KEY LARGO CORAL REEF

America's First Undersea Park

By CHARLES M. BROOKFIELD

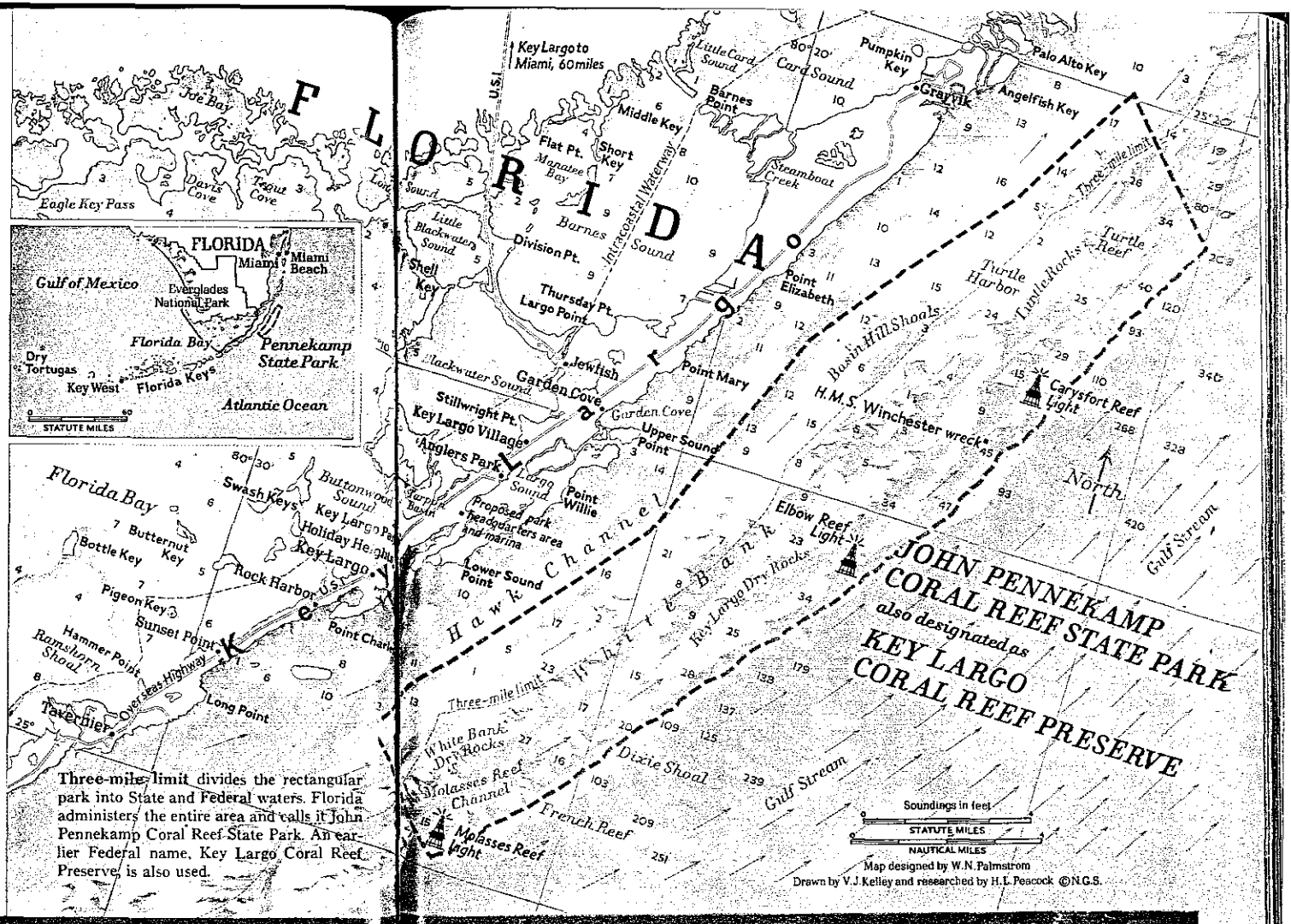
Photographs by JERRY GREENBERG

ALMOST within sight of the oceanside palaces of Miami Beach, a pencil-thin chain of islands begins its 221-mile sweep southwest to the Dry Tortugas.

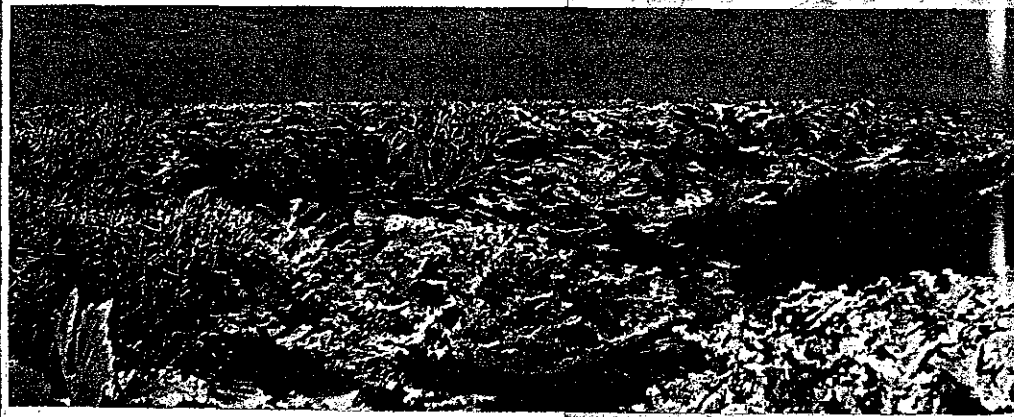
Just offshore, paralleling the scimitar curve of these Florida Keys, lies an undersea rampart of exquisite beauty—a living coral reef, the only one of its kind in United States continental waters. Brilliant tropical fish dart about its multicolored coral gardens. Part of the magnificent reef, a segment roughly 21 nautical miles long by 4 wide, off Key Largo, has been dedicated as America's first undersea park.

I know this reef intimately. For more than 30 years I have sailed its warm, clear waters and probed its shifting sands and bizarre formations in quest of sunken ships and their treasure of artifacts.

Snorkel diver (opposite, right) glides above brain coral into a fantastic underseascape of elkhorn and staghorn in the new preserve off Key Largo, Florida.

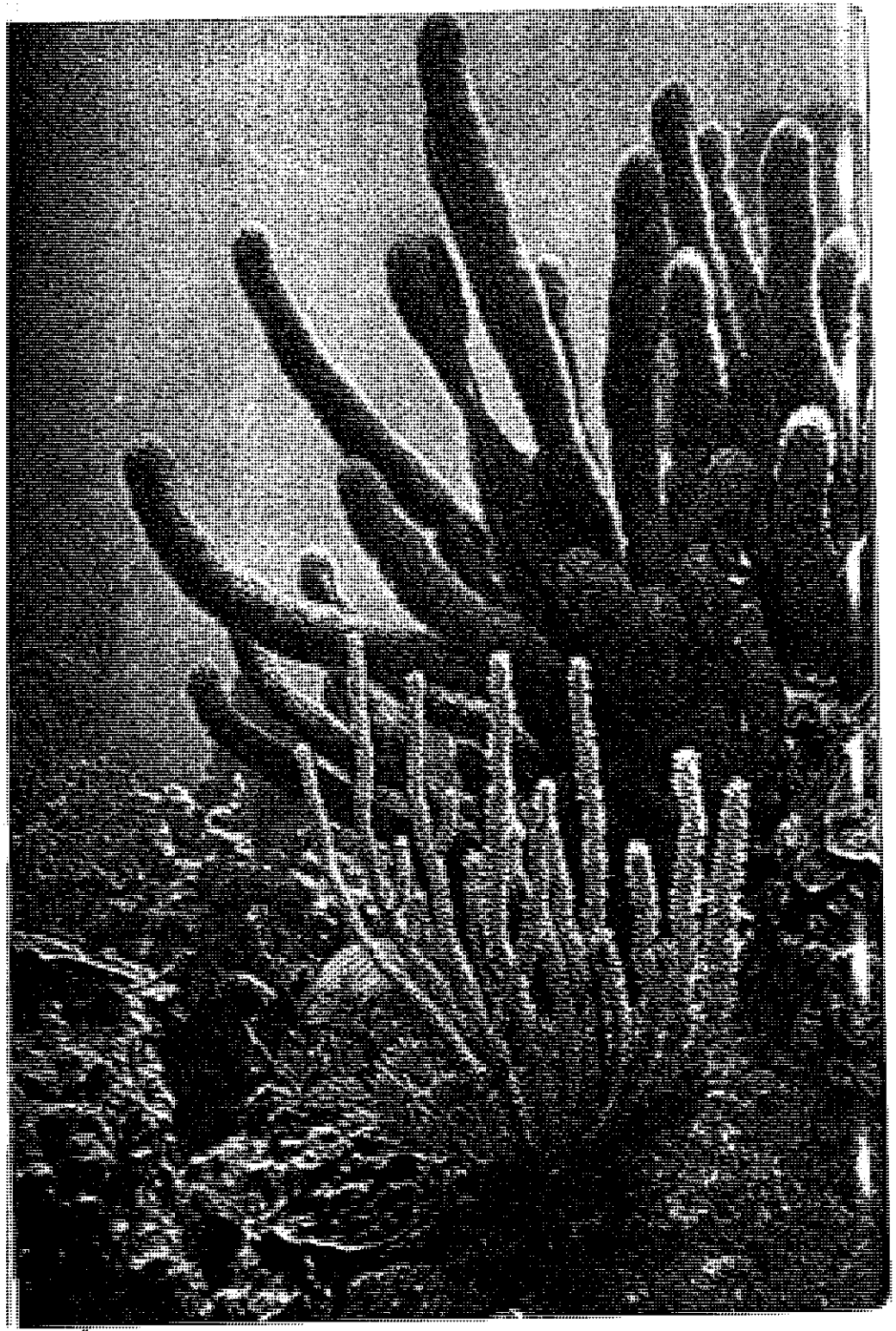


Three-mile limit divides the rectangular park into State and Federal waters. Florida administers the entire area and calls it John Pennekamp Coral Reef State Park. An earlier Federal name, Key Largo Coral Reef Preserve, is also used.





ANSCOCHROME © NATIONAL GEOGRAPHIC SOCIETY



Here is a graveyard of countless brave sailing ships. Spanish galleons, English men-o'-war, pirate vessels, and privateers foundered on the reef's hidden fangs. In the 19th century alone, several hundred vessels met death here, and the wrecking masters of Key West gleaned close to ten million dollars from salvage operations.

In today's salt-water preserve the boundaries are marked by buoys, and visitors eventually will ride glass-bottomed boats above the lovely coral gardens. Even now the more active visitors fasten on mask and snorkel and bob face-down in gentle swells for a closer look at gaudy reef fish. The most adventurous strap on breathing units and descend to the beautiful coral world that underwater photographer Jerry Greenberg describes vividly on pages 70 to 89.

Author Found Wreck of the *Winchester*

Heavy seas break directly on the outer coral barrier, where the seaward edge of the reef comes up abruptly from the deeper waters of the Gulf Stream. Here, 23 years ago, I found the scattered remains of H.M.S. *Winchester,* which went down off Carysfort Reef, five miles east of Key Largo, in 1695.*

A British ship of the line with 60 guns and a crew of 350, the square-rigged *Winchester* fought with the West India Squadron in the war with France, harrying ports of the French islands. Mission accomplished, she refreshed at Jamaica, then set sail for England and home. But scurvy—that age-old plague of the sea—began to lay her crew low. I did not uncover this interesting fact until two years ago, when I learned that the *Winchester*'s log had been saved. Writing to the Public Record Office in London, I obtained photostatic copies of the last few pages.

On September 14, 1695, the unhappy captain recorded that: "... we had not above 7 men Well our Shipp increasing upon us by the water She made in the holds & we Left Distitute of all ability to pump it out our people being all dead and Sick...."

Ten days later a vicious gale struck the ship off the Florida Keys. With the crew helpless, only a few men able to stand, the *Winchester* broke her back on the reef.

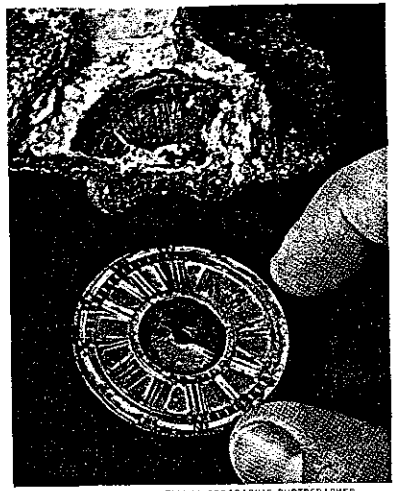
Key Largo, the nearest land, was inhabited only by fierce Calusa Indians, notorious for practicing human sacrifice and keeping slaves. There was no thought of seeking refuge there. An accompanying vessel rescued eight men—the only survivors.

For 244 years *Winchester*'s guns, some weighing more than two tons, lay five fathoms deep, while shipworms made a sieve of her rotten hull. By 1939, when we located the wreck and raised the cannon, the ship had disintegrated.

Eighteen months ago I paid a return visit to *Winchester*'s grave. With an air lift and free-diving gear, I hoped to recover objects overlooked by previous expeditions. Fortune favored us. We raised coral-encrusted cannon-

*For a description of *Winchester*'s last voyage and the discovery of its wreck, see "Florida Cannon Solve Mystery of Sunken Ship," by Charles M. Brookfield, in the December, 1941, NATIONAL GEOGRAPHIC.

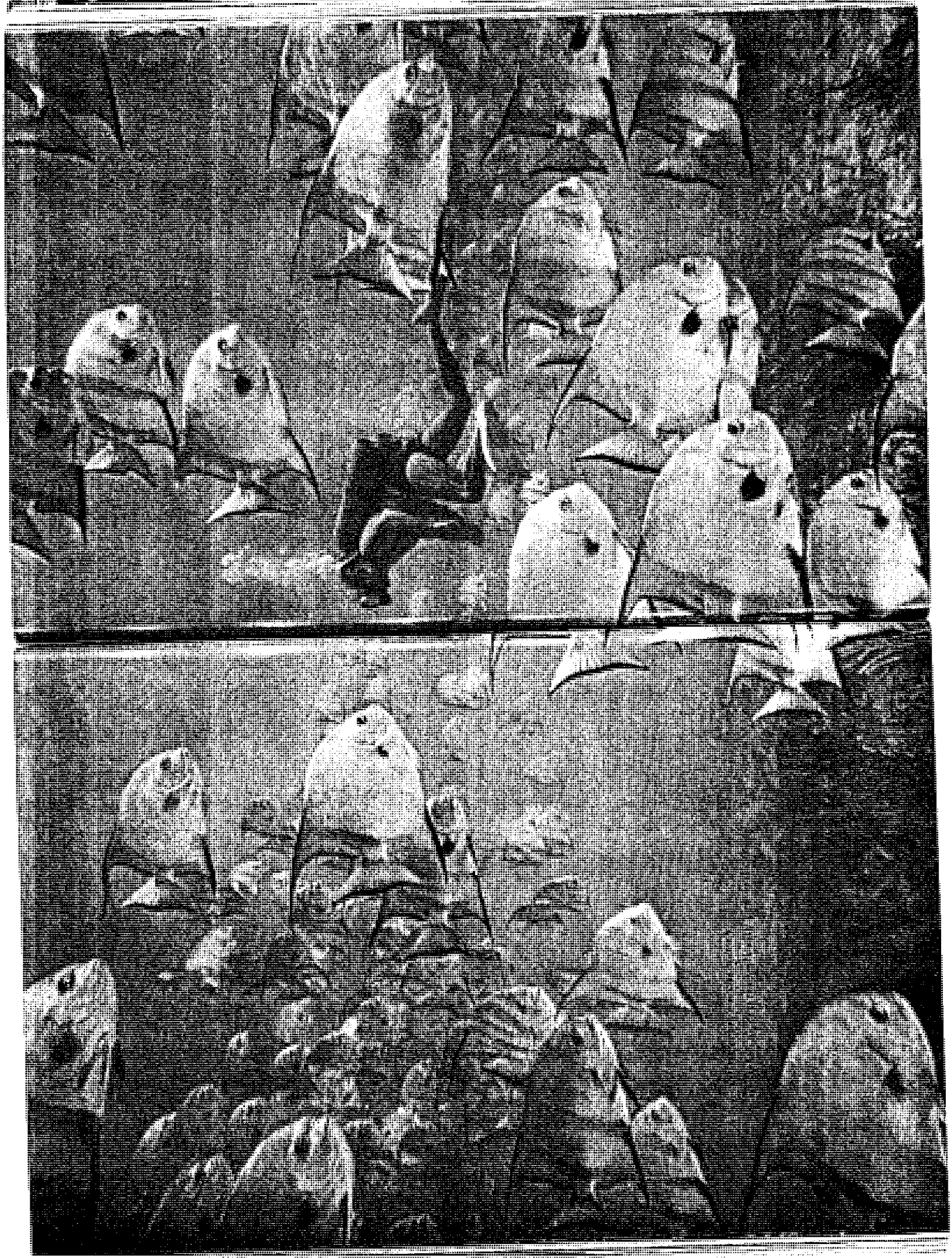
Giant sea whips, or gorgonians, reach for the sun like saguaros in a cactus forest. Blue-striped grunt *(Haemulon sciurus)* peers past the smaller branches below.



Gold watch raised from H.M.S. *Winchester,* which went down off Carysfort Reef in 1695, shows the hours in Roman numerals and the minutes in Arabic. Here a lump of rock bears the imprint of the dial's face in black iron oxide. For 264 years the watch lay on the bottom, sandwiched between an iron fitting and rock ballast.

When he discovered the *Winchester*'s grave in 1939, the author salvaged cannon, cannonballs, wrought-iron fittings, and a brass sundial, as recounted in the December, 1941, NATIONAL GEOGRAPHIC. On a return visit 20 years later, this remarkable watch and a universal ring sundial were recovered.

KODACHROME (ABOVE) BY NATIONAL GEOGRAPHIC PHOTOGRAPHER ROBERT F. SISSON AND ANSCOCHROME BY JERRY GREENBERG © N.G.S.



balls, hinges, spikes, and fittings wrought by 17th-century craftsmen.

One day young Charles H. Baker III popped to the surface with an object wreathed in lumps of the ship's ballast. A hammer blow revealed a gold watch within the black mass. The watch's crystal was broken and its works were filled with grit and sand, but, miraculously, one of the brass wheels still turned on the pivots.

It seemed fitting that young Baker made the discovery. His father was with me when we raised *Winchester*'s cannon, and the Baker sloop, *Mata Hari,* served as the mother ship of the latest expedition.

A second treasure raised from *Winchester*'s remains was a universal ring sundial, used by mariners in the 17th century.

Museum Will Exhibit Relics

Both watch and sundial will be exhibited in a museum which will be constructed in park headquarters on Largo Sound.

Generous citizens have donated 74 acres for exhibit buildings, docks, and launching ramp, and the Florida Legislature has appropriated $150,000 for the center's development. From the marina, glass-bottomed boats will cruise out to the reef.

Here soft-bodied coral polyps—tiny anemonelike creatures that build protective cups of lime—flourish in the warm waters of the Gulf Stream. Billions of their limestone skeletons form the foundations of the reef; vast colonies of the living coral animals grow on the dead, fashioning a fantasyland of strange forms.

Tourists who buy coral at roadside curio shops see only the bleached white skeletons of the once-living colony. But a visitor to the reef may feast his eye on living colors—the green, brown, and gold of stony corals; the blue, purple, and yellow of coral fans and plumes that sway with the current; the pastel tints of towering sea feathers and graceful coral whips (page 60). Altogether, they form one of nature's grandest shows, a submerged landscape of awesome beauty.

A preserve to safeguard this unique underwater world was discussed at a meeting of Florida conservationists in 1957. Dr. Gilbert L. Voss, of the University of Miami's Institute of Marine Science, warned that the gorgeous Florida reef might soon become a watery desert if steps were not taken to protect it.

His statement raised many an eyebrow. What could destroy a reef? he was asked.

"Man," Dr. Voss replied.

Coral From Reef Sold to Motorists

Curio vendors were tearing the reef apart, using dynamite and crowbars. Bargeloads of corals, sponges, and the imposing queen conch shell were piled along the roadsides for sale to motorists. Fish collectors raided the waters, and spearfishermen stabbed everything that swam or crawled.

Despoliation of the reef would have other consequences, Dr. Voss predicted. The coral gardens served as a haven for small tropical fish and a nursery ground for game fish. Without small fish to feed upon, the game fish

The Author: Florida representative of the National Audubon Society, Charles M. Brookfield also heads the State Park Board's Advisory Council on Florida Key Sites. A veteran explorer of Key Largo's reef, he found the remains of H.M.S. *Winchester* there in 1939 (page 61). During World War II he saw action in several theaters as an LST skipper.





ANSCOCHROMES BY DAVID GREENFIELD (ABOVE) AND JERRY GREENBERG © N.G.S.

Water-loving Morays, members of a Miami diving club, leap into the Atlantic's gentle swells above Molasses Reef to explore the sea floor with snorkels, masks, and fins.

Head in Air, Body in the Water, a Diver Prepares for an Inspection Tour of Coral Gardens

Charles H. Baker III clears face mask and breathing tube near Carysfort Light. Refraction of light by water magnifies his body about 25 percent. In this unusual photograph, the camera sees simultaneously in air and water, like the four-eyed fish of Central America which has bifocal vision.



ANSCOCHROMES BY JERRY GREENBERG © NATIONAL GEOGRAPHIC SOCIETY

Bold white grunt *(Haemulon plumieri)* inspects a slice of sea urchin held by Judy Meade above a huge brain coral. Tiny bluehead wrasses *(Thalassoma bifasciatum)* hover near for leftovers. Many reef fish show little fear of humans.

Mountains and Valleys Corrugate Brain Coral

Neon goby *(Elacatinus oceanops)* darts over the maze, approximately three-quarters life-size, at center right. Using fused ventral fins shaped like a suction cup, this tiny fish perches on coral heads. Neon gobies pluck parasites from the mouths and bodies of groupers and other predatory fish.

would go elsewhere. In Florida, where one out of four visitors comes for salt-water angling, such a shift could be of grave concern.

Dr. Voss's plea spurred conservationists into action. The Florida Board of Parks and Historic Memorials approved a 75-square-mile section—10 percent of the entire reef—as a permanent preserve. The National Audubon Society's staff in Miami encouraged Floridians to write to the governor and the United States Secretary of the Interior.

Because the park's suggested boundaries straddled the three-mile line that divides State and Federal waters, approval by both governments was needed.

Complications delayed the park's birth for three years, but in March, 1960, President Eisenhower proclaimed the Key Largo Coral Reef Preserve. At dedication ceremonies the following December, Gov. Leroy Collins gave the preserve the name of John D. Pennekamp, associate editor of the *Miami Herald* and an ardent conservationist. Thus the protected area is known by two names, one chosen by the Federal Government, the other by Florida.

"His pen has struck down the despoiler and exalted those who would conserve," Governor Collins said of the editor who, in the press and in person, has fought more than 20 years to preserve Florida's natural beauty.

Today the 21-mile stretch of sea in the preserve is dotted with chartered fishing boats trolling the surface and smaller craft of free divers floating at anchor. Fleets of flat-bottomed clouds sail the horizon. Now and again one breaks away from the armada and scurries across the sky, darkening the sea with its shadow.

Fish-hunting cormorants ride the waves, and porpoises play leapfrog with whitecaps. A flying fish skims the sea, and a loggerhead turtle pops up for air. Floats bobbing on the surface mark the lobster traps of commercial fishermen seeking the spiny lobster.

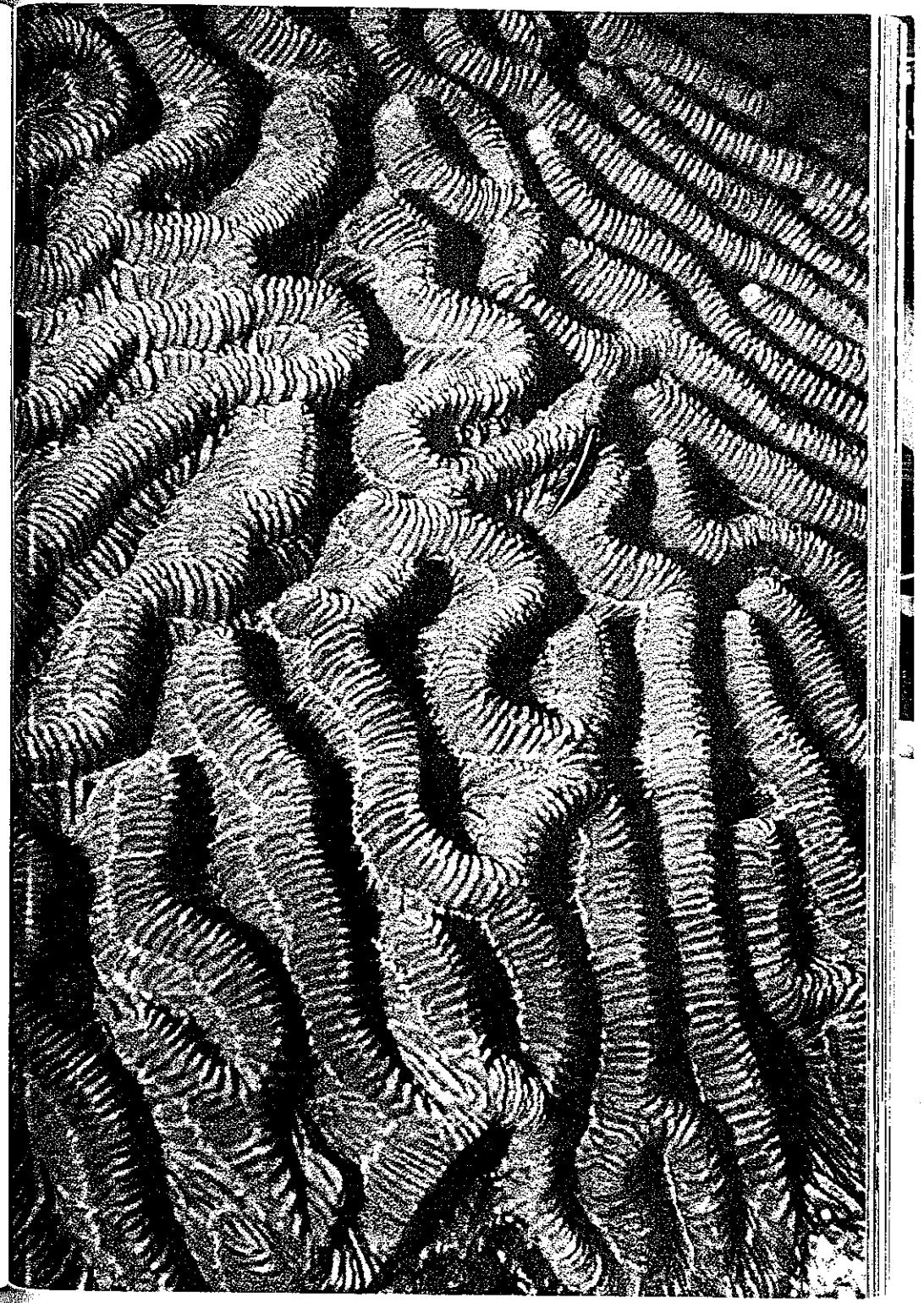
Park rules prohibit spearfishing, but sanction rod-and-reel fishing and lobstering, provided the ocean floor suffers no damage.

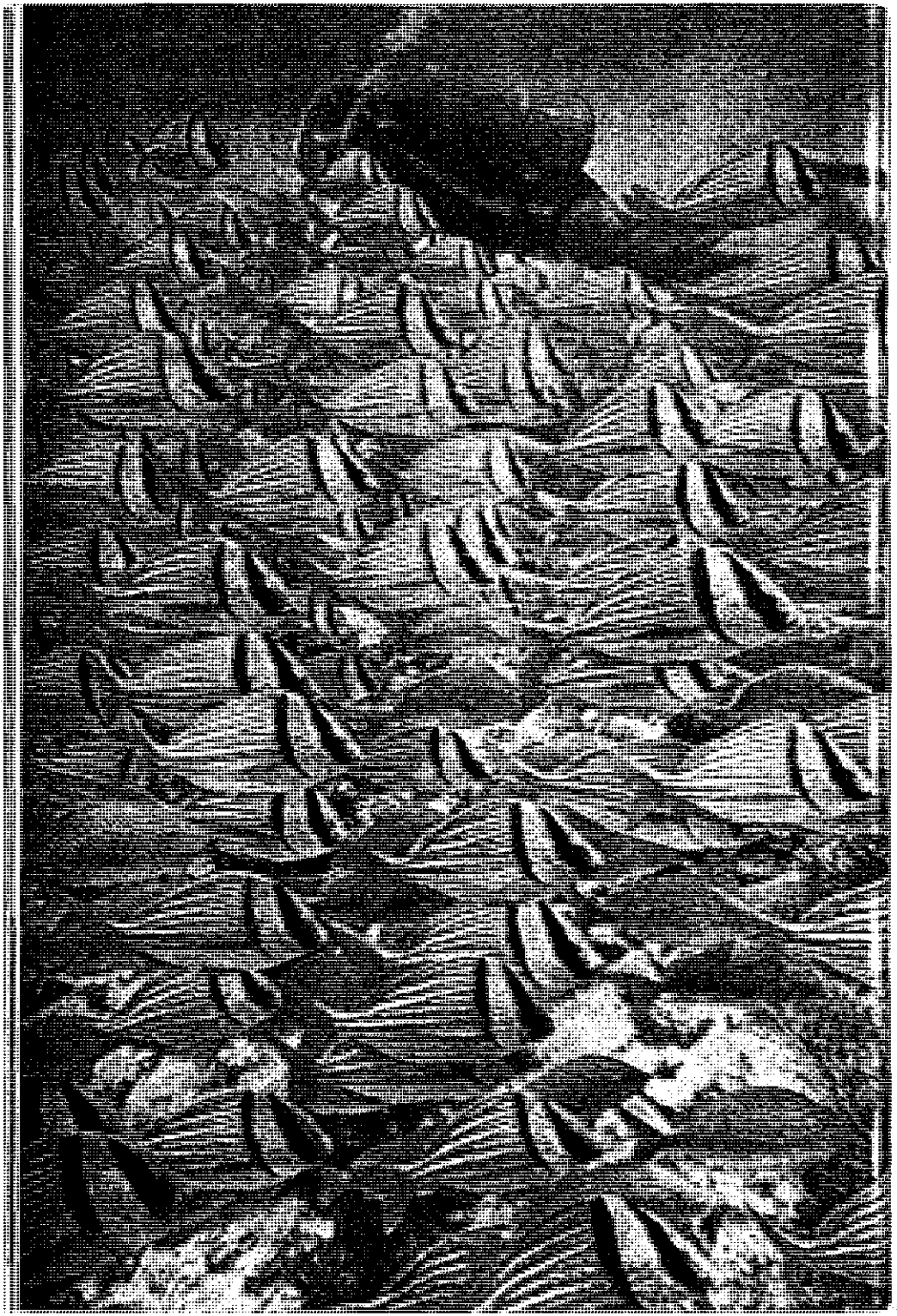
Reef a Center for Marine Research

Marine biologists from all parts of the world work above and below the reef's waters. Dr. Voss and his associates at the University of Miami's Institute of Marine Science are carrying on a three-year research project to determine how fast corals grow and the maximum life a reef can sustain. Aided for the past 11 years by the National Geographic Society, through its Committee for Research and Exploration, they are also studying the food-chain relationship between living plants and animals, and the movements of fish populations.

Other scientists are shedding new light on one of nature's most remarkable associations—the relationship between the coral polyps and hordes of tiny plantlike cells that live within them.

Some of these microscopic cells contain chlorophyll, which tints the soft tissues of the





coral green.* Others lend a golden-brown color to their hosts. These cells benefit from the carbon dioxide and other wastes given off by coral tissues; in turn, they supply the polyps with oxygen. Symbiosis, as their mutually beneficial relationship is known, stems from a Greek word meaning "living together."

Close relatives of the true corals, millepores, or stinging corals, also flourish on the reef. Their stinging cells, touching human flesh, cause a burning sensation. Many of their colonies have distinctive shapes: branchlike, flat, or bladelike (page 86).

Altogether, more than 30 different species of coral have been found in this unique underwater preserve.

Other reservations in the West Indies and Florida include undersea areas, but the new preserve off Key Largo lies totally under water. Lighthouses and tide-exposed rocks alone break the surface. The three lighthouses studding the seaward side of the reef—Carysfort (page 64), Elbow, and Molasses—all perch on iron piles.

Carysfort, only habitable structure within the preserve, is manned by United States Coast Guard men. When I first visited it 35 years ago, the Lighthouse Service was in charge. Keepers then spent two months on the light for every 29 days on "honeymoon," their term for shore leave.

I shall never forget my first night on Carysfort. I had gone out with two friends in my cabin cruiser, *Manatee*, with meat and vegetables for the keeper and his two assistants.

Captain Johnson's Ghost Groans

At bedtime my companions and I settled on the lower deck of the light's dwelling, but I could not sleep. As I lay restless, a groan echoed through the lower deck.

"Did you hear that?" I asked.

My friends snored blissfully. I had just about convinced myself that my imagination was playing tricks when the moan was repeated, as if from a soul in torment.

Jumping up, I climbed the steps to the upper deck and circled the dark stairs to the tower, where Harry Baldwin, one of the assistants, was standing watch at the lantern.

"Harry," I panted, "have you ever heard any funny noises down below?"

"Oh, sure," he said, "but we don't pay attention to 'em any more. It's only Captain Johnson, and he just comes around to see if all's well. He died out here on the light, you know. Must have been a great sinner, he groans so. Sometimes he rattles his chains."

Thus reassured—I use the word loosely—I went below and slept, groans or no groans.

Next morning I solved the mystery of the moans, I believe. Under the hot sun, the tower's iron walls expand; in the cool of darkness, they contract. Shrinking, they make sounds startlingly human. My theory may not be true, but I have clung to it ever since.

Seminoles Ambush Lightship Crew

Oldest of the reef lighthouses, Carysfort was first lighted in 1852. But for more than a quarter of a century before that, a lightship had been stationed within the reef. Since the main source of supply for the crew was Key West, about 100 miles away, they cultivated vegetables in a little harbor they called Garden Cove, on near-by Key Largo.

One fine day in 1837, Capt. John Whalton and three of his crew lowered boats and headed for Key Largo to gather firewood. The Seminole Indians had been on the warpath in southern Florida for some time, but there had been no recent attacks on the Keys. It seemed safe enough to go ashore for a few hours.

But dark, hostile eyes watched from ambush as the boats beached. Without warning the Indians attacked, and the captain and one of his crew were killed. The two other men escaped with the boats.

In that earlier tragedy, when the warship *Winchester*'s keel struck Key Largo's coral barrier, the crew thought only of cruel rocks and surging seas. Crushing timbers were falling all about them, and the sea was rushing in through gaping holes in the ship's bottom. Soon the swirling waters brought merciful death.

No man aboard the ill-fated vessel could have dreamed that the treacherous reef possessed a rare beauty which man would one day deem worthy of preservation.

*See "How the Sun Gives Life to the Sea," by Paul A. Zahl, NATIONAL GEOGRAPHIC, February, 1961.

Mixed Battalions of Porkfish and Grunts Maneuver in Close-order Drill

Distinguished by its yellow stripes and black bars, the porkfish *(Anisotremus virginicus)* often travels with its relative, the white grunt. Like many reef fish, both species feed by night. This school will disband when the members go foraging for food.

NS EKTACHROME © NATIONAL GEOGRAPHIC SOCIETY

Florida's Coral City

Beneath the Sea

Article and photographs
by JERRY GREENBERG

Exploring the wonders of the reef, a diver finds another world and photographs its denizens in color

"BUT THE SHARKS... aren't you afraid of the sharks?" This is a familiar question. My answer is "No," with some reservations.

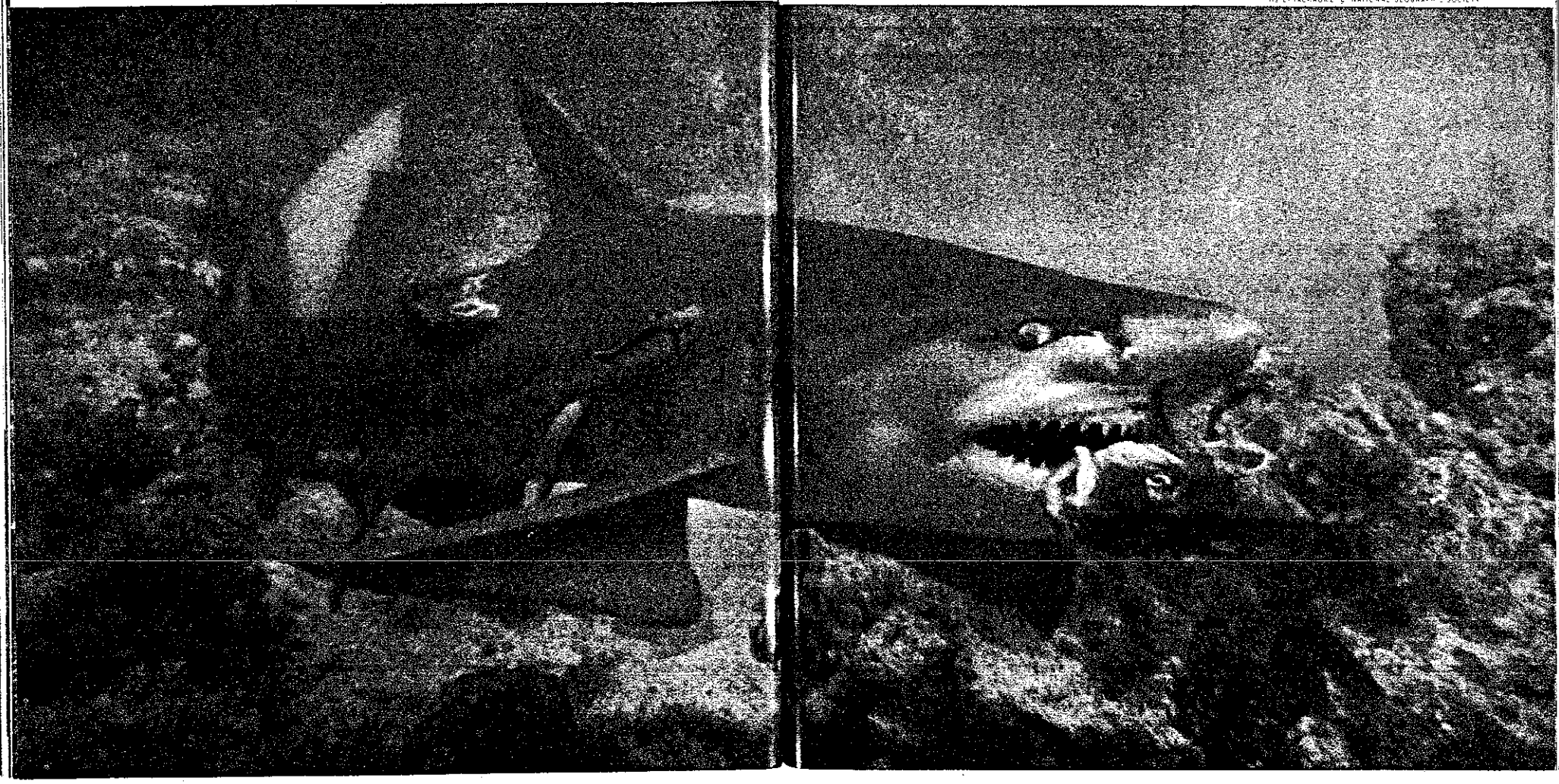
When working under water, I regard sharks as the man in the jungle does the tiger, or the midtown pedestrian does the reckless driver. I know they are there; sometimes I see them. But I go out of my way to avoid them.

For more than 10 years I have been diving for pictures of fish and coral reefs off the Florida Keys. I have spent thousands of hours in the depths, and I have seen countless sharks—hammerhead, blacktip, lemon, nurse, bull, tiger—but not one of them has ever attacked or even threatened me. I photographed the lemon shark below from a distance of only seven feet.

A shark is cautious; usually it steers clear of a diver if he doesn't bother it. But a shark is unpredictable; no one can say what it will do on any given encounter. "Don't provoke the animals." The admonition to zoo visitors also applies to an underwater reef.

Recently I spent two months roaming beneath the waters of the new John Pennekamp Coral Reef State Park (see preceding article). Here some fifty thousand acres—about 75 square miles—make up America's first park totally under water. This unique preserve

Lemon shark, 10 feet of malevolence, seizes a snapper in razor teeth. Hitchhiking remoras loosen suction disks and rush for scraps



HS EKTACHROME © NATIONAL GEOGRAPHIC SOCIETY



Silhouetted against blazing sun, a diver glides to the floor of the coral reef preserve.

Scrawled Filefish With Puckered Mouth Seems Asking for a Kiss

Actually, *Alutera scripta* is making a grunting sound as he swims. Other brilliant reef fish share John Pennekamp Coral Reef State Park with artist-diver Judy Meade. Wide-eyed French grunt *(Haemulon flavolineatum)* inspects her fingers; gaudy sergeant major *(Abudefduf saxatilis)* darts between her flippered feet. Bluehead wrasses and yellowtail snappers *(Ocyurus chrysurus)* swim past leisurely. Stinging coral at upper right resembles a basket of flowers. Lobed star coral decorates the reef at lower right.

welcomes the free diver, the rod-and-reel fisherman, and the fish watcher. But to the spearfisherman, it is forbidden territory.

While exploring this magnificent marine realm, I encountered only three or four sharks. They did not molest me or any member of my diving party, and we interrupted their privacy only long enough to capture their portraits (pages 71 and 80).

My crew members, who doubled as models, included Judy Meade, a commercial artist; Carl Gage, Paul Dammann, and young Van Cadenhead. Van learned to use an Aqua-Lung three years ago, when he was 10 years old. Now he swims and dives with the best.

Working off my 20-foot runabout, I dived four or five days a week. Many days I stayed submerged six hours, ascending only to switch air tanks and reload the cameras.

Often we made underwater photos at dusk. Sometimes we dived under a full moon, and the visibility was good enough to see 30 feet in any direction.

To photograph the reef's eerie beauty, I used four Rolleiflex cameras in Rolleimarin housings, four Leicas in special Seahawk housings, three electronic flashes in underwater casings, and assorted flash guns. To facilitate the changing of cameras, I suspended all gear on lines dropped over the boat's side. We worked mostly in depths of 15 to 30 feet,

where a tank of air can last an experienced diver about an hour and a half.

And what wonders we saw!

Let me show you this world beneath the waves that I find so intriguing and that claims so much of my life. Slip a mask over your face, clench the Aqua-Lung's rubber mouthpiece between your teeth, and drop down with me into the sea.

Awed Diver Feels Like Trespasser

As you sink slowly, you experience an exhilarating sense of buoyancy. The air tank felt heavy above the surface; now you are scarcely aware of it on your back. Freed from the demands of gravity, you move like a bird, free to dive or soar with no other power but your arms and flippered feet.

Just below the surface, jellyfish pump past as you submerge. Living parachutes, they range in size from a dime to a dinner plate. At 20 feet you touch down on the reef. What had seemed a blurred tapestry of color at the surface now assumes dimensions and patterns.

