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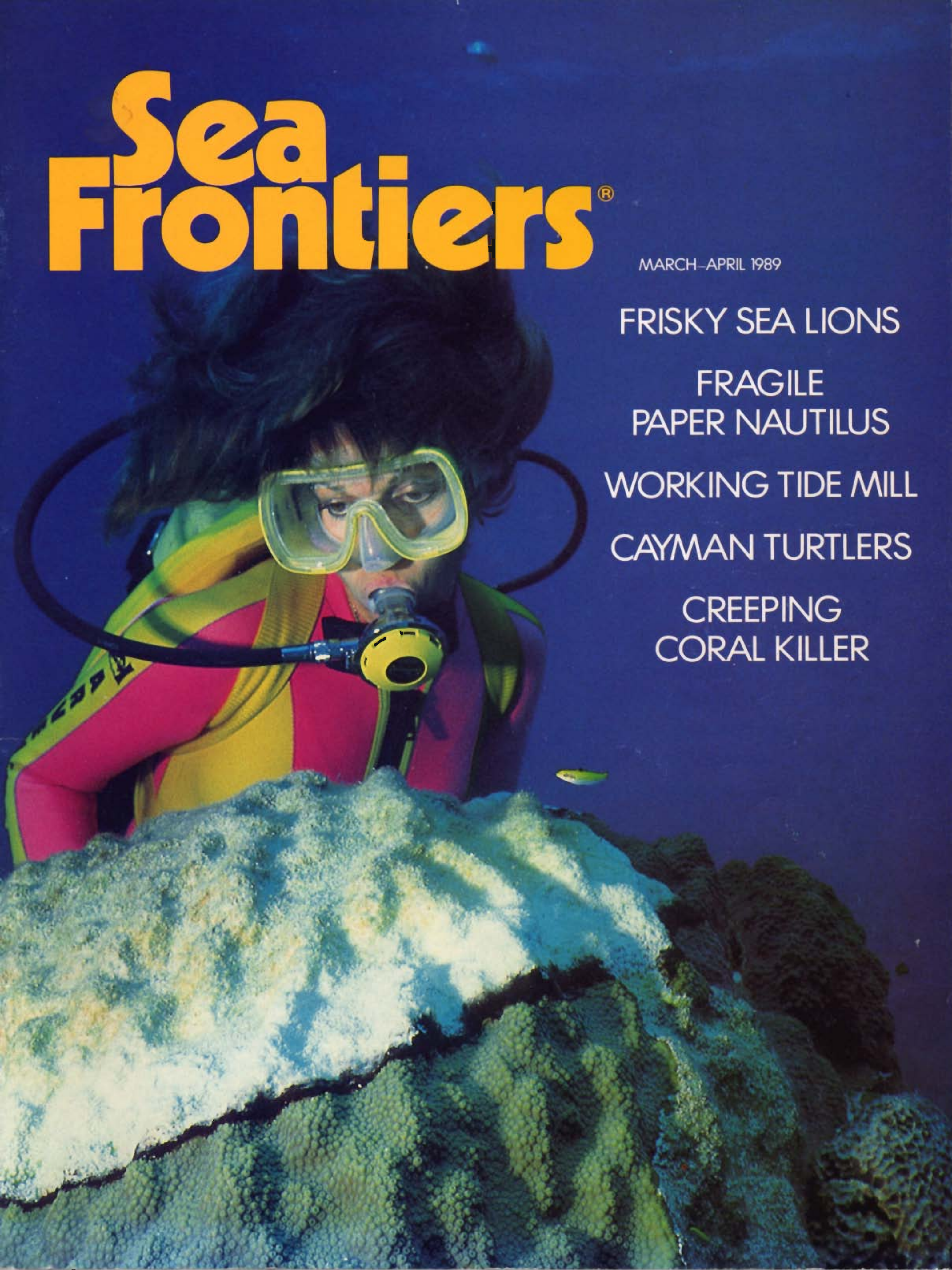

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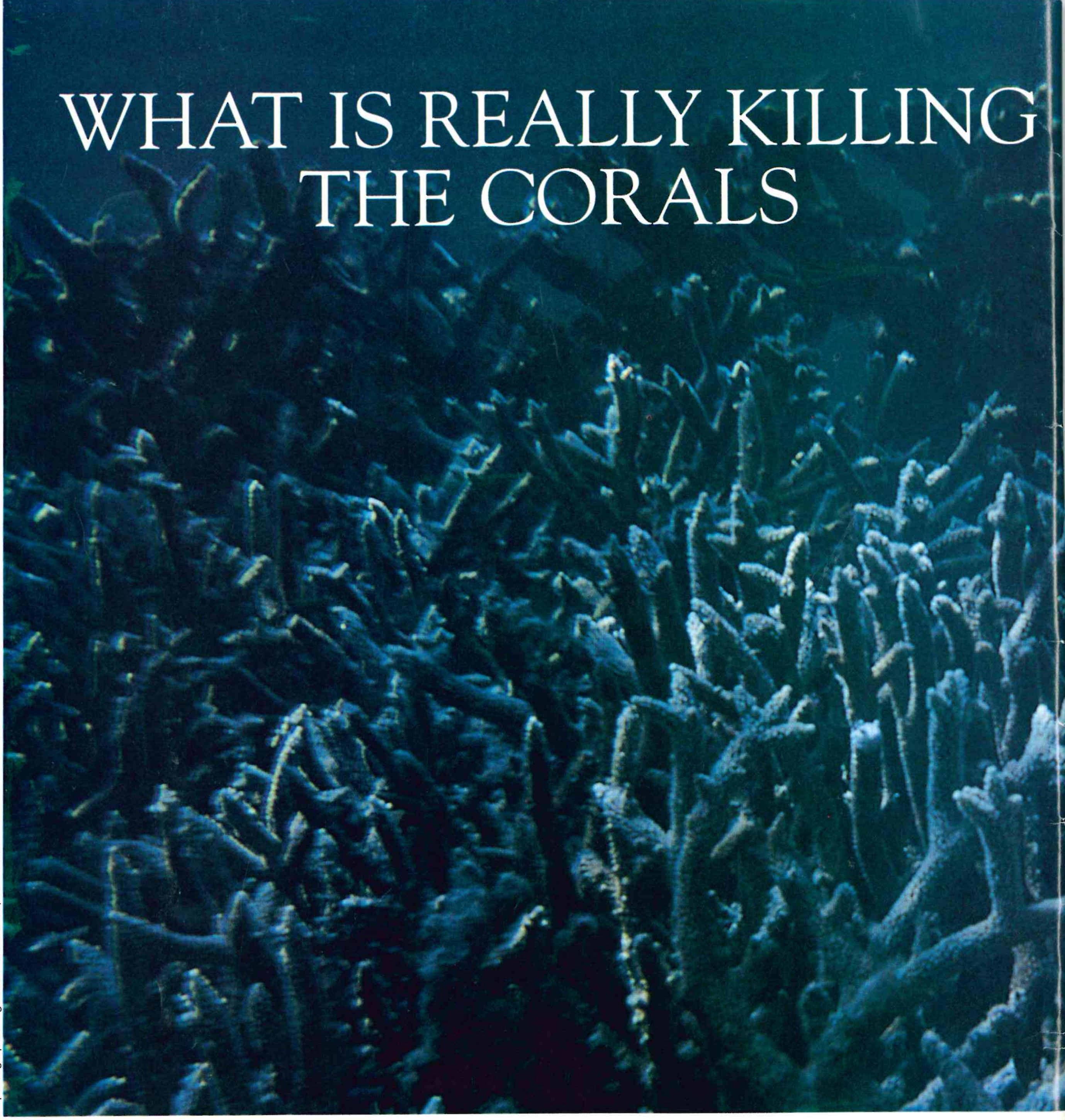
CREEPING CORAL KILLER

