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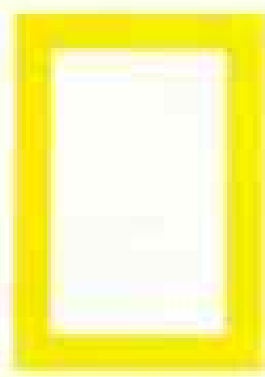
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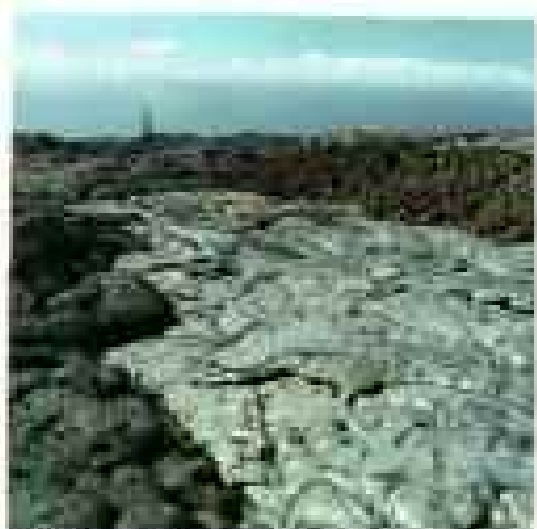
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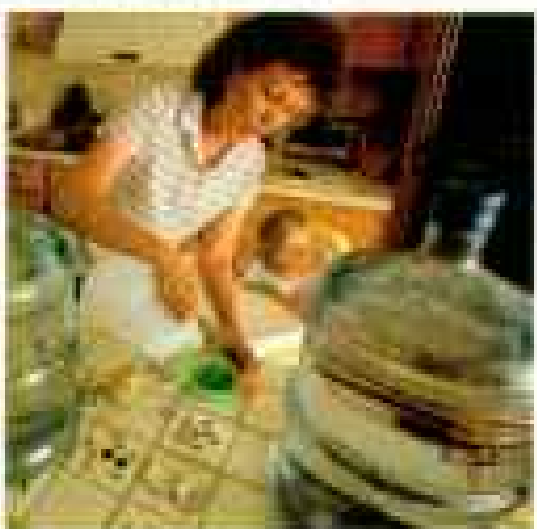
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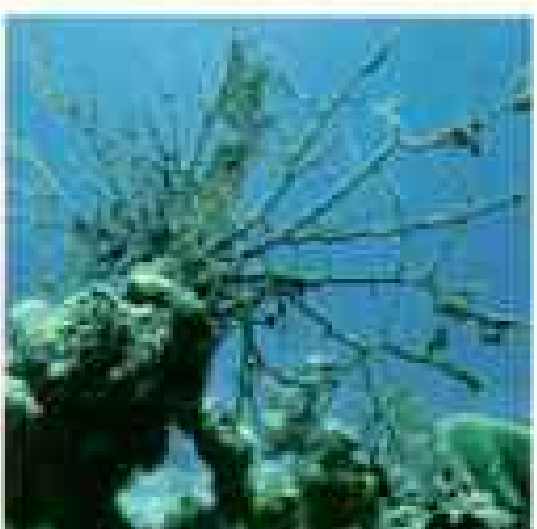
SIFTING FOR EMERALDS IN BRAZIL



LAVA COOLING ON HAWAII



BOTTLED WATER FOR A FLORIDA FAMILY



SEA TURTLE AT DEATH'S DOOR

Long Journey of the Pacific Salmon 3

Returning to their riverine birthplaces to spawn and die, Pacific salmon face dangers beyond hungry eagles and Indian nets. Commercial fleets, multiple dams, and the effects of clear-cut logging take an increasing toll. Jere Van Dyk and photographer Natalie Fobes study the prospects for seven prized species.

The Timeless Mystique of Emeralds 38

Coveted by kings and commoners alike for thousands of years, these green gems are still wrested from the earth, cut, and polished mostly by hand. And some are still transported the old-fashioned way—by smuggling, says author-photographer Fred Ward, who tracks their journeys around the world.

Hawaii's Volcanic Cradle of Life 70

High on the slopes of volcanoes that gave birth to these islands, ferns sprout in lava cracks and spiders spin webs in the molds of incinerated trees—models of adaptation. Biologist William H. Amos shows how a handful of microscopic life-forms arriving by chance from distant lands have exploded into a diversity of species found nowhere else.

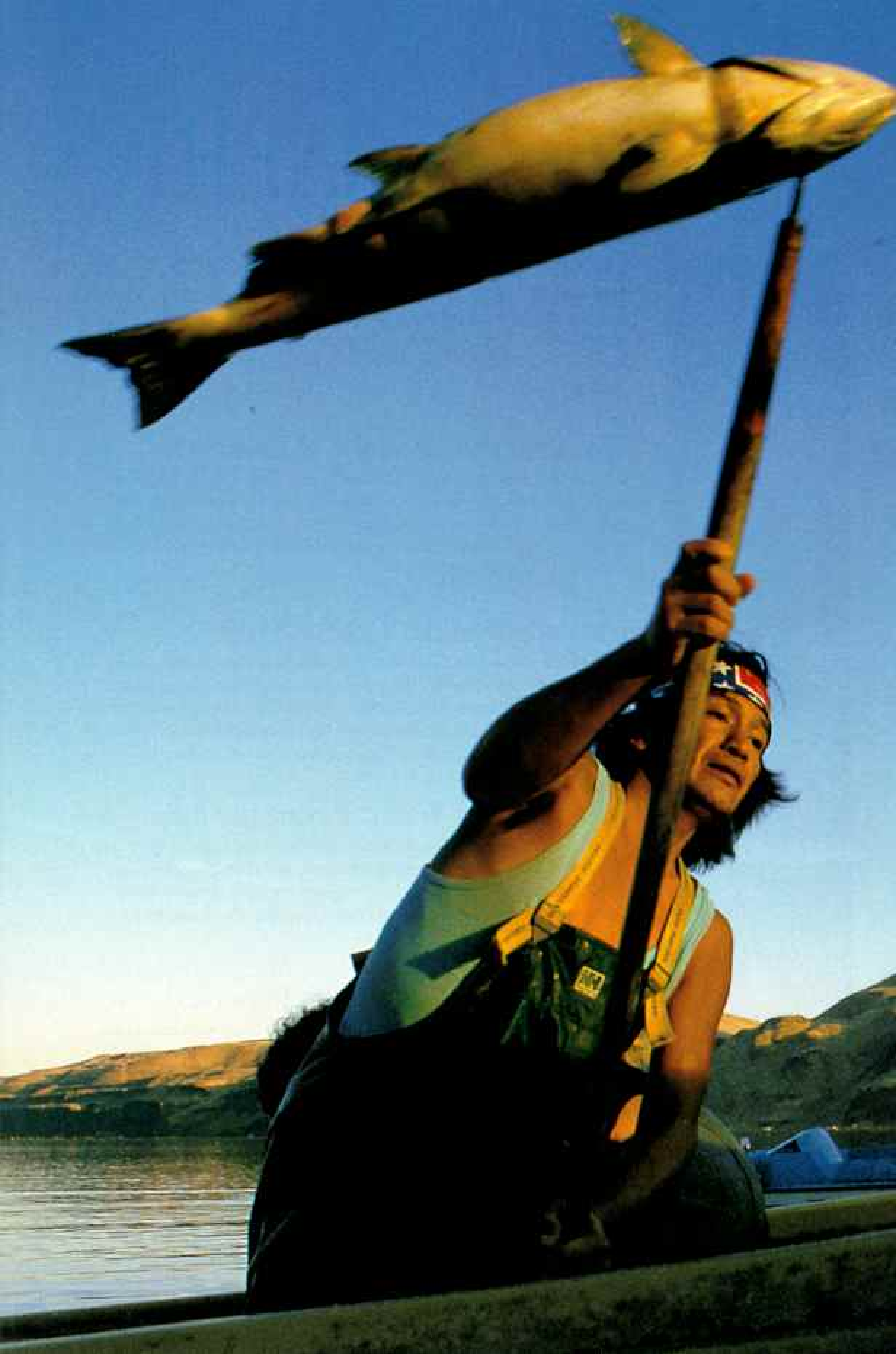
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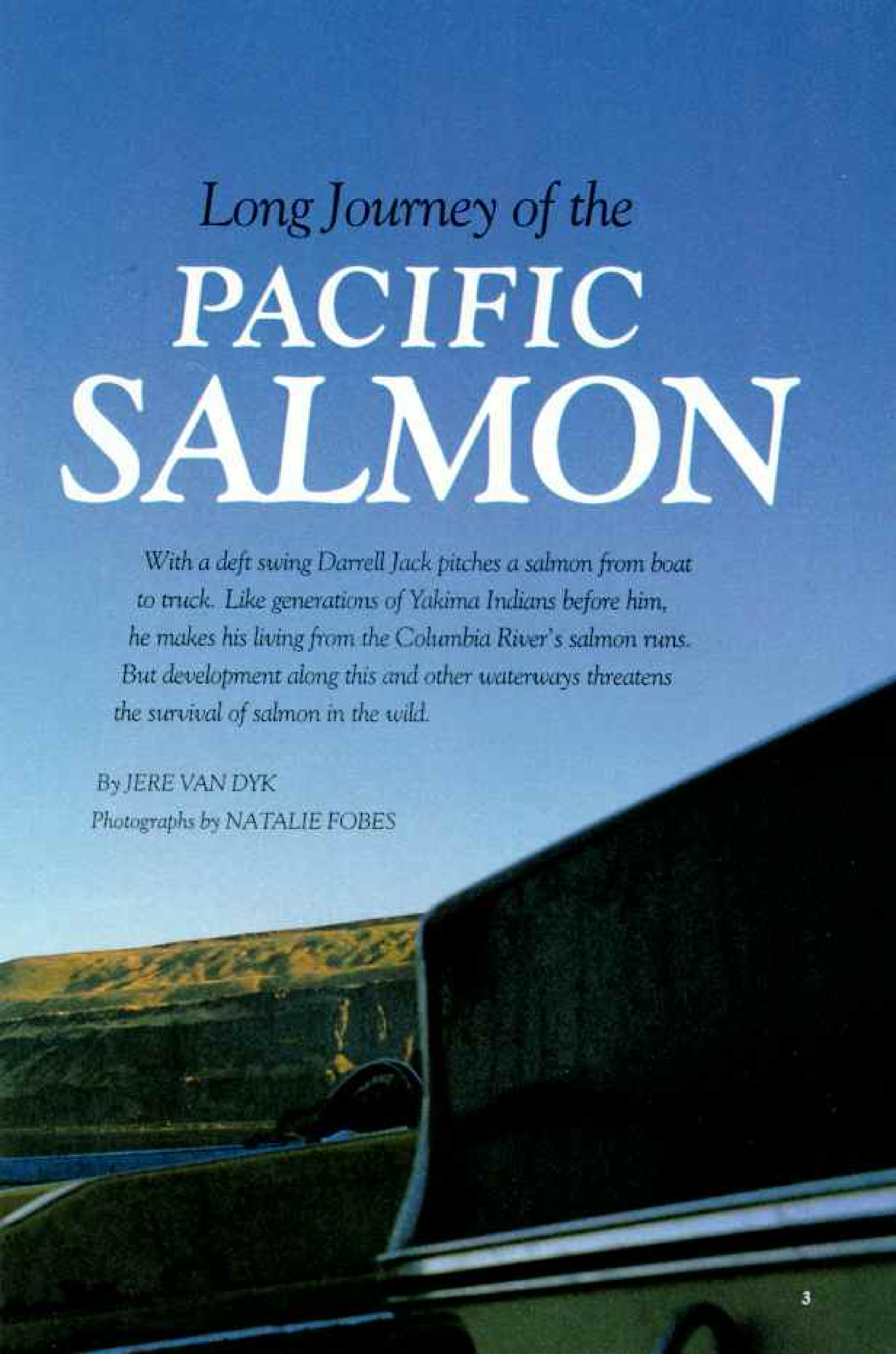
Once shunned as mosquito-infested swampland, the watery wilderness of south Florida has been drained, dredged, and diked for farms and cities. But these spectacular feats of engineering have wreaked havoc on the environment, according to Nicole Duplaix. Photographs by Kevin Fleming.

Florida's Coral Reefs Are Imperiled 115

Formed by tiny marine organisms called polyps, coral reefs take centuries to grow—and only years to decay. Water pollution and damage by careless boaters and divers threaten their survival. For three decades author-photographer Fred Ward and photographer Jerry Greenberg have witnessed the deterioration of the reefs along the Florida Keys.

COVER: Flamboyant plumes called aigrettes mark the breeding phase of the great egret, a year-round resident of south Florida wetlands. Depleted by plume hunters at the turn of the century and now protected, this heron has regained its former numbers. Photograph by Farrell Grehan.



A photograph of a boat on a river, with hills in the background. The boat is in the foreground, and the river flows through the middle ground. The hills are in the background, under a clear blue sky. The text is overlaid on the top half of the image.

Long Journey of the **PACIFIC SALMON**

With a deft swing Darrell Jack pitches a salmon from boat to truck. Like generations of Yakima Indians before him, he makes his living from the Columbia River's salmon runs. But development along this and other waterways threatens the survival of salmon in the wild.

By JERE VAN DYK

Photographs by NATALIE FOBES





BILL CURTSINGER (ABOVE)

A fierce face and fiery body mark a male sockeye ready to spawn at the end of his upstream migration (left). With strong sweeps of her tail a female chin scoops a redd, or nest, into a streambed (above). Hovering over the hollow, she will deposit eggs as a male fertilizes them. Pacific salmon die soon after mating. Hatchlings, called alevins, consume their yolk sacs during the weeks they stay in the nest.





Salmon swarm about a diver inspecting a saltwater net pen on a British Columbia fish farm. This view from 85 feet down shows a third of the area in



which 57,000 chinook will grow to market size. After an industry boom, falling prices sent many farms, including this one, into receivership.





A kiss for luck from Pete Blackwell greets the season's first salmon on a fishing boat in Bristol Bay, Alaska. "It was one of our biggest hauls in years: We probably made \$10,000 to \$15,000 in half an hour." Another Bristol Bay crewman fans his boat's take for nine days in 1988—some \$24,000. But catches are uncertain, expenses high. Many fishermen, especially outside Alaska, work second jobs.



Mouths agape in a final grimace, salmon carcasses seem to puzzle a passing goose on Seattle's Duwamish River in September 1986. Some 2,500 salmon



leaped from the water in distress and inexplicably died before spawning. Tests for pollution were inconclusive; currents may have washed away any toxins.

CAPTAIN Yuri Nikolaevich Nevolin drew on a cigarette, then flicked it away into the calm gray Sea of Okhotsk. On the afterdeck of his fishing boat a frayed hammer and sickle fluttered in the August breeze.

"There are not enough boats to get all the fish out of the water," said Captain Nevolin, looking out through the ragged fog. In front of us, in a setnet, hundreds of glistening black dorsal fins turned on the water's surface. Our net lifted under them, and the hundreds became thousands of trapped salmon, splashing for the last time off the coast of the island of Sakhalin in the Soviet Far East (right).

A crewman swung a mesh basket under the mass of fish, scooped up 50 or so salmon, and brought them on board. "We can catch a hundred tons in 24 hours," Captain Nevolin said, shouting to be heard over the drumroll of fish thrashing in our hold. Soon the catch was so great it overflowed the hold in a silver carpet a foot deep. The morning's catch of ten tons would fetch the equivalent of \$60,000. And in the long winter ahead it would supply a canned source of protein and calories in far-away Moscow and Leningrad.

In the Soviet Union, where some citizens still think of salmon as the tsar's fish, nothing is wasted: Heads go into soup, milt glands into frying pans, roe into jars for red caviar, a delicacy to be savored on holidays and at weddings. The indigenous Ainu people of Japan remember the salmon as "a present brought from heaven," which fed their forefathers. Across the sea in Alaska even a modest chinook salmon of 15 pounds can bring a wholesale price of \$45 — more than twice as much as a barrel of crude oil.

In a good year the whole catch of salmon from the Pacific Rim might amount to 800,000 tons worth five billion dollars, about the gross national product of Panama.

Given the value of these prolific fish, is it any wonder that people have followed their movements for thousands of years, or that the ancient tribes of the Pacific Rim honor them still, or that natives and newcomers fight bitterly over the right to fish for them, or that nations argue over who owns them, or that sportsmen spend hundreds of millions of dollars a year to catch them?

Seven species of salmon can be found in the waters of the Pacific. All of them belong to the



genus *Oncorhynchus*, from Latin for the "hooked snout" that describes the upper jaw. The largest is *Oncorhynchus tshawytscha*, the chinook, or king, salmon, which can weigh as much as 125 pounds. There are also the coho, *O. kisutch*; the chum, *O. keta*; the pink, *O. gorbuscha*; the sockeye, *O. nerka*; and the cherry, *O. masou*, an Asian species that seldom ranges beyond the fringes of Japanese and Soviet waters. Scientists of the American Society of Ichthyologists and Herpetologists added the seventh species in 1989, reclassifying the seagoing steelhead, formerly *Salmo gairdneri*, as *O. mykiss*, based on the anatomy, behavior,



and DNA structure of the fish. Including all seven species together, there are hundreds of thousands more Pacific salmon than there are *Salmo salar*, their Atlantic cousin, also an important commercial fish.

Although Pacific salmon travel under a range of local names—tyees, reds, springs, dogs, bluebacks, humpies, to mention a few—all, with the exception of steelhead, follow the same life cycle: They hatch in rivers, travel to the sea, fatten on rich ocean fare, return at maturity to spawn in their natal rivers, and die shortly after spawning. Atlantic salmon and steelhead may live to spawn repeatedly.

Using stout oars, Soviet fishermen maneuver their rowboat beside a setnet in the sea off the island of Sakhalin. Hand over hand they will haul in the net, crowding thousands of salmon toward the main fishing boat. Once its hold is filled to overflowing with 10 tons, the boat will head for the processing plant in Poronaysk. The fishing fleet works around the clock for every salmon harvest, but it pressed even harder during this 1989 run, the largest in 115 years.

EVEN PEOPLE who have no interest in catching salmon for fun, profit, or food will gather by the hundreds just to watch their spawning runs. The fish announce the coming of fall and, more than that, the comforting resiliency of nature. Although the wild salmon's numbers have been greatly diminished by dam construction, logging, pollution, and irrigation schemes, millions of the salmon still arrive with the seasons, pushing up the Columbia and the Skeena, the Sacramento and the Bella Coola, the Yukon and the Amur.

When I arrived on Sakhalin, there were so many fish at the mouth of Ochepukha River it looked as if you could walk across on their backs. People splashed after them with little nets, old wooden crates, even their bare hands. An elderly man in a blue sweater, standing knee-deep in the swift stream, held his hands under the water waiting for the fish to come. He turned to the boy wading next to him and offered a bit of fatherly advice: "Relax, be patient," he said.

I thought of home and the time 33 years ago when my father took our family to watch the Indians catch salmon for the last time at Celilo Falls on the Columbia River, before it was flooded by The Dalles Dam. The men strained to net huge shiny salmon out of the river. Meriwether Lewis and William Clark had smoked a peace pipe here with the Indians and admired their catch 150 years before; then, as on Sakhalin, the fish came so fast and thick the people could harvest only a fraction of them.

My guide, Valery Efanov of the Pacific Research Institute of Fisheries and Oceanography, told me this salmon run was the biggest in 115 years. "We can't harvest them all."

As he spoke, I watched the salmon pushing upstream to a point where a net blocked the river, too warm for the fish due to a drought. Thwarted, they turned back, milled about, and tried again and again. A few rolled up onto the sand with their mouths open, gills heaving, exhausted, pointing home. "We'll open the river tonight, when it is cooler," said Dr. Efanov. His daughter Nastij leaned over and gently pushed a few back into the water.

JERE VAN DYK, a native of Washington State, has written about the Brahmaputra River and East Hariem for the magazine. Seattle photographer NATALIE FOBES studied salmon while on a grant from the Alicia Patterson Foundation. This is her second NATIONAL GEOGRAPHIC assignment.

Before the first people are supposed to have crossed over the Bering land bridge, the huge salmon runs sustained ancient tribes all along the Pacific coast of Siberia. At Ushki, a dig located on the Kamchatka Peninsula, archaeologists have unearthed salmon bones among the remains of communal living sites 11,000 years old.

What led the scientists to look for salmon bones at Ushki?

"There was a spawning ground there then," said Nikolai N. Dikov, an archaeologist with the Soviet Academy of Sciences, "and there is a spawning ground there now." The ancients may have gathered at the Ushki site to ask the gods for a plentiful run.

"Early people crossed the land bridge," Dr.





Shielded from slime and bundled against the cold, workers at the processing plant in Poronaysk gut freshly caught salmon and pass them along for salting. In another room women take a break from the tedium of the cannery. Part of the Druzhba collective farm, the plant operates three eight-hour shifts and recruits students and soldiers as extra help during the peak salmon run. Workers get paid according to the production of their team.





Dikov stated, stroking his small white goatee. "We are working to define the exact time and pathway. Hunger drove Paleolithic people to migrate, following the bison and the mammoth. When those land mammals were gone, Neolithic groups moved down along the water hunting the giant sea mammals, whales and walrus, and eating salmon."

NOBODY EATS as much Pacific salmon as the Japanese, who consume the fish raw, pickled, baked, salted, fried, souped, pasted, and smoked. They eat salmon livers, salmon milt, and salmon skulls, and they process the fish into burgers and sausage. They eat 300,000 tons of the fish each year, a third of the world's total catch. The center of it all is Tokyo's Tsukiji fish market, the largest on earth.

Long before sunrise the market is buzzing. Hundreds of men and women rush around between stalls, shout orders at one another, slice fish, work the telephones, and joke under bright strings of lights that shine on acres of iced-down fish steaks, shark fillets, and thick red slabs of tuna stacked like wood. The concrete floors are newly washed and swept. The whole place smells fresh, like the sea.

I make the rounds with Atsushi Udo, an independent buyer who supplies fish to a number of companies in the Tokyo area. Udo, a salmon specialist, ushers me to a bin displaying salmon. He runs his hand over a salmon's bright silver skin. "It's not just the size of the salmon that counts," he points out, "but the fat in the belly." He opens the fish and brushes aside the ice to show me. "See, the flesh is fresh and clean, no blood, a nice healthy pink."

Udo and I hurry to another stall, where he

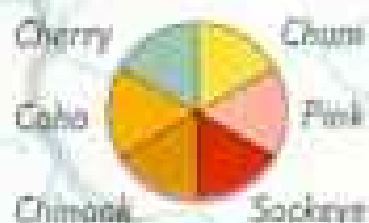


Glistening salmon fins surround a swimmer in the sea east of Sakhalin. Ready to spawn, the fish feel the pull of the Ochepukha River. But officials have blocked their way because a drought has made the water too warm. The salmon collect at the river's mouth until the barrier comes down in the cool of evening.

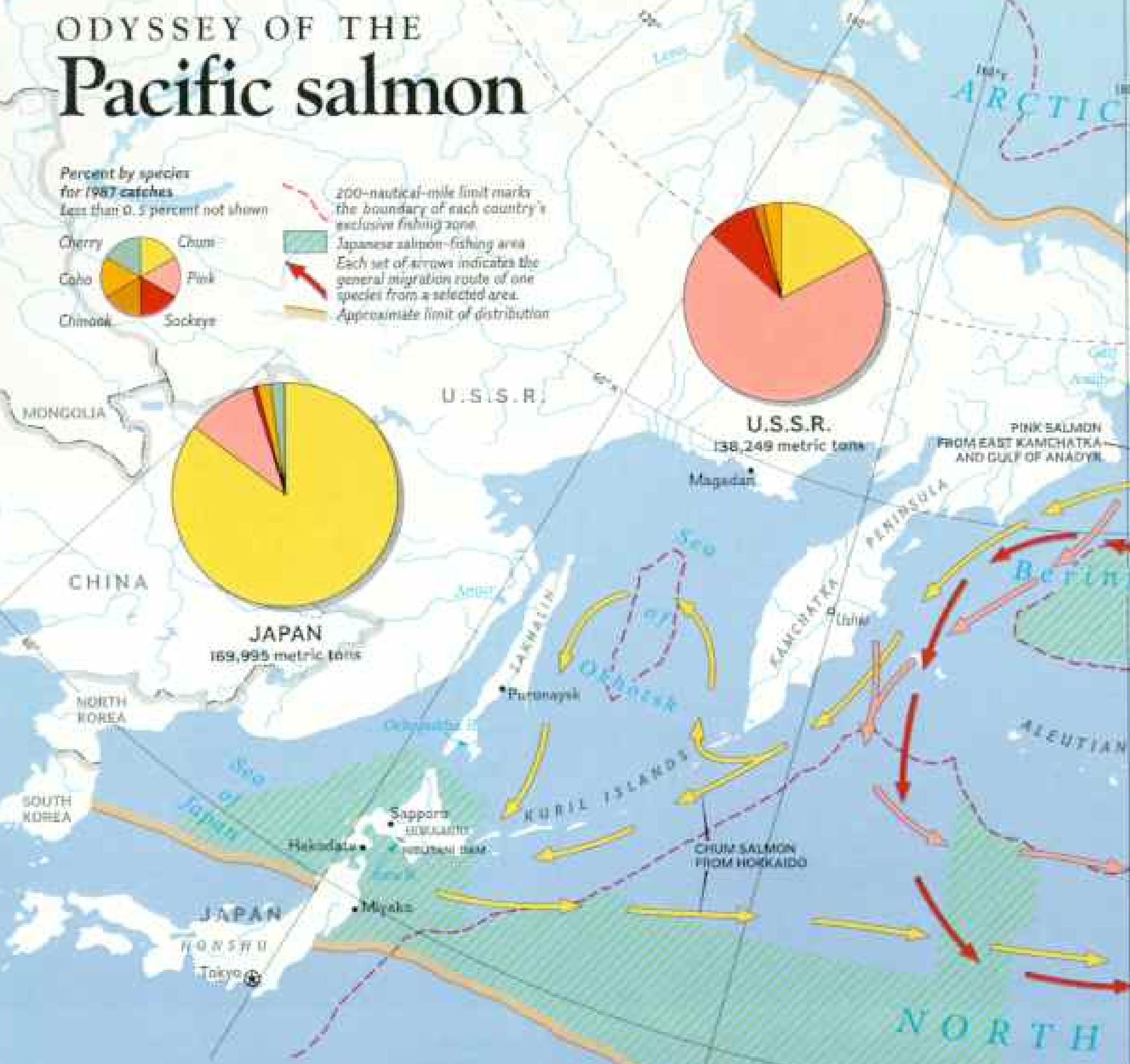
In Poronaysk, Valery Efanov, the author's guide, savors salmon cheeks as Kim Nacho demonstrates how her people, the Orochi, traditionally prepare the fish.

ODYSSEY OF THE Pacific salmon

Percent by species for 1987 catches
Less than 0.5 percent not shown



200-nautical-mile limit marks the boundary of each country's exclusive fishing zone
Japanese salmon-fishing area
Each set of arrows indicates the general migration route of one species from a selected area
Approximate limit of distribution



LEAVING their native rivers as finger-size smolts, salmon grow rapidly in the rich feeding grounds of the North Pacific Ocean. They stay in coastal waters at first, then move to sea, where they feed on zooplankton and smaller fish. The Pacific nourishes seven species of salmon—including the steelhead, classified as a trout until recently. Males in spawning colors appear at right.

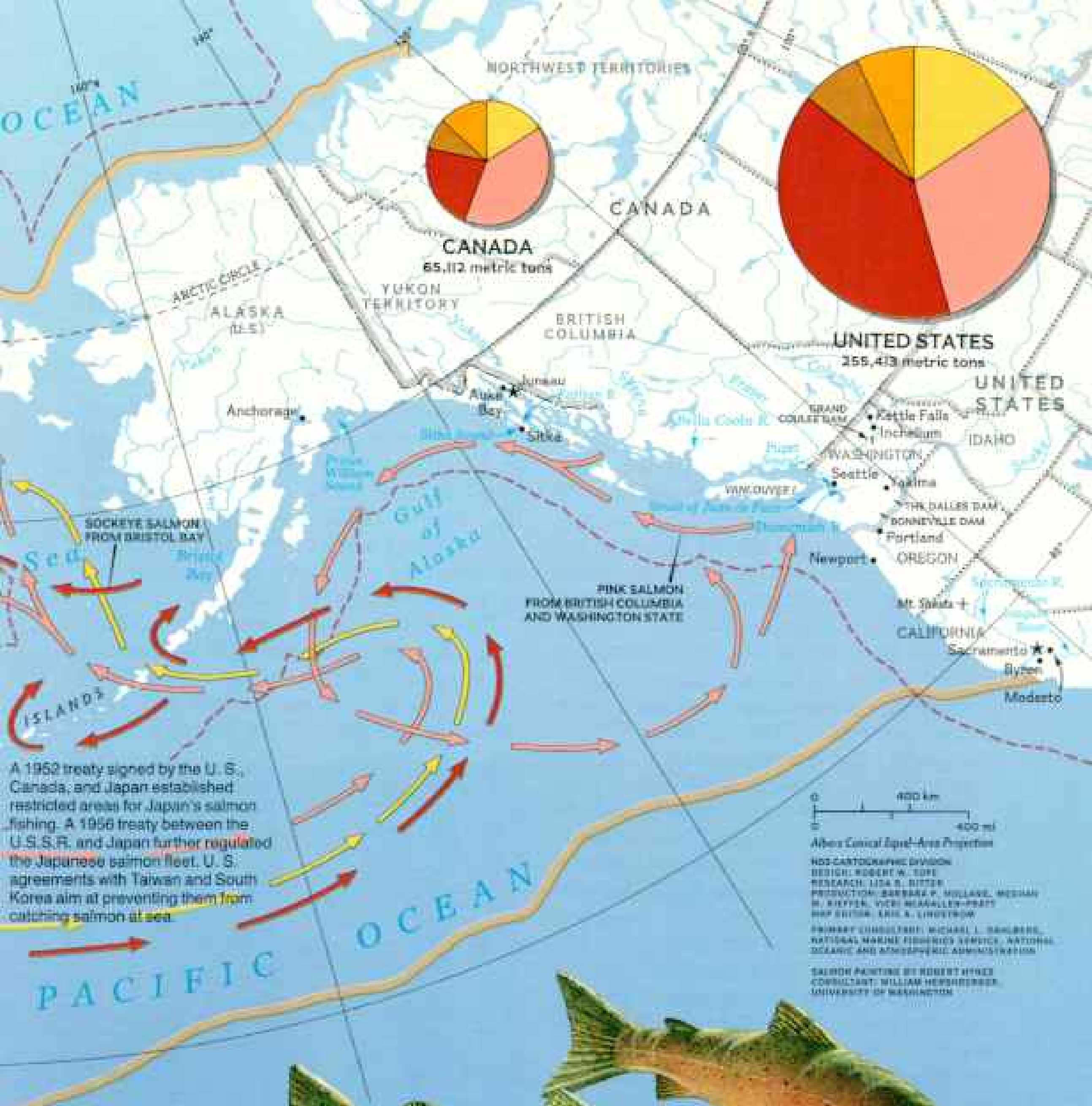
Fleets from the U. S., Canada, and the U.S.S.R., three of the principal salmon-fishing nations of the Pacific, catch adults returning to the rivers of their respective countries. The Japanese also catch the silvery salmon still at sea whose firm, oily flesh they prefer. International agreements restrict Japanese catches to the areas shaded in green. Taiwanese squid boats with massive drift nets have been caught poaching salmon at sea.



Pink
Oncorhynchus gorbuscha
average weight 4 pounds, average length 20 inches



Cherry
O. masou
weight 9 lb., length 23 in

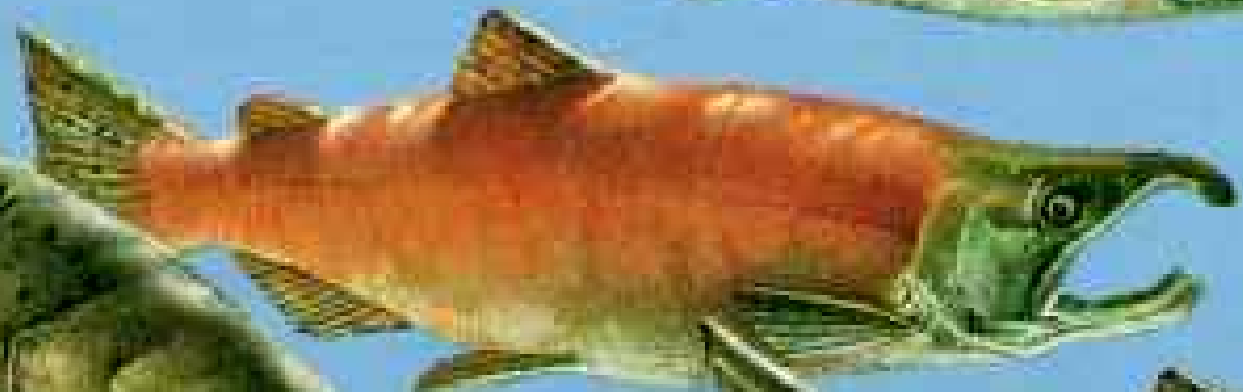


Steelhead
O. mykiss
weight 9 lb,
length 24 in



Coho
O. kisutch
weight 10 lb,
length 24 in

Sockeye
O. nerka
weight 6 lb,
length 25 in



Chinook
O. tshawytscha
weight 22 lb,
length 36 in



Chum
O. keta
weight 9 lb,
length 25 in



bargains over a stack of frozen chinook, then to another stall, where he pops a salmon egg into his mouth for a taste test. He closes his eyes and nods approval: "Not bad," he says. He holds another egg to the light, like a ruby. To him the ideal salmon egg is transparent. It melts in your mouth. "It must taste dry. It must have a light delicate flavor. I look for size, firmness, and color. If the eggs are too dark, they haven't been prepared properly." Even the container has to be just so, made of fir, not cedar or pine. "If you have the wrong wood, the smell affects the eggs."

In this nation of fish-eaters a tiny 6-by-13-foot stall at Tsukiji fish market costs more than a million dollars, but stalls seldom go on sale. The high stakes and exacting standards can be punishing, as Atsushi Udo told me: "An independent buyer has to work harder than everyone else. I lost 17 pounds in the first three months of business." Udo, still lean, finished his breakfast of raw squid, tuna, and salmon, and wiped his hands on a hot towel. "I don't see my wife and two daughters much. I visit customers on Sundays. I was in Thailand yesterday. I'll go anywhere." It was 6:30 a.m. Udo would probably work until 10 p.m.

