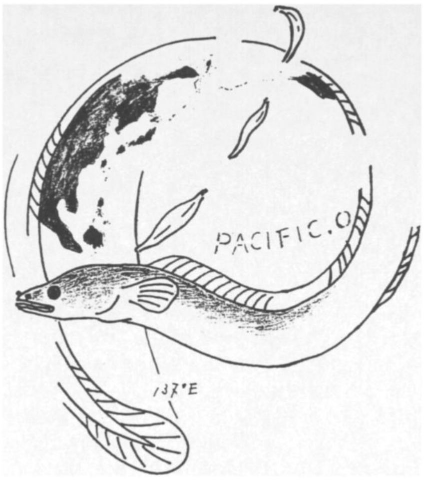


Gone Eeling

Luck and science face off in two eel-seeking adventures

By ELIZABETH PENNISI

Needles in a haystack are easy to find compared with eels in the open ocean. Yet three winters ago, I tried to do just that as a part of a research team that scoured the Sargasso Sea for American eels (*Anguilla rostrata*). That's where these snakelike fish and their European cousins end a several-thousand-mile journey from North American and European rivers with a final mating orgy.

Last summer, Japanese marine biologists set out on a related, but perhaps more difficult, quest. They sought the spawning grounds of the Japanese eel (*Anguilla japonica*), a species with a similarly arduous life history. They planned to find this patch of ocean by catching newly hatched eel larvae, called leptocephali.

Our group returned almost empty-handed; the Japanese expedition got lucky. In late July, on a national holiday noted for eel feasts, Japanese newspapers heralded the team's success in finding Japanese eel leptocephali. Science works that way sometimes.

Our task had looked easy compared with the challenge facing the Japanese. More than 60 years ago, Danish biologist Johannes Schmidt cruised the Atlantic collecting thousands of eel larvae. On the basis of some 170 specimens that were up to 10 millimeters long, he identified the Sargasso Sea, in the southwestern North Atlantic, as the spawning grounds. His work cemented the connection between eels and their young (scientists once considered leptocephali to be a group of species separate from eels) and firmly established the eel as a long-distant migrant. Several other expeditions followed over the decades, amassing lots of data. Yet no one ever spotted adults in the spawning grounds.

My chief scientist, James D. McCleave of the University of Maine, Orono, had closely examined the existing data on eels and had made several forays to the Sargasso, collecting larvae and analyzing the temperature and salinity of the collection sites. He developed the theory that the eels used rapid changes in ocean temperature — the marine equivalent of a weather front — as the landmark for their spawning grounds.

On our 1989 trip, McCleave intended to use satellite data and shipboard measurements to find that landmark and, he hoped, adult eels. He teamed up with Stephen B. Brandt, a biologist at the University of Maryland's Chesapeake Biological Laboratory in Solomons, Md. Brandt used sophisticated sonar equipment to pinpoint and identify fish hidden behind the ocean's watery curtain. The equipment sends out sound pulses and analyzes the echoes to determine what lies below. Once we "sighted" eels, we planned to net them or lure them into baited cages and traps designed and hand-sewn by the researchers' graduate students.

So much for grand plans.

Once we reached the Sargasso Sea, the dozen members of the scientific staff started working 12-hour shifts so they could take hourly temperature and salinity measurements and watch their acoustic monitors around the clock. Though once characterized as an "ocean desert," these waters seemed to teem with life. Often, blips would fill up a depth layer on the monitors' screens, then move up and down over the course of the night. This regularity suggested that the blips represented a dense layer of life that moved to different depths on a daily rhythm.

We were convinced that some of those blips represented eels.

But night after night we cast our nets — trawl nets smaller than but similar to those used by commercial fishermen. Though we sometimes towed the nets for several hours before retrieving them, we caught no eels. We tried different nets and varied our towing strategies, to no avail.

Several times we sent down an underwater videocamera mounted on a propeller-driven submersible. But the most exciting thing we saw was a whale that came up and nuzzled the lens. Our traps also failed. One set came up completely empty. A second set got loose from the tethers and drifted away.

For almost a month, the ever-changing marine environment presented us with daily challenges and frustrations. In the laboratory, researchers often must modify a technique bit by bit, time and time again, before they get their experiment to work. Our "experiment" at sea was no different, but it seemed harder. The rocking deck endlessly threatened our balance, and empty horizons heightened our sense of isolation. We could make changes, but we could not see their effects underwater. I felt as though we were groping in the dark for something just beyond our reach.

No matter how resourceful our crew was in honing the acoustic tracking apparatus and devising new ways to rig the nets, we never even saw an adult eel. We all worked so hard and solved each problem as best we could; yet in the end, nature won, keeping its secret about what happens to adult American eels.

