far differently. "At NASA, there is a close understanding of the relationship between technology development and the ability to do science in the future," says Kennel, a former associate director at NASA. "I don't see a similar strategy in ocean technology." Marine geophysicist Fred Spiess of Scripps, who has developed instrumentation since the early 1950s, goes further: There is "no question," he contends, that funding is being squeezed to the point where ocean science suffers.

"Funding ocean instrumentation is a really tough job," says Mel Briscoe, director of the Processes and Prediction Division at the Office of Naval Research (ONR). "A normal 2- or 3-year proposal will barely get you started, and both the funder and the scientist have to be prepared for a long series of failures." Of the agencies that fund most instrumentation development—ONR, NSF, and the National Oceanic and Atmospheric Administration—the Navy has traditionally been the most willing to provide long-term support, says MBARI's McNutt. ONR, Briscoe maintains, is "perhaps singular" in its willingness to fund risky proposals and to encourage technology transfer from military applications to the research community.

Since the end of the Cold War, however, ONR's support for new instrumentation has dwindled, McNutt and others contend. Last year ONR spent $102 million on basic ocean science, compared to $98 million in 1990. "In inflated dollars, our budgets are smaller," Briscoe acknowledges. As a result, he says, "I don't think we are seeing as much instrumentation development." Briscoe adds that ONR'S funding emphasis shifted away from the open ocean to the coastal zone as the Navy's priorities changed at the end of the Cold War. Although ONR still supports AUV programs, nearshore observatories, and other select technologies, says Robert Gagosian, director of WHOI, researchers in fields such as acoustics and deep-sea research may feel left out to dry.

Despite its own flat budget for instrumentation, NSF is trying to fill the gap, says H. Lawrence Clark, who directs the agency's Oceanographic Technology and Interdisciplinary Coordination Program. Clark's program provides $4.5 million a year—about one-third of the agency's budget for ocean technology—as dashes of "venture capital" for projects that might otherwise fall through the cracks. And MBARI thrives because of its founder, the late electronics pioneer David Packard, whose gifts of more than $200 million endowed big-ticket items such as the *Western Flyer* and *Tiburon*.

The notion that private patronage is becoming more important in keeping ocean technology afloat makes Gagosian, for one, uncomfortable. "If we don't succeed in funding the instrumentation we need now with federal support, we will miss a window of opportunity unique to our generation," he says. "We have learned the scientific questions to ask, but we may lose the technical experts. They'll leave oceanography and go where the challenges are."

–ROBERT IRION

Robert Irion is a science writer in Santa Cruz, California.

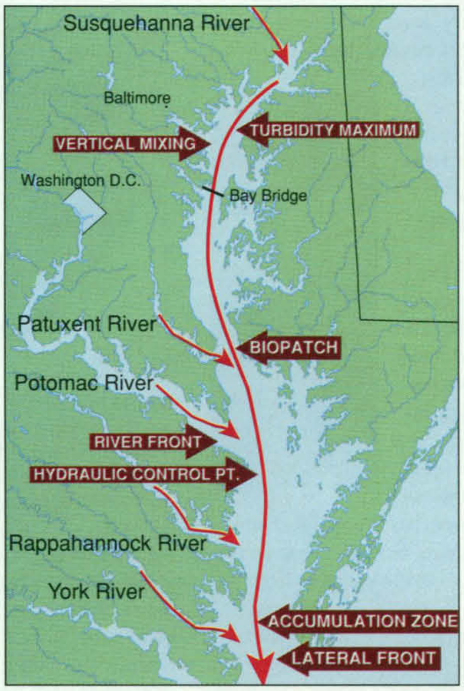
Stirring Up the Chesapeake's Cradle of Life

NEWS

Scientists are teasing out how the bay's currents and crannies create lavish nurseries for fish

Some say the best beachcombing spot along the Chesapeake Bay lies at the tip of its Eastern Shore, just north of where the bay spills into the Atlantic Ocean. Now that corner of the Chesapeake is drawing notice for a reason other than the fishing lures and driftwood that litter the sand there. Last year, Raleigh Hood, a biological modeler at the University of Maryland's (UMD's) Horn Point lab in Cambridge, proposed that everything from flotsam to plankton should be pulled together, like soap scum in a draining bathtub, by a 16-kilometer-wide eddy near the bay's mouth. At first Hood's colleagues were skeptical—his prediction, after all, relied on an error-prone mathematical model. Then last year, Hood says, scientists began tracking scads of jellyfish and anchovy larvae "right smack dab in the middle" of that part of the bay.