As Japan's appetite for salmon grows, the nation is looking to the rest of the world to add to the supply from its own rivers and estuaries. The Japanese fly salmon eggs to hatcheries in Chile, where fry are released into rivers and streams. Between 1983 and 1985 Japan provided 12.6 billion yen's worth of hatchery equipment to the Soviet Ministry of Fisheries. Near the Soviet city of Magadan, I saw the makings of this venture—new plastic incubation trays for roe, shiny steel pumps, and plastic tubing—gathered under a half-built shelter of wood and concrete. Japan also buys fish from North America and deploys its own commercial fleet of 200 vessels to ply international waters for salmon.

CONTROVERSY GROWS with the demand for salmon. The governments of the United States, Canada, and Japan maintain that every migrating salmon belongs to its country of origin, even beyond the 200-nautical-mile limit set by international agreement. The fishermen of other maritime states, such as Taiwan and South Korea, believe that fish, a gift of nature, belong to everyone.

Some seagoing salmon get snared in drift

nets, each set to a depth of 30 feet across 30 miles of ocean. This method—used by Taiwanese, South Korean, and Japanese squid fishermen—picks up most everything that swims by. Many of the experts I talked to said that Japan regulates its squid fleet, that most of the illegal salmon fishing is done by Taiwanese and South Koreans using squid vessels as a cover. As in everything involving salmon, there is hot debate over who is doing what to whom and over the extent to which drift netting damages the salmon fishery.

"We don't usually know where the illegal fish are actually caught," said Michael Dahlberg, high-seas salmon expert with the National Marine Fisheries Service in Auke Bay, Alaska. "Most are probably of Asian origin. Alaska had a record catch this year," Dr. Dahlberg added. Alaskan fishermen did not seem to be suffering—yet.

There is also concern over the long-term impact on other species. Most island states in the South Pacific, including Australia and New Zealand, have banned drift netting in territorial waters. And the United Nations



General Assembly recently condemned the practice as indiscriminate and wasteful.

In Tokyo I showed Daishiro Nagahata, a deputy director with the Fisheries Agency of Japan, an angry editorial from the U. S.

"SAY NO TO DRIFT NETS," read the newspaper headline.

Nagahata studied the clipping and pushed it back across the desk to me. "The Americans



Relics of early salmon hunters

BY A WICKERWORK WEIR built to stop salmon swimming upstream, an Ainu fishes with a hand net. This 1860s watercolor by Japanese artist Byozan Hirasawa belongs to a set of 12 showing Ainu customs that were soon to disappear. A native people of northern Japan and nearby islands, the Ainu freely hunted, fished, and gathered food for thousands of years. They believed that the salmon, one of their staples, were spirits who returned every year, sacrificing themselves so that the Ainu could live. With the dawn of the Meiji period in 1868, Japan colonized the Hokkaido wilderness and pressed its Ainu inhabitants to take up farming.

Deputy director of the Sakhalin Regional Museum, Valery Shubin shows off a salmon-skin robe once worn by Ainu on special occasions.

HAKODATE CITY MUSEUM, HOKKAIDO

consider the high seas a fish sanctuary. Japan considers them common ground, although we respect the country of origin principle."

In an effort to ease the controversy, Japan closely regulates its fleets and now allows foreign observers aboard some of its drift-net vessels. It has even agreed to equip its ships with radio transponders, which would give a constant fix on their position.

"The biggest argument is that drift netting is a waste," says Jim Salisbury, a fisheries attaché at the U. S. Embassy in Tokyo. "The salmon you get at sea are small. They'll be almost twice as large when they return, a tremendous resource for the U. S. If the Japanese want salmon, they can buy them from us."

They do—and they do. Most of the commercial catch from Alaska, the richest salmon

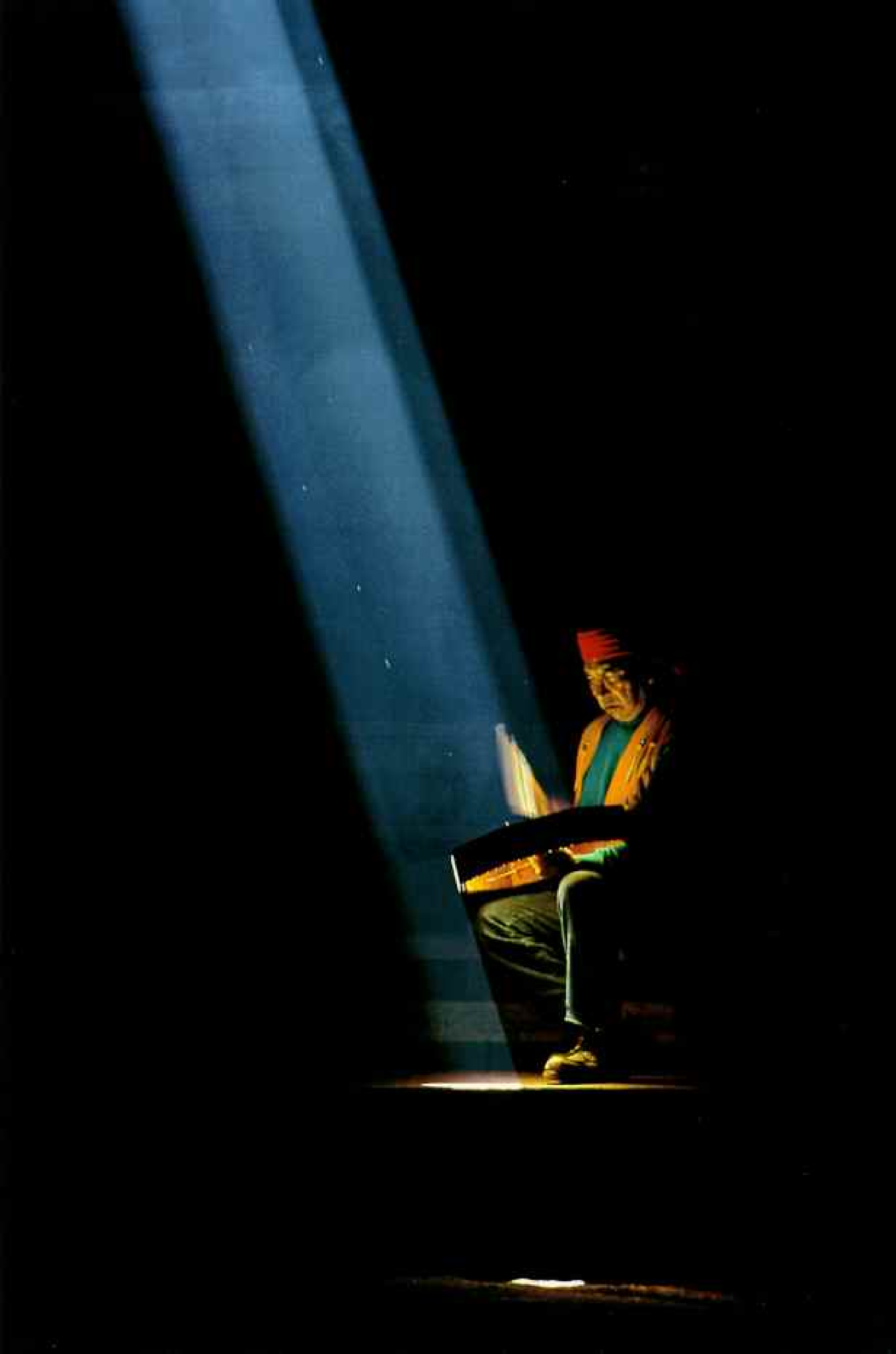


By the light of a sunbeam Raymond Moses tunes his drum before joining a salmon ceremony (below) in the Tulalip longhouse in Washington State. His ancestors were among the many peoples of the North Pacific who created legends about the salmon and celebrated its return. Modern Tulalip have revived their

ceremony from customs kept alive by individual families.

Traditionally adorned, Sute Orita takes part in the Ainu salmon ceremony, revived in Sapporo ten years ago. Forbidden by the Japanese a century ago to fish for salmon in the old way, the Ainu may now catch 20 fish for each year's ceremony.





grounds in the world, goes to Japan. And because they purchase such great quantities every year, the Japanese set the world price.

To make sure the fish are handled properly and to assure supply, Japan has invested in many salmon canneries and processing plants in Alaska and British Columbia. Japan also sends an army of technicians over to supervise processing the roe Americans once discarded.

"We'd be in a world of hurt without them," says Harold Thompson, president of Sitka Sound Seafoods, a major processor in southeast Alaska.

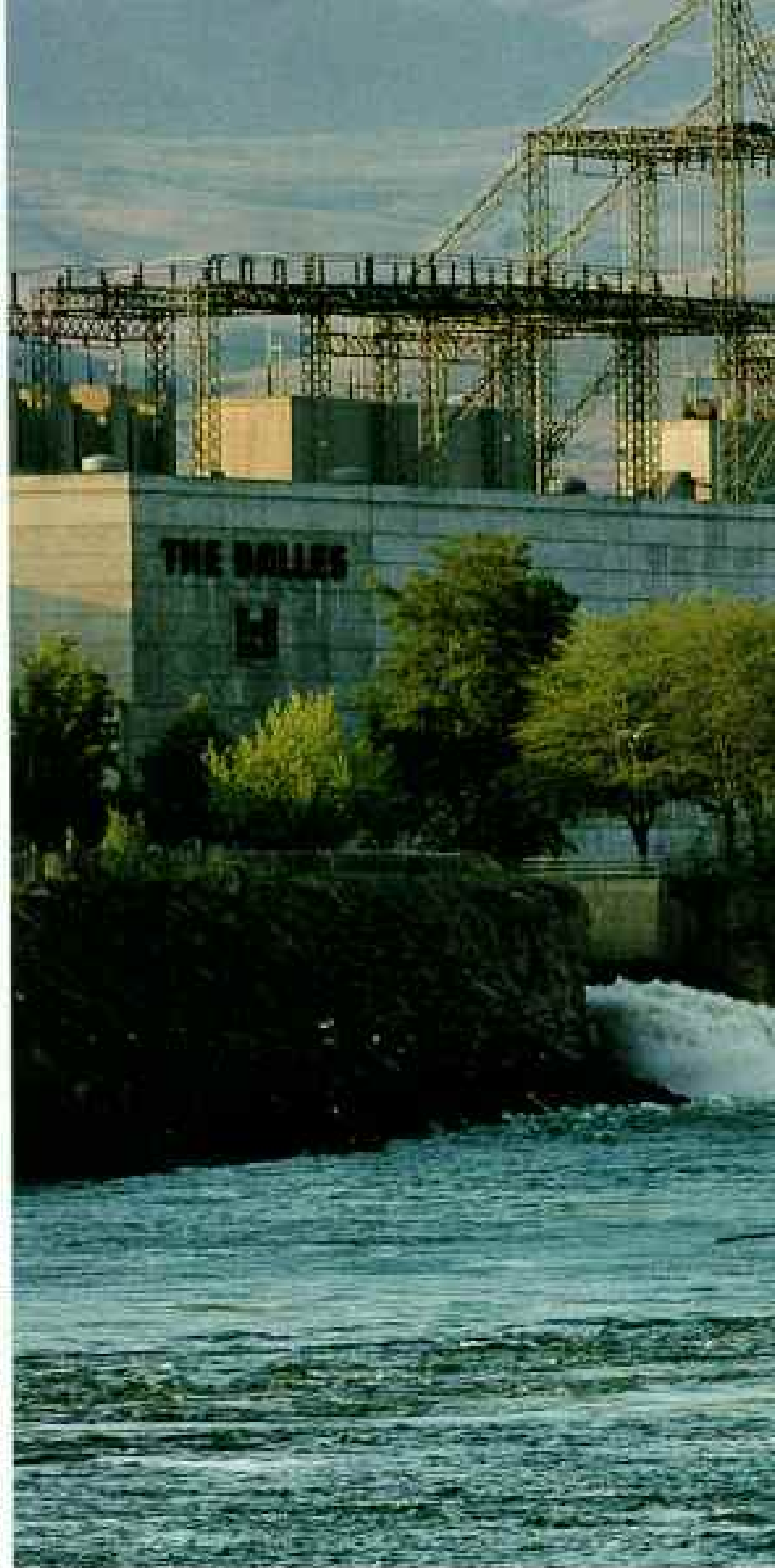
THERE WAS A HINT of winter in the October wind when I set out across Sitka Sound with Gregg Jones, one of 1,700 commercial fishermen licensed to troll for salmon in Alaska. Even though the best part of the season was over, as a favor to me Jones went out fishing that day. He took a sip of hot coffee and pushed a trolling rig out over the water, then went inside to scramble eggs on his marine stove. The sun was just clearing the snow-covered mountains.

"I traded my house and pickup for my first boat," he reflected, pouring another coffee to ward off the chill. "The woman in my life didn't like it." A sleeping bag lay rumpled on his bunk. "It's like living in a house, only it goes up and down, and there's a different view every day."

One of the lines jiggled. Jones hit the hydraulic reel and brought up a shiny chinook of perhaps 15 pounds. He gaffed it on the head, then punctured its ventral aorta. "It's like cutting the jugular vein of a cow," he said. After the blood drained out, Jones ran a long knife up its belly and pulled out a herring's ragged skeleton. "She isn't ready to spawn yet. She has an immature egg sac. At this weight, I'd say she's been in the ocean two years."

He washed her off, making sure no blood remained inside, because that is the first thing that goes bad. He went below, packed the fish on ice, and calculated that it would bring \$37.50. He smiled, feeling better now that the first fish was on board. But after ten cold hours it would be his last—the only fish we caught that day.

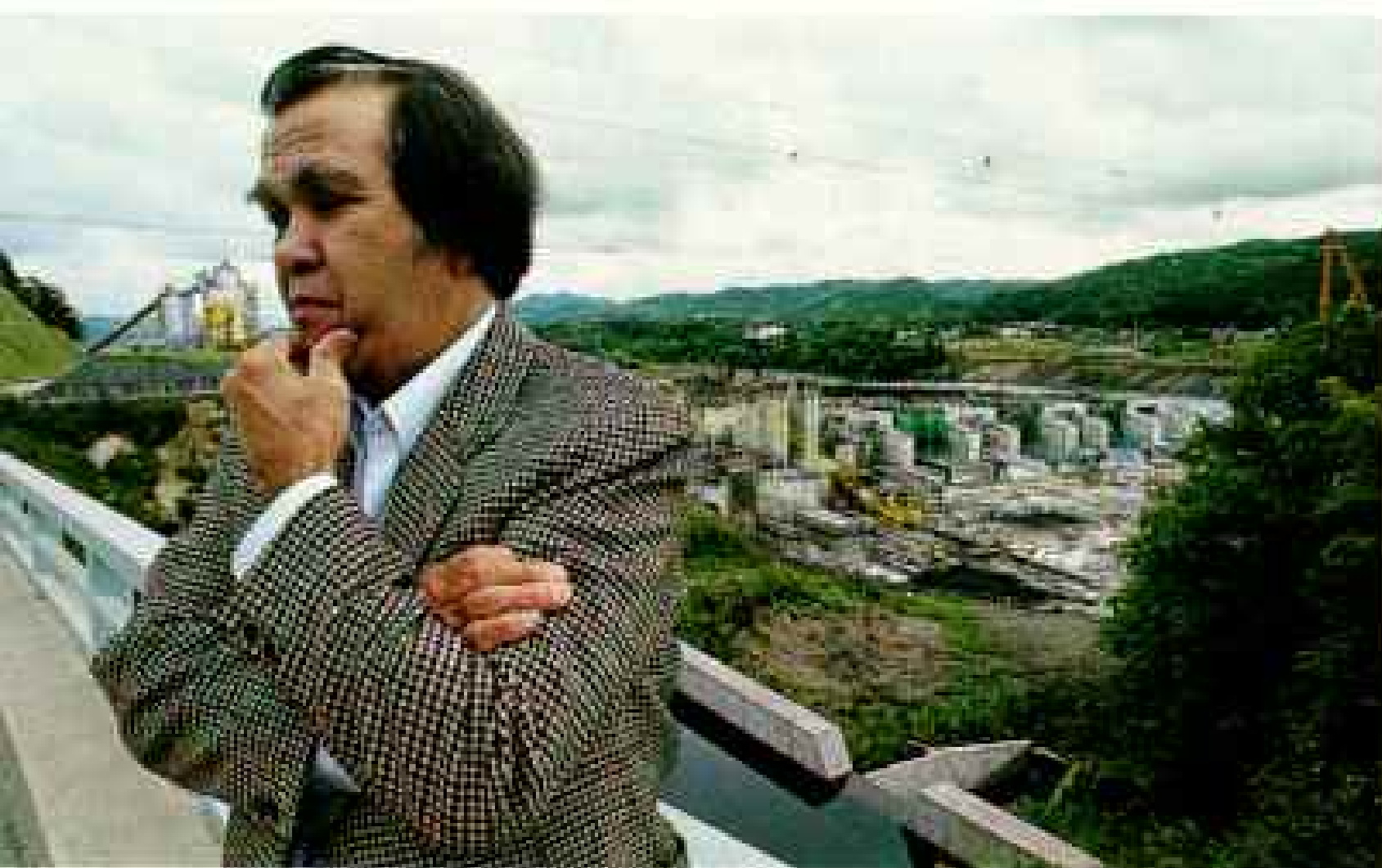
The big money makes it worth the risk and labor. A salmon troller can earn as much as \$70,000 in a good season, and a deckhand can get \$10,000—one reason college kids often



follow salmon to Alaska. A few good summers and you pay your way through college.

Toward sundown we returned to Sitka under low clouds. A single totem pole was silhouetted against the sky. We ate halibut cheeks that night with some fishermen who brought along a fiddle, two guitars, even a clarinet. When the music stopped, I heard outside the squeal of old rubber tires against the pier, then a gull crying. "The sea is the last place I know where a man can be free," said Jones.

That night, I knew, the last of the season's coho were running inland, tasting the familiar waters of the nearby Katlian River for the first time in more than a year at sea. Perhaps by now they held deep in the safety of a pool under the drifting snow. There they would rest for a



All but insignificant in the face of The Dalles Dam, a Yakima fisherman casts a line into the Columbia River. A series of dams has seriously diminished this river's salmon runs.

Japan's Nibutani Dam rises behind Ainu folklorist Shigeru Kayano. When construction ends, the Saru River will flood his fields. In return, he wants the government to restore to the Ainu the right to fish for the river's salmon.

A perilous life cycle

A salmon hatches and dies in the same stretch of a cool, fast-flowing river. During its lifelong journey to sea and back, it confronts both natural and manufactured dangers. The coho, shown here, lives in fresh water for more than a year, then in salt water for another eighteen months or so.

Death

Their mission accomplished, the salmon soon die.

Early development

Alevins hatch after 50 to 100 days. Weeks later, fry emerge from the nest and begin to swim and feed, often becoming food for birds and other fish.

DOWNSTREAM



Spawning

The female distributes some 2,000 to 5,000 eggs among several nests. More than one male may fertilize them with his milt.



while, then move upstream again into the silent mountains, traveling on stores of fat and muscle from their sea-feeding years. Spawning salmon stop eating in fresh water, even if their river journey is a thousand miles. Their purpose now is to breed. Each fish finds its way up the river's main stem—even into the branching, rebranching, and constricting tributaries—to the place where it had hatched.

The fish find their birthplace within a small margin of error, guided by the smell of the home stream and by other means that humans do not yet understand.

When a hen salmon finally gets home, she begins digging a nest in the riverbed, thrashing with her whole body to make a hollow. Two or three males hover nearby, fighting for breeding rights until the nest is finished. The hen, now accompanied by the strongest male, shudders and releases her eggs, dropping them into the nest. Simultaneously, the male shudders too, releasing a milky cloud of sperm to fertilize the eggs. With her tail the female sweeps a protective cover of gravel over the nest, at the same time scooping out another nest for more eggs.

Not long after the spawning is done, both

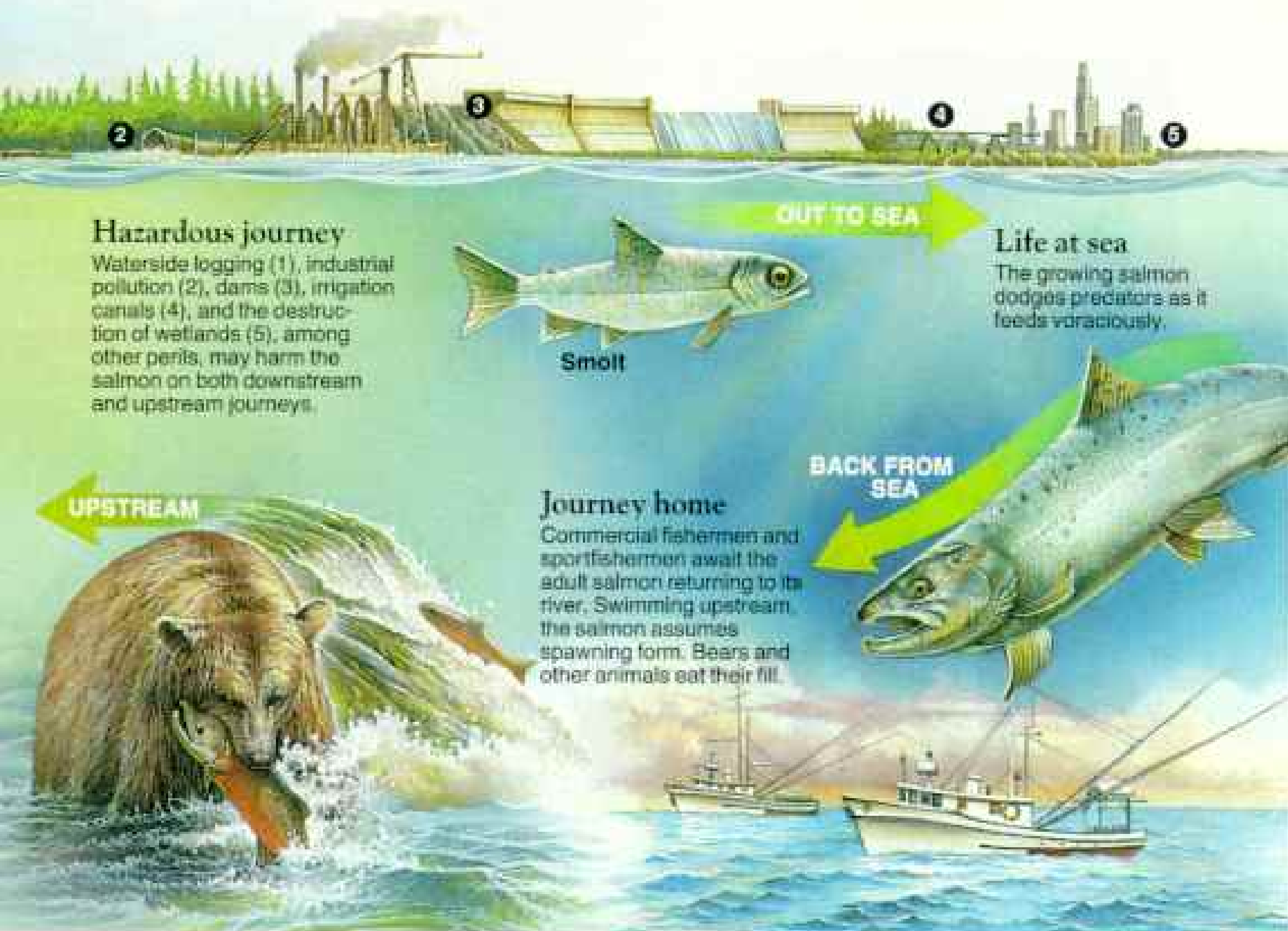
parents die, spent from the process, from the weeks of fasting, from the territorial fights, from the nest building. They become food for eagles and bears. Their decomposed bodies add nutrients to the water, which in time will nourish their progeny.

Then the cycle restarts: From the eggs hatch alevins, translucent fish carrying pouches of food on their bellies, which feed them for weeks. Alevins become fry, fry become smolts, and smolts are salmon headed to sea.

Most never make it home again. If a female lays 3,000 eggs, no more than 300 or so survive as fry; of that 300, no more than four or five reach maturity and fewer still return to spawn. The survivors beat the odds, traveling as much as 10,000 miles in the ocean, eluding predators, fishermen, pollution. Given the natural and man-made perils faced by a salmon, the amazing thing is that any survive at all.

But they do.

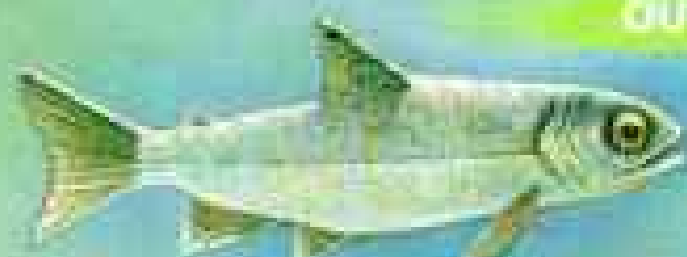
When the tanker *Exxon Valdez* spilled 11 million gallons of oil into Alaska's Prince William Sound in March of 1989, it appeared to doom the salmon that normally mass there before summer spawning. In fact, when the fish returned, fishermen reaped more than 20



PAINTING BY ROBERT NYRE; PRIMARY CONSULTANT: WILLIAM HEDDINGER, UNIVERSITY OF WASHINGTON

Hazardous journey

Waterside logging (1), industrial pollution (2), dams (3), irrigation canals (4), and the destruction of wetlands (5), among other perils, may harm the salmon on both downstream and upstream journeys.



Smolt

Life at sea

The growing salmon dodges predators as it feeds voraciously.

BACK FROM SEA

Journey home

Commercial fishermen and sportfishermen await the adult salmon returning to its river. Swimming upstream, the salmon assumes spawning form. Bears and other animals eat their fill.

UPSTREAM

million pink salmon, a fourth of the state's catch. It was one of the biggest seasons since 1878. The long-range effects of the spill remain to be seen. A year later researchers noticed that fewer eggs survived in some areas, and young fish were smaller than normal.

Like other wild creatures that man relies upon for food, the salmon offers constant lessons in humility.

"We're wrong more than 50 percent of the time," says Herman Savikko, a biologist for the Alaska Department of Fish and Game. "We predicted 16.1 million sockeye for Bristol Bay in 1989," he said. "There were 29.3 million. Once salmon reach the ocean, it's a black hole. Are the drift nets taking them? Is there increased predation? Warmer current? A cold snap? Mother nature decides."

TO AVOID the uncertainties mother nature inflicts on fishermen, people are turning to salmon farming, which now accounts for three out of every ten salmon consumed in the world. Roger Engeset runs such a farm, tucked away in a rocky cove on the coast of British Columbia. There he grows fish the

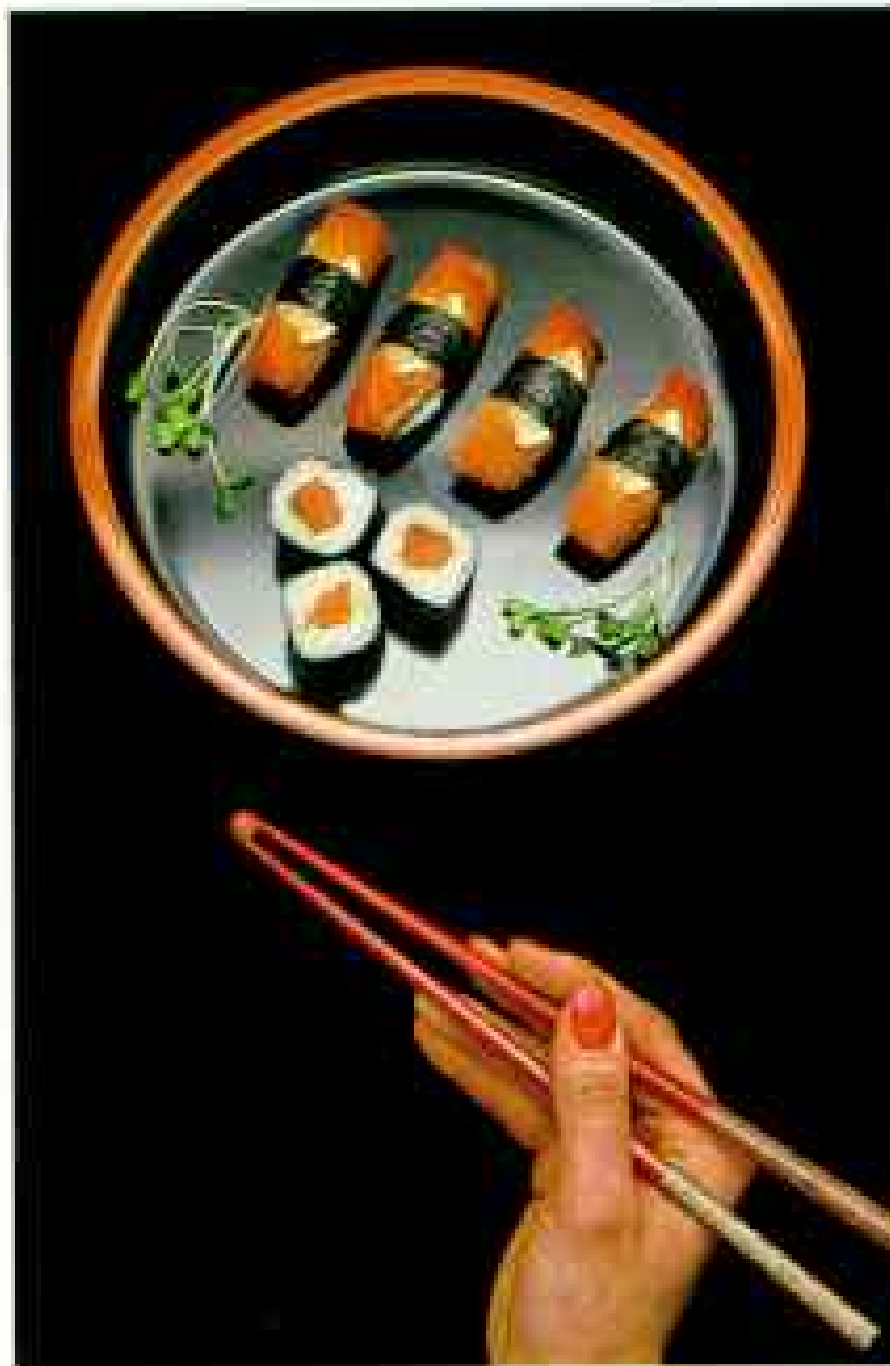
way other farmers grow hogs—in feedlots—except that his lots are fenced by nets and afloat in salt water.

"In 48 hours we can get the salmon from pen to restaurant anywhere in Canada or the U. S.," says Engeset, standing by one of 16 pens that holds as many as 25,000 salmon. "We don't hunt pigs any more," he says, scooping up a handful of salmon feed. "We farm them. It will be the same with salmon."

He casts a handful of the food pellets into one of the pens, and his salmon swarm to the surface, like pet goldfish at feeding time.

Smolts are dropped in by helicopter, 10,000 to 15,000 per load. Dumped into the pens, the smolts stay there, never going to sea, never joining the hazardous migrations of their wild cousins, never being tested by the rigors of courtship. For as long as 24 months, they live only to eat. When they weigh about five pounds, they are netted for market.

Kept on ice, the fish have a shelf life of three weeks. If you eat salmon that has not been cooked or frozen, you risk ingesting a parasite that can cause discomfort in your digestive tract, although permanent damage is unlikely. Almost all salmon is safe, even good for you.



Working through the night in Bristol Bay, crewmen load a Japanese freighter with freshly frozen salmon from a processing barge. The Japanese buy 75 percent of the Bristol Bay catch. At a fisheries cooperative in Miyako, Japan, a worker sorts salmon roe, which the Japanese value even more highly than the fish itself. Delicately held with chopsticks, a perfect pearl of roe accompanies salmon sushi.



High in protein, they also contain oils rich in omega-3 fatty acids, which can lower blood cholesterol and reduce the risk of heart disease, according to medical research. That makes the fish attractive to consumers and encourages farmers like Engeset and the many corporations now entering the market.

Engeset, a Norwegian, started his company with two employees five years ago. Now he has 60. "In Norway I tried for five years to start a salmon farm, but out of a thousand applications the government accepted 50, so I decided to look elsewhere." He chose the Canadian coast, an ideal environment, with its clean water and isolated coves. Last year, farms like his produced more chinook salmon in British Columbia than commercial fishermen could provide.

Ron Ginetz, chief of the Pacific aquaculture division in Canada's Fisheries and Oceans Department, believes that trend will continue:



"By the year 2000 we believe the farm salmon harvest will equal or surpass the commercial catch," he said. "Farming production costs will fall, and salmon will be available year-round, like chicken."

WHAT WILL BECOME of the wild salmon, those that still make their ageless rounds on the Pacific currents? Will they be just another commodity?

"Salmon," said the professor, "is a food item. Economics most often wins out. The environmentalists will lose." The speaker was William McNeil, a researcher at Oregon State University's Hatfield Marine Science Center. We were sitting in an office at Newport discussing the fish's future.

"The supply of salmon is as robust as it ever has been and is even increasing," he said.

I didn't understand.

"The wild stocks are being overfished," he explained. Pollution and dams also take their toll of wild stocks, but the burgeoning farms and hatcheries more than make up the deficit.

Farms, of course, keep their fish in one place. Hatcheries, operated privately as well as by state and federal governments, release their fish into hundreds of rivers, streams, and saltwater bays, to be caught on returning from sea. That is a boon to sport- and commercial fishermen, but there is a trade-off: If hatchery fish breed with wild stock, which are adapted to one particular river, a genetic resource built up over tens of thousands of years could be weakened.

"We're very concerned about genetic erosion," says Peter Paquet, senior fish and wildlife biologist with the Northwest Power Planning Council in Portland, Oregon. "We're concerned that we could lose unique gene pools," Dr. Paquet emphasizes. For that

reason, smaller hatcheries may be established on more streams in the Pacific Northwest, to protect each watershed's unique strain of fish. "It looks like the offspring of a hatchery fish bred with a wild fish has less chance of surviving," he says.

Many a sportsman will tell you that hatchery fish don't fight as hard as wild ones. And many consumers feel that the taste and appearance of a farm fish can't compare with that of its wild brothers — one reason Japanese buyers prefer Alaska's wild salmon.



