EASTERN PACIFIC

ASSESSMENT OF THE PRESENT HEALTH OF CORAL REEFS IN THE EASTERN PACIFIC

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Reef-building corals in the eastern Pacific occur from the upper reaches of the Gulf of California, Mexico, through Middle America to the southernmost coast and offshore islands of Ecuador. Oceanic islands also included in the eastern Pacific region are the Revillagigedo Islands (Mexico), Clipperton Atoll (France), Cocos Island (Costa Rica), and the Galapagos Islands (Ecuador). The limits of reef construction extend from approximately 24°N, from near the tip of Baja California, to 2°S, including the mainland coast of Ecuador and the southern Galapagos Islands.

Thirty-three species of reef-building scleractinian corals and hydrocorals in 11 genera make up the Recent eastern Pacific fauna (Glynn, in press). The main reef-building genera are Pocillopora *(5 species)* Porites *(1 species) and* Pavona *(4 species). Other genera are often present, but unimportant in terms of reef building (*Psammocora, Leptoseris, Gardineroseris, Millepora*), rare (*Acropora, Siderastrea*) or not associated with reef formations (*Diaseris, Cycloseris*).*

Pocilloporid fringing reefs occur south of La Paz, Baja California, at Cabo Pulmo and Los Frailes, in the Revillagigedo Islands, and at a few localities along the mainland coast of Mexico (Reyes Bonilla 1993a). Several recently discovered pocilloporid fringing and patch reefs at Huatulco, Oaxaca, suggests that this area harbors the highest density of coral reefs on the Mexican west coast. Most eastern Pacific reef formations occur at shallow depth i.e., 6-10 m. Clipperton Atoll, located about 1,300 km SW of Acapulco, is the best developed coral reef in the eastern Pacific (Glynn et al. 1996). A reef surrounds the entire atoll and is built principally of Porites, *with* Pavona *and* Pocillopora *also contributing to its structure. High live coral cover at Clipperton extends to 50-60 m depth. In general, eastern Pacific pocilloporid reefs are fragile and tend to develop in bays or along shores protected from strong swells. Massive reefs built of* Porites *and* Pavona *are, however, occasionally well developed at more exposed sites.*

Most of the Central American coast between Huatulco, Mexico, and Costa Rica is unexplored relative to coral reef development. Aside from relatively small patches of reef corals present off the south coast of El Salvador, coral reefs are not known along this coastal stretch until reaching Costa Rica. Perhaps numbering 100 or more, fringing and patch reefs occur along the coasts and on offshore islands from Costa Rica to Ecuador (Glynn and Wellington 1983; Guzman and Cortes 1993). Coral species richness is highest off Costa Rica (20 species) and Panama (23 species). Although several species occur in the southern Central American area, many of these, about 50% of the fauna, are rare or have recently experienced local to regional extinctions (Glynn, in press). The majority of the reductions in population size were coincident with the 1982-83 El Niño disturbance. Prolonged sea warming caused coral reef bleaching, which resulted in high coral mortality (Glynn 1990; Guzman and Cortes 1993).

In addition to El Niño-related disturbances, heavy sediment loading resulting from poor land management (Cortes 1990), phytoplankton blooms (Guzman et al. 1990), intense upwelling pulses (Glynn and D'Croz 1990), extreme low water exposures (Glynn 1976), tectonic activity, volcanism, and anthropogenic contaminants (Guzman and Cortes 1993) have all had measurable impacts on eastern Pacific coral reefs. Moderate levels of predation by *Acanthaster planci* can reduce live coral cover, affecting relative abundances of corals and coral species diversity in certain areas (e.g., Gulf of California, Mexico, and Gulf of Chiriqui, Panama), but sea star outbreaks have never been observed in the eastern Pacific (Glynn 1974). Hurricane damage to reefs is also relatively rare, affecting chiefly the Mexican coast, Revillagigedo Islands, and Clipperton Atoll.

Local fishermen are the principal users of eastern Pacific coral reefs, from which are harvested fishes, spiny lobsters, shellfish (conch and scallop), and ornamental corals. Until recently, pocilloporid corals were collected and sold as souvenirs from reefs in Mexico and Costa Rica. This practice has been outlawed and is reasonably well enforced. Live rock is still occasionally harvested illegally and shipped chiefly to the U.S.A. An especially destructive form of exploitation has been observed recently in Panama. This involves breaking live reefs apart with tuna bombs and then dredging through the broken corals in order to collect sea shells, which are sold to collectors.