WHAT IS REALLY KILLING THE CORALS



All photographs Eugene A. Shinn except as noted

BY EUGENE A. SHINN

Anchors, boat groundings, dredging, touching by divers, spearfishing, and oil drilling are a few commonly cited threats to corals. This litany of cliches is repeated over and over in dive magazines, newspapers, environmental and other publications. There are, however, more serious causes of coral death.

These unheralded and misunderstood causes receive too little attention and are subject to even less research. Some are natural, some are caused by humans but, singly or in combination, they are deadly. Coral diseases, the agents of death, are related to worldwide rise in sea level and an overabundance of nutrients. Together, this combination can wipe out entire stands of reef corals in months, weeks, even days.

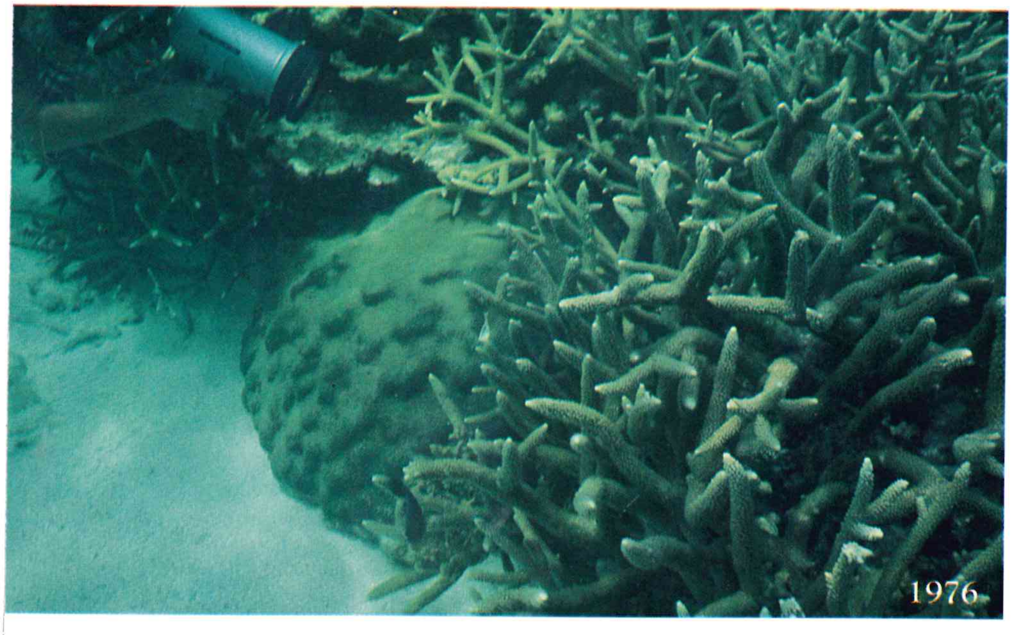
It would be irresponsible to claim the mechanical action of anchors, boat groundings, divers, and so forth has no obvious or detrimental effect on coral growth and health, especially in localized areas. Dive on any popular reef, and one can see the effects of people. White coral skeletons showing through bruised or broken tissue on massive coral heads will be seen almost immediately. Effects of people are especially noticeable where branching corals, such as fragile staghorn coral (*Acropora cervicornis*) or elkhorn coral (*Acropora palmata*), have been broken and pieces scattered about. The scene can be uglier still where a sailboat or powerboat has cut a swath through live branching-coral thickets, not to mention the wholesale destruction caused by larger ships, such as the 1,285 square meters of devastated bottom caused by the cargo ship *Wellwood* at Molasses Reef in 1984. Nevertheless, during 30 years of diving

and conducting coral-reef research in Florida and other parts of the world, I have seen change but little lasting effect caused by the threats listed in the first sentence. The type of breakage caused by anchors, divers, and so forth is minuscule compared with the devastating effects of hurricanes. Yet even after hurricanes, the reefs bounce back.

