WILLIAM McCLOSKEY

CHESAPEAKE BAY RESEARCH INSTITUTIONS: A BAY-WIDE PRESENCE

Dedicated Chesapeake Bay researchers have worked for decades to produce a literature of interdisciplinary knowledge on Bay properties and species, but some say that the work is just beginning. The first formal research institution on the Bay was established in 1925. More recently the four organizations of the Chesapeake Research Consortium, as well as other institutions, have increased this presence manyfold. The 1980s have marked the start of stronger political backing and more widespread public support for Bay research. Meanwhile, a rich variety of Bay research projects continues to seek knowledge of the chemical, physical, and biological processes that dictate the life of this great estuary.

People interact with the Chesapeake Bay year-round. Nothing but the bitterest cold stops oystermen throughout the winter, while shipping continues from the Atlantic Ocean to Baltimore and through the C&D Canal even if the Coast Guard must form an ice-breaking convoy. Here it was, a chilly day in early spring, still months away from the time when flotillas of pleasure boats would blanket the surface of Chesapeake Bay or when swimmers would mob the beaches; but scientists and fishermen were busy on the water.

In the lower Virginia part of the Bay's western shore, an aquatic botanist from the Virginia Institute of Marine Science, protected by a wet suit, takes cold spray as he bounces across the York River in an open skiff. He passes fishermen in oilskins, pulling gillnets heavy with an early run of sea trout. Dropping anchor in a tidal area that he had been monitoring, he dives into 5 feet of water to dig up mats of eelgrass from the bottom. Back at the Institute he will measure leaf lengths to study the growth of this submerged vegetation, an essential habitat of Chesapeake Bay life that in recent years has declined below all previous known levels.

Some 150 miles north, in the upper Maryland part of the Bay's eastern shore, a fishery biologist and his assistant from the Applied Physics Laboratory of The Johns Hopkins University slosh in waders through a still-cold stream that feeds the Chester River. They net blueback herring as the fish swim upstream to spawn. By fertilizing the roe, they will be able to grow thousands of larvae in order to study the effects on them of various contaminants that are believed to be decimating the river-spawned fish of Chesapeake Bay.

R/V *Ridgely Warfield,* owned by the Johns Hopkins Chesapeake Bay Institute. The 106-foot catamaran has been a familiar presence among Bay researchers since CBI acquired it in 1967. (Photographs by the author.)

The research of scientists has been a vital part of the Bay scene for decades. In recent years, the fate of the great estuary has also become a matter of intense

William McCloskey is a frequent contributor to the *Technical Digest*. As a freelance writer he has become particularly identified with issues concerning the sea. His most recent novel, *Highliners,* is about Alaskan fishermen.

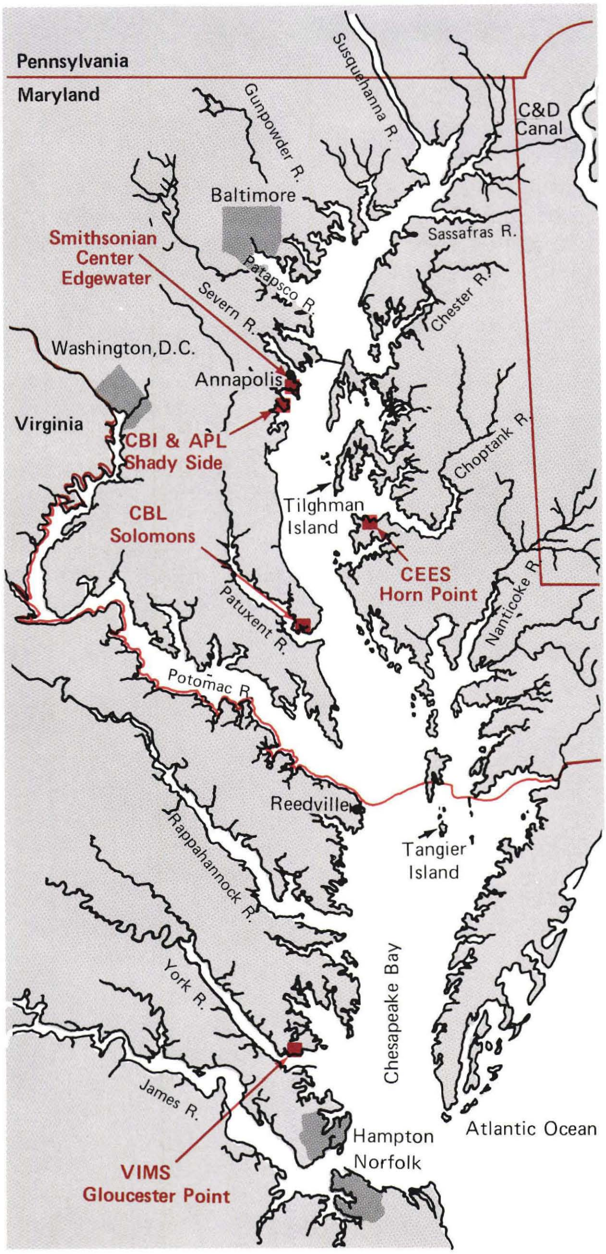
public attention.[1] Many who use the Bay for livelihood or pleasure have long watched some of its assets deteriorate. A more widespread concern began in 1977 when a bi-state conference signaled serious Bay-wide problems. In 1983, the Environmental Protection Agency (EPA) released its conclusions from a monumental 7-year study of Chesapeake Bay water quality. The study, completed and released in late 1983, consolidated existing information to reveal several alarming patterns that were changing the Bay's ecosystem. Among these patterns were a noncyclical decline of bay grasses and the habitats they provide, the retention of toxicants in bay sediments, the spread of oxygen-depleted water in which little or no life can survive, and an overload of nutrients from farm, urban, and suburban runoff. By mid-1984, this concern was translated into new legislatively funded programs in Maryland, Virginia, Pennsylvania, and the District of Columbia, as well as within the EPA itself. Despite budget-cutting pressures, additional federal agencies are now also contributing, while the funding for Bay work in all of the above constituencies was renewed the following year. The commitments are expected to continue.

