ECOLOGY:

Brighter Prospects for the World's Coral Reefs?

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Just a few years ago, scientists sounded the alarm that coral reefs around the world were seriously ailing. Some were bleaching a ghostly white as warmer than usual sea temperatures caused corals to expel their symbiotic algae. Others were being buried in silt, overrun by seaweed, or devastated by violent storms and disease. Scientists convened meetings, launched new research initiatives, and declared 1997 the International Year of the Reef to promote a greater awareness of the plight of these rich marine ecosystems.

But now, midway through that year, some coral reef scientists are beginning to suspect that reefs may not be quite as widely imperiled as they once thought. Increasingly, researchers are wondering whether the decline may be local or regional rather than global in scope. "I don't think reefs remote from centers of population are as bad as the horror stories [we've heard]," says marine geologist Robert Ginsburg of the University of Miami in Florida. Although reefs in the Philippines are dying, for instance, those of Palau, French Polynesia, the Marshall Islands, Micronesia, Fiji, and the Cook Islands seem, for the most part, to be thriving. Likewise, although corals throughout the Caribbean are crumbling, those in the Gulf of Mexico seem to be stable.

No one is suggesting that the major threats facing reefs have diminished or disappeared. In many fast-growing regions of the globe, such as the Caribbean and Southeast Asia, ship groundings, oil spills, and fishing with dynamite or cyanide are damaging reef communities, possibly beyond recovery. But new research indicates that some of the more tractable problems, such as simple overfishing, may be playing a larger role in reef decline than was once believed. Further, there's growing evidence that reefs do recover when given a chance. When communities or nations tighten restrictions on reef fishing or clean up pollution, reefs have rebounded.

"If we can begin to curb these [stressors], I think the oceans would be much healthier, [and] I think you would see reefs respond," says coral ecologist Phillip Dustan of the University of Charleston in South Carolina. Says Barbara Brown, an ecophysiologist at the University of Newcastle in the United Kingdom, "Some reefs will certainly deteriorate, and they are certainly going to change. But I don't think coral reefs are going to disappear."

Globalized anxiety. Concerns about a global decline began to gel 10 years ago, when a severe wave of coral bleaching in the Caribbean coincided with rising concern in the United States about global climate change. At congressional hearings in 1990, scientists and environmentalists portrayed reefs as fragile sentinels warning of the dire consequences of global warming. A handful of studies showed that corals were sensitive to even small temperature changes, which, to many marine biologists, suggested that ocean warming ultimately would lead to the loss of many reef communities.

The focus--although not the level--of concern shifted in 1991, when scientists gathered in Miami to discuss the implications of global climate change for reefs. They concluded that the gradual warming expected in coming years was the least of their worries. "Most coral reef scientists [were] concerned that by the time reefs had to cope with global warming, they would be dead anyway" from pollution, destructive fishing, and other more immediate threats, says Judy Lang, a coral reef scientist at the University of Texas, Austin. The assembled scientists realized that "the coral reefs were disappearing so fast from [direct] human impacts that we had to get a handle on that first," says John Ogden, director of the Florida Institute of Oceanography at the University of South Florida, St. Petersburg.

In a much-cited study the following year, coral reef ecologist Clive Wilkinson at the Australian Institute of Marine Science in Townsville calculated that these activities had already destroyed 10% of the world's reefs. He also estimated that another 60% would effectively collapse in the next 2 decades or so if no actions were taken and if human populations along tropical coastlines continued to skyrocket. In Southeast Asia, which encompasses almost a third of the world's reefs, he warned that a mere 5% of reefs were safe.

What the experts overlooked in the frenzy to convey the severity of the problem, however, was how narrowly reefs had been surveyed. Scientists don't even have a good handle yet on the location and extent of all coral communities. Over the past 20 years, published estimates of the total area of reefs have ranged from 100,000 to as high as 3.9 million square kilometers. "They are just wild, seat-of-the-pants estimates," says Charleston's Dustan. The navigation charts often used to estimate the size of reefs tend to include only those that pose a shipping hazard. Figures also vary according to how the researcher defines a reef, explains Joanie Kleypas, a marine biologist at the National Center for Atmospheric Research in Boulder, Colorado. For instance, some surveys only include reefs that break the surface and ignore those in deeper waters.

