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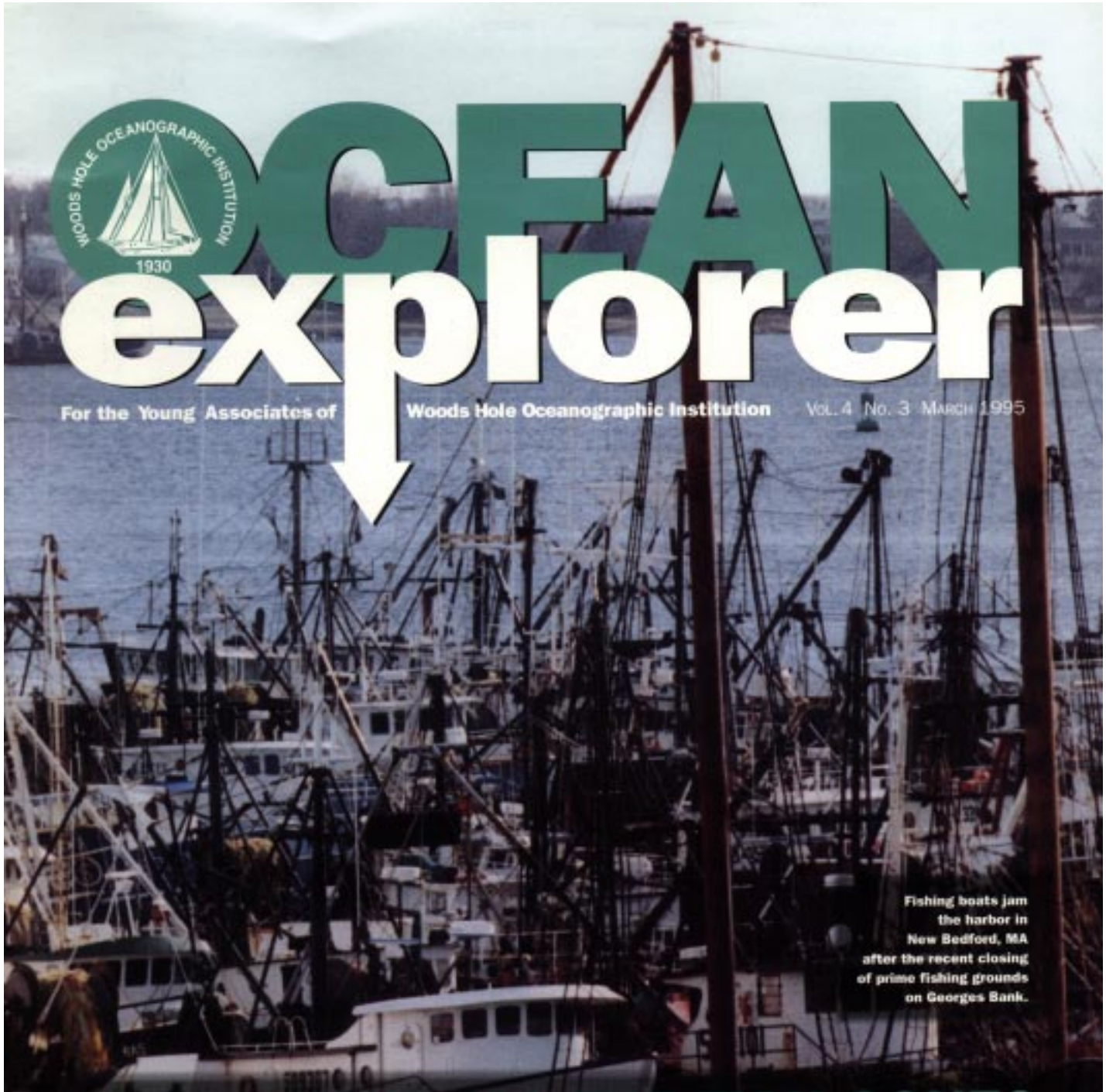


Fishing boats jam the harbor in New Bedford, MA after the recent closing of prime fishing grounds on Georges Bank.

WHERE HAVE ALL THE FISH GONE?