Political recognition of the Bay's dangerous state is a necessity for marshalling the funds, resources, and civic support needed to alter trends in a system as vast and intricate as Chesapeake Bay. But the present action would not have been possible without the groundwork laid many years ago by the scientific research community.

THE CHESAPEAKE RESEARCH CONSORTIUM

Although more than a dozen laboratories in universities and other organizations have contributed basic research in specific areas, most of the sustained involvement in Chesapeake Bay research has emanated from four large institutions: the University of Maryland, the Virginia Institute of Marine Science, The Johns Hopkins University, and the Smithsonian Institution. In 1972, the four combined their efforts under an association, the Chesapeake Research Consortium, in order to broaden the impact of their resources through joint program development and coordination. First funded by the National Science Foundation through the RANN program (Research Applied to National Needs), the Consortium has since 1977 been supported by its members.

The Consortium is a unique organization in American science because of the comprehensive interinstitutional effort it can focus on the problems of a single, complex entity. The four member institutions have a combined talent pool of scientists in all the disciplines related to estuarine research. According to L. Eugene Cronin, the Consortium director during 1977-1984 (whose earlier career as a marine biologist concentrated on the Chesapeake Bay blue crab before he became director of the University of Maryland's Chesapeake Biological Laboratory): "No other research group exists that can assemble the kinds of multidisciplinary



Map of the Chesapeake Bay region, showing principal communities and rivers as well as locations (in color) of Chesapeake Research Consortium facilities.

staffs and specialized facilities needed to tackle problems as large-scale as those dealing with the entire Chesapeake system. Our concern is Bay-wide, every day."[2] The director since 1984 has been Maurice P. Lynch, who also heads the Virginia Institute of Marine Science, Division of Marine Resources Management. As public interest increases in "cleaning up" the Bay, Lynch sees one of the Consortium's most important roles as that of liaison between the research community and the state and federal agencies that make the decisions. "In the Bay, there are traditional and strong links between the four institutions and the management agencies. We're able to bring a high sensitivity to the agencies' needs," Lynch declares.

The objectives of the Chesapeake Research Consortium are stated in its charter: "To identify and catalogue the principal environmental, marine, atmospheric, terrestrial, societal and technological problems of the Chesapeake Bay and its contiguous region. To conduct, sponsor, contract for, and otherwise foster and facilitate study and research directed toward the solution of such problems. To assist in the management of the resources of the Chesapeake Bay region by collaborating with agencies in government and society, by participating in the dissemination of information, and by contributing to education programs." At the center of its effort, the Consortium develops proposals and works to get them funded, drawing on the strengths of its member organizations.

While each member of the Consortium participates in cooperative projects, each has separate, major, Bay-related programs. In certain areas, such as the courses of anoxia and hypoxia, several of the institutions are studying different aspects of the same large-scale process. A sampling of some investigations illustrates the character and diversity of Chesapeake Bay research.

UNIVERSITY OF MARYLAND CENTER FOR ENVIRONMENTAL AND ESTUARINE STUDIES

The Center for Environmental and Estuarine Studies (CEES), the environmental arm of the University of Maryland, is chartered by the State of Maryland. Established in 1973, it was an outgrowth of the University's Natural Resources Institute that had opened more than a decade before and had direct roots back to 1925 via CBL (see below). CEES comprises three separate research facilities in Maryland—the Horn Point Environmental Laboratory (HPEL) near Cambridge, the Chesapeake Biological Laboratory (CBL) at Solomons (both dealing primarily with the Chesapeake Bay), and the Appalachian Environmental Laboratory (AEL) in Frostburg. Annual funding of $7 million includes $4 million from the state and the rest from independently solicited grants and contracts. More than three quarters of the effort is concentrated in the two Bay laboratories, with Horn Point accounting for $3 million of the total CEES budget. The combined facilities have a personnel complement of 230, which includes a faculty of 50, as well as 80 graduate students.

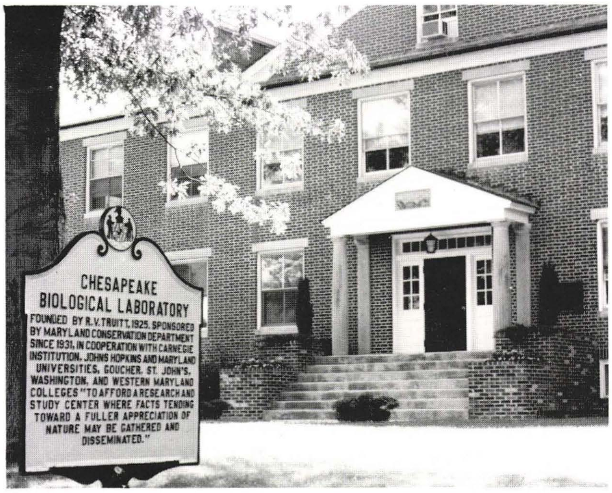
Phytoplankton culture for feeding striped bass is grown in enriched water at the University of Maryland's Chesapeake Biological Laboratory of the Center for Environmental and Estuarine Studies at Solomons, Md. Transferring some of the culture is graduate student Dave Jenkins.

