trained import and export personnel about coral to reduce illegal coral trade and has worked with businessmen, fishermen, divers, and other local community members to prevent coral damage.[56] NOAA has also devoted effort to the refinement of coral reef science. These attempts include the implementation, with the help of other government partners, of a network dedicated to long-term monitoring of Caribbean coral sites.[57] NOAA has also supported research to understand reef response to increased levels of nutrients and sediment.[58] With regards to bleaching, NOAA has used satellite images of the sea surface to monitor ocean hotspots to predict, confirm, and study worldwide bleaching events.[59]

The U.S. Coral Reef Initiative, whose achievements are primarily attributed to NOAA and its partners, has filled some of the gaps left open by inadequate state and congressional statutes in terms of coral reef monitoring and the ability to effect change within local communities across the nation. The USCRI and NOAA can locate bleaching events and measure their severity, but their role is merely one of reaction, not action. The USCRI and NOAA have only enacted tools to chart the *results* of increasing greenhouse gases emissions and global warming. There exist no efforts to tackle the issue of

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[51] Environmental Protection Agency: Coral Reef Initiatives, at http://www.epa.gov/owow/oceans/coral/initiative.html.

[52] NOAA Coral Reef Initiative at 5-6 (Washington D.C., 1996), available at http://www.publicaffairs.noaa.gov/cri.pdf.

[53] *Id*. at 7.

[54] *Id* at 9.

[55] *Id*. at 9-10.

[56] *Id*. at 10.

[57] *Id*.

[58] *Id*. at 11.

[59] *Id*.

emissions in any direct and preventative manner. They thus provide no relief to the *Acropora* spp.

The United States All-Islands Coral Reef Initiative (USAICRI) is a united effort by island members of the Coral Reef Task Force to identify coral reef management needs of the islands and to build local and federal support for local projects.[60] The members consist of the U.S. Flag Islands of American Samoa, Hawaii, Guam, the Commonwealth of Northern Mariana Islands (CNMI), Puerto Rico, and the U.S. Virgin Islands.[61] The *Acropora* spp. corals concerned in this petition are found near only two of these islands: Puerto Rico and the U.S. Virgin Islands. Completed projects for the year 2000 by USAICRI that include the coral species include the designation of Puerto Rico's first no-take coral reef reserve and the development of the U.S. Virgin Island's Marine Park Management Plan.[62]

Neither island has addressed global warming and bleaching in its five-year (1999-2004) plan. Puerto Rico's future goals include the installation of 200 mooring buoys, the implementation of new fishing regulations, and the establishment of a permanent monitoring program.[63] Future all-island projects include the development of long-term coral reef management plans for the islands, the expansion of partnerships to support local coral reef management initiatives, and the increase of long-term monitoring efforts in island areas.[64] While the U.S. Virgin Islands plan acknowledges that its coral reefs are being threatened by "higher than normal wave and water temperatures," it does not mention any efforts to curb greenhouse gases emissions or to alleviate bleaching in any way.[65] Instead, the plan dedicates most of its plan and its financial resource commitments to creating baseline information, a comprehensive assessment of coral reef resources and monitoring.[66]

The Commonwealth of the Northern Mariana Islands, where the *Acropora* spp. do not exist, is the only island entity to include the issue of global warming as a prospective project.[67] In its prospective projects list for the years 1998-2002, CNMI separated projects into three categories: high priority, medium priority, and low priority.[68] High priority projects include creating an inventory of the islands' reefs and identifying and recovering contaminated sites. Medium priority projects include establishing marine protected areas and implementing management practices to tackle non-point source pollution.[69] A global warming study (to research whether global warming is a threat to

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[60] FY2000 Accomplishments at 7.

[61] *Id.*

[62] *Id.*

[63] U.S. Islands Coral Reef Brochure: Puerto Rico (2000), at http://www.hawaii.edu/ssri/Broch_PR.html.

[64] *Id.*

[65] U.S. Virgin Islands Coral Reef Initiative 1999-2004, at http://www.hawaii.edu/ssri/8USVIcri.pdf.

