The Living Reef

By Sandy Fritz

As the sun rises, the sea turns aqua, revealing dark shapes grouped offshore: an entire city—the reef. Fluorescent sea fans sway in the currents, blood-colored crabs amble across sandy patches, yellow-spotted fish, silvery barracuda, giant manta rays, and a host of other, improbable creatures dart from point to point, overwhelming the eye.

While the land surfaces of our planet have been extensively mapped and explored, much of the sea and its marine metropoli are still worlds waiting. A mere 10 percent of the known reefs in the Pacific Ocean have been visited by scientists; the extensive reefs rimming the Bahama Banks archipelago are poorly known; and large segments of the most luxuriant array of reefs in the Western Hemisphere and the second largest barrier reef in the world, the Belize Barrier Reef complex, remain unmapped.

This is a surprising state of affairs for an ecosystem thought to house one in every four marine species on our planet. For species diversity, coral reefs rival terrestrial rain forests, and as with rain forests, the untapped potential for science, especially medical science, is enormous.

Coral reefs also resemble rain forests in the way the lush, complex ecosystem sustains itself despite the paucity of nutrients. The crystalline waters of the tropics achieve their breathtaking clarity because there are virtually no nutrients in the water. Yet reef communities thrive in these ecological deserts, largely because of the ceaseless labors of an animal called the coral polyp.

Builders of the stony masses we call reefs, polyps are the cornerstone of the community. Colonies of coral polyps enter into remarkable partnerships with algae, allowing them not only to use solar energy to manufacture food by photosynthesis, but to consume small planktonic animals as well. (See "The Reef Builders.") One of the most beneficial results of the partnership is its mysterious ability to accrete calcium carbonate from seawater to fashion stony strongholds. The shelter coral polyps provide for themselves attracts the myriad creatures that compose the reef ecosystem.

JEFF ROTMAN PHOTOGRAPHY

Three ingredients for a coral reef: ample sunlight, warm seawater, and a hard surface to build on.

Where in the World…

It's estimated that about 268,600 square miles of coral reefs exist in the world's oceans, but they vary widely in degrees of health. Here's a sampler of some major reefs and their vital signs:

Australia's Great Barrier Reef: About 1,245 miles long. It is composed of 2,500 individual reefs, most of which are in good condition. The longest barrier reef in the world, it harbors about 400 species of coral.

Red Sea Reefs: About 2,635 miles in combined length, these reefs are shared by Egypt, Sudan, Ethiopia, Saudi Arabia, and North Yemen. Sections suffer from the effects of industry and tourism, but North Yemen's reefs are nearly untouched.

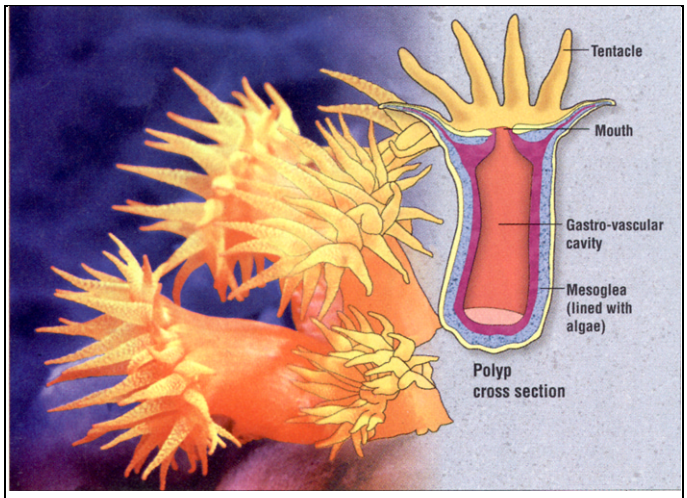
Florida Keys National Marine Sanctuary: About 230 miles long. Natural damage from storms and periodic cold temperatures, along with boat groundings, threaten some areas.

Philippine Reefs: About 13,941 miles long. Thirty percent of the reefs are dead; 39 percent are only partly alive. They have been heavily damaged by dynamite and cyanide fishing. They are also stressed by tourism.