Helicoptered from the hatchery, 20,000 chinook smolts spill into a saltwater net pen at one of British Columbia's many salmon farms. In about two years these salmon will be ready to harvest, weighing six to nine pounds. On another farm Brad Anderson nets feisty chinook bound for the processing plant, then perhaps the United States or Japan.

HOW CAN A SPECIES that has endured for thousands of years in wild, open rivers survive in a world of diminishing wilderness? Some can't.

Wild coho have disappeared from the upper Columbia River. The sockeye are almost gone from the Snake River of Idaho. And in California's Sacramento River, once a great salmon stream, the winter race of chinook is on the threatened species list, and fisheries specialists believe that the spring run of wild chinook may face the same fate. Many feel that there is not enough water in California to sustain fish, subsidized agriculture, and a human population that grows by 700,000 a year.

Jason Peltier, manager of the Central Valley Project Water Association, explained it this way: "Seventy percent of the rainfall in California is above Sacramento," he said; "80 percent of the demand for water is below." To sustain growth in the hot, dry south takes water from the northern salmon country.

"We just want to keep the salmon in water," said Forrest Reynolds, of the state's Inland Fisheries Division. "California does not have enough water. One goal," he added, "is to keep the environment clean for the value salmon provide, over and above fishing. We stress wild salmon for their intrinsic value and for tourism. They are part of the California lifestyle people want to experience."

To keep salmon, as well as striped bass, coming to the Sacramento River, the state built a 20-million-dollar complex near Byron, where fish are strained out of the river at the Skinner Fish Facility.

"Water from the channel passes through a series of louvers," said Marvin Niemi, water operations chief at the facility. "That causes the water to ripple, which causes the fish to shy away into bypass pipes." He ran his hands over one of the metal louvers, which looked like a giant vertical window blind. "We take the salmon out of the bypass pipes, put them into holding tanks, and cart them 25 miles downstream beyond water diversion pipes and closer to the sea." On a good day in April or May, when chinook are running, the plant handles more than 5,000 a day.

Flying over the Central Valley, I wondered how so many salmon had managed to make their way so far south. The Sacramento River moves like a thin snake, wriggling down past the base of Mount Shasta through hills that go



from green to brown, then crossing into a flat landscape of squares, dams, channels, levees, pumping stations, and ruler-straight waterways. What was once prime habitat for salmon is now prodigious farmland, source of a third of the fruits and vegetables produced in the United States.

It was a trade-off. Was it worth it? Outside of Modesto I met a rancher who answered the

question bluntly: "What's more important, sportfishing or food? We're the cheapest fed nation in the world." Those words carried over a quiet stretch of his leased pasture, and the sound of his voice made his cows moo in the autumn night.

BY LATE OCTOBER the rain was slashing in sideways from the Pacific, into the Strait of Juan de Fuca. I had come home to Washington. The waves crashed brown and white over the rocks. Gulls screamed overhead in the mist, and I imagined how it was when the Makah Indians paddled out to sea in their cedar canoes to fish for salmon.

For as long as anyone can remember, the

At a waterside work station in Idaho Steve Achord weighs smolts (below). The computer chip (bottom) that he has inserted in their bellies (middle) will let scientists track the smolts' passage through dams. Snorkeling on a different Idaho creek, Russell Kiefer counts smolts for a study of habitat improvement.



lives of coastal Indians and salmon have been linked. The fish was a mainstay of their diet, and their customs reflected that dependence. To the Bella Coola of British Columbia it has long been taboo to throw refuse in a salmon stream, and peoples all around the Pacific celebrated the arrival of the season's first fish.

"When we saw the first salmon jump, we would go up to Kettle Falls, catch and cook two fish," recalled Breaking of Dawn, great-grandson of a Colville Indian salmon chief. "Between 1,500 and 2,000 Indians came from all four directions to take a small piece of the first salmon. Then the season began."

Breaking of Dawn is 84, and he is sometimes bitter. I found him playing solitaire in a trailer by the Columbia River, far upstream near the

village of Inchelium. He showed me a slab of dried salmon. "This fish is what I've been deprived of by you white people," he said, handing it over. "I have to buy it now. Costs \$20." He took it back.

Breaking of Dawn lives too far upstream for salmon now. They can't get past two dams below him on the Columbia, one of the world's most dammed rivers. Its main stem has 14 dams, with more than 100 on the Snake and other tributaries. It is no longer a mighty river but a series of lakes with mostly hatchery fish. In fact, concern over the decline of three wild runs—the Snake River chinook and sockeye and the coho of the lower Columbia—is spurring petitions to the federal government for protection under the Endangered Species Act.





A bright spot amid devastation, biologist Kelly Wilcox takes a stream's temperature at a logging site in British Columbia. The loss of shade plants along the banks may have made the water too warm for salmon. Bare hillsides may erode to produce smothering silt.

Rescuing salmon from an irrigation system, California fisheries biologist Jon Polzine grabs a chinook by the tail. Many salmon migrating up the San Joaquin River stray into these channels of agricultural runoff.





I often heard that the wild fish make up only 20 percent of the Columbia runs. No one seemed to know how those figures were derived, but everyone agreed that the region's hatcheries had introduced hundreds of millions of fish into the river over the years.

There is, of course, no going back to the days when salmon ran free on the Columbia. But a visitor cannot help but feel amazed, even touched, at the lengths to which man will go—having utterly transformed the salmon's world—to set things right for the fish again.

Every spring barges make daily trips down the Snake River to the Columbia with an unlikely cargo—each one carries 250,000 or more chinook smolts from Idaho. When barges are downstream of Bonneville Dam, 140 miles from the sea, the fish are released to make their own way. If the migrating fish had

to swim the whole distance, many would die, eaten by predators, slowed by the artificial lakes, or destroyed in the turbines of dams.

Almost 140 million dollars has recently been committed to install and upgrade fish passage-ways and screens on four of the Columbia system's dams, so that more fish can get around them. Each spring water is released from the dams to ease migrating fish on their way, at a cost of as much as 70 million dollars a year in lost electrical generating capacity. Many people would happily pay higher rates for the fish's sake.

"It's smolts versus volts," quipped Steve Pettit, a biologist with the Idaho Department of Fish and Game. "The power people say our rates will go up a dollar a month to save the salmon. We in the Northwest have to convince the power people that we have to do it, regardless of the cost."

ALL ALONG THE RIVER, people seem preoccupied with the salmon and its well-being. Lucille Worsham is one of them. From a dark room built into the base of Bonneville Dam, she keeps tabs on salmon traffic. I found her at the counting station, staring through a green window, watching for fish in the swirling green water.

"It doesn't get boring," she said. "When the fish are running, all I can do is count, using both hands. Sometimes we get 10,000 chinook a day. I count every one."

A small silvery male salmon passed, glowing in the light. Worsham hit a key on an adding machine. Then the salmon reappeared, drifting backward, downstream. She hit another key, deleting him. We waited. He came by again. She entered him. That made it eight chinooks for the day, 375,418 for the year.

Everyone along the river seems to count fish. How many did you catch today? How many passed the dam? How many this time last year? The fixation with counting intensified in the 1970s, when U. S. courts ruled that certain Indian tribes in the Pacific Northwest were entitled, by treaty, to as much as half the "harvestable" salmon returning to traditional tribal fishing areas each year. Until then, no extensive surveys of salmon populations had taken place, so it was impossible to know exactly how many there were. When the surveys were completed, the scarcity of fish was confirmed. To ensure an adequate supply of fish



Among many animals dependent on salmon runs, a bald eagle dines in a tree in Alaska. Submerged branches, reflected on the water's surface, hold the spawned-out body of a British Columbia sockeye. As it decays, the salmon returns nutrients to the river where spring hatchlings will renew the cycle.

for the future, regulations limiting the catch were strengthened. State and tribal officials try to allocate the catch fairly among Indians, commercial fishermen, and sportfishermen. To do that, state, federal, and tribal officials analyze data from dams, tagging studies, and previous runs, turning all information over to the Pacific Fishery Management Council. Then the council tries to predict the unpredictable—what next year's run of salmon will be.

"The science gets to be a nightmare," said David Sones, assistant fisheries director of the Makah Tribal Council, one of the Indian tribes entitled to half of each year's catch.

"We are the first in line for any salmon returning to Puget Sound," Sones told me, "and we have to deal with 19 other tribes and a gantlet of management zones. Our own fishermen complain that we don't let them fish enough," he sighed. "Other tribes are always threatening to take us to court. It's hard to let the salmon go by."

Although the allocation system has been in effect for more than 15 years, the feelings still run strong.

"The Indians are taking our rights away," said Scott Watson, a young commercial fisherman I met at the mouth of the Columbia River. "We've got to let the fish go by so they can take their 50 percent. We used to fish year-round. Now it's two months. It's maddening."

Others accept the allocations.

"For a fisherman there's never enough

fish," declared Jim Suomela, another Columbia fisherman. "The Indians get blamed for the cutbacks." His father, who had been on shore, climbed on board their boat and spoke up: "The Indians don't ruin the runs," he said, looking across the wide river, where it was rainy and sunny at the same time. "They don't even fish around here."

FAR UPSTREAM I met Yakima Indian chief Levi George. His long hair was braided, tied with leather straps. Before the dams came, he used to race beside the river on horseback, chasing salmon at spawning time.

"We have a gentleman's agreement with the white man now," he explained. "We won't fish below Bonneville Dam, and he won't fish above it. I don't think it's fair, but we do it. We all have to work together now. If we could bring the salmon back like before, the people would be happy."

That was it. All along the river and all around the Pacific Rim, it was the same. From Japan to Kamchatka, from Alaska to California, people felt better if they were catching salmon or at least if they had a fair *chance* of catching salmon. After all these years the fish was still a part of their lives. It was their heritage, a symbol of plenty, of community, of a healthy environment, of hope for the future. As long as the salmon kept coming, you had the feeling that life would be all right. □





In the Old World, Egyptians, Greeks, and Romans cherished these bewitching green stones.

Potentates of India and Persia clamored for them.

In the New World, Spaniards seized Colombian emeralds such as these adorning a gold cross from the *Atocha*, a Spanish galleon that sank off Florida in 1622. The cross and its gold chain recently sold for \$1.3 million.

EMERALDS

Today the demand continues. An inner fire seems to glow from a 380-carat Brazilian crystal inspected with a fiber-optic light. The gem is part of a \$350,000 purchase by a three-dealer partnership. The quest for emeralds requires risk takers willing to chance a no-holds-barred market replete with intrigue, smuggling, and murder.

Article and photographs by FRED WARD
BLACK STAR



CROSS, MLL FISHER TREASURE EXHIBIT, KEY WEST, FLORIDA, 8.25 CM





Iran's crown jewels: another world

Emerald seas girdle this colossal globe, mapped by some 51,000 gems, including rubies, sapphires, and diamonds. The 18-inch gold sphere bears treasures wrested from India's Great Mogul by Persian conqueror Nadir Shah in 1739. The globe became part of the crown-jewel collection first displayed publicly in 1960 at the National Bank in Teheran.



Half of all Zambian emeralds wind up on the black market, despite rigid security at the state-controlled Kagem mine, where workers remove debris from rough emeralds and sort them. In 1988 the Zambian government banned the



export of rough stones, intending to cut and sell its own finished emeralds. Filling demand for uncut stock, smugglers buy from independent Zambian miners and sell to Swiss dealers, to whom Israeli and Indian buyers beat a path.

MY WINDOW to the Santa Teresinha emeralds in Brazil was the blackest hole I'd ever seen—300 feet straight down and just over a yard square. No elevator serviced this Third World mine. Instead, a skinny steel cable, with a piece of automobile tire bolted to the end, snaked from a dilapidated winch. Already soaked with sweat from the blistering tropical sun and the anxiety associated with jumping over the edge of a 30-story unsupported rock shaft, I climbed inside the tire for the most hair-raising ride of my life.

Senhor Wilsão, the smiling mine owner, assured me, "There is nothing to worry about

eternity—the unseen operator threw on the brake, jerking me to a stop two feet above the mud. To no one in particular, I sighed, "Welcome to the glamorous world of emeralds."

Miners, stripped to their shorts to cope with the heat and humidity, were using picks and an air hammer to dig out the ore. Gemstones actually protruded from the walls of the mine, as in the treasure cave of the Seven Dwarfs, sparkling green in underground talc schists where an ideal combination of elements, heat, and pressure initiated the growth of the precious crystals.

Emeralds, far and away the most prized and expensive of the beryls (minerals composed of beryllium aluminum silicate), have been known since at least 3500 B.C. The earliest sources of emeralds, the legendary Cleopatra's Mines, are located in the Sikait-Zabara region of Egypt near the Red Sea. Egyptians worked them for thousands of years, followed by Alexander the Great, Romans, and Turks.

One of 12 stones in the breastplate of judgment described in Exodus was called an emerald, and, if real, no doubt came from Cleopatra's Mines. According to Revelation, the fourth foundation of new Jerusalem's walls, where the pearly gates were located, was garnished with emeralds. But were they the real thing? Many early references to emeralds in biblical and Roman times pertained to peridot, a green gem found at the time on St. John's

Island (Zabargad) in the Red Sea.

Emeralds are usually considered more valuable than diamonds, and second only to rubies. To appreciate how concentrated this portable wealth is, consider attempting to carry a million one-dollar bills, which would fill 42 cubic feet of space and weigh about a ton. A million-dollar gold brick (with gold at \$450 an ounce) would be difficult to lift at 152 pounds. But weighing just 14 carats (a tenth of an ounce), a perfect million-dollar emerald I examined in New York City fitted quite nicely into the palm of my hand.

With diamonds the best color is the absence of color. The abiding allure of emeralds lies in their unique color. Pliny the Elder, a Roman scholar, wrote, "No other color is more



Blasts of neighbors' dynamite echo around workers 300 feet deep in Brazil's Santa Teresinha emerald mine (opposite), where 200 claim owners have sunk shafts in a chaotic, dangerous operation. A grimy wildcat prospector (above) faces even greater risks at Colombia's Muzo mine (following pages).

—you'll be a lot cooler when you hit the water!" Water? *What water?*

First came a drizzle. Then groundwater poured from the walls, and I was plunging through a waterfall. The darkest darkroom doesn't begin to compare to the pitch-black inside the mine shaft. I couldn't look upward at the patch of daylight above for fear of drowning. After about three minutes—an





In this seething pit, the pendulum of violence swings at will among thousands of guaqueros, treasure hunters seeking the emeralds of Muzo, source of the world's biggest and best for perhaps a thousand years. Atop the slope at the government



mine bulldozers scrape away shale to expose likely emerald deposits, then shove tailings down the hill. Guaqueros tap streams to hose through the leavings. Guns or knives are standard equipment; murders average one or two a day.

agreeable — because nothing greens greener.” To some, diamonds and the people who buy them, sell them, and wear them are boring. As a provocative bumper sticker belonging to hard-charging Dallas dealer Ray Zajicek puts it: “If she won’t live forever, why give her a diamond?”

A vibrant green emerald from the Muzo mine in Colombia is considered the stone against which all others are judged, the emerald that determines what color an emerald should be. “But with emeralds there are thousands of gorgeous color combinations,” explains New York dealer Maurice Shire. “People buy what appeals to them.”

But what exactly is an emerald? The question is the basis of one of the most intriguing and controversial arguments in gemology. During the thousands of years before modern chemical analysis, almost any attractive green stone was called an emerald.

In the mid-19th century, mineralogists decided that an emerald was any beryl colored by chromium (less than one percent) and green enough to be valuable. This definition, strict on chemistry but loose on color, served for a century, until a 1963 Brazilian find at Salininha of rich green beryls colored by vanadium.

At first the gem world refused to recognize these crystals as emeralds. Jules Sauer, a well-known Brazilian dealer, fought the rejection and submitted stones to the Gemological Institute of America (GIA) for analysis. The GIA certified the stones as emeralds, but some Colombian emerald dealers and European gemologists rebelled. Later, several new African mines were discovered that also produce vanadium-colored gems, and those stones were generally accepted as emeralds.

But how green must a beryl be before it is called an emerald? Even the GIA has trouble with this one because stone colors span a spectrum from pale yellow-green to lush bluish green, depending on their chemistry. Richard Liddicoat, the GIA’s chairman, says, “Everyone except some Europeans has agreed on the chromium-vanadium issue. We say if a beryl has emerald color, it’s an emerald.” That works almost all the time — but not with green beryl, a variety colored by iron. “Green beryls,” says Liddicoat, “should really not be called emeralds, even though they’re deep enough green to *be* emeralds.”

Other beryls are goshenite, a colorless stone; pale green beryl, which is often heated to

produce aquamarine; aquamarine itself; golden beryl, aptly called heliodor; pink morganite; and red beryl, which is being marketed as American Red Emerald.

“WELCOME to the most comfortable emerald mine in the world,” John Chatham exclaimed as he opened the door to his laboratory north of San Francisco International Airport. “You’re the first person from outside the company who’s ever been in here.” In his laboratory Carroll Chatham, John’s father, produced his first synthetic emerald in 1935. A synthetic gem is defined as a laboratory-grown crystal with the same chemical composition as its natural counterpart. An important and expanding public market enthusiastically considers 200-dollars-a-carat synthetics a bargain compared with the 2,000 dollars a carat for a comparably colored natural emerald.

Carroll Chatham’s sons now operate the world’s largest gem-synthesis company, growing emerald, ruby, and sapphire crystals. Tom is president and in charge of marketing. “Even though we get only a 10 percent yield when the rough is cut, we still account for about half the 40-million-dollar global synthetic emerald business,” he told me.

John manages the production furnaces, where more than a million carats of emeralds are “grown” annually. He heats lithium molybdate to temperatures around 1800°F in his washing-machine-size crucibles. To this “mother liquor” he adds beryllium oxide, aluminum oxide, silica, and chromium to duplicate nature’s proportions. John, sweating over his artificial inferno, explained, “Lots of people have tried this, but few have ever made gem emeralds. I use the right mix, put in a seed crystal from a former run, and wait a year to see what comes out.” When the earthquake hit San Francisco last fall, the electricity was off for 36 hours, long enough to cause a million-dollar loss.

In addition to the fine crystals grown by Biron International in Australia are synthetics from Japan and the Soviet Union. A small but vocal segment of the trade objects to synthetics being called emeralds, but the public and most dealers accept them as legitimate.

On the other hand, I have examined old jewelry in famous collections that includes Egyptian stones, very few of which could be



"If steeped in verdant oil. . . Its deepened hues with perfect luster shine." Thus did an 11th-century poet describe a process much refined today to improve an emerald's appearance—temporarily.

Emeralds are the crystalline aristocrats of the beryl family, minerals composed of beryllium aluminum silicate. Yet virtually every emerald bears natural inclusions, often considered distinctive, though undesirable if too numerous. If the flaws reach a finished emerald's surface, they



can be masked with oil.

At a Bogotá laboratory a technician dries a wholesaler's Colombian emeralds after cleaning. The stones are then soaked in a heated oil such as cedarwood or palm, which is driven even farther into their cracks in a pressure chamber, from which one customer's order is removed (left). A 28-carat example (far left) shows improvement (above). But within a year or two the oil evaporates or seeps out. Oiling can puzzle and dismay emerald owners.



sold today as emeralds. Peter C. Keller at the Los Angeles County Museum of Natural History thinks most such stones should accurately be classified as green beryl. Usually pale, translucent to opaque, and mixed heavily with cloudy minerals, green beryl looks nothing like the deep green, nearly transparent true emeralds we see today. Nevertheless, until Cleopatra's Mines played out, those shafts into Egypt's desert walls provided the world with its only known source of emeralds. Later the Romans worked the Habachtal region of Austria, and some antique material apparently came from what is now the Soviet Union. I had numerous jewelry examples from 200 B.C. to A.D. 600 analyzed by Robert Kane and John Koivula of the GIA and Roger Harding at London's Natural History Museum. Some of the beryls have been identified as almost certainly originating at Cleopatra's Mines.

THE WORLD OF EMERALDS changed forever when the Spanish arrived in South America in the early 1500s. Although they originally plundered gold and silver, the conquistadores had also seen emeralds in Mexico and went looking for their source. By the time they fought their way through Colombia's mountains to the area around Chivor in 1537, they had looted more than 7,000 emeralds from local Indians.

And the real prize was still to come. The Spanish had heard of a mine with even larger, finer crystals. Muzo was its magical name, and even today Muzo is unlike any other mine in the world. For perhaps a thousand years it has consistently produced the biggest and best emeralds ever found. Muzo lay hidden from the conquistadores until 1558. But once in control, the Spaniards enslaved the Indians to mine emeralds on a grand scale.

At first diamond-loving Europeans ignored the New World gems. However, royal personages of India, Persia, the Ottoman Empire, and Egypt soon sported green crystals as big as fists. Colombian emeralds were carved, engraved, domed, and sculptured into boxes. Thousands of those emeralds, as large as 300 carats each, were carted off by Persia's Nadir Shah in 1739 after his sack of Delhi. They and several enormous diamonds became the glittering seedbed of the crown jewels of Iran.

The emerald drain from New World to Old is still going on. Now, however, Colombia

loses its emeralds to smuggling. The best guess is that half a billion dollars' worth of emeralds is mined each year in Colombia. Félix Rueda, the chief mining engineer at ECOMINAS, which oversees Colombia's mining industries, says, "Our ministry estimates 60 percent of Colombia's emeralds are exported illegally. We think most of those go to the U. S. The real illegal production is at Coscuez, another major mine. But even when the production is legal, the exportation is largely illegal. What can you do?"

Texas trader Ray Zajicek, who buys emeralds in Bogotá, says Coscuez "has to be the most dangerous place on earth. They hold two sales a year there, which only total about \$360,000, while the mine produces maybe 180



Bogotá, emerald city: Wizards of street-smarts gather at a tense crossroads, where owners offer white envelopes of emeralds to swarming comisionistas, sales agents who then seek buyers waiting in nearby buildings. In three weeks of such transactions in Bogotá, gem dealers Ray and Sheila Falvo Zajicek (above) invested a six-figure sum. "An agent might ask \$1,000 for a stone," says Ray, "I might counter with \$50."



Exceedingly rare, a pre-Columbian emerald forms the body of a fanciful gold beast found in Panama. Spaniards looted thousands of emeralds from Indians. Hernán Cortés returned from Mexico in 1528 with a suite of carved emeralds for his bride. Legend holds that they were coveted by Isabella, Spain's regent and wife of Charles V, and Cortés's stock in court plummeted when he refused to give them up. He later lost them in a shipwreck.

THE UNIVERSITY MUSEUM, UNIVERSITY OF PENNSYLVANIA, LENGTH 12.4 CM

million dollars of emeralds every year." Except for privately owned Chivor, Colombian mines operate on five- or ten-year leases, paying a paltry million dollars in fees annually.

In 1988 Colombia's government figures showed just 11.5 million dollars in legal exports to the U. S. During the same year 42 million dollars of Colombian emerald imports were declared at U. S. Customs in Miami alone. But perhaps another 200 million dollars in emeralds arrived unannounced.

VIOLENCE OVER EMERALDS begun by the conquistadores in Colombia has never stopped. I had to postpone my first visit there last year. Two weeks before I was to arrive, my host, one of the three principals at Muzo, was gunned down at his ranch, along with 17 bodyguards. Later, when I resumed my Colombian plans, I was advised that all ground transportation is risky. Driving to the mine in a car is dangerous because local *bandidos* know passengers carry cash to buy emeralds. Driving back to Bogotá is dangerous because passengers carry newly purchased stones. Either way, a traveler is a prime target. Once last year the mine organized a 50-jeep convoy to take in supplies, and even that was attacked, with eight workers killed.

More than a dozen Colombians I interviewed for this article have since been murdered. When the Bogotá police gave almost a month's warning before an arms check in

a four-block downtown quadrant near the emerald market, they still confiscated over 600 weapons. The safest assumption for a visitor is that everyone but you has a gun. All the dealers I saw had pistols strapped to their ankles, on their belts, in their handbags, in cars, on airplanes, and on tables. A visiting group of Israeli gem traders was offered a kilogram of rough emeralds for six Galil automatic rifles.

After facing all the risks of traveling and buying in Colombia, my pals Ray and Sheila Falvo Zajicek got new inventory safely back to their Dallas office only to watch it stolen at gunpoint. Unaware that two robbers had been hiding in their attic overnight, Ray left the room briefly. He returned to see his wife fleeing from two armed and ski-masked bandits who had dropped through the ceiling. Screaming, Sheila dived under a desk. Ray raced across the street to call for help. One thief stood guard over Sheila while the other grabbed a pair of emerald-filled boxes from the safe. Before police could arrive, the gunmen jumped out the window and got away.

On a drive down the narrow unpaved mountain road from Chivor (considered the only safe emerald mine to visit by car), frantic braking was all that kept some friends and me from slamming into a roadblock of boulders. Before we could start backing up into the dark, someone in the woods started firing. With headlights extinguished, we reversed around one curve unhurt and were just about to run for it when a truck came along with enough people to scare away our attackers. We assumed what we had been through was a simple robbery attempt, but in Colombia one never knows.

For safety's sake I had opted to commute to Muzo by helicopter. There, during an early breakfast with 12 workers, I counted 11 pistols either holstered or stuck into belts. I assumed the one unarmed man just wasn't fully dressed yet. Chatting over eggs and bacon with Muzo manager Neidel Triana about the local violence, I learned that six years ago when the government banned beer and wine sales in the mine areas, the fighting and killing dropped off immediately. "But the workers and emerald sellers objected, so we let it back in, and the violence flared," Triana said. "Actually, though, it's not so bad now. We're down to only one or two killings a day."

From the air Muzo, located about 65 miles north of Bogotá, looks like a giant open-pit

Emeralds from antiquity

"So soothing . . . is the mellow green color," wrote Pliny the Elder of *smaragdus*, a group of stones including emeralds, which grace third-century A.D. Roman earrings (below). A Byzantine pendant bears emeralds, pearls, and an agate. The stone adorning a first-century B.C. Egyptian double ring was assumed to be an emerald until a recent test identified it as green beryl.



SCHMUCKMUSEUM FÜRZENTHEIM,
WEST GERMANY, WIDTH 5.4 CM



COLLECTION OF JOEL HALTER, LENGTH 3.3 CM



COLLECTION OF TED HOROVITZ

The world of emeralds

Perhaps a billion dollars' worth of emeralds comes out of the earth each year, half from Colombia. Zambia mines 20 percent and Brazil 15 percent, followed by Zimbabwe and Pakistan, a new entry. Smaller output comes from Afghanistan, Australia, Madagascar, Tanzania, and the Soviet Union.



coal mine, a series of raw cuts across the face of a promontory defined by the confluence of two mountain streams and a small river. Slick, powdery black shale covers everything and everyone. After a few minutes of digging, a miner is only recognizable as human by his white eyes and teeth.

Colombians maintain that emeralds belong to any Colombian who can mine them. The mining companies (Tecminas holds the principal Muzo lease) get ten-year leases from the government, but thousands of poor and armed *guaqueros* (treasure hunters) believe the leases are neither deserved nor valid. At Muzo the bulk of mining is done on the surface with bulldozers that uncover the large, obvious emeralds but miss the majority. Such short leases foster a frenzy to grab the easy stones and run.

So much shale is scraped from the mountain that the floor of the valley has been raised 100 feet in the last 50 years by emerald-bearing shale tailings.

Emeralds at Muzo are found in hydrothermal veins of calcite buried within black shale. In order to foster employee honesty and enthusiasm, Tecminas practices a unique social program with its 250 workers—a system of pickups, in which each man is rewarded with one day a month at the face, the area actively being mined. As a dozer blade exposes emerald crystals, the whole crew races to the wall in a mad scramble to grab gemstones. After the free-for-all the mine representative, usually a member of one of the three families that control Muzo, keeps the biggest and best for the owners, leaving the rest as a goodwill bonus for the workers.

IN BRAZIL, violence is mainly the result of an economy that has suffered from inflation as high as 3 percent a day: Jewels are a better form of loot than cash. A young gem dealer I know was walking between two fancy jewelry shops near Copacabana beach in Rio de Janeiro when four uniformed policemen in a plainly marked police vehicle pulled up beside him, forced him into the car, and robbed him of \$3,000 in emeralds and the \$300 in traveler's checks I had just given him. They permitted him to keep his tourmaline pendant, after he explained that it had been a present from his mother.

The victim said, "I grew up on this street, but now it has gone mad. Last night saw the fewest number of Rio murders this year. They total in the thousands. Don't ever let anyone know you're carrying stones."

By contrast, in Goiás state, on the main street corner of the town of Santa Teresinha, near the country's largest mine, a daily open-air market has thousands of carats spread on tables as local middlemen sell to Brazilian and international buyers. When I expressed surprise at the lack of security, Daniel Sauer, an heir to the Amsterdam Sauer chain of gem stores, reassured me. "Really, lawlessness and guns are unusual here," he said. "When we strike a deal, unlike in Colombia we buyers take the goods, then have a week to pay. It probably keeps us from being robbed or killed to have possession of the goods here in a vault or safely in Rio and still owe the sellers."

A Brazilian can get a *garimpeiro* (prospector) card and stake a small mining claim,



BEADS, PRIVATE COLLECTION; RING, VICTORIA AND ALBERT MUSEUM, LONDON, 22 X 16 MM (BELOW)

A mythical source of emeralds in India led to the term "Old Mine" for gleaming jewels such as these fabulous beads in Jaipur. Author Fred Ward determined that the stones are actually Colombian. Indians excel at carving emeralds, such as a ring (below) inscribed in Persian with the name of an East India Company official and the year 1797.

usually 30 feet square, in any free area. Successful claims later sell among garimpeiros for \$20,000 and up. At Santa Teresinha more than 15,000 people live around 200 shafts from 60 to 400 feet deep, each sunk on a tiny plot, and each in danger of running into a neighbor's claim or collapsing it with underground dynamite blasts. Fortune may be as close as the next shovelful, or as elusive as the big find that got away.

Hans Stern, the world's best known dealer in colored stones, manages his global collection of 157 stores from headquarters in Rio de Janeiro. "With emeralds," he told me, "everything's a guess."

Brazil probably mines five times as many carats as Colombia, but Brazil's emeralds are smaller and of lower quality. Together the two countries produce as much as 70 percent of the world's supply of emeralds, but Colombia's are sold for perhaps 500 million dollars, while Brazil's wholesale for only about a fifth as much.

Zambia and Zimbabwe account for some 25 percent of world emerald production. Non-commercial mining continues in a few countries, including Afghanistan, Madagascar, Australia, and Tanzania. Since the worldwide

emerald business is almost all black market, no numbers are verifiable.

The Soviet Union has mined emeralds in the Ural Mountains for years but releases little data on the output. Pakistan, a new emerald producer, is already the fifth largest. The government actually works only two of its six sites, both located in Swat, which produce

about 7,000 carats a month, worth \$630,000 a year. Pakistan's Gujar Kili is the most attractively situated emerald mine I visited, situated at 7,000 feet in Swat's northern mountains. The mine, which is reachable only by hiking an hour and a half upstream and fording the Kotkai River three times, is perched some 300 feet above the water.

Most emerald-related activity in Afghanistan was interrupted by the guerrilla war with the Soviet Union and the resident communist government. Mining continues at 8,000 to 14,000 feet in the Panjsher area in the east. Most of the rough is carried into Peshawar, Pakistan, to sell for funds to continue the fighting. Gary Bowersox, a U.S. dealer, walks six days over a 14,500-foot pass to buy at the mines, sometimes spending a million dollars a year. Although Afghan emeralds are





considered good, the supply is, to say the least, unreliable.

North Carolina has this country's only emerald mines. Near Hiddenite, a leisurely two-hour drive north of Charlotte, at least one farm has been turned into a pay-to-dig tourist attraction. Mine owner Mike Watkins says the local operators a few years ago began buying cheap emerald chips from Colombia and Brazil to sprinkle around the place so their tourist customers would be sure of finding something.

Talk about the tail wagging the dog! The practice became so popular that Mike too now seeds buckets of dirt with inexpensive topaz, moonstone, amethyst, and even some scrap emeralds. He offers tourists a choice of either "native" or "enriched" dirt. Most, says Mike, choose the enriched, preferring to find something, no matter how it got there.

THE APPEAL OF EMERALDS is almost universal. As Hans Stern explained in his Ipanema office, "Emeralds are our pre-sold gem. We might have to convince a client that she wants a tourmaline or opal. But an emerald customer comes in ready to make a purchase." Jules Sauer, Stern's archrival across town, says that, like other gems, emeralds are "a onetime harvest" and account for more than half his sales.

Emerald dealing attracts adventurers and risk takers who like to live on the edge and go for the deal. A Chicago jeweler calls them the pirates of the industry: "They certainly don't steal, but they do roam the world looking for treasure, come home, put on a suit, and try to look respectable." After watching Ray Zajicek at work in Colombia, India, Pakistan, and Israel, I sensed the instinct of the breed. Ray might be three offices down the hall from me, but as soon as a packet of emeralds appeared for me to examine, he would instantly materialize to toss out an opening offer to the owner. Ray has uncanny recall of the carat weight, color, inclusions, and price he bid on stones he saw only once in Bogotá five years ago.

