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Enrique Reef: Degradation and Protective Measures

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Background

La Parguera in southwestern Puerto Rico is home to the Enrique Reef, which meanders along the coastline and mangrove channels as well as small and uninhabited islands. Enrique Reef is a complete reef, with both a fore reef and a larger back reef at greater water depths. The back reef consisted of corals growing in colonies sporadically among turtle grass. Most of the coral colonies were small, reaching up to about five feet across and were conglomerations of branching, stony and fire corals. These were home to several species of small fish, such as damselfish and grunts as well as urchins, sponges, sea cucumbers and other small marine invertebrates. Understanding the diversity in fish species in a coral reef community is a commonly mistaken concept – although it may appear that there is a great variety of species, many of the fish initially believed to be different species, are actually the same species in different phases of life, from larval to juvenile to adult. Furthermore, the appearance of the coral was somewhat less than ideal – many were gray or faded purple in color. Several appeared to have broken sections and fragmented branches while others appeared to have undergone bleaching. Upon exploring the fore reef, similar observations were made, although the size and density of the coral was greater. Here, the coral formed an actual reef, part of the fringing reef around Puerto Rico's southern side, with few gaps. The water depth also increased from four to five feet around the back reef to up to fifteen feet. With increasing size of the coral composing the reef, the species living among the reef were also larger and more diverse. Yet, although the general condition of the reef seemed more able to sustain a greater number and variety of species, the reef was not at all in pristine form. The coral lacked its true bright colors and seemed very damaged. Again, part of the coral were broken and fragmented – some areas seemed to have scrapes across it. Also, much of the coral was coated with algae, which often indicates disease. Some coral appeared as if it were eroded away, with caverns and hollowed out sections. In fact, parts of the reef were so degraded that scholarly sources referred to areas of Enrique Reef as a "coral reef graveyard." Image 1 is a photograph from Enrique Reef in March 2008. Image 2 is photograph of healthy coral from a nearby reef in southwestern Puerto Rico.

Image 1: Bleached coral in Enrique Reef (March 2008)

Image 2: Healthy coral and greater species variation in a reef off southwestern Puerto Rico. (2009)

It seems that through thorough research and exploration, a reason could be found to explain the degradation of Enrique Reef, and could potentially be applied to the eroded state of reefs worldwide. As one of the most diverse and life-supporting ecosystems on the planet, coral reefs are often referred to as "tropical rainforests of the ocean." Therefore, in an age of climate change, which affects terrestrial ecosystems, it is easy to associate global warming as the cause of coral reef degradation. Yet, the issue is more complex. It seems that human activities might have much more of an effect on the destruction of reefs than warming temperatures alone. The coral reef off the shore of La Parguera, Puerto Rico, shows signs of damage not typical of coral reef bleaching, a phenomena credited to global climate change. Rather, the reef seems to suffer from the disturbances of direct anthropological impacts, such as run-off water infiltration, sedimentation, coastal development, and tourism.

Coral Reef Composition

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The substrate of a coral reef is mainly composed of calcium carbonate from both dead and living scleractinian corals. Such corals build skeleton networks of calcium carbonate, which they obtain from the water. As the coral polyp dies, the calcium carbonate skeleton remains incorporated as part of the reef system. The scleractinian coral, members of the Phylum Cnidaria, live in a symbiotic relationship with unicellular algae known as zooxanthellae. These single celled organisms are autotrophic microalgaes and are members of the Phylum Dinoflagellata. Zooxanthellae are crucial to the coral in nutrient production and photosynthetic activities. The algae captures and fixes the carbon for energy and calcification, and maintains a constant balance of elemental nutrients. In exchange, the host coral polyps provide the zooxanthellae an environment in which to live and the carbon dioxide for its own photosynthetic processes.