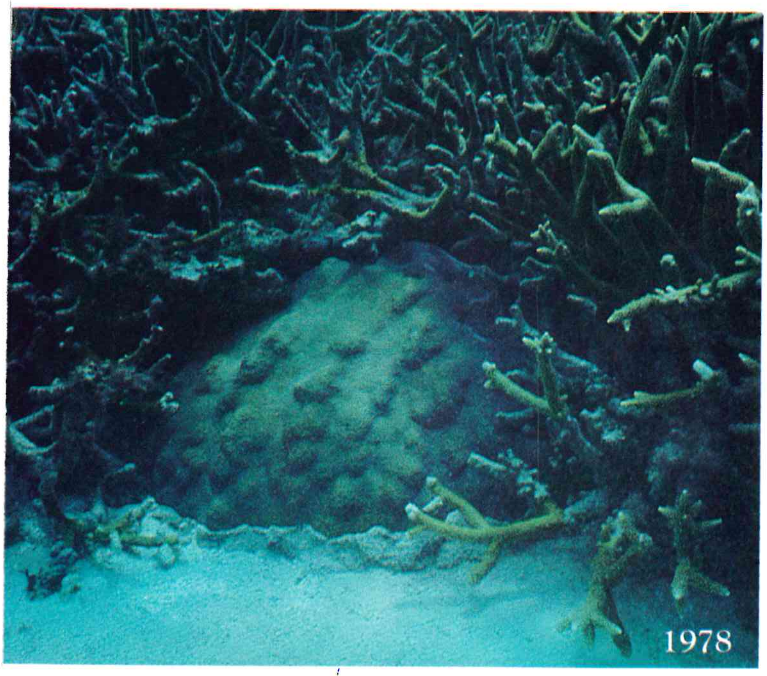
Reproduction through breakage

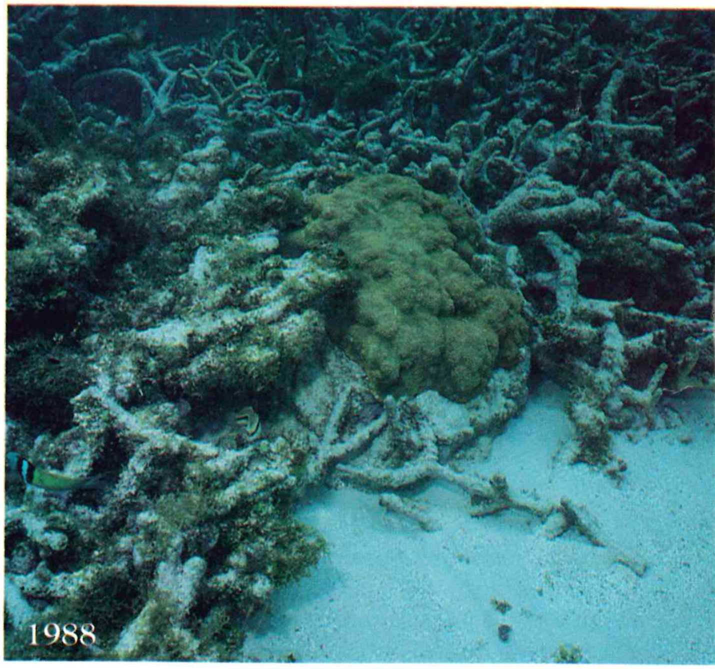
First, consider the major branching corals. Recent research has shown that the major strategy by which most branching corals propagate is through fragmentation. More new colonies are produced from broken branches than from sexual reproduction. This is not to suggest we heedlessly break and scatter staghorn corals, but that is exactly what happened during Hurricane Donna in 1960 and the hundreds of storms that preceded it. Staghorn coral recovers quickly because it is a fast grower. It grows approximately 10 centimeters per year. The most significant aspect of its growth is that it forms an average of about three new branches each winter, each of which grows another 10 centimeters and produces three more branches the following winter and so forth. This kind of proliferation, if

Their new-grown tips less than two months old, these thriving staghorn corals are the product of about ten years of building. Delicate coral forests such as these are often damaged by human carelessness, but natural disasters have even greater potential for widespread and long-term destruction.



Life and death of a reef: Sometimes die-offs occur slowly, as in this sequence of the life of a head coral taken over a span of 26 years. In 1961 a head coral at Grecian Rocks Reef was selected for growth studies, of which the spike and tube in the cinder block are part. Ten years later, the head coral is being overgrown by healthy and fast-growing elkhorn and staghorn corals. By 1976 the staghorn has nearly overshadowed the head coral, and the elkhorn is dead. In 1978 the shaded side of the head coral, and the staghorn to the left and behind it, are dead. In 1988 three-fourths of the head coral is dead, only a few live staghorn tips are visible, and the dead branches are overgrown by algae.





unchecked, means that a small colony with only ten branches can potentially produce 56 kilometers of branches in just ten years. Of course, it never reaches that potential because of repeated attack by disease, coral-eating worms, and periodic storms that break and scatter branches. Unchecked, the coral would choke on its own branches. At 10 centimeters per year, a colony could reach a height of about only 1 meter in ten years. It would be physically impossible to fit 56 kilometers of branches into a hemisphere only 1 meter high.

Elkhorn coral is a major reef builder in the Florida Keys, and it also grows rapidly. At Grecian Rocks, off Key Largo, are two engine blocks lying about 22 meters apart and completely surrounded by unbroken elkhorn coral. They appear as if dropped from the sky! In 1964, when the first 12-meter fishing boat broke up on the reef, it left a swath of devastation up to 18 meters wide as it crashed through the live elkhorn forest. Two years later, there was little trace of the devastation, and the boat had deteriorated, leaving only its engine to mark the grave. In 1978 when a second boat grounded, there was a similar path of devastation. Today, there is no trace of the destruction caused by either boat, because the fragmented corals became new colonies that grew rapidly in the newly created space.