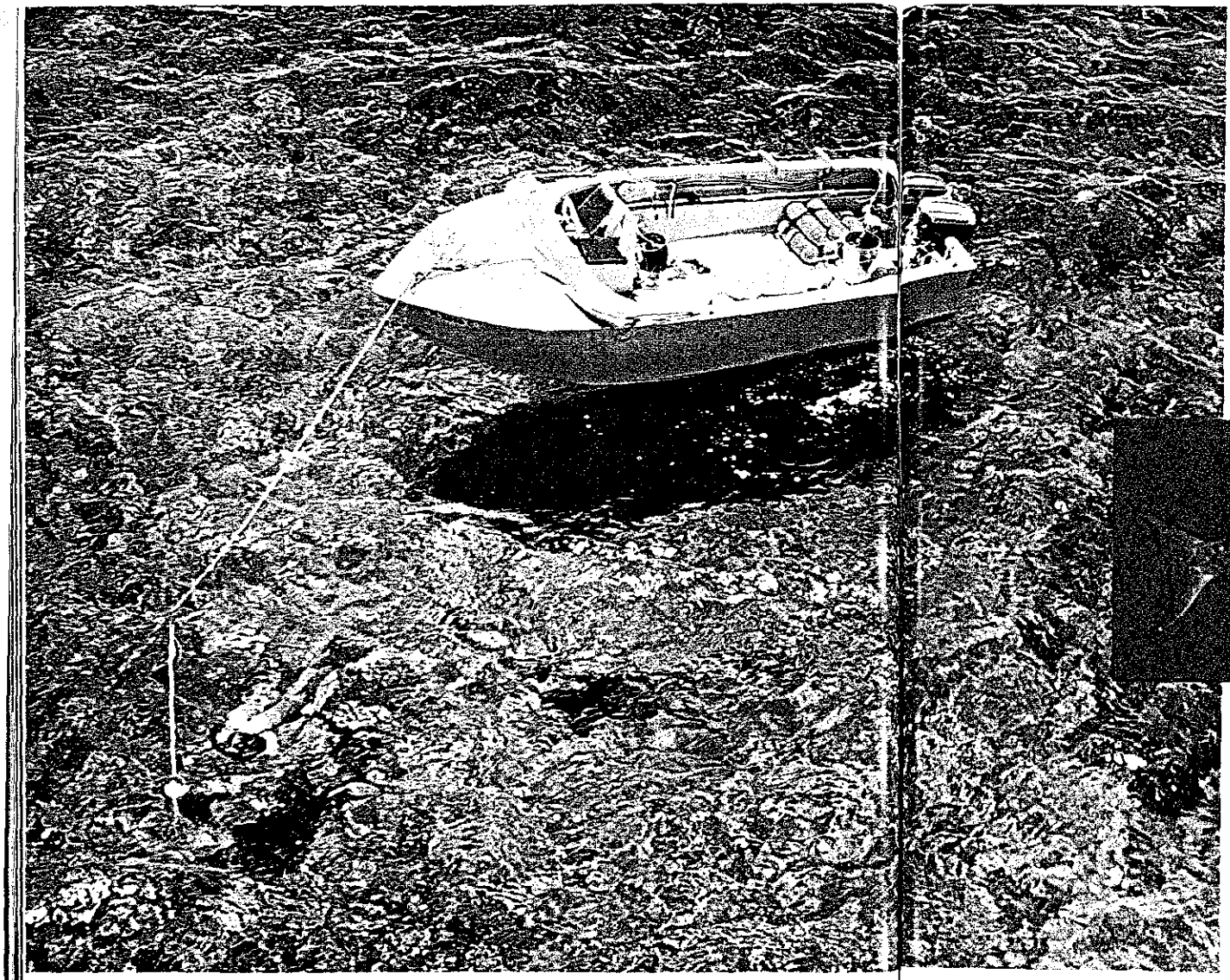
Deep, winding gullies carpeted with sand slice plateaus of coral seemingly so soft, so untouchable you fear they may fade away before your eyes. Such primitive beauty and solitude make a man feel he is trespassing on forbidden ground.

The silence is awesome. Only the sound of breathing through the mouthpiece and

ANSCOCHROME (BELOW) AND NS EKTACHROME BY JERRY GREENBERG © NATIONAL GEOGRAPHIC SOCIETY

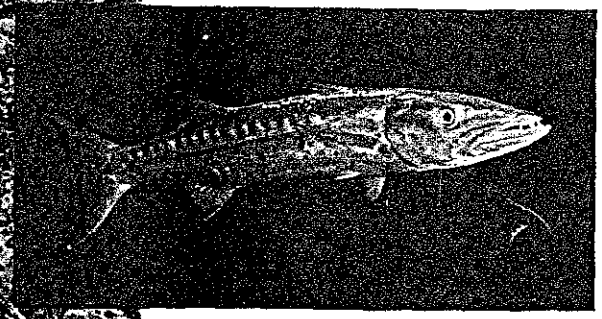


KODACHROME (LEFT) BY DAVID GREENFIELD; EKTACHROME (LOWER RIGHT) AND ANSCOCHROMES BY JERRY GREENBERG © N.G.S.





Queen angelfish glides past elkhorn coral



Razor-toothed barracuda awaits prey



Hawkfish rests on pectoral fins

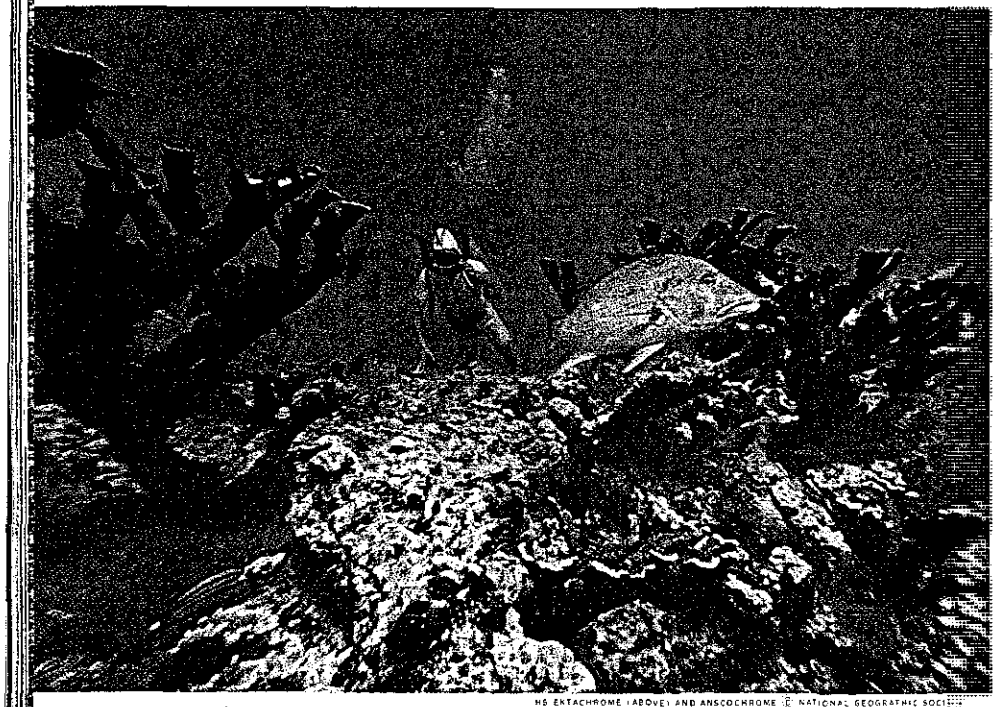


Spotted moray lurks in coral ambush

As a Diver Plants a Warning Flag, His Boat Appears to Float on Air

"Watch out for free divers," the red-and-white banner tells boatmen sailing the waters around Molasses Reef, America's first underwater park, the preserve welcomes divers and rod-and-reel anglers to its fifty thousand acres, but prohibits spearfishing. From a marina to be constructed on Largo Sound (map, page 58), visitors will ride glass-bottomed boats above the coral gardens. Sunlight filtering through the iridescent water glitters against coral of thirty or more varieties and tropical fish of two or three hundred different species. In this kaleidoscopic world, swimmers stare at the fish, and the fish goggle back.

Species pictured opposite are queen angelfish (*Holacanthus ciliaris*); barracuda (*Sphyraena barracuda*); hawkfish (*Amblycirrhitus pinos*); and moray (*Gymnothorax*).



HS EKTACHROME (ABOVE) AND ANSCOCHROME © NATIONAL GEOGRAPHIC SOCIETY

Diver and dog snapper play follow-the-leader among stands of elkhorn coral. Dog snapper (*Lutjanus jocu*), a popular sport fish, attains 50 pounds.

Sea Fan and Butter Hamlet Blend Their Beauty as in a Japanese Print

Members of the grouper family, butter hamlets (*Hypoplectrus*) wear coats of various colors: blue, pink, yellow, and orange. This six-inch specimen floats above a boulder-like colony of star coral and branching fingers of pink coral (bottom left). Filigree sea fan at upper right contrasts with skeletal branches of gorgonians at left.

exhaled air bubbling up from the regulator break the quiet. Later, when you have become more acclimated, you may hear the snapping of shrimp, the crunching of the parrotfish as he feeds, and the grunting noises that many fish make.

Reef Fish Escort Divers on Tour

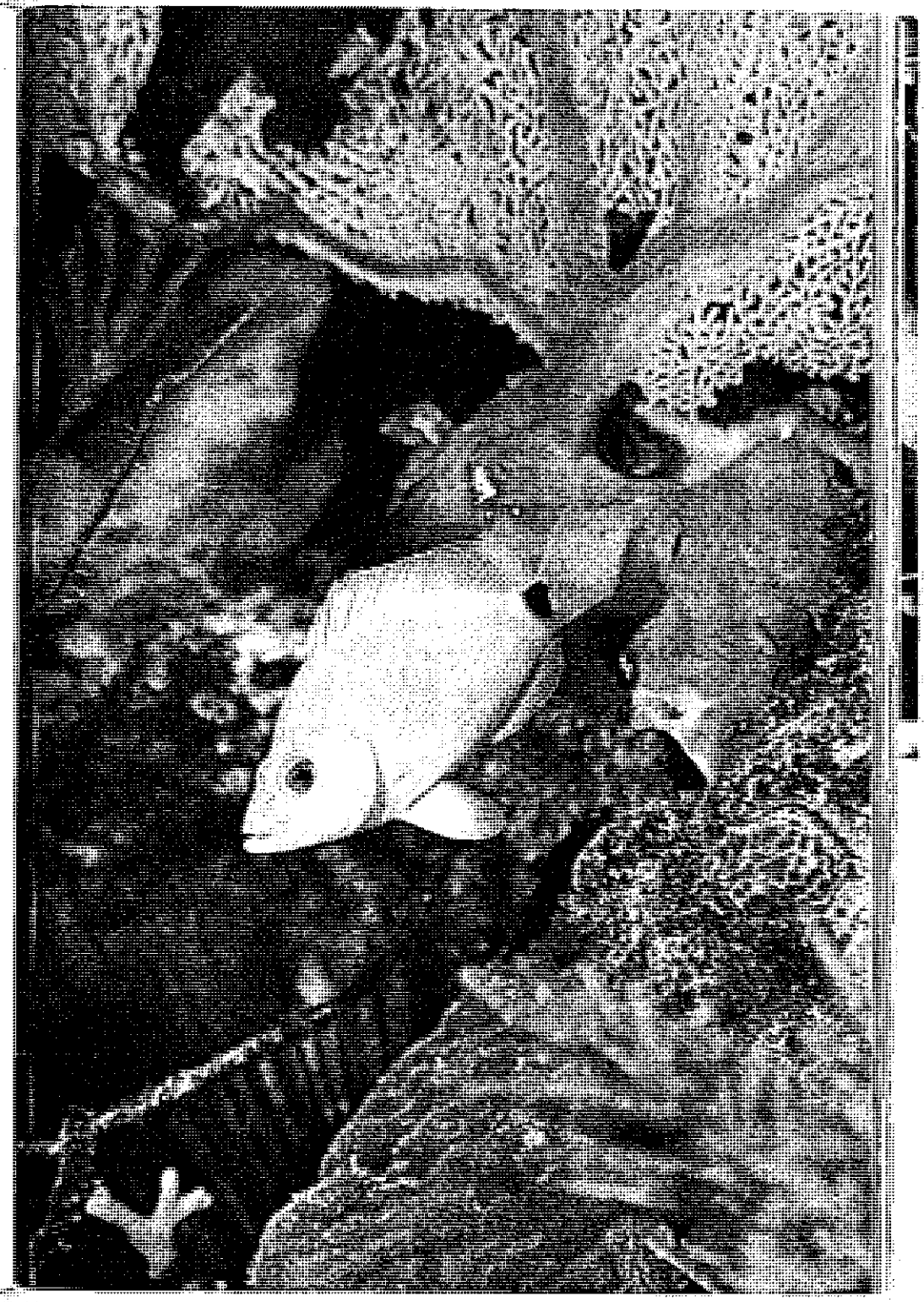
You sense an air of subdued expectancy. The reef waits in hushed judgment until you make clear your intentions, and it is certain that friends have come to call.

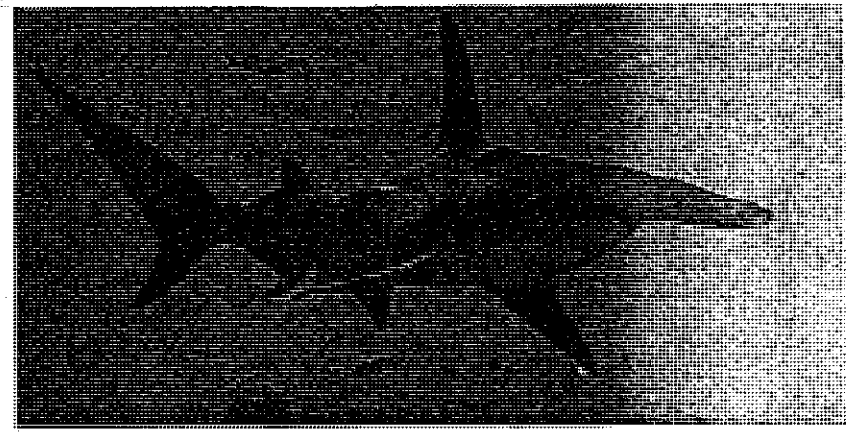
Graceful gorgonians raise arched branches like uplifted arms. These dense stands of horny coral sometimes grow as tall as a man. Pastel-hued sea fans spread their lace to the eddying currents (opposite).

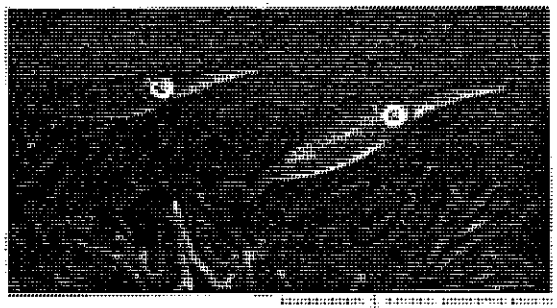
Forests of staghorn coral, amazingly like antlers, crown the crest of the reef. Boulder-shaped brain coral exhibits patterns of twisted grooves that bear remarkable resemblance to the surface of the human brain. Star coral, cactus coral, and leaf coral suggest decorations in a potentate's palace. At least 30 species of coral and 25 kinds of gorgonians adorn the reef (pages 58, 60, and 82).

Three queen angelfish in blue and gold lose their sense of caution, emerge from hiding, and swim toward you. A silvery school of spadefish shimmers into view and floats lazily above, below, and beside you, as though providing a path for your swimming pleasure (page 62).

You accept the welcome and begin the tour of a coral metropolis where every square inch teems with life. A red squirrelfish (page 78),







Hammerhead shark (top), a remora riding its flank, travels with a convoy of yellowtails. Eyes and nostrils of this shark *(Sphyrna)* lie at the tips of the hammer.

Popeyed squid, common on the reef, moves by jet propulsion. As *Sepioteuthis sepioidea* swims, its 10 sucker-bearing arms press together in the shape of a beak.

White grunts hold a meeting beneath a ledge; one club member seems to voice his opinion. "Grits and grunts" fed the Conchs, pioneer settlers on the Keys.

of a coral canyon, and disappear in the distant gloaming.

A pancake-thin sting ray flaps batlike wings, waves a buggy-whip tail, and skims the sand. An evil-looking barracuda bares razor teeth and swims past arrow-straight (page 75). You have heard that barracudas seldom attack man, but you heave a sigh of relief when he is gone. A vicious moray eel keeps vigil in a rock cave. Any unwary fish that swims too close will find quick death in the moray's curved teeth (page 75). He is no menace to you, however, unless you try to dislodge him from his lair.

Now a bright green-and-yellow fish attracts your attention. Swimming closer, you watch a parrotfish hovering like a blimp above a brain coral. With parrotlike beak and small sharp teeth, it nibbles on the living coral.

You approach a sea whip, or gorgonian, and one of the

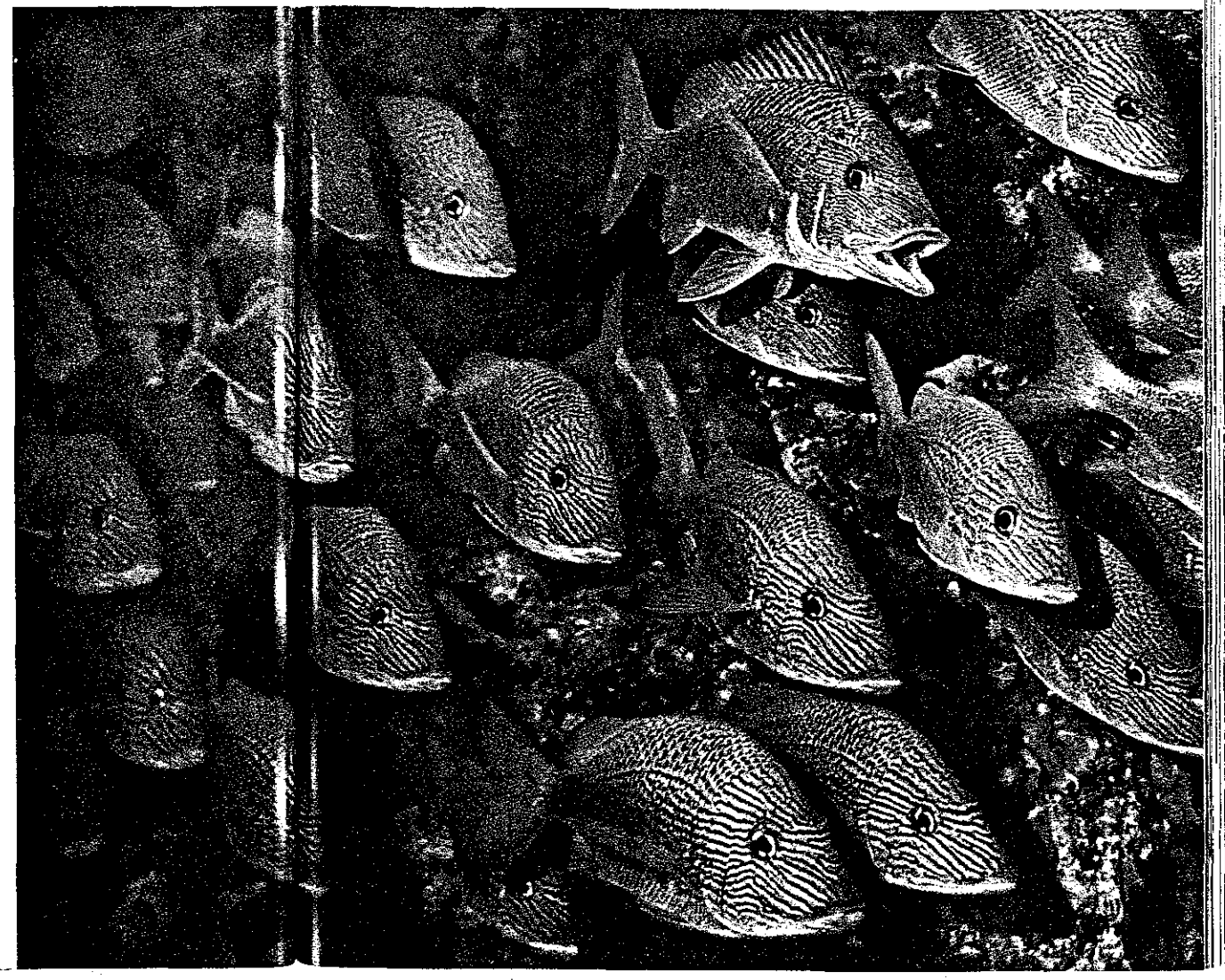
many thin "branches" appears to fall off, slither away, and wriggle into a narrow opening. The branch is a trumpetfish—an elongated species that finds perfect camouflage for itself among the gorgonians, whose branches it so deceptively resembles.

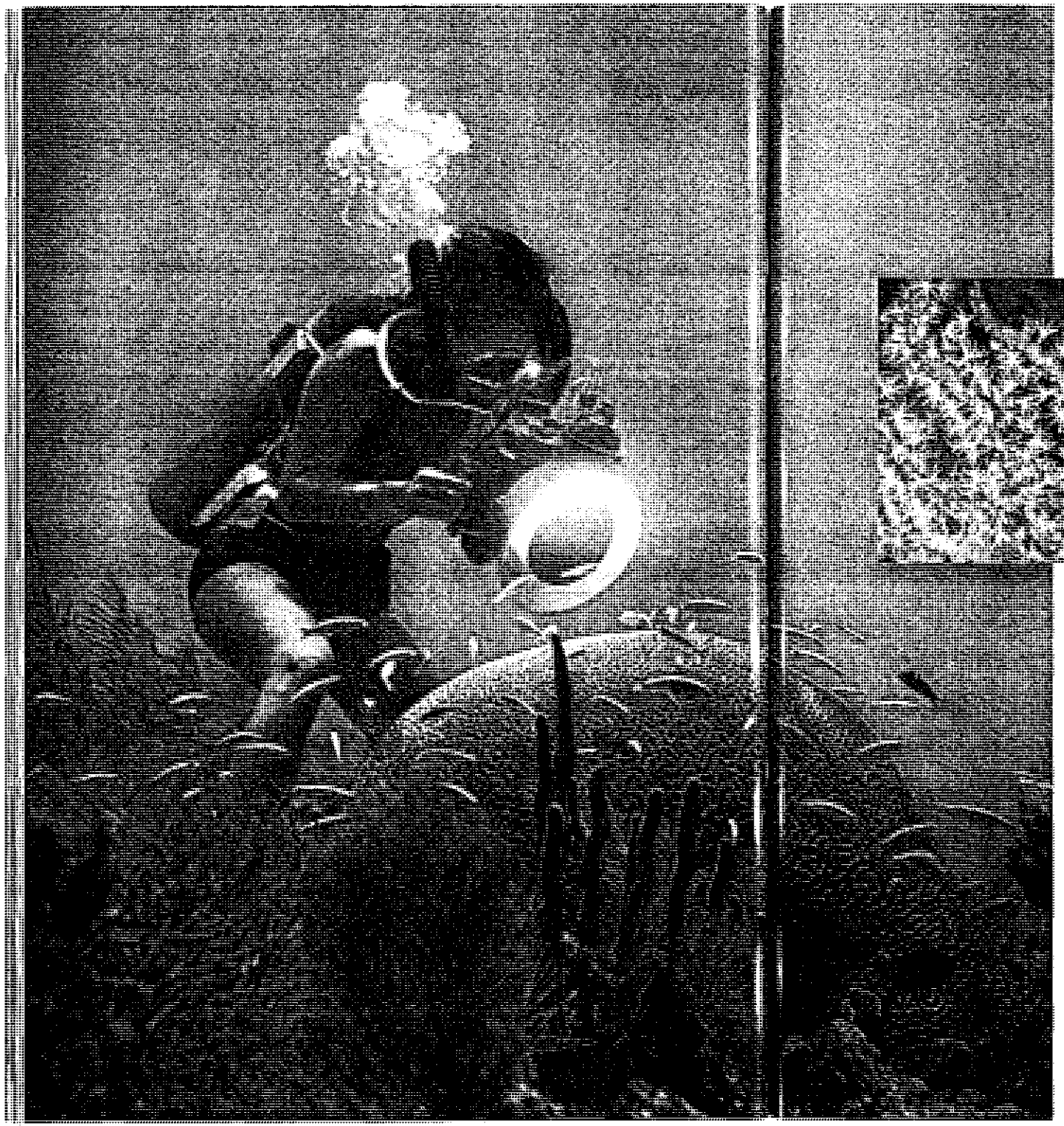
You wave your fins gently and glide along the bottom. Beneath you a small pale-blue fish disappears into the sand. At the spot where it vanished, you spy a patch of coral with a hole at the top. Close examination reveals a mound of fragments built up around the entrance of the burrow in which the fish is hiding. The yellowhead jawfish has excavated this retreat, then built up the entrance by picking up coral fragments in its mouth and piling one on another. The crater on top of the mound serves as a door into which the fish backs, tail first, to escape pursuit.

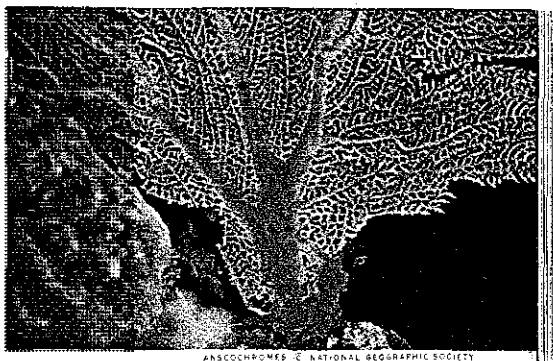
Survival of the fittest is the rule of the underwater jungle; size and might determine the hierarchy. The shark devours the grouper, which feeds on the snapper, which preys on the sardine, which eats the plankton.

Suddenly a flicker of gray cuts through

(Continued on page 88)







ANSCOCHROMES © NATIONAL GEOGRAPHIC SOCIETY

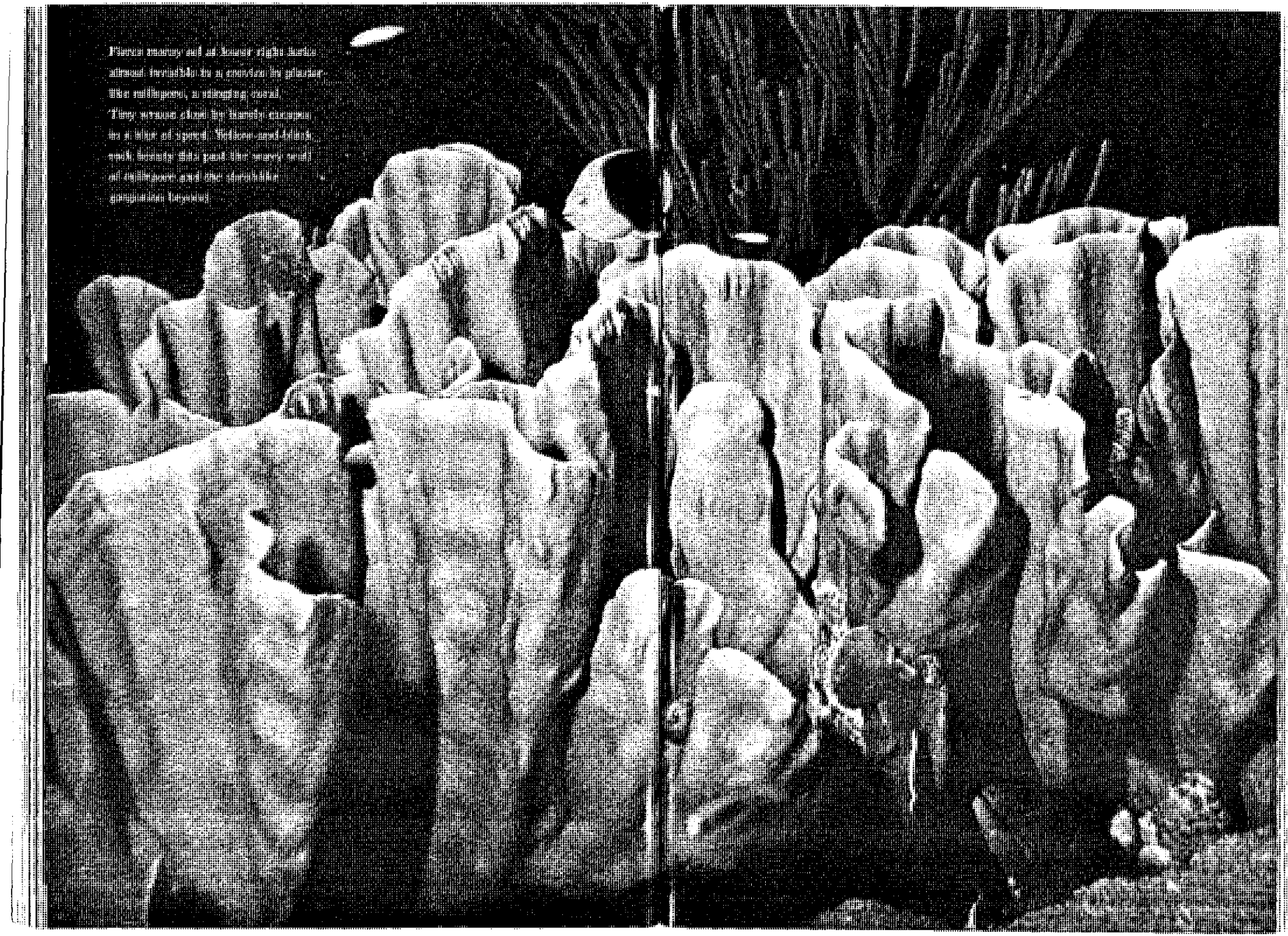
Flash and Camera Capture Subtle Colors of Reef Life

For undersea close-ups, the photographer uses a ring-shaped flash reflector around the lens to eliminate harsh shadows. Here wrasses devour bits of sea urchin above a huge brain coral.

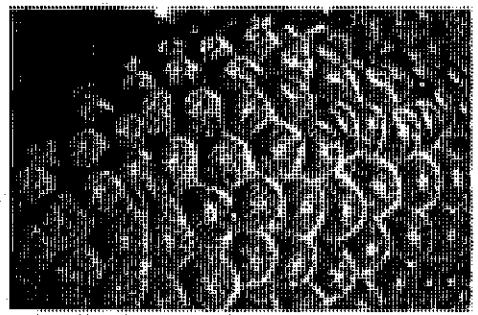
Lavender branches of a sea fan (above) divide in a golden network. Gorgonian polyps at left extend petal-like tentacles to feed. These arms retract at a touch. Gray lettuce coral (below) circles the dark hiding place of a worm. Gaping tube sponges and a red sponge (bottom) feed on microscopic plankton.





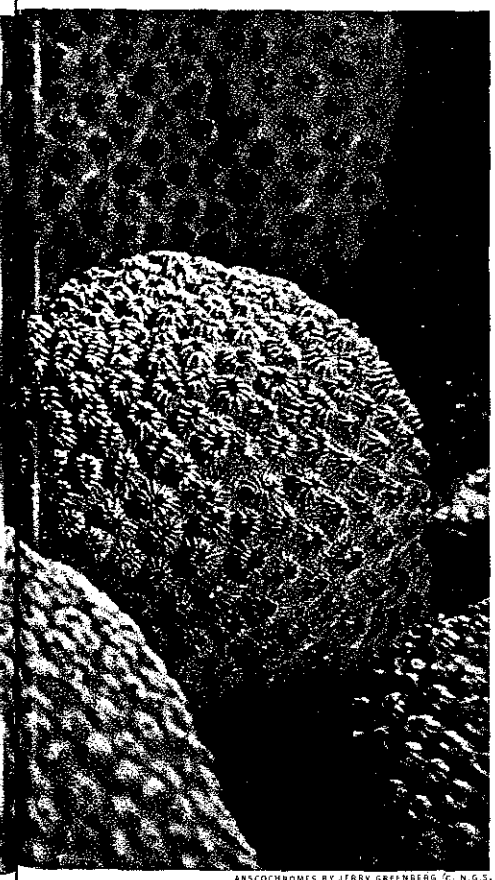


Star coral owes its delicate green beauty to the algae that live within the polyps and help them extract lime from the ocean. The coral that forms living reefs needs some sunlight for survival. Flourishing within 90 feet of the surface, it usually does not grow below 150 feet, where light is too weak.



Spiral-shaped feather-duster worm, living in a star coral, filters plankton swept past by the current.



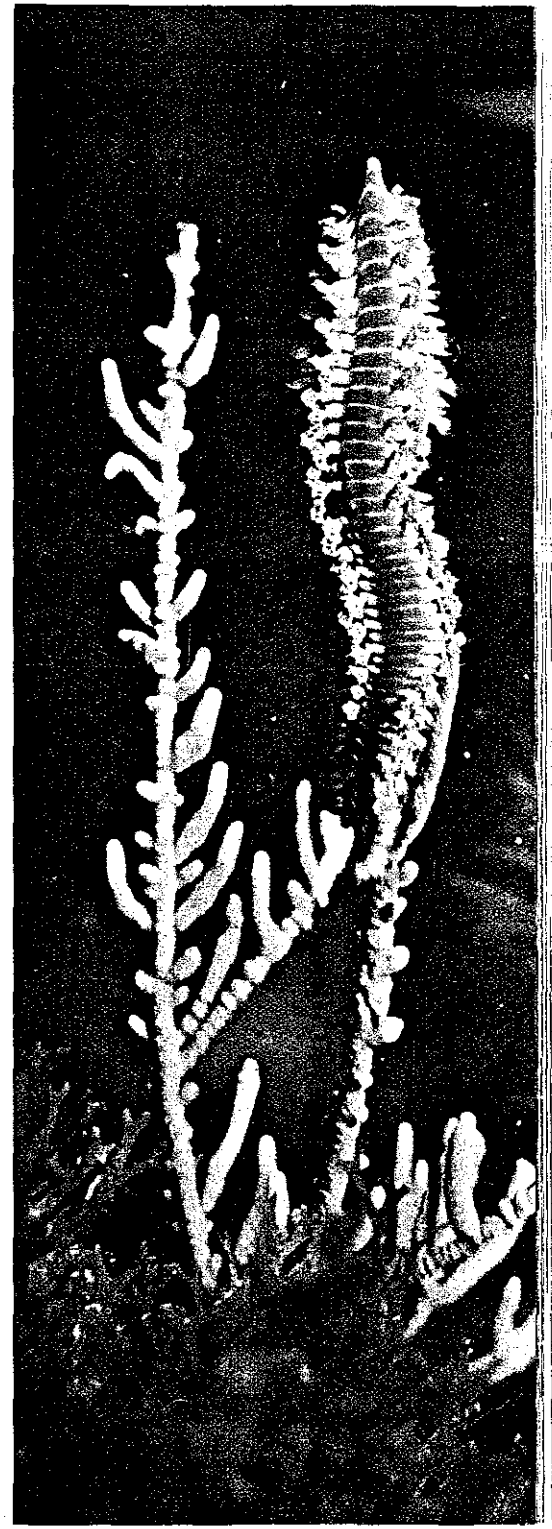


ANSCOCHROMES BY JERRY GREENBERG © N.G.S.

Riding a snippet of stinging coral, a bristleworm reaches the end of the line.

Among the amazing variety of living creatures that inhabit the reef are many equipped with stinging cells or irritating spines. Divers should not touch bristleworms, which are also called fireworms. Stiff, fine bristles on the worm's sides penetrate the skin on contact, producing inflammation and pain. Living under rocks or dead coral heads, the bristleworm comes out at night to feed.

Stinging corals frequently grow on the horny skeletons of dead sea fans and sea whips. Divers avoid them too, for their minute hypodermics irritate flesh and cause a long-lasting rash.



the distant blue haze: A 12-foot tiger shark is rocketing in. You stand motionless, frightened and fascinated as the streamlined giant sweeps through the water, caudal fin swishing. On and on comes the monster. When only 10 feet separate you, he turns away. But relief is short-lived as he shoots upward and traces two fast circles above your head. He leaves as abruptly as he arrived.

Breathing becomes more difficult; your compressed air is running low. You pull the air reserve rod on the breathing unit and earn a brief reprieve before you start a reluctant return to the surface.

As you rise toward the roof of the liquid world, you try to recall the bewildering variety of life on the reef. How jumbled the impressions are in your memory! Many more tours will be required before the mind's eye sorts out all the reef's fleeting beauties.

Tips on Safety for Beginners

For visitors planning to explore the Key Largo preserve, I offer a few simple but vital tips. First, and most important, the beginner who wants to use self-contained diving apparatus should take lessons from a qualified instructor. Before each dive he should make a thorough check of his equipment.

Never dive alone or stray far from the boat on a low tank of air. Always stay upcurrent of your boat; in case of emergency, the current will carry you toward it. If you spend more than two hours in water cooler than 78°, wear a rubber suit. After you've been down for awhile, the water begins to feel chilly at 30 feet.

Coral is sharp; watch your step. Be careful, too, where you place your hand. Beware of treading on long-spined sea urchins or brushing against stinging coral.

First Dive an Incomparable Thrill

I remind the amateur photographer that he needs no special magic. If he can take reasonably decent surface photographs, he should be able to get good underwater shots. Obey the basic rules of surface photography, and you will see the quality improve as you practice and experiment under the sea.

Underwater lighting conditions, of course, will vary with the water, the depth, and the time of day. But if you can see your subject you can photograph it—provided your film gets the proper exposure.

Despite my thousands of dives on the reef, I envy the man who is going below for the first time. It is an incomparable thrill.

James Aldridge, an Australian writer and veteran diver, has expressed it well:

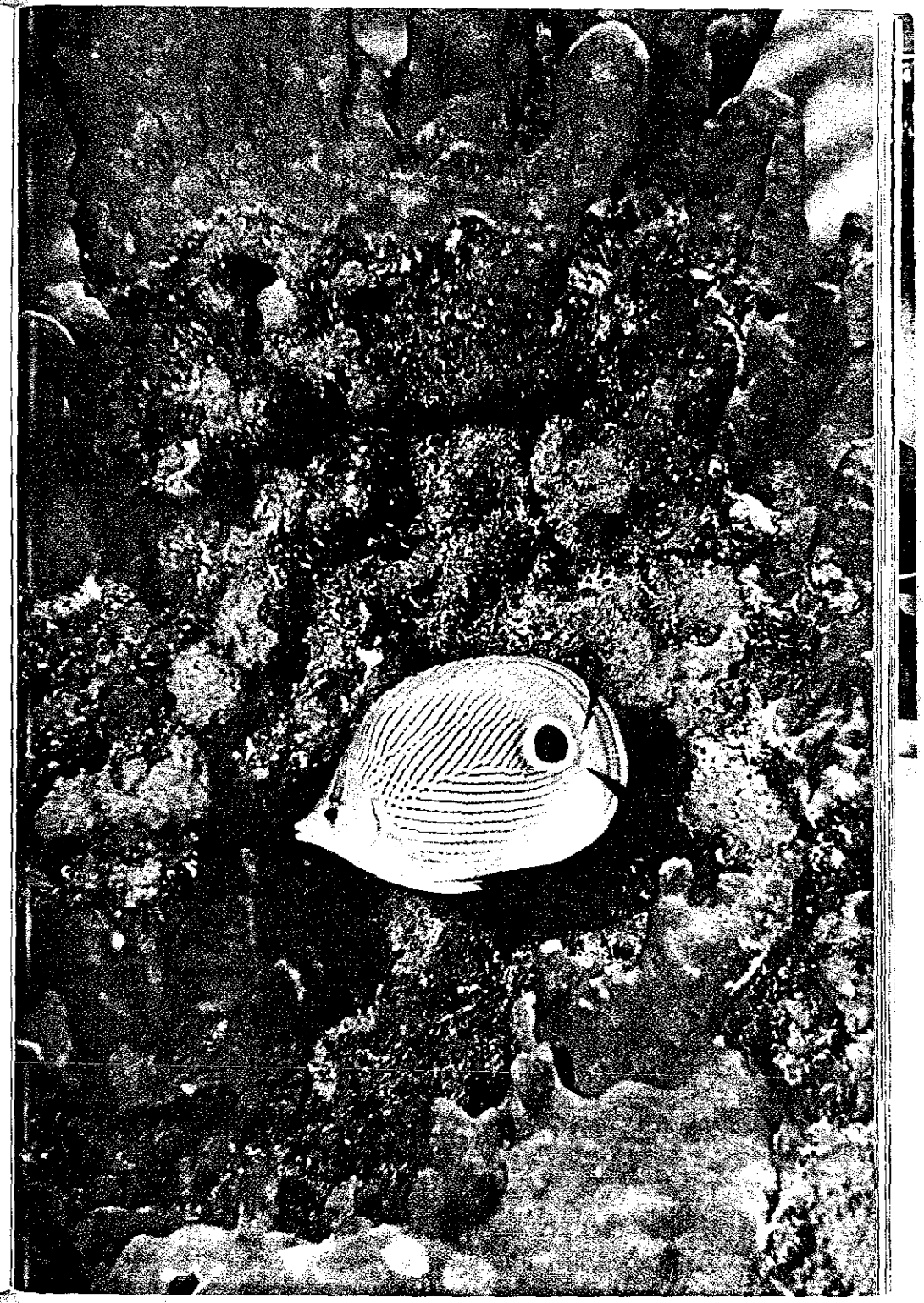
"You are in another world—absolutely—the moment you put your head under the water. This thought will occur again and again, and you will never become tired of saying this trite thing to yourself. *It's another world, it's another world.*"



ANSCOCHROMES BY DAVID GREENFIELD (ABOVE) AND JERRY GREENBERG © N.G.S.

Author-photographer Jerry Greenberg has spent more than three thousand hours roaming the ocean floor off Florida's east coast. He himself designed the Seahawk housings for his cameras and flashes. His formula for underwater pictures: patience, practice, and proper equipment.

Adjusting his electronic flash unit, Mr. Greenberg stands on the ladder of his 20-foot, twin-engine runabout.



False Eyes and Look-alike Ends Save Butterfly Fish From Hunters

Deluded by a stripe that partly obscures the true eye, attackers often lunge for the big dot near the tail. With a burst of speed, the little butterfly (*Chaetodon capistratus*) escapes.

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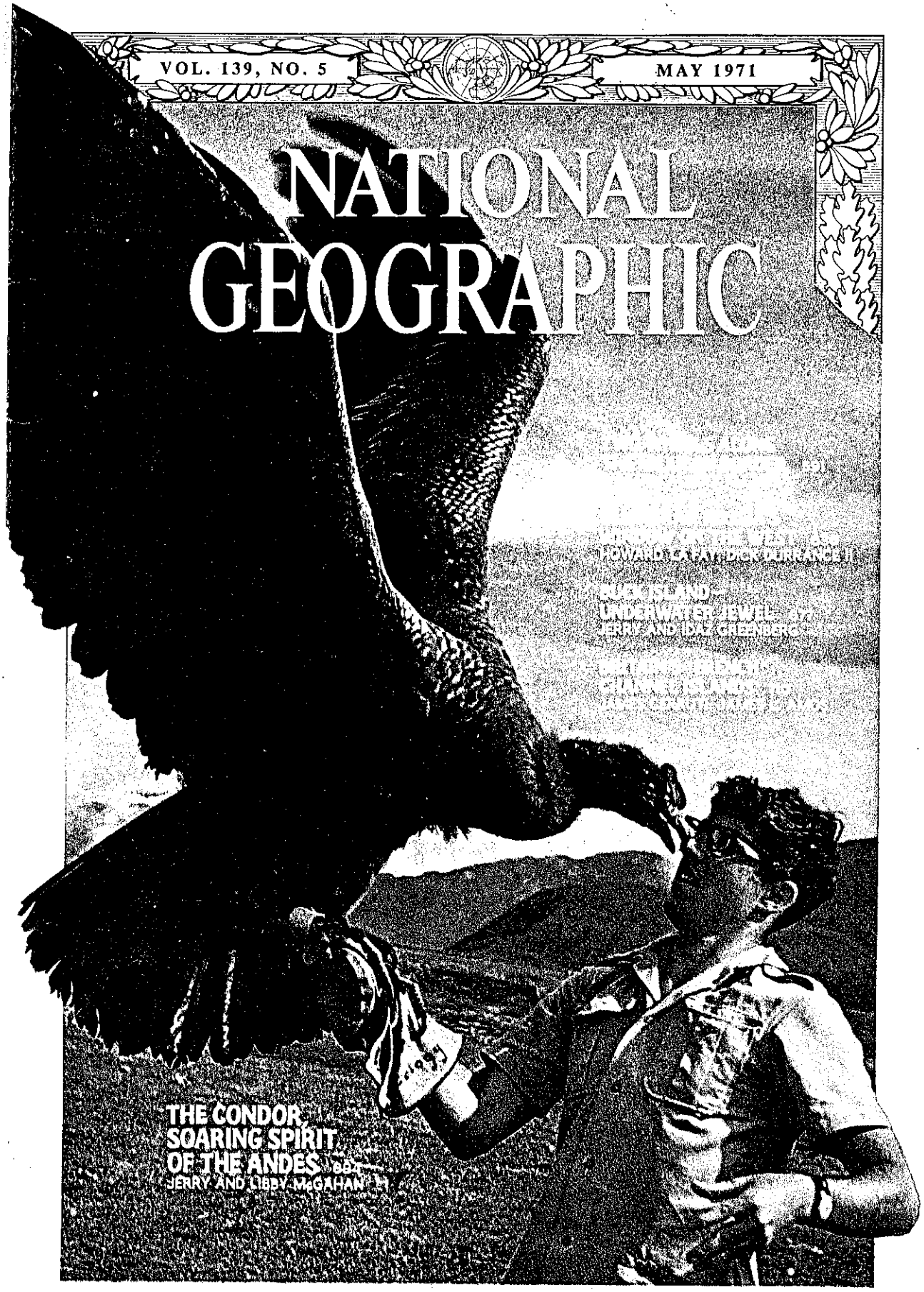


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THE JOURNAL OF THE NATIONAL GEOGRAPHIC SOCIETY WASHINGTON, D. C.

VOL. 139, NO. 5 MAY 1971

NATIONAL GEOGRAPHIC



THE CONDOR, SOARING SPIRIT OF THE ANDES
JERRY AND LIBBY McGAHAN

OFFICIAL JOURNAL OF THE NATIONAL GEOGRAPHIC SOCIETY WASHINGTON, D.C.