Coral Reef Bleaching

The bright colors associated with coral reefs are not in fact the tissue of the coral themselves, but rather are coloration from the zooxanthallae living within the coral polyps. In general, coral reefs experiencing moderate growth contain about 1-5 x 10^6 zooxanthellae cm^{-2} of live tissue surface. When corals undergo bleaching, the commonly lose up to 60-90% of their symbiotic zooxanthellae, and in turn, each zooxanthellae may lose 50-80% of its photosynthetic pigments. Thus, when the pigment is lost, the calcareous coral skeleton, which is composed of translucent tissue, gives the bleached appearance. When coral lose a high percentage of their symbiotic algae, zooxanthellae, bleaching can occur, resulting in a coral with a colorless patch or areas of muted color. Images 3 and 4 are both photographs taken at Enrique Reef during March of 2008.

Image 3: Bleached and eroded coral at Enrique Reef (March 2008).

Image 4: Bleached and diseased coral on Enrique Reef (March 2008).

Bleaching due to Temperature Variation

Ecologically, coral reef bleaching, and the death of the symbiotic zooxanthellae is a response to stress, generally attributed to increased sea surface temperatures. In recent years, especially with increased greenhouse gas emissions, ocean temperatures have risen varying amounts depending on the latitude. Normally, scientists have looked to a general increase in water temperature as a cause of coral bleaching. However, it has been noticed that not all corals bleach in response to increases in temperature to above-normal levels (Sammarco et al. 2006). Thus, coral reef bleaching seems to be linked to more than just increased sea surface temperatures alone. It is believed, then, that the susceptibility of coral to bleaching is linked especially to spikes in water temperature and may vary based on the individual's acclimation to local environmental conditions (Sammarco et al. 2006). However, as seen by Figure 1, major bleaching events have occurred worldwide.

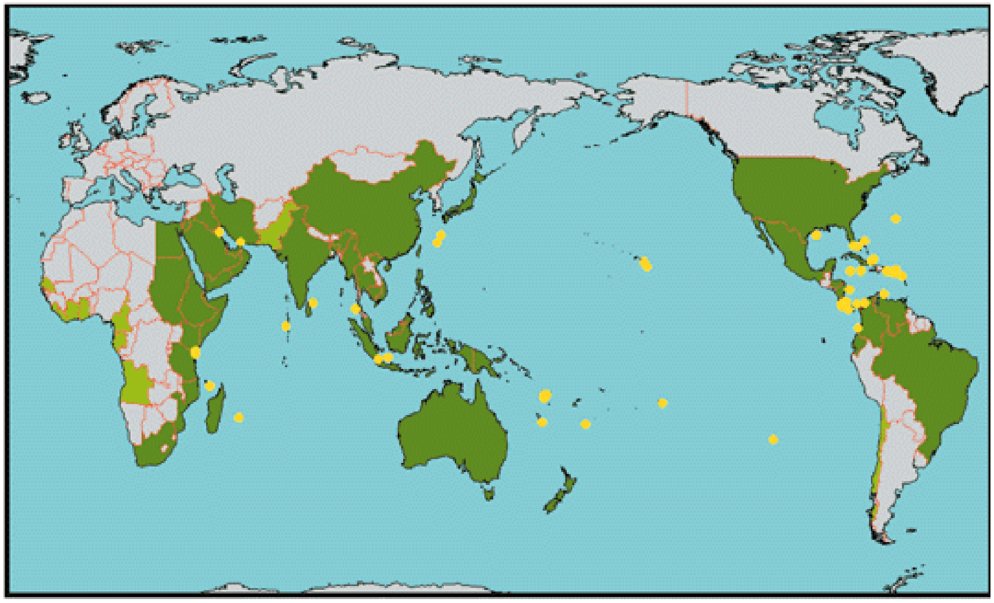

Figure 1: Areas in yellow indicate instances of major bleaching events. The Caribbean area shows a major trend in bleaching.