[66] *Id.*

[67] Coral Reef Initiatives Proposed Projects and Programs: Commonwealth of the Northern Mariana Islands, at http://www.Hawaii.edu/ssri/2Project.PDF at 19-21.

[68] *Id.*

[69] *Id.*

CNMI coral reefs) is low priority, sharing this category with the production and distribution of a coral reef educational video.[70]

Puerto Rico and the U.S. Virgin Islands have done nothing and have planned no projects that will address bleaching and global warming despite experiencing significant losses of *Acropora* spp. Their accomplishments, like the accomplishments of Florida, Congress, and the U.S. Coral Reef Task Force, lay mostly in the prevention of immediate human threat and the continuation of research and monitoring efforts.

Federal Statutes Addressing Coral Reefs

In 2000, Congress passed the Coral Reef Conservation Act to preserve, sustain, and restore coral reef ecosystems, promote sustainable use, develop sound scientific information on coral reefs, support conservation programs (especially those undertaken by local communities and non-governmental organization), provide financial assistance to these programs, and develop a formal mechanism to manage private sector donations for conservation projects.[71] The Act has three main goals: the creation of a National Coral Reef Action Strategy, the financial promotion of governmental, educational, and non-governmental conservation projects, and the granting of additional power to the Secretary of Commerce to protect coral reef ecosystems.[72]

The Act charges the Administrator of NOAA with the development and periodic review of a National Coral Reef Action Strategy that addresses the above coral reef issues, such as sustainable use, monitoring, mapping, and education.[73] More uniquely, the Act directs the Secretary of Commerce, through the Administrator of NOAA and subject to available appropriations, to provide grants to governmental, educational, and non-governmental entities with demonstrated expertise in coral reef conservation for various projects to be approved by the Administrator of NOAA.[74] No less than forty percent of all project funds will be given to coral conservation projects in areas of the Pacific under U.S. jurisdiction, and no less than forty percent will be provided to projects in areas of the Atlantic, Gulf of Mexico, and the Caribbean under U.S. jurisdiction.[75] The rest of the available appropriations can go to funding emergency priority grants.[76] The Act also gives the Secretary of Commerce, subject to available appropriations, the power to map and monitor coral reefs, increase education, assist states in abandoned vessel and fishing gear removal, and heighten efforts to manage and conserve reefs with local, state, national, and international partners.[77] To implement the Act, Congress planned to give the Secretary of Commerce sixteen million dollars each year from 2001 to 2004.[78]

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[70] *Id*.
[71] 16 U.S.C. § 6401, et seq.
[72] *Id*.
[73] 16 U.S.C. § 6402.
[74] 16 U.S.C. § 6403.
[75] *Id*.
[76] *Id*.
[77] 16 U.S.C. § 6406.
[78] 16 U.S.C. § 6408.

The Coral Reef Conservation Act can be viewed as Congress' acknowledgement that the government needs and is willing to fund assistance from outside organizations. The legislature heavily centered the Act on encouraging and providing financial resources for outside conservation projects. Congress, however, has not mandated that any projects focus on bleaching or global warming. It has mandated four research focus areas, one of which centers on the "[p]rimary causes of ecological stresses in reef ecosystems of the study region (such as, over fishing, reef destruction and pollution, climate change, disease, invasive species, sedimentation, etc.) and prioritization of these stresses."[79] While Congress may fund projects that address global warming, it does not guarantee that any of these projects will be proposed or actually funded. Further, there exists is no pledge to enforce or seriously consider the results and recommendations of such projects.

Federal Statutes Addressing Global Warming

Federal statutes that concern global warming can be divided into two groups: 1) statutes that establish national research and education programs and 2) statutes that aim to decrease greenhouse gases emissions on a very small scale. None of these statutes call for a national reduction in emissions despite the acknowledgement of the causes of global warming and its present severity.