The only known mooring buoy established on a coral reef is at Devil's Crown, Floreana Island, Galapagos Islands. However, the buoy is not regularly maintained and is not always functional. A line of anchored buoys was also laid recently to mark the bounds of a large pocilloporid reef (La Entrega) at Santa Cruz Bay, Huatulco, Mexico. Unfortunately, several of the anchors were dropped directly on live corals.

The greatest value of eastern Pacific coral reefs is for fishing and tourism. Regrettably, most fishermen exploit the reefs for fishes and shellfish with little concern for their preservation. Recreational diving is increasing rapidly, and this is exercised mainly by foreign tourists.

PRESENT CONDITION

Coral reefs in many eastern Pacific areas are in reasonably good condition (i.e., they appear to be undergoing net positive vertical and horizontal growth). However, coral reefs in several areas have been severely degraded, largely a result of the 1982-83 ENSO, and are currently in an erosional mode. Nearly all coral reefs in the equatorial eastern Pacific (Galapagos Islands, Cocos Island, mainland Ecuador, Colombia, Panama, and Costa Rica) experienced 50 to 99% mortality, which was coincident with the 1982-83 ENSO (Glynn 1990; Glynn and Colgan 1992; Guzman and Cortes 1992). Coral reefs in the Galapagos Islands (Glynn 1994) and at

Cocos Island (Guzman and Cortes 1992) have shown virtually no recovery since 1983. Reefs in these areas continue to decline due to concentrated corallivory on surviving corals and continuing bioerosion (Reaka-Kudla et al. 1996). Elsewhere, coral recruitment is evident with slow to moderate recovery taking place. In the northern part of the eastern Pacific region (Mexican mainland coast, Revillagigedo Islands, and Clipperton Atoll), most coral reefs exhibit high to moderately high coral cover or are experiencing coral recruitment following bleaching events.

Following is a brief review of coral reef degradation by locality.

Galapagos Islands

All known coral reefs in the Galapagos Islands are seriously degraded. The chief causal factors are ENSO 1982-83 coral bleaching and mortality, anchor damage and fishing activities. The reef structures are 80-100% degraded (i.e., most to all reef surfaces show some signs of damage: dead and eroded corals or collapsed frameworks); 100% of the reefs are affected.

Mainland Ecuador

Many of the Ecuadorian mainland coral reefs are damaged. The causal factors are as above; 50% degradation; 80% of the reefs are affected.

Colombia

All coral reefs at Gorgona Island were affected by the 1982-83 ENSO (Prahl 1983, 1985); 20-30% degradation; reefs have recovered substantially, now with 40-50% cover (Vargas-Angel, pers. comm.). There are some indications that river-born sediments are beginning to affect the coral reefs of Gorgona Island (Vargas-Angel, pers. comm.). In recent years the course of the Rio Patia has been altered such that its effluents flow more directly toward Gorgona Island. Malpelo Island: no quantitative data available, but live coral cover relatively high (Vargas-Angel, pers. comm.). Ensenada de Utria National Park: live coral cover has declined in recent years due chiefly to increased sedimentation stress (Vargas-Angel 1996); 40% degradation; 100% of reefs affected.

Panama

The coral reefs in Panama are located in the Gulf of Panama: Taboga, Otoque, Bona, the Pearl Islands, and Iguana Island, and at most islands in the Gulf of Chiriqui: Coiba, Contreras, Secas, Canal de Afuera, and Montuosa. Also, there are several mainland reefs in the Gulf of Chiriqui. The Taboga Islands reefs appear to be most affected by a fish meal plant (Taboguilla Island), siltation (Taboga Island), and mechanical damage by fishermen. Degradation ranges from about 50% to complete destruction (or burial). About 80% of the reefs are affected. The reefs in the Pearl Islands were about 50% degraded by the 1982-83 ENSO with nearly all affected. Several of these are showing reasonable recovery. A rare group of *Gardineroseris planulata* colonies at Contadora Island is threatened by building and boating activities. Trash is often dumped on top of nearshore colonies. Reefs in the Gulf of Chiriqui suffered about 40-80% degradation during the 1982-83 ENSO and all (100%) were affected. Most of these reefs are showing signs of recovery, however, shrimp boats anchoring near them (e.g., at Uva Island) sometimes drag their anchors over the reefs or run aground, causing extensive damage. Some of the fishing boats discard trash (e.g., motors, cables, nets) directly on the reefs.