For centuries, fishermen have travelled from the New England coast 120 kilometers east to the submerged plateau called Georges Bank, one of the world's prime breeding and feeding grounds for fish and shellfish. There, they would quickly cram their holds to bursting with cod, haddock, herring, flounder, lobster, shrimp, clams, and many other species.

Most people thought the party would never end. But since 1850, when halibut all but disappeared from the Bank after an intense period of overfishing, there have been signs that the resource was not infinite. In fact, decline in fish stocks is a worldwide problem.

Though one species after another has become scarce on Georges Bank, measures strong enough to preserve its wildlife were resisted. Declines in the last twenty years have been especially rapid. Today, even the familiar codfish is hard to find.

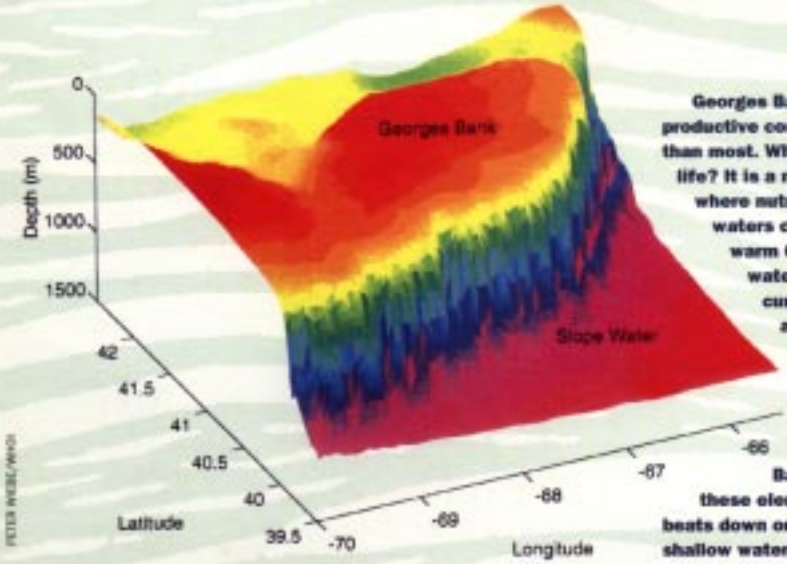
Finally, on December 7, 1994, officials closed 9,600 square kilometers of fishing ground on Georges Bank, home to 60-80% of the commercially valuable fish. If they hadn't taken that step, many say, the Bank would soon be a desert.

Now, boats lie idle up and down the New England coast as families that have fished for generations wonder whether they'll ever fish the Bank again.

Is overfishing the only cause of this crisis? Can the stocks on Georges Bank be replenished? Will fish farms replace the "wild" species that have been lost? This issue, we'll seek solutions to this deep-sea mystery.

PORTRAIT OF GEORGES BANK

Mixing Water Brews A Fertile Cradle for Fish and Shellfish



Georges Bank, measuring 150 km wide and 280 km long, has about the same area as Massachusetts, Rhode Island and Connnecticut combined. It is more than 100 meters higher than the seafloor of the Gulf of Maine that lies to its north.

The Bank is at the western end of a chain that stretches from Newfoundland to Nantucket Shoals. It is part of the continental shelf of North America. Continental shelves are areas of shallow, sloping seafloor that are home to most of the marine life on earth. There is ten times more life in and near a continental shelf than in the deep ocean.

Georges Bank is a more productive continental shelf than most. Why is it so full of life? It is a mixing spot where nutrient-rich Arctic waters combine with warm Gulf Stream waters. A spinning current called an anticyclonic gyre creates a kind of "water lasso" that encircles much of the Bank and corrals these elements. The sun beats down on the Bank's shallow waters, producing an abundant crop of phytoplankton, the microscopic plants that are sometimes called "the grass of the sea." Phytoplankton are a vital part of the marine food chain. They grow on Georges Bank at a rate three times higher than on any other continental shelf, attracting an entire ecosystem of marine animals.

The southern half of the Bank is a smooth plain that dips downward. Along that bank are fifteen submarine canyons that a geologist once described as having "awe-inspiring proportions." He wrote: "If their features were visible, they would compare scientifically with the most impressive canyons of the world." These canyons are between 8 - 20 km long and 3 - 10 km wide, and are between 400 - 600 m deep.