Amos Winter, a marine biologist based in the University of Puerto Rico at Mayaguez Marine Laboratory in La Parguera, collected thirty years (1958-1998) of sea surface temperature in the area and analyzed it with regards to coral bleaching. His data was placed into three corresponding categories: cooler years in which coral did not bleach; warmer years in which severe coral bleaching did occur; and warmer years in which bleaching did not occur (Sammarco et al. 2006). From this data, a coefficient of variance was calculated and indicated that the years in which bleaching occurred, a high coefficient of variance was noted (Sammarco et al. 2006). This simply means that coral bleaching did not occur just based off increased sea surface temperatures. Rather, in order for bleaching to occur, a spike in water temperature must also occur. In fact, even at sea surface temperatures approaching 30°C, with a critical temperature for bleaching at 29.1-29.8°C (Sammarco et al. 2006), coral tended not to bleach as long as the coefficient of variance of the water temperatures were low. However, the study showed that at sea surface temperature below 29°C the coral would bleach with a high coefficient of variance (Sammarco et al. 2006). Thus, this study and data suggest that increasing sea surface temperatures alone are not significant enough to predict coral bleaching. Instead, shifts or spikes in temperature are more reasonable causes of bleaching. Figure 2 diagrams the process of coral reef bleaching.

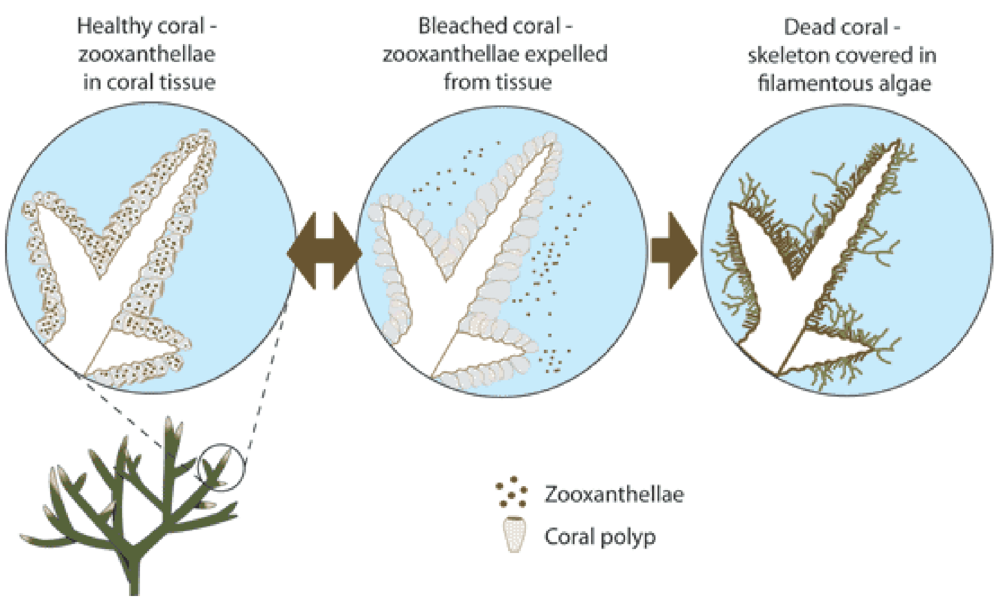

Figure 2: Coral reef before and after zooxanthelle are expelled from polyp tissue.