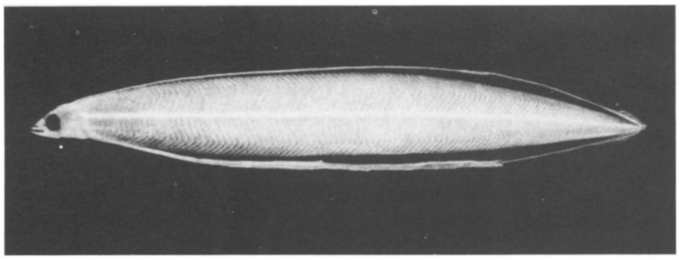
I ended my month at sea understanding all too well why the cruise T-shirts read "Eels of Fortune."

So I felt a bit skeptical when one of my shipmates, Maine graduate student Michael J. Miller, told me he was headed for Japan to look for eels in

Researchers prepare nets on board the eel-hunting Hakuho-Maru.

Miller/Univ. of Maine

To find eel spawning grounds, researchers fish for leaf-shaped larvae called leptocephali. Two-week-old leptocephali are about 10 millimeters long.



Tsukamoto/Univ. of Tokyo

the Pacific Ocean. Researchers know even less about the migration of the Japanese eel than we knew about the American eel. And the Pacific seems so vast. Four times before, the Ocean Research Institute of the University of Tokyo had sent out the research ship *Hakuho-Maru* to discover where these oriental eels spawn. Each time, the ship had returned without much success.

Even Miller expressed reservations. "It's a big ocean out there. You head out into that huge expanse and take thimblefuls of water," he told me, referring to sampling with plankton nets. "No matter how many thimblefuls, it's still hit or miss."

Like American eels, Japanese eels live out a complex and long-distance life cycle. Somewhere in the Pacific, the adults mate and produce the transparent leptocephali. These leaf-shaped larvae drift into the Kuroshio current, which carries them northward to the Japanese coast. By the time the leptocephali reach shallow offshore waters, they have transformed into colorless "glass eels." These tiny snakelike fish pass through estuaries during the winter and then head up rivers the following spring, becoming yellowish as they grow. Five to 10 years later, they begin their final journey back to sea.

More than curiosity drives Japanese scientists to seek the eels' spawning grounds.

Eels figure prominently in Japan's heritage. "Japanese people have much more interest in eating eels compared to Americans," says Katsumi Tsukamoto, a fisheries biologist at the University of Tokyo. Every year, the Japanese celebrate *Doyo no ushinohi,* "day of the cow in midsummer," by feasting on eel. They believe the eel's high nutrient content rejuvenates and energizes spirits worn down by the heat.

During the 1950s, Japanese researchers thought eels traveled to waters south of the Ryukyu Islands (including Okinawa) and north of 22° N latitude. Twenty years later, scientists decided instead that the eels went to waters east of the Philippines, between 15° and 20° N. A decade ago, they revised the scenario once again, postulating that eels ended up at the same latitude but farther east, between 130° and 140° E longitude. In the mid-1980s, fisheries experts concluded that spawning occurs more southward and eastward.

In all, the previous cruises had yielded only 110 larvae, not enough to pinpoint the spawning sites.

However, on the *Hakuho-Maru's* fourth trip, in 1986, Tsukamoto managed to haul in 21 larvae averaging 40 mm long, by far the most plentiful catch of the smallest specimens. These leptocephali provided a key clue. Tsukamoto analyzed the otoliths — tiny spheres of bone in the internal ear — of specimens caught east of Taiwan. Like tree rings, otoliths build up layer by layer, so researchers can use them to determine the age and living conditions of fish.

"The technique was very important for determining the spawning season," says Tsukamoto, who published his otolith analysis in a Japanese journal and in the May 1990 JOURNAL OF FISH BIOLOGY. His data indicated that Japanese eels spawn between April and November — most likely in June and July — and not during the winter as people had thought.

So the scientists scheduled their next cruise for late June 1991. They reanalyzed the locations of all previous catches, and then, taking into consideration deep-ocean and surface currents, charted a new course to look for the larvae.

Setting out from Tokyo on June 14, the *Hakuho-Maru* steamed southeast for more than two days. Then, after christening their net with sake, the researchers began an intensive series of tows along a predetermined grid. During the ship's five weeks at sea, the *Hakuho-Maru* made 262 tows and cruised 16,000 kilometers, crisscrossing a swatch of ocean 2,589 by 1,333 km east of the Philippines and Taiwan. They picked out specific sampling spots in advance but made extra stops as time permitted, says Tsukamoto, the cruise's chief scientist.