Buck Island–Underwater Jewel

ARTICLE AND PHOTOGRAPHS BY
JERRY AND IDAZ GREENBERG

IN A TURQUOISE WORLD of sunlight and shadow, we swim through a multihued garden: clusters of golden elkhorn coral with antlers tall as a man; towering sea fans and feathers swaying in the current; and giant heads of convoluted brain coral. We are exploring a skin-diver's paradise, the fascinating underwater trail of Buck Island Reef National Monument in the U. S. Virgin Islands.

Following a series of submerged markers that point the way, we flipper through seas relaxingly warm and so clear that we can see 100 feet ahead. Everywhere we roam in this coral city, brilliant tropical fish keep us company: yellowtail snappers, blue tangs, French angels, Atlantic spadefish, striped porkfish, varicolored parrotfish, and foureye butterflyfish named for markings that resemble extra eyes. Tiny but pugnacious damselfish nip our flippered feet if we come too near their territorial nooks. Occasionally we spy an ill-tempered spotted moray eel lurking under a ledge in wait for a spiny lobster.

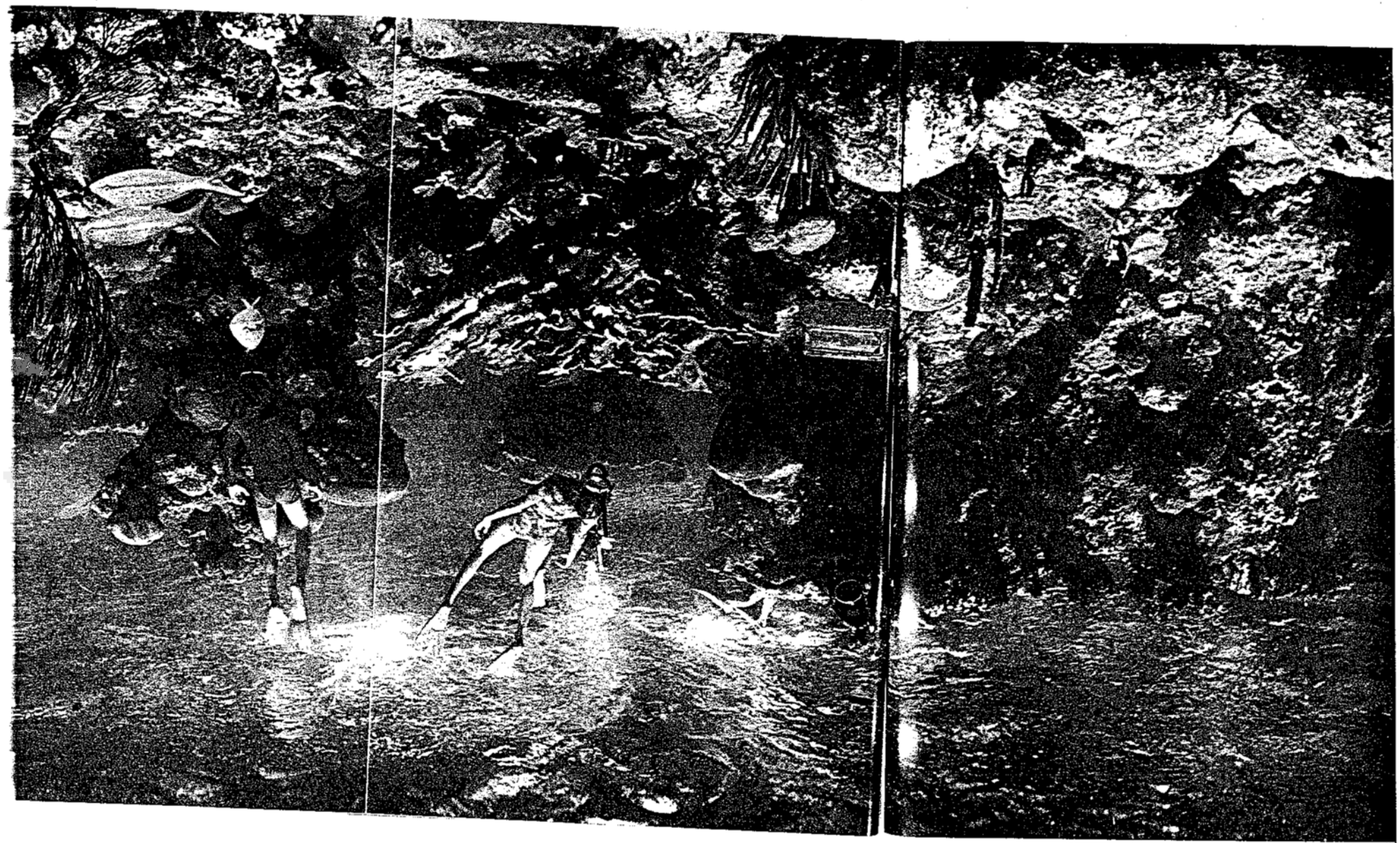
I've been an underwater photographer for more than 20 years. My wife Idaz and our children Susy, 14, Mike, 12, and Mimi, 10, have logged countless hours diving in Florida waters. Yet as we glide past outcroppings crowned with stinging coral and above twisting alleys carpeted with white sand, we are dazzled by this shimmering playground. We move with little or no fear of sharks or barracudas; Buck Island has never known an attack. With numerous shallow spots and deeper sections of 25 to 35 feet, the reef is a favorite training ground for novice snorkelers.

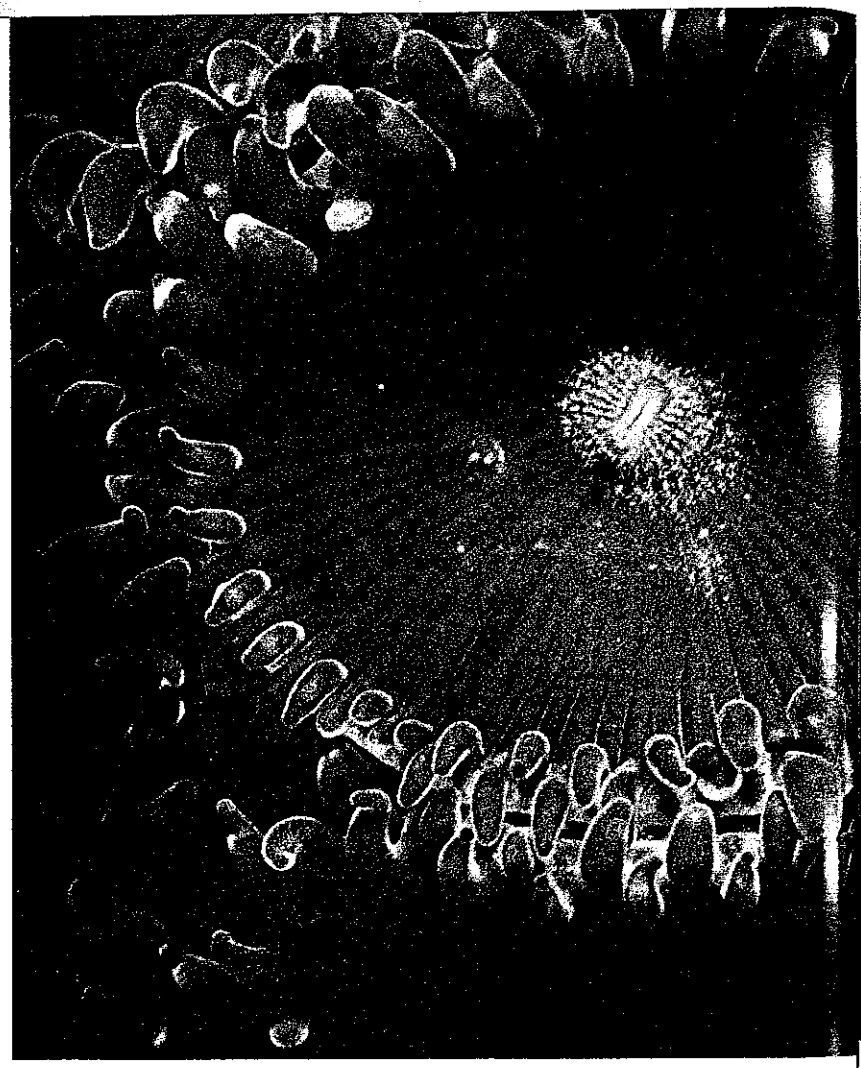
Even after hours of plumbing the marvels of this Caribbean realm, the youngsters plead to stay a few more minutes. Only one rallying cry—"Lunch!"—lures them shoreward across sandy shallows (**below**).

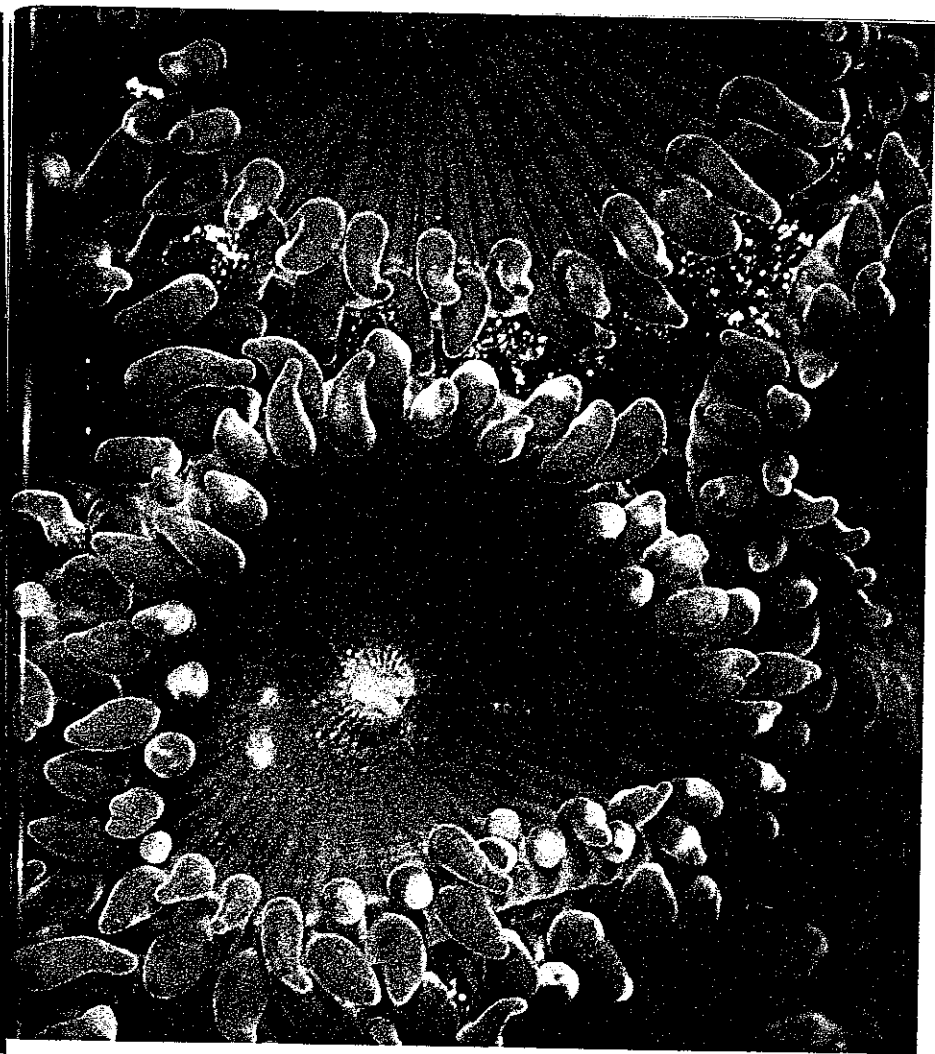
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KODACHROME (BELOW) AND EKTACHROME (FOLDOUT) BY JERRY GREENBERG © N.G.S.







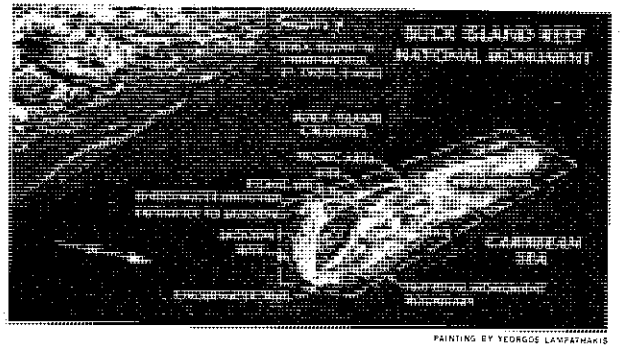


KODACHROME © NATIONAL GEOGRAPHIC SOCIETY



Submarine showcase of Buck Island Reef shelters an amazing variety of life, including sea anemones (enlarged ten times). Like their coral relatives, they are polyps, with a mouth opening and tentacles that trap food.

Miniature barrier reef almost rings humpbacked Buck Island (right), a mile and a half off the northeast coast of St. Croix. Visitors reach it aboard West Indian sloops piloted by local skippers.



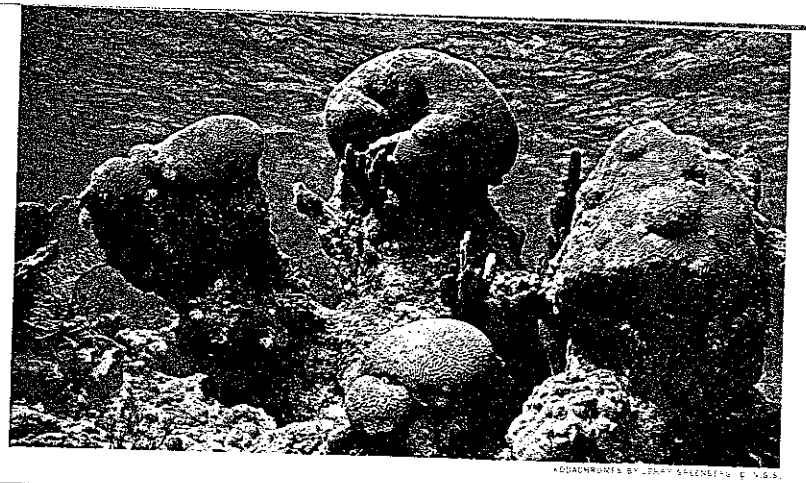
PAINTING BY GEORGOS LAMPATHAKIS

FANTASTIC CORAL FORESTS reach toward the light on Buck Island Reef. Flippering above a giant brain coral encircled by elkhorn, Susy feasts her eyes on the reef's living colors of green and gold.

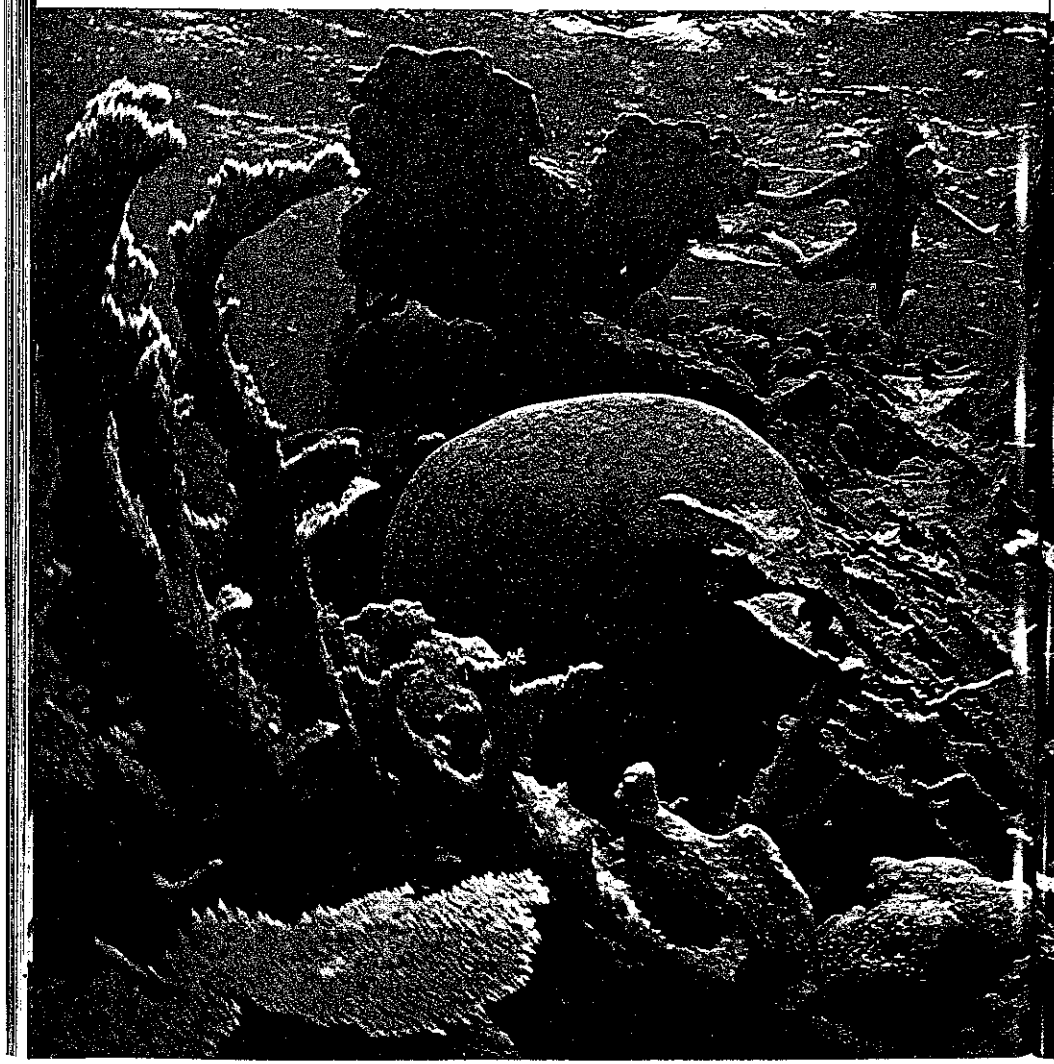
This underwater metropolis is the patient work of billions of tiny creatures. Each coral polyp divides into two or three of its kind, thus perpetuating a chain of survival centuries old. The outer layers grow atop a mass of limestone cups—the skeletal remains of generations of ancestral polyps.

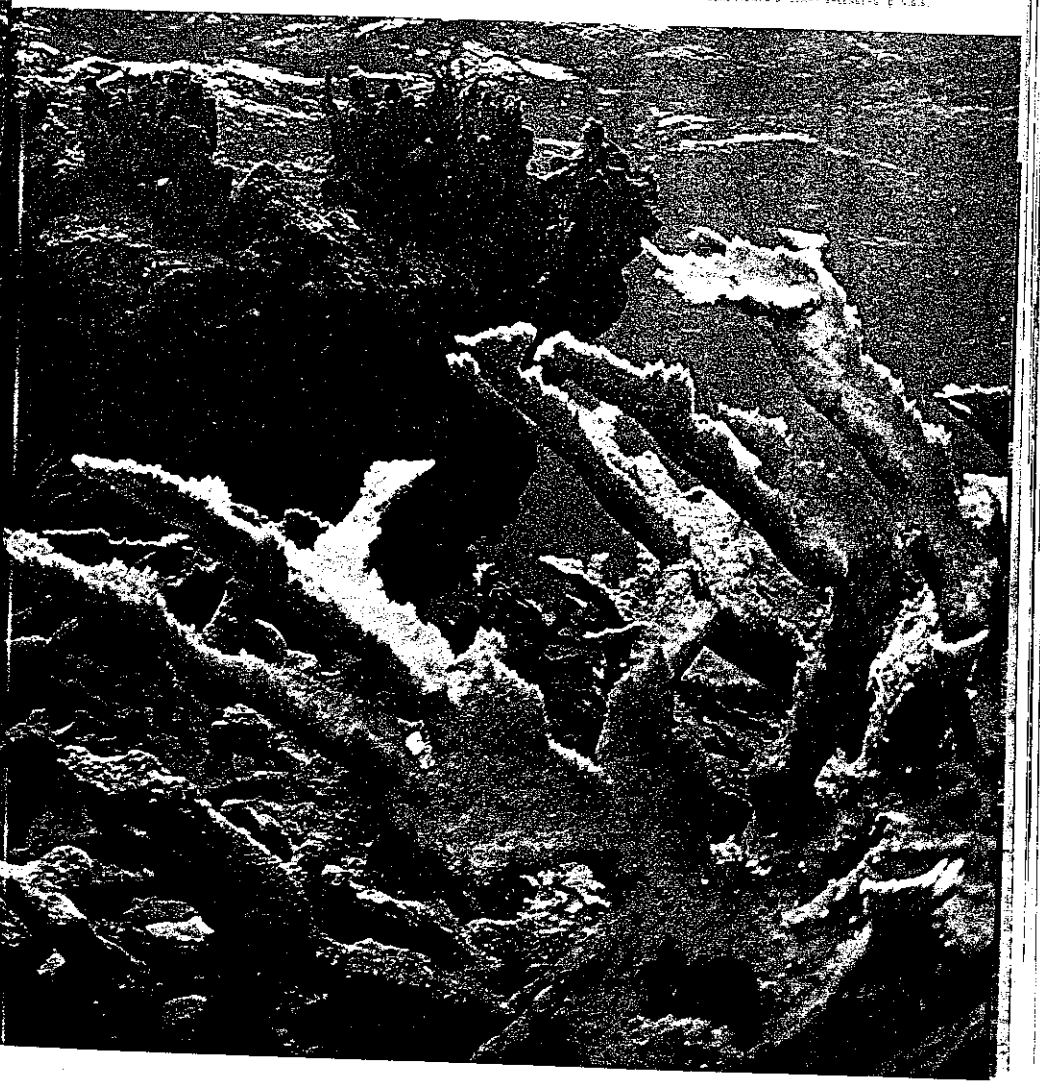
Live polyps contain hordes of microscopic plants in a mutually beneficial partnership. The coral produces carbon dioxide and other wastes useful to the plants; the plants provide the polyps with oxygen in a convenient arrangement called symbiosis, from Greek words meaning "living together." *

*To learn more about coral reefs, see twin articles on Florida's John Pennekamp Coral Reef State Park by the author and Charles M. Brookfield in the January 1962 GEOGRAPHIC.



AQUACHROMES BY JOSEF MUENCHING © N.G.S.







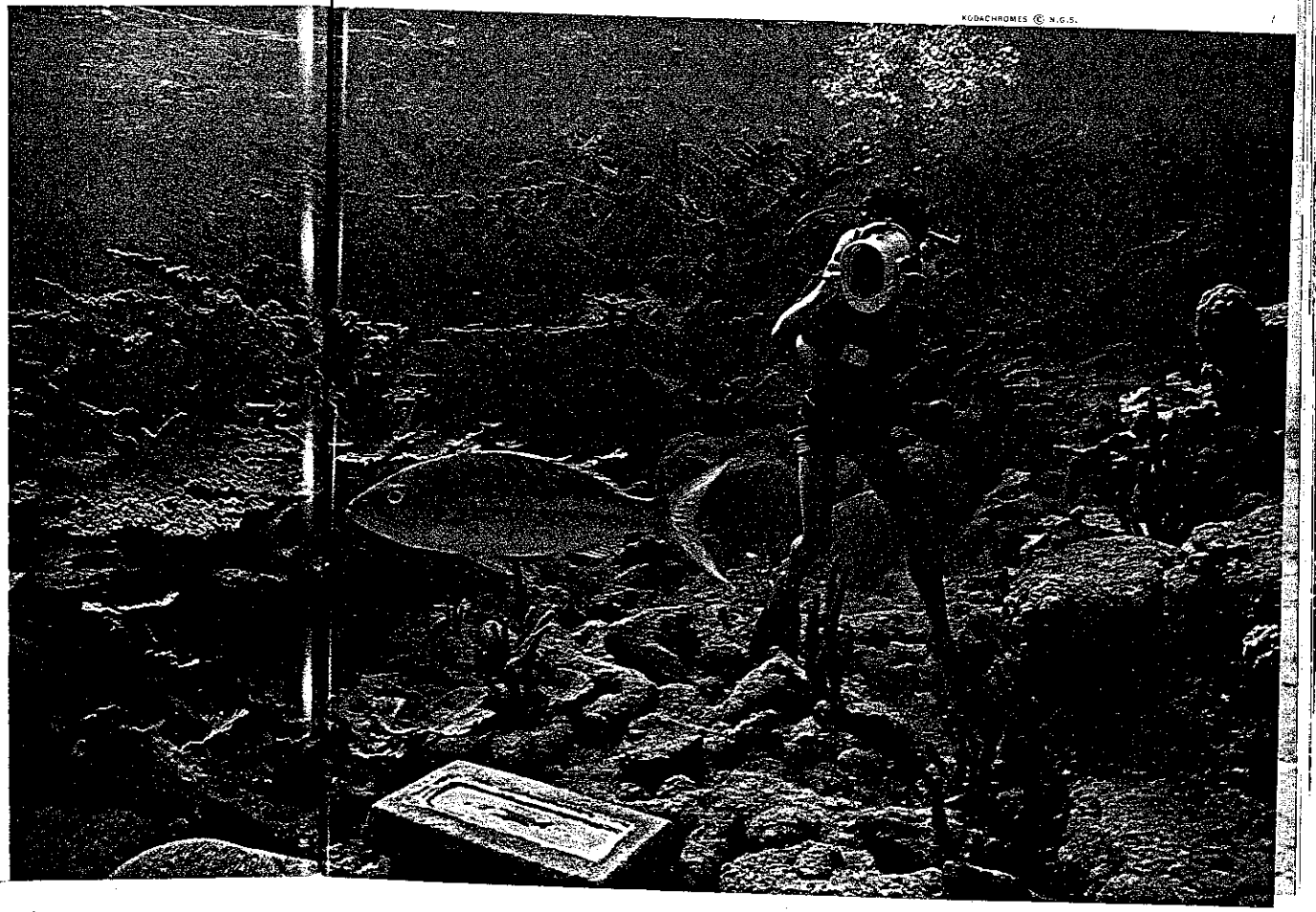


EYES RIVET on junglelike brush when a sudden rustling stops our family as we climb to the 330-foot crest of Buck Island. Then a land crab scurries across our path. Bananaquits and warblers flit overhead, and an emerald-throated hummingbird probes brilliant blossoms. We follow a cactus-studded trail past acacia and poisonous manchineel trees, whose milky sap can burn the skin like lye. Mike likens the tortured branches of turpentine trees to "octopuses in knots."

On our daily run to St. Croix aboard *Sea Angel,* Mike rides the boom (**lower left**), getting a cool dunking in each wave. Mimi likes to believe that our vessel was once a pirate ship, and our skipper says nothing to disenchant her. All of us taste the thrill of lying back against the canvas as we ride the trade winds.

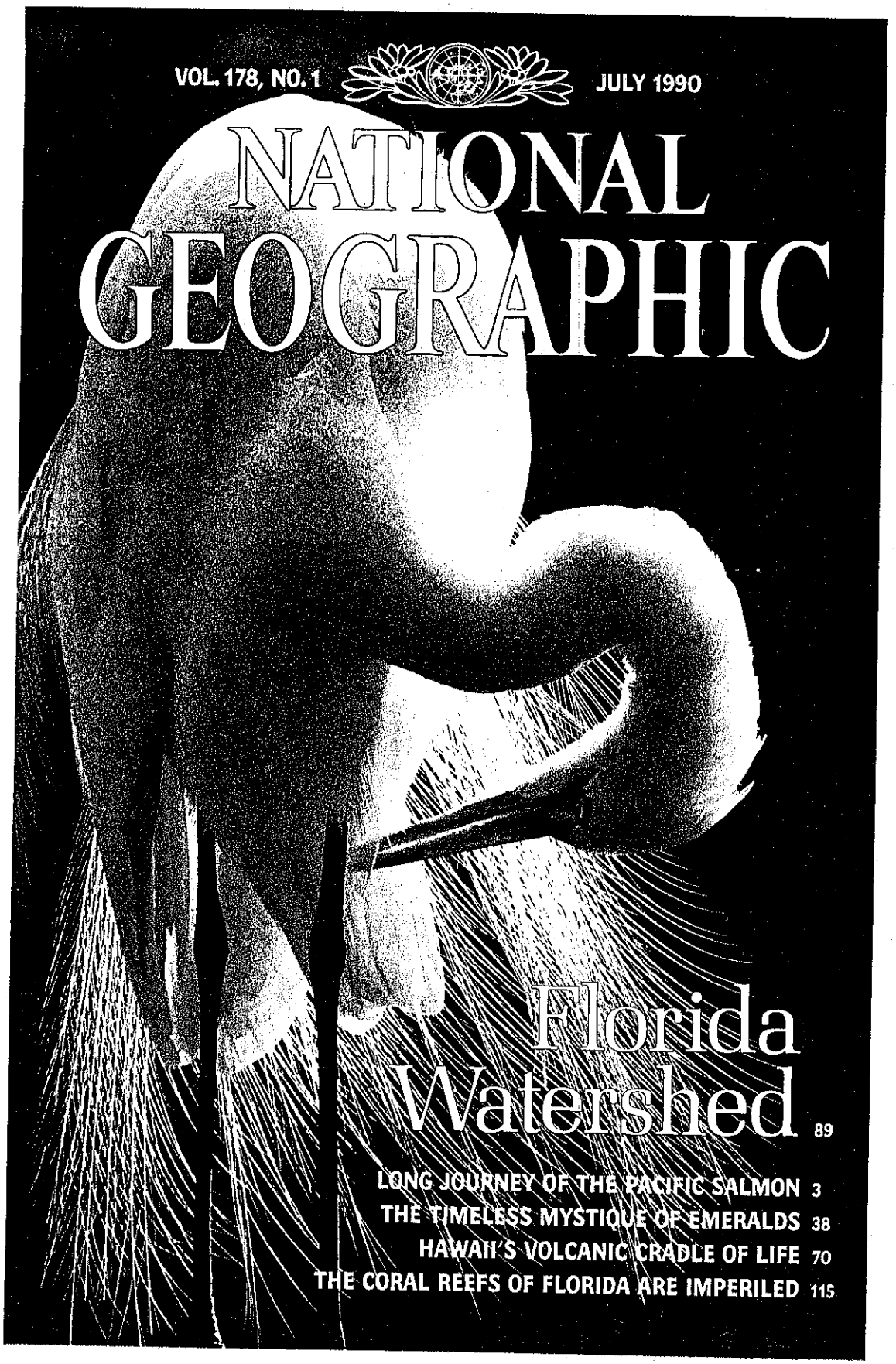
Adding to the fun, tour-boat captains engage in good-natured races on the morning run to Buck Island and on the evening return. Blowing conch horns when passing one another, they exchange tart advice, "Hey, mon, put out yo hat 'n catch mo wind for yo sail!"

On the clearest days we strap on tanks of compressed air for a leisurely hour of movie-making on the underwater trail. Aiming a super-eight camera, Mike frames a yellowtail snapper drifting above a trail marker. Susy and Mimi like to feed the fish and try to pet them. They watch helmet shells and starfish gliding across the reef and see a parrotfish nibble a snack of coral. Then our hour of magic is spent, and we are back ashore, the girls in excited torrents of talk about what they saw, and Mike eager to identify an unfamiliar fish he spotted. If only he can swim Buck Island's underwater trail often enough, he's sure he'll discover a new species someday. □



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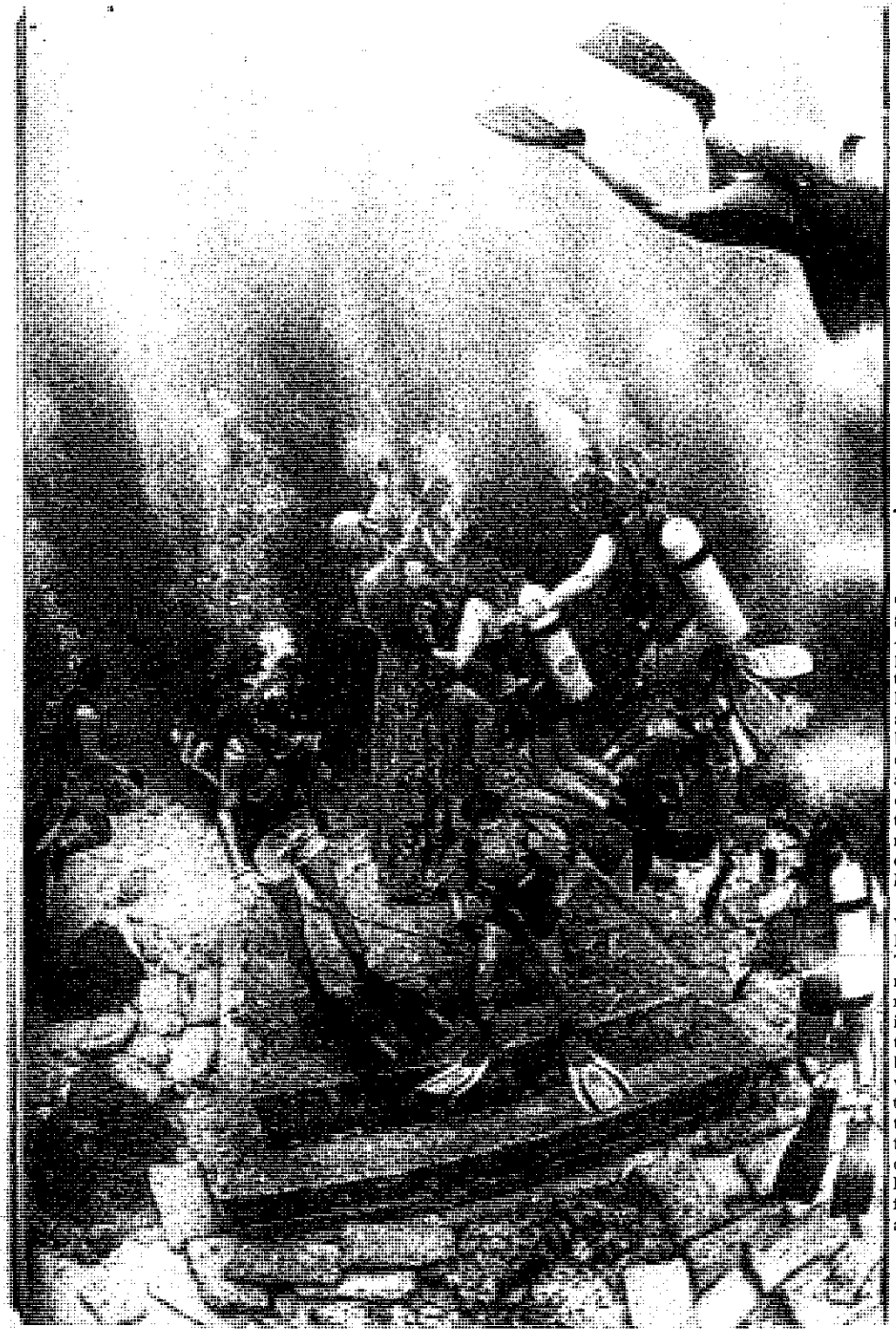
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OFFICIAL JOURNAL OF THE NATIONAL GEOGRAPHIC SOCIETY WASHINGTON, D.C.



FLORIDA'S Coral Reefs Are Imperiled

By FRED WARD
BLACK STAR

Photographs by
JERRY GREENBERG and FRED WARD

WHEN FLORIDA established John Pennekamp Coral Reef State Park off Key Largo in 1960, there was general rejoicing that this great American treasure would be preserved for future generations to enjoy. Less than a generation later many of the state's reefs are dying, not just in the park but throughout the keys. Some experts say the causes are part of a natural cycle, and widespread death is inevitable. Others say the causes are unknown, but the result is still inevitable. And others warn that we are actually killing our reefs.

I first dived the Florida Keys while I was a University of Florida student in the 1950s. Through 35 subsequent years of regular scuba trips and documentation (along with the amazing photographic coverage of the reefs by my lifelong diving buddy Jerry Greenberg), I have watched their steady deterioration. Corals are living organisms that have created the very structure of the reefs over thousands of years. Seeing them suffer is like living with a terminally ill family member whose doctors argue over symptoms while the patient silently slips away.

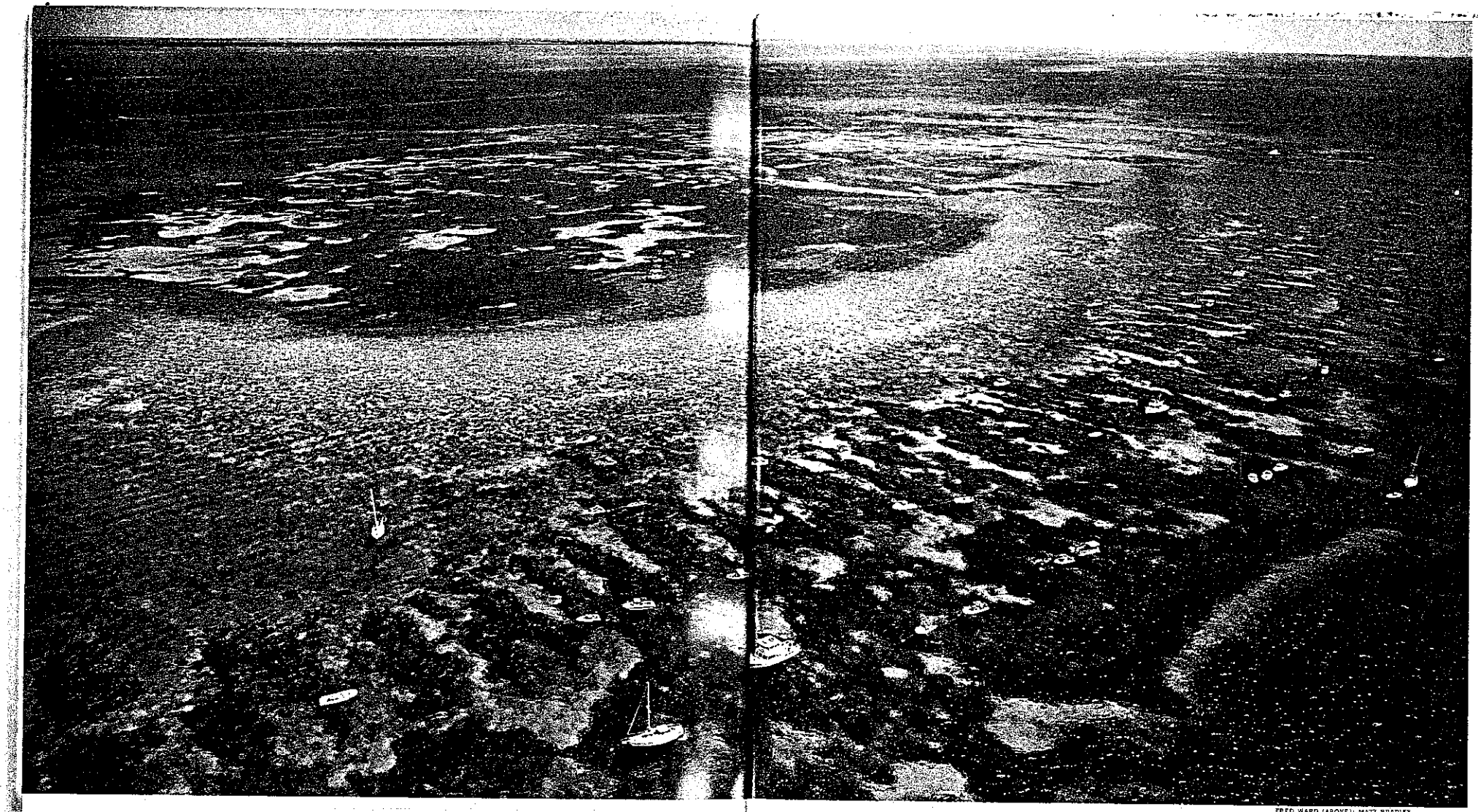


In a troubled underwater world off Key Largo, a school of diving students swarms around the "Christ of the Deep" statue. Fouled waters and thoughtless visitors are destroying growths of coral (above), some of which took centuries to form. Designed to protect an extensive reef system, John Pennekamp Coral Reef State Park and the adjacent Key Largo National Marine Sanctuary are being ruined by too much pollution and too many people.

There is magic in coral. In secret watery gardens, nature plays out her diverse drama for the snorkeling alien to behold: birth and death, beauty and beast, competition and cooperation. What appears to be a large boulder that resembles a human brain is actually a colony of millions of creatures. Each tiny, seemingly independent polyp, taking in water and nutrients and exuding calcium carbonate (limestone), participates in forming a design specific to each species of coral.

Pennekamp is part of a reef ribbon, made possible by the warm flow of the passing Gulf Stream, that reaches from southwest of Key West almost to Miami.

Although most refer to the area along Key Largo as "Pennekamp," little-noted jurisdictional changes in 1974-75 dramatically altered the reefs' future. At that time the federal government took control of all U. S. underwater areas beyond three miles to a depth of 300 feet. These actions diminished Pennekamp Park (administered by the Florida Department of Natural Resources) to the three



FRED WARD (ABOVE); MATT BRADLEY

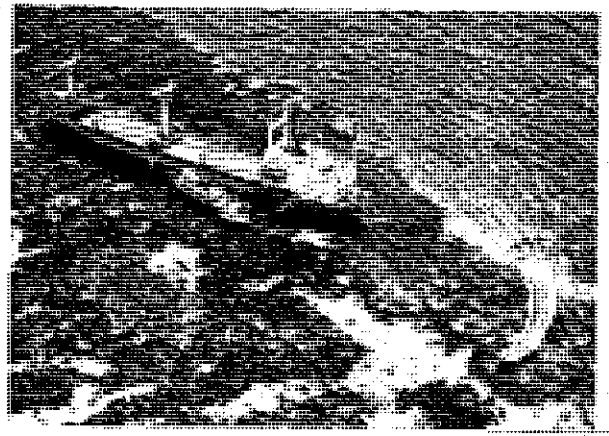
miles closest to shore and transferred the major reefs to the Key Largo National Marine Sanctuary (operated by the U. S. Department of Commerce).

ROCK HARD in appearance, coral reefs are in truth exquisitely fragile, living within a very narrow range of conditions. Water temperature should remain above 70°F; Pennekamp is at the cool edge of reef growth, and its waters dip into the sixties in winter. And the water must have few nutrients and even fewer toxins—Pennekamp has too many of both. In short, since the increase of development and tourism in the keys the odds are against Pennekamp's sensitive ecosystem.

In the derring-do days of 1950s sport diving we felt like pioneers, exploring a private wonderland. After Jacques-Yves Cousteau co-invented the Aqua-Lung, the young and the daring suited up in relatively untested scuba outfits and raced toward this underwater frontier. No laws limited spearfishing or coral and shell collecting. Heedless divers speared tons of the most desirable game fish.

Massive publicity, not the least of which was a major

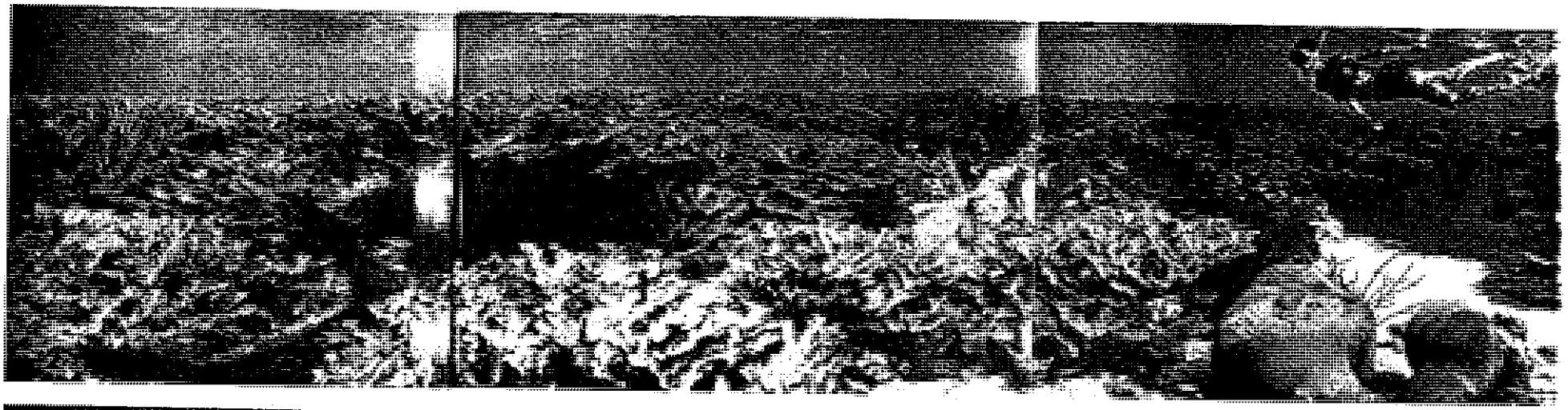
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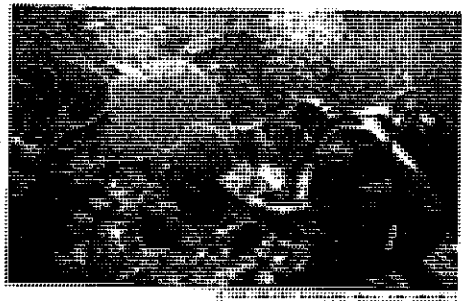
Buoys can be lifesavers for coral by discouraging anchoring directly on the reefs, once the cause of massive destruction. Some boats double up at Molasses Reef in the federal sanctuary (above), where 15 new buoys a year are planned. In 1984 the freighter Wellwood (left) plowed up several acres of coral and went aground. Part of the six-million-dollar fine helped finance habitat restoration.