Storm damage

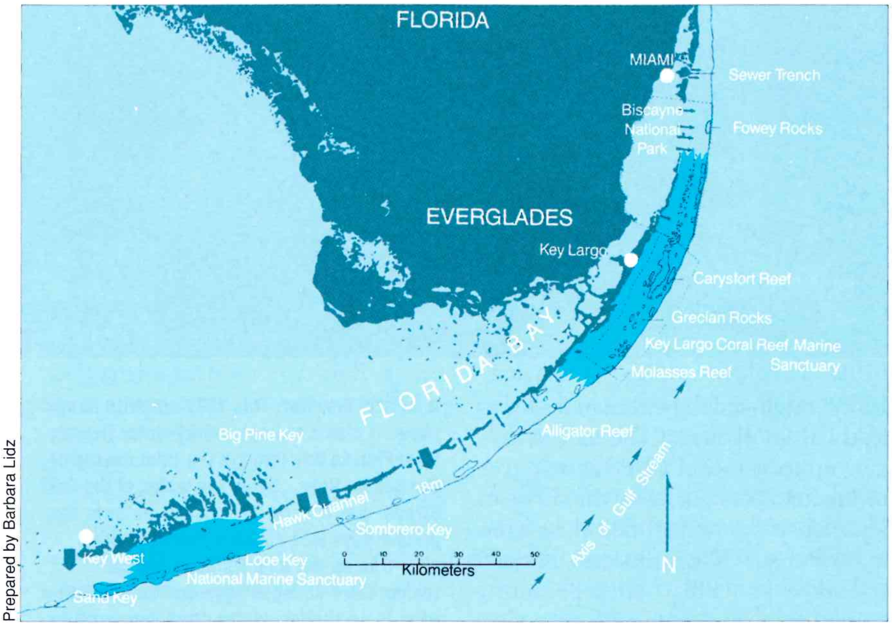
That reefs recover quickly should come as no surprise, considering the frequency of hurricanes and the vast numbers of cargo ships that grounded before the lighthouse service installed the series of reef lighthouses along the Florida Keys. Most reefs and their lighthouses are named after large ships that grounded or sank there, and the building of the lights themselves devastated acres of reef bottom. During a ten-year period in the 1800s, 400 cargo ships were lost, creating a lucrative cargo-salvaging business. If damage from boat groundings, anchors, and divers is as serious and long-lasting as we are often told, one might wonder why there are any live corals left.

But what of the massive head corals like the large star coral (*Montastrea cavernosa*) or brain coral (*Diploria labyrinthiformis*)? How do they respond to physical abuse? These massive species are often scarred by anchors, and one frequently sees the fresh blue or red bottom paint adhering to ugly scars where a boat hit a glancing blow. Sometimes, massive heads are broken in half; yet, if not attacked by disease, the two halves become two colonies.

Fish bites

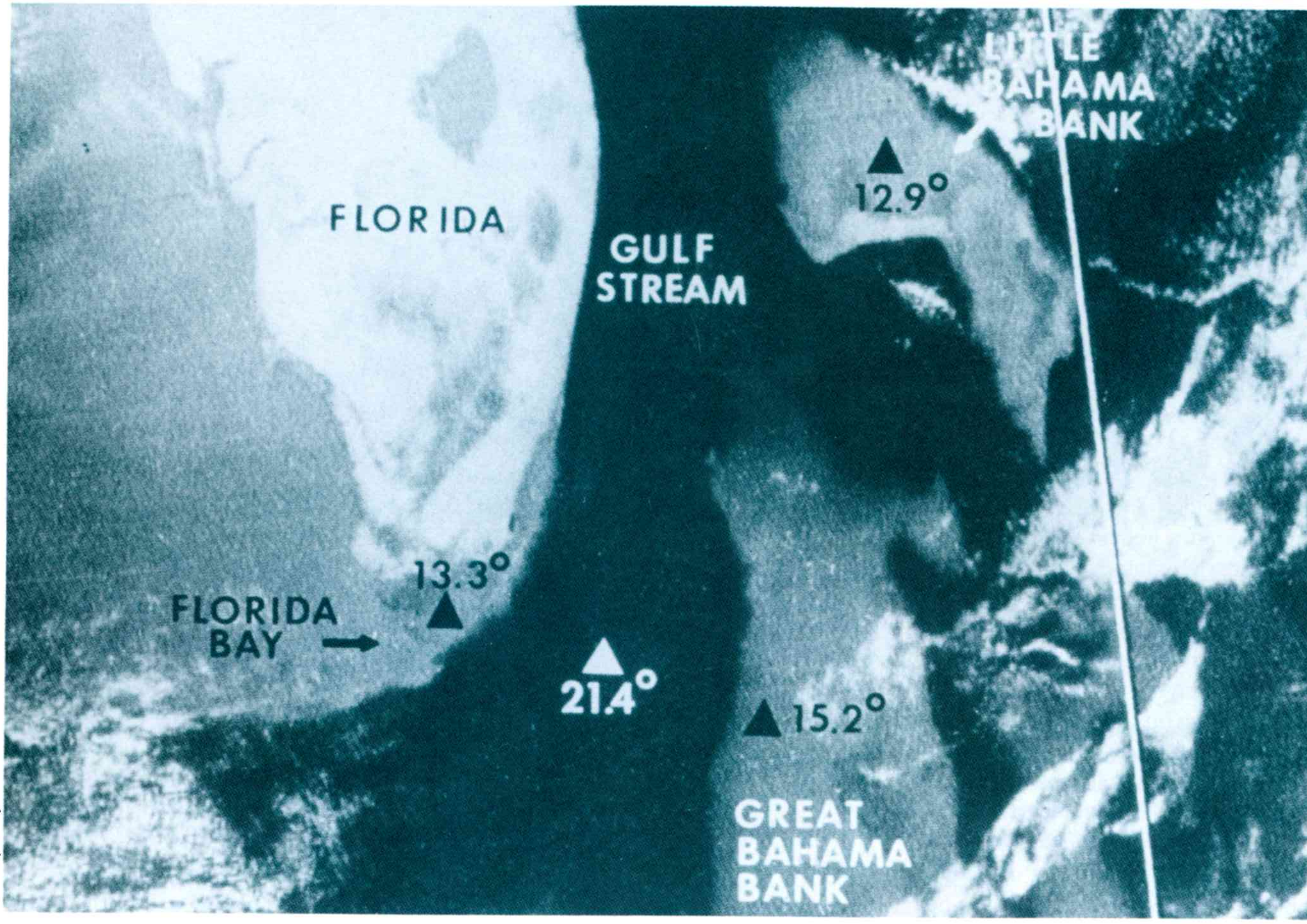
Head corals generally display small lesions caused by the bites of parrotfish. Even on the most popular reefs, fish bites outnumber lesions made by careless divers. During the past 30 years, I have seen coral heads trampled, scratched, drilled, broken by boats and explosives, and still they recovered. They are even immune to hurricanes if not dislodged and rolled or buried. Hundreds of heads in Florida have been cored to obtain material for growth-rate analysis. Yet, even these 10-centimeter holes did not cause mortality. X-ray analysis of the growth bands in such cores shows that growth has not been retarded by past hurricanes. There is no scientific evidence whatever that touching with bare hands harms coral, yet one can be fined for doing so in two of Florida's coral sanctuaries. That spearfishing is a serious threat to coral growth is equally unfounded.