"We're fortunate to be our own campus," says Ian Morris, oceanographer and director of CEES. We were walking under large trees next to the administration building at the CEES Horn Point facility, a former DuPont estate that now houses the Center's headquarters as well as its largest laboratory. A few feet away flowed the wide Choptank River, a major eastern shore tributary of the Chesapeake Bay. Out on the water bobbed a scattering of weathered boats with one or two Bay watermen in each, tonging the last of the season's oysters. The sun glinted on the wet part of the heavy shafts they worked hand over hand, dramatizing the proximity of the men doing research on Bay waters to the men who rely on the productiveness of Bay waters for their living.

CEES remains administratively separate from the other University of Maryland campuses, with Morris reporting directly to the president of the University. The Center does not award degrees. Graduate students do much of their research on location at the laboratories but return to one of the University's teaching campuses for course work.

"It's one of the best structures you can have for an off-campus organization," said Morris with vigorous conviction, his Welch background apparent in a speech lilt just short of a brogue. "Many off-campus environmental or marine laboratories get in trouble once resources tighten and the main campus wants to question having a branch out in the wilds. We run ourselves —we have our own personnel, our own grants and contracts. It means we can be effective within the University structure but also quickly responsive to the needs of the state. The University president can pick up the telephone and tell me directly that some environmental issue within the state should be worked on."

CEES places particular emphasis on physical oceanography, marine and estuarine chemistry and geochemistry, fisheries, and toxicology. As applied to the Chesapeake Bay system, this work includes projects in nutrient dynamics and productivity, long-term trends, changes in water quality, many aspects of fisheries, and the influences of activities within the Bay's drainage system. The organization boasts among its principal investigators several international authorities on fisheries and the ocean sciences. Under the new regional impetus to understand the Bay, CEES is currently enriching its departments with new appointments, and expanding its focus. The basic mission is to serve the needs of Maryland, and, declares Morris with conviction, "you will make your most important contribu-



Original building of the Chesapeake Biological Laboratory of the University of Maryland. CBL was founded in 1925, with Johns Hopkins as one of its sponsors. At the time of its establishment, CBL was the pioneer research organization concerned with the Chesapeake Bay.

tion to the state only by doing the best science on the Bay with the very best scientists."

The expansion was particularly evident at CEES's other waterside facility, the Chesapeake Biological Laboratory (CBL), located at Solomons on the western shore, across the Bay from Horn Point. Here, in sight of a Patuxent River harbor full of boats ranging from skiffs to yachts, stand the square brick buildings of the region's senior estuarine laboratory, established in 1925. (CBL is the oldest permanent state-supported marine biological laboratory in continuous use on the east coast, to give it full credit.) The offices, laboratories, and dormitory buildings might appear mellow and settled. Inside some, however, the dust of construction flies as workmen juggle space to make room for an expanding department of environmental chemistry and toxicology. Eventually, a new building will house the expensive, sophisticated mass spectrometer, radioisotope and atomic absorption units, electron microscopes, computers, darkrooms, and other support equipment. For the moment, Bay sediments and water columns are being examined with this state-of-the-art equipment wedged into converted storage and office spaces.

One major new effort, funded by the National Science Foundation, will examine the disposition of materials entering the Bay, using in tandem the disciplines of chemistry, sedimentology, and microbiology. According to Don Rice, the trace-element geochemist directing the project, "We have some feel for what's coming into the Bay—metals, nutrients, organic substances—on the basis of public record and analytical work done on the water column. The question is: where does it go? What's entering the sediments, what's going into the ocean? What happens when metals and organic substances, for example, arrive at the sediment/water interface in a particulate form? We know that some sediment mixing takes place at once, by worms, burrowing mollusks, storm events. It's a very dynamic physical system there. But how much goes down? How much is mixed in? Of what is mixed in, how much is converted to another soluble form and returns to the water column? How much is immobilized as insoluble material—as, say, metal sulfide—and is eventually buried into the geologic column?"

Sediment core sample of Chesapeake Bay bottom examined by Donald Rice of CBL. The major sediment layers are easily visible, but analytical instruments can identify and quantify the contents of the cores down to the merest traces.

Rice's procedure begins with boat time, as does much of the Bay scientific work on the water. He will take core samples from distinct environments—shallows where the water is frequently disturbed, a creek in a stable but seasonally varied area, deep water where the stability of the estuarine environment is greatest. The project investigators must be sensitive to preserving four components in the samples they take: sediment particles, the water and/or mud between, the overlying sediment at the interface, and the organisms whose habitat is the sediment. Back at the lab, analytical instruments can identify and quantify the elements and compounds of the cores down to merest traces.

Contrary to popular conceptions, Rice points out that much of what enters the Bay is natural. The major source of metals, for example, is weathered rock. "I don't feel that everything man does to nature creates a problem. It's simply not true. Any more than what a lion does or an oyster does to nature is a bad thing. However, if you have too many oysters or too many lions, then you've got problems as they do too much of their own thing. We're part of nature, and as long as we don't exceed the carrying capacity of our environment we can do quite well in it.''