The course was designed to begin outside the region where they expected to find Japanese eel larvae, Tsukamoto says. After two weeks, the ship headed west of Guam and the Mariana trench, where the researchers thought the sea mounts and deep trenches might serve as the signposts that signal the end of the eels' long migration. There, they hoped to start catching larvae, adds Miller.

Instead, all that continued to turn up in the net were a few larval specimens of a different eel species, whose adults swim off the coast of India, Malaysia and other countries in the tropical Pacific and Indian Oceans.

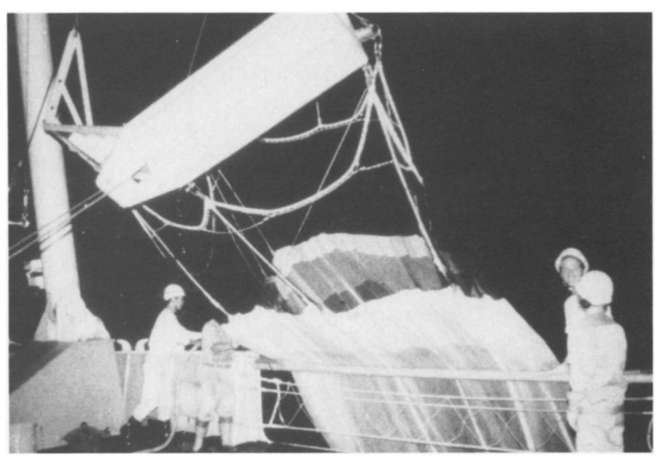
Miller began to wonder whether this cruise would suffer the same fate as his voyage to the Sargasso two years earlier. "There was no visible depression," he recalls. "Everyone kept working like a machine, catching and processing specimens." Yet a paper shrine appeared in the ship's lab with a picture of a Japanese eel underneath, and someone hung up a poster that said, "Wanted: *Anguilla.*"

"I was very anxious," Tsukamoto admits. "But I did have some confidence because I believed in our age determinations."

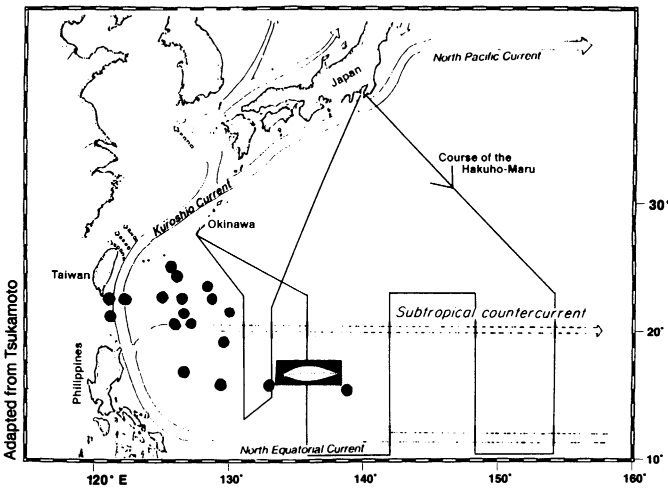
As the ship edged to the north of the Caroline Islands, the scientists held a summit meeting. The tone was grim, Miller recalls. They reexamined their maps showing where previous expeditions had caught larvae, and they discussed oceanographic data about the temperature and salinity of that region. They talked about their results so far. Miller, who studies leptocephali from species other than the Japanese eel, pointed out that his catches of non-*Anguilla* leptocephali seemed to concentrate south of a frontal zone — a region where salinity changes quite rapidly. Could that be a natural barrier, a different signpost for migrating fishes?

Yes, the scientists concluded, although

Scientists fish for eels and their young at night by dropping a net overboard, towing it for about 45 minutes, then retrieving it and combing through its contents for very small leptocephali.



Miller/Univ. of Maine



Adapted from Tsukamoto

This map of the Pacific shows the locations of previous catches of leptocephali (dark circles), the course of the 1991 research trip by the Japanese and the spawning grounds (leptocephalus drawing).

they based their decision on very circumstantial evidence. "They decided to fish like bandits, at night, just south of the salinity front," Miller says. "That's where our best chances would be."

This concentration of efforts in one place represented a big gamble. Because the schedule called for the ship to end the first leg of its cruise at Okinawa four days later, there wouldn't be time for the ship to backtrack if they failed to find eel larvae. On the second leg, the ship would head much farther west. "If we didn't succeed on the first leg, it would have been a disaster," says Miller. "We would have covered all the territory where all the previous research had suggested the larvae would be."

