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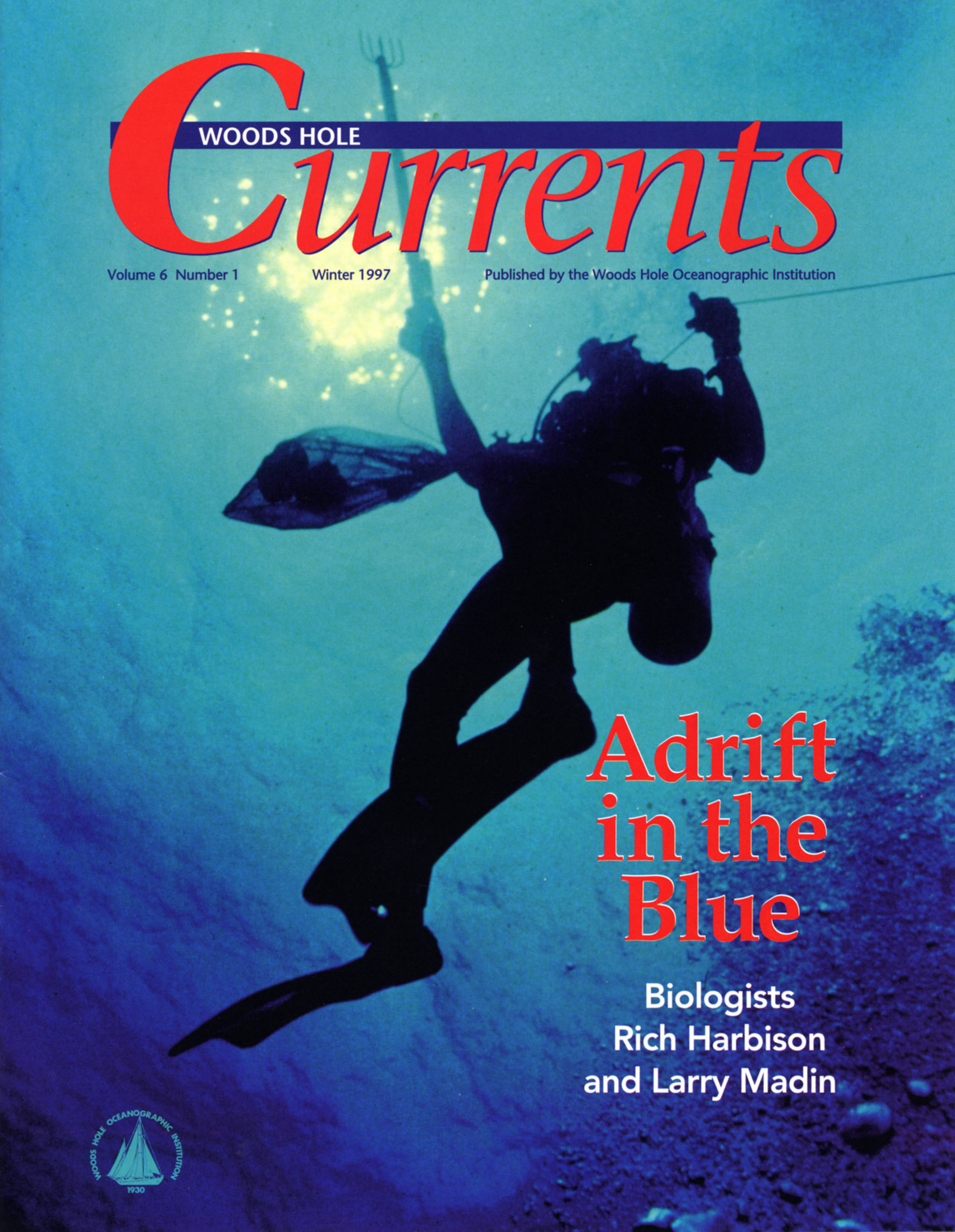


Adrift in the Blue

Biologists Rich Harbison and Larry Madin

Adrift in the Blue

Biologists Larry Madin and Richard Harbison study some of the sea's most beautiful creatures.