960

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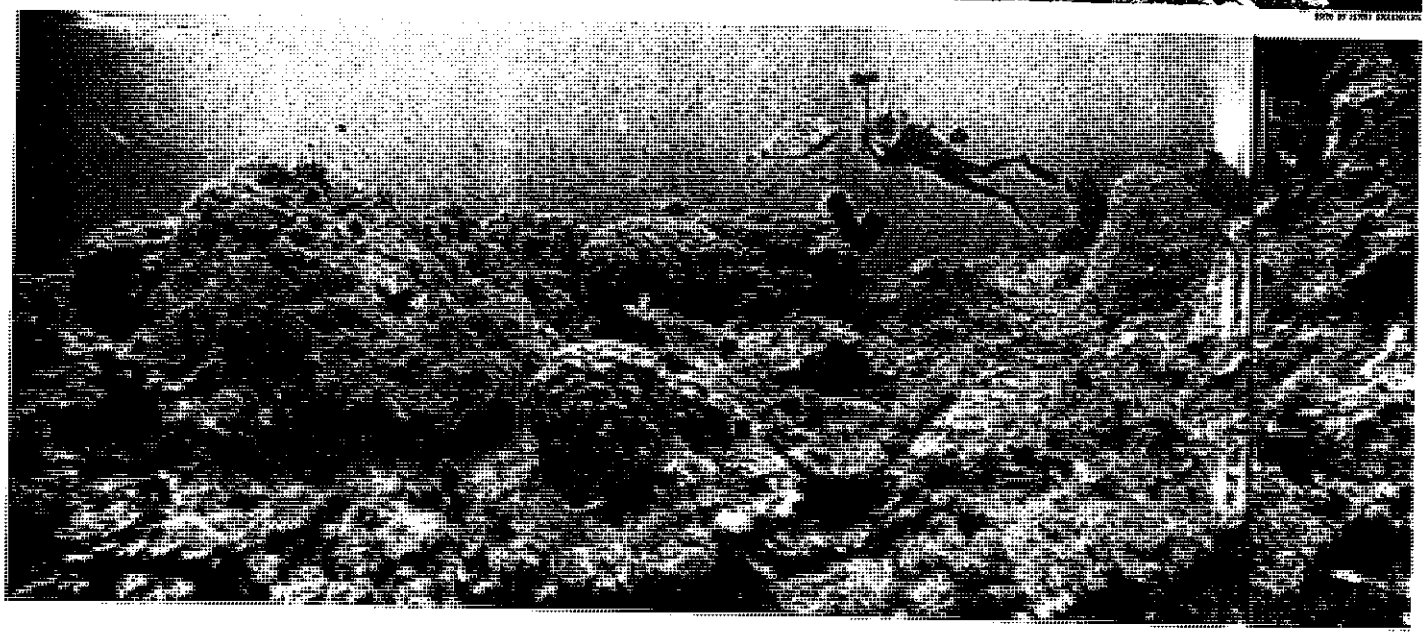


A wondrous realm unfolds in a panorama taken by Jerry Greenberg at Carysfort Reef in 1960 (top). Golden branches of elkhorn coral stand beside brain coral, at lower right. In the same region 29 years later, coral was reduced to a mass of stumps. To compare such areas, author Fred Ward (above) uses laminated old photographs.

Earth's largest formations made by living organisms, coral reefs are the handiwork of small marine animals called polyps, which reproduce asexually. After a polyp dies, it leaves behind deposits of calcium carbonate upon which live polyps build. When nutrient levels soar from such sources as human sewage and fertilizers washed from farmland, algae can overwhelm and smother the polyps.



1983



1989

(Continued from page 116)
article in NATIONAL GEOGRAPHIC magazine in 1962, prompted an almost instantaneous influx of boats and divers, putting new pressures on the underwater environment. A few divers might have caused little noticeable disruption, but safer, less expensive equipment and more leisure time helped popularize scuba diving.

Pennekamp, beautiful, accessible, and irresistible, became one of the most frequented diving destinations in the world, with nearly two million visitors a year (half of whom actually make it onto or into the water). The five most crowded reefs attract 3,000 people on an average day and double that on warm weekends.

Their boats pollute the water and everything in it with petroleum products and sewage. Incompetent operators crash into the reefs. They litter the sea with plastic foam cups, aluminum cans, glass, plastic bags, bottles, and miles of tangled fishing line. This debris does not go away—it is, for all practical purposes, indestructible.

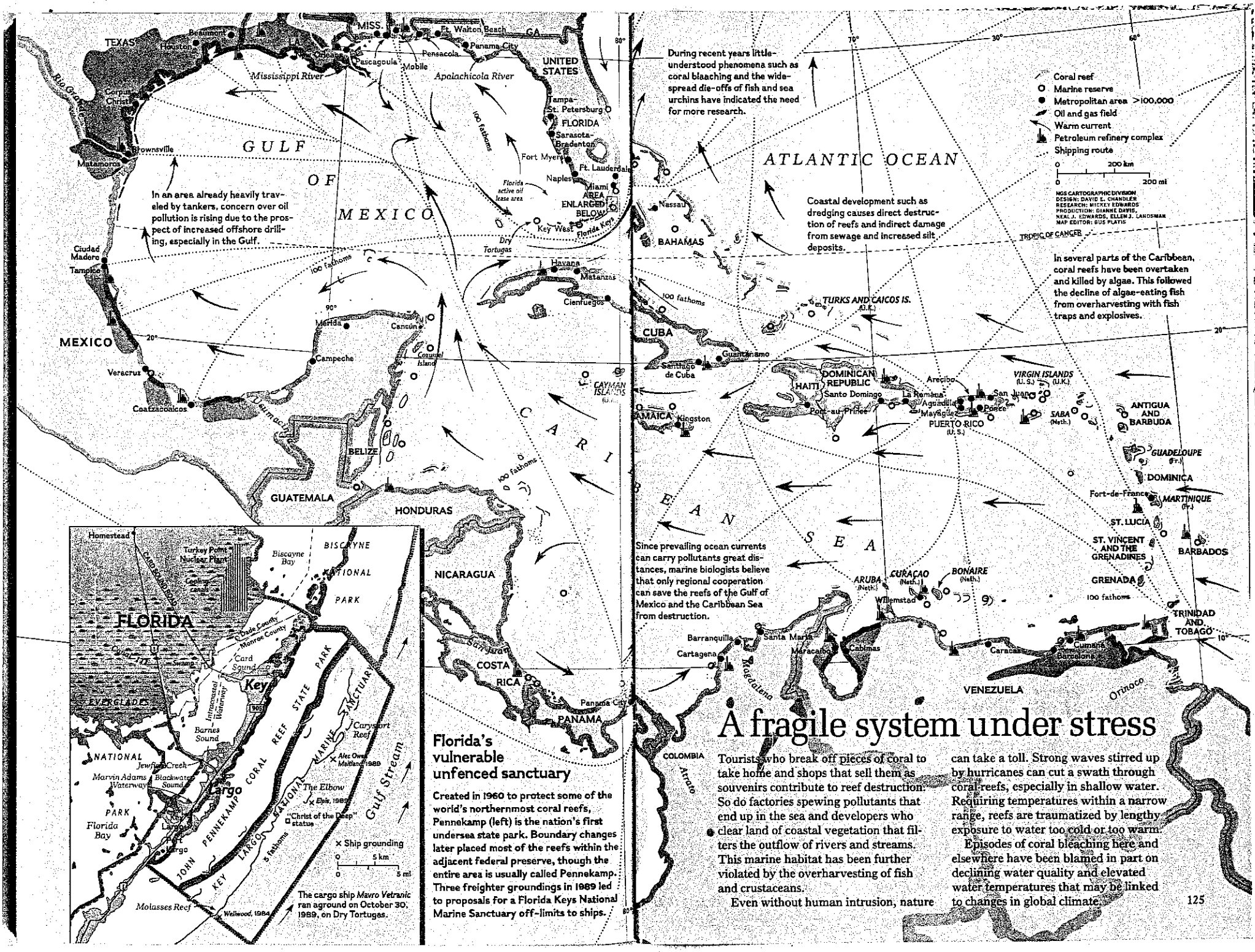
Thousands of swimmers routinely bump, scrape, and step on coral. To a tired swimmer, standing on coral may seem as harmless as resting on a rock. But the slightest contact by a foot, boat shoe, dive tank, or swim fin can weaken a section of living reef. Algae then overcome damaged polyps. If only one person in a hundred scars or breaks off a piece of coral that took a century to grow, the cumulative devastation is enormous. Although spearing and specimen collecting are prohibited in the park, they continue illegally to this day.

Death can be shockingly swift in a coral reef that took some 6,000 years to grow. Thirty feet down in Molasses Reef, boulder coral (top, at left) and branches of elkhorn, at right, were suffering in 1983, but much of the area remained alive. Just six years later the boulder coral was seriously eroded, and the elkhorn had nearly succumbed.

PEOPLE PRESSURE makes money for Randy Pegram, operator of the private park concession responsible for getting half of all the area's visitors onto the water. In his tiny dockside office he still worries about their impact. "The place is literally exploding," he says. "Over half the growth in the last 25 years has occurred in the past six. We're 'maxed out' every other weekend. Pennekamp has to close the gates because there's no more room for cars."

Parking-lot size seems a strange way to determine how many people get in. Carl Nielsen, then Pennekamp's energetic park manager (he has since changed jobs), agreed: "I'm not sure we want to bring in more visitors. We keep an annual list of 'destruction to natural features,' which includes boat groundings, mangrove damage, coral breakage, and boat-prop dredging. There was an increase of nearly 300 percent of such incidents between 1984 and 1989. We may soon be forced to close off parts of the reefs on a regular basis, to give them some breathing room to recover."

Fishing and diving, two main water sports in the keys, have conflicting goals: One enthusiast wants to catch what the other wants to see swim free. Killing major game animals is not allowed in other state or national parks, but the argument for prohibition falls on deaf ears when the issue is fishing; nearly every resident has a boat and rod. Anything that affects recreational or commercial fishing polarizes the keys,



The cargo ship *Mavro Vetranic* ran aground on October 30, 1989, on Dry Tortugas.

Florida's vulnerable unfenced sanctuary

Created in 1960 to protect some of the world's northernmost coral reefs, Pennekamp (left) is the nation's first undersea state park. Boundary changes later placed most of the reefs within the adjacent federal preserve, though the entire area is usually called Pennekamp. Three freighter groundings in 1989 led to proposals for a Florida Keys National Marine Sanctuary off-limits to ships.

A fragile system under stress

Tourists who break off pieces of coral to take home and shops that sell them as souvenirs contribute to reef destruction. So do factories spewing pollutants that end up in the sea and developers who clear land of coastal vegetation that filters the outflow of rivers and streams. This marine habitat has been further violated by the overharvesting of fish and crustaceans.

Even without human intrusion, nature can take a toll. Strong waves stirred up by hurricanes can cut a swath through coral reefs, especially in shallow water. Requiring temperatures within a narrow range, reefs are traumatized by lengthy exposure to water too cold or too warm.

Episodes of coral bleaching here and elsewhere have been blamed in part on declining water quality and elevated water temperatures that may be linked to changes in global climate.

and the economy probably could not survive a substantial loss of fishing revenues. Yet in the absence of constraints, there may be no game fish in the future.

Hook-and-line saltwater fishing is still allowed in the 120 square miles of Pennekamp Park and the national marine sanctuary. The fish that are taken are often the scarcest, the biggest, and the best.

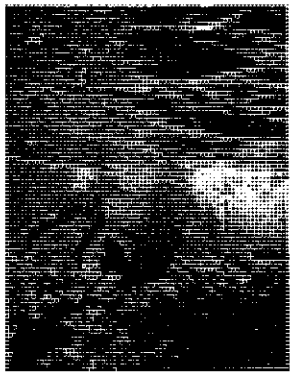
I asked Mike White, manager of the Key Largo National Marine Sanctuary, how the sanctuary and park justify letting people catch the very fish that two million visitors hope to see. He answered, "Our program is responsible for resource protection while encouraging multiple compatible uses. These requirements often conflict. I have another year to make a report on water use and to advise whether all the keys should become part of the federal sanctuary system." Mike believes Florida would condone such an act but has watched the protest movement grow as treasure salvors, commercial lobstermen and fishermen, and tropical fish collectors organize to defeat any further attempt to federalize the reef tract.

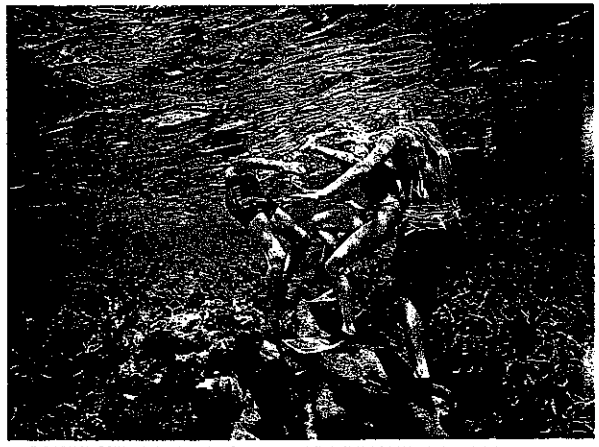
Events, however, have overtaken Mike's study. After three freighters ran aground within 17 days last fall, Congressman Dante Fascell introduced legislation to designate all the reefs from Biscayne National Park to Dry Tortugas as the Florida Keys National Marine Sanctuary. "It doesn't take a congressman to see that the reefs are dying," Fascell told me. Florida's Senator Bob Graham has also introduced legislation.

Lobsters, tender to eat and difficult to protect, raise tensions to the breaking point. It is almost impossible to find a mature lobster at Pennekamp only a couple of weeks after the season opens. I was on the reefs daily for six weeks and saw no more than half a dozen lobsters.

"Any person with a license can take 6 lobsters a day or 24 per boat during the August 6 through March 31 season," says Mike White. "So one man with a boat can take 24 lobsters a day. And that's not the worst of it. Commercial lobster licenses are cheap in Florida, and there's no limit on the number of traps or lobsters taken."

During the summer two-day non-commercial "mini-season," locals say so many amateur lobstermen show up you can walk from boat to boat six miles out to the reefs without getting your feet wet.

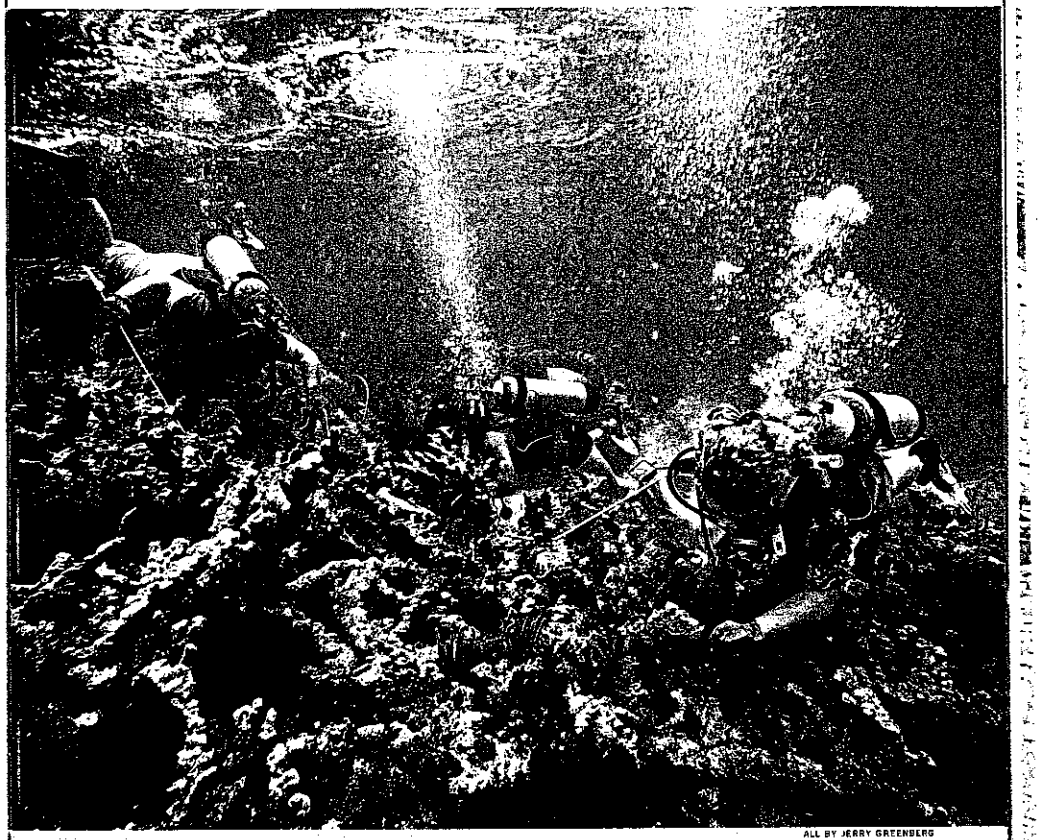




Divers' rest stop that appears to be bare rock (below) is actually an overturned stand of coral. Boaters who ran aground (left) were fined according to a formula that considers coral density, damage, recovery potential, and degree of negligence. Ignoring rules against touching the coral, divers paw through a dying stand of elkhorn in search of lobsters. In 1989 three persons caught with 399 lobsters were fined more than $4,000 apiece for violating size and bag limits.

A few days after the mini-season, Jerry Greenberg returned to finish photograbbing a particularly attractive stand of coral at Carysfort, near the sanctuary's northern border. Only a pile of paint-scarred coral fragments remained, silent testimony to careless boating.

THE REEFS' chief defenders are an unusual coalition of environmentalists and a few of the businessmen whose lives depend on having something alive on the reefs for people to see. One such is Captain Spencer Slate, gregarious owner of Atlantis Dive Center, who has been roundly criticized for continuing to hand-feed barracuda and moray eels even after a number of people have been bitten while imitating him. Slate has recently come down on the side of a fishing prohibition, saying, "Let's protect everything, lobsters and all. I want my guests to experience a living, beautiful reef."



ALL BY JERRY GREENBERG

But divers and fishermen alone do not threaten the reefs' survival. After 1960 Florida Keys development even outdistanced neighboring mainland counties, which themselves had some of the highest growth rates in the country. Key Largo, the nearest island to the reefs, once a rustic collection of trailer parks and weekend fishing shacks, has burgeoned into a development of homes, condos, and shopping centers straddling U. S. 1 and crowding the land between ocean and bay.

Carl Nielsen says, "Onshore development is a continuing problem. Monroe County has no storm-water treatment facilities and no tertiary (or fully processed) sewage plants, which means that street runoff washes right into the water and unprocessed sewage is dumped into the ground. Key West has the only city sewage-treatment plant in all the keys, and it opened just last year."

The rest of the keys use septic tanks, injection, and small, local sewage plants operated by schools, apartment buildings, and shopping centers. The underlying limestone is as porous as a sieve. Anything dumped on the ground soon filters into the water table.

"A coral reef is only as healthy as the water around it," explains Florida regional biologist Renate Skinner, who keeps some of the scarce hard data on Pennekamp's water quality. A tiny woman who works in a cramped trailer, she appears even smaller among her crush of books and papers.

Poring over her computer

printouts of the last decade, she explains, "There is a direct relationship between pollution and disease. Pollutants may lower the resistance of marine organisms. They irritate fish skin, creating a condition that allows bacteria to enter.

"Onshore pollution eventually reaches the park. Where else can it go? Over one 26-month period I found water samples that exceeded the state standards for pesticides 42 different times and for plasticizers 65 times. I even found one PCB sample. Sediment samples collected six miles offshore in 1986 contained DDT. The chemicals people use on Key Largo end up in surrounding waters—petroleum products, heavy metals, pesticides, herbicides, and fertilizers."

A surprising occurrence in 1988 awakened officials to another threat. Faced with heavy rains, south Florida's vegetable farmers petitioned to drain their fields by releasing water from Canal 111.

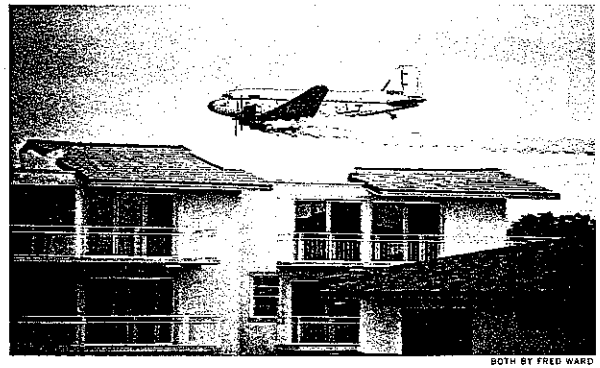
According to Renate Skinner, "Barnes Sound began to die—the discharge of such a large amount of fresh water killed fish, grasses, anything that could not tolerate the sudden change in salinity. Then another unexpected thing happened. We had always assumed that the flow from Barnes Sound went north, into Biscayne Bay. However, after two months the decaying organic matter had flowed south through Jewfish Creek, into Blackwater Sound, through Marvin Adams Waterway, and into the park. Water samples from the organic slicks revealed high levels of several pesticides."

And if that's not enough pollution, a countercurrent between the shoreline and the Gulf Stream delivers runoff onto the reefs from Biscayne Bay and Greater Miami.

PESTICIDES rain down from low-flying mosquito-control planes based in the keys. Lois Ryan, director of the Monroe County Mosquito Control District, is emphatic that people couldn't and wouldn't stay in the keys without her operation: "We spray from planes, helicopters, and trucks twice a week during the wet season, whenever we get more than 20 mosquitoes landing on an inspector's arm in one minute. We use Naled, a pesticide, mixed 4 gallons to 100 gallons of diesel fuel. It's safe, and we perform an invaluable service."

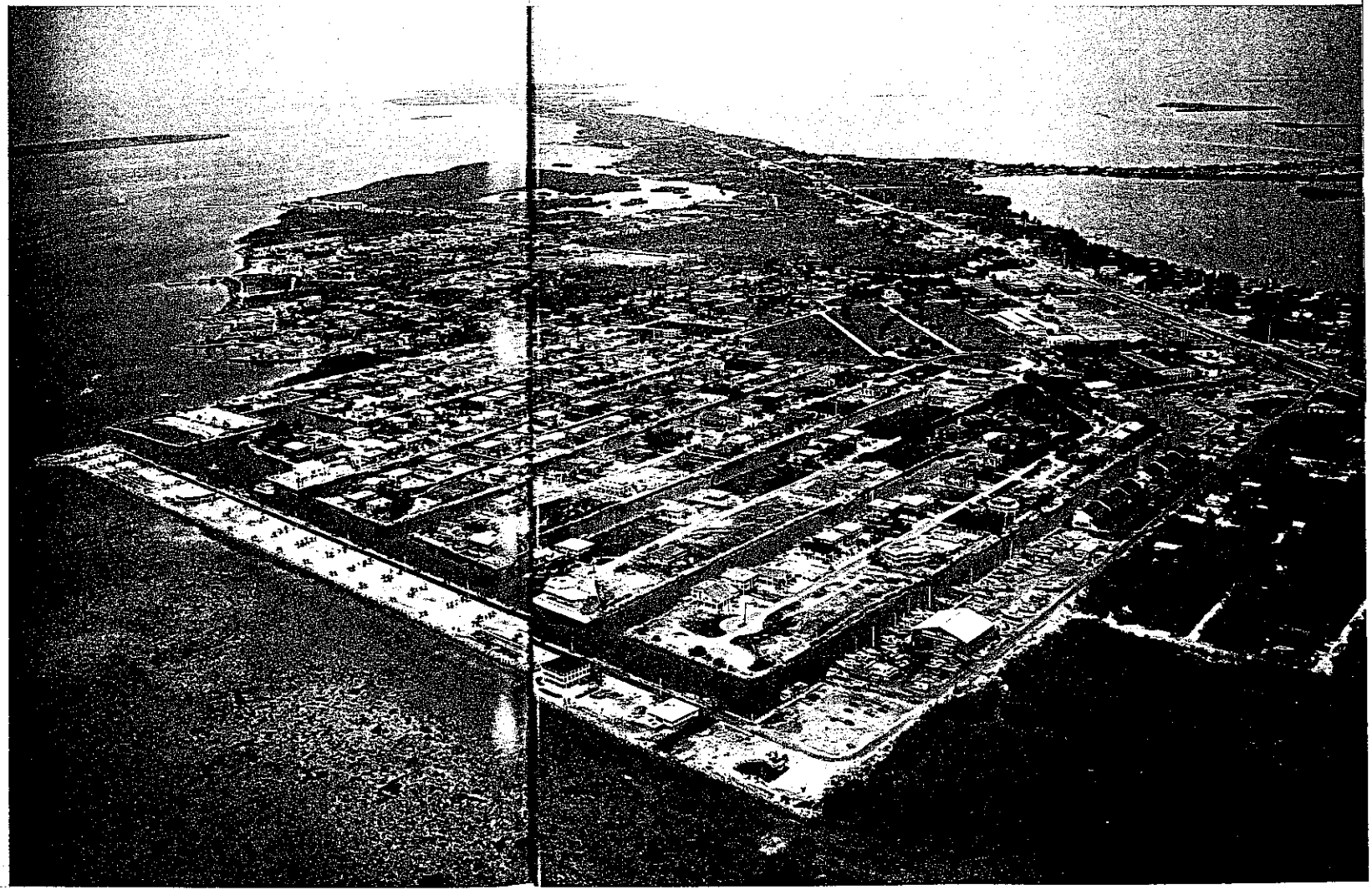
Not everyone agrees that this program is safe or that Mosquito Control should have sole authority over when and where to spray. "Spraying kills larvae, not only of mosquitoes but also of a great many other insects," Mike White of the Key Largo National Marine Sanctuary says. "It's indiscriminate."

A local official lamented,



BOTH BY FRED WARD

Air raids on mosquitoes send fogs of petroleum-based pesticides over Key Largo twice a week during the wet season. The island's porous limestone substrate permits chemicals to filter into the water table and eventually into the ocean. Adding to the pollution, seepage from septic tanks increased in the 1970s with the building of the Port Largo subdivision (below).



The ruddy glow of its branches reflects the health of a sea fan (right), which grows best in warm, clean water with a low nutrient level. A dying coral of the same species haunts the deep like a specter (facing page), perhaps the victim of parasites or polluted water.

Lifeless white limestone discolors a branch of elkhorn coral after the spread of white band disease (bottom left), whose cause remains a mystery. Produced by bacteria, black band disease, here infecting a star coral (center right), can kill a 200-year-old formation in two months. Experiments to stop the disease and treat infected coral so far have failed.

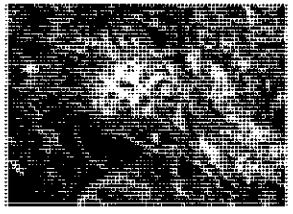
Known as golf ball coral, Favia fragum (bottom right) is smothered by algae, which then use the remains as a base for further growth.

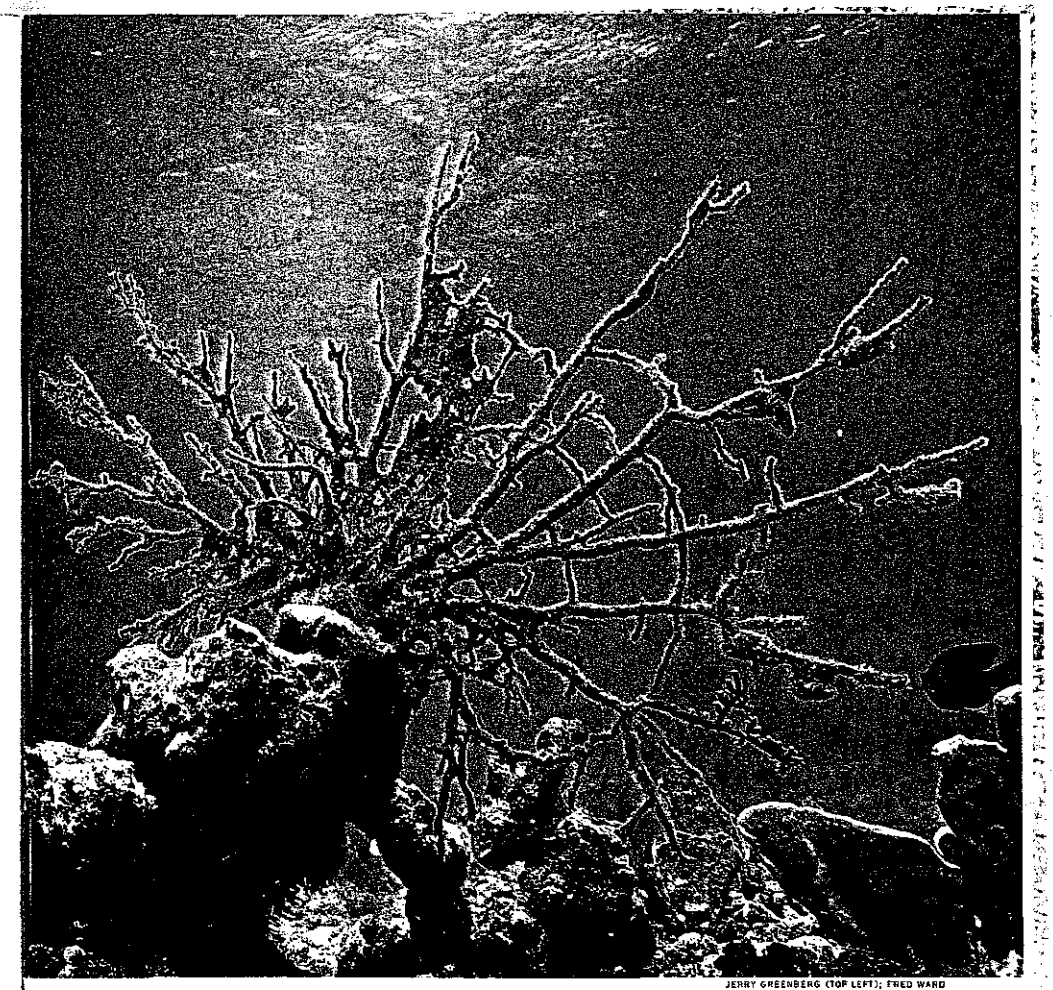
Life on a reef is typically balanced, with a variety of corals coexisting with coral-eating parrotfish, algae, sea urchins, and damselfish. Normally corals have the ability to cleanse and heal themselves of disease and impact wounds. At Pennekamp the reefs may no longer be able to withstand the stresses of their environment.











JERRY GREENBERG (TOP LEFT); FRED WARD

"There are almost no butterflies left where the county sprays. The number of birds has declined because their food is killed in the process of killing mosquitoes."

Carl Nielsen notes the county is supposed to cut off the spray as planes fly over the park or over water, but, he says, "We pick up those pesticides in our water samples. Anything that lands on Key Largo ends up in the park."

Once water quality deteriorates, corals may not have the strength to recover from the stresses of people, boats, storms, silt, chemicals. Anything can push them over the edge.

That fatal "anything" can come from almost anywhere. Richard Curry, resource management coordinator for Biscayne National Park, reports, "We pick up paper plants' residues from the Midwest brought down by the country's sewer, the Mississippi River, mixed in the Gulf of Mexico, and carried here by the Gulf Stream. Every product that people make is found around our reefs—including far too many nutrients."

Agricultural runoff, garbage, sewage, and thousands of products that humans discard have seriously raised the level of nutrients in the water around the keys.

"Nutrient loading could make the Florida Keys reef tract the first in the world to be killed by humans," says Brian Lapointe, water-quality expert with the Florida Keys Land & Sea Trust. Calling the keys an "ecosystem dysfunction," he notes, "Coral reefs thrive only in a low-nutrient environment. Pollution is pushing Florida's reefs beyond their ability to survive. They may not recover."

Algae, which flourish in high-nutrient water, are the key problem. Relentless competitors, they can blanket an entire reef and smother living polyps. Lapointe has studied Caribbean reefs that turned algal in only weeks, the way a swimming pool greens overnight with algal "bloom."

Algae-eating sea urchins, which might have helped save the reefs, suffered a Caribbean-wide die-off in 1983, possibly from a viral disease. The timing was unfortunate. The keys lost an estimated 98 percent of their reef-grooming sea urchins, just when they were needed most.

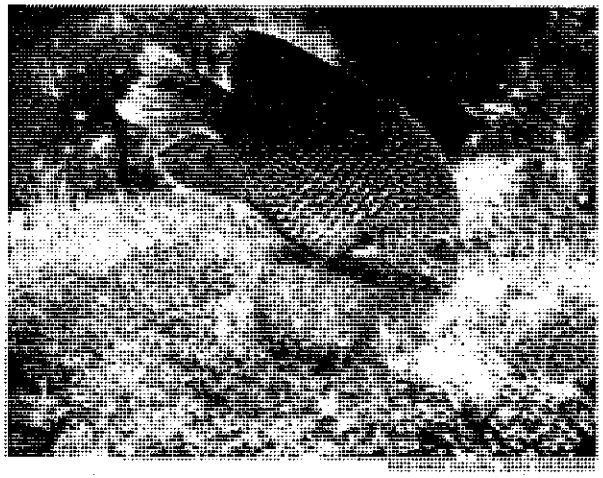
Is death inevitable?

Maybe not, but we need immediate and drastic actions. Man-made threats may well be the end of the reefs unless we change our ways. The area needs a master plan for dealing with water quality, fishing, boating, and visitors.

The reefs are credited with bringing in more than 50 million dollars a year to the upper keys. Restaurants, hotels, boat charters, and dive shops all depend on that money. Logically, the owners of those businesses should be largely responsible for preserving the reefs. Instead, all too often, they bury their heads.

Rather than taking action, many plead that nothing negative be said to deter tourists, who continue coming in record numbers to enjoy the remaining beauty of live areas. Ultimately, healthy reefs and healthy tourism are interdependent.

Saving the reefs means stopping the pollution. Lapointe





Small but feisty, a damselfish guards its turf (below). By picking at polyps, the fish kill patches to create algal lawns (left). In defense, a "chimney" of new growth appears (above). If habitat is destroyed, the fish swarm to nearby reefs, where coral destruction is intensified.

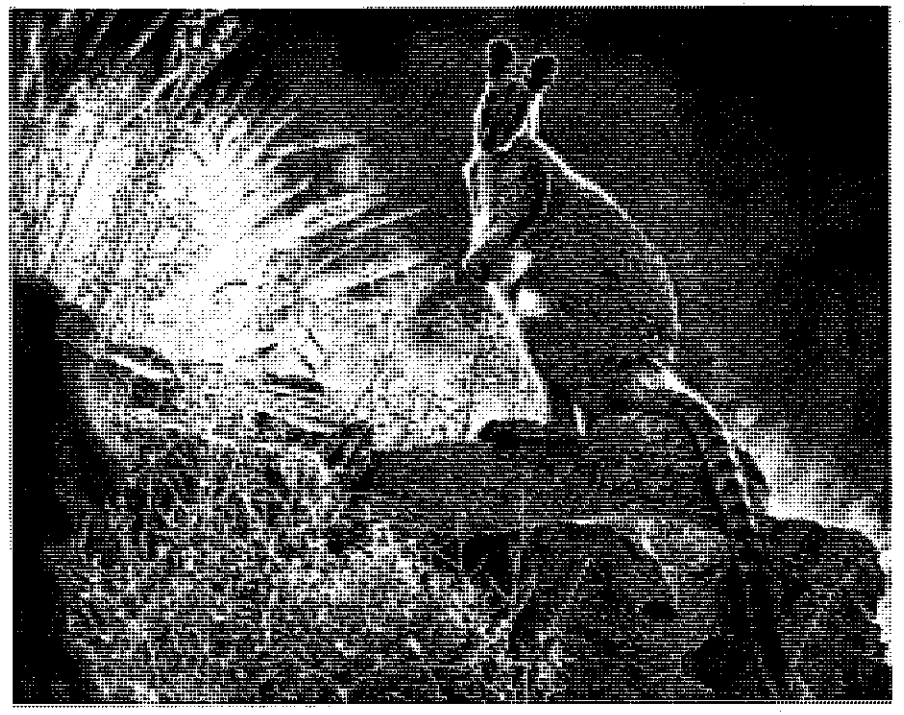


says, "Cleaning up Key Largo and the other Florida Keys and putting them all onto sewage systems would be a major step in the right direction." Agricultural, boating, and industrial pollutants should be kept away from the reefs. Finally, fishing and lobstering should be banned in Pennekamp Park and the sanctuary.

As I photographed one morning from the top of a park concession snorkel boat, its young captain, Kevin Puch, glanced below at nearly a hundred snorkelers leaping onto one small patch of reef. We exchanged concerned looks.

"I make my living driving this boat, and I love it," said Kevin. "But the only way this place will recover, if it even can, is to treat it like a real park . . . restrict activity in the fragile areas, and let it try to heal."

Kevin is probably right that some parts should be closed. But cleaning up the water is the first priority. We will kill the coral reefs if we're not careful, by ignoring their silent plight and loving them to death. □

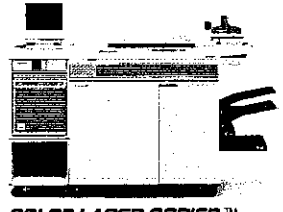


WILDLIFE AS CANON SEES IT

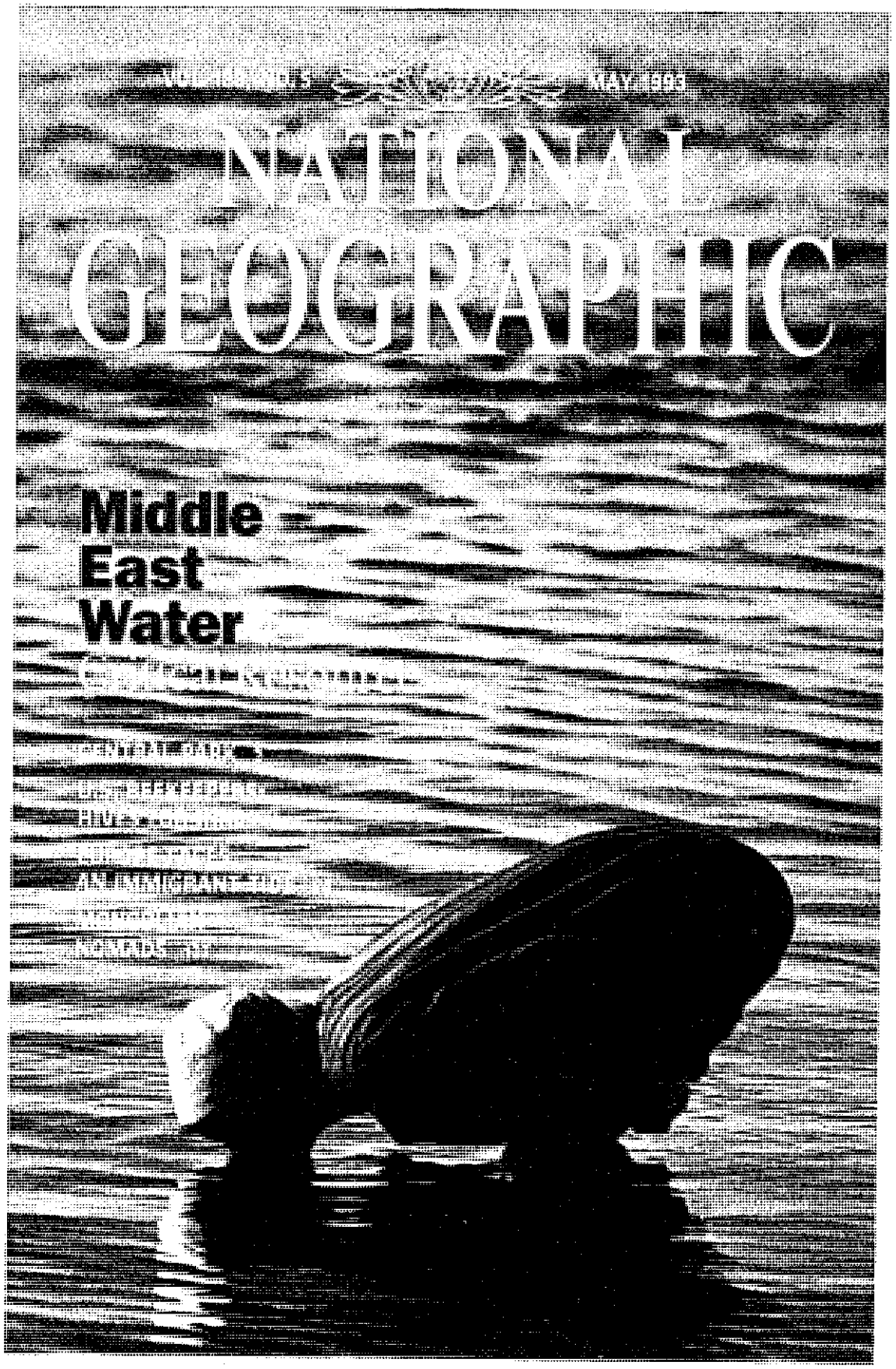


Yellow-footed Rock Wallaby
Genus: *Petrogale*
Species: *xanthopus*
Adult size: Head and body length, 60-70cm; tail, 60-70cm
Adult weight: 6-8kg
Habitat: Rock outcrops and cliffs in semi-arid country, Australia
Surviving number: Estimated at 12,000
Photographed by John Cancalosi

A yellow-footed rock wallaby pauses from foraging in its rocky habitat. European settlements in the mid-1800s brought relentless hunting of these gentle marsupials for their beautiful pelts. By the turn of the century, populations had diminished significantly. In 1912 the yellow-footed rock wallaby was given a protected status, which continues today. To save endangered species, it is essential to protect their habitats and understand the vital role of each species within the earth's ecosystems. Color images, with their unique ability to reach people, can help promote a greater awareness and understanding of the yellow-footed rock wallaby and our entire wildlife heritage.