Costa Rica

Reef formations in mainland Costa Rica occur mainly at Cano Island, in Golfo Dulce, and along the Guanacaste coast. ENSO-related damage to most of these reefs was similar to that noted above for coral reefs in the Gulf of Chiriqui, Panama. The oldest, fringing, poritid reef at Punta Islotes, located in Golfo Dulce, was not examined during the 1982-83 ENSO but nonetheless has been severely degraded in recent years. The living coral cover on this reef is now less than 2%. Increased sedimentation and turbidity were associated with the final stage of reef degradation, probably a result of recent deforestation, mining, and road construction (Cortes et al. 1994). Since so little information is available on the coral reefs of the Guanacaste area, it is premature to assign quantitative values on the extent of degradation or the proportion of reefs affected. All of the coral reefs at Cocos Island, located several hundred kilometers offshore, were severely (90-95%) damaged by the 1982-83 ENSO (Guzman and Cortes 1992). Post ENSO disturbances caused by *Acanthaster* predation and bioeroders have further degraded the Cocos reefs.

Nicaragua, Honduras, El Salvador, Guatemala

Virtually no literature exists on the extent of reef development along the Pacific Central American coast from southern Nicaragua to southern Mexico. Coral communities are known to occur in El Salvador, but these have not been properly described and their condition is unknown.

Mexico

Seventeen pocilloporid reefs have been observed recently in the Bahias de Huatulco area of southern Mexico. Three of these reefs are mostly dead, with less than 3% live coral cover: Santa Cruz fringing reef, Riscalillo reef, and a patch reef offshore of a Club Med resort. The cause of death is unknown, but the Santa Cruz and Club Med reefs are located near extensive development activities, such as harbor dredging and jetty construction. The only other published information on disturbances to Mexican coral reefs pertains to reefs in the southern part of Baja California. Reyes Bonilla (1993a, 1993b) refers to pocillopoird mortality at Cabo Pulmo during the 1987 El Niño, which amounted to no more than about 10% of the coral cover. It is possible that the 1982-83 ENSO had some effect on corals in this area, but no observations were reported. Significant local coral mortality also was noted at Los Cabos sometime between 1988 and 1989. For example, Wilson (1990) described 70-95% mortality of *Pocillopora* spp. at Punta Palmillas and Cabo San Lucas from unknown causes. Reyes Bonilla (1993a) speculated that extreme low sea temperatures could affect corals in this area. Likely, although undocumented, sources of damage caused by humans are anchor damage, extraction of corals for sale as curios, the collection of fishes for the aquarium trade, siltation due to land clearing and hotel construction, and the discharge of sewage. Although no literature was found dealing with the coral reefs of the Revillagigedo Islands, it seems probable that the reefs there would experience occasional hurricane damage.

Clipperton Atoll

Outside of isolated dead patches of *Pocillopora* sp. and *Porites lobata* colonies that had experienced partial mortality, the extensive reef formations surrounding this atoll appeared healthy. Overall, probably <5% of the coral cover was dead.

GENERAL

As a rough approximation, about 10-20% of the coral reefs in the equatorial eastern Pacific region are still in a pristine state. While damage due to ENSO is evident on all reefs, they are now dominantly in a recovery phase. Perhaps 60-80% of the coral reefs in the northern eastern Pacific region are in a pristine state (Reyes Bonilla 1993a).

The following is a subjective ranking of the most serious human-induced stressors to coral reefs in the eastern Pacific region.

1) Physical destruction of reef frameworks by anchors, fishing nets, trash (plastic bags, discarded clothing, scrap metal, etc.) and boat groundings.
2) Siltation stress from river discharge in areas with poor land management (e.g., clear-cutting of forests, mining activities, hotel and road construction).
3) Increased nutrient and sewage runoff near reefs.
4) Harvesting of seashells, coral rock and tropical fishes.

A subjective ranking of natural disturbances follows.

1) Coral bleaching and mortality (El Niño-Southern Oscillation).
2) Severe upwelling events (cold water stress and increased competition with non-calcifying epibenthos due to elevated nutrients). Bioeroder populations, such as sponges, bivalve mollusks, and sea urchins, also interfere with corals on local scales.
3) Flooding episodes with high river discharge carrying sediments and contaminants.
4) Localized mortality due to *Acanthaster* and *Jenneria* (a gastropod) corallivore activities.
5) Tectonism and volcanism affecting reefs on local scales.

No statistical data are available on coral reef resource exploitation in the eastern Pacific.

Scientific Importance and Research

In recent years (since about the 1970s), much of the research on eastern Pacific coral reefs is being conducted by resident scientists at local laboratories rather than by visiting scientists from distant institutions. This offers several advantages, including the opportunity to carry out continuously monitored studies, to observe unexpected events firsthand, and to address scientific problems that are locally relevant.