Reefs of the Pacific Atolls: About 17,000 miles in combined length in the South Pacific. There are more pristine reefs in this area of the world than anywhere else. Polynesian reefs are becoming trashed.

The Belize Barrier Reefs: At 294 miles long, they are the world's second longest barrier reef and are in remarkably good shape. Also renowned for pristine mangrove swamps that interact with reef ecosystem.

Reefs of the Bahamian Archipelago: About 1,072 miles in combined length. There is some damage from tourist activities, but reefs are generally in excellent health.



NORBERT WU; DRAWING BY ROB SCHUSTER

The Reef Builders

Primary reef builders live a Jekyll-and-Hyde existence: benign plants by day, indiscriminate plankton feeder by night.

The Dr. Jekyll component consists of thousands of single-celled zooxanthellae algae that are embedded within the living tissue of a coral polyp, an animal no bigger than the nail of a pinky finger. By day, when the animal element recedes deep into its limestone stronghold, its algal partner rises to the surface to bathe in sunlight. By night, the animal withdraws the algae; a stinging, multitentacled mouth emerges that feeds on any tiny planktonic animal.

The union between plant and animal makes the coral polyp a miniature, self-sustaining ecosystem. The polyp generates waste carbon dioxide and ammonia, which nourishes the algal component. The algae, in return, donate waste oxygen to the polyp and manufacture organic compounds and complex sugars that are absorbed by the coral tissues as food.

In a process that has been carefully studied but is not fully understood, the partnership captures calcium carbonate from seawater and converts it into hard limestone. The polyp secretes this skeleton continuously, remaining on the surface as the reef mass grows.

The living tissue of the polyp extends from its home to join with neighboring polyps. Thus the reef's entire surface is covered with a living mat of tissue.—*S.F.*

Many creatures that make coral reefs their homes live in symbiotic relationships. Symbiosis—literally, "together living"—takes many forms on the living reef. Mutualistic symbiosis, where both partners benefit from the association, exists not only in corals but in some jellyfish and even giant clams, which incorporate algae in their tissues to reap the benefits of photosynthesis.

Another remarkable form of mutualistic symbiosis can be observed between small fish, such as gobies, and bottom-dwelling shrimp. Both creatures live together, sharing the same burrow, and as the nearsighted shrimp spends most of its time digging and maintaining the dwelling, the sharp-eyed fish keeps a wary watch for predators. At the first sign of danger, the fish flicks its tail, and both creatures dive for cover.

Commensal symbiosis, in which one partner benefits while the other is neither harmed nor benefited, is especially common. Examples include shrimp that ward off predators by nestling in the venomous spines of sea urchins, or crabs that protect themselves by pirating formidable, stinging sea anemones and securing them to their shells.

A healthy reef supports these and many other symbiotic relationships. But when the reef is stressed by nature or by human abuse, the relationships can break down and the reef becomes a poor relic of its former wondrous self.

Human-generated stress can be especially damaging for coral reefs. Pollution from pesticides and soil runoff is smothering sections of the small reef that fringes Costa Rica in the Caribbean. Reefs off Jakarta, the capital of Indonesia and a city of 9.5 million, were slowly killed by untreated

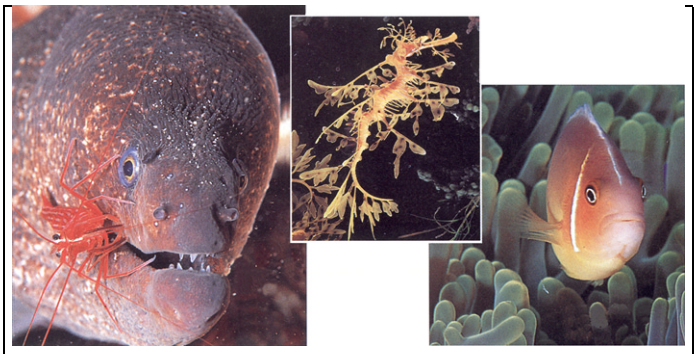
sewage, reef mining, and soil runoff. Dynamite fishing and large-scale, illegal harvesting of coral for the aquarium trade have devastated reef communities ringing the Philippines. Even ecotourism—hoped by many to be the saving grace for the world's wild places—scars reefs, as inexperienced divers inadvertently mar the very places they treasure. A single touch can be fatal to ultrasensitive reef builders.