On another scientific front at CBL, estuarine ecologist Walter Boynton has just completed his part of a massive study on submerged aquatic vegetation that also involved scientists from Horn Point and the Virginia Institute of Marine Science. The CBL contribution led to one of the EPA report's most unexpected conclusions: that the sudden disappearance of submerged aquatic vegetation in Bay waters may be the fault not of toxics, but of overstimulated algal growth that blocks sunlight. Boynton is now investigating the way that inorganic materials such as nutrients and fertilizers interact with components of the Bay system like the primary producers, phytoplankton and zooplankton.

VIRGINIA INSTITUTE OF MARINE SCIENCE

The Virginia Institute of Marine Science (VIMS) is the School of Marine Science of The College of William and Mary. It was established in 1940 as the Virginia Fisheries Laboratory. With growth under the directorship of William J. Hargis, it attained its present status and name in 1962. The mission-oriented VIMS has more of its work dictated by Virginia state charter than is the case with its Maryland counterpart, CEES. From the start, VIMS has emphasized fisheries science and biological oceanography. Its mandate in the Code of Virginia has been expanded to include physical, chemical, and geological oceanography, estuarine engineering, and wetlands ecology. Funding in 1985 is \$10.1 million, with \$8 million of this provided by the Commonwealth of Virginia and the remainder from grants and contracts. This year, the legislature voted an additional \$1.7 million to provide for several new Chesapeake Bay research projects recommended in the EPA study.

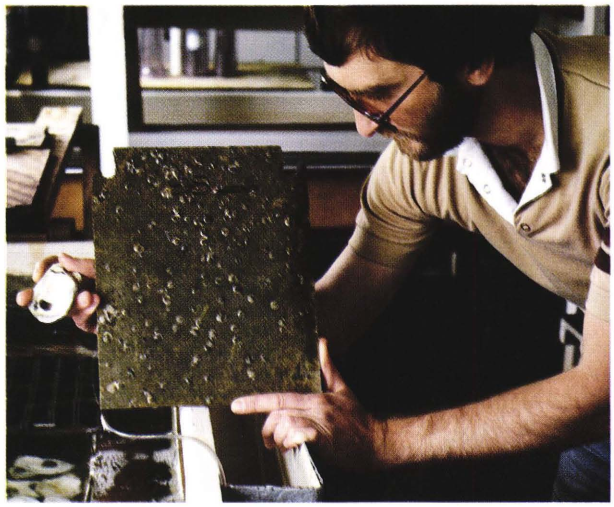
VIMS has an impressive location near the York River Bridge, facing historic Yorktown across the water. Several long, square brick buildings, connected by steps along a hillside, combine an administrative center and library with a congeries of laboratories. Surrounding this nucleus are frame houses converted to the book-strewn offices scientists keep. From the waterside labs, two long piers stretch beyond the tidal shallows so that boats can moor at any time. The boats themselves dock at a complete marina facility, reached either through a breakwater or by a road skirting a small public beach.

''Within the university, we're on a par with law or business administration,'' says Frank Perkins, director of VIMS. ''This is a graduate education program, not an independent state agency. However, the state appropriates funds specifically identified to support our mandates. This is not the case for the other schools of the college.''

We sat in Perkins's roomy office with windows on two sides overlooking the York River. It was still chilly in early May, but just below us a young man and woman waded beyond their waists holding up an assemblage of instruments. Out on the end of the largest pier, three men in shorts and foul-weather jackets transferred an assortment of nets, tanks, and large specimen bottles from a skiff to a pickup truck. In the channel, a larger covered boat pitched toward the open Bay with businesslike speed. Ashore, on the steps leading down to the laboratories, a woman and a bearded man in white lab coats had stopped to talk. ''All VIMS,'' said Perkins. His office was full of artifacts and pictures of the world's mollusks, befitting his international reputation as an authority on oyster diseases.

''I think our greatest strong point is the ability to respond in a timely fashion to the needs of Virginia's managers and users. Another strong point is our ability to mount a multidisciplinary effort. Even though

Virginia Institute of Marine Science (VIMS) researchers wade into the chilly York River in late spring to take readings and water samples around submerged aquatic vegetation at one of several sites being monitored. The two piers are part of the large VIMS facility that includes a hillside of laboratories and offices as well as a marina for research vessels.



Hatchery-raised oysters: Dan Hepworth of VIMS holds the shell of an adult oyster alongside an experiment plate containing recently set oyster spat. The VIMS laboratory contains tanks in which oysters can grow in free-flowing filtered water from the York River during all parts of their life cycle.

we have tenured full professors here, everyone is keyed to the necessity of being a team player. It's a different climate than you find in a normal academic environment. There's more independence of action."

A DAY AT VIMS WITH GREENHEADS AND LITTLE CRABS

Many Bay projects require constant on-site observation and sampling of local marine life. For this purpose, VIMS maintains a fleet of vessels under port captain George Pongonis: an 85-foot former buoy tender, two 40-foot converted fishing boats, and some 30 other boats and skiffs that researchers take out themselves.

At 6:00 one June morning, we met on the long "ferry pier" where a frame building houses rudimentary offices, a wet lab, and a roomful of wetsuits and other diving eqipment. Marine biologist Jack van Montfrans had begun assembling a formidable amount of gear on the wharf: a big net rolled on two staves like a Torah, ice chests for specimens, electronic boxes and wires, plastic buckets, heavy-duty bug spray, and an assortment of longhandled shovels and dip nets. We passed it all to Bill Cooper for stowage in his "Guinea" boat, a wide-beamed wooden skiff with a flat bottom, adopted by local fishermen who work the marshes and tidal flats. By 6:15 we were cruising down the York River, the early sky rosy against the trees and houses of the shoreline. Ominously strong breezes kicked up the water, suggesting that a storm predicted for late afternoon might arrive early and compromise the day's work, which required another boat to meet us at 10 P.M.