Hood and others now suspect that the eddy creates oases of tiny plants and animals that nourish fish and crustaceans. "It took some observations to wake us up," says Bill Boicourt, a UMD physical oceanographer. The area has joined a list of probable ecological hot spots in the Chesapeake now being studied in a 6-year, $3 million National Science Foundation (NSF) project called Trophic Interactions in Estuarine Systems (TIES). The project is testing the idea that an estuary's physics—its bumps and crevices and complex flows of fresh and salt water—largely explain why fishery yields in the Chesapeake and other bays are so much higher than in lakes and the open ocean. "People talk about it all the time," says estuarine ecologist John Day of Louisiana State University in Baton Rouge. "But careful documentation is lacking."



Mixing it up. At several spots in the Chesapeake Bay, swirling currents and unique topography create unusually rich ecosystems.

SOURCE: UMD

TIES has already changed how scientists view estuaries. So far, the group has documented the forces that sustain one of the bay's nutrient mixing areas, termed convergence zones, and even discovered the unexpected new zone near the bay's mouth. Figuring out why the Chesapeake teems with seafood may have a practical payoff, too. It could help agencies make better fishery-management decisions, such as where to dredge channels and how to clamp down on the surfeit of nitrogen and phosphorus running into the bay—nutrients that, at high levels, can fuel phytoplankton blooms that deplete the water's oxygen and kill fish.

The project, part of NSF's Land Margins Ecosystem Research program (see sidebar), traces its roots to studies in the 1960s that hinted at the importance of mixing zones such as turbidity maxima, where fresh river water collides with tide-driven brackish water, whipping up sediments chock-full of zooplankton and detritus. "There's 10 times, 100 times the ambient concentration of food, and that's where you're able to outgrow the competitors," UMD's Mike Roman says. But studies on turbidity maxima in the San Francisco Bay and the St. Lawrence River, for instance, focused mainly on the food pyramid's base, such as plankton and fish larvae, says microbial ecologist Tim Hollibaugh of the University of Georgia, Athens. TIES, launched in 1995, is moving the science up the food chain by exploring how local flow patterns caused by winds, tides, and topography affect higher trophic levels—from tiny crustaceans called copepods on up to striped bass and blue crabs. "TIES is taking on what we want to find out next," says Hollibaugh.

TIES is using high-tech muscle to achieve its aims. Researchers are mapping the bay's physics and biota using an array of data-gathering tools, including algae-tracking airplanes and fish-finding ships. One key instrument is the ScanFish, a flat, sensor-packed device that, lowered from a boat "like a yo-yo," says project co-leader Walter Boynton of UMD, measures temperature, depth, salinity, turbidity, oxygen, and plankton abundance. The ScanFish alone generates 480,000 data points on average per day during three cruises totaling 45 days a year.

Halfway through its term, the project has already yielded insights into how organisms benefit from the Chesapeake's plumbing. The team has found, for example, that light penetrates only a few centimeters into the turbid water of a roughly 50-square-kilometer area below the Susquehanna River. Despite such hostile conditions for plant life, this turbidity maximum supports a thriving food web, Boynton says, because currents carry in phytoplankton and other foods for higher organisms. "There were outrageous numbers of larger zooplankton and fish" in this zone in 1996, he says. Such findings carry "important news" for the U.S. Army Corps of Engineers and other agencies that groom the bay for navigation, says UMD fisheries biologist Ed Houde: Dredging near such zones could alter salt levels or topography and end up harming commercial species such as striped bass.

TIES researchers are studying other types of convergence zones, including "persistent lateral fronts" in the southern bay—essentially short-lived turbidity maxima that form and dissipate as the tides bring cold and warm, or salty and fresh, water masses together. They've also unleashed ScanFish on a region in the mid-bay called the "hydraulic control point," a turbulent area where the shallow bay suddenly plunges about 15 meters. Its violent currents, UMD's Boicourt says, should stir up pulses of nutrients and small organisms that spur plankton and fish growth. The team plans to set out by boat later this month to sample plankton and fish abundance there.