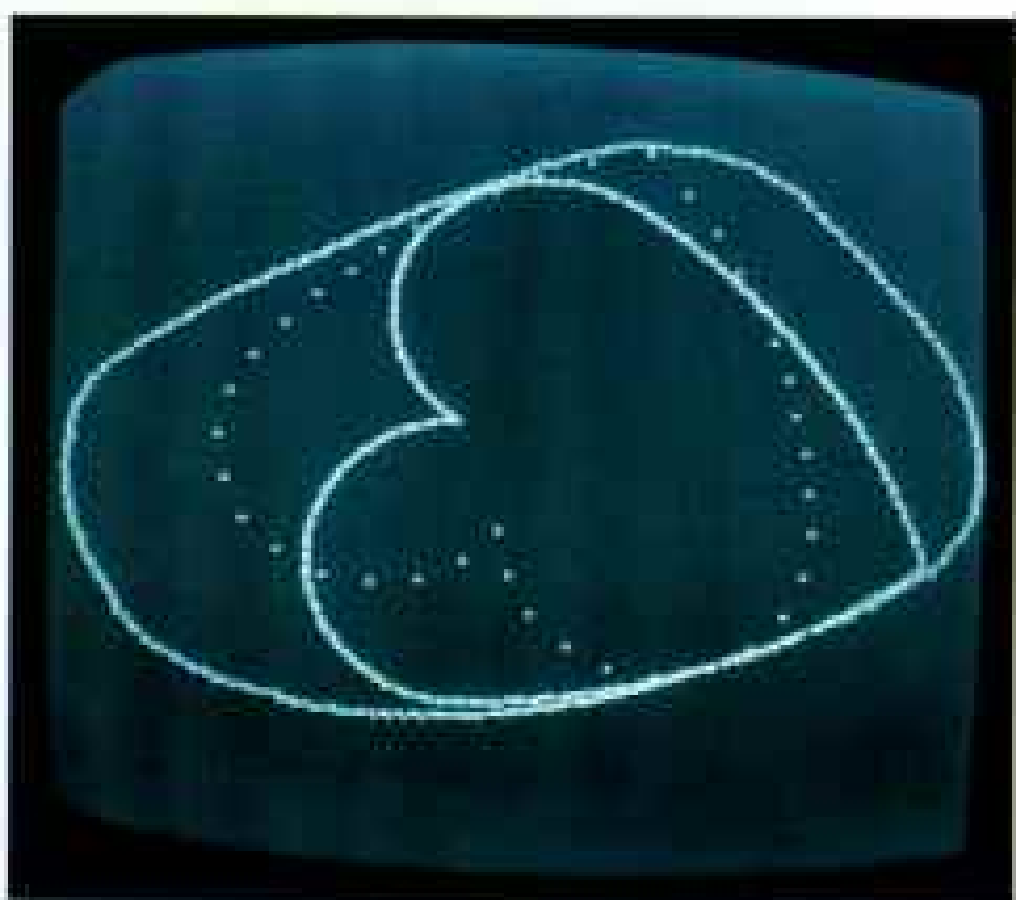
Emeralds travel the world on what my Jaipur host Rashmikant Durlabhji calls a magic carpet. Most emeralds move off the record, untaxed, unseen, buried in a world market that the trade calls black. Almost every high-quality emerald is smuggled at some time in its history.

Maurice Roditi, with 22 gem stores, is



India's gem-cutting tradition lives on as students in Jaipur learn the art with hand-powered abrasion wheels. Tiny emerald chips with 25 facets (above) will adorn watches and other jewelry.

At an Israeli factory a rough emerald (bottom) is preformed by sawing away undesirable portions. Another Israeli firm uses a computer-governed robot to plot a crystal's outline and determine the best way to cut a shape—here, a heart.





Playthings of potentates

An exquisite emerald-and-diamond box resides with the crown jewels of Iran (left). In 1747 its ruler was sent a gift by Turkey's sultan—an emerald-studded dagger with an emerald-lidded watch in the handle—but he died before it arrived. Sultans also fancied such trinkets as an emerald snuffbox and a gold writing box glittering with emeralds and rubies.



BAHAR HELLI 1926, 8 1/2 x 5 CM





TOPKAPI PALACE MUSEUM,
ISTANBUL, LENGTH 30 CM



TOPKAPI PALACE MUSEUM, LENGTH 3.5 X 3 CM



TOPKAPI PALACE MUSEUM, LENGTH 39 CM

Brazil's third largest dealer, after Stern and Sauer. For several years the Zambian government has been in a partnership with an Israeli-Indian syndicate to operate Kagem, Zambia's largest emerald mine. But in 1988 Zambia's president effectively voided the contract by announcing a ban on all rough-stone exports, and the country entered into an agreement with Roditi to cut and polish all emeralds from Kagem, along with the entire output from the independent mines. Roditi's company brought 50 Brazilian cutters to Zambia with an entire factory and promised to train hundreds of cutters. Roditi is trying to run both the factory and his Swiss marketing company, established to sell Zambia's gemstones.

ENTER THE SMUGGLER. As we stood together in Kagem's ankle-deep mud, Roditi confided, "A torrent of emeralds is being smuggled from Zambia. I estimate that the country cut 35,000 carats in 1989, worth 22 million dollars. The government cutting factory is supposed to get all the country's production. Despite the ban on the export of emerald rough, smuggling continues to be a persistent problem."

Even with more workers and equipment, Kagem reported a production decline in all emerald grades for one year from 2,285 pounds to 1,593. Just across the river from Kagem, independent miners move tons of dirt from pits, all the time reporting, "No emeralds yet." Playing the game legally often means selling to the government at a nonnegotiable price, waiting to be paid, and then getting 80 percent of the funds in kwacha, Zambia's currency, which has little value elsewhere.

The conduit for the independent miner is just a footstep away, in the guise of friendly West Africans, usually Senegalese, offering world prices in hard currency on the spot. They walk ten miles unhindered from Zambia's mines across the nearby Zaire border, where they consolidate parcels from other smugglers. Then one or two of them fly to Geneva to sell their goods. This Africa-to-Switzerland connection is currently the most important one on the magic carpet, a global black market in rough emeralds.

Estimates of Zambian rough smuggled since the ban are as high as 50 percent of production. Francis Kaunda, head of Zambia's

A day in the life of Zambian emerald miners yields an armful of crystals destined for a Zambian cutting factory operated by Brazilians, where a technician trains students. The cut gems are marketed by Swiss dealers, who also do a brisk business in Zambian rough emeralds smuggled primarily by Senegalese.



mines, says, "Emeralds are a national asset, and we could produce a quarter of the world's output. We don't intend to sell our rough any longer. But we have to stop the smuggling, since we're losing over half to the Senegalese who carry them to Switzerland."

The two countries left in limbo by Zambia's export ban on emerald rough are Israel and India, neither of which have emeralds of their own, but both of which have large cutting centers built around handling Zambia's emeralds. Israel's cutting industry has depended on high-end, or high quality, Zambian emeralds. India needs the low-end rough to keep thousands of cutters busy. They have too much invested to give up without a fight, and they feel their partnership at least gives them the rights to half the Kagem production. As they

plan possible courses of action to take against Zambia even while seeking a compromise, dealers in both countries are also developing more smuggling contacts.

"We're all scrambling for rough," an Israeli dealer confides. "No matter how good a face the others try to show, emerald rough is scarce." In the Tel Aviv suburb of Ramat Gan, a multibillion-dollar cutting industry grew up around diamonds and colored gems. Emerald dealer Eli Eliezri looked worried as we talked about recent Zambian developments. "In two decades Israel built a 40-million-dollar emerald business cutting a million carats a year," he said. "We get the cream of every country's stones except Colombia's and Pakistan's. Dealers buy in their own offices here, in Africa, and in Switzerland,



where 90 percent of our emerald sales are."

To explore Israel's dilemma, I talked with Israeli dealer Ben-Zion Harel, who helped move his country into emeralds. Sitting in the center of his circular mineral display, Harel explained: "Frankly, we thought we could improve on the Indian-cut emeralds with our diamond-cutting expertise and automated equipment. To do this, at 20 times India's labor costs, means we must have high-quality rough. We put Zambian emeralds on the map. Now look what's happened."

What's happened is that Israel spent millions to automate a business that depends on hand labor everywhere else in the world. Israeli factories introduced symmetrical cutting, calibrated sizes, and standardized cuts to maximize brilliance. One Israeli robot can cut

and polish 1,800 emeralds a day; it would take 90,000 pieces of emerald rough in inventory to allow such a selection. This robotic capacity depended heavily on Zambia, which then cut off Israel's legal supply, forcing a dependence on Muslim smugglers. And, as Eli Elizieri remarks, "It's a bit difficult for Israelis to develop a solid business relationship with devoutly religious Muslim West Africans."

INDIA FACES similar supply difficulties at a different end of the market. With more than a million workers in the gem trade, India wins all prizes for import and export volumes. But by specializing in the smallest and lowest quality stones, the value of its cutting trade is only a fraction of Colombia's. Suresh Gupta, who



TRAFALGAR EMERALD, POWERSTONES, HOUSTON, AUSTRALIAN SYNTHETIC EMERALDS, BAHON INTERNATIONALS LTD.

What is an emerald?

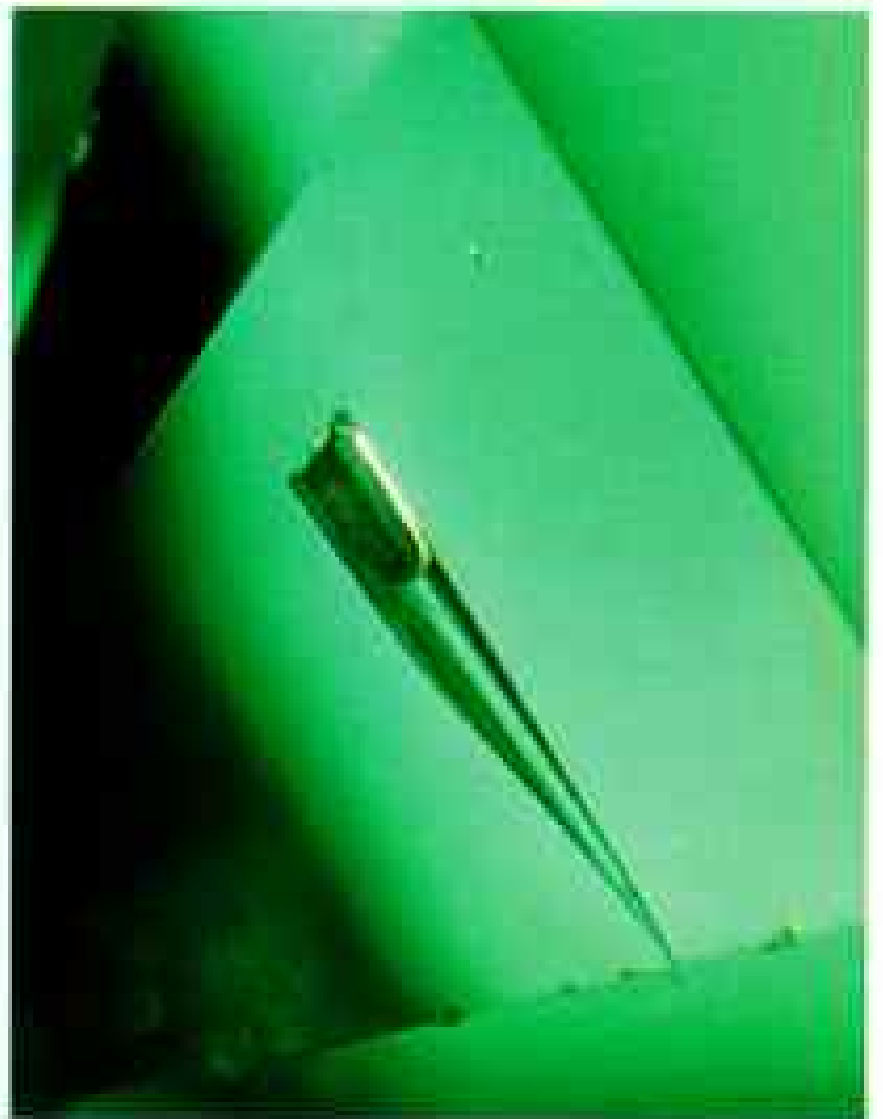
A beryl colored green by the presence of chromium was long held to be an emerald. But in 1963 beryls greened by vanadium were found in Brazil, and later in Africa. After much debate such stones are now generally accepted as emeralds, though they defy simple testing. The array above was photographed with a Chelsea filter, which makes emeralds with chromium appear red. Beryls that reflect no trace of red are usually emeralds colored by vanadium.

The test also holds true for synthetic emeralds. The large red cluster was made in the U. S. by Chatham Created





PHOTOMICROGRAPHS BY ROBERT E. NAREL, GIA



Gems. The firm uses a furnace to melt lithium molybdate into a "mother liquor," then adds beryllium oxide, aluminum oxide, silica, chromium, and a seed crystal. After growing for a year at 1800° F, 3,000 carats of Chatham emeralds cool (left).

Both natural and synthetic emeralds contain distinctive inclusions. One in an Australian man-made stone resembles a nail head (above). Natural Colombian stones often bear a three-phase inclusion of water with an air bubble and a salt crystal (top).

Only from Colombia come trapiche emeralds (facing page), named for the Spanish word for a cogwheel used to grind sugarcane. The owner of this gem named it *Star of the Andes*.

employs some 300 cutters in Jaipur, and his father, in Bombay, may be the world's largest dealers in terms of volume, and perhaps in value too.

No place except India could or would make the packet of emeralds Suresh spread in my hand, losing some under my fingernails. Each tiny stone had 25 facets, and it would take 230 of them to weigh one carat. (A U. S. copper penny, by comparison, weighs 12.5 carats, and a quarter weighs 28.35 carats.) Microscopic faceted material is often used to decorate expensive watch faces.



BANCO DE LA REPÚBLICA

Too glorious to be cut, a 1,759-carat crystal from Colombia's Coscuez mine is one of five giants safeguarded by the national bank in Bogotá that operated Coscuez and Muzo between 1946 and 1968.

"India buys rough that no one else can process," Suresh explains. "We even cut what other countries discard. In fact dealers here have standing orders with Israeli factories to buy their scrap, which we turn into tiny emerald beads that we sell for 20 cents a carat."

This notion of India as an emerald dumping ground greatly disturbs Rashmikant Durlabhji, an elegant sixth-generation Jaipur gem dealer. In his upstairs office in the heart of the

city's historic gem district, Rashmi recalled India's traditional role.

"For centuries all the great emeralds of the world were cut here," he told me. "If India didn't exist, then the top stones would cost twice as much because we pick up the slack in every country, buying the cheap goods that let producers hold down their costs. Everybody benefits. If a U. S. bank runs a promotion giving away five- to ten-dollars-a-carat real faceted emeralds, there's only one place in the world to get them—India."

So many fabulous emeralds have flowed through India in the past that lore and reality mingle. India's style and skill with emeralds either provided the actual material or the inspiration for the unprecedented collections that followed in Persia and Turkey. With so much secrecy surrounding gems and a liberal dose of chauvinism, the fanciful story grew that the emeralds India cut, consumed, and marketed actually originated in India (or a nearby source). The term "Old Mine" crept into Indian literature to describe these ancient and almost always "perfect" stones. There is hardly an Indian who does not firmly believe that the fine, deep green, clear emeralds in museums and private collections throughout India are Old Mine.

I borrowed a set of emeralds that well-respected, experienced Jaipur dealers agreed were Old Mine and asked the GIA in Santa Monica, California, to identify their source for me. As I expected from looking at the stones, none was, in fact, Old Mine. Legends notwithstanding, the great priceless Indian-cut emeralds in important collections arrived after the Spanish conquered South America and are actually Colombian.

ZIMBABWE is the fourth largest emerald producer, after Colombia, Zambia, and Brazil. The country probably mines five to six million dollars of emeralds annually, but once again most are smuggled out. Traditionally the high-end emerald rough went to Israel, and the cheaper goods were sold to India. "The situation is more complicated now," said John Williams, chief mining engineer with Rio Tinto, the British conglomerate that owns Sandawana, Zimbabwe's largest emerald mine. Accompanied by Abdon Ncube, the socialist government's overseer of gem sales, we drove 300 miles between Harare

and the mine because an annual meteorological condition called *guti* put us into 100 percent humidity with enough moisture hanging in the air to make flying impossible.

Williams described Sandawana as “probably the world’s most efficient and most expensive emerald mine. It’s all underground [like Santa Teresinha in Brazil, but deeper, down to 500 feet], and it complies with Western safety standards. We don’t miss much, and what we mine is intense green—but small. Our average finished stone is only eight points, eight-hundredths of a carat.”

Sandawana is the best run emerald mine I saw anywhere in the world, with no close second. But as Dr. Ncube said, “Sandawana is not our problem. Zimbabwe has 27 emerald mines, and only two regularly report finding any emeralds. Two weeks ago I paid an unannounced visit to a mine that had never reported a find, and what do you know? That very day they had discovered their first emeralds! Soon the stones showed up at our office, and we sold them for 16,000 Zimbabwe dollars [7,000 U. S. dollars].”

EMERALD SMUGGLING may seem trivial to foreigners, but it is a serious, deadly, and highly profitable business. The Zimbabwe government loses about three million dollars a year because it claims it can’t police 27 mine sites. In fact smuggling is possible only because so many officials there, as in other countries, are bribed to look the other way. On our drive to Sandawana we made some unexpected stops at mines. In every case crews and bulldozers were in evidence, as were enormous and expensive holes. Miners told us, with looks of perfect innocence, that the mine had not produced a single emerald in years, if ever.

Over lunch at Sandawana, Dr. Ncube told me the most horrifying smuggling story I’ve ever heard. It seems a few years back a Senegalese family brought a dead child to the airport for shipping home. The following year the same family was back with another dead baby. Next year they came again, with yet another dead child. Suspicious at last, authorities examined the small corpse and discovered it was filled with emeralds.

Other deceptions in the emerald business include treatment and imitations. Let the buyer beware. Emeralds are the only gems accepted

with enough inclusions, internal imperfections, to make a diamond unsalable. The reason is simple—very few natural emeralds come without them. A colorless beryl is often flawless, but it seems to me there is a relationship between the green in emeralds and the growth stresses that cause inclusions.

In two important ways such inclusions are a blessing. Most useful to a gemologist, typical emerald inclusions are the first indication that the stone is natural, and the actual mine site can often be determined by these distinctive “fingerprints.” We were able to trace the



“A phenomenal green,” actress Elizabeth Taylor told the author, explaining her love for emeralds. Her ensemble includes a diamond-and-emerald necklace, earrings, bracelet, and rings.

origins of alleged Old Mine material from India by identifying jagged-edged three-phase inclusions (microscopic pockets containing a liquid, gas, and solid) in every stone that are unique to Colombia.

Oiling is a controversial practice to mask emerald inclusions. In these high-tech times almost all types of gems receive some kind of treatment. Infinitesimal laser holes are drilled in diamonds to burn away internal debris.



POWERSTORES, HOUSTON

A little something for evening

"I envisioned a woman coming out of the ocean wearing only this belt," says New York designer Ralph Esmerian. With a 113-carat cabochon emerald as the centerpiece, the belt includes gold, diamonds, and ruby and emerald beads. Houston designer Ronald Winston Hartgrove created earrings of trapiche emeralds, black onyx, and diamonds.



B. EDWARDS, INC.

Rubies and sapphires are heated to lighten, darken, or clean them up. Clear topaz is irradiated with nuclear material to turn the stone blue. If an emerald inclusion reaches the polished surface, it is possible to force oil of a similar refractive index inside to obscure the crack. Oiling does not harm the emerald. But it's a short-lived treatment.

I spent a day inside an emerald treatment

Knee-deep in a wastewater pit, a Brazilian worker near Itabira endures primitive conditions as he sifts gravel for emeralds brought up from a nearby 30-foot shaft. His employer paid more than \$20,000 for a lease to work this mine, newest in the nation. Demand rides high, and the digging goes on.

lab in Bogotá, where the stones were first cleaned with two boiling acids, then washed with water, rinsed with acetone twice, and put into a vacuum to remove all residue. Then they were placed in "Mary's bath," a pan of boiling water holding several vials of emeralds submerged in cedarwood oil. Heating the emeralds forces air out of the inclusions and lets oil enter. After cooling overnight, oil and emeralds are placed in a pressure chamber, which is raised to 100 to 500 pounds per square inch to drive more oil even deeper into the cracks. For all that, the lab manager conceded that the oil would not last for more than a few months to a year or two—and only that long if the emerald is kept away from heat and out of the sun.

Treatment techniques vary considerably



around the world. In addition to cedarwood oil, Colombia also uses balsam, palm oil, and several darker oil varieties. Although the manager I visited claimed not to use green-colored oil, I saw two bottles of it on a nearby shelf. The colored-stone trade has accepted treatment with clear oils but has not agreed on whether to disclose oiling to customers. Trade organizations condemn green oils as unethical. But India still uses them. Brazil uses a plastic material called Opticon, which hardens inside inclusions. It doesn't leak out as oil does, but it may cloud the stones somewhat. Israel routinely oils emeralds. In fact, as Ray Zajicek says, "No matter what anyone says, you can be sure that almost any emerald for sale today with inclusions reaching the surface has been oiled."



Then there are the simulants and imitations. These products are made of entirely different materials, such as glass, garnets, tourmaline, and sandwiches of two or more green pieces. Available for a few dollars a carat, imitations are all too often passed off to a gullible public as valuable. I tracked down a firm advertising a "miraculous gemstone discovery" for \$280 a carat. When tested, it was green-colored YAG, a man-made crystal that sells cut and polished for five dollars a carat. All too often, fakers, the unwary, and the misinformed have described many hard, green, shiny materials as emeralds.

Green imitations sold as inexpensive emerald substitutes have a role, as long as they are represented and priced as fakes. But in some of the world's most famous museums, proud gem curators showed me green glass, chalcedony, and fluorite, all with emerald labels. Professionals are fooled along with the public.

NO GREATER CONTRASTS exist in gems than are apparent with emeralds. Lustrous green ice crystals grace the perfectly groomed regal necks, wrists, ears, and fingers of grandes dames of Europe and Asia, and of Hollywood. And yet emeralds originate in some of the most miserable places on the planet, plucked from a reluctant earth by some of its most miserable and desperate workers. It is one of the emerald trade's exquisite ironies that most of the people who find the stones cannot even imagine accumulating enough money to wear one.

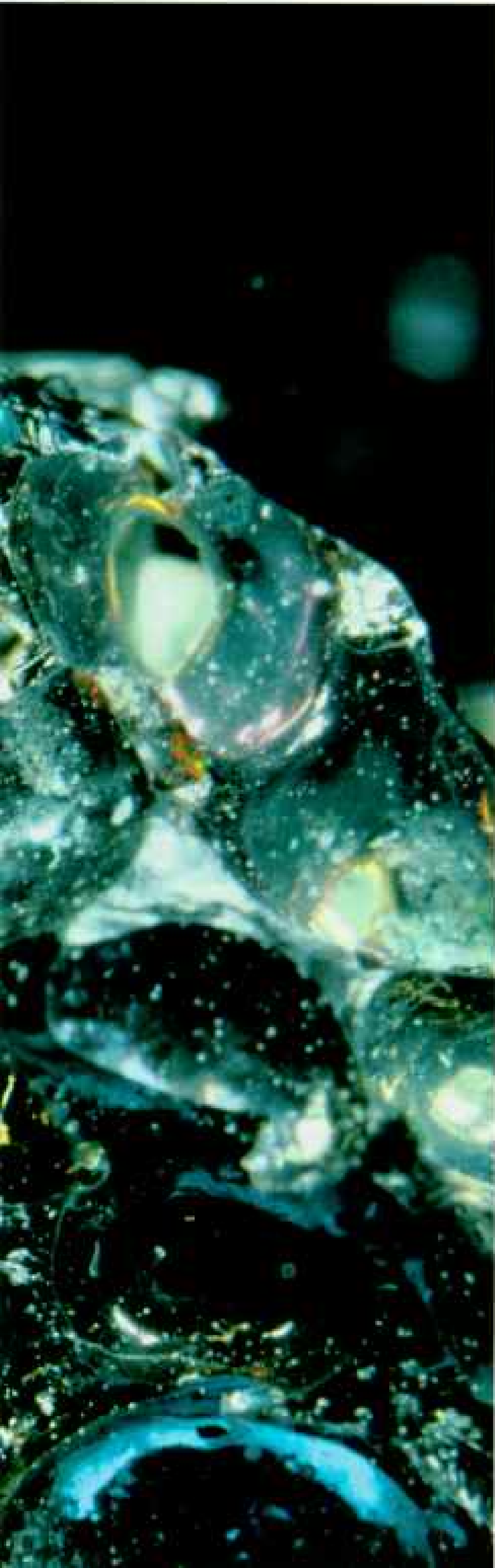
One day I was walking along the top of a tailings dump at an emerald mine in Bahia, Brazil's stiflingly hot northeastern state, when I came across a very old toothless woman, dressed in rags. Our eyes met as I watched her smashing rocks together by hand. After a few wordless—and for her unsuccessful—minutes she must have wondered why I was so interested, because she leaned my way and said, "I'm looking for something I didn't lose."

She had said it all, explained the search and the hope. I understood why people go on looking. Gems satisfy primal needs—the lure of instant wealth, some sort of desire, perhaps, to join with the secrets of the earth. They fulfill our longing for beauty. They are our link to mysteries we can appreciate but cannot explain. Gems are as near the eternal as anything we can ever own. □

Hawaii's Volcanic



Cradle of Life

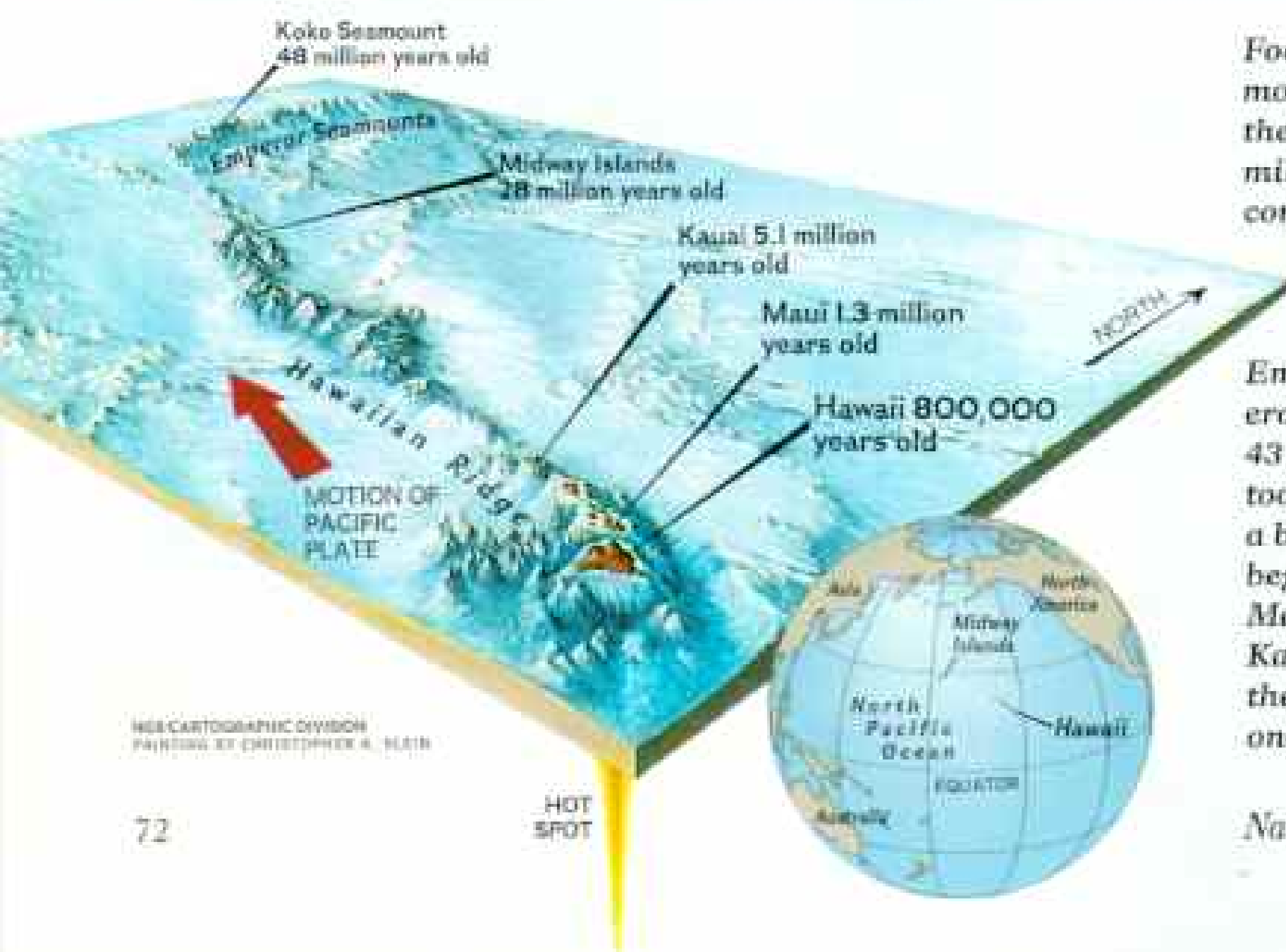


Tongue of liquid fire flows through a lava tube created by Kilauea volcano. Thus the Hawaiian Islands were born — and remake themselves—in the Pacific's vast isolation. How does life colonize such naked new land? Crawling on a lava fragment, a spiderling may have arrived on the wind, riding a strand of self-spun silk.



JOHN F. KJERGAARD

Article and photographs by
WILLIAM H. AMOS



Footholds for new life, seamounts have been rising from the Pacific for at least 70 million years. Like a tectonic conveyor belt, the Pacific plate first crept northward over a stationary volcanic hot spot, giving rise to the Emperor Seamounts, now eroded beneath the waves. Some 43 million years ago the plate took a northwest turn, creating a bend where new upheavals began the Hawaiian Ridge. Major islands now range from Kauai, 5.1 million years old, to the island of Hawaii, less than one million years.

National Geographic, July 1990



PELE, HAWAIIAN GODDESS of volcanoes, shows little respect for terrain, and surely none at all for mere mortals and their traffic signs (below left). For the past seven years lava has flowed sporadically from one of Pele's most active outlets, the east rift zone of Kilauea volcano on the Big Island of Hawaii. Some subdivisions have been overrun, repeatedly in the case of Royal Gardens (left). Although no lives have been lost, more than a hundred dwellings have collapsed and burned, while others, built on small elevations, remain untouched. Automobiles that might have been moved early to escape the lava lie abandoned, charred hulks for future archaeologists to ponder.

Yet such utter devastation is deceiving. While Pele lays waste to existing life with one hand, she also presents a clean slate where other life can take hold, evolve, and write new chapters for biology. Over the past decade my wife, Catherine, and I have seen pieces of this miraculous process on the Big Island and Maui, amid cinder fields, hidden valleys, and alpine stone deserts. We almost always have worked above 4,000 feet, ascending into such habitats as rain forests, since the zones below are dominated by introduced plants and animals.

In this lofty environment we sought Hawaii's endemic species, the hardy natives whose nurseries may be bare lava, packed ash, and crumbling cinder cones. This steaming, trembling land, existing in its present form for only a moment in geologic time, supports endemic life-forms that may predate the exotic newcomers by a million years or more. Here grow indigenous *koa* and *'ōhi'a-lehua* trees, shrubby *pūkiawe* and *'ōhelo* plants, with *'apapane* honeycreepers and *'io*—Hawaiian hawks—on the wing and invertebrates such as bizarre spiders, banded tree snails, and highly evolved pomace flies.

These islands have never been directly influenced by continental landmasses. Whatever life appeared in past ages arrived strictly by chance, borne on the high winds of the jet stream, on the feathers and feet of birds or in their digestive tracts. Some life possibly rode on drifting tree trunks and mats of vegetation. Thus eggs, spores, seeds, larvae, and other wanderlings made their haphazard landfalls.

I have spent a lifetime attempting to put into words, in writing or in the classroom, my feelings for such inspiring natural phenomena. No one has said it better than Sir John Arthur Thomson, a Scottish biologist, who wrote in 1920: "Living creatures press up against all barriers; they fill every possible niche all the world over. . . . We see life persistent and intrusive—spreading everywhere, insinuating itself, adapting itself, resisting everything, defying everything, surviving everything!"



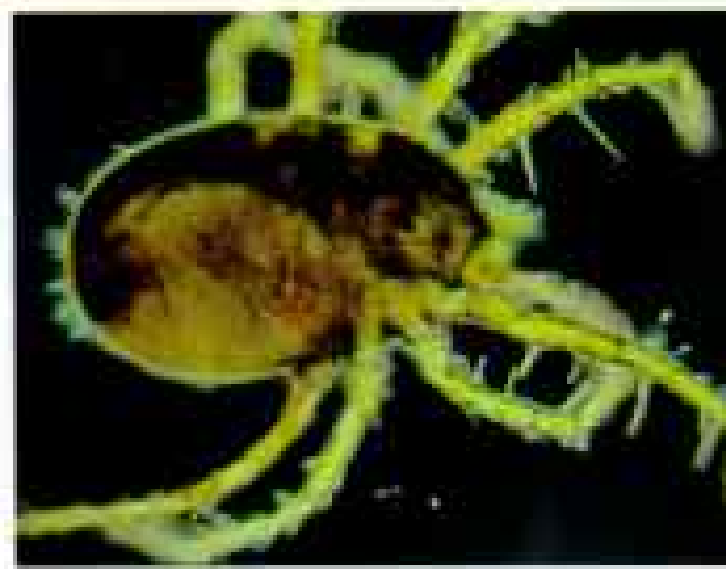
supported blow away in the trade winds, perhaps to prosper in another small aquatic world elsewhere on the shoulder of the great volcano.

We found evidence of one such furnace 20 yards beneath Catherine's feet. It still heats rainwater that percolates down from the floor of Kilauea Iki ("little Kilauea"), not far from the main volcano. Condensing in the cool mountain air, steam provides the moisture that sets the stage for life to grow along fissures between lava plates (right).

Kilauea Iki's 1959 eruption littered the floor of the crater with cinders blown 1,900 feet high from a vent in the rim, creating a vast, fragile, roughened surface that crackles when stepped upon. Soon this apparent wasteland became inhabited by sword ferns, mosses, lichens, and other plants.

Among the first to appear was a minute moss (below), its initial stalk only millimeters tall, at first dwarfed by the peanut-size cinders it grew among. The moss produces progeny en masse in the form of spores that are carried away on the trade winds—the very means of dispersal that wafted colonizing spores to Kilauea Iki after the eruption.

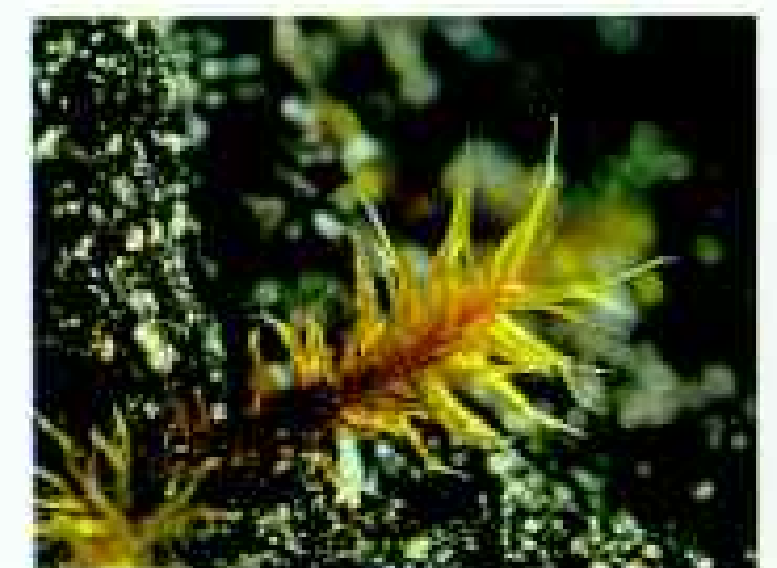
When filled with decaying plant matter, a fissure also houses microscopic mites (center). I have found larger predatory mites, snails, wasps, beetles, and spiders securely established within Kilauea's warm, moist fissures.