Cooper, an aquatic ecologist on sabbatical to VIMS from Michigan State University, steered when he could into calmer water sheltered by islands of marsh grass. Our passage startled the resident herons and egrets into flight. At one point, the water, although at high tide, became so shallow that buff-colored sand appeared close enough to touch.

The area is known as the "Guinea Marshes," inhabited and worked by descendants of watermen said to have fled to this remote area after the surrender of Cornwallis at nearby Yorktown in 1781. As British sympathizers, they continued to use the currency of shillings and guineas while living in the protected marshes. The area remains remote, and the speech of local watermen has a turn all its own. The situation is a reminder of the role Chesapeake Bay and its tributaries played in early American history. Not far away, on the James River that flows into the Bay only a few miles by land from the York River, stands the reconstructed first permanent settlement in the New World, Jamestown.

We reached the project site at the mouth of a creek that wound back through fields of marsh. The early sun gleamed on a few white houses—the only ones in sight, miles away—and on the wide wings of birds scouting the grasses for food. Fiercely biting greenhead flies descended on us immediately, along with an abundance of mosquitoes, as we waded through clusters of sea nettles to unload the boat. Despite the heat, we wore slip-on dive boots, old jeans and long-sleeved shirts for

Catching, tagging, and monitoring the movement of recruit crabs in the marshes of lower Chesapeake Bay. Field lab work on such a project includes coping with aggressive insects and gumbo mud for Jack van Montfrans of VIMS (setting up a tag detector) and William Cooper of Michigan State University (working a net in the water). Magnetic tags inserted in crabs captured briefly two days before help document the migration patterns of juvenile blue crabs.

as much protection as possible. Even so, we stripped momentarily to spray against the chiggers that van Montfrans warned from experience can also be "plentiful and awful."

The tide was just beginning to ebb, pulling ripples along a sand bar at the creek mouth. The two scientists unrolled the long net and, sloshing sometimes chest-deep through the water, secured it across the opening and tightly against each bank. This would trap any crabs leaving the creek on the tide.

"The marsh is an important crab habitat," explained van Montfrans as he pulled his feet out of gummy black mud and climbed to dry ground. "One way to measure the importance is in terms of residence times. How long does a crab spend here? In the case of a tidal creek like this one, he may just come in to molt, then leave at once. Or he may come in for longer if he can find food."

According to van Montfrans, the pattern of the blue crabs' adult migrations is well documented, but not that of juveniles. This is because most studies use external tags attached to the outer shell, which young crabs shed during frequent molts. To obtain accurate information on juvenile residence times, he needed an internal tag that could not be shed. To provide this, he inserted a thin magnetic wire into the "backfin" muscle. Two days before, he had captured and tagged 253 crabs by this method. In the experiment today, he planned to pass the crabs we caught through a detector (which he began to assemble on a makeshift table) to see how many of those tagged 48 hours ago remained in the creek.

Bill Cooper had come along to help because the catching and tagging, however scientific, is also labor-intensive. His own project since March concerned life in the beds of eelgrass, in an area offshore of the marshes at the point where low tide remains high enough to support submerged aquatic vegetation. Once a week he anchored in the grasses all night long and pulled gillnets of several mesh sizes every 2 hours to catch a sampling of every fish feeding below. (Shallow-water marine life generally feeds under cover of darkness.) "In March the water was cold enough," he explains, "that I could just come back to the nets in the morning, but with warmer water the crabs are active. All I'd get now of other species in the morning would be noses and tails with no stomachs left." Cooper, along with VIMS student Cliff Ryer (due this morning in the second boat), spends the rest of the week analyzing the contents of the stomachs in the fish he nets, to determine their eating habits. "Eelgrass beds are important feeding and nursery grounds for lots of species. The consensus is that predation causes part of the structure in this biological community. But so little is known specifically."

Cooper's major work has been with freshwater fish in the Great Lakes, where the stomachs of fish like bass and bluegill show a diversity of food from flies to arthropods and zooplankton. But, he says, the saline water species in the eelgrass act quite differently. (Remember that the location is near the mouth of York River which interacts with Chesapeake Bay tides only a few miles from the salty Atlantic.) "The fish here seem to feed quite specifically: silver perch on shrimp, spot on benthic worms and arthropods. Some fish within the same school have fed exclusively on different things. Why? And, what strategy do they use?"

We pulled an open net through the water where we blocked the exit to capture a few crabs and lots of small fish. "Anne asked for some *Fundulus*," noted Cooper, and he carefully selected a number of brown and silver hopping little fish of this species (known colloquially as mummichogs or killifish). Back at VIMS, Anne Weeks was conducting an extended study on the ways pollution in the environment affects the immune systems of fish. The findings promise to relate directly to humans, since the chemicals identified as local pollutants are mostly carcinogens that are known to suppress the human immune system. "Obviously," Weeks had told me earlier at her VIMS lab, "if this pollution depresses immunity, then these fish will be more susceptible to disease or the effects of toxins. We've been concentrating on the microphage cell, the most important cell of the immune systems, which kills bacteria and viruses by engulfing them, and which also removes toxic chemicals from the host."