Congress has charged the President with the creation of several programs to research climate and global change. In 1980, Congress directed the President to establish a National Climate Program and the Secretary of the Department of Commerce to create a National Climate Program Office within his department.[80] The legislature hoped that this program would help the nation and the world understand and respond to natural and man-induced climate processes and to enact sound policy decisions.[81] Ten years later, Congress charged the President with the creation of a Committee on Earth and Environmental Sciences and an interagency United States Global Change Research Program.[82] These entities would help the nation understand, access, predict and respond to natural and human-induced global change, including global warming.[83] In 1991, Congress, citing the nation's inadequate education concerning international environmental problems such as global warming, also created the Office of Environmental Education within the Environmental Protection Agency.[84] While the creation of these agencies and offices will increase global warming research and education, they do not address the immediate solutions needed to decrease or at least maintain the current levels of greenhouse gases emissions.

Congress has taken small and inadequate steps to reduce greenhouse gases emissions. These measures have failed to improve the global warming situation because they depend solely on the voluntary efforts of government agencies and officials on the national and local levels. In 1978, Congress attempted to promote urban tree planting to reduce

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[79] 67 FR 9251-03.

[80] 15 U.S.C 2901, et seq.

[81] *Id.*

[82] 15 U.S.C. 2901, et seq.

[83] *Id.*

[84] 20 U.S.C. 5501, et seq.

carbon dioxide buildup by providing local governments with financial, technical, and educational assistance.[85] In 1988, Congress sought to increase the utilization of alternative fuel use vehicles by charging the federal government with purchasing and driving these vehicles in the "maximum number practicable."[86] In 1990, the legislature granted the Secretary of Agriculture power to help countries maintain and conserve forestland and focused this power on key countries that could have a substantial impact on emissions of greenhouse gases related to global warming.[87] None of these statutes mandate immediate or comprehensive action. Local cities do not have to plant more trees; they are only encouraged to do so. The federal government must purchase alternative fuel use vehicles only in the amount practicable in light of budgetary constraints. The Secretary of Agriculture has the power to help countries, but the officer is not under any mandate to provide substantial assistance to countries with large greenhouse gases emissions. While the statutes are attempts in the right direction, they are subject to governmental and budgetary constraints and do not address global warming on a wide scale.

Kyoto Protocol Substitutes

Under the Kyoto Protocol agreement in 1997, industrialized nations pledged to cut greenhouse gases emissions by an average of 5.2 percent of 1990 levels by 2012.[88] Under the Kyoto Treaty, the United States would have to meet a mandatory emissions cut of around 7 percent of 1990 levels.[89] In March of 2001, President George W. Bush rejected the Kyoto Treaty on the grounds that it was an "unsound international treaty."[90] More specifically, Bush could not support the treaty because he thought it would severely harm the American economy and would result in the loss of approximately 4.9 million jobs.[91] He also rejected the plan because it exempted developing nations and nations responsible for large-scale pollution, such as India.[92]

Instead, the President presented a plan in February of 2002 that relies mainly on voluntary participation by businesses.[93] The difference between the Kyoto Protocol and Bush's plan are extremely wide. Kyoto's goal of cutting American emissions by 7% of 1990 levels is significantly higher than Bush's goal of cutting emissions by 4.5% of 1990 levels.[94] The most important difference, however, is the kind of participation each plan calls for. The Kyoto plan *requires* cuts in emissions by about 30 of the most developed nations.[95] The Bush plan, however, relies solely on the *voluntary* participation of businesses. The incentives provided by the Kyoto treaty are also more attractive for

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[85] 16 U.S.C. 2105.
[86] 42 U.S.C. 6374.
[87] 16 U.S.C. 4501, et seq.
[88] CNN, "Cool response to global warming plan," (Tokyo, 2002) at http://www.cnn.com/2002/WORLD/asiapcf/east/02/15/japan.climate/index.html.
[89] *Id.*
[90] CNN, "Bush unveils voluntary plan to reduce global warming," (Silver Spring, 2002), at http://www.cnn.com/2002/ALLPOLITICS/02/14/bush.global.warming/index.html.
[91] *Id.*
[92] *Id.*
[93] CNN, "Cool response to global warming plan," supra note 129.
[94] *Id.*
[95] *Id.*

nations as a whole. The treaty allows nations to buy and sell carbon credits on the international market or reduce their quota by expanding forests or farm land that absorb carbon dioxide from the atmosphere.[96] Bush's plan provides businesses with tax incentives for investing in and using "clean" technology.[97] The Bush plan has been widely criticized by environmental groups, former Vice-President Al Gore, Japan's Environmental Minister Hiroshi Oki, and the European Union.[98] Greenpeace has maintained that Bush's plan will allow emissions to rise twenty-nine percent above 1990 levels by 2012.[99]