Moreover, many known reefs have not been surveyed. "There is not much published that quantitatively and objectively asks the questions: Are reefs of the world dying; if so, exactly where and at what rate?" notes Robert Steneck, a marine ecologist at the University of Maine's Darling Marine Center in Walpole. Wilkinson, for example, had based his global estimates primarily on his work in Southeast Asia, but it appears that less than 10% of those reefs have been thoroughly surveyed, says John McManus, a coral biologist at the International Center for Living Aquatic Resources Management (ICLARM) in Manila, the Philippines. Scientists' grasp of the condition of reefs is just as patchy in the Pacific, where some 90% are unexplored. "We need more data," says McManus.

Reef gladness. Further, some reefs that have been extensively surveyed in recent years have been found to be in good shape, particularly when they are surrounded by deep water and protected from land-based runoff. In Palau, Charles Birkeland of the University of Guam resurveyed 12 spots studied by Japanese researchers in the 1930s and found them "richer and apparently better off" than before, he says. All but a few spots along Australia's 2000-kilometer Great Barrier Reef are thriving. Even Wilkinson now finds cause for optimism. "Most reefs in the Pacific are in good health," he notes, and those in the Indian Ocean, the Maldives, and the Chagos Archipelago, southwest of India, "are in great shape."

Just as researchers are realizing that they may have overgeneralized about the extent of the damage, they also are realizing that they may, at times, have jumped to conclusions about the causes of reef mortality. Over the past 25 years, for example, scientists have watched Jamaica's once spectacular reefs become smothered in seaweed. Some biologists have argued that the algae are thriving because unchecked development in Jamaica has dosed coastal waters with high levels of nitrogen, phosphorus, and other nutrients. Corals, unlike algae, they say, evolved to deal with a low nutrient environment and fare badly in enriched water.

But coral reef paleobiologist Jeremy Jackson at the Smithsonian Tropical Research Institute in Panama and Terence Hughes, a coral reef biologist at James Cook University in Townsville, Australia, contend on the basis of a close examination of historical demographic and fishing records and experimental data (*Science*, 9 September 1994, p. 1547) that centuries of overfishing set the stage for the algal takeover. In the Caribbean, 17th- and 18th-century hunters almost eradicated algae-eating turtles, and subsequent generations of fishers have rid reefs of most of the large herbivorous fishes. For a long time, Jamaica's reefs seemed to function just fine without these creatures, because algae-grazing sea urchins kept the seaweed under control. But in recent years, two hurricanes and an epidemic nearly wiped out the sea urchins, and the reef communities could no longer keep down the algae. As a result, reefs quickly turned into beds of seaweed, Jackson reported in June at the annual meeting of the Society for Conservation Biology, held in Victoria, British Columbia. "This is happening all over [the Caribbean]," he asserts.

Similarly, there is new evidence from the Florida Keys that attributing algal overgrowth to excess nutrients in the water may be oversimplifying the situation. While high nitrogen and phosphorus concentrations in water carried across the Keys from Florida Bay correlate with the decline of some reefs along this island chain, in other cases there doesn't seem to be a link. "It is true that coral reefs can be overwhelmed by nutrients, [but] it takes quite a bit of nutrients to do that," says Alina Szmant, a physiological ecologist at the University of Miami.

Birkeland found no indication that sewage outfall from a treatment plant harmed a reef site in Palau, which he studied in 1976 before the plant was built and again 17 years later. "The coral and fish communities hardly changed at all," he notes.

The lack of a clear smoking gun, even for reefs as well studied as Florida's have been, is due partly to the tendency of reef scientists to focus their research on a single parameter--say, water quality or fish abundance--in a small geographic area. Such narrow projects haven't been able tease apart the effects of several insults, says Steneck, or reveal global trends. "In my opinion, too many folks are looking at the mechanistic level without having demonstrated that there is a pattern [to the decline]," says Steneck.

And in those few instances where patterns have been sought, the results have been mixed. Florida's Ogden has coordinated a 16-country, 25-site reef monitoring program called CARICOMP to look for regional trends in the Caribbean, but after 5 years, no clear patterns have emerged. In some cases, the source of the problem is a "no brainer," says Ogden, but in general, the picture is still quite murky: "What we are finding are patterns of variation across the whole range."

Scientists' efforts to unravel the causes of reef decline also have been complicated by the fact that reefs respond to stresses in a nonlinear way, contends Jackson. A coral community may appear to be unaffected by heavy fishing, excess nutrients, or some other stress until a certain threshold is reached. Then the decline may be precipitous and may appear to have been prompted solely by the most recent assault.

Call to action. For some scientists, the data on the extent and causes of reef decline are already convincing enough to warrant immediate action. "We don't need one more bit of science to know there really is a crisis," says Jackson. Tim McClanahan, who works for the New York City-based Wildlife Conservation Society overseeing coral reef monitoring programs in Kenya and Belize, argues that burgeoning populations will only increase assaults on reefs. "The decline is worse than most people think--and scientists admit," he says.