We kept Dr. Weeks's *Fundulus* alive by changing the water in their bucket regularly as the sun heated it. The day's work in the marsh turned mucky and sweaty, punctuated by a steady tattoo of biting insects. As the tide in the creek receded, we stalked the banks with dip nets (trying to avoid clouding the water with our feet), then pounced to capture crabs we saw. Blue crabs, even those no longer than an inch, proved to be belligerent survivors. If the net missed, they were gone. If captured, their little claws bit the thick rubber gloves we wore. These were "recruit" crabs, believed to have hatched one year ago at the mouth of the Bay in high salinity water, now enacting one phase of their migratory cycle.

The receding tide bared more and more mud. Sometimes while pursuing a crab we sank to our knees in gumbo, and a fetid odor rose from all the decayed matter it held. The validity of the experiment hinged on the number of crabs we could sample. Van Montfrans was the first to kneel in the mud and work his fingers through it. When we followed suit we found a new crop of wriggling, snapping little crabs an inch beneath the surface.

The second boat arrived on schedule around 10 o'clock. Low tide required anchoring a quarter mile offshore, so Cliff Ryer and Elizabeth Bowden needed to hike across the exposed tidal flats to join us. We now had enough crabs in the live box for van Montfrans, assisted by technican Bowden, to begin counting and recording. The rest of us continued to stalk recruits.

Van Montfrans held each crab gingerly (we had taken care all along not to injure them) and passed it back and forth through the tag detector. After a quick examination, he measured it on a metric scale and tossed it into a pound from which it would be released after the census. "Female, R-4 missing" (i.e., fourth right leg), "white line" (molt condition: early stage peeler), "79" (carapace width in millimeters). . . ,"Female, inner molt, 86, strong as hell," Eleven crabs into the catch, the detector emitted a sturdy electronic beep. "Tag," announced van Montfrans, and everybody cheered. If no crabs had registered, it could have indicated that all the crabs tagged 2 days before had already gone—or that the system didn't work. The beep was reassuring. "Male, R and L-1 missing. Oh!" (It had pinched his finger.) "75."

We captured 240 crabs, and 36 of them had been tagged. "This indicates they're spending some time in the creek," said van Montfrans. The experiment will continue as long as tagged crabs appear and then will start over. The trip back to VIMS had us bucking a headwind and taking sheets of spray as gray cumulus built in the sky above an approaching wall of pure black. Just before the storm struck, we veered into a little fishing harbor and found shelter ashore against volleys of lightning and rain.

Not all forays into the field are this dramatic. On a calmer day, I rode a larger VIMS boat with two young technicians to sample the water around selected stands of eelgrass (*Zostera marina*). Under the direction of aquatic botanist Dick Wetzel, several sites were being monitored to study the disturbing disappearance in Bay waters of the submerged aquatic vegetation that provides habitat for a number of ecologically important species in the estuarine food chain. As other studies at VIMS and CEES had indicated, the blocking of light caused by extreme phytoplankton and algal growth might be a decisive factor in the decline. Nutrients in the water might be the cause of the excess algal growth. Only controlled experiments and monitoring can determine for sure.

In an attempt to understand the growth requirements of the grasses, the VIMS researchers chose five locations along a 12-mile stretch of the York River, from the mouth (affected by cleaner saltwater inflows) to an upriver site (where salt water mixes with freshwater runoff to provide a more turbid condition). While all the sites had once supported sea grasses, only the one at the mouth still grew it in any abundance. New grass had to be planted in the upstream locations. Monitoring had continued every 2 weeks since fall (it was now June), even when it meant dodging winter ice, according to Matt Pavarnik and Kim Olsen who both had clocked some cold, windy hours in the process. On the sunny day I rode with them, they took water samples and read instruments with which to record temperature, salinity, dissolved oxygen, and light at different depths. Back at VIMS, the water samples would be tested for suspended solids and for nutrients. The morning of data collecting went smoothly, except for an engine problem that required an exchange of boats when we reached the Number Three site of transplants, located conveniently just offshore from the brick buildings of VIMS. Research in the field is never completely predictable.

THE JOHNS HOPKINS UNIVERSITY

The Johns Hopkins University performs most of its Chesapeake Bay research from a facility at Shady Side, Md., that houses the Chesapeake Bay Institute as well as APL's aquatic ecology program. Several departments on campus also conduct individual Bay-related projects—the Biology Department in marine biology, the Department of Geography and Environmental Engineering in water quality, the Department of Earth and Planetary Sciences in geochemistry and fluid mechanics, and the School of Public Health in aquatic toxicology. Funding for JHU Bay research is provided by grants and contracts rather than through legislative subsidy.

Chesapeake Bay Institute

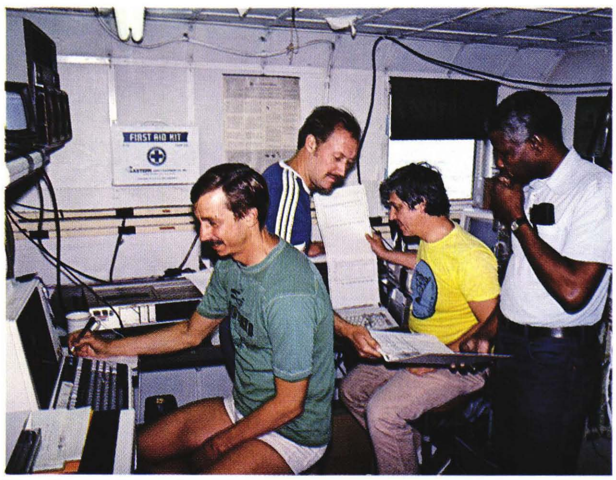
The Chesapeake Bay Institute (CBI), established in 1948, remained for many years Maryland's physical oceanography presence on the Bay. Under its former director, Donald W. Pritchard, CBI gained an international reputation, particularly in estuarine and coastal research. The departure of key personnel curtailed the work of CBI in the mid-1970s, but with several new appointments the University is now gearing CBI to resume its major role in Bay research. Many projects have continued at CBI—some on a worldwide basis—in the areas of biological oceanography and marine microbiology. The CBI research vessel R/V *Ridgely Warfield* remains an important presence on Chesapeake Bay, since CBI maintains the 106-foot catamaran for its own projects, for use by National Science Foundation grantees, and for lease to other Bay researchers.