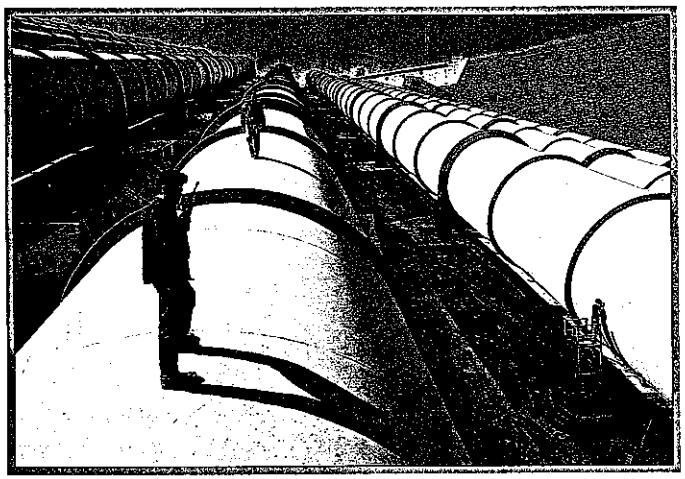


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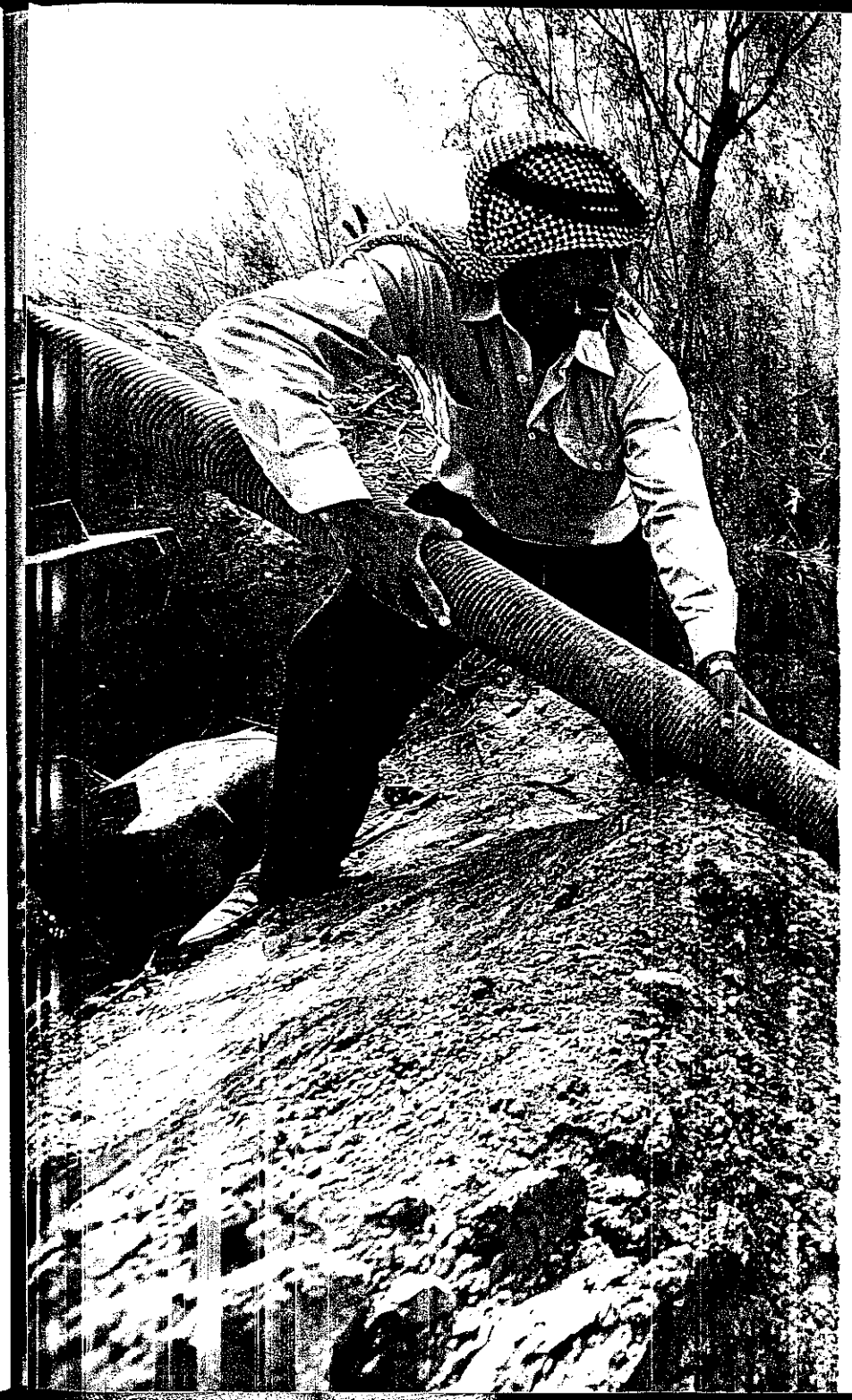
The Middle East's WATER
Critical Resource



By
PRIIT J. VESILIND
NATIONAL GEOGRAPHIC
SENIOR WRITER

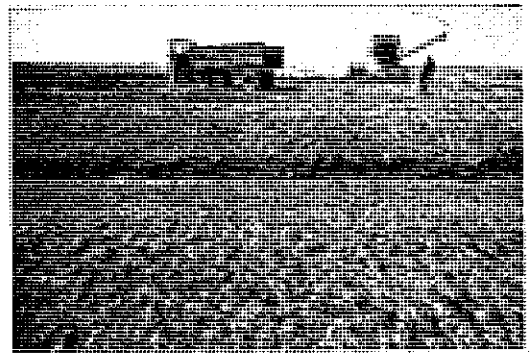
Photographs by
ED KASHI

From the plains of Anatolia to the eastern Sahara, rivers are lifeblood to this arid region, where growing nations compete for a shrinking water supply. Workers inspect giant pipes that will channel waters of the Euphrates to generators in the Atatürk Dam, keystone of a plan to transform southeastern Turkey. North of Egypt's Aswan High Dam, a tour boat eases past a boy and his horse in the shallows of the Nile.





FRESH WATER, life itself, has never come easy in the Middle East. Ever since the Old Testament God punished man with 40 days and 40 nights of rain, water supplies here have been dwindling. The rainfall only comes in winter, *Inshallah*—God willing—and drains quickly through the semiarid land, leaving the soil to bake and to thirst for next November.

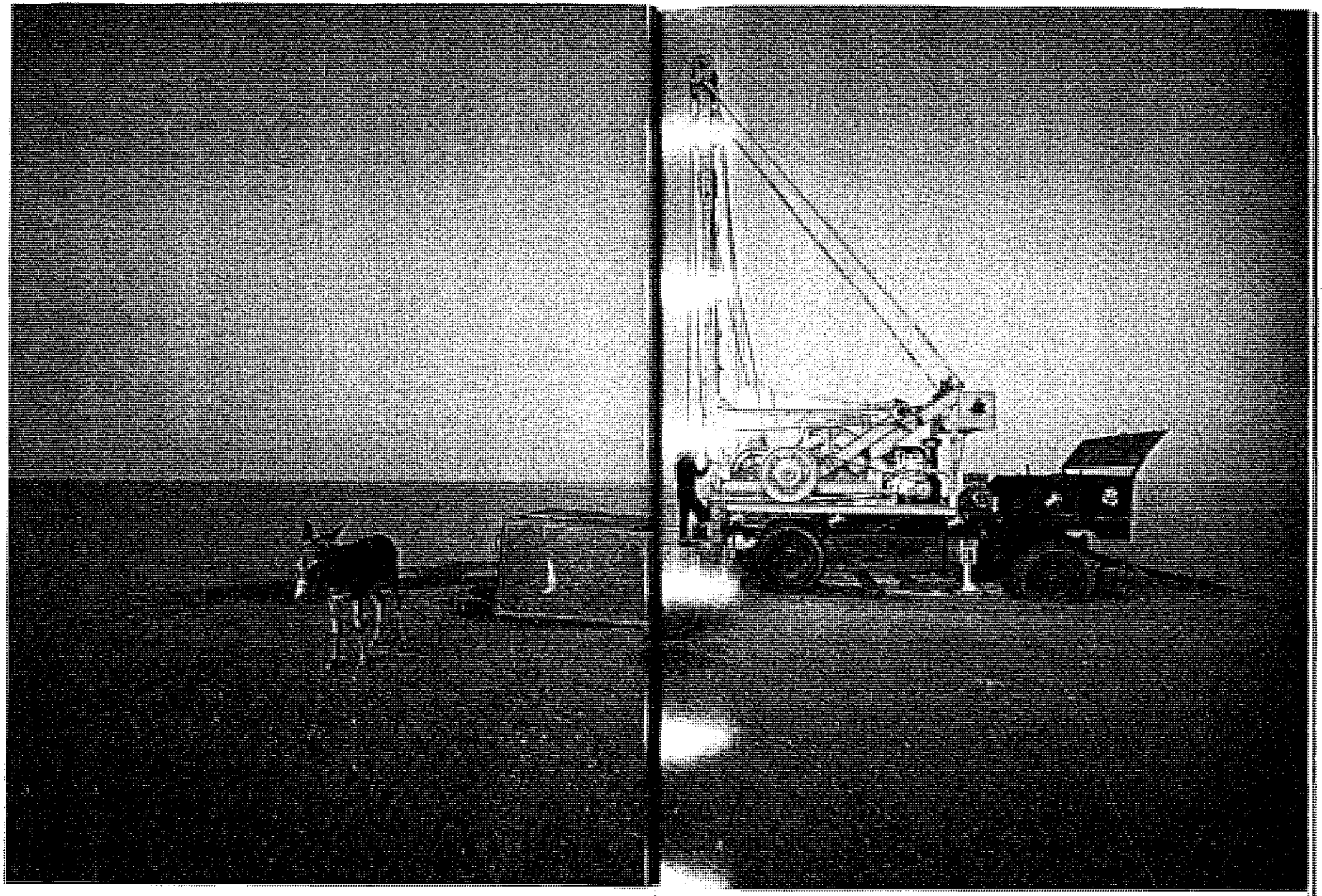


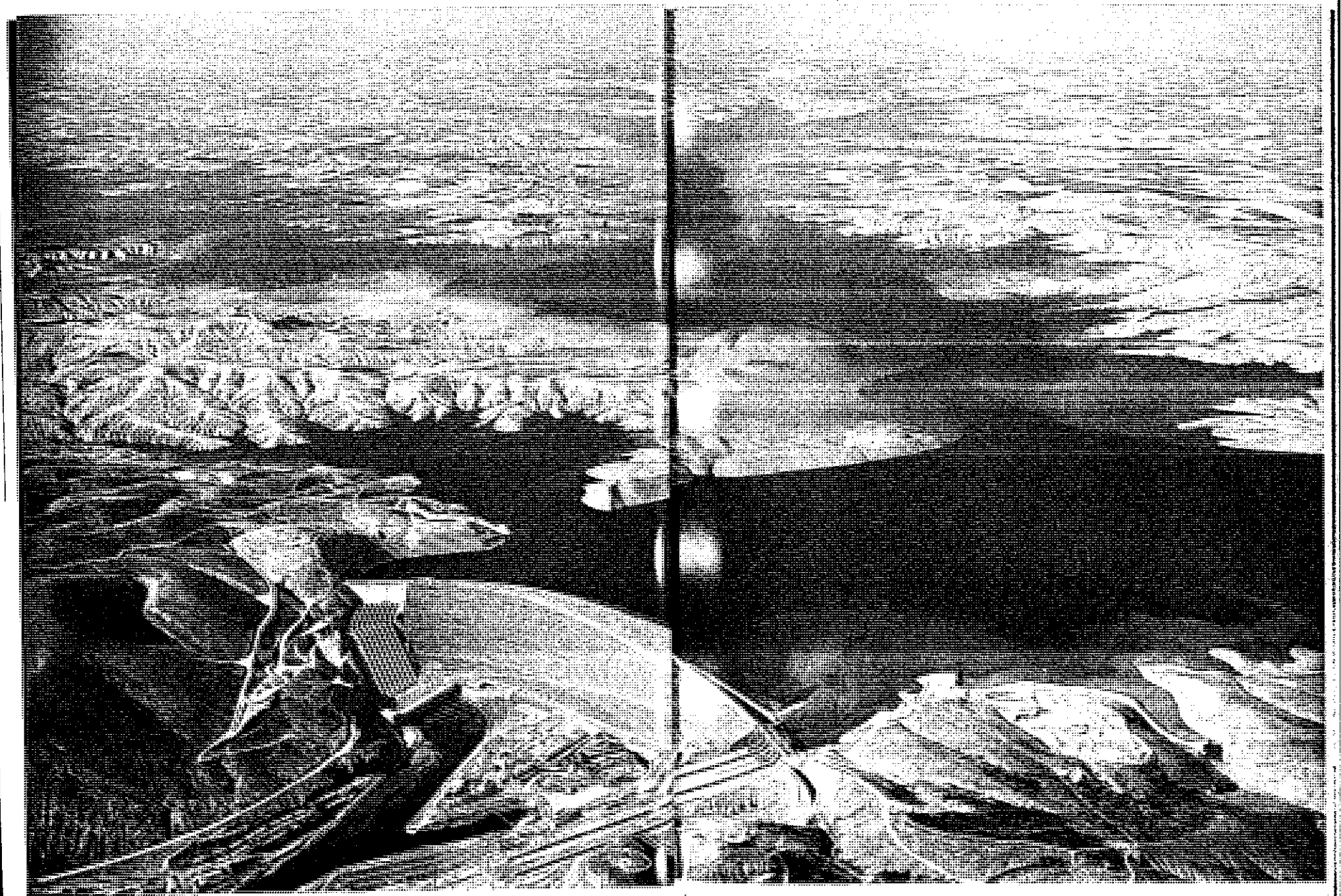
■ **JORDAN: Farmers pumping brackish Jordan River water say that drought-resistant olive trees barely grow where citrus once thrived. The river, usually a stream salty from diversion of feeder streams and leaching of minerals from irrigated fields, runs swollen after a wet winter.**

■ **IRAQ: War has undermined agriculture east of Baghdad, where a dry canal borders a patchy wheat field.**

The region's accelerating population, expanding agriculture, industrialization, and higher living standards demand more fresh water. Drought and pollution limit its availability. War and mismanagement squander it. Says Joyce Starr of the Global Water Summit Initiative, based in Washington, D. C., "Nations like Israel and Jordan are swiftly sliding into that zone where they are using all the water resources available to them. They have only 15 to 20 years left before their agriculture, and ultimately their food security, is threatened."

I came here to examine this crisis in the making, to investigate fears that "water wars" are imminent, that water has replaced oil as the region's most contentious commodity. For more than two months I traveled through three river valleys and seven nations—from southern Turkey down the Euphrates River to Syria, Iraq, and on to Kuwait; to Israel and Jordan, neighbors across the valley of the *(Continued on page 48)*





■ TURKEY: A giant pipe, feeding dams combine the Euphrates River, filling a reservoir

expected to hold more than two times the volume of the flow of the Euphrates. Atatürk anchors

Turkey's Southeastern Anatolia Project, a plan that envisions 22 dams and 19 power

plants in the Tigris-Euphrates basin, heavily dependent on the Euphrates, Syria

and Iraq watch anxiously for reduced flow. Both complained of shortages of water and

power in 1990, when Turkey held back the river to begin filling the Atatürk reservoir.

(Continued from page 43) Jordan; to the timeless Egyptian Nile (maps, pages 52-3).

Even amid the scarcity there are haves and have-nots. Compared with the United States, which in 1990 had a freshwater potential of 10,000 cubic meters (2.6 million gallons) a year for each citizen, Iraq had 5,500, Turkey had 4,000, and even Syria had more than 2,800. Egypt's potential was only 1,100. Israel had 460, Jordan a meager 260. But these are not firm figures, because upstream use of river water can dramatically alter the potential downstream.

Scarcity is only one element of the crisis. Inefficiency is another, as is the reluctance of some water-poor nations to change priorities from agriculture to less water-intensive enterprises. Some experts suggest that if nations would share both water technology and resources, they could satisfy the region's population, currently 159 million. But in this patchwork of ethnic and religious rivalries, water seldom stands alone as an issue. It is entangled in the politics that keep people from trusting and seeking help from one another. Here, where water, like truth, is precious, each nation tends to find its own water and supply its own truth.

As Israeli hydrology professor Uri Shamir told me: "If there is political will for peace, water will not be a hindrance. If you want reasons to fight, water will give you ample opportunities."



■ **IRAQ: Frosted by salt, a field that once grew barley lies barren near the confluence of the Tigris and Euphrates Rivers. Southern Iraq's soils are badly damaged by saline waters, as the Euphrates carries runoff from fields upstream into the area. Over-irrigation and poor drainage compound the problem: As the stagnant water evaporates, it leaves behind a crust of salt. Consumed by wars since the early 1980s, the government has had little time or money to spare for soil improvement programs.**

MY JOURNEY STARTS in springtime, high in the Anti-Taurus Mountains of southern Turkey, where I shiver among the dripping snow beds. In the distance I can trace the silvery strand of the Euphrates, gathering force for its step-down south into Syria, then into Iraq, where it joins the Tigris to empty into the Persian Gulf.

It was in the land between these rivers—Mesopotamia—that agriculture arose in the Middle East. Turkish tradition says Abraham himself first tilled the soil on the Harran Plain, just beyond the horizon.

The generous snows of the Turkish mountains have brought little wealth to the semiarid plains of the southeast. Without irrigation they have yielded only one crop a year. But now Turkey has finally begun to harness its waters.

In the haze I can see the Euphrates swelling with backup from the great Atatürk Dam, dedicated last year. Soon its waters will rush through the world's two largest irrigation tunnels—25 feet in diameter—to revitalize the Harran Plain 40 miles away. The Atatürk will also generate nine billion kilowatt-hours of electricity a year.

Eventually 22 dams will impound the waters of the Euphrates and the Tigris, which also rises in eastern Turkey, all part of an ambitious and diverse development scheme called the Southeastern Anatolia Project. Arab neighbors joke uneasily about a new Ottoman Empire.

From the mountaintop I inch down twisted dirt roads, dwarfed between boulders, crossing earth slides and streams milky with limestone, where Kurdish farmers spread manure on tobacco fields. A patriarch with a bristly white mustache comes to wave his arms and complain, thinking I am a government agent.

"We don't have enough land, and people are hungry," he says. As for the dam: "It just benefits the Harran Plain, and land there has been bought by the rich."

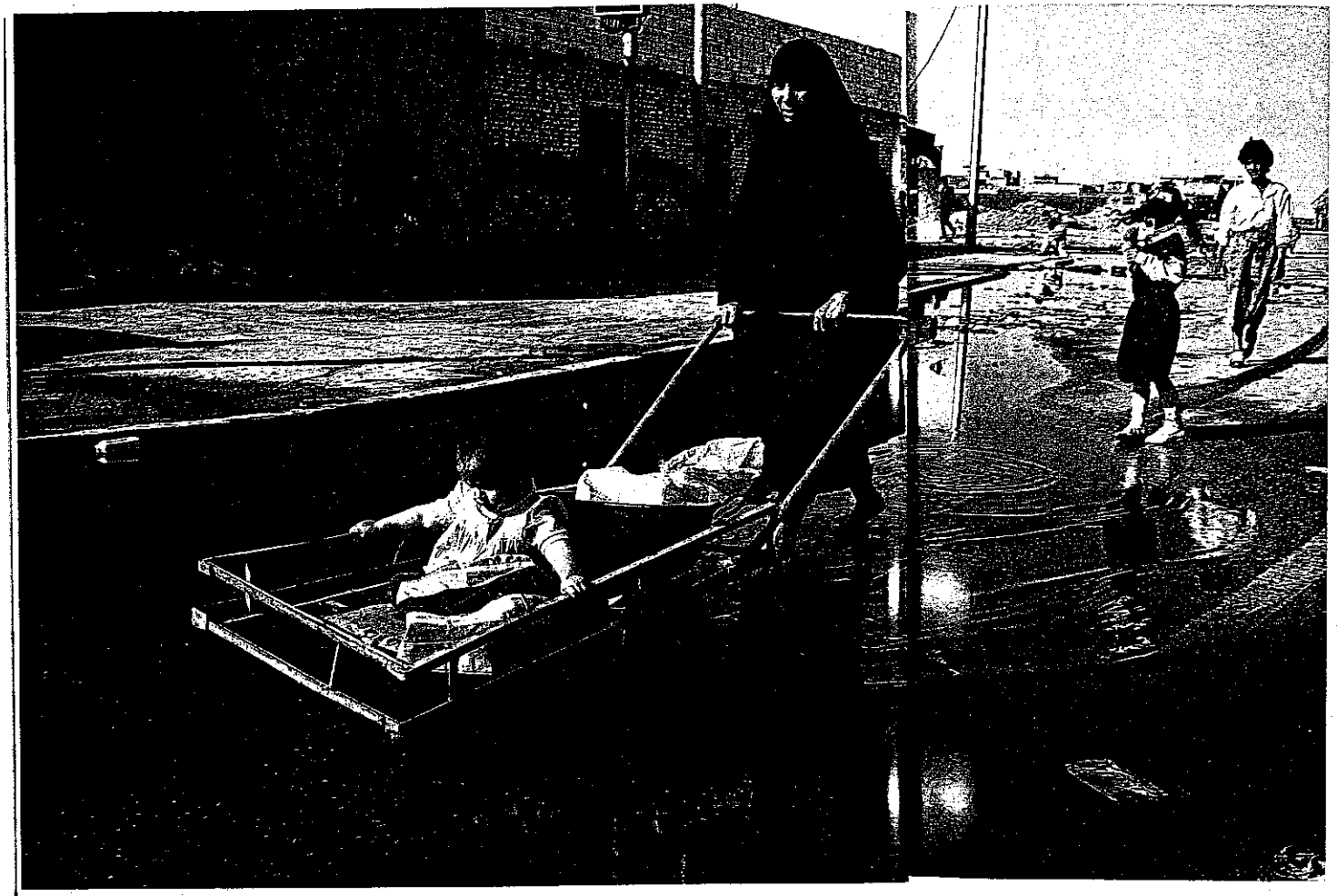
On the Harran, now lush with spring grass, the mood is optimistic. At a government experimental farm at Koruklu, agronomists test patches of peaches, pecans, nectarines, pomegranates, and grapes as candidate crops for the coming waters. Local farmers, many of them Arabs, attend irrigation classes with anticipation.

The massive Atatürk sits 40 miles north of the regional capital of Urfa. It is essentially an immense pile of rocks guarded by men with machine guns. With officials I drive along its mile-long top. What looked like pebbles from a distance grow into car-size boulders of basalt, each placed according to size, like a mosaic, by a machine with a monstrous but artistic claw. The blue-green Euphrates thunders below the dam with a kind of virile, elastic power that seems closer to electricity than water.

I ask dam official Necmettin Sasaoglu if he and his colleagues feared sabotage during the gulf war, when Turkey assisted coalition forces against Iraq. "It's impossible to destroy this dam," he answers. "Besides, the floods would ruin Iraqi lands and cities downstream. It would have been self-destruction."

When nations share the same river, the upstream nation is under no legally binding obligation to provide water downstream. But the downstream nation can claim historical rights of use and press for fair treatment. In 1989 President Turgut Özal alarmed Syria and Iraq by announcing that Turkey would hold back the flow of the Euphrates for a month to start filling the Atatürk, despite an earlier guarantee to provide an average flow of 500 cubic meters a second at the Syrian border. To offset the loss, Turkey increased

ED KASHI's photographs illustrated "Struggle of the Kurds" in the August 1992 GEOGRAPHIC. Before that he spent two years covering Northern Ireland for the documentary work, *No Surrender: The Protestants*. He lives in San Francisco.



■ IRAQ: Ankle-deep in pools of sewage, residents of a Basra neighborhood suffer war's ravages long after the bombs have stopped. "We can't endure this any more," a woman shouted as she passed the author on the fetid streets of this once prosperous port city, 300 miles downstream from Baghdad. Years of pounding during the Iran-Iraq and gulf wars crippled the city's sewer and water-supply systems, flooding neighborhoods with pools of liquid waste. Though some sections of the system work periodically, they often break down: United Nations sanctions against Iraq have led to a shortage of spare parts.

the flow for two months before the cutback, but even this did not prevent an outburst of criticism. Full development of the Anatolia project could reduce the Euphrates' flow by as much as 60 percent. This could severely jeopardize Syrian and Iraqi agriculture. A technical committee of the three Euphrates riparians—Turkey, Syria, and Iraq—has met intermittently to share hydrological information but has made no real headway.

If seen as a commodity, water can be packaged, bought, and sold, and may soon move between nations like so much wheat. But political mistrust hampers many promising schemes. In 1987 Turkey proposed a "peace pipeline" of water from two Turkish rivers—the Ceyhan and the Seyhan—that flow south into the Mediterranean. The dual pipelines would deliver potable water to millions in Syria, Jordan, Saudi Arabia, and other Arab gulf states. Few nations were receptive, and the concept sits in limbo.

"In this region," Turkish Foreign Ministry official Burhan Ant told me in Ankara, "interdependence is understood as the opposite of independence. Every country here seeks a kind of self-sufficiency in every field, because they don't trust the others."

HARRAN'S GOOD FORTUNE is seen darkly in Syria, a nation that needs the Euphrates to keep pace with its population growth of 3.8 percent a year. Less water in the river has meant low power output at Syria's own large-scale Euphrates Dam at Tabqa. In Syrian cities power is routinely shut off several hours each day. Kerosene lamps glow orange through apartment windows.

"Only two of the dam's eight turbines are working," says Ministry of Irrigation official Hamdan Odeh in Damascus. "There has never been enough water for them all."

Predictably, Syria's big dam has kindled fear of scarcity downstream in Iraq. The Iraqis dispatched troops to rattle sabers at the Syrian border in 1975, when the reservoir was filling.

But Syria sees the great project as vital to its future security. The nation's rain-fed western farmland is already heavily used. The government looks now to its arid eastern steppes, where the Euphrates Dam irrigates 500,000 acres. Authorities estimate that a million more will have to be pushed into cultivation, and that cannot be done without more river water.

"There is no other choice," says Syria's director of international waters, Majed Daoud. "We will have 25 million people by 2010, and these people will need food."

In Aleppo I spend several days at the International Center for Agricultural Research in the Dry Areas (ICARDA), where researchers are devising strategies for coping with a drier future. "Water harvesting" is one way. Research agronomist Theib Oweis explains: "If one acre gets 150 millimeters (six inches) of rain a year, that is not enough. But, if you can get the water from one half of this acre to the other, you have land with 300 millimeters. Then you can grow a crop.

"For example, you plow the land in alternating strips. Water will run off the area you don't plow, so it will flow to the other strip. I don't see how any dry country can afford not to use such techniques."

When water is short, disease can spread, partly because untreated sewage water is used to irrigate vegetables. In 1989 Aleppo suffered a cholera outbreak blamed on contaminated parsley.

"I always soak my vegetables in chlorine," an Aleppo housewife tells me. "When I go to the market, the maid says, 'Don't get the onions with the black dirt on them; get the ones with the red dirt.' They were grown farther from the river."

Later I approach a merchant in the outdoor market by Aleppo's medieval city walls, one whose radishes bear the telltale black earth. "I eat these," he tells me, "and I don't wash anything. The only people who get sick are already slightly affected in the head. Dust and mud don't make you sick. It all comes from God."

Islam forbids alcohol, and water is the table drink, along with tea and coffee. Those Syrians

who can afford it buy plastic bottles of Boukein mineral water, whose label assures all drinkers, in English: "The best to prepare baby's food and to conserve his teeth healthy."

From Damascus, I drive with government escorts to the Golan Heights. The western slopes, where streams flow down to nourish the Sea of Galilee, were captured by Israel during the war of 1967. The humiliation still stings.

At the border there is a no-man's-land. The Israeli flag flutters on the other side. "See that flag?" says border official Mohammed Ali. "Those blue stripes represent the Nile and the Euphrates. The Israelis think this is where their land should extend, all the way from Egypt to Turkey. And they are working to get this area."

Actually, their blue-striped flag is patterned after the Jewisb prayer shawl, but the misinformation suits the Syrian government, which has made a martyr city out of Al Qunaytirah. The regional Golan capital was destroyed. Nothing has been rebuilt. Busloads of Syrian and Iranian tourists trundle through the wreckage to see the "work of the Zionists." And the city itself is quietly returning to nature. I hear only sparrow song and the gurgle of pure water.

THE ONLY ROAD TO IRAQ for an American begins in Amman, the capital of Jordan, then shoots northeast through 500 miles of desert, through the cannon-shaped end of Jordan. I ride in a hired Chevrolet through a grit-filled haze called *khamsin*—"50 days"—for the duration of the winds that blow from the deserts. Curiously, a circle of blue sky shines overhead, like a skullcap on an immense bald head of ocher dust.

The landscape turns fertile when we reach the valley of the two rivers—ancient Mesopotamia. The Euphrates flows flat and strong, and in a few miles Baghdad arises on the Tigris, modern and bombastic. It shows few outward signs of the punishment it absorbed during the gulf war.

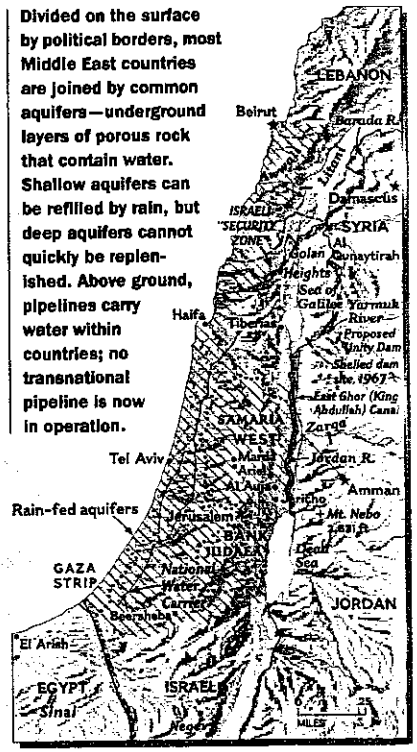
Bridges are repaired, tap water runs, and toilets flush. Portraits of President Saddam Hussein—depicted as a war hero, a son of Islam, a friend of the poor, a workingman with a wrench—hang heavy over the streets.

But Baghdad, like the rest of Iraq, merely survives. Its standard of life has collapsed since the gulf war and under the United Nations embargo. Duct tape and cannibalized parts hold city plumbing together, says Adnan Jabro, director general of water supply and sewage treatment.

"Can you imagine," *(Continued on page 56)*



Divided on the surface by political borders, most Middle East countries are joined by common aquifers—underground layers of porous rock that contain water. Shallow aquifers can be refilled by rain, but deep aquifers cannot quickly be replenished. Above ground, pipelines carry water within countries; no transnational pipeline is now in operation.

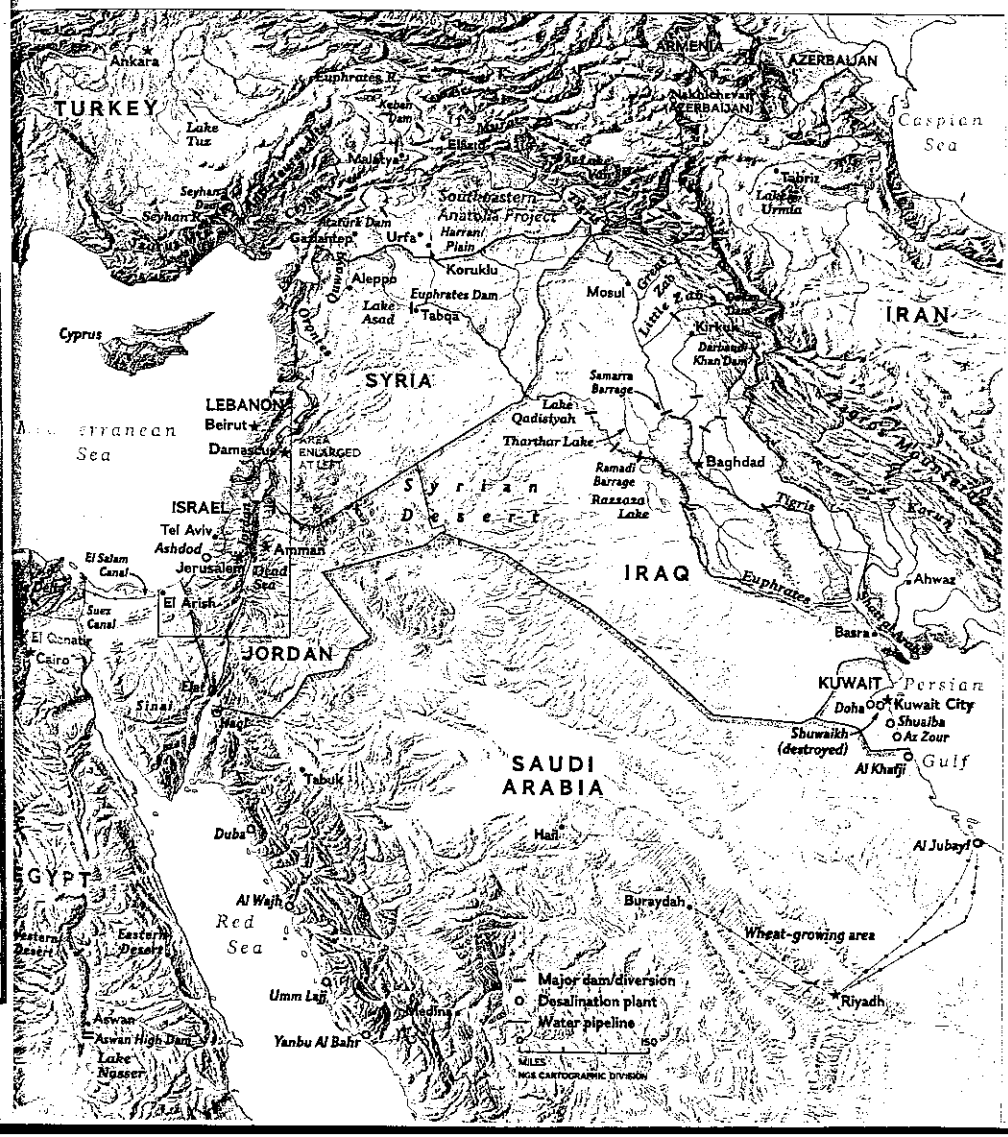


HIGH STAKES FOR THIRSTY NATIONS

"The next war in the Middle East will be fought over water, not politics," UN Secretary-General Boutros Boutros-Ghali warned in 1985, while he was Egypt's minister of state for foreign affairs.

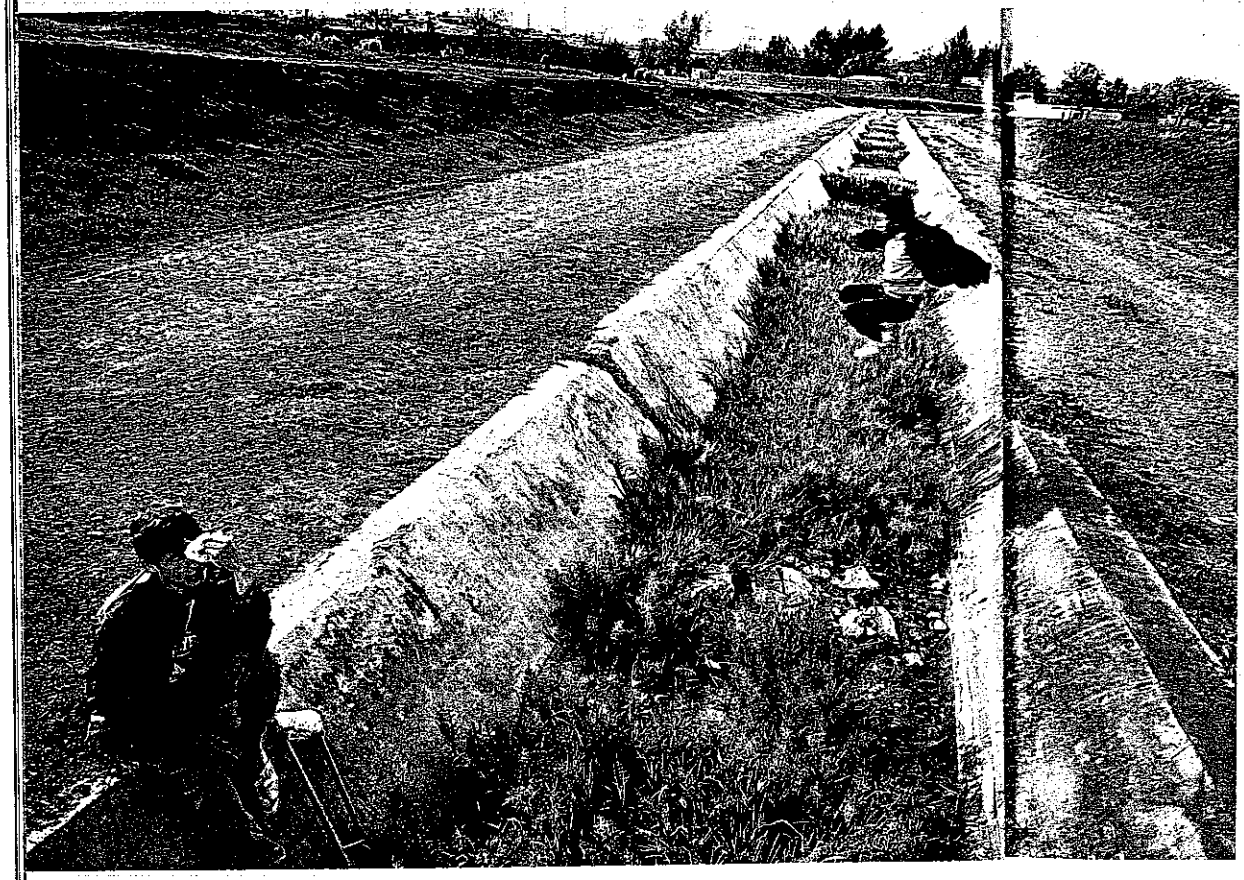
Localized water conflicts have raised tensions in the region for decades. In 1967 Israelis shelled a dam site shared by Jordan and Syria on the Yarmuk River. In 1975 Syria and Iraq nearly went to war after Syria and Turkey filled reservoirs behind two new dams, causing a sharp drop in the Euphrates River. More recently Palestinians and Israelis have wrangled over access to a failing groundwater supply in the West Bank.

Almost wholly dependent on the flow of the Nile, Egyptians now worry that countries upstream will demand a greater share of the river's waters.





■ SYRIA: "O believers, when you stand up to pray, wash your faces, and your hands up to the elbows, and wipe your heads, and your feet up to the ankles." Faithful Muslims gathered for midday prayer at a Damascus mosque obey the words of the Koran nearly 14 centuries after Arab conquerors brought Islam to this city on the Barada River. A failing network of leaky pipes contributes to the frequent water shortages that plague Damascus's galloping population, which has more than doubled since 1970.



SYRIA: Where the Quwayq River once flowed, a weed-choked ditch enters Aleppo, filling with sewage and industrial waste as it crosses the city. Aleppo's river dried to a trickle decades ago after farmers upstream diverted its waters. Today the city's nearly two million residents receive drinking water from the Euphrates, though hard-pressed local farmers tap into the stream of sewage to irrigate produce. The result: occasional outbreaks of cholera, typhoid, and dysentery.

he says, "43 straight days of bombing, with no electricity, and you—*you*—are responsible for supplying water to 4.5 million people? It was a nightmare. People were using polluted water from ditches. And without electricity to operate the pumps, Baghdad was flooded with sewage."

Jabro feels that Iraq has done everything the United Nations wants. "Government officials can drink bottled water," he says, "but what can the other people do? If the United Nations really intends to kill people, they should come out and say it."

Iraq has a surplus of river water; its shortcomings are in management, investment, and control of pollution. During four decades of oil wealth, Iraq gave its rivers and agriculture low priority. For ten years of war, water projects were further set back. And water arrives already degraded by salts, agricultural runoff, and chemical pollutants from upstream users, for Iraq sits at the tail end of the drainage.

At the same time, drought has intensified, and as Turkey begins massive irrigation this spring Iraqis fear even lower levels. Seasonal floods that once leached and washed the soil have been rare. With over-irrigation and poor drainage, salinization has affected huge areas; in southern Iraq, where brackish marshes surround the Shatt al Arab waterway formed by the confluence of the Tigris and Euphrates, thousands of acres have been glazed with an icing of salt.

In the infirmary that is Iraq, the city of Basra is on the critical list. Basra suffered more than three years of shelling from Iran and was savaged again by coalition bombing and by street fighting between Shiite rebel forces and Iraqi troops.

I fly to Basra from Baghdad. Saad, my official guide and handler from the press office in Baghdad, advises me of practical things en route: "To shampoo in Basra, buy two bottles of mineral water. If you don't, your hair will stick straight out with the salts."

In the stricken city barefoot toddlers wade casually through ponds of sewage. Our taxi driver, Abu Hekmat, says, "When we drink from the tap—it's directly to the hospital!" Waterborne diseases—typhoid, cholera, amebic dysentery—have bred.

About 20 cases of gastroenteritis arrive at the children's hospital in Basra every morning. In the wards, acrid with the smell of antiseptic and diarrhea, mothers whisk flies from pale babies hooked to plastic tubes and IV bottles. Stray cats stride boldly in the heat of the corridors.

"The main drugs, even diagnostic kits, are simply not here," says hospital manager H. A. Borak. Smoldering quietly, he demands: "Why is America doing this?"

KUWAIT, THE OIL-RICH NATION that Iraq still covets, has little fresh water, but it has the money to make it. To utilize seawater, Kuwait constructed six large-scale oil-powered desalination plants.

The plants use a complex distillation process, in which water "flashes" into a salt-free vapor. This requires huge amounts of energy and produces a cubic meter of fresh water that costs more than two dollars, compared with 20 cents in Chicago. But the water is heavily subsidized. Consumers pay less than a tenth of the cost.

Says Abdulla Mohammed Al-Minayes of Kuwait's Ministry of Electricity and Water, "Availability and reliability are very important to us. Economics does not mean anything."

Kuwait City in the spring of 1992 is a shell. Rubble litters the quiet streets. Bitterness and recrimination between those who stayed and struggled through the Iraqi invasion and those who left for the comforts of London or Paris polarize Kuwaitis. Half the population of two million, primarily the foreign laborers, is gone. The four surviving desalination plants produce a surplus—204 million gallons of drinking water a day for a demand of only 174 million gallons.

Saudi Arabia, farther down the Arabian Peninsula, leads the world in desalination. Its 22 large plants produce 30 percent of all desalinated water in the world. It is also a leader in the pumping of fossil water—water accumulated in an earlier geologic age—lying deep in aquifers spread under northern Africa and the Middle East. Mining nonrenewable water is like extracting oil—someday it will run out. Various estimates of the life span for Saudi fossil-water reserves at the present rate of pumping range from 25 to 100 years. Saudis themselves say longer.

Using such water, Saudi Arabia has exceeded its goal of self-sufficiency in wheat. Surprisingly, it has become the world's seventh biggest exporter, selling the wheat at one-quarter of cost. The government absorbs the loss.

"The Saudis are shortsighted," says Elias Salameh, professor of hydrology at the University of Jordan. "Someday they will need that water. And taking out fossil resources has its impact on the geologic structure of the area. The ground level may drop. Water is pressurized, and if you



take it out, no one knows what will happen."

For drinking water, the Saudis will increasingly rely on desalination. They fear only sabotage and pollution, as dramatized by the 600-square-mile oil slick that blackened the Persian Gulf during the war against Iraq, threatening to clog desalination intake pipes.

SADDAM HUSSEIN remains a hero to the Palestinians. Many of those who labored in Kuwait welcomed the Iraqi warlord, then fled before Desert Storm. More than 300,000 flooded cities and refugee camps in the Hashemite Kingdom of Jordan, already burdened with two prior waves of Palestinians in 1948 and 1967. They severely tax the nation's meager water resources.

In Baqaa refugee camp outside Amman, I visit Mohammed Abu Ghoname, his wife, and their 18 children. The family shares one brass faucet to wash babies, scrub laundry, and fill pots. One son, six-year-old Shadi, steps up and demands: "Do you like Saddam?"

I reach for a positive answer: "He has a fine mustache." The father translates. The child stares up at me, then lunges with a tiny fist and socks me hard in the stomach.

Times are tough in Jordan. Its aquifers are overpumped, and before the inundating winter of 1991-92, years of drought had worn agriculture to stubble. In Amman water rationing has been a fact of life; the water authority pumps only two or three times a week to the metal tanks that sit on every rooftop.

■ **ISRAEL: "Mines. Beware!" reads a Hebrew sign on the Golan Heights. The former Syrian territory, annexed in 1981, is key to controlling 35 percent of Israel's water supply. In the valley below lies Israel's main reservoir, the Sea of Galilee, where members of Kibbutz Haon raise fish in rectangular ponds.**

■ **WEST BANK: "If there is no rain, what can we do? Nothing," says Jihad Ahmed Jamaat. He coils irrigation hose after a failed banana harvest near the village of Al Auja in the Israeli-occupied West Bank, a 2,270-square-mile area seized from Jordan in 1967. Al Auja's Palestinians say deep wells dug for Jewish settlers made their ancient spring run dry.**

Jordan controls no major rivers. The Jordan River forms part of its border with Israel, but the Jordan's headwaters rise mainly in the mountains of Lebanon, northern Israel, and the highlands of Syria, and the river is heavily tapped upstream. Jordan must depend on the river's main tributary, the Yarmuk, which forms part of the kingdom's northern border with Syria. But the Yarmuk is also crucial to Syria and Israel. Only the small Zarqa River runs within Jordan.

Recognizing early on the volatility of the water issue in this area, U. S. President Dwight D. Eisenhower sent an envoy to devise a sharing plan for the Jordan in the 1950s. Technical experts from all four riparians—Syria, Lebanon, Israel, and Jordan—accepted the Johnston Plan in principle. But there was no agreement on exact quotas, and governments would not ratify it. The plan was abandoned, but Jordan and Israel agreed to quotas in return for U. S. aid in financing a major water project in each nation.

In the 1960s Israel finished its project—the National Water Carrier—tapping the Sea of Galilee to channel water as far south as the Negev desert and virtually drying up the southern Jordan River. Jordan and other Arab states were outraged, calling the transfer of water from the Jordan basin a breach of international law. Israel maintains that it has the right to do what it wants with its own water.

During the 1967 war Israel captured the Golan Heights and the West Bank, effectively gaining control of almost the entire Jordan River basin. Jordanian farmers in the valley, under shelling and fearing a full-scale Israeli invasion, temporarily abandoned the east bank, and agriculture shriveled there.

In the 1970s Jordan completed the extension of its major project, the East Ghor (King Abdullah) Canal, which runs from the Yarmuk River south, parallel to the Jordan. Farmers returned, induced by promises of continued land reform.