On the sheltered side of Grecian Rocks, several large star coral heads surround an old cannon brought in from another reef about 20 years ago. The tops of the heads began to die in 1980, and most tour guides and rangers are



Prepared by Barbara Lidz

Bad for growth: Across the Florida Keys, bay waters flow through tidal passes (large and small arrows), carrying silt and dissolved material toward the reef. Reefs opposite areas with heavy flow are poorly developed and lack major reef-building corals. The well-developed reefs (shaded) are protected from sediment-laden waters by the land masses of the larger islands.



Courtesy Harry Roberts

A natural disaster: This 1977 satellite image shows a plume of cold, murky water flowing from Florida Bay through the tidal passes of the middle Keys. While the water of the Gulf Stream was a warm 21.4°C, the water in the middle Keys was actually measured from 13.3°C to as low as 9°C. Such radical temperature changes have drastic and lethal effects on shallow-water coral communities.

firmly convinced they were trampled to death by snorkelers. The fact is they grew up to sea level (they grow 8 to 9 millimeters per year). In the 30 years between 1950 and 1980, they grew upward about 30 centimeters, enough to expose and kill their tops during spring low tides. Although they died from natural causes, they probably would have eventually succumbed to the trampling of tourists. The spot has become so popular that during peak days of the tourist season, at least 150 snorkelers can be disgorged from commercial dive boats there *every hour*.

Massive coral heads have shown surprising resistance to abuse. Huge head corals even survived 0.8 kilometer from a hydrogen bomb blast at Enewetak Atoll that was thousands of times greater than the Hiroshima bomb. Growth-band studies of these corals by Harold Hudson of the U.S. Geological Survey revealed slight radioactivity in the growth band that formed in 1960 when the bomb was exploded, but growth rates after the event were the same as before the event.

In reality, we are chronically beating the reefs to death in local, highly publicized places but, fortunately, an evolving system of mooring buoys is partially alleviating the problem. However, compared with wholesale destruction caused by hurricanes, which we cannot control, the localized effects of anchors, groundings, and divers are minor. Until 1965, hurricanes struck some place in the Keys once about every seven years. The reefs have been spared since 1965. Radiocarbon dating of material from borings through the reefs has shown the reefs began growing about 6,000 years ago (the rock beneath the reefs was land just 8,000 years ago). A rate of one hurricane about every seven years means the reefs have been attacked by serious storms more than 800 times during the last 6,000 years. That Florida's reefs have survived these attacks of hurricanes and ships is testament to their amazing resistance to physical abuse.

Sediment kills?

Basic texts and environmental literature tell us with authoritative certainty that sediment kills corals because it smothers or blocks out sunlight needed by the photosynthetic algae within their tissues. These statements are only partially true. Corals are incredibly resistant to suspended sediment when it is not accompanied by the additional stress of excess nutrients or extreme temperature fluctuations. For three to four months of the year, the reef at the Smithsonian Tropical Research Laboratory at Goleta Point, Panama, is inundated by water with the color and clarity of coffee with cream. A braille marking system had to be put on experimental settling plates to distinguish the various experiments, because divers had to feel their way over the reef during monsoon season.

Those who have ventured offshore after a hurricane will remember that the reefs in the Keys become inundated by sediment-laden water for a week or more. The water becomes so murky you cannot see your hand before your face. In aerial photographs taken in 1965 at Carysfort Reef after Hurricane Betsy, only the lighthouse is visible. The coral reef under 0.6 meter of water was obscured by muddy water. A frightened Coast Guardsman, who survived Hurricane Donna at the Alligator Reef lighthouse in 1960, described the aftermath this way, "We looked out and saw a sight we will never forget if we live a thousand years. Scattered over the ocean, like croutons on a dish of soup, were derelict small boats, pieces of boats, chairs, bedsteads, boxes, lumber, trash, rising and falling on a 12-foot sea that still ran frothy and gray." Yet, extreme murkiness caused by storms has had no noticeable effect on coral growth rates. Sediment is a sure killer if it buries or permanently smothers coral, but it seldom kills coral when it remains in suspension.

Cold a killer

Many blamed the 80 to 90 percent death in 1970 of star corals at Hen and Chickens Reef on nearby dredging in the mangrove swamps of Snake Creek. However, an analysis of coral bands in the more hardy individuals that survived indicated the weaker ones were killed by chilled water during the severe winter of 1969-1970. The water was so cold it killed tropical fish around marinas throughout the Keys. Sediment, or more likely its nutrients and hydrogen sulfide released by dredging, probably contributed to coral mortality, but it was the severe cold that did them in. Many lived but recorded the chilling crisis as a distinctive dense band within their skeletons.

Every diver knows that the sediment between corals on reefs is coarse grained but the reason is overlooked. The agitation of water required for coral growth also removes fine-grained sediment, leaving only the breakfast cereal-size grains that compose reef sand. Thus, even after a hurricane, suspended mud does not settle permanently on or around live coral. If mud does settle, it is soon removed by waves and currents and transported either to deep quiet water where it settles to the bottom, or it is trapped in grass beds behind the reef. Some mud filters down into cavities beneath the living corals. This relation between wave energy, reef sand, and coral growth is usually not considered or is quickly forgotten when there is a perceived threat of sedimentation from dredging or oil drilling muds.

The effects of offshore oil-drilling mud on five species of common reef corals were studied by Jack Thompson of Texas A&M University in the field at Carysfort Reef and in tanks at the U.S. Geological Survey facility on Fisher Island adjacent to Government Cut, the main ship channel into the port of Miami. One of the unusual discoveries of the study was that even the clear incoming tidal waters in Government Cut killed coral faster than the heaviest doses of drill mud. Within three days, a bacterial infection caused tissue to slough away. Eventually, water had to be brought in from the Gulf Stream twice a week for the experiments. This was a dramatic example of the potency of bacteria or nutrification.