Although much of the TIES effort is aimed at sharpening a murky view of the bay whose broad outlines are well known, the team has come up with a few surprises—including the convergence zone in the lower bay where the beachcombers like to roam. Hood realized that nutrients might accumulate there after running computer simulations of how particles are washed through the bay. Verifying that this nutrient-rich zone supports a thriving community of fish and other organisms will likely require more passes with the ScanFish and other instruments, says Hood, whose group reports on the zone in a paper submitted to the *Journal of Geophysical Research*.

Experts say they're impressed by TIES so far. Findings on how fish larvae exploit turbidity maxima to hide from predators and eat in peace "caught me by surprise," says University of Rhode Island, Narragansett, estuarine ecologist Candace Oviatt. "It was completely new to me." Others say the jury is still out on whether the Chesapeake's physics accounts for the bay's booming wildlife. Still, "the detail of spatial variability they're getting is unprecedented," says ecologist Wim Kimmerer of San Francisco State University. "This is interesting stuff, well done, and it's going to produce a lot of good results."

—JOCELYN KAISER

Bringing Ocean 'Fringe' Research Into the Mainstream

Broad coastal studies such as the effort to map links between biology and physics in the Chesapeake Bay (see main text) are all too rare. Topping a list of hurdles impeding ambitious projects, experts say, is that much of the federal spending on coastal research—more than $200 million a year—gets frittered away on rote data collection. Congressionally mandated monitoring programs churn out statistics on everything from water oxygen levels to fish population size that tend to gather dust on agency shelves, says ecologist John Hobbie of the Marine Biological Laboratory in Woods Hole, Massachusetts. Very little money, he contends, goes for "anything that results in a publication."

That's bad news in light of the ecological threats menacing coastal waters. "We've learned in the last decade how important [coastal ecology] is to us," says Jim Cloern of the U.S. Geological Survey in Menlo Park, California, citing everything from dead zones in the Gulf of Mexico that suffocate marine life (see p. 190) to the possibility of vanishing coastlines if sea levels were to rise as a result of global warming. Potential perils such as these are underscored by the numbers of people living near coasts: According to an estimate by Harvard University's Andrew Mellinger, 38% of the U.S. population lived within 100 kilometers of a sea coastline in 1994.

Although officials acknowledge that coastal research dollars must be spent more wisely, a federal drive to instill science into monitoring programs has been halting at best. A White House–organized interagency project begun 3 years ago to coordinate ecological monitoring—including coastal studies—across agencies to develop a snapshot of the country's environmental health hasn't gotten off the ground, asserts marine ecologist Robert Huggett, research vice president at Michigan State University in East Lansing. Huggett calls the floundering effort "the greatest disappointment" of his recent 3-year stint as science chief at the Environmental Protection Agency.

Some agencies are forging ahead on their own to give monitoring a better scientific underpinning. Earlier this year, the National Oceanic and Atmospheric Administration (NOAA) set up a committee of outside scientists that will be "directly involved in designing and carrying out" the coastal component of the agency's U.S. Global Ocean Observing System, a program designed to beef up data collection from satellites, buoys, and boats, says Don Scavia, senior scientist at NOAA's National Ocean Service. The point, he says, is to convince both academics and staffers that "monitoring is another form of research. We're trying to change the perspective."

LMER COORDINATING OFFICE

Only marginal value? Plum Island Sound is the sole land-margin ecosystems research site added to NSF's LTER network so far.

One of the few programs to which experts give high marks for integrating monitoring and research is NSF's Land Margin Ecosystems Research (LMER) network, which for the past decade has funded multiyear projects (this year at Chesapeake Bay and three other sites). But NSF is now phasing out the LMERs, and the program tasked with continuing this sort of research—the Long-Term Ecological Research (LTER) network—has been slow to pick up the slack. In a coastal competition last year, only one proposal—from Plum Island Sound, Massachusetts, an LMER—made the cut to become an LTER. Although NSF plans to hold another competition this year, some worry that the end result could be fewer U.S. land-margin projects. And that would be another setback for a discipline that, in Hobbie's view, languishes as "almost an immature science."

—J.K.