Bleaching due to Sedimentation

In addition to fluctuations in sea surface temperatures, increased terrestrial sedimentation into the reef from shoreline development can have devastating effects on the vitality of the ecosystem. Sedimentation can decrease the availability of sunlight to coral, smother sections or complete coral colonies, and increase turbidity (Ryan et al. 2008). In La Parguera, on a road along the coastline, there was a significant amount of new developments being constructed, such as small hotels and condominium complexes. It seems that these developments, if not adequately monitored, could have devastating effects on the nearby reef because of careless sedimentation in runoff into the water. La Parguera, a community in Puerto Rico undergoing modest tourism-related growth can be looked at as an area with a minimal impact (Ryan et al. 2008) yet if a decline in reef health is noticed, it can be assumed that similar destruction would occur in areas experiencing more pronounced growth. Furthermore, it seems that sedimentation from the coastline would also affect the mangrove community, which affects the vitality of the nearby coral reef. A study on the history and changes in terrestrial sedimentation on coral reef was conducted at Corral Reef off the shore of La Parguera. By analyzing collections of sediment from the reef area, the amount of land-originated sediment can be determined by assuming that non-carbonate sediment is terrestrial (Ryan et al. 2008). This study assumes that any carbon and calcium containing particles are of natural origin from the coral and was fixed out of the seawater by the symbiotic zooxanthellae. From 1920 to 2000, the terrestrial percentage of the mixed layer of the reef has increased from 6 percent to nearly sixteen percent (Ryan et al. 2008). This increase is potentially the result of careless shoreline construction and development in order to draw more tourists to La Parguera. An interesting paradox exists here: La Parguera is economically sustained through tourists visiting the coral reef, yet, development to bring more tourists degrades the reef which they come to see. Although the effects of sedimentation in La Parguera are minor now, future development could overrun the reef. Furthermore, the stress of sedimentation, coupled with other already present stresses, like increased sea surface temperatures, could have devastating effects on the health of the reef (Ryan et al. 2008).

Bleaching due to Eutrophication

Similar to sedimentation, eutrophication, the over-fertilization water by nutrients in fertilizers, sewage and animal wastes can also have a devastating effect on coral reef ecosystems (Agardy 2004). The overabundance of such nutrients causes algal species to overgrow coral colonies, smothering the coral and blocking sunlight from the zooxanthallae. Being especially nutrient sensitive ecosystems, coral reefs are susceptible becoming eutrophic. Coral reefs can become overgrown by weedy algae, at nutrient levels that are so low that they would indicate nutrient starvation in any other ecosystem (Cervino 2005). Reefs nearby developed coasts, especially those serving as tourist destinations are especially at risk. Runoff containing fertilizers rich in nitrogen and phosphorous, often used in maintenance of golf courses and gardens, such as those at hotels, are detrimental to nutrient levels. As with sedimentation, coastal development is a major concern regarding eutrophication. Runoff into near shore waters can increase the stress on coral, especially in the colonies part of the back reef, closest to shore with the least amount of water passing through it. Overall, it seems that both sedimentation and eutrophication can add to the likelihood of reef degradation and make coral more susceptible to bleaching and mortality.

Bleaching due to Freshwater Runoff

Because coral reefs can be only short distances from the mainland, land-based sources of stress, such as sediment and fertilizers, as well as freshwater, often end up on coral reef substrate. Fresh water alone is a stressor for coral reefs, and even natural levels of runoff can significantly affect species distribution, reproductive successes, and larval survivorship (Richmond et al. 2007). In addition to rivers depositing freshwater into oceans and affecting the pH, coastal development can re-route freshwater flows both from rivers and runoff and can devastate reef health. Changes in freshwater flow can affect water flow over areas of coral reef and are likely to flush out nutrients, as seen in Figure 3. Zooxanthellae require certain water flow speeds in order to filter enough nutrients and fix sufficient amounts of carbonate for reef construction. In addition to flushing nutrients out of the reef area, the increase in freshwater dilutes the overall availability of nutrients present for which the zooxanthellae fix and the coral polyps require to flourish. The proximity of rivers to coral reefs is a very important determinant . Not only are they the principle source of sediments, nutrients, and salinity stress along tropical coastlines, but also they carry a range of other substances that many impact on corals and coral reef organisms (Hoegh-Goldberg 1999).