Throughout the canyons are "pueblo villages" — holes in the rock walls — that are home to many kinds of fish and shellfish. Fishing gear can't reach the animals that live here, so their numbers have never been seriously threatened.

The relatively flat surface on top of the Bank is the area most often fished. 100 species of fish are found at Georges Bank, as well as 32 species of marine birds, whales, dolphins and porpoises.

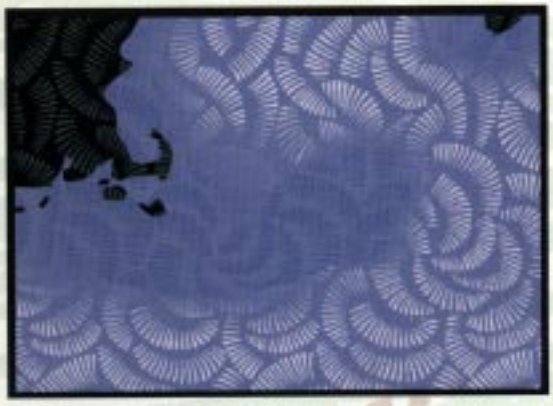
GEORGES CAPE... GEORGES ISLAND... **GEORGES BANK**

A Brief History of the Past 26,000 Years

Once, when thick sheets of ice covered North America, the sea was much lower than it is today. Then, the area we call Georges Bank was part of the mainland. It stretched into the Gulf of Maine from the end of what is now Cape Cod. Geologists call that early form of the Bank Georges Cape.

Twenty-six thousand years ago, the ice that covered Georges Cape began to melt. After about 1,000 years, the surface was fully exposed. But the air was so cold that the only life that could survive there was tundra. Georges Cape measured 53,000 square km, a little more than one-third bigger than the area Georges Bank encompasses today.

About 11,500 years ago, the sea rose high enough to flood a lowland area at the southwestern end of Georges Cape. The Great South Channel was formed, and Georges Cape became Georges Island. Its surface had shrunken to 22,500 square km. Temperatures were now warm enough to support many forms of life, including pine and spruce trees, and later oaks and other plants. Mammals made their home on Georges Island as well, including walruses, mammoths, mastodons, giant moose, musk ox, giant sloth, tapir, and man, who lived and hunted for giant prey on Georges Island 10,000 years ago. Today, fishing boats sometimes haul in remains from this distant era.



About 6,000 years ago, the level of water rose high enough to submerge Georges Island. It became Georges Bank, as it is today. Giovanni da Verrazano discovered the Bank by bumping into it in the early 1500s. He named it Armelline Shoals, after an evil papal tax collector. Later, in 1605, English colonists renamed it for St. George.

Henry David Thoreau wrote in his book Cape Cod: *"Every Cape man has a theory about Georges Bank having been an island once, and in their accounts, they gradually reduce the shallowness from 6, 5, 4, 2 fathoms to somebody's confident assertion that he has seen a mackerel gull sitting on a piece of dry land there."*

The MYSTERY of the DISAPPEARING FISH

Overfishing may be only part of the reason why Georges Bank is becoming deserted. Read on to find out how scientists are trying to solve this puzzle.

Two important species on Georges Bank are haddock (above, left) and cod (above, right). The areas they're often found are shown in the maps. GLOBEC hopes to shed light on their lives.

In 1887, the biologist G. W. Wilcox wrote: "Yet where the mackerel come from in the spring, where they go late in the fall, why they are found in great abundance off the New England coast for a series of years, and perhaps next year in the Gulf of St. Lawrence, remains as much a mystery and matter of theory as one hundred years ago"

In 1995, that mystery still remains. But aided by technology that collects information on very large and very small scales, scientists are beginning to make progress.

One project that is putting pieces of the puzzle in place is GLOBEC (GLOBal Ocean ECosystems Dynamics). This five-year project brings together a team of seventy scientists from twenty-two research institutions in the United States and Canada. The scientists want to understand how changes in the world's climate affect the abundance and production of animals in the sea. This may lead to better techniques for managing the existing stocks of fish.