Several notable studies have been conducted by reef researchers at the Charles Darwin Research Station (Galapagos Islands, Ecuador); the Universidad del Valle, and the Universidad de los Andes (Colombia); the Departamento de Biologia Acuatica, Universidad de Panama, and the Smithsonian Tropical Research Institute (Panama); the Centro de Investigacion en Ciencias del Mar y Limnologia (CIMAR), the Escuela de Biologia, Universidad de Costa Rica (Costa Rica); the Centro de Investigacion Cientifica y Educacion Superior de Ensenada, and the Departamento de Biologia Marina, Universidad Autonoma de Baja California Sur (Mexico).

Guzman and Cortes (1993) offer an informative overview of the sorts of research that have been conducted on eastern Pacific coral reefs: physical oceanographic influences (e.g., tides, currents, upwelling, El Niño events), reef growth history, paleoclimate analyses, systematics, biogeography, ecology (coral growth, competition, predation, bioerosion, symbioses), natural

and anthropogenic disturbances, coral community recovery, and management and conservation. More recently molecular genetic studies on the systematics of pocilloporid corals and the identity of dinoflagellate strains vis-a-vis coral bleaching have been initiated at the Smithsonian Tropical Research Institute in Panama.

Some of the more pressing research needs are listed below: (1) develop an inventory of the regional distribution of coral reefs and their species composition; (2) establish research collections of corals and other reef-associated species; (3) establish an international network of coral reef monitoring to assess water quality (e.g. temperature, salinity, sediment loading, turbidity, irradiance, nutrients) and the condition of coral reefs, and to quantify variations in the abundances of key (e.g., chief calcifiers, corallivores, herbivores, bioeroders) reef species; (4) determine environmental impacts, both natural and anthropogenic. Financial support is needed to coordinate these tasks among the various research groups. Planning and training workshops are necessary to decide on critical study areas, and to intercalibrate instruments and standardize methodologies and sampling protocols.

Management

Although some attention has been directed toward the management of eastern Pacific coral reefs, generally these efforts have been inconsistent, transitory and largely ineffectual. A mooring buoy is sometimes available at a popular diving site (Devil's Crown, Floreana Island) in the Galapagos Islands. I am aware of only one other attempt to protect a coral reef from boat traffic, namely the buoy line established on La Entrega reef, Santa Cruz, Huatulco, Mexico. Coral populations that were devastated by the 1982-83 ENSO have been restored by transplantation efforts at selected sites in the Galapagos Islands (Academy Bay; Glynn 1994), and in Colombia (Gorgona Island), Panama (Iguana Island), and Costa Rica (Cano Island) (Guzman 1991). Several national parks or protected areas now exist near coral reefs in Ecuador (in the Galapagos Islands and on the mainland), Colombia (Gorgona Island, Utria), Panama (Iguana Island, Coiba Island and surroundings), Costa Rica (Cocos Island, Cano Island and several mainland sites), and Mexico (Revillagigedo Islands, Huatulco and other mainland sites). While the protection of coral reefs within most of these parks is a priority, they are seldom patrolled by park rangers or law officers. Therefore, much unnecessary destruction continues.

From the ranked list of stressors noted above, the most serious anthropogenic impacts affecting coral reefs appear to be (1) physical damage, (2) siltation, (3) runoff (sewage, contaminants and nutrients, and (4) harvesting (overfishing). Runoff is often exacerbated by natural flooding in high rainfall areas. ENSO events and strong upwelling episodes may also add to the various anthropogenic coral stresses already noted. As for corrective measures to reduce damage, access to coral reef zones should be limited to small boats, artisanal fishermen and swimmers. Tourists and the local populace should be educated regarding the fragility of coral reefs. No dumping of trash on or near coral reefs should be allowed. Clear cutting and construction projects near reefs should be discouraged. An attempt should be made for conservationists and park managers to work closely with developers and others exploiting coral reef resources.

In order to slow down present day degradation of coral reefs in the eastern Pacific, each nation with coral reef resources should establish management teams to work closely with the public and scientific community. While the scientific expertise is now in place in several Latin American countries, trained management personnel are nearly universally in short supply. Most users of coral reefs are ignorant of the many benefits they offer and do not

understand the importance of protecting them for sustainable use. Thus, a program involving managers, conservationists, educational institutions, and scientists should be established immediately to educate the public and users of coral reefs on their importance and value to future generations.

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