According to Richard A. Zdanis, vice provost, The Johns Hopkins University is in the process of rebuilding the Chesapeake Bay Institute "in order to make it the focus of oceanographic interests throughout the university." He sees CBI as a potential focal point for problems encountered in the marine environment, not only in the Bay but also in larger bodies of water.

Applied Physics Laboratory

APL has conducted Bay-related research for approximately two decades, particularly in the areas of power plant siting, aquatic toxicology, and striped bass population dynamics, and recently also in physical dynamics as related to biological productivity and oxygen depletion. Established in 1942 as a division of the University, its primary mission is the development and evaluation of systems for the defense of the U.S. Navy. The pool of scientific and technological talent brought to bear on Navy projects has since then also been marshalled for developments in space, biomedicine, energy, urban fires, urban transportation, and numerous other fields. The APL Submarine Technology Department performs extensive oceanography research. This department's aquatic ecology program, headed by Dennis T. Burton, deals with Chesapeake Bay biological systems.

The potential contribution of APL to the University's effort in physical oceanography interests Zdanis of Hopkins particularly. "First, there is the investment in instrumentation that the Navy has made at APL for



Members of an APL team aboard R/V *Ridgely Warfield* examine raw data plots on the physical properties of a Chesapeake Bay water column. Left to right are Charles Sarabun, Joe Hopkins, Alan Brandt, and Willie Drummond. The APL group worked in conjunction with a team from The Johns Hopkins University and the University of Delaware to conduct interdisciplinary studies of oxygen depletion and its related conditions.

many years, in devising new methods of measuring small-scale phenomena in the ocean. We can surely bring some of that expertise and instrumentation into the private sector. Then, there is the knowledge that APL has gained in remote sensing, which is becoming more and more the preferred method for measuring oceanographic parameters. Such Bay research is a natural outlet for the non-security interests of the people at APL."

Oxygen Depletion in Chesapeake Bay

Last May, working together for a second year aboard the R/V *Ridgely Warfield* and the University of Delaware's R/V *Cape Henlopen*, a team funded by the National Science Foundation from The Johns Hopkins University and the University of Delaware was joined by a team from APL. They conducted interdisciplinary studies of oxygen depletion and its related conditions in Bay waters. Specifically, the project measured the biological, chemical, and physical processes that occurred throughout the water column in several locations during the 26 hours of a complete tidal cycle, i.e., two tidal periods. The studies both years were conducted between April and early June, during the rise of anoxia in the Bay. (Depending on spring runoff and meteorological conditions, varying quantities of anoxia remain until fall, when winds and surface cooling cause the water column to mix and distribute oxygen back to the bottom waters.)

The seasonal lack of oxygen in some Bay waters drives out crabs and fish and kills stationary species such as oysters and clams. In recent years, anoxic conditions appear to have spread over larger portions of Bay waters and to have invaded shallower depths. The condition is blamed as a contributor to the sharp decrease in the Bay's oyster population in recent years—the 1984 and 1985 oyster harvests have been the lowest the Bay has seen in over a century of record-keeping.

With a variety of conditions to be monitored, the researchers worked both as individuals and as a group. Howard Seliger of the Hopkins Homewood Campus gathered data on plankton evolution and the process of plankton transport, as well as on dissolved oxygen and nutrients. The APL team gathered data on temperature, salinity, and velocity, which are the physical properties of the water column. Despite the relatively brief sampling period, the observations can furnish effective glimpses of the longer-term dynamic changes related to the production and consumption of oxygen in Bay waters, and the consequences of anoxia.

The research vessels were anchored in several locations, most of them near Annapolis and the Bay Bridge. Life on board was cramped, busy, informal. Living spaces forward allow the entire midships area to be used for laboratories. The labs connect to the working deck aft through large doors that allow easy movement between the benches and long tables loaded with equipment, and monitoring instruments in the water. A central portion of the afterdeck is open to water, like a reverse skylight, so that instruments can be lowered from a stable platform even in rough weather.

On deck, Randy Loftus of CBI worked a boom to lower a current meter to various depths. He called readings at 2-minute intervals to Alan Brandt, APL, for recording. Joe Hopkins, also of APL, worked on deck with a sturdy, waterproof camera chamber he had devised for underwater illumination and video photography. In the laboratory area, he monitored the video tapes thus made to record a density count of local sea life. Across the screen flitted a multitude of specks and small blobs, occasionally obliterated by the shadow of some larger creature.