While most industrialized nations have signed and ratified the treaty mandating action, the Bush administration believes that his plan will adequately address global warming. Christine Whitman, the Administrator of the Environmental Protection Agency has stated, "You can always put in mandatory in the future, if that's what you think you have to have. But let's get people to put their creativity behind finding the solutions which they do far more rapidly if it is voluntary than if it's mandatory."[100] It is hard to imagine how setting voluntary requirements will cause businesses to act faster or more efficiently, especially if choosing to meet the requirements will greatly increase the financial costs of businesses. The Bush plan, like the Candidate Species designation by NOAA Fisheries and the statues addressing global warming by Congress, centers on voluntary efforts by individuals, government entities, and private businesses whose good intentions may face insurmountable legal and financial constraints or who may prioritize profit over protection and conservation of the environment.

International Protections

International Coral Reef Initiative

The United States, Australia, France, Jamaica, Japan, the Philippines, Sweden, the United Kingdom, and agencies such as the World Bank and United Nations Environmental Programme created the International Coral Reef Initiative (ICRI) at the Small Island Developing States conference in 1994.[101] Its partners now include core government members such as Malaysia, Indonesia, and Mexico, committees such as the U.S. Coral Reef Task Force and international non-governmental organizations such as Coral Reef Alliance, World Wildlife Fund, and Reef Check.[102] The Initiative is a voluntary informal network with no permanent structure or organization.[103] The partners are linked to a Global Secretariat, which is run and funded by the government of one country, but often

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[96] *Id.*

[97] *Id.*

[98] See *id.*; CNN, "Bush unveils voluntary plan to reduce global warming," supra note 131.

[99] *Id.*

[100] CNN, "Bush unveils voluntary plan to reduce global warming," supra note 131.

[101] International Coral Reef Initiative: About the ICRI, at http://www.environnement.gouv.fr/icri/Site_ICRI/Au%20sujet%20de%20l'ICRI/about.html.

[102] ICRI: ICRI core members and networks, at http://icriforum.org/router.cfm?show=secretariat/sec_home.html&Item=1.

[103] ICRI: More information about ICRI, at http://icriforum.org/router.cfm?show=secretariat/sec_home.html&Item=1

with the assistance from others.[104] This body is small and temporary with no permanent staff.[105]

The ICRI has 1) hosted an international and regional coral reef workshops to promote global cooperation on sustainable use, 2) hosted workshops in the U.S. to foster sustainable use alternatives for local coral communities, 3) increased awareness of conservation practices among coral nations, 4) gained cooperative agreements between nations on coral management and conservation, 5) lobbied the World Bank to consider financing mechanisms for sustainable use of coral ecosystems, and 6) launched the Global Coral Reef Monitoring Network.[106] It has also supported the development of marine protected areas, restrictions on cyanide fishing, and control of illegal coral trade.[107]

The ICRI's goals for the years 2001-2002 are to 1) continue raising global attention on coral reefs and their decline, 2) to create ICRI networks to help coordinate coastal management, conduct research and monitoring, and promote awareness especially in the tourism industry, and 3) to support the creation and funding of programs and projects within these networks to allow ICRI partners to help sustain and manage their environments.[108] In 2002, the ICRI issued a resolution on "Coral Reefs, Coral Bleaching and Climate Change" to the World Summit of Sustainable Development (WSSD).[109] The resolution to the WSSD, approved by delegates from Australia, France, India, Japan, the Maldives, Mexico, Sri Lanka, the United States, and the United Kingdom, warns of threats to coral reefs, including bleaching, over fishing, and pollution.[110] It calls on nations to protect coral reefs from pollution, dynamite and cyanide fishing, and global warming by reducing greenhouse gases emissions.[111]

Under the ICRI, many international partnerships have developed. International coral reef workshops, promotion of coral reef issues and awareness across the world, a global coral reef monitoring program, and the beginnings of international networks to promote conservation and sustainability at more local levels all serve to make the world a better place for coral reefs. ICRI is, however, a purely voluntary body and depends on the participation and funding of its member countries and other partners. While it has called on nations to reduce greenhouse gases emission, the ICRI stance has no binding effect on the laws and policies of its member nations, unless a member nation decides to act on its own. While the United States is a member of the ICRI and has approved its resolution concerning the reduction of emissions, the President and Congress have yet to be persuaded. Thus the ICRI does not have the ability to mandate change in this sector.