BY KATE MADIN

All around, there is nothing but blue. The blue above is slightly lighter; the blue below fades to the color of midnight. But there is only blue in all directions, as far as the eye can see. Suspended in this vastness are four human beings who would be awed at their own insignificance if they were not focused so intently on the water two feet in front of their masks.

Several hundred miles west of Bermuda in the southern North Atlantic, eighteen meters (sixty feet) beneath the surface in the great Gulf Stream, the divers are drifting, and thus technically have become plankton, kin to the other organisms that drift in the sea. They don't swim but hang almost motionless, looking slowly about. They carry scuba tanks on their backs, bags of collecting jars on their belts, and are tied with slender lines to a central diver who keeps vigil like a spider at the center of its web. Their buoyancy compensators suspend them at a constant depth. Their wet suits mute their sense of touch, and they hear little save their own breathing, which sends bursts of bubbles to the surface in streams of silvery spheres. There is little but blue everywhere, as if they are drifting through a dream, through a blue sky in a world without gravity, where only bubbles show which way is up.

This is blue-water research diving, and these divers are scientists engaged in a seemingly impossible task. In this limitless universe, where visual cues are few, they seek animals that are frequently tiny, mostly transparent, and sometimes not even there.

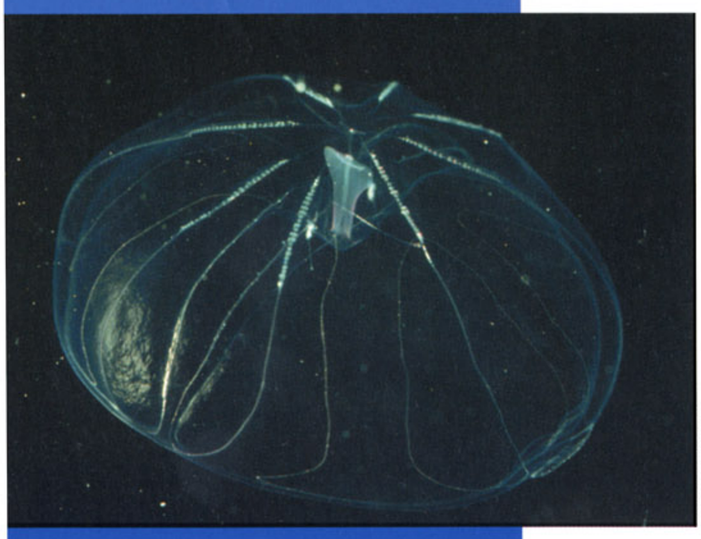
FOR MORE THAN TWENTY YEARS, WHOI biologists Larry Madin and Richard Harbison have done much of their work this way. They have gone to sea and, far from land, left the relative safety of the ship to jump into the open ocean.

(continued on page 10)

LARRY MADIN/WHOI

Blue-water divers hunt for jellyfish in the open ocean.

LARRY MADIN/WHOI



LARRY MADIN/WHOI

Top: This salp, *Salpa cylindrica,* has been dyed with carmine and fluorescein to show the mucus net it has for feeding and the currents of expelled water that propel it.

Bottom: *Thalassocalyce inconstans,* a new midwater ctenophore species named by Madin and Harbison.

Harbison and Madin study gelatinous zooplankton (often collectively called "jellies" by the biologists), fragile and beautiful open-ocean plankton that are too delicate to be netted from ships. They include the jellyfish and stinging siphonophores occasionally seen washed up on the sand, as well as more exotic animals. They represent all phyla, from the salps (chain-forming herbivores that may be six meters long), which are chordates, to heteropod and pteropod molluscs (transparent, fantastic relatives of snails), to ctenophores (jellyfish relatives that look as if they are strung with flickering colored lights).