Dying reefs—shot in the back by their own lagoons

In another set of experiments, Dr. Thomas Bright, professor at Texas A&M University, and his students set up closed-circuit underwater television beneath Carysfort Lighthouse to observe and tape record experiments on a transplanted star coral. Every one-half to one hour for three days, a student dived down and physically coated the coral's surface with drill mud squeezed from a plastic bag. The television monitor, watched night and day, showed that within an hour the coral polyps swelled and the mud either sloughed off or was swept away by wave action. The live coral was subsequently placed back on the reef and six months later was collected for growth analysis. Although chemical analysis revealed the skeleton had incorporated drill mud components, its growth had not been stunted. As a result of this and dozens of studies done elsewhere, the National Academy of Sciences released a report in 1983 concluding that drill mud in concentrations up to 100 parts per million, a level much higher than that usually found less than 30 meters from an offshore oil rig, is not considered a serious threat to marine organisms. This particular coral not only survived doses hundreds of times greater, but its growth was not even stunted.

In 1970 I traveled to Australia to testify before the Great Barrier Reef Commission. Oil drilling near the reef had been proposed and, since it was assumed drill mud or an oil spill would kill the corals, the authorities wanted to know how fast they might recover. To see if oil would kill corals, I did a simple experiment. Plastic bags of Louisiana crude oil and mixtures of seawater and oil were placed over staghorn and star corals. As soon as the oil-polluted water came in contact with the staghorn coral branches, their polyps retracted. Both the staghorn and star corals were exposed to the oil and water for one-and-a-half hours, because on the Australian barrier reef, unlike Atlantic reefs, corals have become adapted to exposure to air. They are exposed daily for more than one hour at low tide. It was agreed that the only time corals could come into direct contact with floating oil would be at low tide. The following day, the polyps were fully extended and all the corals had normal color. Fourteen days later, they still appeared normal. How was this possible?

This simple experiment demonstrated something unsuspected. The natural mucus of corals prevents oil from adhering to their surface. Even when live specimens are dipped directly into the goo, the oil does not stick, and later tests showed staghorn coral will even survive one-half hour of total emersion in Louisiana crude oil! Processed oils or crude oil treated with dispersants, however, kill it quickly.

These experiments need to be repeated in a more controlled fashion. However, few people want to hear that oil is not as threatening as everyone says.

We all know corals are dying, but what we have been discussing is not the principal killer. So, what really is killing the corals?

Rising waters

First, there is nature itself. There is a worldwide phenomenon, known as the greenhouse effect, that is causing polar ice caps to melt and the sea to rise. During the last 15,000 years, the sea has risen at least 100 meters, slightly more than length of a football field, and most of that rise took place between 15,000 and 10,000 years ago. During the last 10,000 years, the rise has been rather slow, and even slower during the past 3,000 years. Now it may be speeding up.

Off Florida, the first reefs began to form about 6,000 years ago around offshore rock islands now buried beneath coral and sediment. Sombrero Key, Looe Key, Alligator Reef, and Molasses Reef are examples of reefs that formed this way. Meanwhile, mud and sand were filling low swampy areas, making it difficult for corals to get established, and in most of the low areas there still are few, if any, corals. Carbon-14 analysis of recently discovered peat under Alligator Reef proves there was a swamp there 8,000 years ago. As sea level continued to rise, something happened that has been noted in reef areas around the globe. Lagoons began to form behind the developing reefs; in Florida the lagoon was what we now call Hawk Channel.

As the sea continued to rise, Florida Bay and its muddy shallows began to form. As sea level rose higher, breaks between the Keys, where there are now bridges, allowed Florida Bay and Gulf of Mexico waters to attack the offshore reefs from behind. During winter, the shallow waters of Florida Bay are often severely chilled—chilled to the point of causing massive fish kills as in 1895, 1970, and 1977. Reefs in the middle Keys, such as Sombrero Reef, which is opposite the largest tidal pass, the one crossed by the Seven Mile Bridge, began to die. Some corals remain off the middle Keys, but the species that originally built these reefs, such as the elkhorn and staghorn and many of the star corals, died 2,000 to 3,000 years ago. Drs. Conrad Neumann of the University of North Carolina and Ian Macintyre of the Smithsonian Institution have referred to this worldwide phenomenon as "being shot in the back by your own lagoon." Dr. Peter Davies of the Australian Bureau of Mineral Resources and his colleagues have documented the same phenomenon in the Great Barrier Reef.

Why should water from lagoons kill reefs? Drs. Pamela Hallock-Muller of the University of South Florida Marine Institute and Wolfgang Schlager of Vrije Universiteit in Amsterdam have suggested in recent articles that as sea level rises, the encroaching sea releases nutrients trapped in soils. Corals grow best in clear, blue, nutrient-free oceanic waters; hence, the extreme diversity and luxuriance of atoll reefs located in sterile Pacific Ocean waters. Hallock-Muller and her colleagues have pointed out that the vast majority of hardbottoms suitable for coral-reef development throughout the Caribbean lack coral growth because of excess nutrients.

The release of nutrients, in combination with mud, reduced or elevated salinity, and—most important—extreme temperature fluctuations, explains why reefs in the middle Keys opposite the larger tidal passes began dying 3,000 years ago. The best-developed reefs in Florida remain those opposite Key Largo. Those off Key Largo do not have their backs exposed to chilled fertilized waters emanating from tidal passes because there are no tidal passes there. Because of this geologic circumstance, winter water temperatures on the reefs off Key Largo are generally warmer than those off the middle Keys and even the Dry Tortugas, which are farther south. Dr. Jim Porter of the University of Georgia documented wholesale death of staghorn coral thickets at Dry Tortugas during the freeze of 1977. Similar thickets were not killed off Key Largo, even though it snowed in south Florida that winter. Staghorn corals transplanted to nearshore sites where they do not live naturally were killed during a mild winter when the water temperature dropped to 13.5°C. Head corals transplanted to similar nearshore areas were killed in 1977, when temperature at the transplant site dropped to 9°C.

Some of Florida's reefs will be dead in 20 years

Many researchers have concluded that natural effects, combinations of temperature extremes, sedimentation, salinity fluctuations, and excess nutrients, all consequence of rising sea level, have been the major cause of reef demise, especially in Florida.