GLOBEC will take place in several phases, at different sites around the world. It begins at Georges Bank, where four species of animals are under study. These are larval cod and haddock, and two kinds of copepods, tiny, shrimp-like animals that live alongside the larval fish. All are zooplankton (small, mostly drifting animals) and are key links in the marine food chain.

Something is known about the lives of larval cod and haddock already. Says WHOI biologist Peter Wiebe, who is a leader of GLOBEC: "For the first six months of life, the animals go from hatching out of the egg, to little larvae that can't even feed, to larvae that can feed and then grow up and become more agile and swim and finally settle out and live near the bottom." Yet sometime during those first six months of life, nearly 99% of the larval fish will die. Those that do enter the fishery must survive another three to five years before they are big enough to be caught.

Why do so many die? Are they eaten by predators? What creatures do they eat? Is the water too hot—or too cold? GLOBEC hopes to find the answers.

SMALL-SCALE RESEARCH

To learn more about these animals, biologists travel to Georges Bank to collect and observe them. They collect them with a net system called MOCNESS (Multiple Open and Closing Net and Environmental Sensing System.) This is a series of nets controlled by a shipboard operator at the surface. The MOCNESS system is "flown" to the seafloor, and slowly recovered. Each of its nets opens

and closes in sequence. As each net opens, the system records the temperature, depth, and salinity of the water at that level.

Combining that information with the ability to study the creatures they capture at a very fine level of detail, the scientists can create "snapshots" of life at different levels of the ocean.

EACH IMAGE TELLS A TALE

MOCNESS delivers a lot of important data. But many animals in this environment are too delicate, or too small, to be captured by tow nets. They are destroyed in the process, or they pass through the net's openings. Another piece of equipment, the Video Plankton Recorder, makes video images of those creatures. It lets scientists observe the animals in their own natural environment, without disturbing them.

The Video Plankton Recorder consists of four independent cameras, operating at different angles, and at different resolutions. As the cameras roll, a strobe light flashes at the rate of 60 frames per second, as the system is towed through the water. The strobe lights the section of water in such a way that silhouettes of the animals living there are revealed. The tiny, delicate, often transparent animals could not be seen in any other way.

Says Cabell Davis, a WHOI biologist who developed the Video Plankton Recorder with his colleague Scott Gallagher, "It's a completely different view of what the ocean looks like, by looking at it directly on this small scale. There's a lot of structure down there." He says that at this scale, the marine snow, minute particles of debris that float down from the surface, "almost looks like trees in a forest."

Peter Wiebe adds that with the Video Plankton Recorder "We can now begin to look at the orientation of the animals in space. We can look at what's around them, what they're oriented to, and we can know this very, very precisely." By seeing where the animals place themselves in relation to one another, it's possible to better understand how they live.

MAKING SENSE OF SOUNDS

GLOBEC scientists are using acoustics to tell the story, as well. For this, they rely on a remotely-operated vehicle called the Green Bomber. It carries an echo-sounder that sends high frequency sounds into the water, and records the returning echoes. Each echo tells the scientists the shape and location of the creature off of which the sound bounced. Scientists use the echoes to learn the acoustic size and location of animals at specific levels of the sea.

THE BIG PICTURE

Along with the close-up studies of microscopic creatures, GLOBEC examines the big picture of water flow in and around Georges Bank as well. For this, oceanographers use an instrument called a C-T-D (a Conductivity-Temperature-Depth recorder).