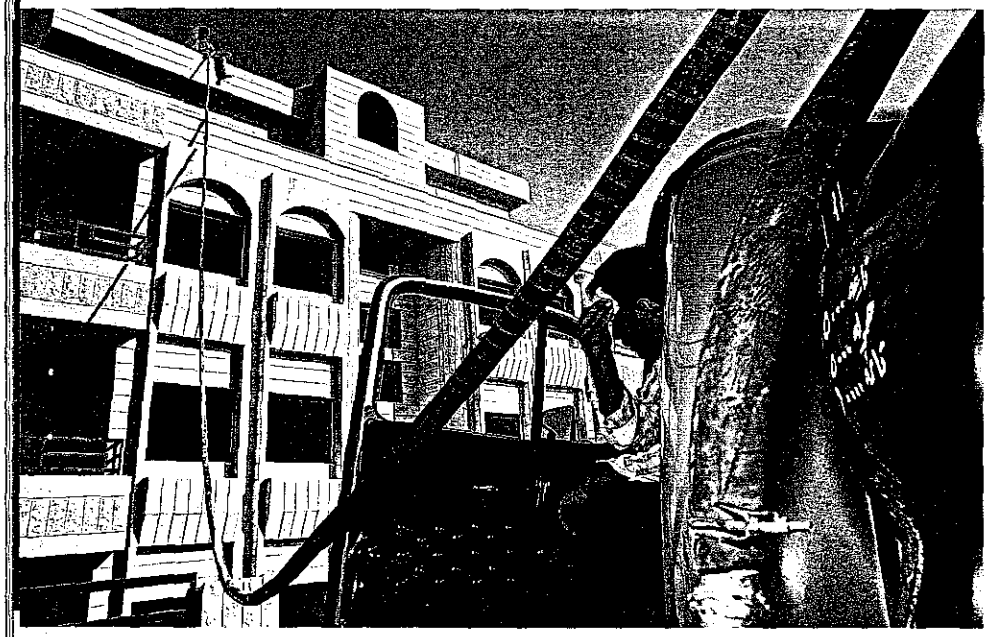
Agriculture now soaks up 73 percent of Jordan's water, but some hydrologists insist that water-poor nations must curb their farmers instead of investing in them. Says the University of Jordan's Elias Salameh, "We should take whatever we need for domestic purposes first, and then use the rest for irrigation, not the reverse. We have a crisis because we are not able to put enough investment into industrialization, so we rely on agriculture, which needs less investment and more water."

"If Israel didn't exist," Salameh allows, "we still would have scarcity in the future. The cake is the same size; we can't enlarge it."

In 1967 the Israelis shelled a joint Jordanian-Syrian dam site on the Yarmuk. Jordan and Syria's current effort to build the Unity Dam on the Yarmuk, to provide hydropower to Syria and more water for Jordan, has been stymied as well. Institutions such as the World Bank will not help finance the project as long as Israel objects to a diminished water flow. Now Syria has built some 20 small diversion dams on the sources of the Yarmuk, leaving even less for Jordan.

Jordanian water experts have been meeting with their Israeli counterparts for years, but the







loss of their water to an enemy eats at the pride of Jordanians. Jordan's King Hussein has said that water is such a volatile issue that it "could drive nations of the region to war." Abdullah Toukan, the king's science adviser, adds, "In this arid region water is life. Money may bring desalination plants, but the real solution remains the restoration of Jordan's rightful share of water."

The East Ghor Canal snakes down the Jordan Valley, radiating life as it flows, into a heat sink where oranges and bananas are grown year-round. Here the barley stands ripe and golden, and white polyethylene hothouses, nurturing melons, carnations, and tomatoes, shimmer under a consuming sun.

Near the Dead Sea, I drive past Mount Nebo, massive in the magenta haze to the east, the mountain where Moses stood and looked over the Jordan to the Promised Land, knowing he could never cross.

ISRAEL DEFINED ITSELF early as a nation seeking to reclaim the land from neglect. Arriving from Europe with memories of green fields and forest glades, the early Zionists toiled to reestablish a Jewish culture based on agriculture. They drained swamps and quickened the desert soil with irrigation.

■ **JORDAN: By the tank or by the can, Jordanians limit water consumption while their country endures the gravest shortages in the Middle East. In the capital, Amman, private truckers sell water for rooftop tanks, supplementing government rations. Near the Yarmuk River by the Syrian border, a mother sponges her son with rainwater from the family cistern.**

Since the early 1960s regional politics have stifled a plan to build a dam on the Yarmuk—and bring running water to surrounding villages.

"Go back a hundred years and you'll see that agriculture determined the borders of what is Israel," says Jacob Bear, professor of hydrology at the Technion, Israel's technological university in Haifa. "So we are still in a state of creation—establishing our borders—if not to say in a state of war."

Israel draws 65 percent of its renewable fresh water from two major aquifers—a limestone aquifer under the mountains and a shallower, partly saline one beneath the coastal plain, including the Gaza Strip. The rest comes from the Jordan River and its great storage basin, the Sea of Galilee. The Litani River in southern Lebanon

has been a temptation, especially since Israel established its security zone there eight years ago, but so far Israel has resisted tapping it.

Israel's major contribution to farming in arid lands has been the development of drip irrigation, bringing precisely the right amount of water to each plant through holes in plastic hoses, with minimal waste. Computerized automation has allowed such refinements as high-frequency pulse irrigation. Farmers have more than doubled their output in the past 20 years, with the same amount of water.

Such achievements prompt recent Israeli water commissioner Dan Zaslavsky to call the Middle Eastern water crisis a myth: "There are local and temporary shortages because it's not the highest priority of the countries involved; that's all, nothing else."

Zaslavsky's brave words belie a growing anxiety. Until the heavy rains of 1991-92 partially refilled aquifers, the government had cut agricultural use of water by as much as 30 percent. Now farmers have succeeded in pressing for a larger allotment. Says water expert Hillel Shuval of the Hebrew University of Jerusalem, "We are living in fear that there will be a return to the old, dangerous policies of overpumping aquifers to satisfy agriculture."

As the population soars with new immigrants, the search for alternatives has taken on urgency. Israel has pioneered in the use of recycled urban wastewater for agriculture; a project in Tel Aviv already generates enough to cultivate 20,000 acres of farmland, water that is pure enough for accidental drinking. The use of brackish water drawn from fossil aquifers is being developed in the Negev. Desalination for agriculture is still too costly, at least until other options run out, or until new technology brings down the price.

Some experts point out that desalination could be a mutual investment between nations. To meet the needs of Israel, Jordan, and the West Bank, for example, would require less than ten billion dollars. By comparison, the gulf war to free Kuwait cost Arab countries 430 billion.

THE ALON ROAD near Jerusalem leads through the wilderness of Judaea, where migrating storks pick their way through waves of wildflowers, and landslides of goats teeter on the ridges. With Israeli historian Mooli Brog I go to see the revived and roaring El Fawar mountain spring that in ancient times supplied winter palaces west of Jericho.

"The sound of the water," says Mooli, shaking his head. "I can't get over the sound. Since 1968 this has been nothing."

Until last year decades of drought and overuse had dried up many springs and wells in the West Bank, where agriculture is suffering. Palestinians, chafing under Israeli occupation, are convinced that Israel is to blame—that it takes more than its fair share of water and denies permits for new Arab wells.

Israelis point out that unlimited drinking water is available to everyone in the occupied territories, but neither Jew nor Arab can dig new wells for agriculture when the water table is so low.

The salient fact about the mountain aquifer is that its waters flow naturally, underground, toward its edges. They emerge as springs and wells in the foothills, in Israel proper. The mountains, much of the West Bank, cannot sustain intensive agriculture, in part because the aquifer is too deep for viable irrigation wells.

But water remains a point of rancor. In the Arab village of Marda, 25 miles east of Tel Aviv, I meet with Palestinian elder Shaher Khufash, who announces gravely, "Israel has stolen our water, and we are thirsty."

How? "They have dug a well on confiscated village land. And they are denying us this water."

Marda could tap into the Israeli state water system, as 250 other West Bank villages have, but it has declined. Its main water source now is a Roman-era well that shrinks deep in summer, leaving 50 steps for the women to climb.

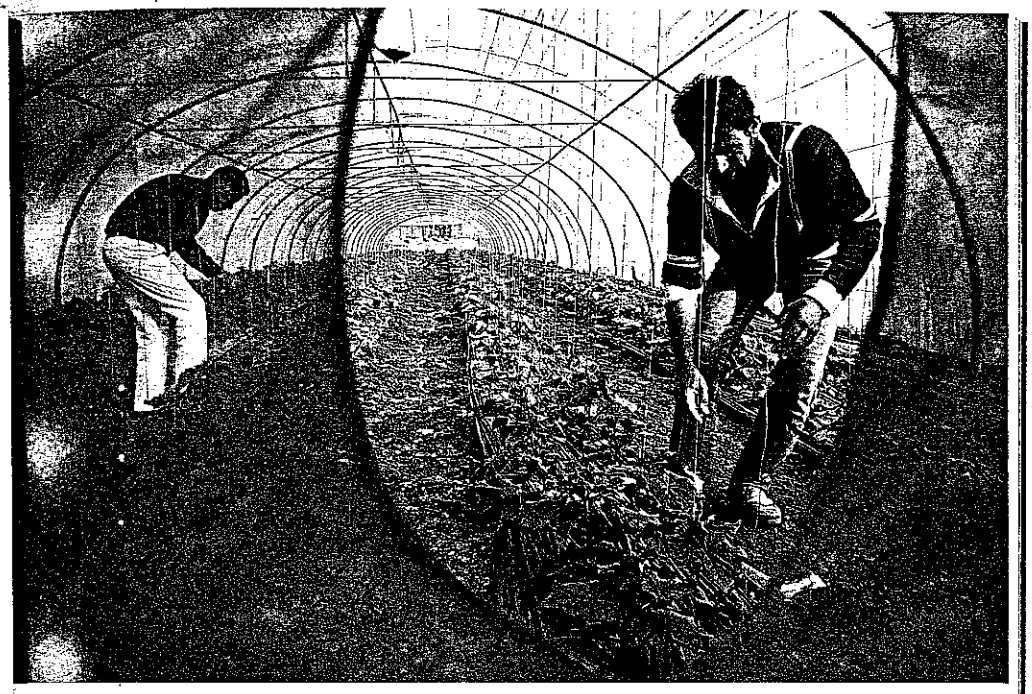
"This well is dangerous," says Khufash. "Four citizens have drowned in it."

Then why not hook up with the Israelis? Khufash rolls his worry beads carefully: "Doing so means accepting them and their confiscations. Also, they say we have to pay for the water then. The people refuse. They say, 'Why should we pay? The water comes from God.' "

In the Jewish settlement of Ariel, built along a mountain ridge that overlooks Marda, the young mayor, Ron Nachman, drives me around town in his new white Ford Scorpio. I tell him what I have heard from Khufash.

"It's pure Arab propaganda," he counters. "We tried to dig this well for the Arabs but got only mud. Hah! No one uses it. We get our water by pipe from the Sea of Galilee. But why don't Arabs build up themselves? Huh? Why not? I'll tell you why not. It's easier to sit and cry."

The mayor guns the car into the parking lot of the Ariel Hotel, with its swimming pool and palms. "Just like Las Vegas," he beams.



■ **JORDAN: An underground transfusion waters beds of cucumbers at a private greenhouse in Baqaa, near Amman. "We are saving about 50 percent of our water," says owner Abdelraouf el-Khatib. In 1978 he was among the first in Jordan to switch to a drip-irrigation system, watering plants through tubes in the ground; plastic sheets discourage insects and prevent water-guzzling weeds. Using the same method, he grows green peppers, tomatoes, and beans.**

Even Arab hydrologists point out that swimming pools are mere thimblefuls in the overall water volume. But pools and green lawns are red flags to the Palestinians, whose cultural resentment runs deep. Israel fears that if a new Palestinian state comes into existence on the West Bank, it might pursue a policy of deep, heavy pumping—not just to use the water but to deprive Israel. Politicians use the argument to resist Israeli withdrawal. Says one water expert, "Anybody, in my opinion, who would give away their water resources is simply mad, sick in the head."

On the road from Jericho to Tiberias on the Sea of Galilee, yellow mustard weeds wave in the ditches, and thistles spike the roadside. I can see Jordan across the river, with its mud-brick villages and spring grass sneaking up the hillsides.

At a Tiberias seaside restaurant I dine on St. Peter's fish from the Galilee, a primitive model of a fish, all scales and spines. The ample winter rains have swamped bushes along the shore. The cup of Galilee is full.

"The water problem is not a problem," says a local hydrologist, who declined to be named. "It's psychological and emotional. A hundred million cubic meters overflowed from the Sea of Galilee this year. If we had peace between Israel and Jordan, we might have developed 30,000 acres of land. Instead, the water goes into the Dead Sea."

Next day I visit the Jordan Valley Water Association, a private agency organized by area kibbutzim. Computers run the irrigation system through cables and radio. "The computer gets information from the fields, decides what pump to run and what valves to close or open," says engineer Gidi Sela. "Want to change levels? Just push a few buttons, and the valves of a holding tank five miles away open to admit water."

On one kibbutz, manager Zvi Rub tells me that 7,000 cubic meters of water per quarter acre were used for bananas each year when they were flood-irrigated. "When we started to drip-irrigate, we were down to 2,000 cubic meters," he says.



■ JORDAN: Old-style sluices flood a banana field 800 feet below sea level in the Jordan River Valley. Since the early 1960s the East Ghor Canal has channeled Yarmuk River waters to the country's main farming area. Now the Jordan Valley Authority is replacing ditches with a network of pressurized pipes and offering low-cost loans to farmers who make the switch to drip irrigation.

Meanwhile lack of water prompted the government in 1991 to limit irrigated lands to less than half the valley's capacity.



■ **WEST BANK: A swimming pool and an ancient well symbolize the separate worlds of two communities less than a mile apart. Ariel is home to 12,000 Israeli settlers; Marda numbers 1,500 Palestinians. Although the Israeli pool is not filled from local wells—but with water piped in from the Sea of Galilee—to the Palestinians it stands as a bitter reminder of their treatment under Israeli rule. The Israelis, they say, have confiscated the land and stolen their water.**

"But aren't bananas still uneconomical?" I ask, remembering a vagrant statistic that a banana costs more to grow in Israel than to import from, say, Honduras. "If you only want to consider economics, you can close down agriculture," Rub said, voicing the Israeli reverence for the soil, "and you can close down the country."

I FLY FROM TEL AVIV TO CAIRO, arriving at night into a chaos of smoke, dust, and whirling traffic. My taxi, with one tire flat and no lights, rattles the wrong way up the down ramp of a major freeway and at last deposits me at the hotel door.

Egyptians have always huddled around the green tendril of the Nile, clinging to it as if to a rope, afraid to let go. Only along the coast and in the Western Desert have they strayed, gathering around oases. But for most Egyptians the desert is as alien as the sea; they are the people of the river. They do not think of themselves as desert Arabs.

Yet to feed a projected 25 million more people by 2010, Egyptian authorities say they must yank a sizable population from its river roots and replant it in the desert. They also need to make better use of the Nile's gift—recycling its waters for multiple use—and to pump water from aquifers.

In the office of the Egyptian Water Research Center, chairman Mahmoud Abu-Zeid says that the nation now depends almost totally on the Nile: "Every inch of this very narrow strip on both sides of the Nile is cultivated twice, sometimes three times a year."

The Nile drains eight other nations: Ethiopia, Sudan, Tanzania, Uganda, Kenya, Zaire, Burundi, and Rwanda, more than 10 percent of Africa. It flows into the Nubian Desert of Sudan and gathers behind Egypt's Aswan High Dam, which has given Egypt's farmers security from destructive floods and drought since its completion in 1971.

Egypt has seldom been challenged for Nile water, but other nations in the catchment will soon need more water for agricultural and power projects. Egypt has organized discussions between riparians—a forum called the Undugu Group—and has made a compact with Sudan for a stable Egyptian quota of 55.5 billion cubic meters a year at the High Dam. But Ethiopia, source of 85 percent of the headwaters, is not a party to the Undugu talks. It has threatened to build its own hydropower dam, rattling nerves in Cairo.

The brutal civil war in Sudan has sidetracked one key water scheme—the Jonglei Canal that was to drain Sudan's southern swamps and provide Egypt and Sudan each with two billion more cubic meters of water a year.

Says Abu-Zeid, "Egypt is not a water-rich country any more. Beyond 2000 our water budget is very dark and very serious."

The next day I fly to the town of Aswan, in southern Egypt, where the daily furnace stokes up by 7:30, and the color bakes out of sunsets. From the Aswan High Dam, Lake Nasser spreads south as if floating on the heat. A hundred twenty million tons of silt settle yearly behind the dam, silt that once replenished the banks and built the Nile Delta. To compensate, farmers have had to increase their use of fertilizer, which contributes to water pollution. But the High Dam has kept its short-term promise. In the years of drought before the previous winter's ample rains, Lake Nasser kept Egyptian agriculture stable and the economy from collapse.

Aswan is the southern terminal for 200 river tour boats. I take a three-day trip down the Nile, visiting monuments, breathing the fresh staleness of life unchanged for millennia. Islands thick with grain and fruit trees quiver with reedy growth, and fellahin till the soil among date palms. The river pulses north, generous to those who trust it. Soil breathes, life appears, man struggles. Time flickers past.

The new Egypt that wants to grow into the desert must tear itself away from this nostalgia. History complicates its mission. The British, who occupied Egypt from 1882 to 1922, discouraged most Egyptians from the desert.

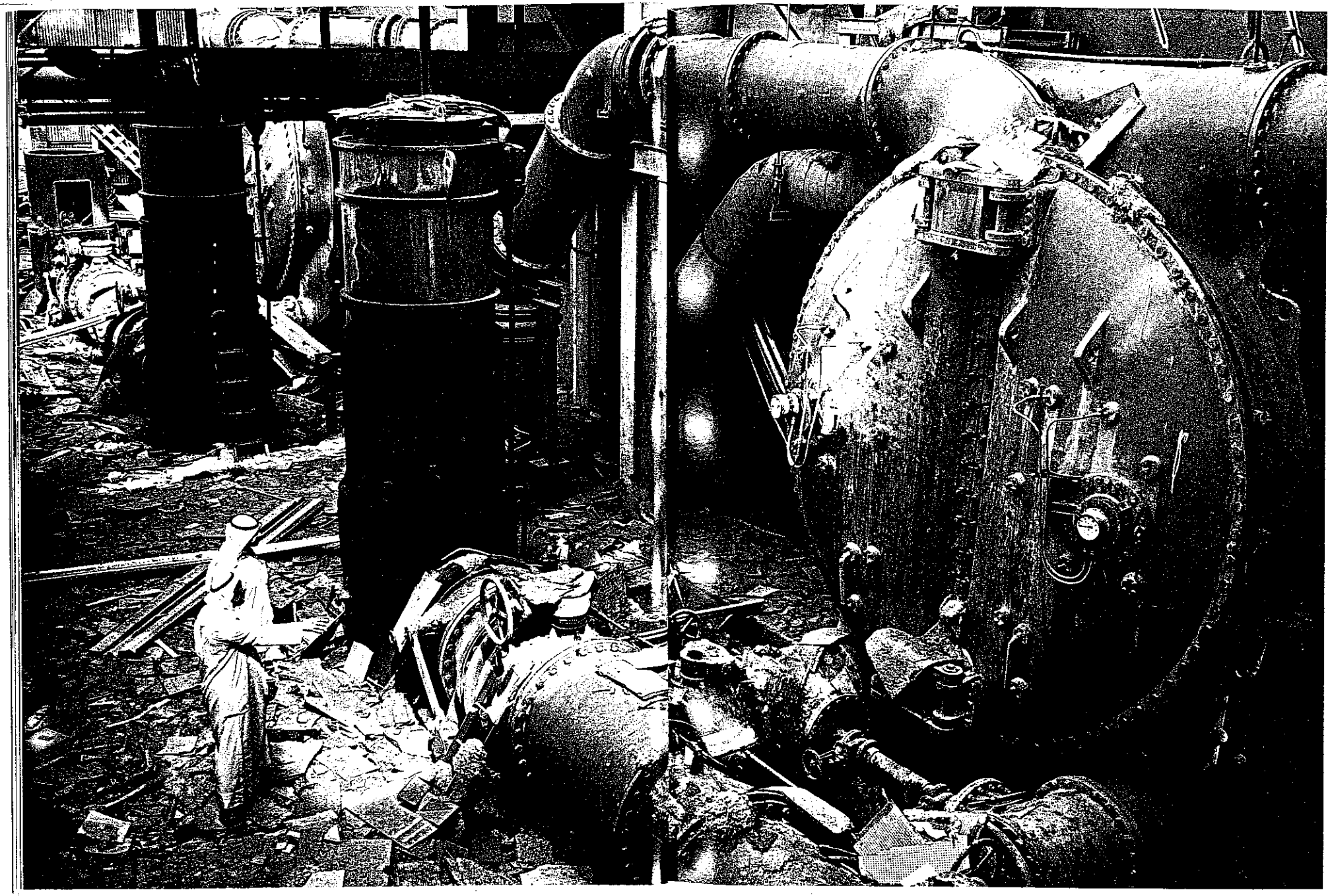
At the Water Research Center in the delta town of El Qanatir, I speak to Bahay Issawi, former director of the Egyptian Geologic Survey. "The British tried to separate valley dwellers and Bedouin, to keep barriers between us," he says. "The desert is full of genies and dangerous things, they said. We Egyptians inherited the idea, without knowing why. In 1965 I still needed a permit to go into Bedouin territory. That policy held Egypt back for a long time from Sinai."

Now, in a "new lands" program, Egypt offers young people livestock, money, and virtually free water to farm the desert. Thousands have accepted. The aquifers that could sustain agriculture in the Western Desert and in Sinai have been identified and drilling programs begun.

In addition, the 103-mile El Salam, or Peace, Canal will soon channel Nile water under the Suez Canal and along the Mediterranean coast to the North Sinai Project near El Arish. This could add 400,000 acres to cultivation.

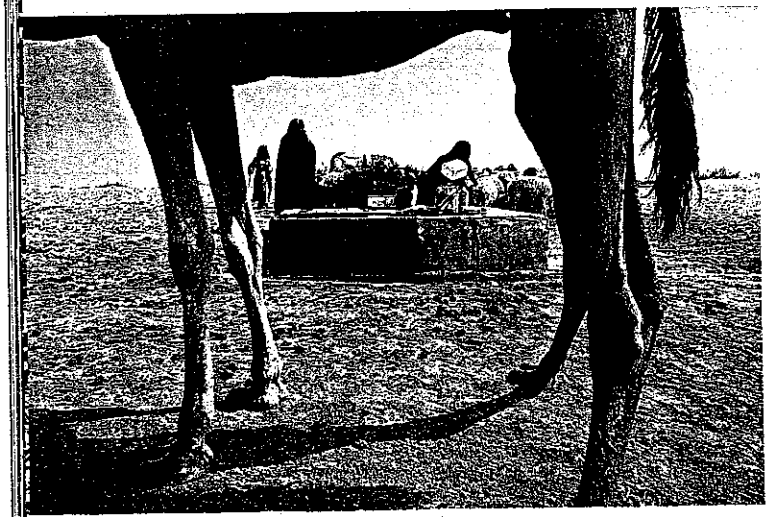
The land is cheap, but too many of the pioneers in the new lands have been wealthy investors, not the young farmers the government wants to encourage. And those who grow staples in the Egyptian desert find that five acres of irrigated desert will grow only as much as half an acre of river bottomland.





■ KUWAIT: "It was like a heartbeat when they were all going, and now it has stopped," a former technician told the author at the wrecked Shuwaikh power and desalination station in Kuwait City. Iraqi soldiers destroyed the station, Kuwait's oldest, in February 1991 as they retreated during the gulf war.

With no rivers and limited groundwater, Kuwait and other gulf states increasingly count on seawater converted at oil-powered stations. Shuwaikh's fate underscored the stations' vulnerability to enemy attacks.



■ **EGYPT: Far from the Nile, Bedouin in the Sinai desert stock up on river water along El Arish pipeline. The hundred-mile line is part of a plan to lure Egyptians from the teeming banks of the river, where a girl fetches water. Just 22 years after the Aswan High Dam ushered in an era of water abundance, Egyptians are asking: Will there be water for the next generation?**

The Nile Delta blossoms like a peony on the stem of the Nile, watered by a network of canals that flood the alluvial earth. I drive along the "farm road" north from Cairo in the early morning, passing horse-drawn wagonloads heading to city markets, shaggy with onions, lettuce, and emerald green berseem clover.

Farmers in the delta have been accused of wasting water by flood irrigation—letting water run onto the fields until they are soaked. But recent studies seem to vindicate them. To properly leach the soil and to keep intact the powerful underground pressure against seawater intrusion, much fresh water must be sunk into the delta.

The key to conservation here, scientists say, is to intercept drainage water for reuse just before it goes into the sea. Twelve billion cubic meters of drainage water, six times the water budget of Israel, once flowed into the Mediterranean each year. Egypt already recycles almost two billion cubic meters of that water. By lining irrigation canals with plastic and by capturing water underground with drain systems, Egyptians hope to salvage five billion more.

Today the water sometimes falls short. On the roadside I talk to farmer Hassan Ibrahim Ghazy, a gaunt, dark man whose face seems squeezed below his turban. He is harvesting garlic in the culverts. "Sometimes I can't get water," he complains. "I'm at the tail end of the canal. Also, the water I get is polluted. There are many villages and many donkeys and ducks between me and the beginning."

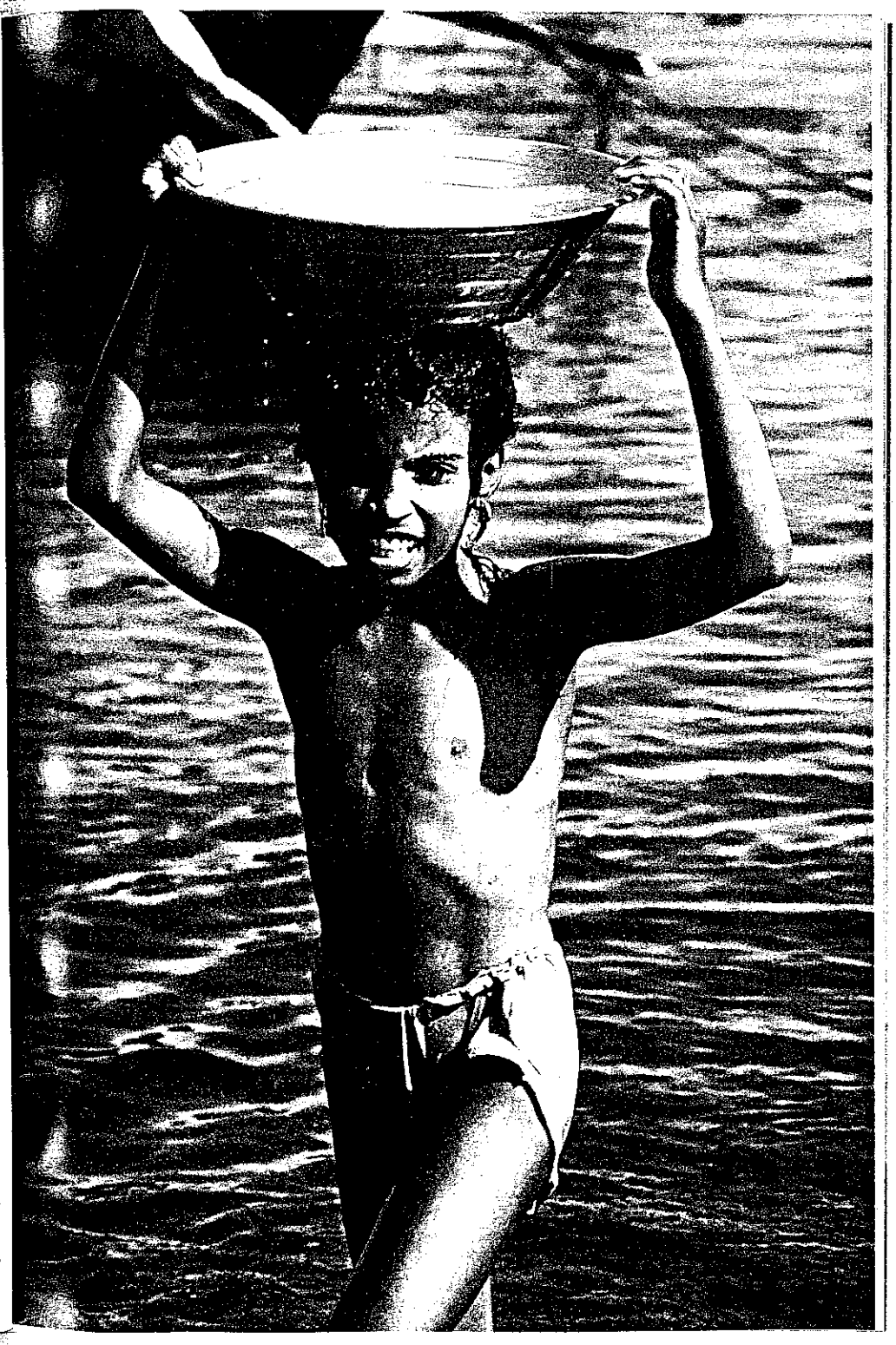
He shifts uncomfortably. "But now I must go do my work. Our son died. He was the strong one. He died of schistosomiasis"—caused by parasites in stagnant water.

On the way back to Cairo diesel pumps along the roadway sputter and crack like artillery, and I must look hard to find a *saqia*, the traditional irrigation wheel turned by an ox. In the old way the animal is blindfolded with a thick pad of cloth. "Otherwise, he will get dizzy and fall down," explains a woman nearby. The beast moans in its yoke, plodding nowhere, but as it turns the wheel, water trickles into the culvert to spread among the clover. And then the trickle passes to the sea, from which all life has come.

"THE FUTURE of the human race is the sea," former Israeli water commissioner Meir Ben-Meir told me, preaching desalination. "The water problem will be solved if we are willing enough, patient enough, clever enough."

In my journey through the Middle East I found much cleverness, little patience, but a growing will. Ancient angers burn; flash points over water rights still smolder. And yet, most nations will concede that water is a mutual, interconnected need. They know that the quest for water, life itself, could foster peace as easily as warfare.

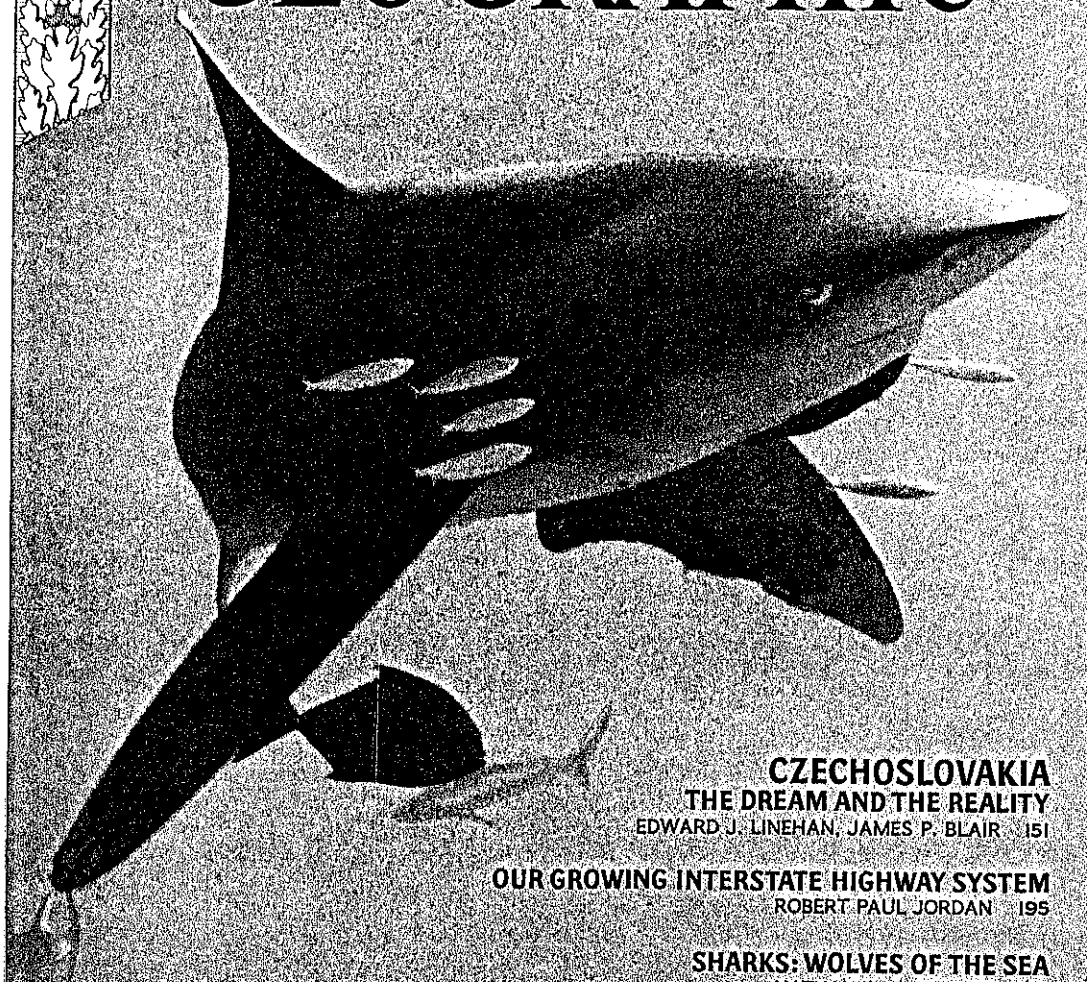
Now minds must be changed, biases curbed, and brotherhood kindled in this infertile crescent. Water must be understood as a resource, not just taken as a gift from God. □



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OFFICIAL JOURNAL OF THE NATIONAL GEOGRAPHIC SOCIETY WASHINGTON, D. C.

SHARKS

By NATHANIEL T. KENNEY
National Geographic Senior Staff

BARING RAZOR-SHARP TEETH, a [illegible] *hammerhead prowls off Key Largo, Florida. Placement of eyes and nostrils on the ends of lobes, coupled with the head's swiveling maneuverability, broadens this shark's food-sensing swath through the sea. The flattened head, like an airplane's wing, aids maneuverability* (painting, page 232).

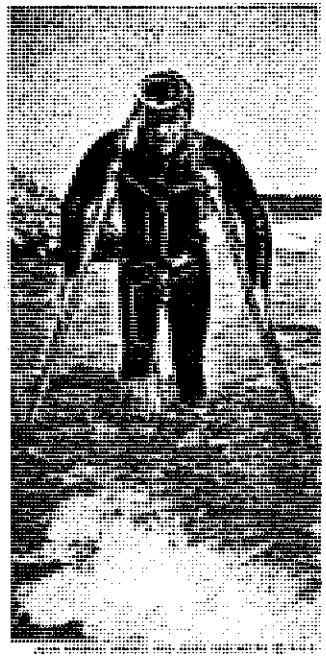
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Wolves of the Sea

IN MASK AND SNORKEL I was diving in 15 feet of water off the western shore of North Bimini, tiny Bahama island. A jumble of coral-encrusted boulders lies on the bottom sands at this point; among them dwell thousands of brilliantly colored small fishes.

One moment I was surrounded by these vivid jewels of the warm salt seas. In the next I was uneasily alone, for my small friends had all dashed for shelter into crevices in the rocks or to concealing jungles of grass and sea fans. Turning seaward to discover what had alarmed them, I saw a shadow in the depths grow into an eight-foot-long torpedo headed directly at me.

Some 20 feet away it turned broadside. An eye the size



Heroic photographer, Australian Henri Bource, who lost a leg to a shark in 1964, still films the marine world with the aid of a special flipper; crutches take him through shallows.

Other equally daring diver-cameramen risked their lives to make the spectacular photographs illustrating this article: Jerry Greenberg and Burton McNeely of Florida; Peter Gimbel of New York; and Ben Cropp, Ron Taylor, and John Harding of Australia. In warm seas and cold throughout the world, they spent countless hours beneath the surface, capturing some of the finest action portraits ever published of the sea's most dangerous and mysterious predator.

As if oblivious to human intruders, a whitetip shark—a species known to attack man—cruises in formation with banded pilotfish. Swimming in Tongue of the Ocean, a mile-deep trough in the Bahamas, diver Donald R. Nelson arms himself with a stout four-foot pole; a stainless-steel barrel at its tip houses a waterproof 12-gauge shotgun shell. Should the seven-foot shark threaten him, Dr. Nelson would jab the muzzle against its head, triggering the firing pin.

of a quarter inspected me from head to toe. Then, with sinuously graceful movements of body and tail, the monster returned to the open sea, never varying its serene cruising speed. Popping to the surface, I also returned whence I came—to the solid, sunny beach. I moved at something better than cruising speed.

I had met a shark, and if the encounter was dull theater, it was meaningful, and I have chosen it deliberately as the opening incident of this article. For in the overwhelming majority of meetings between these fearsome carnivores and humans who enter the sharks' domain, the sinister predators cruise on past.

Equally important: One must not count on it. Any moment the time may come when one of the enigmatic creatures will attack a man.

Results can be gruesome. Razor-edged teeth may remove an arm or leg or cleanly take out a 10-pound piece of flesh. Hide rough as a rasp can flay, edges of fins and tails cut like swords. A shark is all lethal weapon.

Cars Pose Bigger Threat Than Sharks

And what are the odds for or against your becoming a target for a shark's armament next time you go to the beach? To this most important question of all, the experts cannot give a completely satisfactory answer. You have only the assurance that the odds are long—perhaps millions to one—in your favor.

Since 1958 the Smithsonian Institution of Washington, D. C., has been custodian of a shark-attack file on an international scale. Senior Zoologist Leonard P. Schultz, in charge of the file, believes it to be far from complete.

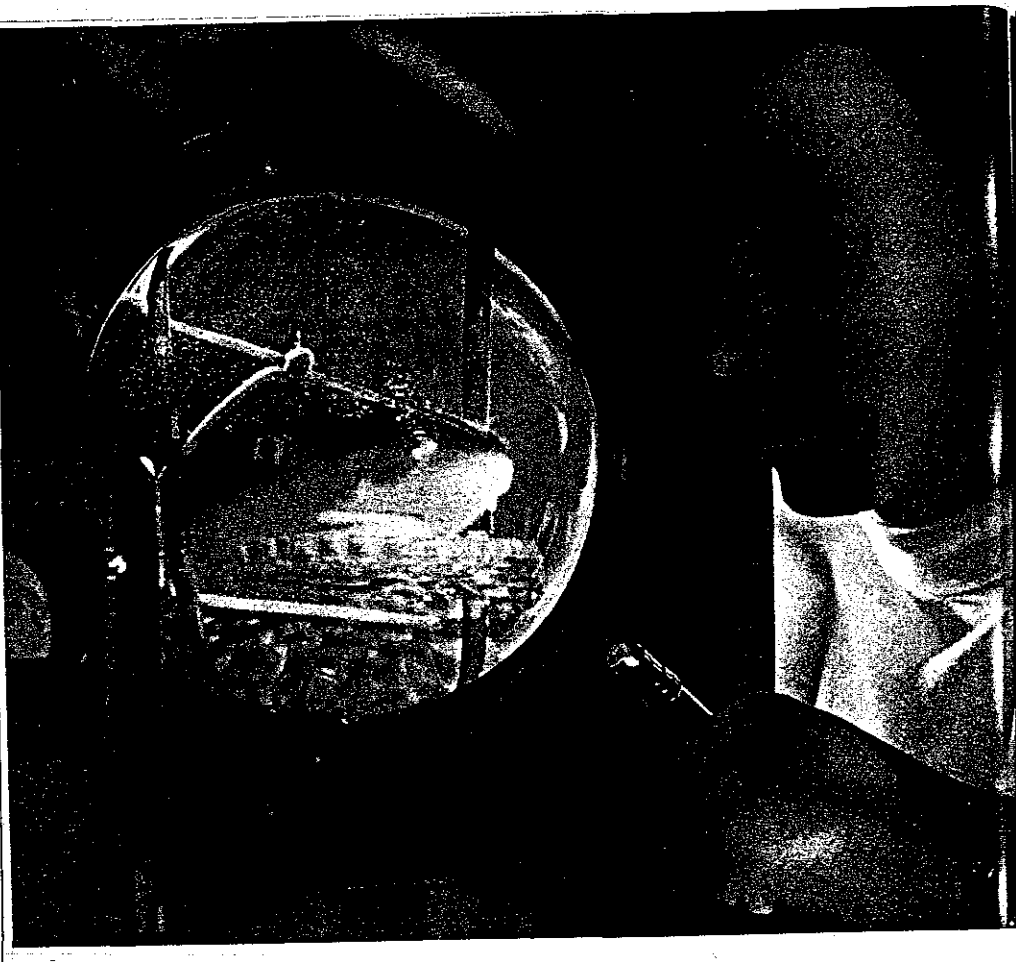
"Faraway primitive peoples do not compile statistics," he explains, "and seaside resorts don't overexert themselves publicizing incidents that could plunge them into bankruptcy."

From the evidence of the file, plus the personal opinions of experts to whom I talked during a year of studying sharks in many parts of the world, I would make an educated guess that in a normal year sharks kill or maim not less than 40 or more than 300 people, without apparent provocation by the victims. In times of war at sea or major marine disaster, the toll undoubtedly rises.

Thus you can go into the sea—any principal sea or ocean, for the shark lives in them all, plus many rivers and a few fresh-water lakes—with far less risk than you run every time you take a trip in an automobile. You will also hear that lightning is a greater danger than shark bite, and the figures of about 150 lightning deaths a year in the United States alone, plus several hundred injuries, support the statement.

You must not, of course, provoke a shark into attacking—not even the small, slow species frequently encountered in coastal waters. If you step on one of these or tweak its tail, it can—and often will—bite hard.

Despite the odds against unprovoked attack upon us, we attach a sinister mystique to the shark. The sight of a gray fin in the surf, even the rumor that somebody has seen one, brings unreasoning panic. Add, on a more





KENROME (ABOVE) AND KODACHROMES BY JERRY GREENBERG © N.G.S.

impersonal level, the shark's inroads on commercial and sport fisheries, and you have a malefactor of some consequence. But it was not until fairly recently that science organized to study sharks and seek ways of controlling them.

Disasters at Sea Spur Shark Research

Blood-chilling mass attacks on survivors of torpedoed ships and crashed airplanes in World War II gave the initial impetus to the search. After the war, interest in sharks not only increased but broadened: We not only wanted to know how to protect swimmers and divers; we also sought an insight into the undoubtedly large part sharks play in the ecology of the seas.

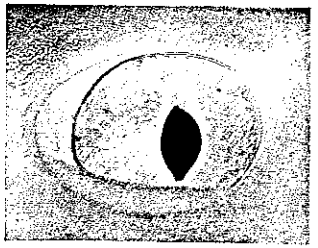
The postwar human population explosion spurred this interest in sharks. One day, we realized, earth's soil might no longer support us all, and we must exploit the waters—71 percent of the world's surface—or perish.

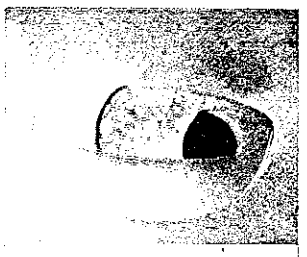
Divers in unprecedented numbers began searching the depths for oil and metals and ways to farm the oceans, in which are locked vast quantities of protein yet to be tapped; some worked from self-contained sea bottom communities pioneered by Edwin A. Link, the U. S. Navy, and Jacques-Yves Cousteau.*

Encounters with sharks became everyday occurrences. Plainly, more knowledge of the fish was needed. In 1958, the American Institute of Biological Sciences, Washington, D. C., agreed to meet the challenge. It offered to serve as an international clearinghouse and repository for shark knowledge, and formed

*See, in the GEOGRAPHIC: "Working for Weeks on the Sea Floor," April, 1966, and "At Home in the Sea," April, 1964, both by Capt. Jacques-Yves Cousteau; and "Outpost Under the Ocean," April, 1965, by Edwin A. Link.

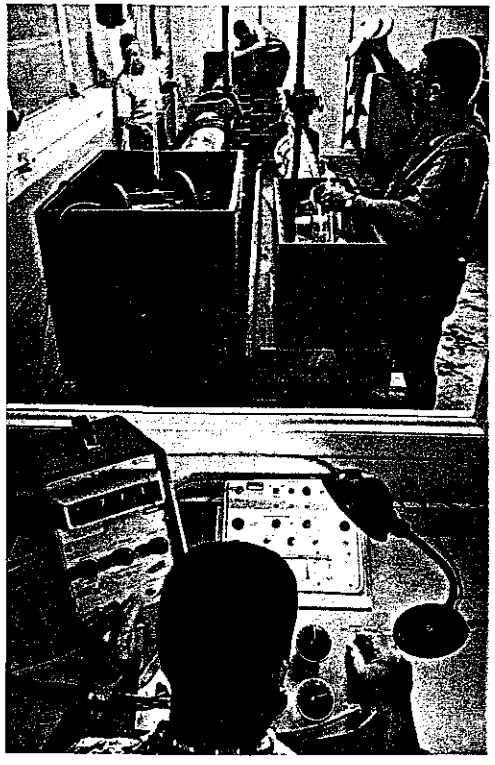
Testing the vision of a young lemon shark, research assistant Samuel Gruber of the University of Miami's Institute of Marine Sciences employs an ingenious apparatus that he devised. The shark is lashed down in a tank of circulating water, its nose fitting into a Plexiglas hemisphere. At intervals the lamp at right flashes filtered light of varying color and intensity; at the same time a mild electric shock causes the fish to blink. Eventually, the shark becomes so conditioned that it blinks when only the light is flashed, an indication that it can see that particular color or level of light. Utilizing this approach, scientists hope to determine whether sharks distinguish colors. The knowledge would be invaluable in designing garments and gear for use in the open sea.