But what have humans done? There is real danger that they are exacerbating the situation both locally and on a global scale, a point often stated by Dr. Gilbert L. Voss of the University of Miami Rosenstiel School of Marine and Atmospheric Science, who was one of the first to sound the alarm. Not only do the cities of Key West and Miami pump their nutrient-rich sewage offshore, but also wastes from the vast majority of the exploding Florida Keys population are pumped into septic tanks by a population ironically lured there by the beauty of offshore reefs. Septic tanks may not pollute bacteriologically, but they release nitrates and phosphates into the porous and permeable limestone, where they mix with the tidally fluctuating water table. At low tide, this clear but nitrate-rich groundwater dribbles into the seawater along the shore, especially in finger channels where the permeable limestone is nakedly exposed. This kind of fertilization may be good for seagrasses and mangroves, but it is deadly to corals unadapted to nutrient-rich water.

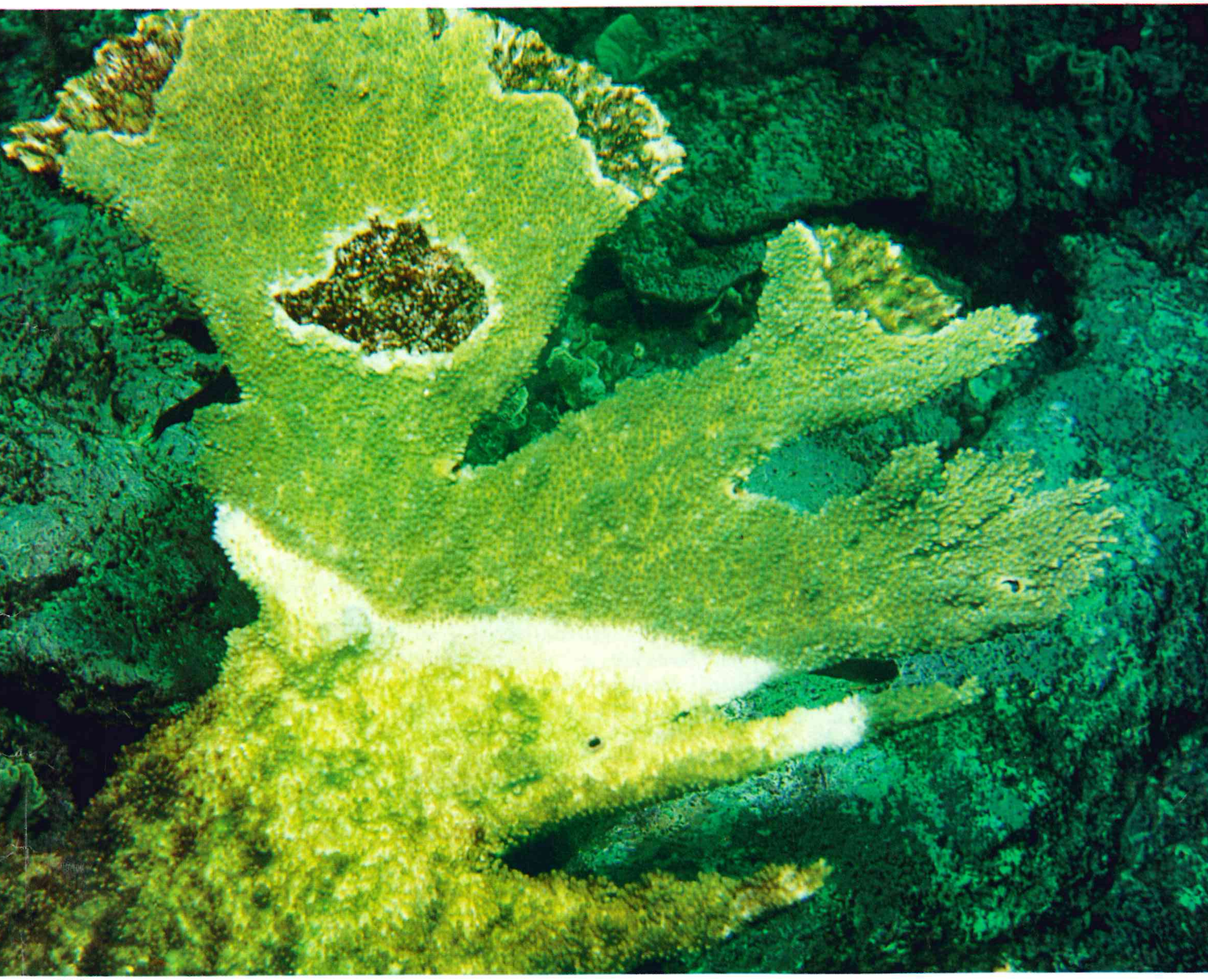
Algal bands kill corals

When over-fertilized, rapidly growing blue-green algae, fungi, and bacteria, normally held in check by herbivorous fishes and sea urchins, out compete the corals. The first signs of runaway growth are algal tufts on coral scars. These may spread, leading to black-band disease. Like a ringworm, the black band of death expands outward, leaving a lifeless white skeleton. At Carysfort Reef, dozens of 100- to 200-year-old star corals have completely succumbed to this plague during the past ten years. Death of an entire colony has been shown to occur during a single summer, when the disease spreads most quickly.

In branching corals, death is more rapid; in these corals, there is a white-band disease. Tissue simply sloughs away, producing a zone of white, lifeless skeleton that spreads rapidly down the branches. In yet another malaise, the coral loses its dark golden-brown color, becomes pale, then develops small splotches where algal tufts can get a foothold. The disease affects both staghorn and elkhorn corals.

Scientists of the Finger Lakes Research Laboratory on San Salvador

Coral diseases, major reef killers, receive little attention.



Bill Causey

A deadly disease: This elkhorn coral is afflicted with white-band disease. The dead white area will expand rapidly along the branch, killing and sloughing away the tissues. Unlike the whitening caused by coral "bleaching," in which only the pigment is usually affected, coral polyps do not recover from this affliction. Dead coral near the tips of the branch have been infested with algae.