QuickTime™ and a
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Figure 3: The image diagrams the effect of river discharge on a coral reef. The arrows indicate areas of sediment deposition from mud as well as the nutrient flushing over the coral reef area. (Richmond 2007)

Destruction by Marine Life

In addition to the effects of warming sea temperatures and sedimentation on coral reefs, other marine life can cause havoc on reef communities. In La Parguera specifically, a large population of Long-Spined Black Urchins, live in the reef areas. Urchins feed on turtle grass, which normally grows on the seafloor on the shoreline side of coral reefs in shallow waters, such as Enrique Reef off La Parguera. However, urchins can also feed on the reef substrate and cause significant damage. In fact, urchins are considered major bioeroders in coral reef communities (Griffin et al. 2003). Thus, an overabundance of urchins could be a significant factor in the degradation of reefs. In a study conducted in two patch reefs off La Parguera, Palmas and Mario, both slightly west of Enrique Reef, the rate at which red sea urchins, *Echinometra viridis*, bioerode the reef was calculated by determining the amount of calcium carbonate in their feces. Ultimately, it was determined that red sea urchins have a significantly higher rate of bioerosion in shallow reef areas, up to three meters deep, than in areas of six meters or deeper (Griffin et al. 2003). Therefore, this could explain some of the degradation in the portions of Enrique Reef because little of the reef exceeds a depth of six meters. Furthermore, the bioerosion caused by sea urchins in characterized by large dug out cavities and gullies, unlike scars left by scarid erosion from parrotfish and sponges (Griffin et al. 2003). This type of erosion seemed evident in observation of Enrique Reef – much of the coral looked as if caverns or holes had been worked into it.

Anthropological Activity

Aside from the ecological impacts of the vitality of Puerto Rico's Enrique Reef, a significant amount of damage could be the result of direct anthropological activity.

Effect of Tourism on Coral Reef

Puerto Rico, especially the vibrant beach town of La Parguera, is becoming a more popular tourist destination for recreational visitors. Divers can cause damage to the reef by careless swimming and simply just a lack of information about the fragility of the coral reef with which they are in such close contact. Divers are especially likely to cause damage to the reef at the beginning of their dive while they are still adapting to being underwater (Hawkins et al. 2005). Furthermore, it is not entirely clear how much tourism a reef can sustain and a great deal of variation is possible. Reefs already exposed to other stresses, increased sea surface temperature or sedimentation, combined with heavy tourisms are more likely to bleach or die. The World Bank questioned how much tourism the coral reef in Bonaire Marine Park, known for maintaining some of the most pristine reefs in the Caribbean could sustain when the reef was presented with a rapidly increasing number of divers per year (Hawkins et al. 1998). Ultimately, it was concluded that very few coral colonies were broken as a direct result of divers, with only 1 colony in 40 showing damage (Hawkins et al. 1999). Yet, when the amount of coral cover in areas of the reef protected by Bonaire Marine Park were compared with unprotected dive sites, the results show a significant difference: Reserve sites had significantly more coral cover (Hawkins et al. 1998). Perhaps this indicates that a different type of tourist is drawn to the protected reef compared to the unprotected reef. It seems that tourists informed and specifically interested in reefs, such as our class in Puerto Rico, would chose to visit the protected area of reef and would be more cautious about their dive.

Although increased tourism is a factor linked to coral reef degradation, it alone is not significant enough to negatively effect coral and fish communities (Hawkins et al. 1998). In fact, tourism is a crucial component in the economies of many tropical islands, including Puerto Rico. Population analysis reveals that 75 percent of the people living within 100 kilometers of coral reefs are in the poorest developing nations, and up to 70 percent of these people live outside urban areas, indicating that the more likely to be dependant on reef resources (Donner, 2007). Thus, tourism on the reef is inevitable and an economic aid to many of the world's poorest nations.