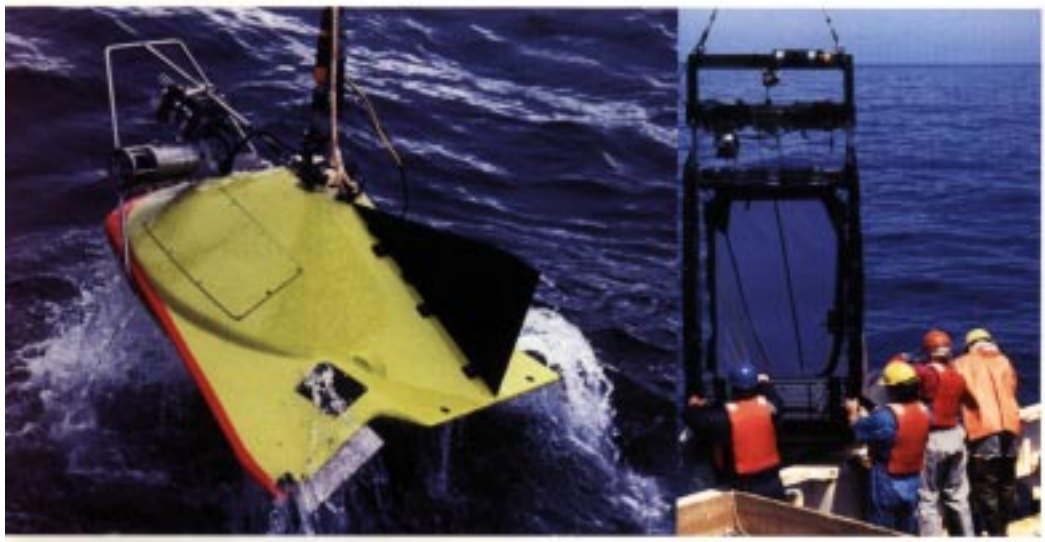
The CTD tells the researchers the temperature and salinity of a given section of water. Those calculations, coupled with the depth at which the readings are taken, make it possible to calculate the flow and movement of the Bank's water.

Satellites help provide big-picture information as well, sending back data about the temperature of the water, and the location of blooms of phytoplankton, the microscopic plants eaten by many sea creatures.

FITTING PIECES TOGETHER

What is the bottom line? "We want to be able to say how fast the animals are growing, how fast they're reproducing, and what kinds of controls exist to either enhance that growth or cause it to be less than optimal," says Peter. With that type of information, when changes take place on the Bank, in temperature, in salinity, in currents, or in abundance of phytoplankton, scientists may be able to predict the effects on fish population.

The investigators haven't yet solved the mystery of the disappearing fish. But they have their hunches. They suspect that rising water temperature, particularly in January and February, the start of the growing season for cod and haddock larvae, may be partly responsible. As the study continues, more evidence needed to solve the mystery will doubtless be revealed.



TOOLS OF THE TRADE
The discoveries being made by the GLOBEC team would not be possible without special technology. The MOCNESS net system (near left) brings back samples from many different water levels. The "Green Bomber" (center) creates acoustic pictures of the underwater world. The Video Plankton Recorder (far left) sends back images that, for the first time, let scientists observe microscopic life forms, undisturbed, in their natural environment.

LEFT: CABELL DAVIS/WHOI; CENTER AND RIGHT: SHEA PHOTOS

FARMING for FISH: Is Aquaculture Part of the Solution?

On a forty-acre salt pond at the western end of the tiny island of Cuttyhunk, MA, a farmer tends his crop. He motors out into the pond and hauls up a cage filled with oysters. He selects those that are ready for the market, and lets the others and their cage sink back into the water column, where they will continue to filter-feed on natural nutrients in the clean, well-circulating water.

JOHN TEWKEL

Seth Garfield has raised oysters on Cuttyhunk for the past thirteen years. He's one of a small but growing number of people who hope that fish-farming may be one answer to the steep decline in fish and shellfish to be caught in the open ocean.

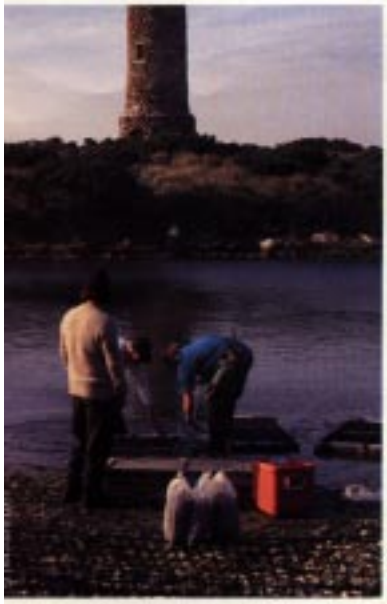
West End Pond on Cuttyhunk is an unusual, almost ideal site. It has an inlet to the ocean, which mixes the pond's water twice a day, and brings in new nutrients for the oysters and clams Seth grows from seeds, which are young, fingernail-sized oysters. Because Cuttyhunk is ten miles from the mainland, the ocean water that surrounds it is practically unpolluted, though pleasure boats can create problems.