ON THE BLEAK SURFACE of a cooled lava flow on Kilauea, at first glance the only sign of life appears in the background—our son Bob, a geologist (top). Yet even here, life is establishing itself among two different forms of lava, *pāhoehoe*, at center, and 'ā'ā beyond. Although the two are identical in chemical composition, smooth, billowing *pāhoehoe* is very fluid and streams rapidly, while rough, clinker-like 'ā'ā becomes thoroughly stirred and generally moves slowly, with a noisy,

tumbling front. Here cracks and rubble present labyrinthine opportunities for pioneering life to take hold, such as small ferns already visible.

On *pāhoehoe* flows, small pools of warm water condense from steam rising through fumaroles, heated by 2000°F temperatures far below the ground. Although only temporary, such pools permit the growth of microbial life (above left) and algae that arrive in airborne spores. Later, when the pools evaporate, spores and cysts of the life they recently









LIKE THE "LOST WORLD" of Sir Arthur Conan Doyle, an island of vegetation called a *kipuka* (above) shelters life—here forest-dwelling insects and other invertebrates marooned by Kilauea's lava. Surviving in such pockets of high ground, most life here will remain isolated for centuries until the surrounding

lava becomes reforested.

When such a forest of 'ōhi'a-lehua trees—in the myrtle family—is covered by incandescent cinders, the trees often topple as their lower trunks are incinerated (left). In death new opportunities for life arise. Fog condenses on fallen trunks; where water drips, newly arrived plants grow. Lichens take

hold on the hard 'ōhi'a wood, while the tree holes trap spores and shelter young plants as they grow into the world of light.

When flowing lava kills 'ōhi'a trees, exposed wood burns at once. Below ground the lava turns the trunks to charcoal, which burns slowly, leaving impressions in the sides of the molds (below) immediately available for the webs of enterprising spiders.

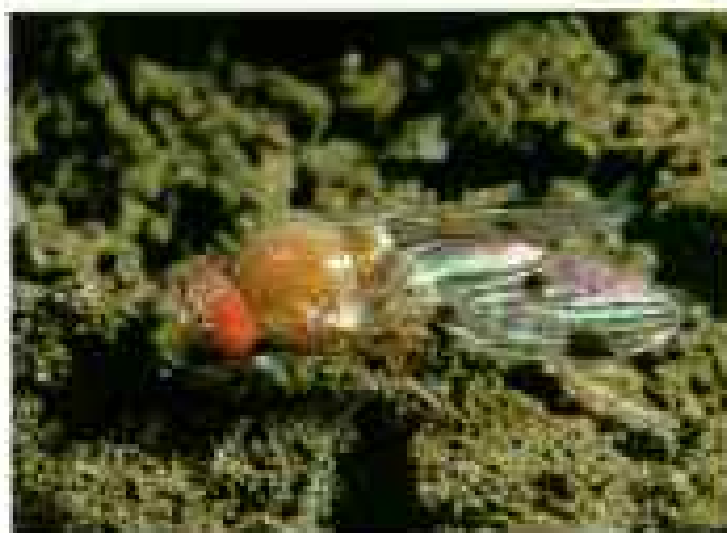
After a flow ceases and subsides, some lava-covered trees remain grotesquely erect (below left), often cooling into ghostly forests of blackened tubular "lava trees." Lava spatter from small subsequent eruptions adorns the tips of this pair.

An 'ōhi'a tree is tenacious of life. If one side of its fire-ravaged trunk remains unburned, new growths called adventitious buds (bottom) sprout to help the tree rebuild itself.



EVERY STEP reveals the diversity and contrast of these life-forms and their habitats. We walked only short distances between totally different ecosystems, such as a forest of mature 'ōhi'a trees and *hāpu'u* tree ferns (opposite) adjacent to the nearly barren, steaming floor of Kilauea. Endemic life fills this forest, from thornless raspberries to the honeycreepers whispering songs in the underbrush.

The wonderfully adaptive 'ōhi'a plants may tower as rain forest trees or mature as dwarfed shrubs under desert-like conditions. Where loose volcanic cinders permit rainwater



to percolate instantly out of reach, an 'ōhi'a often produces aerial roots (below) to catch condensation from fog-borne water.

Hawaii is a showplace of adaptive radiation, the evolution of many forms from a few ancestral types. Consider the endemic insects. Colonizers arrive by chance, as did this vividly hued pomace fly (left center), an alien species I found on the 10,000-foot summit of Maui's Haleakala Crater. Other pomace flies, arriving over long periods of time, have given rise to some 500 endemic species.

Like a hand-painted twig, a giant Hawaiian damselfly lights up the forest (top). These



damselflies apparently separated from their cousins elsewhere in the world more than ten million years ago, initially settling on ancient high islands that have long since been submerged. As new islands arose, the damselflies migrated along them as if they were stepping-stones.

Opportunistic nocturnal hunters, Hawaiian long-jawed spiders (left) range from rain forests to lava fields, where they may hide under volcanic slabs, seeking refuge from the sun.



A violent landscape shelters a world of its own

A SYNTHESIS of Hawaiian evolution (following pages) fuses all major islands together in one landmass, superimposing flora and fauna upon a geologic composite that spans millions of years of development. The blend of scenes ranges from the Big Island at upper right — with some actively volcanic portions less than a year old — to the heavily eroded Na Pali Coast of Kauai at upper left, 350 miles away and 5.1 million years older. Pioneering plants and animals occupy younger land at right, with mature communities at center and left. Several of Hawaii's 150 recognized

ecosystems — 80 of them are endangered — are portrayed, including new and old lava flows, leeward deserts and alpine stone deserts, rain forests and mesic, or moderately watered, forests.

Some 70 species of plants and animals are depicted, almost all of them unique to Hawaii; many are endangered, while others are rare or restricted to extremely limited habitats. This illustrative concept took root in my mind more than a decade ago, as I began planning the best means of representing the evolutionary success of these islands' extraordinary life-forms.

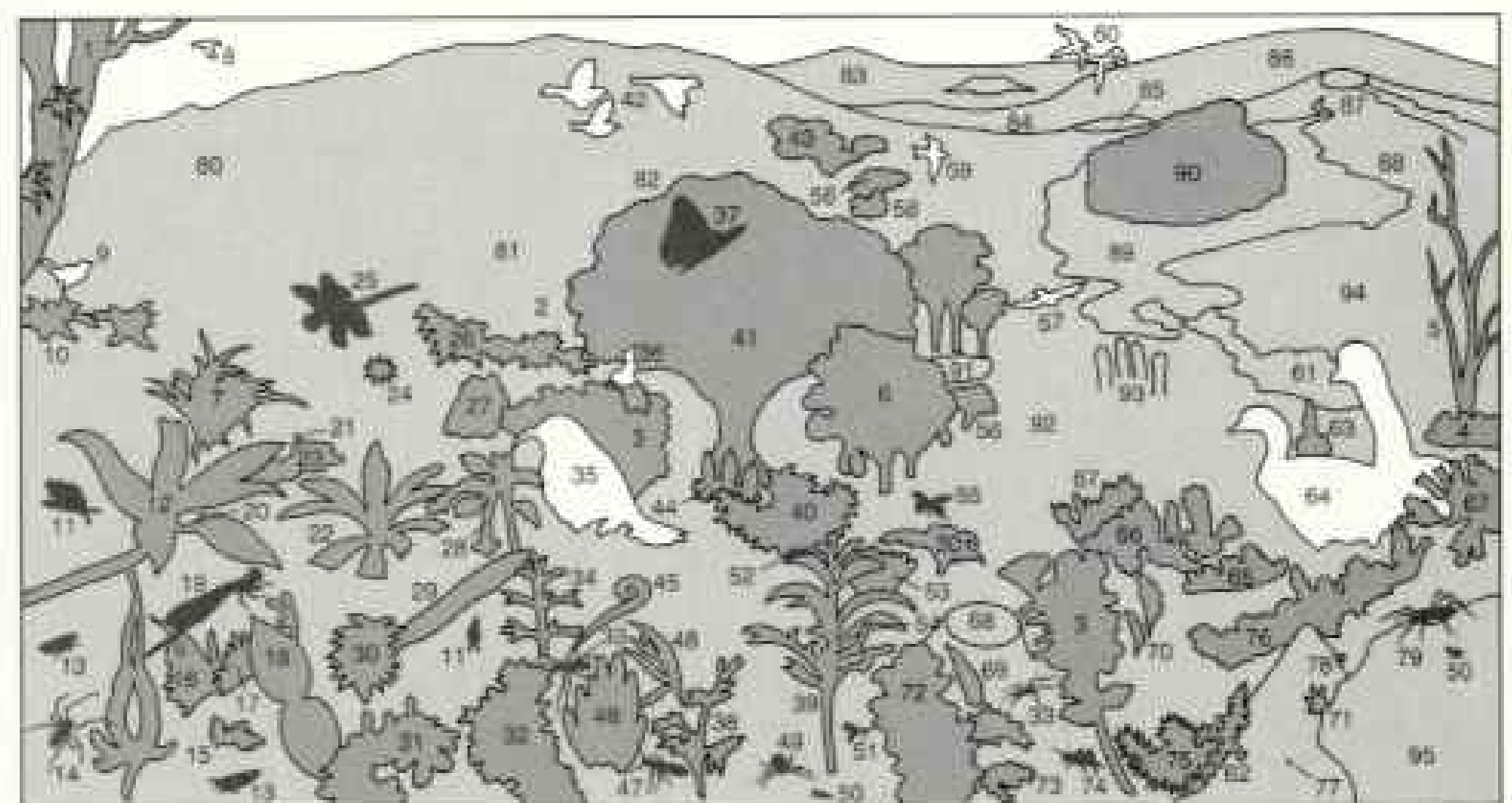


DIAGRAM BY MARK SEIDLER

- | | | | |
|--------------------------------|--------------------------------|---------------------------------------|-------------------------------|
| 1. 'Ōhi'a-lehua | 28. Mint | 55. Yellow-faced bee | GEOLOGIC FEATURES |
| 2. in rain forest | 29. Laukāhi fern | 56. Māmane | |
| 3. flowering | 30. 'Ama'u tree fern | 57. Hoary bat | 80. Heavily eroded valley |
| 4. skirt surrounding dead tree | 31. Peperomia | 58. Hinahina | 5.1 million years old |
| 5. killed by eruption | 32. Mākole | 59. Lesser golden plover | 81. Rain forest |
| 6. with aerial roots | 33. Long-jawed spider | 60. White-tailed tropic birds | 82. Mesic forest with koa |
| 7. Pa'inu | 34. Wāwae-'ole club moss | 61. "Hawaiian snow" — lichen and moss | 83. Eroded crater |
| 8. 'Ākōhekohe | 35. 'I'iwi | 62. Hawaiian snow lichen | 800,000 years old |
| 9. 'Elepaio | 36. 'Āpapane | 63. Silversword | 84. Alpine stone desert |
| 10. Kaniwao | 37. Kamshameha butterfly | 64. Nānē | 85. Pit crater |
| 11. Tree snail | 38. Koa seedling with leaves | 65. Pūkiawe | 86. Shield volcano |
| 12. Lobelia | 39. phyllodes replacing leaves | 66. 'Ōhelo in berry and flower | 87. Cinder cone eruption |
| 13. Leafhopper | 40. phyllodes only | 67. 'A'ali'i | 88. Lava flow |
| 14. Stilt spider | 41. mature tree | 68. Spider web in tree mold | 89. 'A'ā lava |
| 15. Liverwort | 42. 'Ā'kepa | 69. Sword fern | 90. Kīpuka |
| 16. Wāhine noho mauna fern | 43. Sandalwood | 70. 'Āe fern | 91. 'Ōhi'a roots in lava tube |
| 17. Lichen | 44. Greensword | 71. Moss | 92. Pāhoehoe lava |
| 18. Orchid | 45. Fiddlehead of tree fern | 72. Psyllid galls on 'ōhi'a leaves | 93. Lava trees |
| 19. Damselfly | 46. Stiff club moss | 73. Spleenwort | 94. Cinder field |
| 20. Predatory caterpillar | 47. Damsel bug | 74. Lava cricket | 95. 'A'ā lava rocks |
| 21. Maui parrotbill | 48. 'Ekeha 'ākōlea fern | 75. Kūpaoe | |
| 22. Lobeloid | 49. Crab spider | 76. Lopo-nānē | |
| 23. Gunnera | 50. Pomace fly | 77. Mite | |
| 24. Tree lobelia | 51. Ichneumonid wasp | 78. Spiderling | |
| 25. Dragonfly | 52. Flightless lacewing | 79. Lava wolf spider | |
| 26. Hāpu'u tree fern | 53. Mōa | | |
| 27. Uluhe fern | 54. Leaf bug | | |

Painting by John D. Dawson from a concept by William H. Aron







BRILLIANCE and beauty of some Hawaiian endemics rival the islands' showy exotics. Visitors may overlook the golden *māmāne* flower (right), so closely matched in shape to the bills of certain pollinating honeycreepers, or fail to notice scarlet *ōhelo* berries (middle right).

One of the world's most spectacular plants, the silversword, or *āhinahina*, blooms among the clouds in Haleakala Crater (left). Only once, at the end of its life span of a decade or more, does a silversword send forth this glorious cluster of blossoms. To Catherine and me their fragrance resembled raspberries.

Once so abundant here that they covered cinder cones like snow, silverswords became endangered around 1900, serving as food for feral goats and as playthings for visitors who enjoyed kicking them downhill. Now vigorously protected by the National Park Service and the Nature Conservancy, this remarkable plant is making a successful recovery.

Related to sunflowers, the silversword has evolved into perhaps the best example of adaptive radiation among plants. Its local relatives include two other species of silverswords, two greenswords, and 25 other plant species. Silverswords grow in a rotund cluster of curved, spikelike leaves in a



setting as unworldly as Mars. Flat, silvery hairs protect leaf surfaces from the sun.

One of the silversword's primary pollinators is the endemic yellow-faced bee (bottom left). The bees' declining population, due to habitat loss and the introduction of alien insect competitors, is cause for alarm.

Such concern has long aided the Hawaiian goose, or *nēnē*. Around 1850 hunters and introduced wild predators began to decimate the population. In 1918 Herbert C. Shipman started raising the geese on the Big Island. After 1950, with the birds near extinction, the Wildfowl Trust joined Shipman's cause by breeding *nēnē* in Europe for reintroduction into the wild in Hawaii, where perhaps 350 now survive.





WATERFALLS cascade at the gateway to a spectacular Maui rain forest called Kipahulu (below). Careful inspection of the underside of dripping leaves revealed a host of small endemic creatures such as a tree snail (above right). About 20 original land mollusk colonizers have evolved into

roughly a thousand species.

Likewise leafhoppers, insects related to cicadas, have become greatly diversified. This species (above left), one of at least 60, may be new to science.

A stilt spider bears a spotted abdomen (middle); others of the same species, often seen elsewhere in Hawaii, display markings resembling a grinning face.

Unlike exotic orchids bestowed upon visitors, Hawaii's three endemic orchid species, including this one (below), are very small and very rare. In Maui's Waikamoi Preserve, forester Bob Hobdy, who had pointed the orchids out to me, also displayed an 'ape'ape, or gunnera, plant (right), an endemic relative of the milfoil family with leaves as big as a beach umbrella. Despite such luxuriance, the soil is thin; beneath lies the island's lava foundation. Waikamoi's rain forest is fragile and needs protection, as do all Hawaii's ecosystems. Throughout the islands some 5,000 species of exotic plants have been introduced. Yet endemic Hawaiian life-forms usually succeed where invaders fail—if we afford the offspring of these islands' original colonists that opportunity. □









South Florida Water

Paying the Price



Caught wet-handed, a Cape Coral resident argues against a \$48.50 ticket for watering her lawn. A drought that began in 1988 forced the Gulf coast city to restrict water usage. All south Florida followed suit this past winter as water supplies reached an all-time low.

Just outside Everglades National Park, pump trucks tap wells to irrigate tomatoes with water that, some argue, should nourish the park. In this rapidly growing state, where agriculture trails only tourism in profit, managing south Florida's fresh water is hot politics.

By NICOLE DUPLAIX

Photographs by KEVIN FLEMING

FLORIDA. To many tourists it is the world's premier travel destination; 39 million vacationed there last year. To retirees it is a welcome mat to sunshine and low taxes. To political refugees from the Caribbean and Central America it is a gateway to freedom. Small wonder that Florida has one of the highest growth rates in the nation and ranks fourth in population, after California, New York, and Texas.

The magnet is south Florida. Roughly 365,000 newcomers, 1,000 a day, come to stay each year. They head to the Tampa-Orlando-Daytona Beach corridor and south along each coast all the way to Key West. Each of these new residents uses 200 gallons of fresh water a day, meaning 200,000 more gallons must be found daily to meet their needs.

The visitor sees water everywhere in abundance: in endless miles of canals, majestic cypress swamps, shimmering lakes. The key elements of south Florida's vital water system are the Kissimmee River, Lake Okeechobee, and the Everglades. Today they stand at a turning point between environmental viability and possible collapse.

Few areas in the United States have been so intensively drained, diked, developed, and otherwise bent to man's use. The paradise of south Florida is almost totally under the manipulation of man.

Some of the heroic engineering feats that have altered the area, however, are becoming environmental nightmares. As a result, canals and dikes may be dismantled on an unprecedented scale, and a channelized river is slated to be set free. Nature adds to Floridians' problems: As I write, the worst drought on record parches the southern peninsula.

I know these troubled waters well. For three years I worked for the South Florida Water Management District (SFWMD), which oversees the water resources of a region twice the size of New Jersey.

The Florida peninsula is a great flat sponge of porous limestone. Pockets in the limestone hold a huge volume of groundwater—more than in any other eastern state—that wells to the surface in lakes, springs, and marshes.

Until a hundred years ago south Florida's

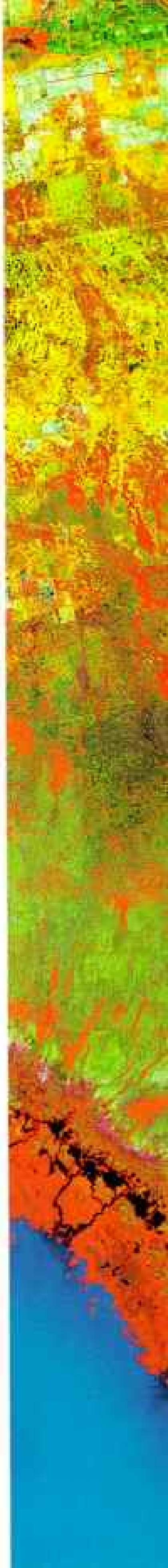
Environmentalist NICOLE DUPLAIX has written NATIONAL GEOGRAPHIC articles on giant otters and fleas. This is KEVIN FLEMING's ninth photographic coverage for the magazine.

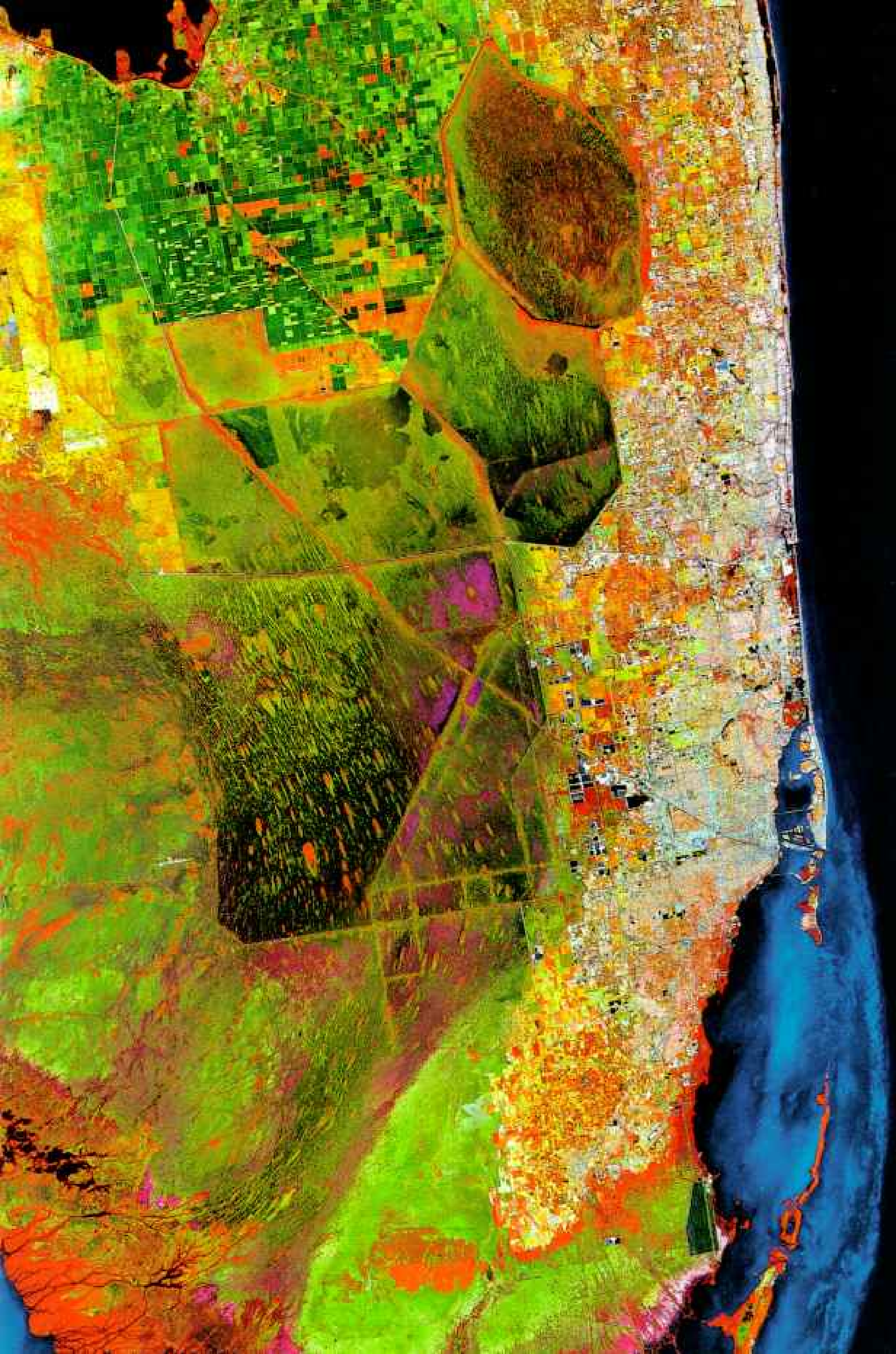


"The whole southern part of Florida might as well be an island," wrote naturalist Marjory Stoneman Douglas. Dependent on rain for fresh water, the subtropical stretch of the peninsula receives a drenching 40 to 65 inches a year, largely from May through October. But this flat, porous limestone land has little surface storage capacity, and after evaporation, transpiration, and runoff only a fifth of the rainwater remains to recharge the underlying aquifers and shallow lakes.

Dotted by tree islands, the Everglades—"grassy water" to its Indians—once swept from the southern banks of Lake Okeechobee across most of southeast Florida. Cypress and mangrove forests dominated the southwest. To drain the lakeside checkerboard of farmland and to allow development to march west off the narrow Atlantic Coastal Ridge, natural water flow was harnessed by 1,400 miles of levees and canals. "Mother nature has been taken out of a lot of the decisions," says John Wodraska, executive director of the South Florida Water Management District. "For better or worse, man is now trying to make them."

ESSET, LANHAM, MARYLAND







High-rise crossroads of Miami reflect the region's extraordinary population growth. Five million people live in south Florida, far exceeding what planners once anticipated. Daily per capita water use is 200 gallons, double the national average.

Guardian of water quantity and quality, the South Florida Water Management District—a 175-million-dollar-budget state agency—seeks a mechanical equilibrium with 18 pumping stations along Lake Okeechobee and its canals to move water.



"Big Water," Lake Okeechobee covers 730 square miles but averages only 12 feet in depth. Famed for bass, it yearly generates as much as 40 million dollars from sportfishing. Its waters irrigate adjoining farmlands and are a primary drinking source for local communities.

Prime polluters, 45,000 dairy cows north of Lake Okeechobee produce as much raw waste daily as a city of 980,000 people. State law now requires treatment of this phosphorus-laden manure; by 1992 a buy-out plan will have reduced the number of cows by nearly one third.

fresh water circulated in a slow, majestic, rain-driven cycle that nurtured an ecosystem unique on earth. Starting at a chain of lakes south of Orlando, water flowed south into the Kissimmee River. Carrying the system's lifeblood, the Kissimmee meandered through palmetto-studded savannas to Lake Okeechobee, which has an average depth of only 12 feet but covers 730 square miles.

Periodically spilling over the lake's low southern rim, the water spread in a 50-mile-wide sheet, moving south across the saw grass of the Everglades at about a hundred feet a day. Named the "river of grass" by Florida writer Marjory Stoneman Douglas, this great sheet of water contributed to the rain machine that constantly renewed the cycle.

Rainfall is generous—40 to 65 inches a year. But most falls in the soggy summer season. Because the flat relief limits the construction of conventional reservoirs, rain that the land cannot quickly absorb is channeled into the sea. Much water is also lost to evaporation and transpiration by plants. During the dry winter months, when tourist demands peak, wells deplete the aquifers, especially on the teeming coasts.

THE DISRUPTION of south Florida's natural system began after the Civil War, with the appearance of northern investors with grandiose dreams. In an environmental onslaught, Philadelphia toolmaker Hamilton Disston undertook to drain the Everglades and connect Okeechobee via a boat canal to the Gulf coast, lowering the level of the flood-prone lake. Promoter Henry Flagler built railroads and brought hotels to the east coast.

With the new century came Governor Napoleon Bonaparte Broward, who promised to drain the Everglades once and for all. A vast network of locks, dams, and hundreds of miles of canals further lowered Lake Okeechobee and snaked deep into the Everglades. The

"It's my grandson I worry about," says Linda Valladares, whose well was contaminated by carcinogens, perhaps from a leaking landfill. Broward County supplied bottled water for six months and now pipes in water. Porous land and a high water table raise the risk of leaching. Liners, now required, anchor a new Dade County landfill (top) at the base of an older landfill that is unlined but monitored.

newly drained muck soil provided extraordinary crop yields, and farming boomed.

But farmers soon discovered that their prized soil burned like tinder during the dry months, the fires spreading for miles. Worse, the land itself was disappearing. As fields were drained, the top layer of muck dried to a fine powder and blew away, or it decomposed through an oxidizing process, releasing nutrients that washed into surrounding canals.

Devastating hurricanes in 1926 and 1928 burst low earthen levees around the lake, killing more than 2,000 people. The state appealed to Congress, and at its direction the U. S. Army Corps of Engineers started the massive Herbert Hoover Dike that now encircles Lake Okeechobee, constricting the heart of the system. After another hurricane in 1947 the corps launched other ambitious plumbing projects—surgery that changed the watery





Straitjacketed into a canal for flood control between 1961 and 1971, the meandering Kissimmee River lost half its length and most of its marshes. Now, in the first reversal of a U. S. Army Corps of Engineers project, the river is slated to regain its curves, some already reflooded by test weirs. The restoration will bring back wildlife and stave off development.



Few states give water managers such policy-making clout. The South Florida Water Management District, largest of five, is defined by the natural flow that begins with the headwaters of the Kissimmee. Governor-appointed board members (opposite) head operations but may, say critics, put interests of their individual regions above the health of the system.

wilderness forever. By 1980 dredges had carved 1,400 miles of canals and levees in the SFWMD, including three impoundments, or water conservation areas, covering 1,350 square miles of the Everglades. Pumping stations muscled water across the flat expanse.

Special treatment was given to the Kissimmee. When downpours drenched its headwaters, sluggish meanders could not carry off the water, and floods were frequent. Cutting straight through the floodplain, the corps dug a canal 300 feet wide. By 1971 the looping river, once a hundred miles long, was reduced to 52 miles and renamed Canal 38.

The entire Everglades watershed showed signs of malaise. How could it go so wrong so quickly? How could it be cured?

A plea for action came from Arthur R. Marshall, a former U. S. Fish and Wildlife Service biologist whose passionate concern caught the ear of the press and politicians. Charging in 1973 that delicate heart surgery had been performed with a meat cleaver, he called for the restoration of the Kissimmee River and the Everglades: "It is a single water system, a living entity that has been carved into parts by all these canals, its flow impeded and redirected. It can't function that way!"

TO VISIT ailing Lake Okeechobee, I left the condos of West Palm Beach and drove through miles of bamboo-like sugarcane, each tract rimmed by an irrigation ditch twinkling in the sun. Along the dike that encircles the lake, one small town gave way to another, each intent on its own special industry: fishing, ranching, agriculture.

On the south shore spread fields of lettuce and celery. The area around Belle Glade is one of the nation's winter vegetable baskets, filling salad bars across the land.

"There are 20,000 people out there in the Everglades Agricultural Area working to produce sugar and vegetables on 450,000 acres of land," said farmer George H. Wedgworth. Palm Beach County alone has the fifth largest farm income in the nation.



CAPE CORAL

FT. MYERS

LAKE OKECHOBEE

LAKE GLADES

FT. LAUDERDALE

MIAMI BEACH

FT. LAUDERDALE

MIAMI

BISCAYNE BAY

EVERGLADES NATIONAL PARK

FLORIDA BAY

A sign at Belle Glade proclaims, "Her soil is her fortune." But oxidizing muck is taking a costly toll. A concrete marker at the University of Florida's agricultural research station shows that more than five feet of soil have been lost in the past 67 years (page 105). Experts predict that in places the surface will reach bedrock within 25 years.

At the town of Okeechobee, famed for its bass fishing, I headed out onto the lake to try

"Many growers were skeptical," says Jack Ross, who uses purified sewage water to irrigate. "But it works." It also insulates his tangerine trees during freezes. Orange County and Orlando devised this water-recycling method, an alternative to well irrigation, to solve their sewage-disposal problem. When needs are low, the water is filtered through sandy basins (below) to recharge the Floridan aquifer.

my luck. Boats of all shapes and sizes crisscrossed our wake. Between a succession of four-pounders I wondered how much longer the lake could serve so many masters.

The most demanding of these, according to biologists, is agriculture, including dairy farming. The contaminated runoff from fields in the Everglades Agricultural Area, south of the lake, contains abundant phosphorus and nitrogen, from fertilizers and the disintegrating muck.

On the dairy farms to the north 45,000 cows each produce raw waste equivalent to that of 22 human beings. The 2,295 tons of waste contribute to the 1.5 tons of phosphorus that flow into the lake each day.

These huge inflows of phosphorus and nitrogen, accumulating in the silty bottom of Lake Okeechobee, hasten the natural aging process of eutrophication. The danger signals



are blooms of blue-green algae that resemble broad splotches of pea soup.

Farmers point out that the lake has always known phosphorus and nitrogen, naturally deposited by rainfall. But now the human contribution is several times that of nature.

In 1979, pressured by conservationists who were worried that increased nutrients might irretrievably damage the lake's water quality, the SFWMD stopped pumping runoff from the cane and vegetable fields north into the lake, except in drought or flood. Instead the water was discharged south into the water conservation areas.

In 1985 then governor Bob Graham created the Lake Okeechobee Technical Committee, a team of scientists, engineers, and environmentalists, to study the problem.

Dangerous algal blooms exploded on the lake in August 1986, spreading over 120

square miles and attracting wide media attention. It was an election year, and candidates flocked to the "dying" lake. From biological dilemma to political opportunity, the lake was in the limelight, and the district was taken to task. The clamor to save the lake grew louder.

The committee considered new canals (more plumbing) to divert the agricultural runoff to nearby estuaries. Coastal residents vehemently objected. Another fix involved pumping the polluted water down wells, in the hope that the limestone would filter out nutrients and the cleansed water could be recovered. "Bio-manipulation by brute force," snarled a critic.

The estimated cost of these changes was more than 200 million dollars. Even then, the team cautioned, predicting the lake's response was "not an exact science."