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[104] *Id.*

[105] *Id.*

[106] Environmental Protection Agency: Coral Reef Initiatives, supra at note 92.

[107] NOAA Coral Reef Initiative (1997), http://www.publicaffairs.noaa.gov/cri.pdf.

[108] ICRI: Future directions for ICRI, at http://icriforum.org/router.cfm?show=secretariat/sec_home.html&Item=1.

[109] UNEP Coral Reef Unit, "Status of implementation of UNEP Governing Council decisions on coral reefs," (2001), at http://www.unep.ch/coral/crprogress.htm.

[110] *Id.*

[111] *Id.*

Synergistic Effects

The threats facing these coral species are particularly troublesome because of their interrelated nature. The effects of these threats are synergistic, indicating that addressing each threat independently will not be sufficient to preserve these species.

ACROPORA PALMATA, *ACROPORA CERVICORNIS*, AND *ACROPORA PROLIFERA* SHOULD HAVE CRITICAL HABITAT DESIGNATED

Critical Habitat is Beneficial to Listed Species

Critical habitat is defined by Section 3 of the ESA as:

> (i) the specific areas within the geographical area occupied by the species, at the time it is listed in accordance with the provisions of section 1533 of this title, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and
> (ii) specific areas outside the geographical area occupied by the species at the time it is listed in accordance with the provisions of section 1533 of this title, upon a determination by the Secretary that such areas are essential for the conservation of the species. (16 U.S.C. §1532(5))

The designation and protection of critical habitat is one of the primary ways in which the fundamental purpose of the ESA, "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved," is achieved.[112] Critical habitat designation offers an added layer of protection to ensure that a listed species' habitat – the loss of which is widely recognized to be the primary reason for most species' decline – will not be harmed.

The designation of critical habitat provides listed species with additional protections under Section 7 of the ESA. The Section 7 consultation requirements provide that no action authorized, funded, or carried out by any federal agency will "jeopardize the continued existence of any endangered species or threatened species *or result in the destruction or adverse modification of [critical habitat]*."[113] The 5th Circuit Court held in 2001 that consultation is required when the adverse modification of habitat affects the recovery of the species, even if the survival of the species is not threatened.[114] The ruling upholds the original intent of critical habitat designation under the ESA, which is to provide a mechanism for both survival and recovery of the species.

Without critical habitat designation, a listed species' protection under Section 7 of the ESA is limited to avoiding "jeopardy" to the species in its occupied habitat, without separate consideration of the potential for "destruction or adverse modification" of habitat or suitable unoccupied habitat which may be essential to the species' recovery. The U.S. Fish and Wildlife

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[112] 16 U.S.C. §1536(a)(2) (1994).
[113] 16 U.S.C. §1536(a)(2) (1994) (emphasis added).
[114] Sierra Club v. USFWS, 245 F.3D

Service nicely summarized this distinction in the final rule designating critical habitat for the northern spotted owl:

> The Act's definition of critical habitat indicates that the purpose of critical habitat is to contribute to a species' conservation, which definition equates to recovery. Section 7 prohibitions against the destruction or adverse modification of critical habitat apply to actions that would impair survival and recovery of the listed species, thus providing a regulatory means of ensuring that Federal actions within critical habitat are considered in relation to the goals and recommendations of a recovery plan. As a result of the link between critical habitat and recovery, the prohibition against destruction or adverse modification of the critical habitat would provide for the protection of the critical habitat's ability to contribute fully to a species' recovery. *Thus, the adverse modification standard may be reached closer to the recovery end of the survival continuum, whereas, the jeopardy standard traditionally has been applied nearer to the extinction end of the continuum*.[115]