Each of these researchers has had a long-standing interest in these animals. Harbison credits the film *Creature of the Black Lagoon* for sparking his interest in marine animals. Of the jellies he has studied the longest, Madin says, "I became interested in salps in 1966 as an undergraduate at Berkeley when I first saw one pickled in a jar in a biology lab. I had never seen anything like them before. I was amazed to find out that little was known about how they lived in the ocean." The animals were truly fascinating to study, beautiful and ethereal, insubstantial but successful, abundant but little known. A sense of discovery and adventure accompanied every dive: What new species would appear on this dive? What more awaited discovery?

One of the basic motivations for these oceanographers is the fun of finding out new things about the ocean and how it works. "The open ocean is about as different an environment from the one we inhabit as any place on Earth," says Harbison. "Studying open ocean animals in their native habitat provides a fascinating opportunity to do the same kind of work that the pioneering eighteenth and nineteenth century biologists did in other environments." Harbison came to WHOI in 1971 as a postdoctoral student of the late biologist Frank Carey, and by 1974 was a staff scientist who could, in turn, take Larry Madin as a postdoc. In California Madin had studied with Bill Hamner, a marine biologist who pioneered the blue-water diving methods that proved to be the best and only method for collecting gelatinous zooplankton alive, intact, and in perfect condition, so that they could be studied in shipboard labs.

Originally working together, Harbison's and Madin's interests diverged. Each progressed from scuba diving to using various research submersibles to observe and collect the gelatinous animals of the midwater, down to 800 or 1,000 meters. Although most of their recent work includes the use of submersibles, net collections, and even immuno-assay techniques, both continue to use blue-water diving to understand ocean animals and ecosystems.

BLUE-WATER RESEARCH DIVING IS both like and unlike other forms of diving. Scientists may use the same gear, tank, and wet suit as recreational divers, but the dives take place far from shore, where the blue water owes its clarity and color to the absence of nearshore influences such as pollution, particulates, and nutrient-rich runoff that stimulates phytoplankton productivity. Thus, a ship is a must—a research vessel with labs and experimental equipment and an inflatable boat to carry divers safely away from the ship's massive hull and propellers. Like other oceanographers, when Madin and Harbison go to sea they assemble a group of scientists beforehand, including their lab assistants, students, colleagues, and guests. On their cruises, however, members of the scientific party must also be certified divers.

After a group of three to six divers enters the water, they clip themselves to tether ropes that fan out from a central point, which is in turn connected to a surface float that the dive boat driver watches. The tether system is the innovation that allows safe blue-water diving. Tethers help keep the divers oriented, provide a limit to excursions, and offer a visual reference point in the sea's seamless blue. One member of the dive team, designated the safety diver, stays at the central point from which the tethers radiate. This person watches the surrounding water during the dive, looking for what the other divers may not see. Intent on scanning the water inches from their faces for the transparent jellies, they might not notice if their tethers have become tangled or the approach of larger animals such as sharks, whales, dolphins, and swordfish, or the stinging siphonophores such as the Portuguese Man-o'-War (*Physalia*). The safety diver also keeps track of time and depth and decides if the dive should be terminated early for any reason.

Diving tethers serve much the same purpose as mountain climbing or space walk tethers. For instance, almost all blue-water divers have dropped things on a dive—perhaps a collecting jar, once even a camera—and the natural instinct is to pursue it, to catch it before it drops out of sight into the deep blue-black below. Swimming down fast can allow a diver to retrieve it, but without tethers they could easily swim dangerously, irrevocably deep.

Blue-water diving can present challenges and surprises to even the most experienced. Harbison has worked in the Arctic and Antarctic, where dry suits are mandatory and ice is both beautiful and treacherous. His dive teams have had run-ins with leopard seals and with the ice itself. "Once I was serving as safety diver, when all of a sudden it became very dark, and then we were run over by a small iceberg which passed between us and the rubber boat. Finding myself plastered against the ice, I quickly learned that one cannot push an iceberg out of the way." And once Madin and a filmmaker, diving without tethers, found on surfacing that they were separated from both ship and dive boat—adrift in the Atlantic with nothing in sight for about an hour before they were rescued. "It was a little unnerving," he says, "and was the first and last time I ever went diving without a tether system."