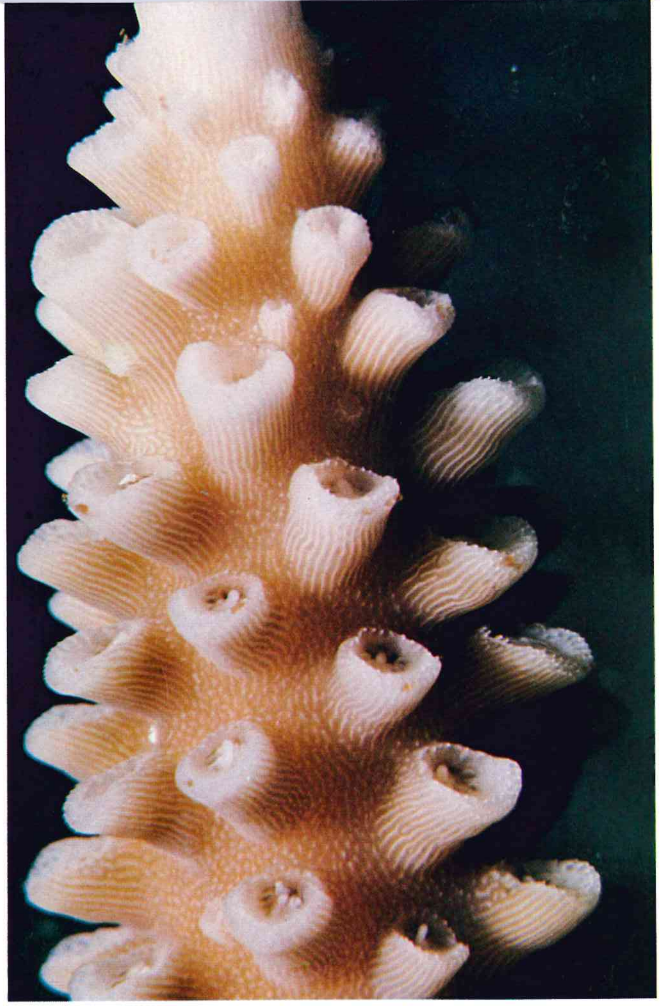
Not so serious: Oil spills have been long decried as reef killers, but experiments applying crude oil directly to live staghorn polyps showed no direct harm from short-term exposure. A diver encased the coral in an oil-filled bag for over an hour's exposure. When the bags were removed, the coral polyps were retracted (center), but no oil clung to the coral. Twenty-four hours later, the polyps were extended (far right) and appeared healthy.

documented the death of a photogenic reef, the focal point of a nearby dive resort, over a period of a few weeks. The dive resort closed. At other reefs off San Salvador, huge 3.5-meter algae-covered elkhorn coral colonies stand unbroken and lifeless in growth position. Some reefs in the eastern Caribbean Grenadines area were recently observed by Billy Causey, scientist at Looe Key Sanctuary, to be in the same condition.

Ironically, San Salvador is a relatively unpopulated island and, like the Grenadines, rises from oceanic depths surrounded by clear blue oceanic waters, so the coastal pollution and green water associated with the Florida Keys can be ruled out, or can it? Is it possible that nutrient levels in the clear offshore Atlantic have also risen dangerously high? Is the increase in atmospheric carbon dioxide, which in turn raises the level of dissolved carbon dioxide, stimulating marine plant and plankton growth? Or is there a viral or bacterial plague such as the one that killed long-spined sea urchins throughout the Caribbean in 1983? The urchins died in the clear blue waters of San Salvador at the same time they were dying in the greener, nutrient-rich waters of the Florida Keys. Was this waterborne plague like the one that killed commercial sponges and wiped out the Caribbean sponge industry in the 1930s?

In the summer of 1987, one of the warmest, calmest, and most hurricane-free summers in Caribbean history, corals expelled their symbiotic algae and became snow white. The consensus among coral-reef scientists is that the unusually warm, still water broke the essential bond between the algae and their coral hosts. Although relatively few corals actually died from the "bleaching" and most regained color with the onset of cooler water, many were weakened and later succumbed to disease. That diseases readily attack distressed corals was shown in 1980 after passage of Hurricane Allen on the north coast of Jamaica. Scientists were documenting the recovery of scattered and battered sticks of staghorn coral when a sudden outbreak of disease almost completely wiped the corals out.

The bleaching event of 1987 should serve as warning to what may occur as worldwide temperatures rise. Dr. Robert Buddemeier of the Lawrence Livermore Laboratory believes we are



seeing the first effects of greenhouse warming and is currently distributing a newsletter to coral-reef scientists in an effort to establish a consensus of policies to be formulated in the face of a warming, rising sea.

The real problem

Diseases, whether they are natural or caused by humans, are far more devastating and long-lasting than the mechanical effects of storm and humans. Diseases or nutrients can wipe out huge areas at the flick of an eye, yet they receive little attention. Researchers such as Drs. Peter Glynn, Phillip Dustan, and Esther Peters in the United States have been concerned with the microbial causes of diseases, but they find that funding for these kinds of basic studies are practically nonexistent. Anchors, ship groundings, and a host of other dramatized threats attract public attention, and those concerned with coral protection respond quickly to public pressure. Enforcement of regulations designed to protect reefs from the mechanical effects caused by humans are higher on the priority list than is basic research on unglamorous diseases and nutrification.

One cannot legislate or write regulations against diseases, but if the causes are understood, then possibly the causes can be eliminated. Unfortunately, results from the unglamorous study of diseases may be a long way off, and those funding such work may not receive the public attention they often need to justify their existence, but such research is essential. As Porter pointed out at a recent coral-reef workshop, ongoing reef monitoring suggests that if the present rate of decline continues, some of Florida's reefs will be dead in 20 years.

Eugene A. Shinn was born in Key West, Florida and grew up diving in and around the Florida Keys. For fifteen years following his graduation from the University of Miami, he did marine geological research for the Shell Development Company in the Keys and the Persian Gulf, and studied ancient reefs in the hills of Central Texas. In 1974 Shinn established the U.S. Geological Survey Field Station at Fisher Island, Florida. No stranger to controversy and discovery, in the past Shinn has written for *Sea Frontiers* on the Atlantis hoax off Bimini, the mystery muds of the Bahamas, coral banding, and stromatolites.

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