Critical habitat designation also protects species by helping to define the meaning of "harm" under Section 9 of the ESA, which prohibits unlawful "take" of listed species, including harming the species through habitat degradation. Although "take" through habitat degradation is not expressly limited to harm to "critical habitat," it is practically much easier to demonstrate the significance of the impact to a species' habitat where that habitat has already been deemed "essential," or "critical," to the species' continued survival.[116]

Critical habitat further helps species by providing for agency accountability through the citizen suit provision of the ESA. The citizen suit provision permits members of the public to seek judicial review of the agency's compliance with its mandatory statutory duty to consider the habitat needs of imperiled species. Also, the designation of critical habitat provides valuable information for the implementation of recovery plans.

Additionally, NOAA Fisheries notes that critical habitat assists federal agencies in planning future actions because critical habitat establishes in advance those areas that will be given special consideration in section 7 consultations.[117] The designation allows conflicts between development and listed species to be identified and avoided early in the planning process.[118] NOAA Fisheries also states that critical habitat provides a benefit to species by focusing federal, state, and private conservation and management efforts in areas designated critical habitat.[119] Recovery efforts can then address special considerations needed in critical habitat areas, including conservation regulations to restrict private as well as federal activities.[120] Finally,

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[115] 57 Fed. Reg. 1796 at 1822 (emphasis added).

[116] See Palila v. Hawaii Department of Land and Natural Resources, 852 F. 2d 1106 (9th Cir. 1988).

[117] *Id.*

[118] *Id.*

[119] *Id.*

[120] *Id.*

NOAA Fisheries points out that there may be other federal, state, or local laws that provide special protection for areas designated as critical habitat.

When designating critical habitat, provided such considerations would not cause extinction, NOAA Fisheries can assess the costs and benefits associated with protecting critical habitat. The Supreme Court has provided guidance for this assessment by declaring that species are of "incalculable" value.[121] Therefore, in order to make this assessment meaningful NOAA Fisheries must carefully consider only the values of critical habitat designation and protection, and not the benefits or costs of listing the species itself. To do otherwise would be to engage in the impossible task of balancing an object of infinite value against finite costs. Finally, NOAA Fisheries should note that designation of critical habitat can in fact be a source of economic benefit, particularly if the survival and recovery of the species is vital to an entire ecosystem. In a 2003 report to Congress, the Office of Management and Budget (part of the Executive Office of the President) noted that designating critical habitat for four species of fish in the Colorado River had a net beneficial economic effect of $7.92 million.[122] This effect was attributed to 710 new jobs, increased earnings of $6.62 million, and an increase in government revenue by $3.2 million.[123] The coral reef ecosystem in four Florida counties alone has been valued $7.8 billion each year (Johns et al. 2001), and world-wide, coral reefs account for approximately $375 billion each year (Costanza et al. 1997). Protecting the habitat of these species will be beneficial from any perspective.

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[121] TVA v. Hill, 437 U.S. at 187.

[122] "Informing Regulatory Decisions: 2003 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities." Office of Management and Budget: Office of Information and Regulatory Affairs, pp. 105, (2003).

[123] *Id.*

CONCLUSION

For the reasons detailed throughout this petition, *Acropora palmata*, *Acropora cervicornis*, and *Acropora prolifera* deserve recognition as threatened or endangered species under the Endangered Species Act. Concurrently, critical habitat should be designated along with the listing designation. These *Acropora* spp. face increasing threats everyday. Without intervention to protect them and their habitat, not only do they face extinction, their demise puts in serious condition the sustained health and wellbeing of thousands of species and ecosystems, including humans. We urge NOAA Fisheries to take action immediately to halt and reverse these disturbing circumstances.

This petition requires NOAA Fisheries to formally make an initial “may be warranted” finding within 90 days of receipt of the petition. NOAA Fisheries must then conduct a status review of the species, and subsequently make a final determination about the species’ status within 12-months of receipt of the petition. The Center believes that prompt compliance with these mandatory deadlines are necessary to insure that imperiled species are properly protected under the law, and intends to enforce these timelines vigorously.

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