Seth carefully monitors the health of the pond, working with local and state officials, and, from time to time, with marine biologists. (Several WHOI researchers were studying the pond's health last summer.)

Still, the success of his crop is anything but certain. "A land-based farmer can buy a farm and be farming the next day," says Seth. "That farmer could have a field full of lettuce a month later. Oysters take two to three years to grow to maturity." In that time, many things could go wrong. In 1991, Hurricane Bob swept much of the nutrient base out of West End Pond, which created a serious crisis for the farm.

AQUACULTURE IN AMERICA

Aquaculture, or the captive growing of fish, shellfish and marine plants, it is not yet a big enough business in this country to absorb all those thrown out of work by the fishing crisis. Hank Parker,



A rare spot: Clean and isolated, West End Pond on Cuttyhunk Island is home to the Cuttyhunk Shellfish farm (left). Seth Garfield checks on his crop (center). Asa Lombard, who works at the farm, holds a "japanese lantern" net used to grow oysters in different levels of the water column (right).

Aquaculture Program Coordinator for the United States Department of Agriculture says that "less than ten percent of U.S. fisheries production comes from aquaculture." By far the biggest U.S. aquaculture crop is catfish. Oysters, salmon, crawfish, trout, baitfish and ornamental fish are also important. But he adds, "We're a drop in the bucket compared to other countries."

For hundreds of years, Asia has led the world in aquaculture.

OLD AND NEW

Hundreds of years? Isn't aquaculture a new field? Not at all. Archaeologists have found shell heaps left thousands of years ago by coastal tribes. These people kept fish and shellfish they gathered alive by placing them in holding baskets and submerging them in fresh-flowing water. There, the animals would grow until their captors ate them.

Today, science and technology are changing the way fish and shellfish are farmed. Genetic engineers breed strains that resist disease. Chemists experiment with nutrients. Engineers create new ways to hold the plants and animals as they grow to market size.

Aquaculture is also being seen as a way to re-use resources, such as heated water, that are output by factories. Farmers can re-use water and nutrient resources via aquaculture as well. Says Hank Parker: "There is clearly an industrial need for a 'whole earth' philosophy to happen. Aquaculture is an alternative, a way to capture and reuse what might otherwise be waste."

STOCKING UP

With the worldwide decline in wild fish stocks, the need for new ways to raise these important protein sources is more apparent than ever.

Dale Leavitt, a biologist who works as a fisheries and aquaculture specialist in the WHOI Sea Grant program, is using aquaculture to replenish wild stocks of sea scallops. Scallops are raised from eggs in a hatchery on Martha's Vineyard. Dale and others are taking the baby scallops into the ocean, to a depleted area. "We'll see what kind of return we get from that," he says.

Restocking scallops is tricky. "They are interesting animals," says Dale, "because they're mobile. They move all over the place. They look like butterflies, taking off with each valve clap. You can't just put them on the bottom and expect them to be there a year later."

Dale, a former fisherman, is committed to aquaculture. But he's cautious. "Aquaculture is very popular right at the moment," he says. "A lot of people are trying to sell it as being the saviour of the fishing industry." Perhaps in time the industry will be big enough to try to solve fisheries problems.

IDEAL SETTING

Still, operations like Seth Garfield's send a message of hope. Each summer evening, Seth motors through Cuttyhunk Harbor, selling shellfish to boaters relaxing and enjoying the sunset. By adding a taste of just-harvested seafood to the pleasures of a beautiful spot, and a happy moment, Seth also puts forward a message of conservation. For without the clean waters in which his oysters grow, a tasty aspect of that moment's pleasure would not be possible.

PAM COMSTOCK

CUTTYHUNK SHELLFISH

Seth Garfield scoops up some seed oysters. In two years, they will be big enough to sell (top). At left, he culls market-ready oysters.