Ecotourism

The solution regarding tourism is perhaps, a shift to transform the uninformed tourist to the ecotourist to Puerto Rico. A movement to create a balanced sustainable tourism industry is crucial for the survival of the coral reefs not only in Puerto Rico, but surrounding most islands, especially the shallow reefs easily accessible to snorkellers and divers. If one 'googles' the phrase "tourism in Puerto Rico" the first website to appear is the popular gotopuertorico.com. Here, the site boasts of the ease of snorkeling over coral reefs and explains how calm the water is because the large waves are blocked by the coral formations. This, coupled with the shallow water depths, indicates that tourists unaware to the delicacies of coral reefs are swimming in close proximity to such ecosystems. Scuba and snorkel equipment rental sites rarely teach tourists about the intricate relationship between the coral polyps and the zooxanthellae or the harms in touching the reef. Furthermore, knowledgeable guides rarely accompany divers and swimmers in viewing reefs. Thus, it seems that significant reduction in physical coral reef destruction due to human impacts could be teaching tourists about reefs, providing guided reef tours, and managing reef sites accessible to swimmers.

Legislative Remedies

Blue Flag Program

However, Puerto Rico recently began efforts to make tourists and beach-goers more conscientious of the offshore coral reef ecosystem. In November 2009, Puerto Rico became one of 41countries or territories that are part of the Blue Flag Program. The Blue Flag Program is a voluntary eco-label to which countries can apply. It is run and owned by the independent non-profit organization Foundation for Environmental Education (FEE). The Program works to achieve sustainable development at beaches and marines by maintaining strict criteria regarding water quality, environmental management and safety, while pursuing the environmental education of visitors. Blue Flag criteria includes ensuring that environmental education activities are offered and promoted to beach users, as well as providing information relating to local eco-systems, such as reefs, and environmental phenomena. In addition, the Program provides detailed criteria regarding environmental management, such as standards for on-site restrooms and runoff water areas. Puerto Rico currently has six Blue Flag beaches and two marinas. One of the Blue Flag beaches, Boqueron Beach, in the Cabo Rojo municipality, is about five miles away from La Parguera. This is an indication that Puerto Rico's coral reefs, including Enrique Reef, are in the early stages of gaining protection from tourist-inflicted harm.

Rivers and Harbors Act

Beyond siding with the non-profit Blue Flag Program, a series of legislative acts, enforceable by law, need to be established to continue the protection of the coral reef. Coral reefs can only be sustained and protected by minimizing the impacts that humans have on the surrounding ecosystem, indicating that stricter laws regarding coastal development, waste and runoff management, fishing, and tourism, be put into place immediately. Furthermore, movements to fight global climate change and curb green house gas emissions would also benefit the longevity of coral reefs. Nevertheless, improved legislature specifically targeting coral reef vitality is essential. In 1899, the United States began creating laws to manage waters, both marine and fresh, within boundaries. The *Rivers and Harbors Act* (1899) granted authoritative power to the US Army Corps of Engineers to regulate any structure, organic or inorganic, within navigable waters of the United States. However, the US Army Corps of Engineers treated coral reefs as a hazard to sea navigation due to the abrasions they potentially could cause to ships and little was done in their protection. Because power was given to an agency that lacked scientific and biological expertise, the maintenance of the reef was ignored.

Fish and Wildlife Coordination Act

In 1958, the *Fish and Wildlife Coordination Act* was passed which stated, "whenever the waters or channel of a body of water are modified by a department or agency of the U.S., the department or agency first shall consult with the U.S. Fish and Wildlife Service." Because this Act targeted fish, it indirectly provided a minimal level of protection for coral reefs. The Act made plans to study the effects of domestic sewage, trade wastes, and other pollutions on wildlife and marine life. Furthermore, it subjected those in violation to the Act to a misdemeanor offense and a range of fines from up to $100,000 for individuals and $200,000 for organizations. However, the Act still did not specifically mention coral reefs and provide specific legislation for their protection.