LARRY MADIN/WHOI

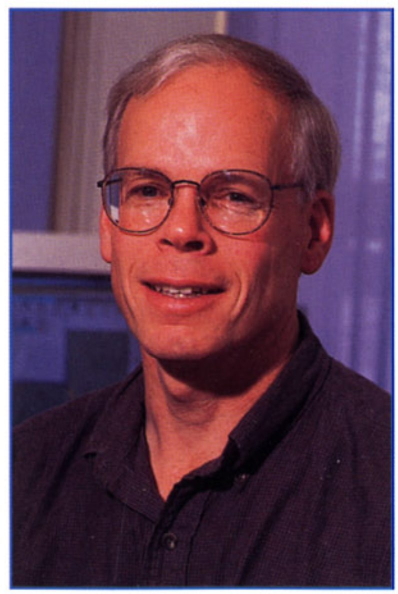
Weather can be a factor on any oceanographic cruise, but it can put a complete stop to diving if the inflatable boat cannot be lowered safely into the water. "One time on WHOI's research ship *Oceanus*, the weather blew up while we were diving at night. When we surfaced, the dive boat engine would not start. It seemed to take a long time in the dark to get back to the ship," says Madin.

But what keeps both Harbison and Madin diving is the direct experience of watching the living animals in their own habitat. Gelatinous zooplankton are so fragile that they are often destroyed by collecting nets dragged by ships, so many of the animals they study were seldom seen alive twenty-five years ago and were known only from dead and preserved samples.

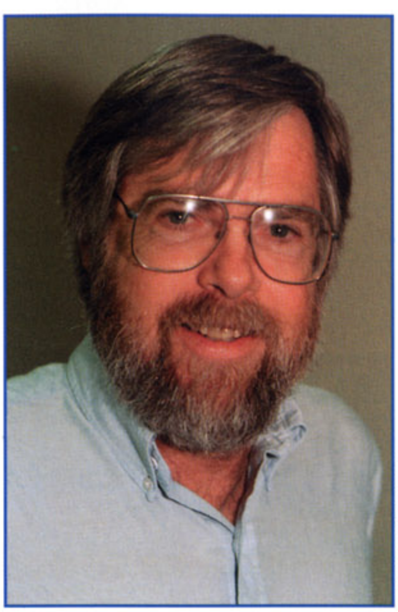
Because of this, much of Madin's and Harbison's work over the last two decades constitutes basic natural history: What gelatinous animals exist? How do they swim? What do they eat? How have they adapted to their transparent world?

Madin guesses that scientists have made somewhere around 2,500 blue-water dives, painstakingly amassing data on the jellies' presence, behavior, and interactions. Each dive is assigned a number; each animal seen is recorded. The rewards of this method are that each scientist feels he or she knows these exquisitely beautiful animals well, and that the work is frontier science—much of what they see is new.

"One clear result of the blue-water work is that we now know that many kinds of gelatinous animals are more abundant, occur more often, and are represented by more species than was previously thought," says Madin. "They fill all sorts of niches in the ocean." Some jellies, such as the salps, are important herbivores; some, such as the planktonic heteropod molluscs, are voracious hunters; jellyfish and ctenophores are serious predators with



TOM KLEINDINST/WHOI



TOM KLEINDINST/WHOI

Top: This salp, *Salpa cylindrica*, is host to two species of amphipod crustaceans that inhabit the salp for their entire lives. One species merely shares the salp's food; the other nibbles on the salp itself.

Center: Biologist Larry Madin became interested in jellies when he first saw them in a jar in a lab.

Bottom: Biologist Rich Harbison has studied jellyfish in the tropics, the Atlantic, Antarctica, and the Black Sea.

LARRY MADIN/WHOI

The divers are clipped to safety tethers while they hunt for jellyfish, and one diver keeps watch at the center of the web of tethers.

some species eating only other jellies and other species eating fish.