In the following years the algal blooms

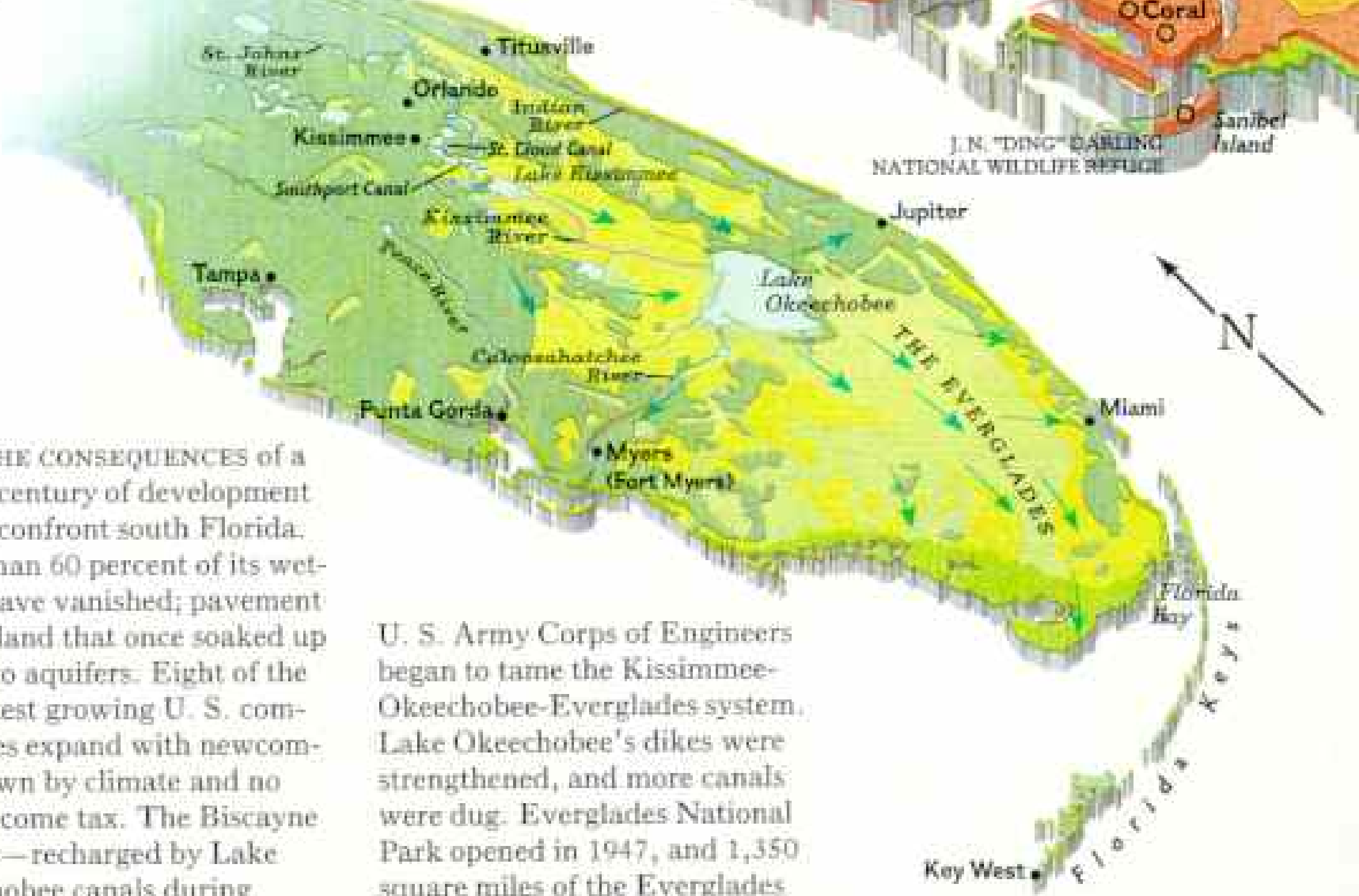


A watershed besieged

South Florida today



South Florida 1900



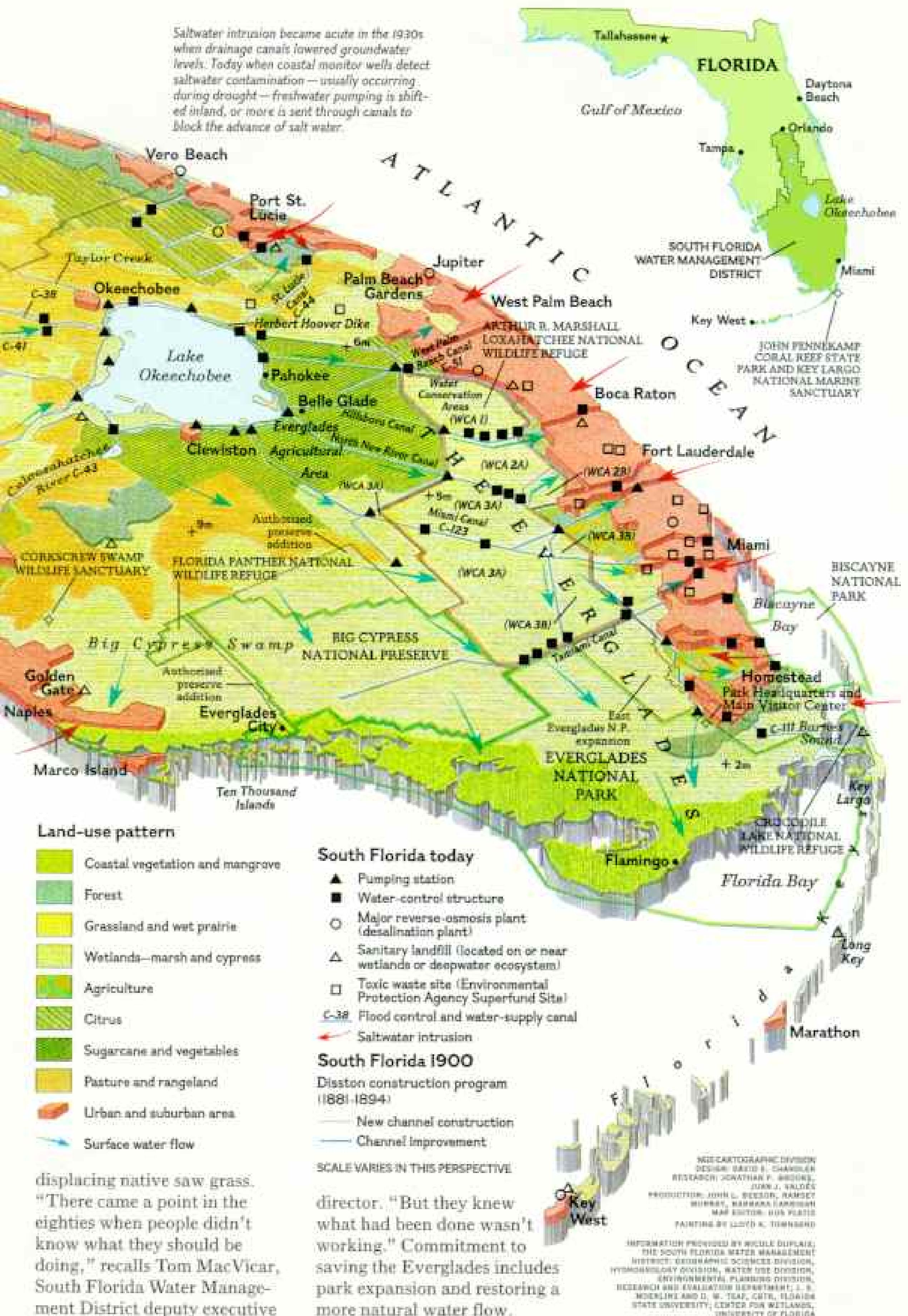
THE CONSEQUENCES of a century of development confront south Florida. More than 60 percent of its wetlands have vanished; pavement covers land that once soaked up rain into aquifers. Eight of the ten fastest growing U. S. communities expand with newcomers drawn by climate and no state income tax. The Biscayne aquifer—recharged by Lake Okeechobee canals during drought—amply supplies the east coast. But, less blessed, the west coast increasingly drinks desalinated water. And during winter, when water supplies are falling, 12 million tourists arrive.

After hurricane floods killed thousands in the late 1920s, the

U. S. Army Corps of Engineers began to tame the Kissimmee-Okeechobee-Everglades system. Lake Okeechobee's dikes were strengthened, and more canals were dug. Everglades National Park opened in 1947, and 1,350 square miles of the Everglades outside the park were later impounded as water conservation areas for flood control and wildlife preservation. Water was diverted for human needs during dry periods and released to the flooded park during the rainy season.

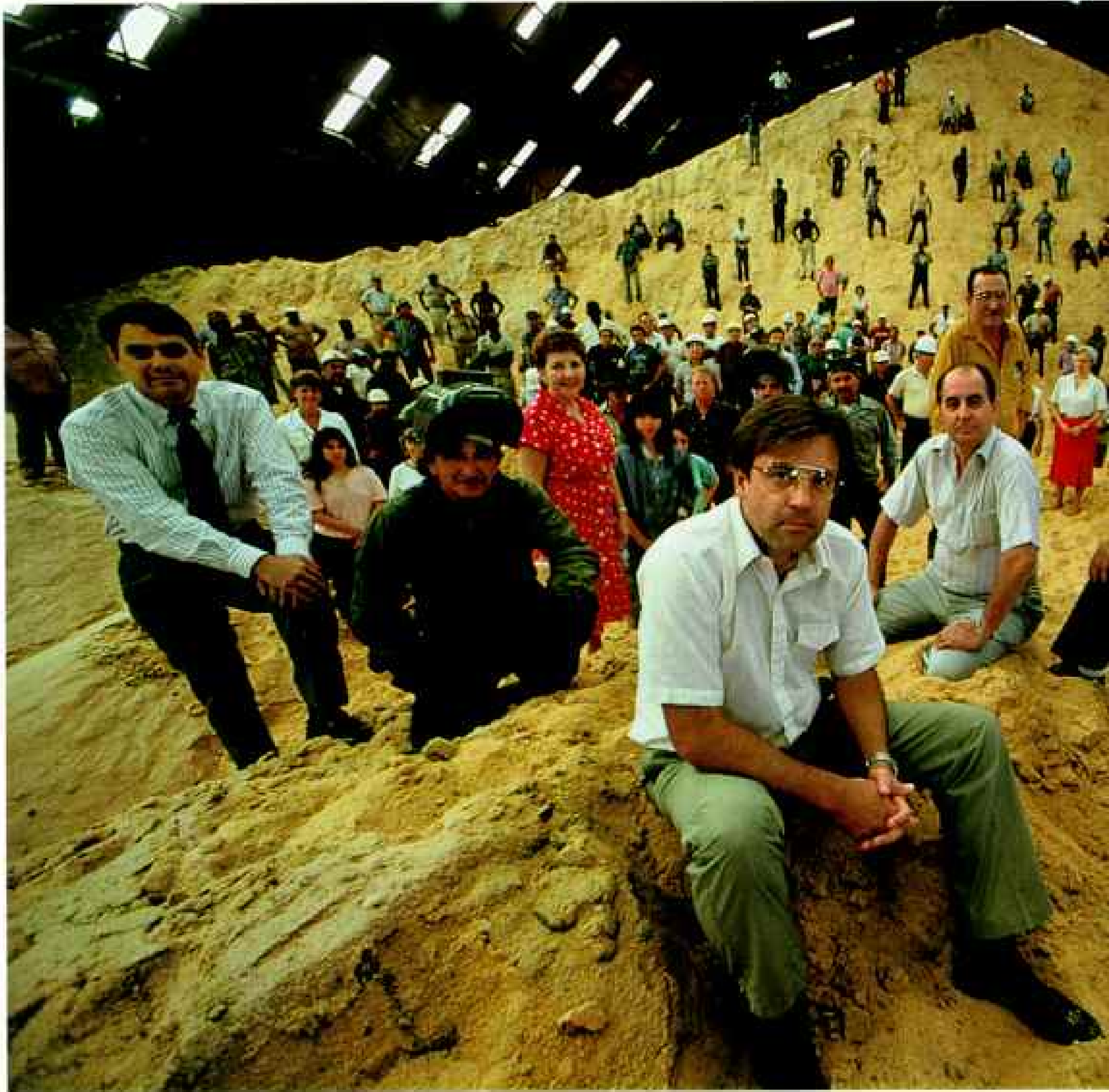
Lake Okeechobee choked on algal blooms provoked by nutrient-laden runoff pumped from dairies and sugarcane and vegetable fields. To protect the lake, runoff was diverted to conservation areas; cattails began

Saltwater intrusion became acute in the 1930s when drainage canals lowered groundwater levels. Today when coastal monitor wells detect saltwater contamination — usually occurring during drought — freshwater pumping is shifted inland, or more is sent through canals to block the advance of salt water.



displacing native saw grass. "There came a point in the eighties when people didn't know what they should be doing," recalls Tom MacVicar, South Florida Water Management District deputy executive

director. "But they knew what had been done wasn't working." Commitment to saving the Everglades includes park expansion and restoring a more natural water flow.



returned as scientists continued to discuss solutions.

"We may lose the lake before we can rehabilitate it," said Paul Parks, a scientist with the Florida Wildlife Federation. "The problem was clearly identified by the mid-1970s. It didn't take this long to put men on the moon."

THE EXTENSIVE MANIPULATION of the Kissimmee River and Lake Okeechobee was also adversely affecting the sensitive Everglades downstream.

Forty-three years ago President Harry Truman dedicated 1.4 million acres of the Everglades as a national park to "protect hundreds of kinds of wildlife which might otherwise

soon be extinct." The park's birthright, declared Congress, is clear and abundant water.

Last in line in the 250-mile-long Everglades watershed and competing with the thirsty urban corridor to the east, the park for years had little say as to how much water it received and when. A yo-yo effect prevailed. When a summer downpour filled the water conservation areas or flooded adjacent Dade County's vegetable empire, the excess was quickly released into the brimming park. In drought, cities and tomatoes drank first, and the Everglades withered. Never mind that a few inches of water spell life or death to crops and wood storks alike.

"Water unquestionably is the park's number one problem," then superintendent Mike Finley told me as we choppered low over the Everglades. A no-nonsense conservationist who now oversees Yosemite National Park, the Oregon native had vowed to battle any agency in federal court to protect the park's dwindling wildlife and water supply.

As the watery stillness of grass and tree islands rushed beneath us, Mike pointed out trouble spots: forest fires near the Ten Thousand Islands estuary, tomato fields pushing against the park boundary, thick stands of melaleuca trees from Australia that guzzle water and spread like wildfire.

In 1983 concerned park biologists drew up a list of requests, urging that water deliveries follow the seasonal rainfall pattern to dampen the yo-yo effect. Governor Graham called for the creation of a buffer zone around the park by purchasing as much land as possible with state and federal funds.

WATER MANAGERS cooperated. First they designed a computer model to mimic seasonal rainfall conditions and annual water deliveries along the park's northern boundary. This new model has significantly improved the timing and distribution of water allotments, but problems still exist. When the current drought imposed restrictions on



On a mountain of sugar, employees of the Atlantic Sugar Association near Belle Glade look sour at the prospect of losing their jobs. The mill may close if new state requirements for filtering field runoff prove to be too costly to the growers. After the juice is extracted, sugarcane fiber powers the region's seven mills.

Florida's "black gold," the organic muck of the drained Everglades sustains the nation's largest sugarcane crop and second largest vegetable output. But, exposed to air, this soil decomposes. At the University of Florida's Belle Glade agricultural research center a marker records dramatic soil loss, one inch a year on average. Much of this land, it's predicted, may be abandoned within 30 years.



Miami residents in 1989, no water was released to the park for 37 weeks.

Other events affect water delivery. When 12 inches of rain pelted south Florida one August day in 1988, the district relieved flooded farmlands by releasing a plume of fresh water from Canal 111 into Barnes Sound, adjacent to the park, temporarily wiping out this marine breeding ground for shrimp and fish—a source of food to humans and to thousands of wading birds. A drastic measure to protect the vegetable fields.

North of the park a levee was breached to help restore the natural water flow, allowing more water into Big Cypress Swamp, home to some of the few remaining Florida panthers.

There were also other improvements. In 1983, 55,000 acres around the park's perimeter were purchased to act as a buffer zone. In the 1989 Everglades expansion act, Congress authorized 107,000 acres of land to be added to the park, including 35,000 acres from the 1983 purchase.

Some of these laudable adjustments came too late. The last 25 years have seen an 80

percent drop in pairs of breeding wood storks—an endangered species (page 111). Nesting wading birds, 300,000 strong 60 years ago, today number 15,000. Park biologists believe that with improved water deliveries some bird populations can recover, although there is no longer enough natural freshwater marshland left for huge flocks of waders.

Saltwater wading birds pose another problem. Their finicky requirements make remedial adjustments difficult. "In Florida Bay the mix of brackish water needs to be just right to produce the small fish and shrimp the birds need to survive," said biologist George Powell of the National Audubon Society. "Otherwise they desert the bay, and their nestlings starve."

The improvement in the water supply accompanies the emergence of an equally grave threat, that to water quality.

"Pollutants entering the water conservation areas have damaged the ecosystem over the past ten years," said Steve Davis, a biologist with the SWMD. They come from the agricultural runoff south of Lake Okeechobee.

This contaminated water carries ten to twenty times normal concentrations of phosphorus and nitrogen. The remorseless tide threatens to change the entire vegetative pattern of the Everglades. Flowing into the delicate marshes of Water Conservation Area 1 (within the Arthur R. Marshall Loxahatchee National Wildlife Refuge) and the other conservation areas, it is spreading its plague to the park.

Where the pollutants have penetrated the refuge and conservation areas, the original saw grass swamp is retreating before the advancing ranks of cattails. In the past decade these hardy, nutrient-loving plants have displaced thousands of acres of native saw grass in the water conservation areas alone.

Growing more than ten feet high on their rich diet of phosphorus, cattails tower over saw grass and soon crowd it out with their roots and leaves. The invaders also shade out

oxygen-producing periphytic algae, base of the Everglades food web. Less desirable species of algae that support fewer organisms proliferate on the nutrients. Soon all that is left is a thick stand of cattails and foul-smelling mud.

I saw this change with Nancy Urban, an SFWMD research environmentalist measuring cattail/saw grass ratios in the 110,720-acre expanse of Water Conservation Area 2A. Dwarfed by the tightly packed cattails, we waded through the growth. In minutes I was soaked with sweat, forearms lacerated by the few remaining blades of saw grass. "Already plots at the northern end are choked with cattails," said Nancy.

Some estimates say cattails are strangling the water conservation areas at an average rate of four acres a day, one reason that the national refuge is listed among the nation's ten most endangered.

WHILE still Everglades Park superintendent, Mike Finley urged stopping the environmental havoc at its source. "Industries that produce harmful waste should clean it up and not expect the state or feds to do it for them. We demand it of canneries and pulp mills—even Boy Scout camps. Why not of agriculture?"

The past few years have seen a dramatic turn of events. Florida's 1987 Dairy Rule requires that by 1992 pastures drain into special holding ponds to prevent manure nutrients from reaching Lake Okeechobee. Also in 1987, the Florida legislature passed the Surface Water Improvement and Management Act, which requires the state's five water-management districts to come up with detailed plans for pollution reduction and environmental restoration. New regulations—if enforced—will turn the tables on polluters, with stiff penalties for farmers and dairymen whose effluents exceed acceptable phosphorus levels.

In 1988 Governor Bob Martinez proposed converting a 3,742-acre tract of state land, former sugar fields, into filtration marshes. By 1992, when the lands are diked and the marshes begin filtering, the project will have cost 13 million dollars.

The SFWMD proposed adding another 14,000 acres to filter agricultural runoff, sharing the cost with growers. Many people see a bitter irony in the fact that government price

guarantees to U. S. sugar growers support the polluters.

A lawsuit has churned the waters. The U. S. Attorney's office in Miami sued the SFWMD and the Florida Department of Environmental Regulation in 1988, charging that state and federal water-quality regulations had been violated by allowing agricultural runoff to damage Loxahatchee Refuge and Everglades



Park. The defendants recently countersued, alleging that the U. S. Army Corps of Engineers has refused to apply for state storm-water management permits, and that it must accept equal responsibility with the SFWMD for the water-control structures it owns.

ISHIFTED MY ATTENTION upstream, to the headwaters of the Kissimmee River. In the rehabilitation of the channelized river, careful research was paying off.

The decision to resurrect the natural river was unprecedented. In 1971, just months after the serpentine Kissimmee was straightened into Canal 38, Florida reconsidered. In 1976

the state's Kissimmee restoration act pledged to return the river to its vital role in the Everglades system. For the first time in the nation's history a Corps of Engineers project may be reversed.

Why this reversal? The corps' original purpose was in keeping with the viewpoint of the fifties: Control seasonal flooding that damaged agriculture and hindered development south of Orlando. But the effect of the dredging project was dramatic. Scenic oxbows stagnated, disconnected from the free-flowing stream. Gone were the marshes harboring bald eagles and migratory waterfowl.

The SFWMD, given the lead in the restoration project, decided in 1984 to begin with a large-scale experiment. Engineers placed three sheet-metal weirs on a short stretch to divert the canal's flow, reflooding old oxbows and marshlands. Emulating seasonal variations, they raised and lowered water levels for

three years to determine if rehabilitation was possible. The experiment proved that the Kissimmee could be restored.

I visited the site with SFWMD research environmentalist Lou Toth. He had monitored the changes and was enthusiastic. We launched our boat at the south end of the 12-mile project and headed upstream.

From the surface of the canal, banks of sloping spoil cut off the view of grazing cattle. We threaded the first weir via a 39-foot-wide navigation notch for small fishing boats.

At the oxbow above the weir enough water had been diverted to scour out accumulated mud and vegetation. The oxbow flowed perceptibly. The impression of a barren water highway was replaced by that of a tropical stream. It reminded me of savanna creeks I had seen in Brazil, alive with waterfowl and birdsong.

Lou reduced speed and pointed to metal





"A swamp-peddling scam," one state official says of Golden Gate Estates (top), a 111,000-acre development east of Naples that went bankrupt in the 1960s. To restore the region's natural water flow, the state plans to buy 41,000 acres in the southern section. "But we're still fighting," says Chris Durphy, one of 66 people who have built here. At a picnic (above) owners locate their land on a plat. "We're not anti-environmental," says Durphy. "We just want the state to leave us out of the acquisition."

Stronger development laws today include control of urban storm-water runoff, the greatest source of pollution. Artificial lakes threading new home sites in Palm Beach County (left) capture runoff and allow contaminants to settle out.

Counting turtle grass in Florida Bay in Everglades National Park, researchers track a mysterious die-off that has killed 15,000 acres since 1987. The decline is allowing other sea grasses to colonize the estuary, increasing animal and plant diversity. Hurricanes may keep turtle grass in check, but no major storm has hit since 1965—an environmental wild card for all of south Florida.



pipes sticking out of the water on either side of the oxbow. "That's my sampling transect. We'll take a sediment analysis to see how the bottom is doing." Four years ago he had brought up muck that smelled like sewage.

We lowered a brass box over the side and retrieved a sample. White sandy soil dripped out. This indicated the current flowed well, bringing oxygen to fish and small fingernail clams that had returned to their former haunt.

Lou identified native marsh plants as we pried the oxbow's lazy loops. "See that climbing dayflower? It's a threatened species." Then, with pride: "That wax myrtle on the bank is dead." Wax myrtle trees prefer dry conditions, proof that the Kissimmee floodplain was indeed wet again.

To learn more about the restoration study, I turned to an engineer 2,500 miles away in Berkeley, California. Professor Hsieh Wen Shen knows every bend of the Kissimmee, just as he learned about the Nile when the United Nations hired him to study environmental effects of Egypt's Aswan High Dam.

Commissioned by the SFWMD to examine

alternatives for reflooding the oxbows and marshlands, Shen used two thousand-foot flumes to simulate the movement of water and sediments. In a hangar nearby we waded across a 60-by-80 foot simulation of a Kissimmee bend, marsh area, and stretch of canal. A computer measures flows in the elaborate miniature to reveal the river's behavior under flood conditions.

Floridians are finding that restoring a river will not be cheap. To undo the 30-million-dollar channeling job and procure 50,000 acres of floodplain where cattle now graze could cost as much as 300 million dollars.

The Kissimmee is also benefiting from an Orlando water cleanup, one of the state's many innovative water schemes.

Once a sleepy citrus center, Orlando has mushroomed into one of the ten fastest growing metropolitan areas in the nation (along with seven others in Florida). Eight

years ago it received an ultimatum from the Environmental Protection Agency: Stop discharging wastewater into the headwaters of the Kissimmee. A 200-million-dollar solution resulted in one of the largest citrus irrigation projects in the country using reclaimed water.

The city teamed up with Orange County to build a 20-mile pipeline to a distribution center in the middle of the citrus belt. There 25 million gallons, soon to be 50 million, of reclaimed sewage water is on tap daily for irrigating 15,000 acres of citrus trees.

When rainfall is high, the water is diverted instead into RIBs—rapid infiltration basins (page 98). A hundred oblong plots dot more than 1,500 acres in western Orange County. Water filters through the sandy soil in these mini-reservoirs to recharge the aquifer.

IF THE SUN is missing elsewhere in Florida, you will find it at the very tip of the United States, in Key West. Sunshine, but precious little water. So precious that one of Florida's first millionaires, William Curry, a Key West entrepreneur, bolstered his

fortune selling water by the barrel to passing ships and pioneers.

Today a 130-mile-long pipeline carries 12 million gallons of water a day to the keys. But it is not inexpensive—in the keys water costs five times as much as it does in Miami. Will Florida, like California, be forced into water wars and longer pipelines before it imposes strict conservation and curbs development?

Heading back to Miami along narrow U. S. 1, I passed the Key West landfill, rising 90 feet to one of south Florida's highest points. Many such landfills exist in south Florida. Plastic liners and leachate collection systems, required by law since 1987, prevent or diminish the risk of groundwater contamination.

Every day a million gallons of noxious liquid from old, leaky landfills ooze into the water table—corrective measures are almost nonexistent. No one wants to pay more taxes to protect their water supply. "You can't be fourth in growth and rank 47th in taxes," warns Professor John M. DeGrove of Florida Atlantic University. "Sooner or later we're going to have to bite the bullet and pay the taxes to protect our resources."

ONE MORNING I went to my neighborhood gas station in West Palm Beach and found it missing. Bulldozers had dug up rusting underground tanks and rolled them to one side like stranded whales. Recently enacted well-field-protection ordinances ban leaking gas-storage tanks that might contaminate groundwater, and tests pointed a finger at my neighbor.

It reassured me that Florida is serious about protecting its water. Much of it is pumped from less than 150 feet below the surface, and the SFWMD watches aquifers closely. "You spill it, you drink it," goes the admonition—and sooner or later you do.

Protecting land above water supplies is now state policy. Florida has acquired a million acres of water-sensitive areas in the past seven years and proposes to buy more.

"There are no other Everglades in the world." Concerned for this "superb monotony of saw grass," Marjory Stoneman Douglas wrote The Everglades: River of Grass. Its 1947 publication coincided with the opening of the national park for which she had lobbied for 20 years. Of today's restoration effort she says, "It isn't a question of being optimistic or pessimistic. It's got to be done."



An inadequate water supply in the east-coast town of Jupiter led to a high-tech solution that is increasingly popular in south Florida.

After drilling through the surface source to a thousand feet, Jupiter's water engineers hit another, slightly brackish aquifer.

"We put our water supply in the 21st century by installing a reverse-osmosis system," said Mayor Mary Hinton. Such membrane-filtering desalination systems, greatly improved in recent years, remove 99 percent of water contaminants, including salt, at very competitive cost.

One of the most insidious threats to the water supply is from encroaching seawater. An elaborate sentinel system guards aquifers along Florida's coasts. The most dangerous time is winter, the season with the least rainfall and maximum tourists. Then use is high, levels are low, and saline water invades.

Sensors in coastal wells warn when fresh water drops below the danger point, and managers switch pumping to inland wells. Reverse osmosis is often the answer for towns





BOTH BY FARRELL GREHAN

“They tried to adjust and they failed,” says ornithologist John Ogden of wood storks (above), hardest hit in the 95 percent decline of Everglades wading birds, now numbering about 15,000. Some 500 nesting wood storks remain here. Man-made changes in water flow have caused the storks to postpone winter nesting until spring, when rains disperse the fish needed to feed chicks. More flexible to change, a great egret stalks fish in a cypress swamp (left).

where saltwater intrusion is permanent.

What about reducing water demand? Many Florida towns take pride in their lush but thirsty landscaping. Such areas use 1,500 gallons per person a day, compared with 105 gallons on average nationwide.

One solution is xeriscape (pronounced ZERUH-scape), or dry landscaping. Thanks to an aggressive public-information program, the use of drought-tolerant plants and water-saving mulches is now taking hold with cities, developers, nurseries, and gardeners.

IN A 1988 POLL most of the Floridians surveyed felt a need for stronger anti-pollution laws and water-conservation measures. Until the recent drought they were far more concerned about the quality and taste of their drinking water than about shortages or flood control. They made little connection between what comes out of the tap and the vast plumbing system that gets it there. Most have never seen Lake Okeechobee. Most do not realize that Florida relies on unpredictable rainfall for its water and possesses little capacity for surface storage.

As more and more faucets drain the aquifers, urban sprawl paves over the land and short-circuits its absorption properties.

Fifth-generation Floridian John DeGrove, the mastermind of his state's sweeping growth-management legislation, believes that the framework is now in place to promote growth with resource awareness. Some 130 south Florida towns are drafting plans to comply with stringent new requirements.

South Florida has entered a period of new sensitivity to its water problems. From eras of overdraining and damage to the environment, the state seems to be moving into balanced management.

What lies ahead? Both water pundits and managers agree: South Florida will never run

Nature's land manager, lightning fires keep hardwoods from overwhelming the Everglades. But in recent drought years, smoke pollution and the threat to residential property have required fire control costing millions of dollars. In natural winter dryness alligator tracks cross sunbaked muck (top). "The 1990s will see battles between Everglades and urban water needs," says Tom MacVicar, designer of the plan to restore natural water flow to the park. "Are we willing to pay more for water so the Everglades can have its share?"

out of water. Stricter regulations for wasters and polluters will help see to that, along with desalination technology. Inevitably the cost of water will rise to pay for the innovative solutions required for an ever growing population. Formerly taken for granted, water will be used more sparingly as citizens become water managers.

Nathaniel Pryor Reed, former member of the SFWMD's governing board and one of the state's foremost environmentalists, sums it up: "Great things are being done now. Ignorance and lack of interest were the hallmarks of the sixties, the age of glorification of public works. But today we have on all sides the very best scientific minds, agencies meeting problems head on, a public that wants to do good, and an aroused media that covers every step of our unfolding saga. We are battling on all fronts at once!"

And we haven't seen the end of the fight. □







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



BOTH BY JERRY GREENBERG

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.

patient silently slips away.

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



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
(Continued on page 123)



FRED BARD (ABOVE); NAPT BRACKET



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.

1960



1989





© 1962, 1991 JERRY GREENBERG (AQUATEL); JERRY GREENBERG

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



BOTH BY JERRY GREENBERG



(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

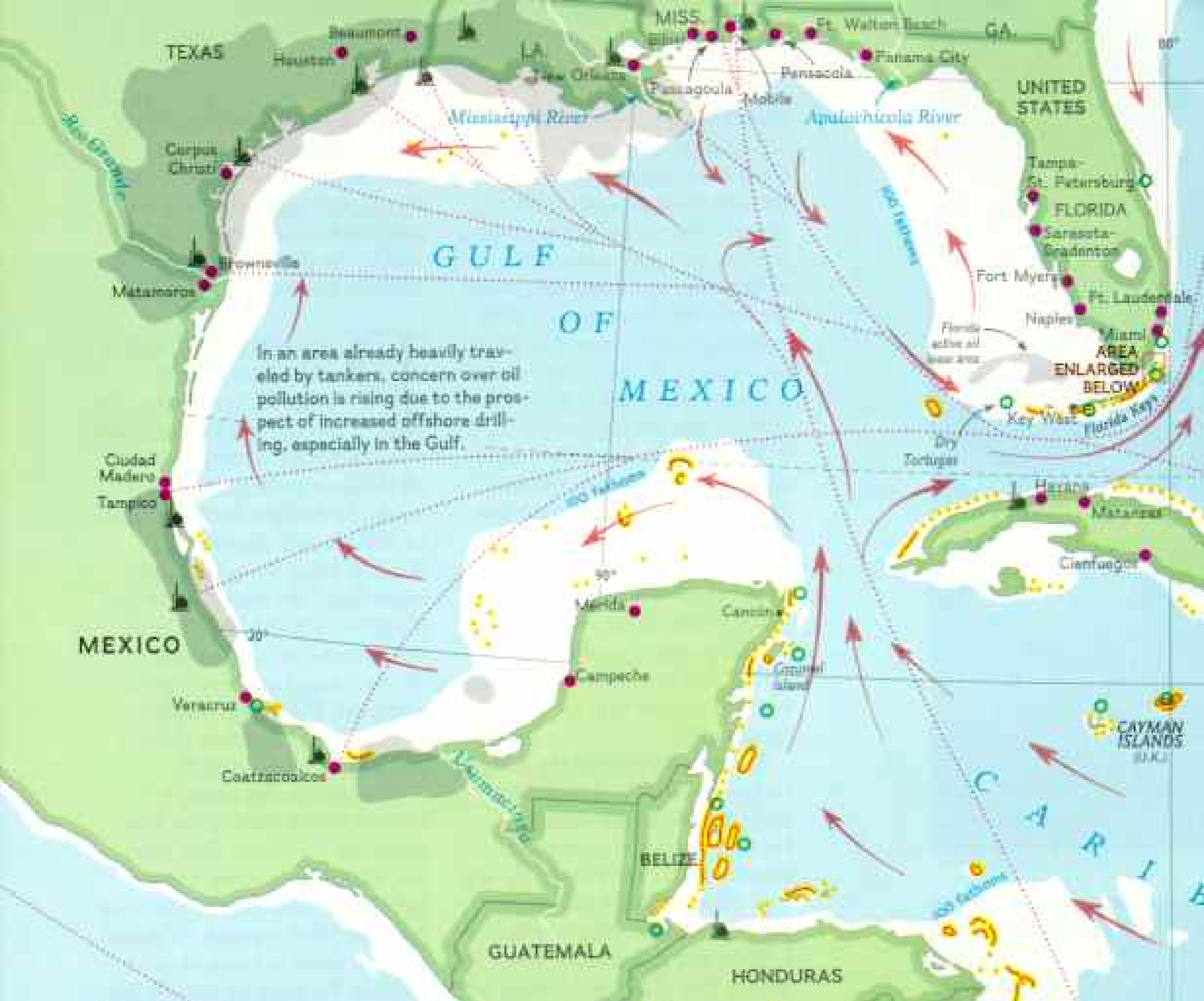
Death can be shockingly swift in a coral reef that took some 6,000 years to grow. Thirty feet down in Molasses Reef, boulder coral (top, at left) and branches of elkhorn, at right, were suffering in 1983, but much of the area remained alive. Just six years later the boulder coral was seriously eroded,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

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.

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."