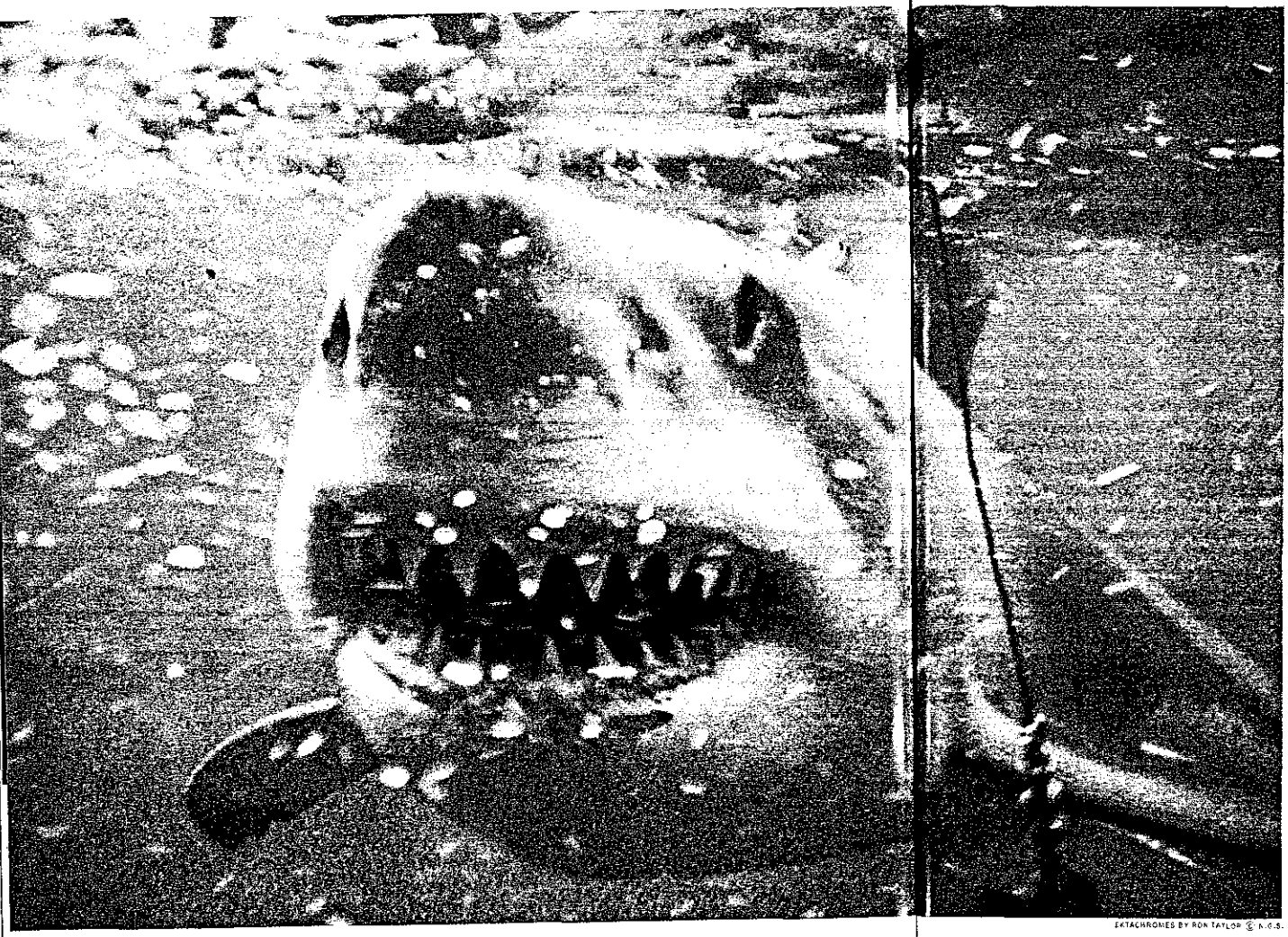




With a blink—the upward movement of a nictitating membrane that serves as an eyelid—the lemon shark responds to a shaft of light. Infrared detector enables scientists to observe each "wink" during the experiments in a darkened testing room at the institute. As the shark's eyes gradually become adapted to the darkness, its pupils begin to expand (right).

How sensitive is a shark to sound? It can hear moving objects in the water at a greater distance than it can see them, tests on young lemon sharks reveal, and its ability to locate the source of the sound is highly developed—vital to a predator (diagram, pages 230-31). A scientist at the institute prepares to place a live specimen in a water-filled tube into which sounds will be projected from the electronic equipment in foreground. Conditioning the shark with electric shocks, the researchers learn what frequencies the fish can hear and its degree of sensitivity to sounds.





EKTACHROMES BY RON TAYLOR © N.G.S.

Rapacious ruler of the jungle deep, the great white shark is often called simply "man-eater." Leaning overboard from an Australian fishing boat and submerging his camera, Ron Taylor made this rare portrait of a 12-foot great white. Bait line dangles beneath the vessel at right.

Fangs of death: The great white moves its upper jaw forward when seizing prey. Like all sharks, it has reserve sets of teeth behind the outer row. When the creature loses teeth, new ones begin to work forward into place within 24 hours.

the Shark Research Panel for that purpose.

Dr. Perry W. Gilbert, Professor of Neurobiology and Behavior at Cornell University and probably the foremost American authority on sharks, is chairman of the panel. Other members are Stewart Springer, Biologist, U. S. Bureau of Commercial Fisheries; Dr. John R. Olive, Executive Director of AIBS; Dr. Sidney R. Galler, Assistant Secretary for Science at the Smithsonian; Dr. Albert L. Tester, Senior Professor of Zoology, University of Hawaii; Deane Holt, Biologist, Office of Naval Research; and Dr. Schultz.

Military funds still largely support the work of the panel, and consequently it devotes considerable effort toward finding ways of protecting shipwrecked sailors or airmen against sharks. Obviously, you begin such a quest by noting that a shark is a predator and normally attacks for food. In a way, it is like a wolf.

"A shark is an opportunist," Perry Gilbert said. "It frequently hunts the weak, the old, the stupid, and the crippled. Like any predator, it may improve the prey animals by taking misfits out of the breeding stock.

"In the shark's case, the prey animals often are weakened fishes. Thus a man in the sea should avoid appearing like a crippled fish."

And how does a crippled fish attract a shark? I asked Dr. Warren J. Wisby, then with the University of Miami's Institute of Marine Sciences, now Director of the National Fisheries Center and Aquarium planned for the Nation's Capital.

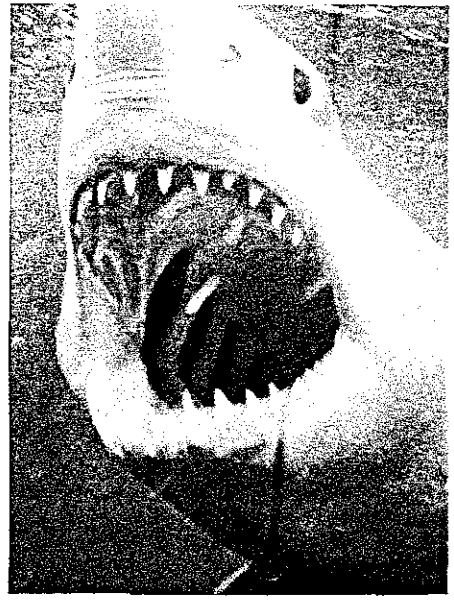
"Obviously, if the fish is belly-up," said Dr. Wisby, "the shark can see that something is wrong with it. But from far beyond visual range, other shark senses can pick up distress signals.

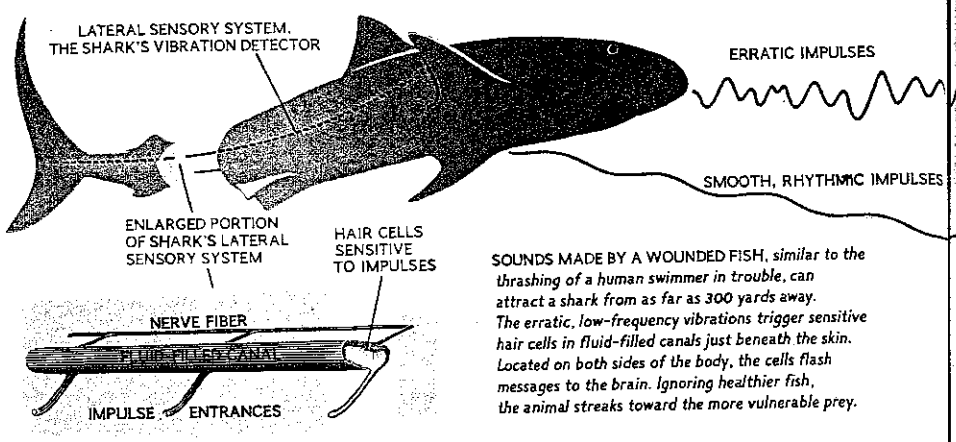
Thrashing May Whet Shark's Interest

"Low-frequency sound or pressure waves interest sharks, which have adequate hearing as well as pressure sensors, called the lateral line system, running the lengths of their bodies [next page]. Swimming motions, of fish or of man, generate low-frequency vibrations, and I suspect that sharks almost always become curious as to their source.

"If the sound is rhythmic and regular, denoting normal swimming activity, a shark's appetite may not be unduly aroused, and the predator may go on its way. If, however, the noise is something out of the ordinary—jerky, or thrashing, or struggling—then the shark may sense easy prey and follow it purposefully.

"We put the sounds of wounded fish and thrashing swimmers on tape and played them in the sea off Florida. From a plane I saw sharks





SOUNDS MADE BY A WOUNDED FISH, *similar to the thrashing of a human swimmer in trouble, can attract a shark from as far as 300 yards away. The erratic, low-frequency vibrations trigger sensitive hair cells in fluid-filled canals just beneath the skin. Located on both sides of the body, the cells flash messages to the brain. Ignoring healthier fish, the animal streaks toward the more vulnerable prey.*

KODACHROME BY FRED WARD, BLACK STAR © N.G.S.



Cruising lemon shark at the Lerner Marine Laboratory on North Bimini Island circles Dr. C. Scott Johnson, testing a "survival sack" of his own design. Attached to a life jacket, the plastic bag can be quickly inflated.

cease whatever they happened to be doing to home on the sound.

"They came in several instances from 300 yards. Had we continued the tests, I believe we would have found they heard the sound from far greater distances."

How else does a wounded fish tempt shark appetites?

"It bleeds," said Stewart Springer. "A small amount of blood attracts sharks from afar, especially from down-current. They have extraordinarily sensitive noses."

Following blood trail or sound, the shark approaches to within sight distance of a possible meal. It circles cautiously, gradually narrowing the circles. Eventually, if still alone, it bumps the object with its snout. A bite comes next, delivered with a savage shaking of the head. The rest is mayhem.

This is the normal feeding pattern of a lone shark. If other sharks appear, all may short-circuit the pattern, attacking in a competitive rush without the preliminaries. As feeding continues and the blood and flapping stimuli increase, the sharks become wildly excited and snap at anything they encounter, including other sharks.

One species of shark is a cannibal even before it is born. The eggs of the sand tiger hatch within the uterus, where the young remain until they are sufficiently developed to enter the ocean. The first baby hatched feeds on its weaker brothers and sisters as they emerge from other eggs. As there are two separate uteruses, two young sand tigers survive to be born.

This is the only known case of intra-uterine cannibalism in the animal world. Stewart Springer discovered the remarkable process the hard way: As he was examining a pregnant shark, an unborn baby bit his hand!

Violent habits might not make sharks welcome at a swimming party, but the creatures do have their uses. Generations of premedical students of comparative anatomy, for example, have studied spiny dogfishes, small sharks that are cheap and readily obtainable.

Being boneless, dogfishes and other sharks are easy to dissect. Not as complex as mammals, they provide simple diagrams of features and processes common to many life forms.

Sharks Have Cancer Shield

Scientists now believe sharks to be resistant to cancer and less prone than human beings to heart diseases and other major ailments. At the University of Miami School of Medicine, Drs. L. William Clem and M. Michael Sigel, collaborating with Dr. Parker A. Small of the National Institutes of Health, discovered that sharks possess only one class of serum antibodies.

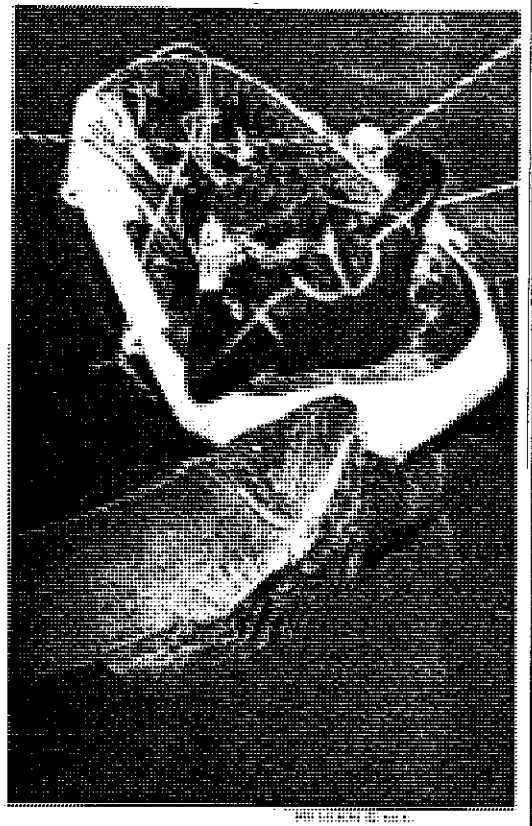
These are like the ones a human infant produces to protect itself against disease, and which adult humans make in comparable quantity only when afflicted with certain blood cancers. It could be of importance to learn how sharks synthesize such high levels of these proteins.

Through studies of shark blood, livers, and brains, Drs. David P. Rall and Richard H. Adamson of the Federal Government's National Cancer Institute seek knowledge of the machinery by which sharks detoxify cancer-producing agents in their bodies. Other researchers look for this process in various organs, such as the kidneys and gills.

(Continued on page 237)

Nudging a rubber raft in the narrow shark channel at the Miami Seaquarium, a bold lemon shark risks a rude reception. The craft holds an electronic repellent under test by inventor John Hicks. When he activated the device, Hicks says, it emitted shocklike radio waves that sent the shark fleeing. Later trials in the Atlantic reportedly caused large hammerheads to retreat hastily when they came within range. Other tests ended less conclusively.

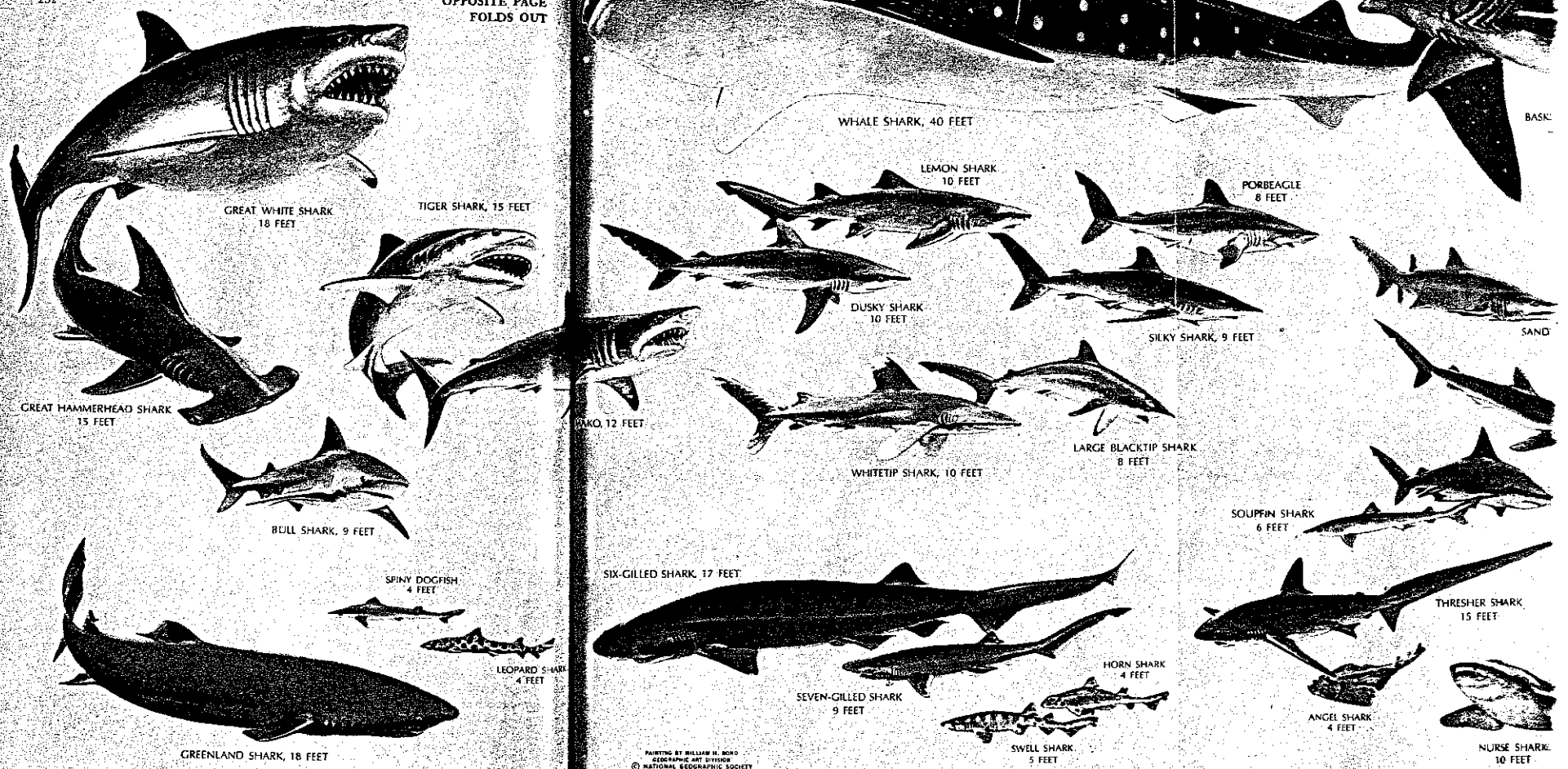
The United States Navy has long endeavored to develop an infallible shark repellent to protect seamen adrift in infested waters. Chemical-dye clouds have been the most widely used but have not proved satisfactory. Scientists today are optimistic about development of a new



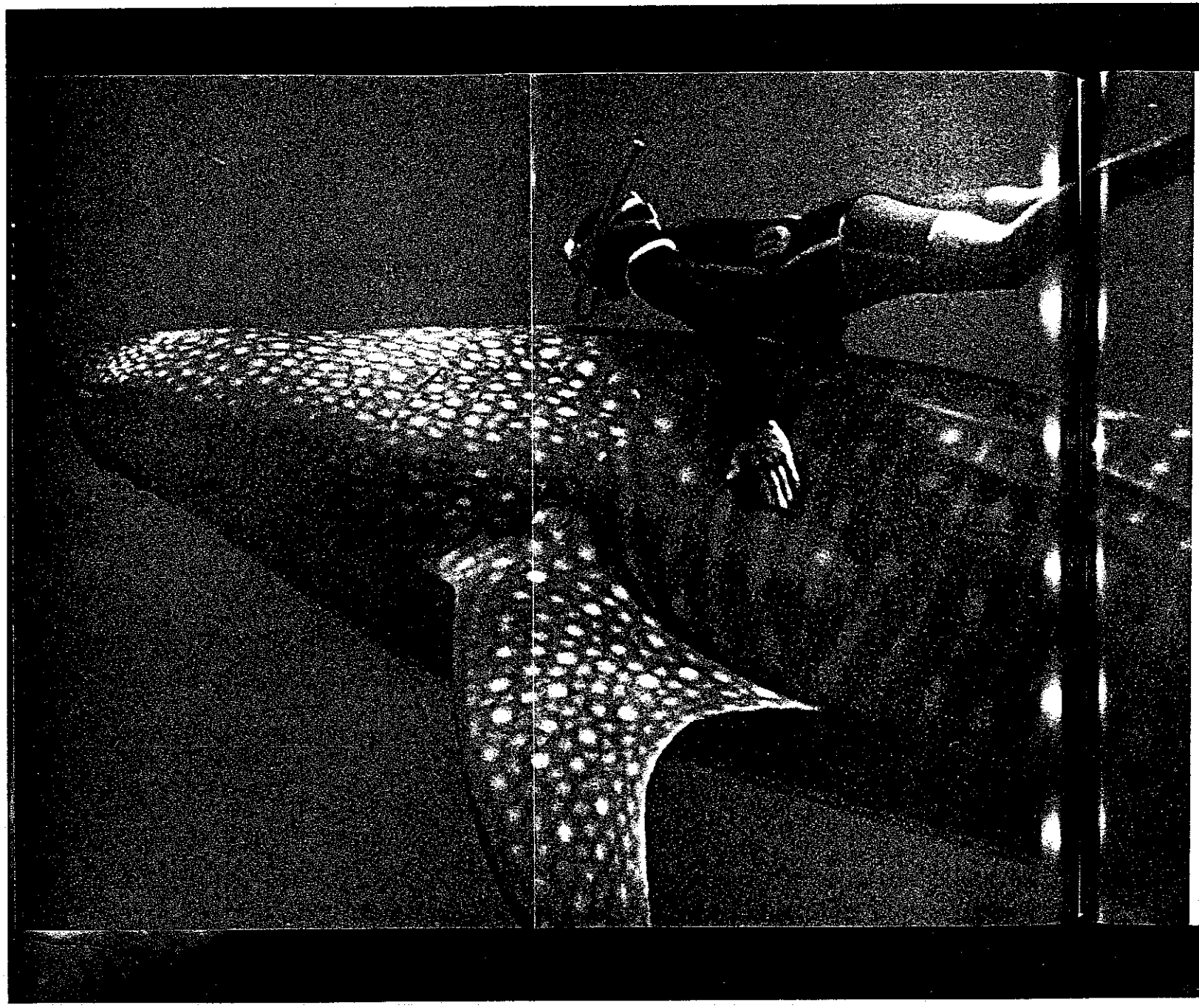
device, the survival sack (opposite), which is scheduled for tests in the fleet. Three air-filled rings, colored yellow for visibility, buoy the six-foot-long bag, called Shark Screen.

Ferocious yet fascinating, the sharks in this rogues' gallery comprise 27 of the more than 250 species, including nine known man-eaters: great white, bull, tiger, great hammerhead, lemon, whitetip, mako, dusky, and blue. Oddly, the whale shark, the biggest of all, and the basking shark, second largest, dine on plankton and small fish. Four possibly dangerous sharks—porbeagle, Greenland, six-gilled, and seven-gilled—offer little threat because they inhabit very cold or very deep waters. Large blacktip, sand tiger, sandbar, silky, and thresher show a preference for fish as food. Nurse shark has small, powerful jaws but seldom attacks. Wing-shaped pectorals, not a sweet disposition, inspire the angel shark's name. Experts regard other species shown here as too small or sluggish to be classed as dangerous. All sizes are average adult lengths.

OPPOSITE PAGE FOLDS OUT



PAINTING BY WILLIAM H. BOND
GEOGRAPHIC ART DIVISION
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Finned hitchhikers waiting to dine on scraps, rem
a whale shark. With a cavernous mouth almost as
shark gulps down great loads of small fish and plankto
organisms with sievelike gill rakers and hundreds o

Human hitchhiker clings to the 35-foot whale shark
Australian waters. Straddling a shark or hanging
exhilarating, but the Shark Research Panel of the
Biological Sciences labels the sport "dangerous and
hide and sharp fins of even the docile whale shark c

Wondering why sharks' hearts gave their own
Dr. Kjell Johansen of the University of Washi
one summer meticulously charting the vascul
Coast species, keeping his anesthetized subjects
designed respirator that fed water to their gills.
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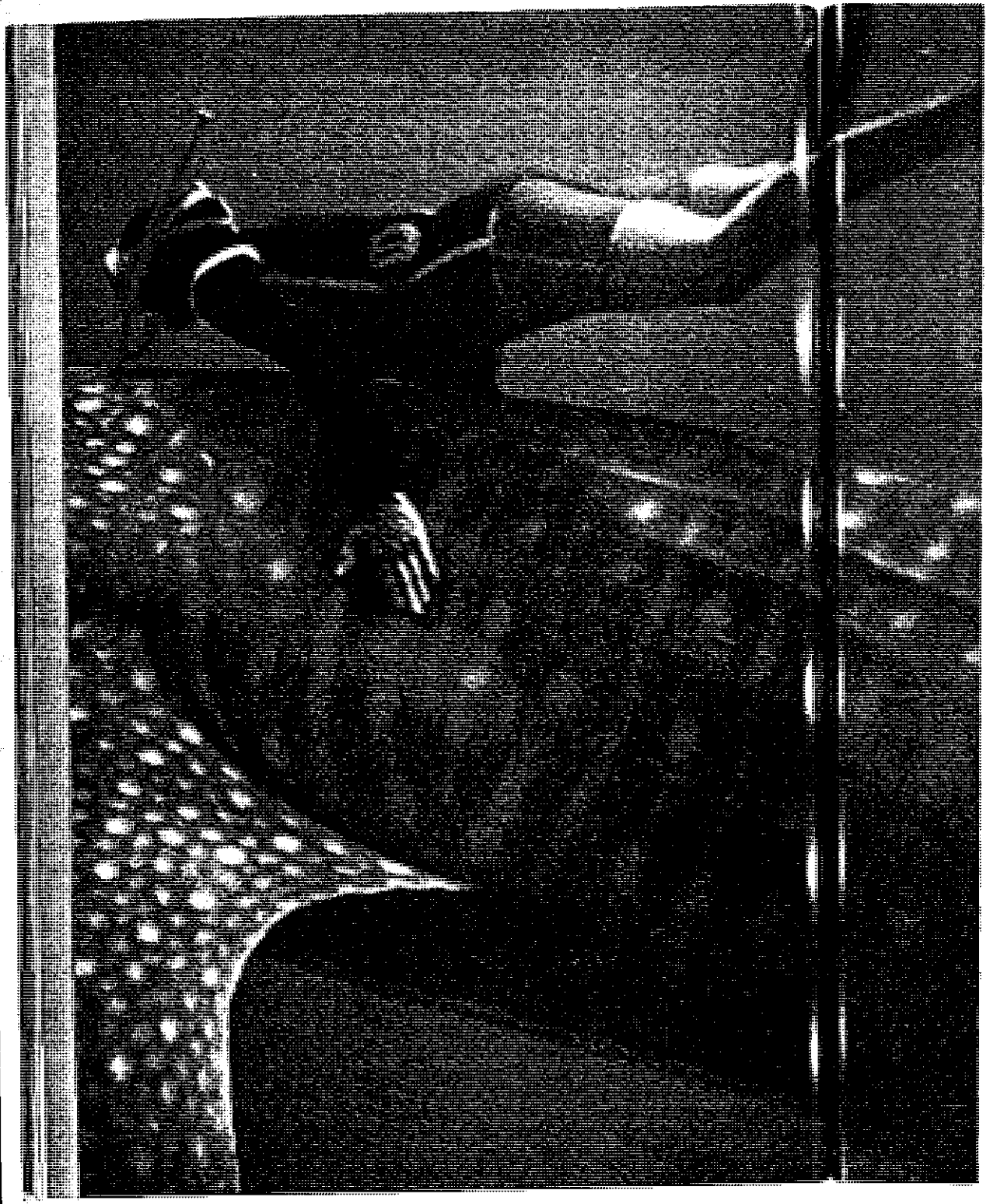
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KODACHROMES BY BEN CROPP, KEYSTONE © N.G.S.

Finned hitchhikers waiting to dine on scraps, remoras beard the chin of a whale shark. With a cavernous mouth almost as broad as its head, this shark gulps down great loads of small fish and plankton, straining out larger organisms with sievelike gill rakers and hundreds of tiny teeth.

Human hitchhiker clings to the 35-foot whale shark as it lumbers through Australian waters. Straddling a shark or hanging on to its tail may be exhilarating, but the Shark Research Panel of the American Institute of Biological Sciences labels the sport "dangerous and foolhardy." Sandpaper hide and sharp fins of even the docile whale shark can inflict wounds.

Wondering why sharks' hearts gave their owners so little trouble, Dr. Kjell Johansen of the University of Washington, Seattle, spent one summer meticulously charting the vascular systems of West Coast species, keeping his anesthetized subjects alive with a specially designed respirator that fed water to their gills. Dr. Igor Klatzo of the National Institutes of Health is investigating why sharks show less reaction to brain injury than mammals.

Source of Boots and Belts, Soup and "Steak"

Shark hide makes tough, good-looking leather. For more than 40 years, the Ocean Leather Corporation of Newark, New Jersey, has been tanning shark hides and furnishing them to makers of belts and boots, wallets and golf bags, luggage, watch bands, and a dozen other objects.

Shark livers, huge organs making up as much as a quarter of the owners' weight, contain vitamin A in quantity. Until the early 1950's, the livers alone made Japanese and California shark fishermen rich. Then someone learned how to synthesize vitamin A in large quantities, and there is little demand now for shark livers.

Dried shark fins provide the costliest ingredient of sharkfin soup, fancied by Oriental gourmets. Fresh shark meat is eaten in many parts of the world, particularly in lands around the Indian Ocean.

Anyone who has ever ordered scallops or "steakfish" in a restaurant might very well have eaten shark. San Franciscans once bought it knowingly as "grayfish," but these days it is beginning to find a market under its own name, shark.

And just what is a shark? It is a somewhat unusual fish, numbering billions of individuals grouped in about 250 separate species

(painting, pages 232-4). I am forced to say "about": Here is yet another gap in the body of shark knowledge, and the figure could be wrong by at least 10 either way.

Of all the shark species known at present, only a handful can be listed as proven eaters of man. Against some of these there is the incontrovertible evidence of human remains found in stomachs, teeth left in wounds of victims, and eyewitness identification by unimpeachable experts. Against others stands the strongest kind of circumstantial evidence, including the characteristics of wounds and the proven presence of the shark species at the scene of attack.

Nine Killers Admit No Argument

Every list of proven man-eaters agrees on nine sharks. These are the great white, which also bears the name "man-eater"; mako; bull; lemon; tiger; dusky; blue; the largest hammerheads; and the whitetip, a pelagic shark, meaning one that dwells at or near the surface of the open seas away from land. All these sharks have attacked living humans as well as corpses.

To the sinister roster, some authorities add the Pacific Ocean gray and the Australian whalers. Several species may share these same names, and some of these may prove to be sharks known under yet other names in different parts of the world.

In addition to the "proven" man-eaters, there is a category of sharks—and the experts don't always agree on the individual species—best characterized as "reasonable suspects." The porbeagle is one, and the sandbar, or brown, is another. So is the silky, named for its relatively glossy skin, a rarity in the shark world. Confusingly, there is another whitetip which might be dangerous, but it is a coastal or reef species, not the pelagic shark of the same name.

One other shark group can be called "potentially dangerous to humans," and all the experts agree on its members. They cite every shark which because of size, power, armament, and general disposition might be expected to make a meal of a man if the man got in its way. An example is the big Greenland shark. But it lives in waters too cold for swimmers and divers, and no one knows what it might do if it chanced upon a human.

The thresher and sand tiger could kill or injure humans, but both appear to feed entirely on small living fishes. The sand tiger once had a bad, but undeserved, reputation in South Africa, where it is named ragged-tooth (page 244), and in Australia, where it is called grey nurse—and it should be pointed out that this is not the small-mouthed, bewhiskered nurse shark that ranges most of the world's tropical and subtropical waters.

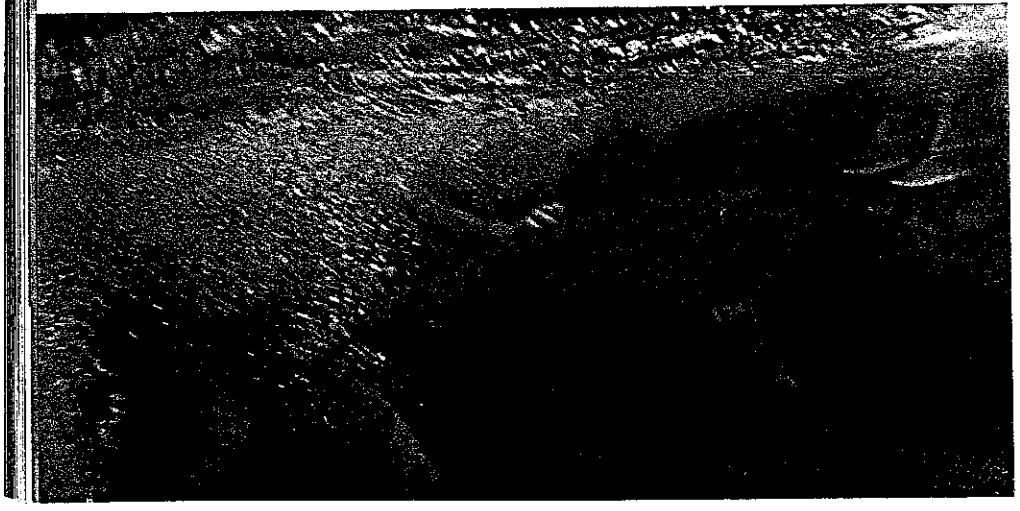
Add all the sharks on these lists and you come up with no more than 40 or 50 species. The others, it can safely be said, never dine on human flesh at all, or do so more or less accidentally, as when they bite in self-defense. In spite of this, no shark should be described as entirely "harmless," and a wise swimmer treats them all with the same respect he accords a strange fox terrier.



Real-life Moby Dick, a great white shark matches the fury of fiction's famous whale in a sudden attack off Canada's Cape Breton Island. Seas swamped the splintered dory of two lobstermen; one of them drowned, and the other clung to the wreckage until rescued. Apparently scorning them, the animal swam away to seek a meal elsewhere.

The painting re-creates the harrowing experience of John MacLeod, who survived, and John Burns, who died, on a summer morning in 1953. A tooth embedded in the battered boat identified the species. The shark's length was estimated at about 12 feet, and its weight probably exceeded 1,000 pounds.

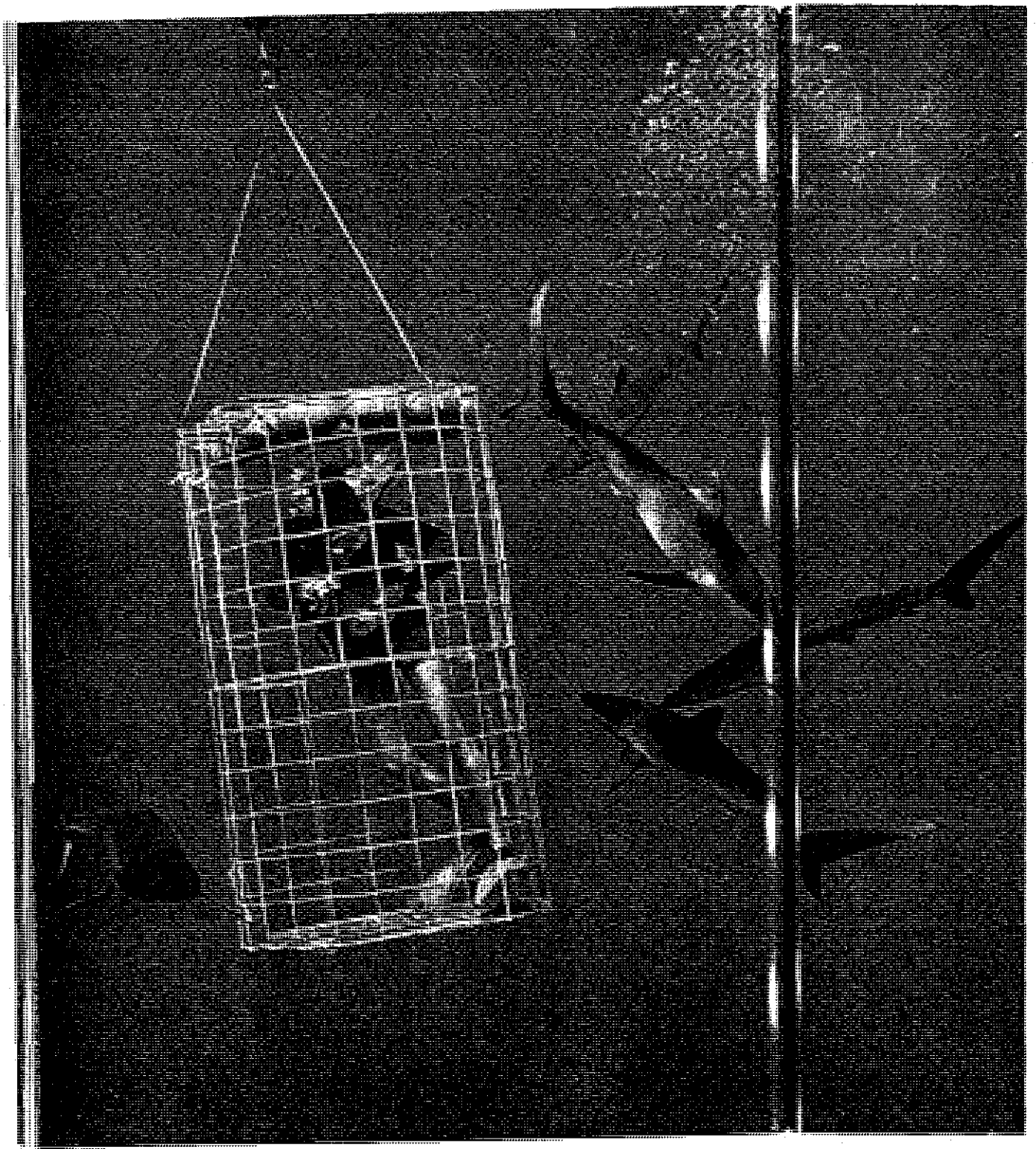
Mr. MacLeod still fishes the same North Atlantic waters.



Ravenous silky shark charges diver Donald Nelson. Frantically, Nelson pushes away the six-foot attacker with one hand and with the other aims his short-handled underwater gun at the shark's head. An instant later the would-be killer swam away to thrash out its own death agony.

Photographer Greenberg, swimming with Nelson off Florida, snapped this remarkable picture even as he himself desperately maneuvered to avoid attack.

PAINTING BY PAUL CALLE; EKTACHROME BY JERRY GREENBERG © N.G.S.



Sharks are close relatives of skates, rays, sawfish, and guitarfish, the latter named because of their unusual shape. All these have skeletons of cartilage and are called elasmobranchs; the other (far more numerous) fish, the teleosts, have true bones.

Between bony fishes and cartilaginous sharks lie many other differences. Most shark species produce live young, although some lay eggs. The horny egg cases from which skates and certain small sharks have hatched in the water are the "mermaids' purses" washed up on ocean beaches.*

No other fish can match a shark in jaw power. Perry Gilbert has measured this force with ingenious apparatus. The readings came out in tons, not mere pounds (pages 250-51).

From 20 to several hundred teeth, depending upon the species, stand in the ready-for-business rows at the front of shark jaws (page 229). Normally, five or six sets—but in some species as many as 15—wait in reserve behind, continuously moving forward so that when front teeth drop out, new ones take their place; in the young of at least one species, this occurs as often as every eight days. New teeth are always larger than the old to match the shark's growth.

One of the most persistent shark myths holds that, to use these teeth, the animal must roll over on its back or side. Not so. Of hundreds of sharks I have watched feeding, not one ever turned over to attack its prey. Sharks, however, are agile, and could do so if they chose.

Rough Hide Once Used as Sandpaper

Shark teeth grow not only in the jaws, but on nearly every square inch of hide, in a crude form called placoid scales, or dermal denticles. Abrasive shark hide, known as shagreen, was once used as sandpaper in cabinetmaking.

Air-filled swim bladders give bony fishes buoyancy. Sharks have no such thing. If they stop moving, they no longer plane on their bellies and fins, and they sink to the bottom.

Most sharks swim from birth to death for an even more vital reason. Their breathing machinery lacks adequate pumping apparatus; only forward movement passes oxygen-bearing water over their gill surfaces.

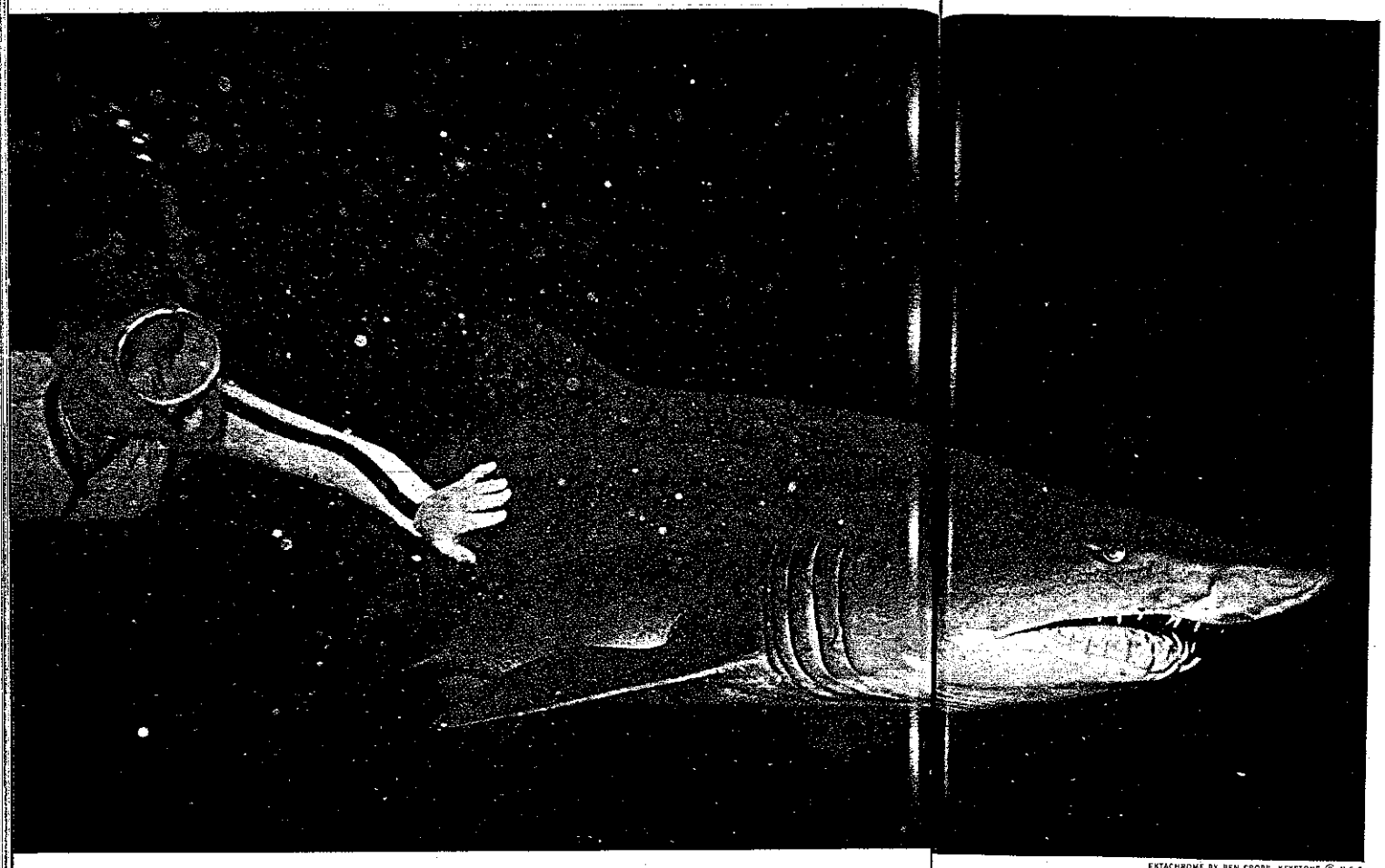
Dropping dynamite into a school of bony fishes will injure their swim bladders and kill or cripple them. Unless it is a direct hit, an explosion doesn't appear to harm sharks. In fact, it seems to attract them.

*See "Miracle of the Mermaid's Purse," by Ernest L. Libby, NATIONAL GEOGRAPHIC, September, 1959.

