

◀ **Artificial limbs.** Thai researchers attempt to save tsunami-damaged coral in January 2005; robust growth 2 years later (*below, right*).

algae.” Put another way, “soon we’ll be having jellyfish and chips,” says biologist Michael Kendall of the Plymouth Marine Laboratory in the United Kingdom. In the darkest scenarios, most corals will be toast.

A multiheaded monster

As coral reefs slip toward chronic frailty, a picture of what this means to the world has begun to emerge. Coral scientists, backed by an army of snorkeling and diving volunteers, have put a watch on critical reefs among the nearly 300,000 square kilometers charted to date. Hidden gems continue to come to light, including a giant deep-water reef in turbid waters off northern Australia. “Not much is known about the reef because nobody wants to swim in that area. It’s infested with crocodiles,” says oceanographer Alan Strong, senior consultant to the U.S. National Oceanic and Atmospheric Administration’s (NOAA’s) Coral Reef Watch.

A recurring theme of this heightened scrutiny is that reefs are vulnerable on many fronts. A March 2005 earthquake off Indonesia, for example, was as brutal as the 2004 tsunami, lifting some reefs clear out of the water (*Science*, 20 October 2006, p. 406). Corals are susceptible to pathogens and predators, too. The crown-of-thorns starfish, a periodic invader, denudes coral outcroppings with the efficiency of a slash-and-burn farmer. Meanwhile, corals are perpetually besieged by filamentous algae, which are held in check by fish that nibble at them. Overfishing can tilt the balance, as can sewage or agricultural runoff, which infuse seawater with algae-feeding nutrients. These abuses, along with coastal development, “are having fantastically large and negative impacts on reefs around the world,” says John Pandolfi, a coral reef expert at the University of Queensland in Brisbane, Australia.

The latest and perhaps biggest present danger for reefs is bleaching. When sea surface temperatures exceed their normal summer high by 1°C or more for a few weeks running, coral polyps, for reasons not entirely understood, expel their zooxanthellae, the symbiotic algae that lend corals color and provide nutrients. The polyps turn pale and starve. “If they don’t get their zooxanthellae back in a month or so, they die,” says Obermeyer.

The dangers of bleaching came to the fore in 1998, when a potent one-two climate punch—a strong El Niño warming in central tropical Pacific waters, followed by a La Niña that heated western Pacific regions—killed 16% of living corals worldwide (*Science*, 27 October

2000, p. 682). Some reefs have rallied from severe bleaching—recently and dramatically, off Darwin Island in the Galápagos. “We’d given up on the Galápagos” after a 1982–83 bleaching event annihilated most of the archipelago’s reefs, says Strong. Now, he says, “it seems to be really coming back.” However, many bleached reefs are still sickly. At least half of those destroyed in 1998 have not recovered, according to the authoritative *Status of Coral Reefs of the World: 2004*, compiled by the Global Coral Reef Monitoring Network (GCRMN).

The catastrophic 1998 bleaching, and regional occurrences since then, highlight the

vulnerability of reefs to global warming. “That’s when we realized that corals could be a kind of canary in a coal mine,” says Jeremy Goldberg, co-author of a GCRMN report on tsunami-inflicted reef damage. Delicate staghorn and elkhorn corals, for example, were listed as threatened in the Caribbean in May 2006 under the U.S. Endangered Species Act. “Branching corals that are sensitive to bleaching might disappear,” warns reef ecologist Thamasak Yeemin of Ramkhamhaeng University in Bangkok.

Some reefs are more tolerant to bleaching. However, says Hoegh-Guldberg, “the movement toward hardier communities of



FRACTURED PARADISE

PHUKET, THAILAND—Like thousands of tourists who flock to the chic resort island of Phuket in southern Thailand, marine biologist Nippon Phongsuwan recently spent a weekend under the waves, taking in the region’s breathtaking coral reefs. Unlike the tourists, Nippon had an extra reason to enjoy the view: His innovative attempt to rehabilitate tsunami-damaged reefs is showing remarkable progress.

Two of the most-savaged reefs lie off Phuket’s Paradise Beach and Lolana Bay on nearby Phi Phi Island. During surveys carried out a few days after the tsunami, Nippon and his colleagues at the Phuket Marine Biological Center discovered the shallow seabed at Paradise and Lolana littered with pieces of branching corals, particularly staghorn and other members of the *Acropora* genus. Realizing that the polyps would be abraded to death in the rough-and-tumble waters, Nippon’s group gathered up hundreds of *Acropora* fragments in a bid to save them.

Aboard a research vessel, the team glued the coral fragments into holes drilled in concrete cinder blocks. They joined blocks with steel bars to help the structure weather strong currents and placed them in various configurations in either shallow reef flats, less than 2 meters deep at low tide, or on reef slopes about 7 meters deep. Blocks in the reef flats—natural *Acropora* habitat—were battered by waves, and most polyps died. But corals transplanted to reef slopes at Lolana Bay thrived and have grown at a rate equivalent to naturally occurring Phuket corals, Nippon says. The “unexpected” findings, he says, suggest that *Acropora* “can adapt well to a new environmental setting.” The hope is that the growing thickets of branching coral will provide a breeding population: seed stock for polyps that mend damaged reefs and pioneer new ones.

The coral growth over 2 years is “impressive,” says oceanographer Alan Strong, senior consultant to the U.S. National Oceanic and Atmospheric Administration’s Coral Reef Watch. For *Acropora*, he says, the low-tech cinder blocks may offer a cheap alternative to the leading artificial reef product: Reef Balls, molded concrete forms that cost as much as several thousand dollars and range up to 2 meters in girth.

Strong and others caution that although coral reefs can be rehabilitated, they cannot be built from scratch. “No one has ever reconstituted a reef,” says Hughes. And some experts wonder whether reef rehab is worth the effort at all, as it addresses a symptom of decline, not the cause. “Inevitably, this kind of work is like treating cancer with a Band-Aid,” says John Pandolfi, a coral reef expert at the University of Queensland in Brisbane, Australia. “It makes us feel good, but our money is better spent elsewhere.”

—R.S.