It was when their diving progressed to using submersibles in the mid 1980s that both Madin and Harbison began to see "rare" species commonly and to find new species with regularity. Scuba diving allows the direct exploration of only a tiny fraction of the ocean's surface waters, and submersibles expand the scientists' range. Although hard-bodied animals such as fish or shrimp are well known from net collections, many deep-living jelly species had never before been seen or been recognizable when gathered—and mangled—in deep-towed nets. Madin, Harbison, and other scientists have discovered dozens of new species using the submersibles *Johnson Sealink,* operated by the Harbor Branch Oceanographic Institution, and WHOI's *Alvin.*

Underwater observations also reveal a surprising number of associations between different species. Many open-ocean crustaceans are found living on, or in, gelatinous planktonic animals. These are most often "commensal" amphipods, small crustaceans that ride around on jellies, sharing their food or consuming their hosts directly. Some amphipod species, for instance, reside inside a barrel-shaped salp, picking food from the salp's food stream—and some species simply eat the salp. But the purposes of associations are not always obvious: For example, lobster larvae carry small jellyfish as if they were parasols, and no one knows why.

A large part of Madin's work has been the study of salps. Many species of salps have specific amphipod commensals. In one project, Madin and former student Carol Diebel investigated sensory mechanisms in the amphipods that allow them to find the correct salps in the vast ocean. In another project, Madin used red carmine particles and green fluorescein dye to demonstrate that salps feed and swim simultaneously: The same muscular contraction that forces water through the animal's food filtration net also forces water out the salp's tail in organized pulses, providing a kind of jet-propelled locomotion.

The early work of Harbison, Madin, and a handful of other biological oceanographers at various institutions showed that jellies form a large component of the plankton and are important factors in the oceanic ecosystem. For example, salps package large quantities of "recycled" phytoplankton into their fecal pellets, which sink into the sunless depths where other animals consume them.

Harbison's and Madin's studies have evolved in many directions. Harbison is revising the entire taxonomy, or classification scheme, of ctenophores to include the discoveries of all the new species. This work will allow more accurate estimates of the number of species, their populations, and comparisons of current identifications with those of the past. Madin is investigating a salp behavior known as vertical migration. Salps may travel hundreds of meters up and down in the water column each day, perhaps timing their feeding and reproduction to environmental cues. Interestingly, both Madin and Harbison have begun separate studies that address the impact of jellies on vertebrates of great concern to humans—fish.

In the past few years, Harbison has researched the ctenophore *Mnemiopsis leidyi.* This seemingly innocuous predator was introduced into the Black Sea in discharged ship ballast water. With abundant food and no predators, the ballooning ctenophore population has seriously affected several commercially important Black Sea fish species. Harbison has proposed introducing fish that preferentially feed on gelatinous animals to control *Mnemiopsis* populations.

Madin has also worked recently on the problem of gelatinous predators on larval fish. On Georges Bank, a once-bountiful fishing ground fifty miles east of Cape Cod, there are few cod and haddock left due to prolonged overfishing. After the fishery's collapse, Madin and his colleagues discovered abundant colonies of predatory hydroids in the Bank's waters. They are raising and studying these animals at Madin's lab to determine their impact on remaining cod and haddock larvae populations.

Work on gelatinous zooplankton has come a long way, from the first glimpses into how and where these animals live, to the role they may play in large-scale ecosystem changes. But to these two biologists, the work has never lost its quality of surprise and adventure. Says Harbison, "There is a real sense of excitement in being among the first to observe the ways that these animals feed, escape, and interact with one another. We are, in spirit, nineteenth century naturalists using twentieth century tools."

For more information on this subject, (and many more photographs) read *Beneath Blue Waters: Meetings with Remarkable Deep-Sea Creatures* by Deborah Kovacs and Kate Madin, published by Viking Children's Books.

To order, call the WHOI Exhibit Center: (508) 289-2663.