But even he supports efforts to fill out the picture of global reef health by compiling results of scattered studies in more useful ways and by conducting more extensive surveys. In one such effort, ICLARM's McManus is coordinating the development of a database containing information on some 7000 reefs. Called ReefBase, the database is available on a compact disc that can be queried by both scientists and conservation managers. At this point, "the data matrix is quite sparse and geographically patchy," McManus points out, because researchers have taken many different approaches to studying reefs. "To do any serious analyses, we have to develop a solid block of information through standard techniques," he says.

There are several efforts under way to collect data more systematically. ReefBase will include information from a new monitoring program, the Global Coral Reef Monitoring Network (GCRMN), which Australia's Wilkinson is setting up as part of the International Coral Reef Initiative, a multilateral agreement signed in 1994 to encourage coastal zone management and more sustainable use of reefs. Another program, called ReefCheck (*Science,* 6 June, p. 1494), is enlisting groups of recreational divers led by coral reef scientists to take a global snapshot of reef conditions. A fourth effort, developed by Steneck and Austin's Lang, and called the Rapid Assessment Protocol, calls for coral reef scientists to complete a standardized survey of their particular reefs in addition to carrying out their normal research.

Uncertainty about how best to assess reef health may well hamper efforts to get a better understanding of global conditions. "We still don't have a good definition of an unhealthy reef," asserts McManus. For instance, coral reef biologists have long assumed that if a high percentage of a reef was inhabited by living coral, the reef was healthy; less coral cover meant the reef was in trouble. Coral cover is what the GCRMN divers will use to assess reef health, for instance. "The problem is that some reefs have low coral cover regardless [of their health]," explains Miami's Ginsburg.

Indeed, some scientists now think that a better measure of long-term reef health may be whether tiny coral animals, called polyps, are gaining a foothold on a reef's limestone skeleton. A reef with a lot of coral cover may look healthy enough, but in some cases the lack of new recruits means it's "on its way out," asserts Birkeland, who studied reefs in American Samoa between 1979 and 1995. At times, a region's reefs may be so damaged that there's no longer a local source of polyps. In other areas, reefs may be so overrun by mats of algae that recruits that do drift in don't stand a chance. Steneck and Lang also argue that it is most important to get a handle on the overall dynamics of the reef's corals. They want to know the rate at which polyps are dying, and how quickly they are laying down new skeletal limestone.

By any criterion, though, there has been a little progress toward stemming the decline of reefs. Governments and conservation groups have begun to set up marine reserves (see p. 489). Although many are designed primarily to replenish fisheries, those around reefs should also help the corals, because more fish can help keep algae in check. For instance, in 1990, Bermuda established no-fishing zones on its deteriorating reefs, which bring in some 9 million tourist and recreation dollars a year. The government paid fishers $75,000 each to stop pot fishing on the reefs and then helped them develop other marine-related occupations. Similarly, in 1994, Palau, recognizing that coral reef fish were worth more as a tourist attraction than as an export product, passed a law to phase out the export of reef fish.

Reefs are now a priority for both the public and the policy-makers, says Wilkinson. "There's a much greater awareness at the level of vice presidents and presidents. ... It's gone from the departments of environment and fisheries to departments of state." If countries and their citizens curb overfishing, stop destructive harvesting practices, and improve water quality, he says, then reefs may be able to come back.

This "sentinel" is still breathing, adds Wilkinson. The reefs that are still flourishing may fuel this comeback, by providing new coral recruits. Others point to the fossil record, which indicates that reefs have persevered for many millennia,

disappearing and reappearing several times. "I've seen reefs thriving under arduous conditions and coming back under [even] worse conditions," says Newcastle's Brown. "Maybe they are not so fragile as people have portrayed them."

RELATED WEB SITES:

A map of the world's reefs can be viewed up close on the ReefBase Web site
http://www.cgiar.org/iclarm/resprg/reefbase

International committee looking at effects of global change on corals
http://ghsun1.kgs.ukans.edu/welcome.html

U.S. National Oceanic and Atmospheric Administration's coral health monitoring network; provides a directory of coral reef scientists and links to other coral reef sites
http://coral.aoml.noaa.gov/

Australian Institute of Marine Science
http://www.aims.gov.au/

International Center for Living Aquatic Resources Management in the Philippines, ReefBase
http://www.cgiar.org/ICLARM/

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