National Environmental Policy Act

Beginning in the late 1960s, environmental law became a rising topic in both local and national legislative councils. The *National Environmental Policy Act* (1969) was passed in order to "encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man." Perhaps the most significant and lasting effect of this law was to establish procedural requirements for all federal government agencies to prepare Environmental Assessments and Environmental Impact Statements, which contain documentation of the environmental effects of all proposed federal agency actions. Furthermore, the Act was designed to ensure that environmental factors are weighed equally when compared to other factors in the decision making process taken by federal agencies. Yet, this is a difficult statement to enforce. In addition, though the Act makes several valuable claims towards environmental protection, including the protection of coral reef ecosystems, it does not target single issues directly.

In accordance with the *National Environmental Policy Act*, the Council on Environmental Quality was established in 1970. As a division of the Executive Office of the President, the Council on Environmental Quality was designed to manage federal environmental efforts in the United States and work in coordination with the agencies and White House offices in the development of environmental policies and initiatives.

Coastal Zone Management Act

In 1972, the *Coastal Zone Management Act* was established to "encourage coastal states to develop and implement coastal zone management programs." This Act extended to commonwealths and territories as well, many of which held jurisdiction over coral reefs. This act, administered by the National Oceanic and Atmospheric Administration's Office of Ocean and Coastal Resource Management, was implemented to manage the nation's coastal resources and balance economic development with environmental conservation. However, economic development often took a front seat to environmental conservation, especially in Puerto Rico and other Caribbean Island areas. While the coastal zone management programs were critical elements, often, these areas lacked the legal force to prevent damage, especially where local laws and political will were weak.

Endangered Species Act

The *Endangered Species Act* (1973) indirectly benefited the health of coral reefs by pledging to provide for the "conservation of endangered and threatened species of fish, wildlife, and plants." This Act, administered by two federal agencies, the United States Fish and Wildlife Service and the National Oceanic and Atmospheric Administration, intended to protect species at risk for extinction due to economic growth and development. While this act protects habitats in general, only a few coral reef species and no entire ecosystems were affected by this legislation because at the time, they were not in danger of extinction.

Clean Water Act

In 1977, the *Clean Water Act*, now currently in effect under the Federal Water Pollution Control Amendments of 1972, established goals of elimination releases of high amounts of toxic substances to water, and ensuring that surface waters would meet standards necessary for human sports and recreation by the set year of 1985. This Act did significantly expand prior legislation regarding water purity, yet it lacked enforceable standards and agencies to pursue the maintenance of the law. The Act benefited coral reefs by limiting the amount of runoff containing pollutants as well as sediment, yet, because it primarily affected surface waters, and areas used for human recreational activities, some major reefs were excluded. Only shallow and fore reefs were protected by this Act.

Comprehensive Environmental Response, Compensation, and Liability Act

Soon after, in 1980, the *Comprehensive Environmental Response, Compensation, and Liability Act* was released, which “created a tax on the chemical and petroleum industries and provided broad federal authority to respond directly to the releases or threatened releases of hazardous substances that may endanger public health or the environment.” While this Act provided legal consequences in the form of fines on polluters, it did not necessarily deter pollution. Often, for large corporations, paying the fee for dumping into oceans or rivers was lower in cost than paying for proper disposal of chemicals and hazardous substances. In addition, polluters were often unnoticed, and thus, not penalized. In general, corporations found means to evade the fee and continue to pollute.

Executive Order 13089 on Coral Reef Protection

In 1998, the most significant legislation regarding the protection of coral reefs was established by *Executive Order 13089 on Coral Reef Protection*. This provided enabling legislation for the US Coral Reef Task Force (USCRTF) to oversee implementation of the Executive Order and develop and coordinate efforts to map and monitor US coral reefs. The Task Force operates under two main themes: the first, to “understand coral reef ecosystems” in order to gain a better understanding of complex ecosystems to improve the management and conservation of resources, and the second, to "reduce the adverse impacts of human activities" essential to conserving reef ecosystems. In 2000, the US Coral Reef Task Force adopted the *National Action Plan to Conserve Coral Reefs (National Action Plan)*, which served as the first national blueprint for US domestic and international action to address the growing coral reef crisis. USCRTF members meet biannually to discuss key issues facing reef health, propose new actions on conservation, present progress reports, and update the coral community on past accomplishments, while still setting future goals. In addition, the USCRTF has led initiatives called Local Action Strategies to identify and implement priority actions needed to reduce key threats in each US coral reef jurisdiction. In 2002, the "Puerto Rico Resolution" was passed, which mandated that three-year Local Action Strategies be set to provide a goal-oriented roadmap for collaborative and cooperative action among federal, state, territory, and non-governmental partners.