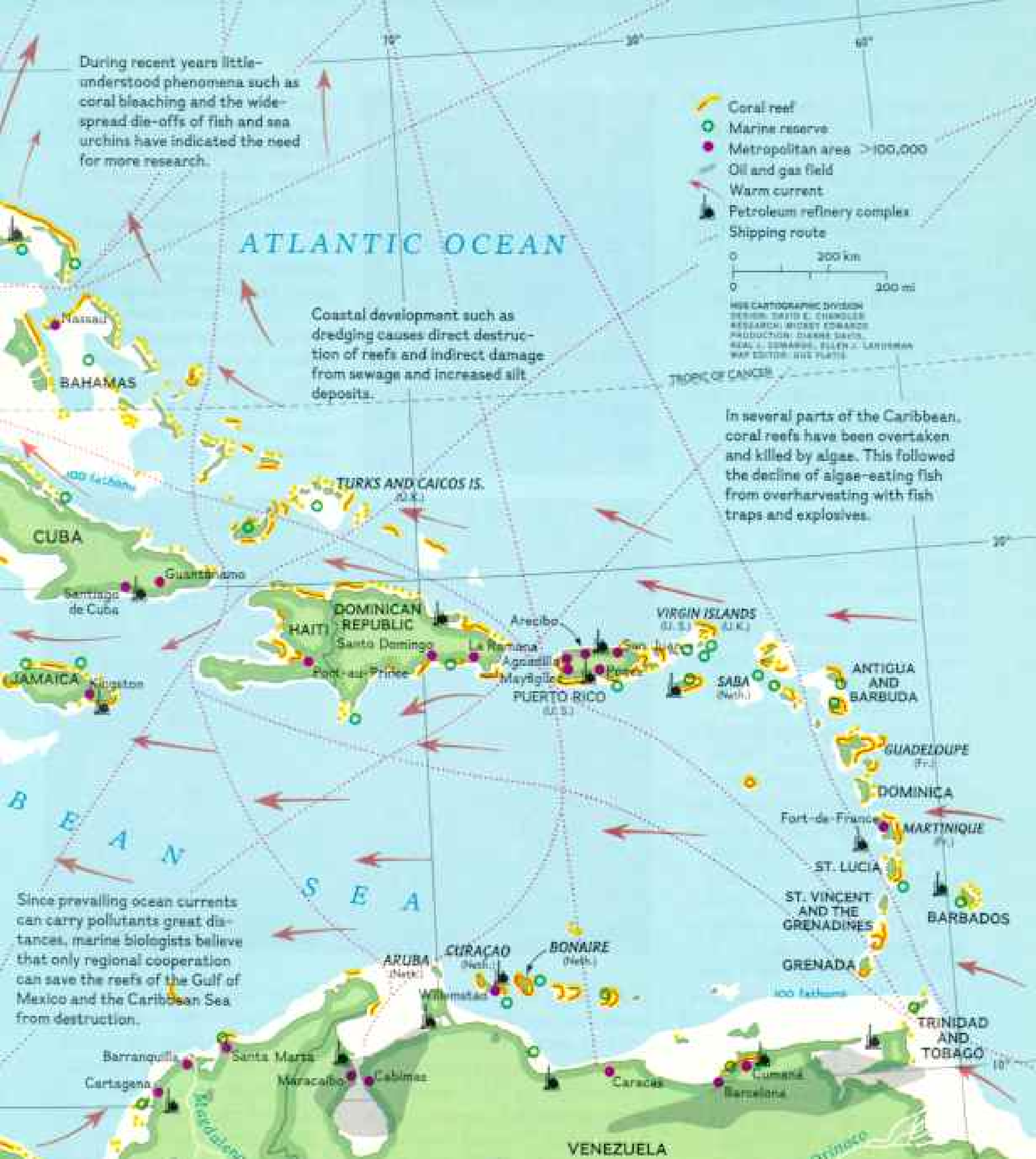
Parking-lot size seems a strange way to determine how many people get in. Carl Nielsen, then Pennekamp's energetic park manager (he has since changed jobs), agreed: "I'm not sure we want to bring in more visitors. We keep an annual list of 'destruction to natural features,' which includes boat groundings, 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,



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.



During recent years little-understood phenomena such as coral bleaching and the widespread die-offs of fish and sea urchins have indicated the need for more research.

Coastal development such as dredging causes direct destruction of reefs and indirect damage from sewage and increased silt deposits.

In several parts of the Caribbean, coral reefs have been overtaken and killed by algae. This followed the decline of algae-eating fish from overharvesting with fish traps and explosives.

Since prevailing ocean currents can carry pollutants great distances, marine biologists believe that only regional cooperation can save the reefs of the Gulf of Mexico and the Caribbean Sea from destruction.

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.

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.

Even without human intrusion, nature

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



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.



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.

A few days after the mini-season, Jerry Greenberg returned to finish photographing 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



ALL BY JERRY EICHENBERG

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."

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 Pennkamp'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,





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).

BOTH BY FRED WARD



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 Pennnekamp the reefs may no longer be able to withstand the stresses of their environment.



"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."

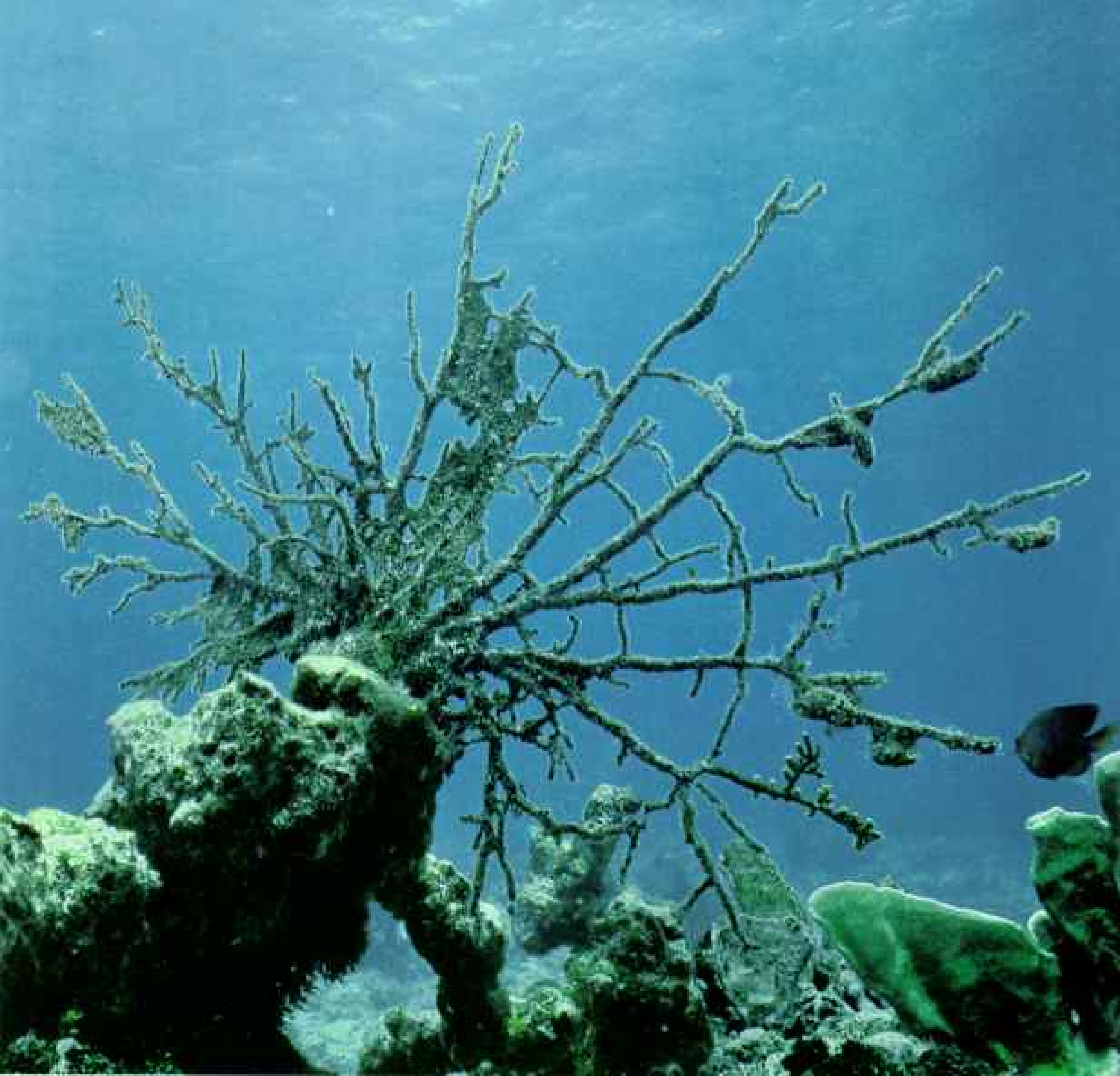
Once water quality deteriorates, corals may not have the strength to recover from the

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



JERRY GREENBERG (TOP LEFT); FRED WARD

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



FRED WARD (BELOW); JERRY GREENBERG



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. □

February 24, 1990

**“Americans just don’t
understand the
quality of our cars...
And that’s
gonna change.”**

Lee Iacocca



March 29, 1990


Chrysler Imperial has the highest quality rating of any car built in America.

- 1990 EARLY BUYER STUDY, FROM C. A. R. INC.



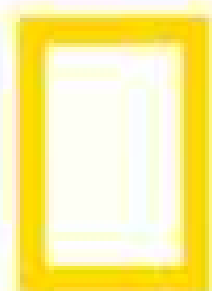
In its very first year of production, the new Chrysler Imperial has already shown America what Chrysler is achieving in quality. In an independent buyer perception survey by Consumer Attitude Research, Imperial had the highest rating of any car built in America. In fact, it was highest in 13 of 16 quality categories. In the Overall Opinion ranking, Imperial had the highest percentage of completely satisfied customers.

Imperial: The highest quality
rating of any car built in America.

Advantage: Chrysler. 

CHRYSLER - PLYMOUTH - DODGE - DODGE TRUCKS - JEEP - RAM

* Owner Attitude Survey Source: 1990 early buyer survey, C. A. R. Inc. First 60-90 days ownership.



FROM THE PRESIDENT

A Lifelong Commitment to Conservation

THE NATIONAL GEOGRAPHIC SOCIETY

THE DAUNTING PROBLEMS we face in preserving our nation's open spaces—fighting pollutants, protecting wetlands from development, managing urban growth—might tempt us to shrug our shoulders and say, “What difference can an individual make?”

Well, if the individual is someone like Laurance Spelman Rockefeller the answer is—a tremendous difference. During a career of public service that has spanned more than five decades, Laurance has helped make it possible for literally millions of Americans to enjoy the outdoors in parklands and forests.

His contributions have been so significant that the U. S. Congress in May awarded him a gold medal, an honor bestowed on only 96 other individuals since the first one was given to George Washington.

My father, Melville Bell Grosvenor, invited Laurance to join the Society's Board of Trustees in 1957, a position he held for 29 years. Through those years he served National Geographic well as a voice for conservation. Our involvement in establishing Redwood National Park in California was largely the result of his influence.

His contributions to the nation have been even more profound. He gave the conservation movement a tremendous boost during the early 1960s through his chairmanship of the Outdoor Recreation Resources Review Commission (ORRRC), which was created under President Eisenhower to conduct the first nationwide inventory of recreation facilities. From that four-year study came an astonishing number of landmark initiatives.

Among them was the Land and Water Conservation Fund, which has distributed nearly 7.2 billion dollars since 1964—mainly from offshore oil leases—for conservation and outdoor-recreation projects. Others were the National Wilderness Preservation System, which has grown from 9 million to 91 million acres since 1964; the Wild and Scenic Rivers Act, which has extended protection to 119 rivers since 1968; and the National Trails System Act of 1968.

In our 1987 report we on the President's Commission on Americans Outdoors applauded these historic measures, even as we noted the urgency of continuing to support them. Unfortunately, our report was shelved. In fiscal 1990, Congress appropriated only 233 million dollars for the Land and Water Conservation Fund, a far cry from the billion dollars a year that the commission called for.

Yet we must have patience. That's something Laurance Rockefeller has taught me. You cannot expect quick results from a report. But when we look at what Laurance accomplished with ORRRC, we can't help but have similar hopes for a new generation of outdoor-recreation programs—for greenways, for urban parks, for scenic byways and private conservation corps.

“Laurance's hand has stayed at the tiller of the conservation and recreation movement all this time,” says Patrick Noonan, president of the Conservation Fund and a National Geographic trustee. “He was the father of many important initiatives, and now I think you could call him the grandfather.”

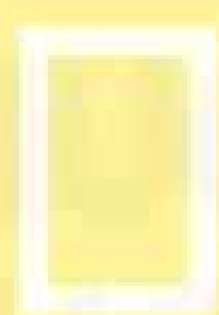
On May 26 Laurance S. Rockefeller celebrated his 80th birthday. I think we owe this grandfather three cheers for the outdoor legacy he has created.



ROCKEFELLER ARCHIVE / GEORGE

Sharing a love of the outdoors with his brother Nelson, then governor of New York, Laurance Rockefeller, left, guided the expansion of the state's park system during the 1960s. He has served on the boards of the New York Zoological Society and the Palisades Interstate Park Commission as well as the National Geographic Society.

Melville B. Grosvenor



Theft at Herculaneum: 280 Artifacts Stolen

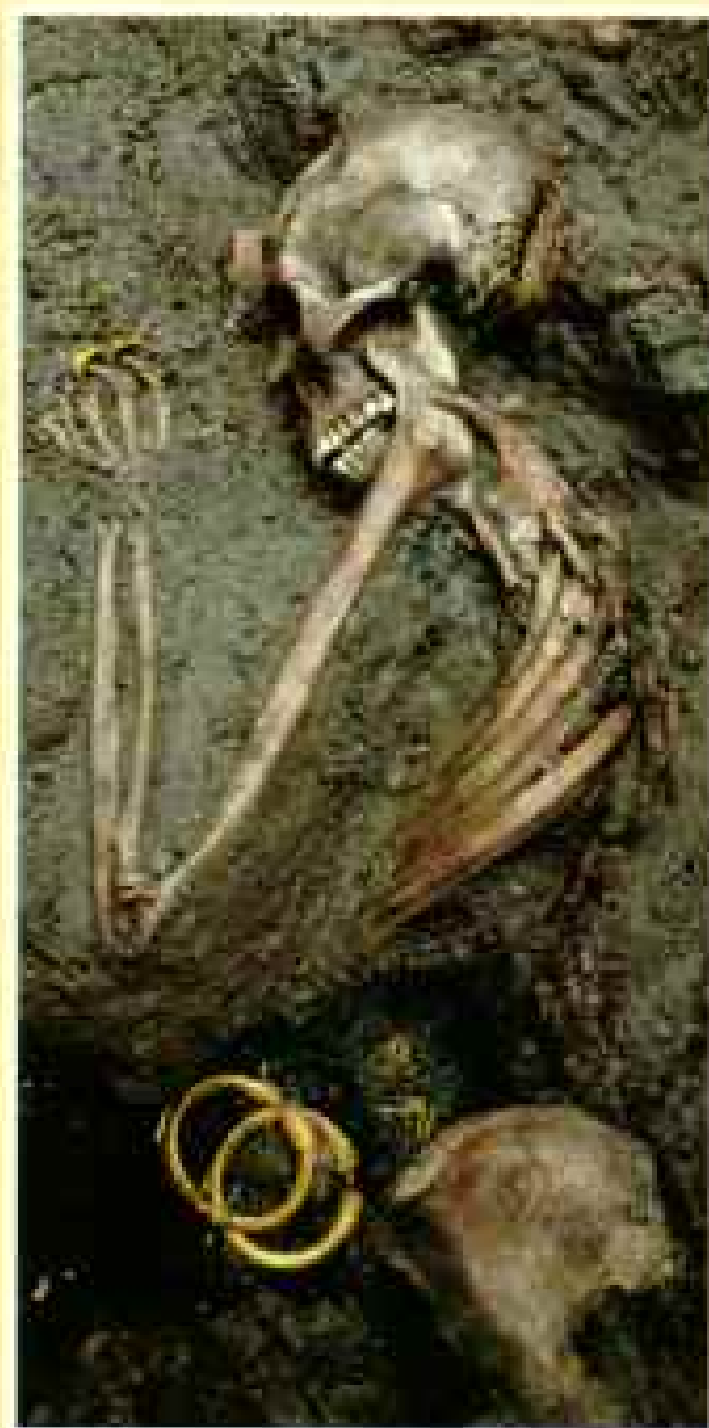
It was, Italian authorities said later, as if the thieves had a catalog and knew just what they were after.

Armed bandits bound and gagged six unarmed guards, entered a store-room containing artifacts from the Roman town of Herculaneum (NATIONAL GEOGRAPHIC, May 1984), and stole about 280 objects—gold rings, bracelets, earrings, and precious stones, including items found with the so-called Ring Lady (right). All had been discovered during excavations of the seaside town, buried by the same eruption of Mount Vesuvius in A.D. 79 that destroyed its larger and better-known neighbor, Pompeii.

Authorities said that the stolen items also included a small bronze statue of Bacchus inlaid with copper and silver, a bronze vase (left), and a box of coins. The total value of objects taken

during the late-night February robbery was estimated at 1.6 million dollars.

Art historians and others criticized lax security that permitted two gunmen to climb a wall, enter the site, and break through a flimsy partition to get into the room where the artifacts were kept. Some of the critics also complained that the guards were unarmed.



© LARRY MARZATTI/NOI, INC.

Officials said it would be hard for anyone to sell the stolen objects because all had been cataloged and photographed, and most had been exhibited and published.

One fortunate note: The thieves missed a box of gold jewelry and other precious objects excavated recently (GEOGRAPHICA, October 1989).

El Niño Brightens a Desert Landscape

A barren desert stretches along the Pacific coast of South America from northern Peru to northern Chile. It is broken only by isolated tracts called *lomas*, where sea fog settles on small hillsides, enabling vegetation to grow.

Normally *lomas* are dusty brown, spotted with an occasional cactus. But when the recurrent climatic phenomenon called El Niño occurs and rain falls, the *lomas'* plants begin to bloom. When El Niño is of historic proportions, as in 1982-83 (GEOGRAPHIC, February 1984), *lomas* explode with color.

Michael Dillon of Chicago's Field Museum of Natural History was in Peru during that El Niño. He went back in late 1983 with National Geographic Society support and returned again in following years.

"In 1983 there was a green flush over the *lomas* that you don't usually see," he says. "Then other species became dominant, spewing pinks or yellows across the landscape." There was so much vegetation that ranchers in the mountains to the east drove their cattle herds to what normally was desert to graze, Dillon noted.

In later, drier years the number of flowering plants and the variety of species present were far lower, Dillon found. But the dried remains of the plants that bloomed during El Niño could be seen for at least three years.

Whatzat? An Odd Bird With a Cow's Stomach

The hoatzin is an odd bird. Not only does it eat leaves—far more than any other bird—but it digests them like a cow or a sheep, grinding the leaves up in its specialized, muscular crop. Up close the hoatzin smells bad, and it flies poorly.

Scientists have known a bit about the hoatzin for years (GEOGRAPHIC, September 1962). But a research team led by the University of Florida's Alejandro Grajal and Stuart Strahl of Wildlife Conservation International conducted a long study in the bird's Venezuelan habitat, supplying many more details.

Grajal says that about 85 percent of a hoatzin's diet is made up of green

leaves. It prefers young, fresh leaves, which are richer in protein and easier to digest. Since a hoatzin, unlike a cow, has no teeth, it "chews" the leaves up by rubbing them against sandpaper ridges in its crop. It keeps food in its gut 20 hours or more; a chicken digests its food in a few hours. Like a cow, the hoatzin practices "foregut fermentation"; the fatty acids that result lend the bird its smell. But Grajal says the smell has been exaggerated. He resents the fact that the hoatzin is often called the stinkbird.

The hoatzin's digestive system has a price: The large crop results in a small breastbone and undersize muscles that limit its ability to fly, and on landing it may crash into branches. But Grajal says the bird can fly—"enough to avoid predators, or researchers like me."



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You told us you'd consider buying a GM car or truck if we changed more than just the looks. And that's exactly what we've done.

We've listened to what you said about quality. We've heard your demands for reliable, durable cars and trucks. And we've responded with new vehicles, with new technology, with new production methods in new and refurbished plants.

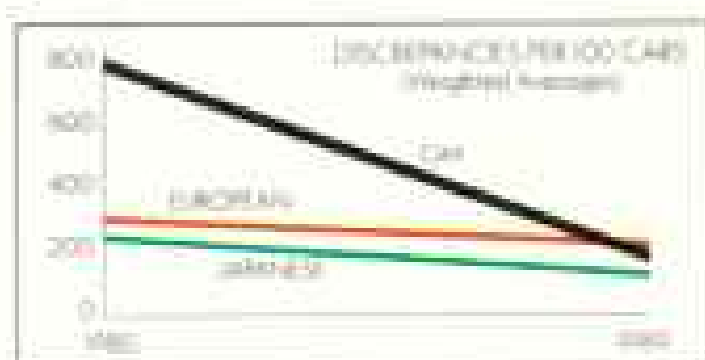
THE HEART OF GM QUALITY

We've introduced 77 all-new models since 1985. Almost all the cars and half the trucks we make. All re-designed and engineered to dramatically improve quality.

The looks are new. But that's not all. The big improvements are in the engines, transmissions, and electrical systems—the heart of any car or truck. And we're continuing to improve.

MEASURABLY BETTER

GM builds cars you can count on for the long term. No U.S. carmaker has done that job better in the last five years. In fact one measure of dependability, the J. D. Power dependability study of 1985 models, ranks GM highest in vehicle dependability among all American manufacturers.†



Since we built those cars, independent measures have confirmed that our quality has improved substantially. The differences today between GM and the best imports are very small indeed.

According to one quality study by Harbour & Associates, we're better than the average European make, and the difference between GM and the average Japanese import is less than one-half of one discrepancy per car. Our own tracking confirms GM's significant improvement.

GREATER DURABILITY



According to R. L. Polk Registrations, a higher percentage of 10-year-old GM cars are still on the road than 79s from Ford, Chrysler, Mazda, Nissan, Toyota, or Honda.

RELIABLE ENGINES

GM's engines are more dependable than those of all other domestic carmakers. The 2.3-liter Quad 4 is as problem-free as 2-liter engines from Toyota or Honda.

Our 3800 V-6 is at the top in engine quality among engines from all makers, foreign or domestic. That's the finding of the most comprehensive customer-based



survey in the auto industry. And Cadillac owners report fewer engine problems the first year than Toyota or Mercedes-Benz owners—a tribute to the 4.5-liter V-8 in Cadillacs.

BETTER-BUILT AIR CONDITIONING

The reliability of major mechanical systems is important to our customers. GM's new cars have better-built air

conditioning systems than cars from Honda, Nissan, or Mazda.

PROBLEM-FREE TRANSMISSIONS

Any car or truck is only as reliable as its transmission. And our automatic transmissions are more problem-free than those of any domestic competitor—and most imports.

This year GM is introducing an electronically controlled transmission that is linked with the engine's control system. An electronically integrated powertrain raises fuel efficiency, lowers emissions, and improves response.



TECHNOLOGY THAT LASTS

GM is the only domestic manufacturer to design and build multivalve engines. And we build them to last. Our 16-valve Quad 4 has already run the equivalent of 100,000 miles at 100 mph without stopping under test conditions.

On the endurance track, a full-size Chevrolet sport truck equipped with GM's

All of GM going all out for you.



NEW CARS AND TRUCKS. NEW LEVELS IN GM QUALITY ARE!

350 cu. in. V-8 captured the Hulman Trophy for sustaining 100 mph for 24 hours at Indianapolis.

MOST TROUBLE-FREE U.S. CAR LINE

A study of 1990 models done by an independent market research company ranks Buick as the top domestic nameplate, based on problems per car in the first 90 days of ownership. LeSabre was the top U.S. model, with Electra and Skylark in the top ten.

Cadillac Eldorado and the Oldsmobile 88 and Cutlass Ciera also made the list, giving GM six of the study's ten best-built American cars.



CORROSION PROTECTION

We offer the highest level of exterior galvanized corrosion protection in the world. In fact, we're the only high-volume carmaker extensively using two-sided galvanized materials to protect against rust.



That's how we can stretch our limited warranty's corrosion coverage to six years or 100,000 miles minimum.¹

99.9% CERTAIN STARTS

Virtually every engine in every GM car or light truck features electronic fuel injection. Electronic sensors measure temperature and



engine conditions.

Re-designed injectors and engine control computers meter the right amount of fuel for sure starts.

These GM cars start the first time, hot or cold, in any weather, regardless of where you live in the United States.

HIGHLY SATISFIED CUSTOMERS

GM's Cadillac division has been the highest-ranked domestic nameplate in customer satisfaction for the past three years.²

The customers of every other GM division are highly satisfied as well. After six months of ownership, at least 95% of all Chevrolet, Pontiac, Oldsmobile, Buick, Cadillac, or GMC Truck owners would recommend a vehicle from that GM division to a friend.

ENDURING VALUE

Over the last 10 years, cars built by General Motors have kept more of their original value, on the average, than cars made by any other U.S. manufacturer. Chevy and GMC trucks retain more of their original value than trucks sold in the U.S. by any other manufacturer in the world—foreign or domestic.⁴

WE COVER EVERY PART

We back our vehicles the way we build them. Our Bumper-to-Bumper Plus limited warranty covers every part of every GM car or light truck. For three years or 50,000 miles.⁵



WE CARE ABOUT YOU

We care what you think about GM quality. People throughout General Motors—the GM Quality Network—have taken a long, hard look at the cars and trucks we build. And the way we build them.

Today there is a new pride at GM. A new commitment to quality. A clear focus on our customers and on their needs. A dedication to continually improving our vehicles. Year after year. Until every model is as good as the best in the world.

We've accomplished much already. We invite you to take a good, close look at the results: our new GM cars and trucks, and the new level of General Motors quality.

1: J. D. Power and Associates Vehicle Dependability Index Study™. In a ranking of the three domestic manufacturers, based on things gone wrong to 4-to-5-year-old 1985 model vehicles in the past 12 months.

2: See your GM dealer for details of this limited warranty covering corrosion. A deductible applies.

3: J. D. Power and Associates 1987-1989 Car Customer Satisfaction with Product Quality and Dealer Service™ studies. After one year of ownership.

4: GM corporate study of 3-to-5-year-old used vehicles resold between 1979 and 1990.

5: Cadillac's Gold Key Bumper-to-Bumper limited warranty offers coverage for 4 years/50,000 miles, and Cadillac's Allante is backed for 7 years/100,000 miles. See your GM dealer for details of the limited warranty. A deductible applies.

PUTTING QUALITY ON THE ROAD



MARK OF EXCELLENCE

Chevrolet Pontiac Oldsmobile
Buick Cadillac GMC Truck

Ukrainian Catholics: Fighting a New Battle

A serious dispute pitting the Ukrainian Catholic Church against the Russian Orthodox Church has broken out in Ukraine (*GEOGRAPHIC*, May 1987).

As Soviet President Mikhail Gorbachev was meeting Pope John Paul II last year, Ukraine officials announced that Ukrainian Catholic congregations could register with authorities for the first time in more than four decades. Registration would give Ukrainian Catholics—there are four to five million, mostly located in western Ukraine—official recognition by the Soviet government.

Ukrainian Catholics, also known as Uniates, long have asserted that a 1946 synod in which their church was "self-dissolved" was actually engineered by Joseph Stalin. The church, which became affiliated with Rome in 1596,



BYE BOLDREDA, NETWORKCONTACT

was driven underground, and its property, notably buildings, was turned over to the Russian Orthodox Church. More than 700 Uniate congregations have applied for registration, though only a few of the applications have been granted. But in many cases Uniates have regained Orthodox Church buildings that once were theirs, including the massive Church of the Transfiguration in Lvov (above and above right).

Needless to say, the Russian Orthodox Church is not pleased; 60 percent of its holdings are in Ukraine. It has fought legalization of the Ukrainian Catholic Church and condemned as illegal the "seizure" of Orthodox Church buildings. Both sides have engaged in sit-ins and hunger strikes and have accused the other side of violence.

The situation remains unsettled, though passage of a long-promised law guaranteeing Soviet citizens freedom of worship may help ease it.



NIKOLAI VERATZEV, NETWORKCONTACT

Philmont Scout Ranch Grows, Goes Coed

When the September 1956 *GEOGRAPHIC* featured the Philmont Scout Ranch, the title said it "helps boys grow up." Philmont still does, but its trails and backcountry camps now are shared with girls.

The ranch in northern New Mexico was created in 1938 with the gift of a huge tract of land to the Boy Scouts of America by oilman Waite Phillips. After a gift of additional acreage in 1963, the Boy Scouts now own 137,493 acres, says Chuck Buenger, general manager of the ranch. More than 14,000 youngsters visit every year, each staying 12 days. Most are Boy Scouts from the United States, but the ranch also hosts foreign Scouts, Girl Scouts, 4-H units, and church groups. Most campers are 14 to 16 years old. Programs run the gamut from mountain climbing to panning for gold.

Philmont veterans are reverent about the ranch. Ned Gold, Jr., an attorney from Ohio, was a 1955 camper and later a staff member before becoming a lawyer. "Nothing ever had a greater impact on my life," he says. Gold took his son there in 1983, his daughter this year.

Scourge of the South May Be Heading North

Look out, Yankees: The plant that ate Dixie may be coming your way. Kudzu, a vine with lush green leaves and beautiful purple flowers that originated in Japan, first appeared in the U.S. at the 1876 Centennial Exposition in Philadelphia. It became popular in the Southeast in the 1930s,

when soil conservationists urged farmers to plant it to halt erosion.

They succeeded—too well. Kudzu is now a common weed from East Texas to Florida and as far north as southeastern Pennsylvania. It can grow a foot a day and covers roadsides, trees, utility poles, and anything else in its path. Kudzu is tough, too: It takes repeated doses of strong and expensive herbicides to eradicate it.

Thomas Sasek and Boyd Strain of Duke University have studied kudzu and conclude that its northward spread



NEEL CARTOGRAPHIC DIVISION

is limited by low winter temperatures. If carbon dioxide in the atmosphere continues to increase, and if global warming occurs, kudzu may move farther north. Sasek and Strain say that doubled carbon dioxide concentrations and a 3°C increase in the average minimum winter temperature could allow kudzu to spread as far as Michigan and southern New England.

But goat ranchers can rejoice. Research at the University of Georgia has shown that four grazing goats can destroy one acre of kudzu in two years.

Pontiac Grand Prix Sport Sedan.
MotorWeek 1990 Driver's Choice
"Best Domestic Sedan."



Our Latest Award-Winning Performance.

When *MotorWeek*, Public Television's Automotive Magazine, went looking for 1990's best domestic sedan, they tuned into the new 4-door Pontiac Grand Prix,SM powered by the optional 3.1L V6 engine with multi-port fuel injection (MPFI). And the ratings were impressive. "An extraordinary balance of aggressive styling, solid street performance and well-rounded practicality... a clear automotive value."

MotorWeek's reaction to the Grand Prix's available sport bucket interior: "It remembers the family, but doesn't forget the driver. It manages to be roomy in size, yet intimately styled." In their judgment, Grand Prix's overall environment was oriented to "long distance comfort and luxury, with a minimum of gimmicks."

Of Grand Prix's advanced suspension and braking systems, *MotorWeek* concluded: "Disc brakes on all four wheels, on all models... and an available anti-lock braking system (ABS) were significant factors in *MotorWeek's* selection of the Grand Prix Sport Sedan as our Driver's Choice Award's Best Domestic Sedan for 1990!"

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Restoring the Library of Peary's Island Home



SEAN FERRIER

The state of Maine and the National Geographic Society are joining to restore the library of Robert E. Peary's summer home (above) on Eagle Island in Maine's Casco Bay.

A state grant of \$56,000 as well as \$25,000 from the Society will permit restoring water-damaged walls and floors, installing a new roof, and replacing broken stained-glass windows in the library.

Peary, whose Arctic expeditions were supported in part by the Society, bought the 17-acre island in 1881. He built the cottage in 1904 and added the library in 1911, two years after he reached the North Pole. Eagle Island remained in Admiral Peary's family after his death in 1920. In 1967 the family gave the island to Maine, and it became a state historic site.

Eagle Island is open to the public and

receives about 14,000 visitors by boat every year. Sheila McDonald, historian with the Maine Bureau of Parks and Recreation, says the state plans to use the library as a visitors orientation center. It will contain exhibits describing Peary's many connections to Maine, as well as his life on the island.

Reviving the Vital Role of the Dugout Canoe

Dugout canoes were central to the culture of early Indians along the coast of the Pacific Northwest. The craft were fishing boats, works of art, symbols of wealth; they also brought tribes together for racing and the potlatch, where gifts were given, songs were sung, and stories told.

Emmett Oliver, who is a Quinault Indian and a member of the state of Washington's Maritime Committee, decided that canoes should be part of the Indian role in the state's centennial celebration (*GEOGRAPHIC*, December 1989). The celebration included the 1989 Paddle to Seattle, in which 17 tribes—converging on the state's largest city from numerous coastal communities—joined in the spirit of the potlatch. Oliver's Native American Canoe Project helped revive not only the art of making and racing cedar-log canoes but also ceremonial aspects of Pacific Northwest Indian culture. For example, before a cedar was felled for carving, the tree was blessed and assured that its spirit would be of proud service to the tribe.

For the canoe project, carvers spent two years making or refurbishing traditional canoes as long as 70 feet. Youths consulted elders about their heritage and learned how to paddle. "It takes discipline," says Oliver. "The young people told me, 'We don't allow any alcohol or drugs in our canoes.'" The craft will be featured in the 1992 ceremonies marking the 200th anniversary of Euro-American exploration and settlement in the Pacific Northwest.



ALAN BERNER, SEATTLE TIMES

A New Guinea People Battles for Survival

The Hagahai, a seminomadic group of hunters and gatherers who live in the highlands of Papua New Guinea, were largely unknown to the outside world until 1983. Then, fearing that their declining numbers would lead to their demise, they contacted a nearby missionary for medical help.

Can the Hagahai survive? Will they?

Carol Jenkins, a medical anthropologist who has studied the group since 1984, says the jury is still out. When Jenkins began, with National Geographic Society support, the Hagahai population was 294. It dropped steadily until 1988, when Papua New Guinea's government paid a medical worker to live among the Hagahai and administer vaccines and antibiotics against many diseases that threaten them. By late 1989 the population was rising, and Jenkins, who works for the Papua New Guinea Institute of Medical Research,



GEORGE BRIAN

returned to the United States on leave, cautiously optimistic.

But early this year she learned that the medical worker had also taken leave and that, in his absence, six Hagahai had died. "So the situation is as fragile as it ever was," she says.

There are positive signs. Peace Corps workers have been assigned to teach the Hagahai basic literacy and the use of numbers. The Hagahai are seeking an airstrip so they can ship coffee, as well as other potential cash crops, to market.

Jenkins knows this means Hagahai culture will change. "It doesn't worry me," she says. "There's no way they'll survive without change."

Suggestions for *GEOGRAPHICA* may be submitted to Boris Weintraub, National Geographic Magazine, Box 37357, Washington, D. C. 20036, and should include the sender's address and telephone number.



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FORUM

The Gulag

The world is watching political and social changes in Eastern Europe and the Soviet Union unthinkable six months ago. Until all forms of repression have been eradicated, it would be wrong to allow those who are suffering to be forgotten, and thus I was most interested in the article on the gulag (March 1990).

PETER HUDSON

Templecombe, Somerset, England

More than 15 years ago Jewish communities were selling Star of David medallions inscribed LET MY PEOPLE GO, with the name of a "prisoner of conscience" on the reverse. Like many Roman Catholics I purchased and still wear one on High Holidays. I was happily surprised to read that Hillel Butman was released. It is his name that appears on my Star of David.