After midnight, the scientists set up a net as they had 60 times before during the previous 19 days. Forty-five minutes later, they hauled it in and began culling key living specimens. While sorting through bowls of the leptocephali brought to the ship's lab, they found one very tiny eel larva. Noritaka Mochioka of Kyushu University, an expert in identifying larval fish, took it over to a microscope to count its muscle segments, called myomeres. The number of myomeres distinguishes species: Indonesian leptocephali have about 10 fewer myomeres than the 112 to 118 typical of Japanese larvae.

"He eventually concluded that it was an *Anguilla japonica*," Miller says. "It was the first one and it was small." That announcement had an eel-ectrifying effect, bringing applause from the researchers.

"Ten millimeters is quite significant for Japanese eel biology, so that is very exciting," says Tsukamoto. That specimen was half the size of the previous record smallest. Finding more larvae that size would mean the team had closed in on the spawning grounds. They caught only three more that night, but the next evening, their second tow netted 39.

Thus began what the scientific crew came to call "the longest night." The researchers next sent down a complex apparatus that opens and closes different nets at different depths. From their catches at different levels, the scientists decided to concentrate their towing at about 75 meters, a depth where their sampling had yielded the largest numbers. It turned out to be a good decision, because in one tow, they caught 280 Japanese eel larvae. "That's surprising, that [such] very dense aggregations exist," Tsukamoto says.

Miller missed this action, being one of those assigned the task of sorting through the mess of tiny, transparent creatures and identifying the larvae under the microscope. "All I saw were continuous buckets of plankton and trays of leptocephali," he recalls. "I didn't know how we were going to process them all."

About 800 Japanese eel leptocephali passed under those microscopes before the sun rose and the animals could no longer be caught. By then the ship needed to head full speed to its next preassigned sampling spot. "The integrity of the [schedule] would not be sacrificed for anything," Miller says. So even though the size and number of larvae indicated the Japanese had found where eels first began their long, complex lives, the ship did not linger.

Ten days later, the *Hakuho-Maru* began sampling again at spots hundreds of kilometers west. "We never caught more than 10 to 15 [larvae] in any tow ever again," says Miller. A typhoon also forced the ship to alter its course, so the scientists couldn't hit other regions where they thought currents might have carried larger, older larvae.

None of that mattered much. "The magnitude of our success was so great that everyone was in pretty good spirits," says Miller. "It was an extremely historic cruise from the Japanese perspective."

And from his, too. "In the Sargasso there was a feeling of frustration and disappointment," he says. "In the Pacific, there was a feeling of accomplishment and satisfaction." □

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Communicating Science: A Handbook — Michael Shortland and Jane Gregory. This manual, written for scientists, engineers and physicians wishing to improve their communication skills, offers practical advice on public speaking, writing for the general public and interacting with the news media. Although the authors use scientific examples and focus specifically on the needs of scientists, most of their suggestions apply to communicators in any field. Wiley, 1991, 186 p., paperback, $27.95.

For the Love of Enzymes: The Odyssey of a Biochemist — Arthur Kornberg. This Nobel laureate helped launch the field of genetic engineering with his research on the enzymes involved in DNA replication and his efforts to synthesize DNA in the laboratory. His book is an absorbing account of the challenges he encountered in struggling to understand heredity and an enlightening peek at the process of scientific discovery. Skillfully balancing science and memoir, he supplements the text with helpful two-color diagrams. Originally published in hardcover in 1989. Harvard U Pr, 1991, 336 p., illus., paperback, $14.95.

Meant to Be Wild: The Struggle to Save Endangered Species Through Captive Breeding — Jan DeBlieu. An impassioned introduction to the obstacles faced by North American efforts to conserve endangered species such as the red wolf, the black-footed ferret, the California condor and the whooping crane. DeBlieu's detailed yet readable account illustrates the scarcity of time, money and resources, but she focuses in particular on the need to change lifestyles and attitudes about wildlife and the importance of conserving entire ecosystems rather than single species at a time. Fulcrum Inc, 1991, 302 p., b&w plates, hardcover, $24.95.

Trash to Cash: New Business Opportunities in the Post-Consumer Waste Stream — Susan Williams, Ed. This report from the Investor Responsibility Research Center surveys the three major alternatives to landfill waste disposal — recycling, incineration and composting — and details the business opportunities, incentives and obstacles that exist in these fledgling industries. The report also profiles the companies and associations involved in these disposal ventures, describes the technology available and identifies leading users of recycled material in the various recycling industries. IRRC Inc DC, 1991, 317 p., charts & graphs, paperback, $35.00.