Puerto Rican Local Action Strategies

Puerto Rico established their own Local Action Strategies (LAS) through the Puerto Rico Department of Natural and Environmental Resources and builds on the experience of many different stakeholders to improve its efficiency and effect on coral reef protection. A plan for public outreach and awareness was outlined and included completing an economic valuation study on coral reefs in Eastern Puerto Rico as well as posting signs in coastal areas to educate beach users about the surrounding ecosystems and how to protect them. In addition, the LAS planned to distribute educational information to coastal businesses, students and the public about the importance of coral reefs to Puerto Rico's economy. Furthermore, a series of goals regarding land-based sources of pollution were established. The plan outlined increasing public awareness and reaching farmers to encourage them to utilize ideal practices to reduce pollution through agriculture by decreasing pesticide and fertilizer use, as well as ensuring proper disposal of the chemicals. The plan also targeted developers and created mandatory training workshops to teach ways to reduce coastal pollution and to promote watershed protection by creating appropriate runoff channels. To combat the effects of tourists and recreational misuse of the coral reef, the LAS made plans to assess damage by anchoring boats or trampling by swimmers and to install hundreds of buoys over target priority sites. La Parguera was a town specifically mentioned in Puerto Rico's LAS.

Shortcomings in Policy

While such policies have had significant impacts of the protection of coral reef, greater measures and efforts need to be taken to ensure their safety. Primarily, because coral reefs effectively extend into adjacent watersheds, effective management should integrated terrestrial protected areas and marine protected areas as a coupled unit. Relating to neighboring terrestrial areas, accumulated sediment is lethal for reefs due to the nutrient deficiencies and reduction in sunlight, and until this issue is integrated into combined terrestrial and marine efforts, reef health will continue to decline.

Furthermore, in creating policies, the lack of explicit legislative definitions for coral, coral reefs, and coral reef ecosystems limit the capacity of environmental legislation to support needed conservation efforts. Likewise, the vagueness with which community input is collected, weighed, and applied has often reduced the value of public hearings and commentary until they amount to futile formalities. Effective protection will require a comprehensive review of US federal legislation, regulatory agency jurisdiction, and human and financial resource allocation, with stakeholders, researchers, social scientists, and policy makers providing input to help identify roles, opportunities, responsibilities and accountability (Richmond et al. 2007).

In addition, a key issue is the fact that while coral reef restoration activities are conceptually attractive and likely to pass legislative hearings, protective measures are entirely more essential. Due to the ecological complexity of coral reef ecosystems, a damaged or killed reef can take centuries to rebuild, despite the fact that it can be destroyed within moments, depending on circumstances. Therefore, when dealing with coral reefs, prevention of environmental degradation is far more important, as well as cost and time effective than environmental remediation after the fact.

Finally, promoting awareness and providing education regarding coral reef ecosystems and their value as natural resources is a fundamental step in their protection. Education about coral reefs should be taught beginning at elementary levels and should continue into high school. Students should be encouraged to explore coral reefs if they are accessible in their communities, yet should do so under strict guidance.

Summary

Coral reef degradation and bleaching is clearly a complex ecological and anthropological occurrence. Any single factor alone is not enough to disrupt a coral reef ecosystem, yet when combined, the reef suffers. Policy and legislature have taken steps to address the specific needs of coral reefs, however more stringent and enforceable regulations must be established for their protection.

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