ENRIQUE H. MIYARES

Orford, New Hampshire

I was one of the POWs who spent three and a half years in camps of the gulag. I was called into the German Army in April 1945 at 17 years of age. In May I became a prisoner of the Russians, along with 60 Hungarian kids 14 to 18 years old. In Domilino, a camp outside Moscow, we did heavy construction. Each of us was photographed in the only nice uniform in the camp. Later I made this sketch of a "medical" checkup of work group 1, judged "fit for heavy work." I found your report correct but too short to describe the sufferings.

EDUARD ORSECH

Ratingen, West Germany



Siberia

Stalin was not the only leader of the Soviet Union to transport peoples living within Soviet boundaries to Siberia. From the late 1890s through the early days of the communist government, many thousands were transported to Siberia, where they were used as slave labor. Few ever returned. Often communist leaders saw to it that names of the vanished were removed from all records in their home towns. If you were a lucky person who remained behind, you would not jeopardize your life by revealing that you knew the vanished person. My grandparents and others I know here in the U. S., Canada, and South America fled with the skin on their backs during the days of the rise of the communist leaders.

VIRGINIA VOTH

Sacramento, California

You used up a lot of water in the last two issues. In March the article on Siberia stated that Lake Baykal held one-fifth of the world's fresh water. In April the article on Antarctica said that that continent held more than two-thirds of the world's fresh water in the form of ice. Am I to assume that Arctic ice, the continental rivers, all other lakes and streams, and other glaciers total only 13½ percent of the world's fresh water?

THOMAS P. FULLERTON

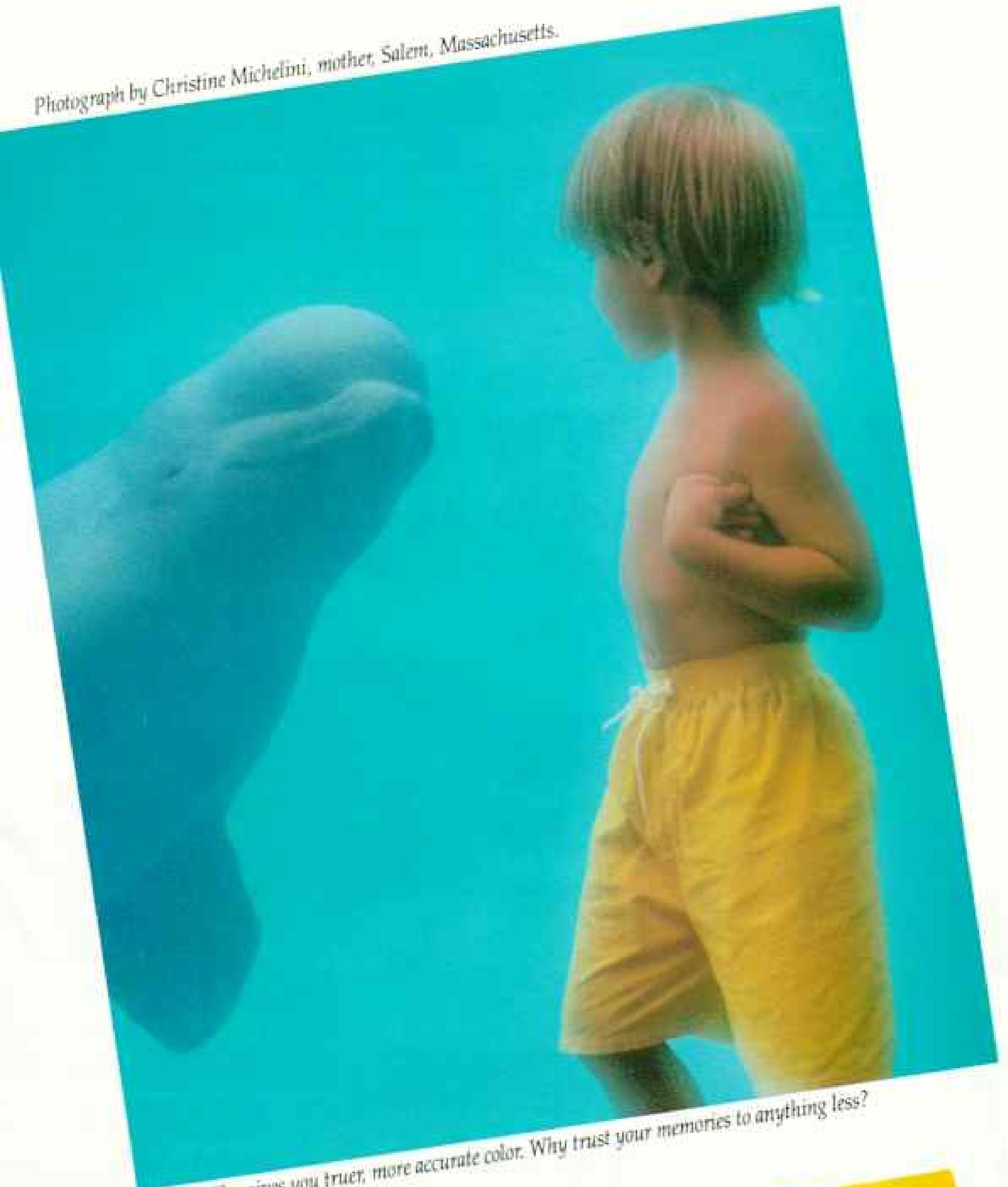
Kalispell, Montana

No. Antarctica locks up some two-thirds of all fresh water on earth. Other glaciers and groundwater account for most of the rest. Of the liquid one-third of one percent on the surface, Baykal holds one-fifth, admittedly a drop in the bucket.

Mike Edwards's two articles on Siberia, enhanced by Steve Raymer's photos, and the superb work of Jean-Pierre Vaudon and Pierre Perrin preserve an important segment of Russian history. I was especially impressed for a personal reason. Perm, Norilsk, and Abakan were the onetime homes of an American, Walter J. Cizek, held prisoner for 15 years. He was working in Albertin (East Poland/White Russia) after completing his theological education in Rome in the 1930s. After the Soviet Army overran that area, he volunteered under an assumed name for Ural lumber camps to ascertain the possibility of spiritual ministrations. When the Nazi armies invaded Russia, Cizek was arrested and sent to Perm; then he spent ten years in slave labor camps in the Arctic and seven years in Abakan as a mechanic. He was repatriated in 1963 and died in 1984. As the wife of William Casey, past head of the CIA, I was invited to friendship with Father Cizek. I submit these reflections as testimony to the



Photograph by Christine Michelini, mother, Salem, Massachusetts.



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victory of honesty and freedom through faith and love. These virtues enabled Father Ciszek to endure the subhuman prison existence that he described in *With God in Russia*.

SOPHIA CASEY
Roslyn Harbor, New York

Soviet Map

That's a great map. I never realized that the U.S.S.R. was so *big*.

WILLIAM SAFIRE
Washington, D. C.

You unwittingly underscored the rapidity of change in Eastern Europe. My birthplace in Estonia was still identified by its Stalinist-imposed

name, Kingisepp. In a 1988 referendum citizens of this charming community almost unanimously restored the name Kuressaare. I look forward to the day when my birthplace, as shown on my passport, appears on your map.

RJURIK GOLUBIATNIKOV
Madison, Wisconsin

Time

I believe that time is one of the imponderables of nature. We can define it, see the results of it, and measure it, but we don't know what it is. Someone once said that there is no such thing as the "present." The present is only where the past and the future meet. We can divide a second

If you can't pack it



infinitely and still never get to a definite point in time.

JOHN D. McCALEB
Phoenix, Arizona

In this day and age when everything seems eclipsed by the clock, your probing and thought-provoking article in the March issue is the type of stimulus needed to keep us all thinking about our use and misuse of the precious time, and space, each of us is allotted.

DOROTHY J. STRIMBU
New Philadelphia, Ohio

The story didn't mention the invention of standard time—with hourly variations according to

established time zones—by the civil engineer Sir Sanford Fleming. Canada's foremost railway surveyor, he realized that the railway made obsolete the old system of each major center setting its clocks by local astronomical conditions. He was instrumental in convening the International Meridian Conference in Washington, D. C., in 1884, at which the standard time system was adopted.

CRAIG HARRIS
Edmonton, Alberta

I was surprised at the suggestion that the week is "the only calendar unit that does not trace its origins to astronomy." I understood that it was

or pull it with this, forget it.

Ah, the family trip. What a moving experience. Things can get emotional just packing up. Before you know it, you're sobbing uncontrollably into that sleeping bag that won't fit.

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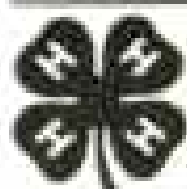
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based on the phases of the moon, each quarter taking approximately seven days to complete. Deriving a seven-day time unit from vague circadian rhythms seems farfetched to me.

PHILIP ANDERSON

Portland, Oregon

Actually the seven-day week may be more closely tied to seven as a magic number in mythology than to either astronomy or chronobiology.

Contrary to what Julian Jaynes says, for Homer time is of the essence. The *Iliad* commences ten years after the Trojan War started and gives "the story so far." For the hero, the culmination of glory is the moment of death, which brings hindsight and a clear vision of the future. The whims and actions of the immortals are shown to sway the ephemeral lives of mere mortals. Also given is a perception of the war as a catalyst that precipitates time itself.

JULIA A. SMITHERS

London, England

Ancient Skywatchers

How inappropriate to compare Inca and Maya world views with Navajo (pages 81-3). The Navajo's ancestral land is in the far north, and they arrived in the Four Corners area no earlier than 1500. They quickly adopted cultural aspects from the Hopi and other Pueblo tribes. It is the Hopi ancestral land that is bordered on the four cardinal points [by physical landmarks]. If you desire to know the origin of the Four World People and the importance of the celestial sphere, ask any Hopi farmer.

VELDA R. ATOKUKU-VITZ

Corpus Christi, Texas

Geographica

Keeping the Boston Light manned rather than automated is a good example of deliberate waste and inefficiency forced on a government agency for political gain. While I agree that historic sites should be maintained for future generations, the route the Massachusetts congressmen and senators chose was inappropriate. Why was automation so terrible, anyway? The Coast Guard will now have to cut funding that could have saved lives, the real Coast Guard mission.

MICHAEL C. DOLDER

*Aberdeen Proving Ground,
Maryland*

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National Geographic, July 1990

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FROM THE EDITOR:

Water— The Growing Crisis

NEARLY EVERY SCHOOLCHILD knows that seven-tenths of our planet's surface is covered by water—seemingly an inexhaustible supply for earth's five billion people. But the sobering fact is that 97 percent of that water is saline and unusable, leaving a meager 3 percent to nourish and sustain all terrestrial life. Moreover, the world's human population continues to explode, while the supply of fresh water remains constant.

Just how that life-giving resource will be conserved and apportioned in the coming century is one of the great problems that face us. Most Americans believe they are blessed with ample water, but the 1988 drought in the Great Plains and Midwest brought a shocking realization: Already, given a bad year, there is simply not enough to go around.

The cost to the American farmer and thus to all of us approached seven billion dollars, but other long-range effects defy a price tag. The drought drastically reduced the levels of many inland waterways, among them the Missouri River. There the reduced level severely affected nesting and breeding habitats of various species of fish and waterfowl. As a result, least terns and piping plovers—already on the endangered list—are further threatened, and they may never recover their numbers.

In this issue Nicole Duplaix offers a profile of another region facing severe water problems: south Florida. Most of the problems are self-inflicted, and some are impossible to reverse. That portrait is repeated thousands of times around the globe, wherever man's greed and lack of vision have outrun common sense and love for the land.

The solutions? Conservation of water, for one. While the United States ranks sixth among water-rich nations of the world, we are third on the list in terms of waste and consumption.

Desalination offers some long-range hope. U. S. research laboratories are exploring an ingenious technique of using heat from the tropical oceans to convert salt water into fresh, thus saving conventional forms of energy.

Technology, however, is only a partial answer. The real solution—like the problem—is mankind itself.

William Graves

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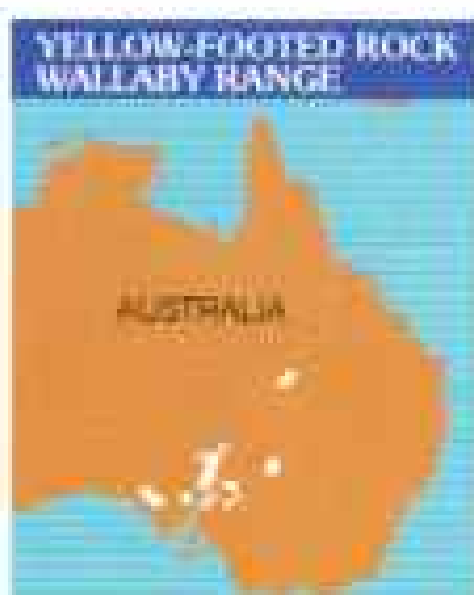
But perhaps the nicest little thing about the Camry is that it’s a Toyota. And that means a heritage of dependability and quality that really makes you comfortable. So you can feel at home.

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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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NATIONAL GEOGRAPHIC MAGAZINE

JULY 1990

Homes for Wildlife in Unexpected Places

A number of American industries are managing their real estate holdings for use by wildlife, an exercise that seems to make everyone feel better.

In a rare show of cooperation, environmentalists and corporations are working together to create natural settings through an umbrella group called the Wildlife Habitat Enhancement Council (WHEC). The more than 60 members include some of the nation's largest corporations and environmental groups: ALCOA, Dow Chemical, Du Pont, Exxon, General Electric, and the National Wildlife Federation, the Trust for Public Land, Ducks Unlimited, and the Frank Walton League.

As much as 25 percent of the contiguous 48 states may belong to corporations, estimates Joyce Kelly, WHEC's executive director. Included are lands bought as buffers around company facilities for safety or security or in anticipation of future plant expansion. With a few alterations at minimal expense, improved habitat can host deer, small mammals, songbirds, raptors, and fish and reap a harvest of goodwill in the local community.

No statistics are yet available on how much corporate land may be available for the use of wildlife, but the total runs into the hundreds of thousands of acres. Chief Executive Officer Edgar Woolard of E. I. du Pont de Nemours & Co., one of the firms originating the wildlife

enhancement idea, has predicted that someday the company will manage as much as a thousand square miles as wildlife habitat.

A sampling of projects:

- Amoco built nesting sites in South Carolina for imperiled least terns near the purified water of a chemical plant's treatment ponds.
- Dow Chemical is catering to wildlife on several sites, including a plant near Joliet, Illinois, where deer roam (above right).
- GE worked to restore a Wisconsin prairie to its natural state.
- Three Chesapeake Bay power companies created projects to nurture popular but disappearing striped bass, then released thousands into local rivers.
- Consumers Power, largest landholder in Michigan, is managing a nesting area for common terns, creating habitat along transmission corridors, and placing kestrel nests on utility poles.



LOUIS RICHARDSON, VULCAN MATERIALS, INC. (LEFT); LAURA DAVIDSON, DOW CHEMICAL

Even small projects sometimes bring unexpected results. Du Pont redesigned an office park near Wilmington, Delaware, to include bluebird boxes and bird and butterfly attractions such as cardinal flowers, coneflowers, and sunflowers. Local schoolchildren and company employees enthusiastically joined the effort.

"A pleasant surprise has been the improved morale of our own employees," said Donald Verrico, environmental affairs manager for Du Pont. "Wildlife management makes people feel good about where they work."

Unusual Mammals Are Bred as Rain Forest Resource

Some of the largest and the smallest ungulates in the world are being bred in captivity in a program aimed at making rain forests economically sustainable.

Endangered wild cattle called gaur, largest of the wild bovines, range from India through Southeast Asia and are believed to have been hunted to near extinction. One captive-bred bull weighed 3,800 pounds, heavier than most compact cars.

The mouse deer, a chevrotain that weighs only three pounds and stands a foot high, is hunted in Malaysia's rain forest as a delicacy. Integrated Conservation Research believes domestication of both ungulates, combined with tourism and growing fruits and nuts, can add more income than logging.

July 9, 1970—President Richard M. Nixon proposes the formation of an Environmental Protection Agency.

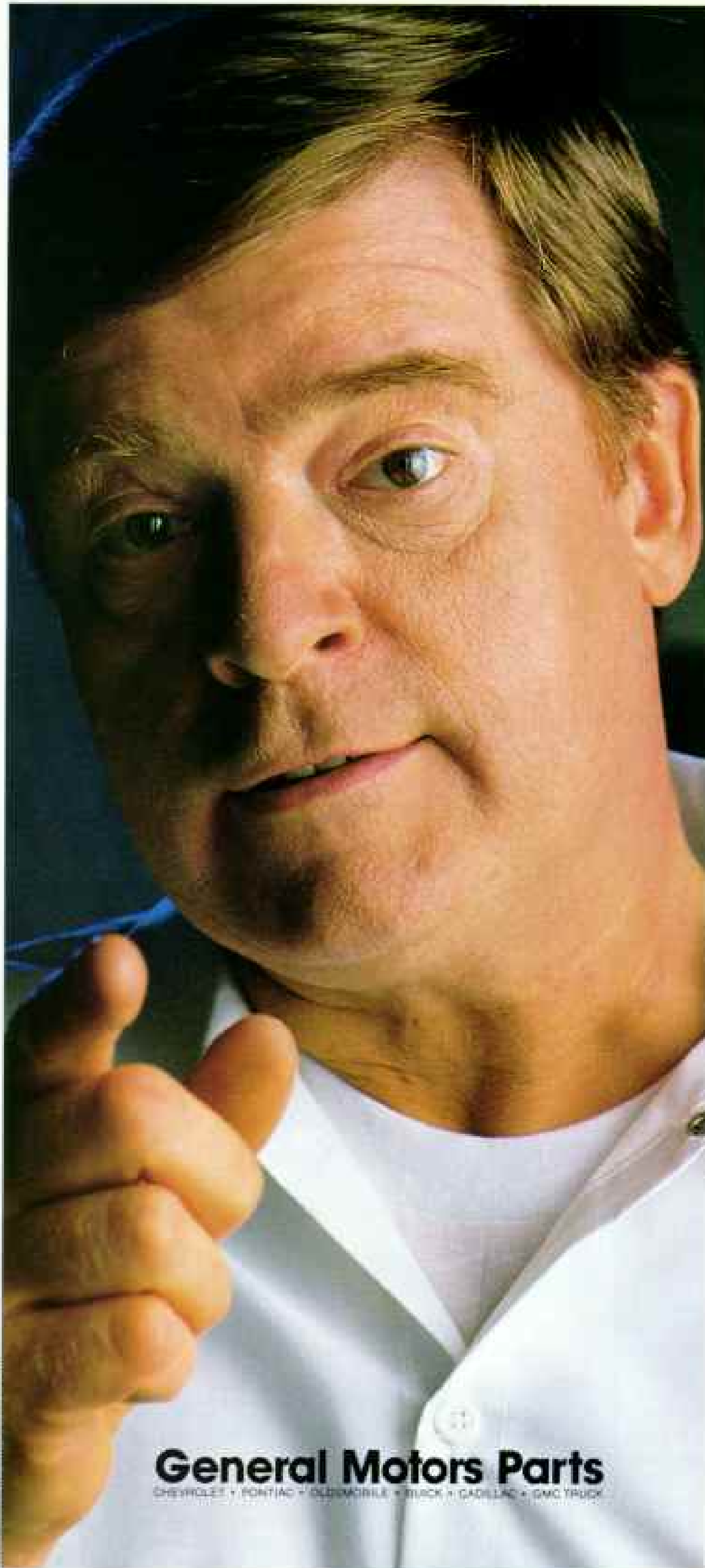
July 16, 1989—Environmental issues play a leading part in a communique issued by seven highly industrialized nations at an economic summit meeting in Paris.

July 18, 1989—President Daniel arap Moi of Kenya sets a torch to 12 tons of ivory to dramatize the need to protect elephants by halting the ivory trade.



RODERICK C. BREWSTER

July 1, 1954—Breeding ground of the endangered whooping crane is confirmed in northern Canada. Whooper population, believed at 2,000 in 1870, reached a low of 21 in 1941, and has now passed 150.



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ANNIE GREIFFING DELT

She Crusades to Save the Wildflowers of Spring

The current popularity of flower gardening and a growing human population are responsible for a dangerous decline in wildflower bulbs, says Mrs. Marjorie Arundel of Warrenton, Virginia, who has helped initiate a crusade to cut down on the trade.

"Wild bulbs are the parents of some of our most beautiful spring flowers, such as daffodils and tulips," explained Mrs. Arundel, an avid gardener for decades and a member of the Garden Club of America. "The hybridized flowers, produced chiefly in the Netherlands, lose some of their genetic strength. If we lose their parents in the wild, we could eventually lose the flowers altogether."

About five years ago bulb distributors began listing wild narcissus, tulips, scilla, and others in catalogs as novel additions to gardens, an appeal to floral elitism. To fill the demand, low-income farmers in depressed

areas around the world increased their gathering of bulbs from the wild, sending them on circuitous trade routes. Three years ago Mrs. Arundel enlisted the help of the World Wildlife Fund and the Natural Resources Defense Council, which investigated the trade routes and the volume of bulbs involved. The Garden Club of America helped get the message to local gardeners. A computer data base was compiled.

The investigation has revealed wildflower losses from countries as scattered as Canada and India, Portugal and Japan, but the greatest losses appear to have been suffered by Turkey. Shipped from Turkey last year, for example, were some 27 million bulbs of snowdrops (*Galanthus*), whose nodding white flowers often appear while snow is still on the ground.

Responding to the conservation campaign, the Netherlands bulb industry is considering a proposal to label parental bulbs as "bulbs from wild source" or "grown from cultivated stock."

Plastic balloons released on Independence Day or any special occasion have been implicated in the deaths of endangered sea turtles and at least one sperm whale.

Air pollution at the Grand Canyon now causes an average of nine days of extremely low visibility each summer, sometimes completely obliterating the view of the opposite rim.

A traveling exhibition on tropical rain forests of the world, produced by the Smithsonian Institution, is appearing in San Diego until September 23.



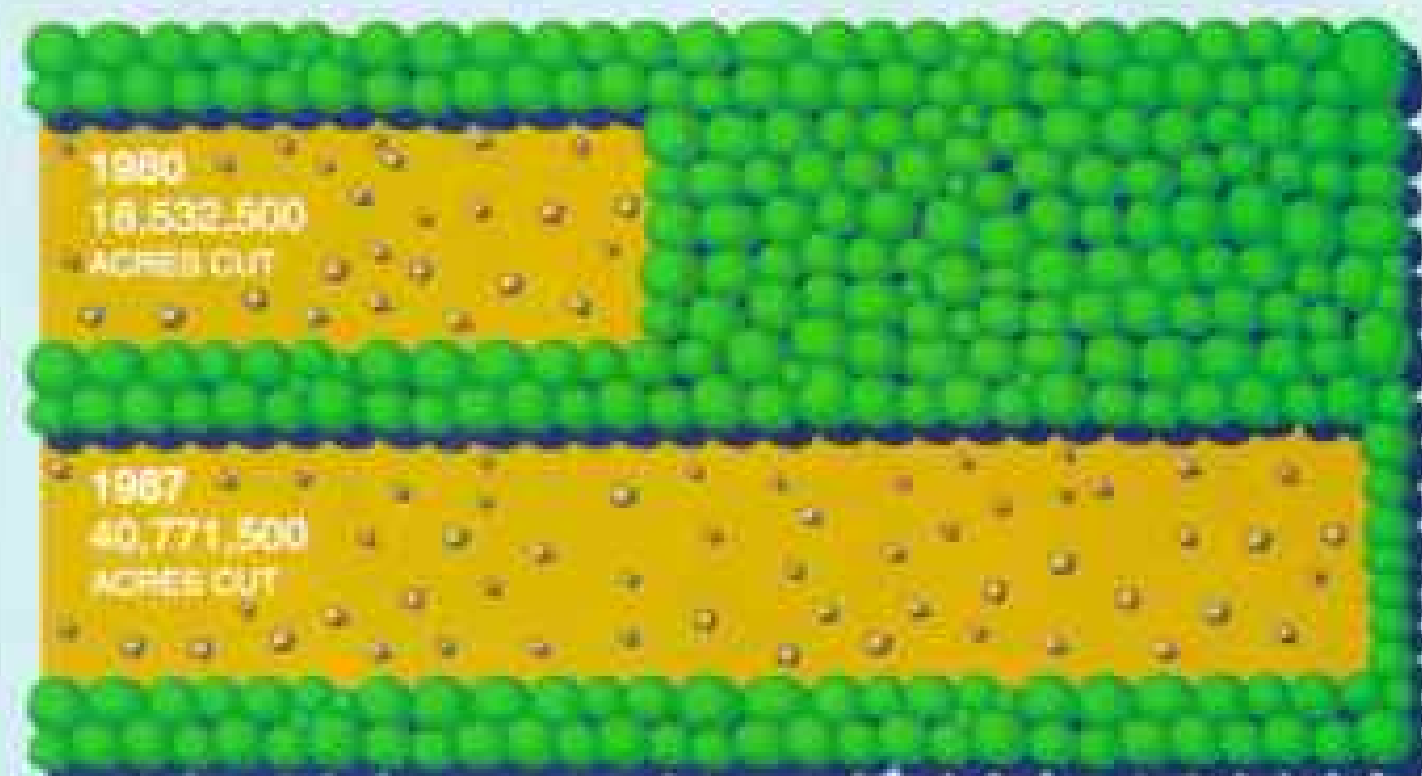
A tern about to fly plays when it helps photographer Norbert Rosing win first prize for humor in the World Press Photo Contest.

U. S. and Baltic Students Exchange Work in Parks

National parks in Latvia, Estonia, and the United States are being spruced up this summer by work teams made up of high school students from all three countries.

Ten Baltic teenagers, five from each of the two Soviet republics, and ten Americans were to meet in Philadelphia before repairing fire damage in Yellowstone. Living in the bush with adult supervisors, they will rebuild foot bridges, clear fallen trees from trails, and reseed fire breaks. In late July the 17- to 19-year-olds move to parks in Latvia and Estonia for more maintenance.

The exchange is sponsored by the Student Conservation Association of Charlestown, New Hampshire, which annually places both college and high school students in conservation internships.



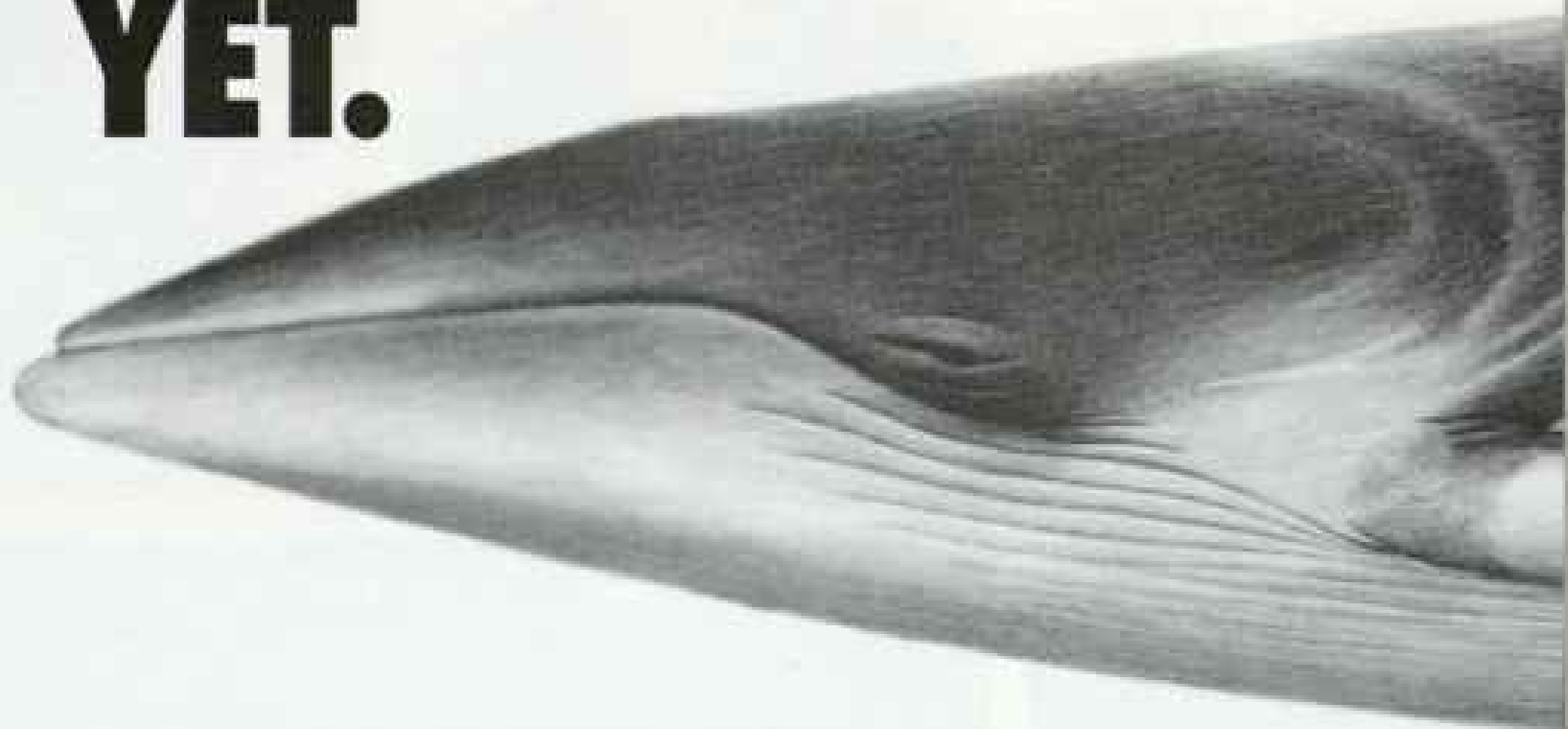
Tropical Forest Loss

Despite repeated warnings that forests are disappearing, the rate of deforestation of tropical closed forest—where trees cover more than 20 percent of the ground—continues to accelerate. According to the World Resources Institute, the destruction is most severe in Brazil but is also increasing significantly in India, Indonesia, and Myanmar (Burma).

ART BY MARK HOLMEL, NDC

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Minke Whale by Larry Foster

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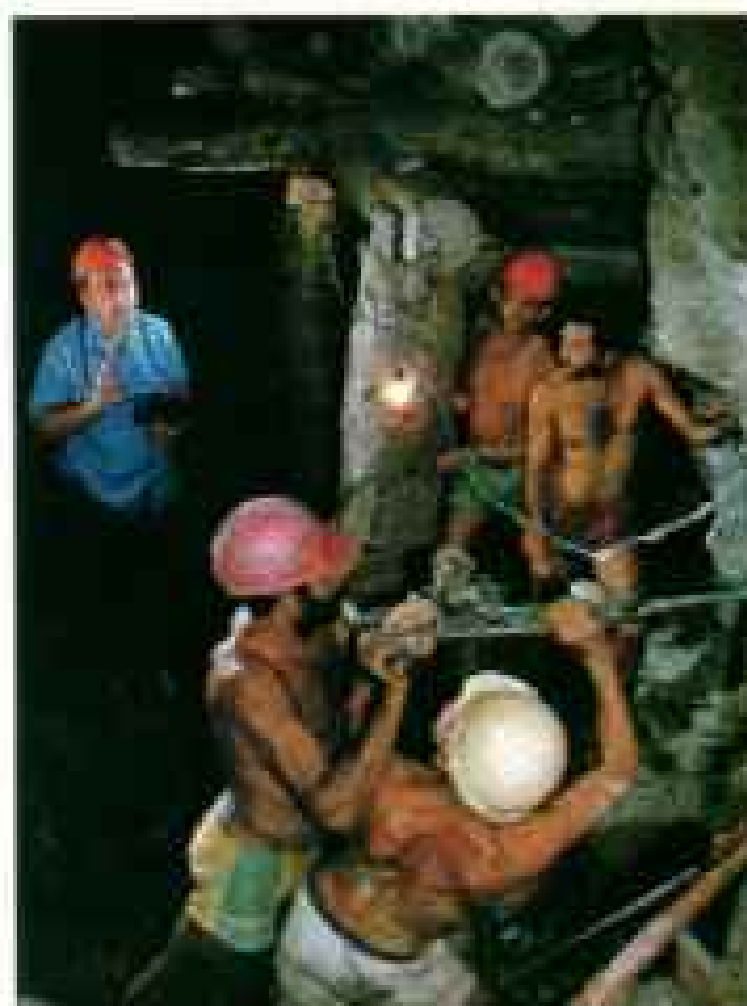
NATIONAL GEOGRAPHIC MAGAZINE

ADVENTUROUS DESCENTS took FRED WARD to the bottom of the two subjects he wrote about and photographed for this issue. Delving into the world of emeralds, Fred rode a cable winched down a narrow 300-foot shaft to reach a Brazilian mine face (below) that shook with blasts from neighboring operations. "It was chaos," he says. "The only way these guys communicated was with dynamite."

It was worse in Colombia, where more than a dozen people Fred interviewed were later murdered, victims of emerald-related violence. An artifact of that mayhem came in handy when Fred lost the shutter button of his camera in the



JERRY GREENBERG (BELOW), CHRISTOPHER D. WARD



FRED WARD (BELOW), MARK JONES

mud near a mine where gun battles often erupt among treasure hunters. He jury-rigged one of numerous spent .32-caliber cartridges (right) as a shutter button so he could keep shooting.

Fred's emeralds story is the latest in his series of *GEOGRAPHIC* articles on gemstones and precious metals. He capped the assignment by completing what is normally a three-year course in only three months to earn a Graduate Gemologist diploma from the Gemological Institute of America. Over the years, he developed a friendship with ardent collector Elizabeth Taylor (top), here bedecked in emeralds.

Fred's other descent took him



scuba diving off Key Largo to Florida's ailing coral reefs. There danger threatened above the surface when a violent squall sent Fred under cover (center); he was nervous sitting in an open boat as lightning danced nearby. He and photographer JERRY GREENBERG were comparing sites in the Pennekamp park and adjacent marine

sanctuary today with photographs Greenberg had made seven to thirty years ago. "It's depressing," says Fred, who grew up in Florida and first dived on Pennekamp as a teenager in the late 1950s. "I remember when it was bright and alive, pink and green and lovely."

Fred's diving adventures are legendary. While covering Cuba in 1976, he explored a reef with Fidel Castro's former photographer. "The only gear we could get was Russian regulators and tanks," he recalls. "I hopped into the water and tried to take a breath—what a regulator! It was like trying to siphon a 20-gallon gas tank five stories below."

(Low light captured on Normal* film.)

(Low light captured on Fujicolor Super HG400.)



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