Descending into the blue underwater world in a protective cage he designed, diver J. G. Stemples finds himself surrounded by aggressive silky sharks. Bag in his hand, containing pieces of herring, attracts the pack into camera range as the strong but lightweight cage dangles 15 feet below the surface in Tongue of the Ocean. Plastic floats at the top keep the cylinder almost weightless. If the buoy line snapped, Stemples would escape through a hatch.

At work on a photographic study of the shark population in these infested waters, Stemples looked down once to see a small silky shark halfway inside the cage, and quickly kicked it out. Jerry Greenberg, outside the cage, found "one nipping at my swimming fins, and another giving my light meter a taste test."

EKTACHROME BY JERRY GREENBERG © N.G.S.



EKTACHROME BY BEN CROPP, KEYSTONE © N.G.S.

Daring woman diver, Van Laman pats the back of a nine-foot grey nurse shark. Captured off Australia's east coast, this specimen has survived for four years in an aquarium at Tweed Heads, New South Wales.

A close relative of the smaller Atlantic sand tiger, the grey nurse may reach 15 feet in length. Some shark experts consider it a dangerous species in Australian waters; others believe it undeserving of such a reputation.

Curiously, several species of small bony fishes like the company of sharks. Pilotfish swim with them (page 225), sometimes apparently riding the sharks' bow waves, while remoras attach themselves to the big predators, using suckerlike disks on top of their heads (page 237). The little fishes probably feed on scraps from shark meals.

Mammoth Shark Ruled Ancient Seas

Sharks first appeared on earth about three hundred million years ago. Judging from fossil remains, their body shape has changed little through the ages, proof of the efficiency of the torpedolike form.

"Fortunately, the most formidable of the ancient sharks are extinct," said Dr. Shelton P. Applegate, paleontologist and Associate Curator at the Los Angeles County Museum in California. "But in a few cases they left descendants of considerable size."

He handed me a tooth recovered from 15,000,000-year-old Miocene fossil deposits, so big it almost covered my palm.

"It belonged to a most dreadful carnivore called *Carcharodon megalodon,*" he said. "This creature was a shark that must have been 40 to 50 feet long."

The biggest fish is still a shark, the whale shark. The second largest is the basking shark. Both, like the largest whales, feed on plankton and tiny fishes. Barring collision, neither of these 40- and 25-foot monsters is dangerous to humans, though one whale shark stomach was found to contain varied items of clothing, probably swallowed accidentally.

Ben Cropp, diver-photographer and a member of the Shark Research Society of Australia, recently took turns with a friend riding a whale shark as it sluggishly cruised Ben's native Australian waters (pages 235-7).

"It didn't seem disturbed even when I knelt on its head and looked down into its mouth," Ben reported. "I stayed with it until I had used all my film. I could easily swim as fast as it was moving."

At the other end of the size scale, the rare *Squaliolus laticaudus* grows no longer than about half a foot. Occasionally caught off the Philippine Islands, it is so little known that it has no popular name.

Large or small, fast or slow, peaceful or aggressive, every shark—and every other marine creature as well—gives sea room to one member of the family, the great white shark, or man-eater. Here is the real lord of the sea, perhaps the most direct descendant of the prehistoric *Carcharodon megalodon.*

In 1916 a shark or sharks attacked five swimmers along the New Jersey coast. Four died of savage injuries. The fifth lost a leg. There was panic and publicity. Shortly afterward a fisherman caught a great white shark with human remains in its stomach.

Great Whites Attack Fishermen

As the years passed, fishermen from Maine to Nova Scotia reported occasional encounters with great whites. In most cases the huge fishes attacked their boats.

Sharks of several species charge boats with disconcerting frequency. In the best-documented Nova Scotia attack, a shark swamped a dory off Fourchu (painting, pages 238-9). In the splintered wood around an eight-inch hole in the dory was part of a shark tooth, the unmistakable serrated, triangular tooth of a great white.

Along the California coast, Barry Wilson died in 1952 and Albert Kogler in 1959, both from massive shark-inflicted injuries. In 1964, off the Farallon Islands, also in cold California waters, scuba diver Jack Rochette survived serious bite wounds. The surgeon found a tooth fragment in the victim's leg. It had belonged to a great white shark.

Two years before, Leroy French, Al Giddings, and other members of a Marin County scuba club had been diving in the same area.

"I was in the water near our boat," Giddings recalled. "Leroy surfaced from a dive 75 yards away. Suddenly he screamed for help and went under. I swam to him fast as I could. The water was red. Leroy came to the top. So did a large shark.

"I towed Leroy to the boat without interference from the shark. The Coast Guard

flew him to a hospital, where he eventually recovered from dreadful bites on a hip, left arm and left foot, and both legs.

"From my father, a California fish and game warden, I had learned to recognize all our local species of sharks. I saw this one quite well. It was a great white."

The most dangerous shark of them all gave an Australian sport fisherman a world record for the largest fish ever taken on rod and reel. He caught a great white shark 16 feet, 10 inches long, weighing 2,664 pounds, with a girth of 9 feet, 6 inches. A great white taken off Cuba measured 21 feet.

How big do these sharks grow?

"No one really knows," said Cliff Townsend, General Manager of Marineland, near St. Augustine, Florida. "But one day a man brought in a tooth dredged up far offshore. It was a great white shark tooth, or that of an ancestor—and it was more than five inches long. The tooth of a 20-footer is two inches."



The lady and the shark: Proving that a ragged-tooth can learn to eat from her hand, Dr. Anne Joy Alexander holds a 4½-foot captive and stuffs fish into its wicked-looking mouth. "I believe the bull, not the ragged-tooth, guilty of most attacks on South African bathers," she told the author at the Oceanographic Research Institute in Durban, where she served as principal research officer.

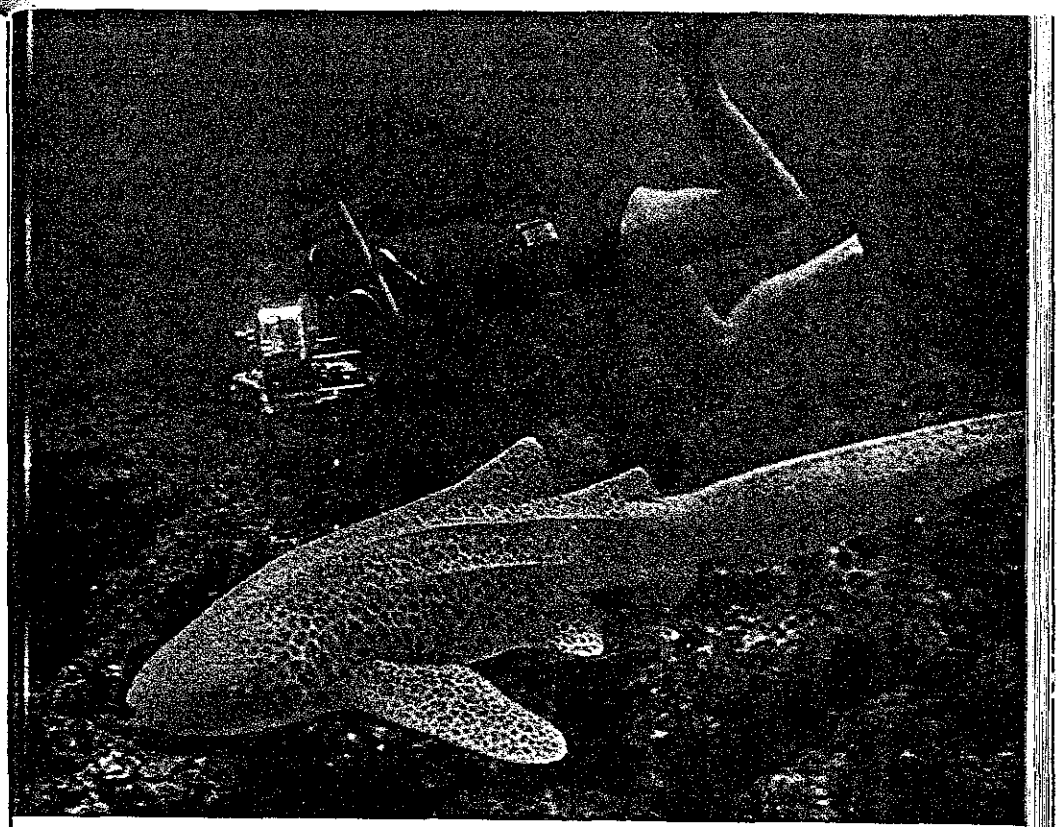


Pancake kin of the shark, the guitarfish can flap winglike pectoral fins to "fly" along the bottom, fanning up small crustaceans and other food.

Calico camouflage of a six-foot wobbegong shark helps to conceil it from its prey off Australia.

EKTACHROMES BY NATHANIEL T. KENNEY (UPPER RIGHT) AND BEN CROPP, KEYSTONE © N.G.S.





EKTACHROME BY JOHN HARDING © N.G.S.

Hovering above coral gardens off southern Queensland, a leopard shark ignores the approach of a diver-photographer. A sluggish creature also known as zebra shark, the leopard can pump water through its mouth and past its gills to obtain life-sustaining oxygen. All pelagic sharks—those living near the surface far out at sea—and most coastal species must forever swim to maintain a constant flow of water through their gills.

Captivity Fatal to Ocean Rovers

No one can yet keep the big, far-ranging oceanic sharks, among them the great white, alive for long in captivity. Most soon die, either of shock or from ramming tank sides.

"That is the main reason we know so little about the behavior of the pelagic species, including the great white," said F. G. Wood, head of the Navy's Marine Bioscience Facility at Point Mugu, California. "We must study them at sea, and there the sharks dictate conditions, not the scientists."

At Point Mugu I also talked with Dr. C. Scott Johnson, Navy physicist studying porpoise hearing. Dr. Johnson, who has worked with sharks, has a porpoise that, while blindfolded, finds small pellets on the bottom of its tank by echolocation.*

"How do porpoises feel about sharks?" I asked.

"From what I've seen," Dr. Johnson said, "they don't like them, although they don't attack on sight as people will tell you. Nor, in all probability, do sharks attack healthy porpoises. Let's call it a standoff, under normal conditions. You'll sometimes find sharks and porpoises quite near each other, but each gives the other room to pass."

If ever there are hostilities, shark teeth would probably have an advantage over the battering rams of porpoise snouts. Both animals are capable of speeds in the neighborhood of 20 knots.

Happily, the great white sharks seem to

*See "Porpoises: Our Friends in the Sea," by Robert Leslie Conly, NATIONAL GEOGRAPHIC, September, 1966.

be rare. Few people have seen more than two together. More than most sharks, they prefer a mammalian diet —whales, seals, sea otters, and so on. Paleontologist Shelton Applegate has a possible explanation:

"The evidence indicates that *Carcharodon megalodon* fed mainly on marine mammals. The white shark still appears to like them. The inference is obvious. Man is a mammal too."

In a rubber diving suit, a man looks like a seal. And according to Perry Gilbert, neither great whites nor any other sharks see things in clear detail.

"It's a matter of visual sensitivity as differentiated from visual acuity," said Dr. Gilbert. "The shark's retina, amply equipped with photosensitive cells called rods, permits the animal to see, in very dim light, the outline of an object against a contrasting background—in short, the eye has great sensitivity.

"But the shark's eye probably doesn't see sharp details, even in bright light, because of its relatively few retinal cone cells, responsible for visual acuity."

Scientists differ on whether or not sharks see color, pending more conclusive research (pages 226-7). Dr. Tester of the shark panel doubts that they can.

"At Eniwetok Marine Biological Laboratory," he said, "we trained sharks to discriminate between different shapes. In one end of their tank we had alternately displayed triangular and square targets of equal area. With the triangles we gave the sharks electric shocks, but left the current off when we displayed the squares. In a remarkably short time the sharks learned to flee the mere sight of the triangles, even without the shocks, but ignored the squares.

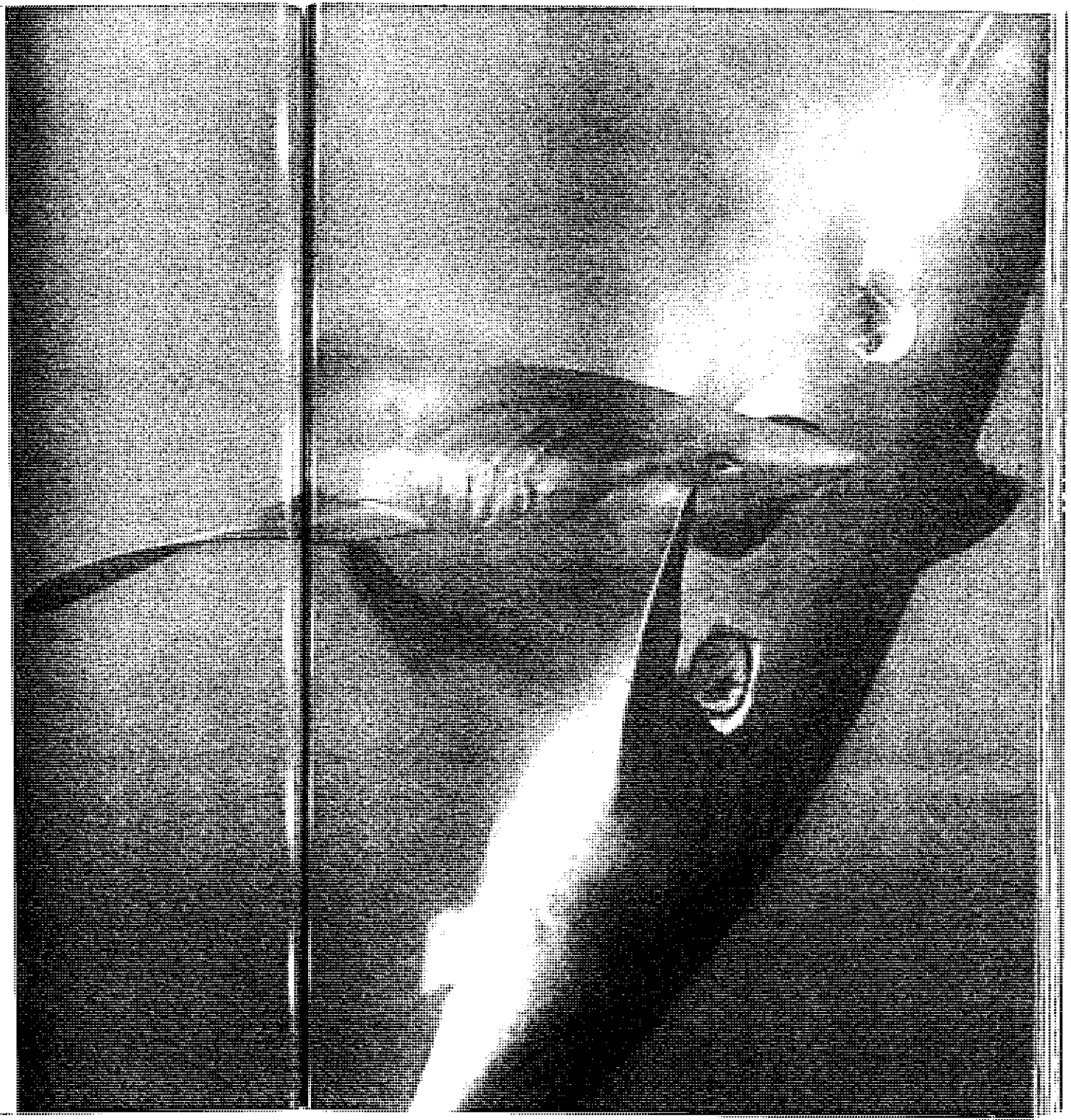
"Then we tried the same experiment, using targets that differed in color, not shape. The sharks didn't clearly discriminate, even after days of trials."

Hammerhead Wears Its Eyes on Stalks

Of the proven eaters of man, I have met several species more or less personally. I have caught hammerheads off Florida, and wondered why they, alone of all sharks, possessed such oddly shaped heads.

"Nobody really knows why," said Perry. "The wide lobes undoubtedly make good planing surfaces and give these sharks maneuverability. Also, since eyes and nostrils are out on the ends of the lobes, the hammerhead samples a wider path of water than other sharks [pages 222-3, 232, and 252-3]."

In the Red Sea, among the islands of Ethiopia's Dahlak Archipelago, I surfaced from an inspection of a bent boat propeller, and an Arab sailor said that a

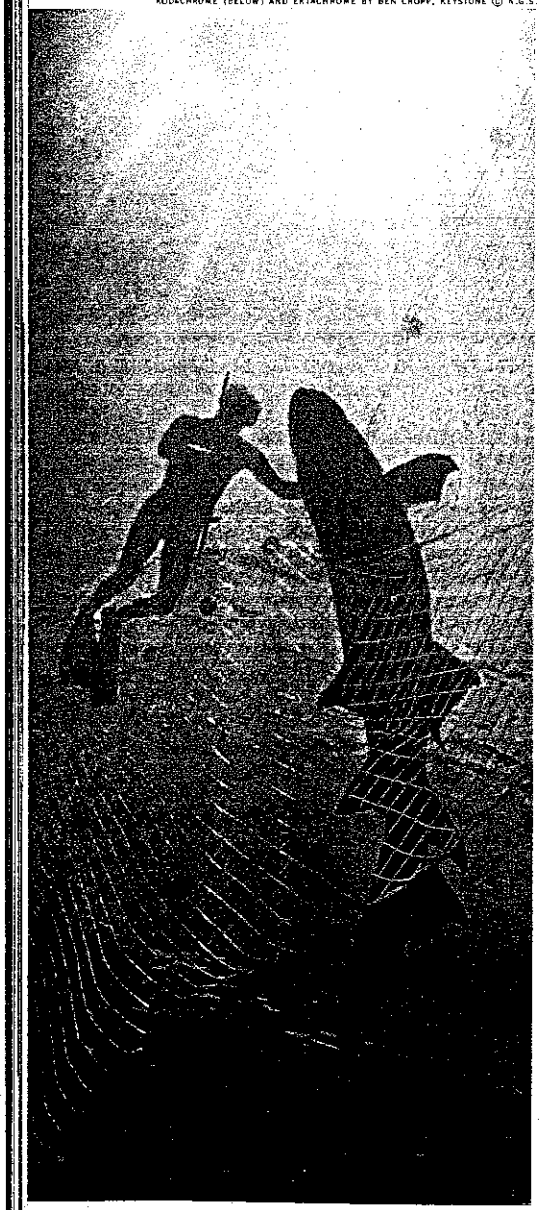


Ripping out ham-size bites of flesh, a blue shark shreds a dead porpoise off Montauk Point, New York. Photographer Peter Gimbel, submerged in an antishark cage, witnessed the carnage. "The jaws opened so wide they seemed actually dislocated," he remembers. "With wild, vicious shakes the blue tore loose ten-pound hunks."

EKTACHROME BY PETER GIMBEL © N.G.S.

Like a grotesque insect snared in a giant spider's web, a ten-foot Oriental nurse shark meets death off New South Wales. The big fish suffocated when the mesh halted forward motion, cutting off its oxygen supply.

KODACHROME (BELOW) AND EKTACHROME BY BEN CROPP, KEYSTONE © N.G.S.



large tiger shark had passed within a hundred yards. The tiger shark, by the way, is not the same animal as the sand tiger. The scientific name for the sand tiger is *Odontaspis taurus,* while the tiger, named for juvenile stripes on its hide, is *Galeocerdo cuvieri.*

More than other large sharks, tigers scavenge. Ceaseless prowlers, especially at night, of shallow reefs, river mouths, and harbors, principally in tropical seas, tigers are known to have eaten such varied items as sea birds, garbage, human remains, tin cans, lumps of coal, and—in one instance—a 30-foot roll of yard-wide roofing paper!

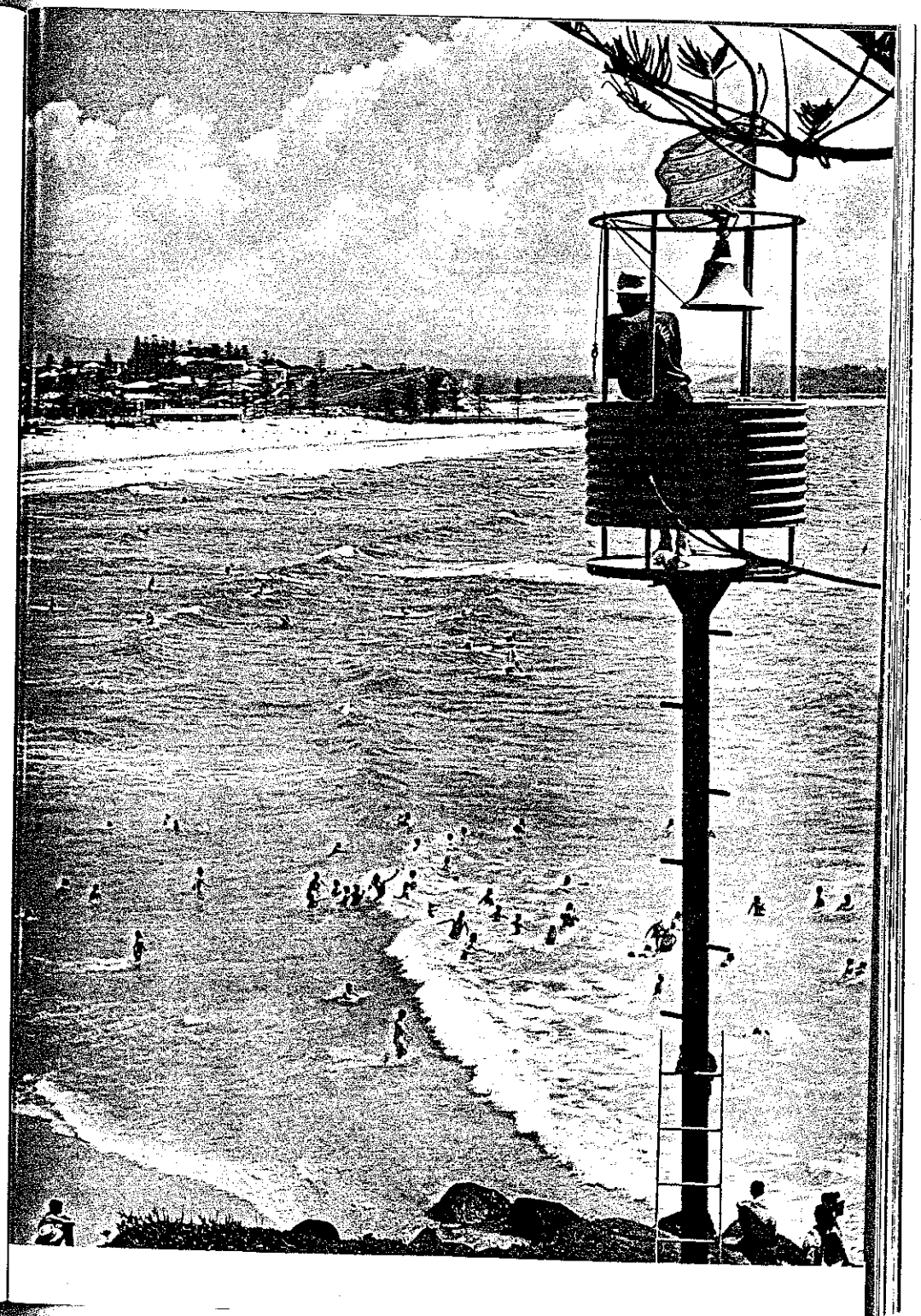
Tigers may reach 18 feet in length. Like other sharks, they have extensible upper jaws; tigers can thrust theirs forward as much as six inches for a better hold on prey.

In several seas I have also met the bull shark, an inhabitant of shallow coastal waters. Even the experts find this animal utterly confusing. Up to 10 feet long, it haunts the beaches of Florida, the Gulf of Mexico, South American coasts, and the Atlantic seaboard as far north as New York.

Within the past few years, Dr. J. A. F. Garrick of Wellington, New Zealand, has discovered that the Zambezi sharks of the South African Indian Ocean beaches and some whaler sharks of Australia—all of them killers and all once believed to be separate species —are bull sharks.

So are the aggressive fresh-water sharks of Lake Nicaragua, Lake Izabal in Guatemala, and at least one lake in New Guinea. Further, it seems likely that the species responsible for human attacks in the Tigris and Euphrates Rivers, and in the Ganges and other streams of Pakistan and India, include bull sharks, *Carcharhinus leucas.*

From Chesapeake Bay, trapped in fish nets, have been taken the three largest bull sharks ever measured. The biggest came from waters in which I have swum since boyhood—the mouth of the Patuxent River near Solomons Island, Maryland. No shark attack upon a human, however, has ever been



Green flag signals safe seas for bathers at Queensland's Greenmount Beach. When the tower watchman sights a shark, he rings the bell and raises a red-and-white flag. Some beaches also send spotters aloft in planes.

To combat the shark menace that plagued its populous east coast, Australia began laying nets in 1937. Not a single fatality from shark attack has occurred at a meshed beach.

recorded in the Chesapeake, and this is a mystery in itself.

Yet at Durban, South Africa, the bull shark seems to change character. There I asked Dr. Anne Joy Alexander, principal research officer of the Oceanographic Research Institute, what kind of shark was responsible for the attacks at Durban and other beautiful beaches along the shore of Natal Province.

"Apparently mostly the bull shark," she said, "although obviously it's difficult to identify an attacker. In 1960 we found bull shark tooth fragments in the wounds of a victim. Since the circumstances of attacks and the wounds of most other people were like those in the proven case, we're inclined to believe our major marauder is this fellow.

"Once we suspected the ragged-tooth, the slightly sluggish shark you Americans call the sand tiger, and it may have been guilty in a few cases. But come with me: I'll show you what a nice shark a ragged-tooth can be."

In a shallow laboratory tank circled a mottled 4½-foot shark, its protruding slender dental array identifying it as a sand tiger, its small size indicating immaturity. Reaching into the tank, Dr. Alexander pulled the shark out by the nose and stuffed chunks of fish into the gaping mouth. It swallowed the bits only after she released it (page 244).

City "Meshes" Its Bathing Beaches

Years ago, Durban tried to solve the shark problem with strong fences completely enclosing the city beaches. They worked, but they were prohibitively expensive, both to build and to maintain in the heavy Indian Ocean surf, and were eventually abandoned.

In 1952, the city engineers turned to a system of "meshing" already in use, with apparent success, in Australia, whose beaches held the world's worst record of shark attacks. To mesh a beach, you simply anchor gill nets at intervals off the shore. During the first year, the nets at Durban took 552 sharks. Since then, the catch has dropped to less than 110 a year. In seven years before the nets were used, the city had ten sure attacks, seven of them fatal, and at least ten probables.

After meshing, there were no attacks until 1965, when a surfer suffered a minor bite on one thigh. Attacks on surfers, incidentally, appear to be on the increase.

"Because a shark can swim over or past a net, it was a mystery at first how meshing protected bathers," said Beulah Davis of Natal Province's Anti-Shark Measures Board. "One reason may be that our sharks mostly belong to a local, nonmigratory population, and the nets caught just about all of them."

Sharks off Hawaiian beaches also appear to be nonmigratory. Last year, under Dr. Tester's direction, the 50th state opened a three-year campaign to eradicate them so far as possible, using set lines with hooks at 60-foot intervals. One of the first results was a noticeable decrease in a concentration of large tigers off Honolulu harbor.

Some 40 miles north of Durban, the golden sands of Zinkwazi Beach used to be lonely, unused because sharks swarmed in the creaming surf. Now they are meshed, and holiday-seekers come in increasing numbers.

Len Flowers, a professional fisherman, tends the nets. I went with Len to overhaul them. They held only a small cow-nosed ray.

"I don't believe you have sharks around," I remarked.

"No?" said Len. "Hang on." With that he headed the boat seaward.

Choosing a spot over a reef a mile offshore, he dropped the anchor, and we began fishing. Immediately we caught several five-pound Cape salmon, or geelbek. We stunned them and tossed them overboard. Within seconds the sea boiled with sharks, some six feet and more long.

"Here are our friends," said Len. "We'll be lucky now to catch a single whole salmon."

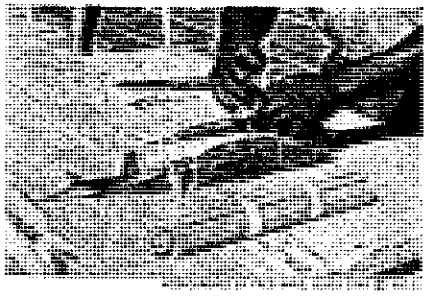
We scarcely had a chance to try before the ravenous sharks began banging against the boat. Fear gripped me. Even Len confessed to some nervousness.

To get through the surf without swamping, the boat had been decked over. We sat on it, not in it. Handholds were few. The sea that day was high. An eight-foot shark struck at the outboard propeller, although we had taken the precaution of tilting the motor to bring the propeller out of water.



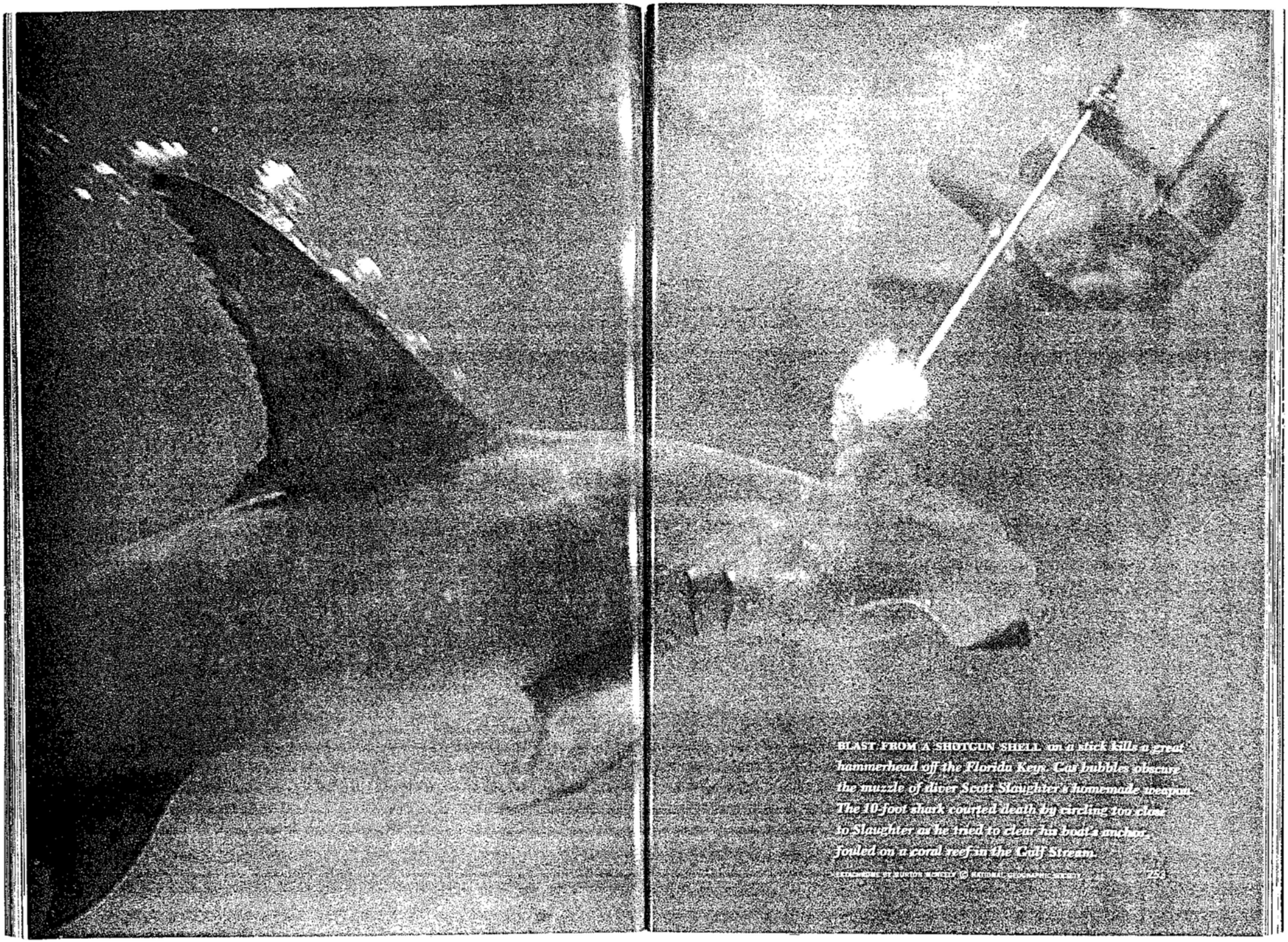
Power of a shark's bite measures in tons, not pounds, as Dr. Perry W. Gilbert discovers in tests conducted at the Lerner Marine Laboratory. One of the world's foremost shark authorities, Dr. Gilbert uses a "bite-meter," a cylinder containing an aluminum core of known hardness enclosed by four quadrants of steel. Twelve stainless-steel bearings lie between the two layers.

Bait wrapped around the device (below) attracts sharks like the 8½-foot dusky at right. It clamps down hard on the apparent meal, then releases the unpalatable offering. Knowing the force needed to dent the aluminum core, Dr. Gilbert estimates the dusky's biting pressure at approximately 18 tons per square inch!





EKTACHROME BY JERRY GREENBERG © N.G.S.



BLAST FROM A SHOTGUN SHELL *on a stick kills a great hammerhead off the Florida Keys. Cut bubbles obscure the muzzle of diver Scott Slaughter's homemade weapon. The 10-foot shark courted death by circling too close to Slaughter as he tried to clear his boat's anchor, fouled on a coral reef in the Gulf Stream.*

PHOTOGRAPH BY BURTON MCNEELY (© NATIONAL GEOGRAPHIC SOCIETY)

"Let's go home," said Len. We picked up the anchor and left.

I photographed sharks as close as two feet. In the pictures Beulah Davis identified bull sharks, duskies, and sandbars, all of the so-called gray shark family. Duskies and sandbars live in most tropical and temperate coastal seas, including those of the United States.

In a feeding frenzy such as this, a man's chances of escaping death or injury would be slight. Stewart Springer says he has seen frenzied sharks eat packets of the chemical repellent issued to U. S. sailors and airmen during World War II. The repellent contains copper acetate and nigrosine dye.

"We'd learned that sharks, even though they're cannibals, won't touch decaying shark flesh," said Stewart, who helped develop the repellent. "As copper acetate is an organic acid like those in decayed shark meat, we put this into the packets.

"We added the nigrosine dye, which forms a dense cloud in the water, for concealment. It raises a man's morale to believe he is hidden. Moreover, the shark's final visual attack may actually be hindered, and it is also possible the fish may view the cloud as an obstacle and avoid it."

Although its efficacy is limited, the services still issue the repellent. The National Aeronautics and Space Administration puts it into the marker dye released by space capsules when they land in the sea.

At least one space landing in the Atlantic area attracted sharks.

"Nothing happened," a NASA spokesman reported, "except maybe the frogmen who helped in the recovery worked faster than usual. The sharks only circled and watched."

But in the same year, a Canadian military plane with 16 men aboard crashed into the same area of the Atlantic. Rescuers arrived within an hour, but it was already too late. Excited sharks nosed through the wreckage, in which dead or injured men were seen. A search vessel reported by radio that recovery of bodies was not feasible because of "many aggressive sharks."

No one survived this tragedy to report what kinds of sharks were involved or the method of attack. Not until the comparatively recent development of scuba gear did anyone meet pelagic sharks face-to-face in the open ocean and come back to tell what happened.

Captain Cousteau, co-inventor of the pioneer Aqua-Lung, may have been the first man to face the pelagic whitetip in its own element and live to describe the encounter. In 1951, in the open Atlantic off the Cape Verde Islands, he and his companions were harassed by one of these marauders.

The fish exhibited a pattern of curiosity, increasing boldness, and eventual attack. Captain Cousteau drove it off finally by banging it over the snout with his camera.

Shark Beaten Off With Boathook

In the Gulf Stream ten miles from Bimini, Jerry Greenberg of Miami, Florida, who took many of the pictures for this article, met a whitetip that behaved in much the same way.

"I was working for the U. S. Navy, photographing the hulls of vessels passing over me," said Jerry. "One moment I was alone, the next I had this shark as company. For half an hour or so it kept its distance, retreating whenever I made a sudden movement in its direction. Then it began circling faster and closer, and soon I had to beat it off with camera, feet, and hands.

"My diving companion, Ed Fisher, joined me, carrying a boathook. With this he jabbed the shark hard in the gills. This drove it off, although it stayed at the edge of visibility.

"No question about the species: We surfaced, baited a hook, and caught it to get rid of it so we could go back to work."

Chuck Henderson, a Washington, D. C., diver, told of a similar experience he had with a large pelagic shark off Delaware. From the description, it could have been a blue.

"I had a dead tautog on the end of my spear gun," Chuck said, "and this attracted the shark. I backed up against the plates of a wreck in 30 feet of water and fed the tautog to the shark, hoping it would then go away.

"It didn't. It kept returning, each time coming a little closer to me until I was pushing it away bodily with the spear. I pushed gingerly, you can be sure. I didn't want to make this fellow mad.

"When I began running low on air, I knew I had to take a chance on sterner measures. I stabbed the shark in the eye, and it rushed off, shaking its head.

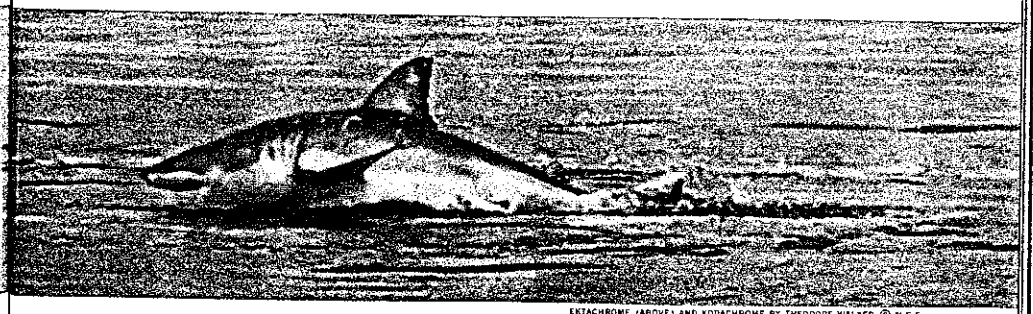
"I could have killed this fish, but I didn't have an underwater gun."

Used skillfully, this weapon is probably the diver's best close protection (pages 225 and 253). Triggered by jabbing against a target, it will kill a shark instantly if fired close to the brain. But it is bulky, a menace to other divers, and likely to give its handler a nasty concussion if the shell used is too large.

Extraordinary gathering of sharks peppers Oja de Libre Lagoon in Baja California. Pacific gray whales breed in these waters, and some scientists speculate that sharks, too, come here to mate.



Pursuing an elusive meal, a young shark—possibly a great white—broaches in San Ignacio Lagoon, Baja California. In recent decades more and more anglers have awakened to the fact that the fighting shark is one of the world's best game fish. The sport of shark fishing began in Australia in the 1920's; an Australian holds the record for the biggest catch on rod and reel, a 2,664-pound white taken on a 130-pound test line.



EKTACHROME (ABOVE) AND KODACHROME BY THEODORE WALKER © N.G.S.

Navy scientists seeking another weapon for divers have tested poison syringes on sharks in the Bimini pens of the Lerner Marine Laboratory, a field station of the American Museum of Natural History of New York. They were seeking a defense for underwater demolition teams. They found that strychnine killed, but took up to a minute for a large shark. In this time, the creature might yet kill or injure a diver.

What Triggers a Shark Attack?

One of the puzzles facing experts is why a shark in one part of the world harasses humans while its brother of the same species in another place does not. The late Dr. V. M. Coppleson, an Australian authority, thought water temperature was one factor. Most attacks occur, he concluded, above 70° F. Great white sharks, however, have attacked California divers in 55° temperature, and the Greenland shark, as well as the northern porbeagle, feeds in even colder water.

Dr. Coppleson also believed that multiple shark attacks in an area could be the work of a single "rogue," the marine parallel of the Indian tiger that has acquired a taste for human flesh. Stewart Springer, on the other hand, feels that entire shark populations living in less than ideal natural conditions may be dangerous to man.

"Principal populations of sharks establish themselves, quite naturally, in areas where food is abundant and other conditions are good," Stewart said. "The area may be large. Some species of sharks migrate over regular ranges, like African big game.

"Around the edges of the principal area you will find an accessory population that includes congenital weaklings, cripples, or possibly neurotics—all of them animals that can't compete with the others and drift away from them.

"Life is harder for these peripheral sharks, and they may be the dangerous ones. As you might expect, they take whatever food comes along. This could be man."

The bull sharks of fresh-water Lake Nicaragua may be an accessory population. Dr. Thomas B. Thorson of the University of Nebraska, who has studied these fish for eight years, is reasonably sure that the sharks come in from the Caribbean Sea via the San Juan River. Scientists once believed the lake sharks to be a separate species, blocked from the sea by the San Juan's rapids. Now they are virtually sure the rapids are no barrier.

The Smithsonian file records attacks on humans by Lake Nicaragua bull sharks. People nevertheless swim in the lake, and Dr. Thorson once watched a party of Nicaraguan soldiers happily splashing near shark lines he had set out!

The Only Certainty: Uncertainty

After I had begun this article, I stopped by to see Cliff Townsend at Marineland of Florida, where I had earlier helped the collecting crew add a pair of lemon sharks to the main fish tank. Both had been caught in sight of St. Augustine in the Intracoastal Waterway; both were big, normal animals.

"What became of my friends the lemon sharks?" I asked Cliff.

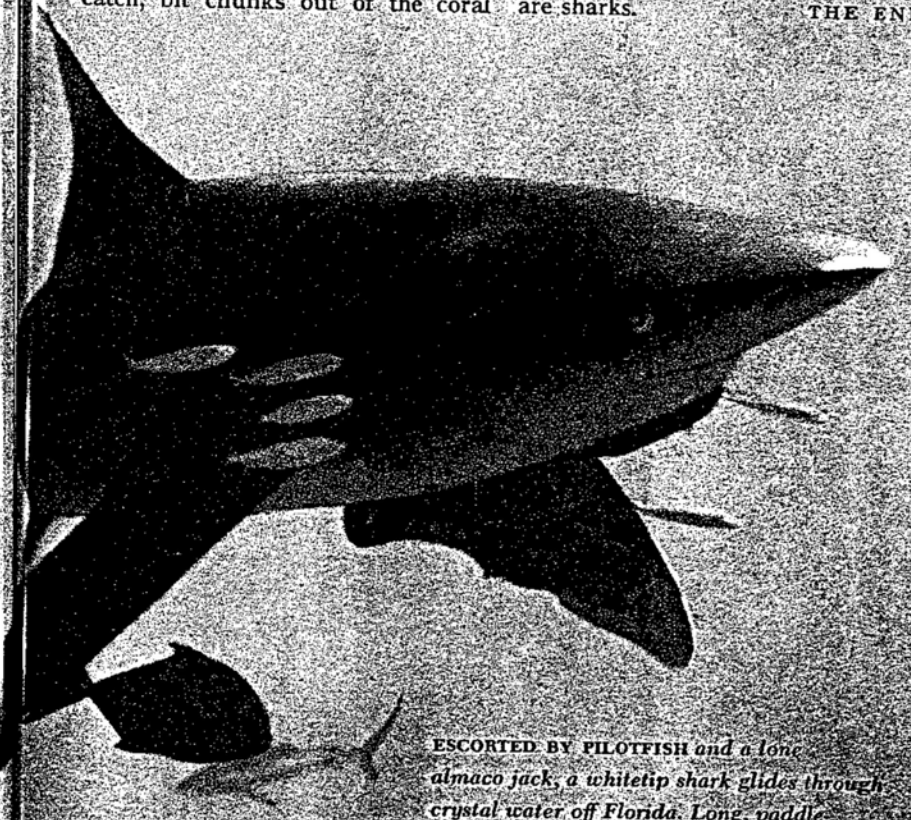
"One is the nicest, calmest shark you ever saw," he said. "It's the only large lemon we've had that never gives the divers a moment's worry, and it eats the food we give it, not its tank neighbors.

"The other killed every fish it could catch, bit chunks out of the coral rocks we put on the bottom for background, and nearly got a couple of divers before we could get it out of the tank.

"I don't know why these sharks were so different, and nobody else does. They did, however, prove one of the few things we know for sure about shark behavior. The animal is unpredictable. Never trust a shark."

No better advice could be given a man about to enter water where there are sharks.

THE END



ESCORTED BY PILOTFISH *and a lone almaco jack, a whitetip shark glides through crystal water off Florida. Long, paddle-shaped pectoral fins, broadly rounded at the tip, distinguish this dangerous species. As man steps up exploration of the deep frontier, he finds it imperative to know more about sharks and how to control them.*

KODACHROME BY JERRY GREENBERG © NGS