"Reefs are among the oldest ecosystems on earth," says Ian Macintire, a marine biologist with the Smithsonian Institution in Washington, D.C. "Yet we are rapidly destroying an ecosystem we are only beginning to understand."

Nature itself can be cruel to the coral reefs. Tropical Storm Gordon, with its three days of strong winds and pounding high seas in 1992, did even more damage to the reefs in Florida's Biscayne National Park than did Hurricane Andrew's three-hour tantrum in 1993. Gordon shattered forests of elkhorn coral and fatally enveloped the heads of other hard corals in sand. Recovery is proceeding very slowly.

Recent discoveries have linked over-warm water, sometimes spawned by the annual event known as El Niño, to a blight known as coral bleaching, in which the algal symbiont in coral polyps dies, turning the colony bone white. Should the warmth linger too long, entire reefs can be killed, as has happened in the Caribbean and elsewhere. And diseases, such as the recently discovered coralline lethal orange, can threaten whole communities. Even diseases that attack just one member of a coral community can open the way to general destruction. In the waters off Jamaica, herbivorous sea urchins fell victim to a complex sickness that thinned their ranks, causing the unchecked growth of algae that overran heads of coral, all but slaying the island's reefs.

These and other natural disasters have long challenged the hardiness of reef communities but have never managed to snuff out the spark of life. The immediate ancestors of today's reef-building corals date back 200 million years and have weathered no fewer than three mass extinctions, including the catastrophe 65 million years ago that wiped out the dinosaurs and many other creatures. And as continents drifted and jostled, as global temperatures waxed and waned, as ocean currents shifted and sea levels rose and fell, the reef survivors had always managed to regroup and form new communities—at least until now.



LEFT: DAVID DOUBILET; CENTER: PAULA A. ZAHL/ PHOTO RESEARCHERS, INC. RIGHT: ED ROBINSON/PACIFIC STOCK

Left: Cleaner shrimp are the reef's doctors.

Center: A seahorse's elaborate apparel.

Right: A clownfish nestles in venomous tentacles.

Immunity, Mimicry, and Protection

In an environment dominated by predators, self-protection is of paramount importance to reef dwellers. Marine scientists have found many different protection strategies.

Perhaps most intriguing is the cleaner shrimp, an animal no creature will eat because it's recognized as a valuable friend. These shrimp (left) perch on a coral outcrop and begin a complex dance. Reef creatures seem to recognize the ritual as a sign that "the doctor is in," so to speak. Normally dangerous larger reef animals such as grouper or moray eels appear and become docile, allowing the cleaner shrimp to comb over their bodies, excavate dead tissue from their mouths, and enter their gills in search of parasites. The fish leave clean and free of parasites, and the cleaner shrimp has enjoyed a meal.

Other creatures enter partnerships with animals that are too dangerous to attack. The clownfish (right) is always found in the company of a sea anemone, frequently nestling in venomous tentacles that would ordinarily kill or wound most animals. The clownfish covers itself with a mucus secretion that protects it from the anemone's stings; in return for using the anemone as a safe haven, the clownfish chases off creatures that are immune to the sting of the anemone's tentacles and attempt to feed on it.

Blending into the background is another strategy used by many animals on the living reef. Bright colors and markings are common ways by which animals mask themselves in sun-dappled waters. The pencilfish or seahorse (center) normally resides in the buoyant grass beds that frequently form on the leeward side of coral reefs. Its camouflage is so detailed that even the appearance of the carbon-dioxide-filled sacks that keep the sea plant afloat is reproduced.

—S. F.