As a result of the equipment available, the data sets gathered in the 2 years of monitoring are considered to be superior in detail and accuracy to any gathered previously in estuarine waters.[3] APL supplied oceanographic instruments and measurement techniques based on those it had originally developed for Navy ocean tests. Three specific instruments were used. One was an accurate profiling system for obtaining mean temperature, salinity, and velocity profiles. Another was a high-frequency (200-kilohertz) acoustic fathometer that allowed visual tracking of internal wave structures in portions of the water column where scattered objects

Aboard R/V *Ridgely Warfield* during an oxygen depletion study, crewmen prepare a waterproof bio-optical video system for lowering over the side. Joe Hopkins of APL, center, developed the system. The chamber at left houses a parallel light source that projects shadowgraph images of small sea life passing through the gap. The video camera is housed in the large chamber. Crewmen, left to right, are Randy Loftus and Doug Hallock.

were present. The third instrument was a moored vertical chain of 10 fast-response thermistors spaced 0.5 meter apart. The thermistors measure high-frequency fluctuations, yielding information about internal waves and turbulence in the thermocline.

Larvae for Fish Toxicology Studies

"We need ripe and running fish," declares Ronald Klauda, fishery biologist of the APL aquatic ecology section, who heads a current project on the effects of acid rain and dissolved aluminum on fish larvae. It was mid-April and the dogwoods in bloom made sketchy patches of pink and white among trees barely in leaf. When we watched the water through Polaroid glasses, which eliminate the surface reflections, we saw the dark foot-long bullet shapes of fish moving in formation by the dozens. The blueback herring had returned from the Atlantic Ocean for their annual spawning rite after a nearly 200-mile swim. The stream, Unicorn Branch, near Millington, Md., feeds the Chester River, a major northern tributary of the Chesapeake Bay.

Soon Klauda, with mud sucking at the feet of his floppy waders, was stalking the fish, along with his lab technician, Steve Fischer, from the University of Wisconsin. They stretched a net from bank to bank. At a bridge and alongside the dam, a few local people were also trying their hand with net and line to catch a fry for dinner.

The blueback herring, as well as other herrings and shad, are among the Bay's anadromous fish—those that hatch in the fresh water of rivers but spend their adult lives in the salt water of the sea. The Bay species also include such semianadromous fish as striped bass (locally called rockfish), white perch, and yellow perch.[4] All have shown alarming population declines in recent years. The succulent shad has virtually disappeared from the Chesapeake where it once was abundant, while striped bass—treasured by commercial fishermen and sportsmen alike—have become so endangered that in January 1985 the state of Maryland imposed a total ban on catching them. The most vulnerable time for the fish appears to be during the hatching stage when, as larvae and then fingerlings, they are located in the tributary waters of the Bay that are most likely to be polluted by sewage treatment chemicals, industrial wastes, urban and suburban runoff, and acid rain. However, considering the difficulty of changing any of these conditions, Klauda says: "It is important to know which pollutants may be affecting the fish and to what degree. The answers can only be obtained accurately through disciplined research."

In some places, the stream surface erupted in splashes as the spawning process began. Klauda needed to capture several females with ripe eggs and some males with sperm to fertilize the eggs. The only way to appreciate the flitting speed with which a healthy fish can elude capture is to try netting one. The water might be crowded with their graceful shapes, but at the slightest moving shadow or motion of a dipnet they spook and scatter. Eventually, Steve grew skilled enough as he stood on the downstream side of the barrier net (in cold swirling water up to his waist, his waders leaking a bit) to jerk up a long-poled dipnet fast enough to capture one to four fish. But often the net came up empty.

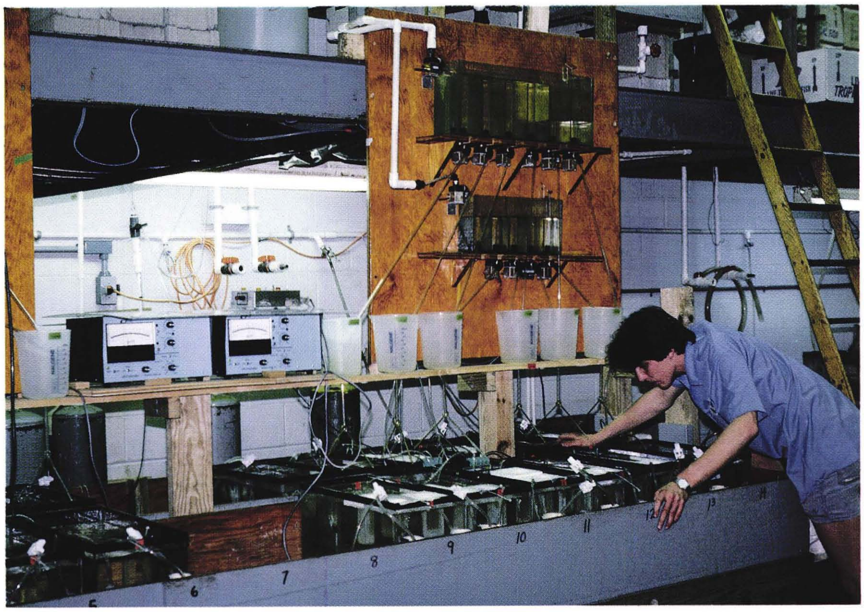
Klauda's study, funded by the state of Maryland under the Department of Natural Resources' Power Plant Siting Program, will test the reaction of anadromous fish eggs and larvae both to water with lowered pH levels designed to simulate the influence of acid rain and to water with high levels of trace metals, particularly aluminum. Since the project requires thousands of young fish, the first step was to obtain the eggs from which they would hatch. Klauda carefully extracted the female's eggs and transferred them into a basin that contained stream water. The pale orange eggs, each barely a speck, emerged by the thousands in a sticky mass. Klauda added the milky sperm from some male fish (gently squeezed from the fish's underside with less effort than removing toothpaste from a tube), and mixed it among the eggs with a stiff white turkey feather. The motion separated the individual eggs although a few clung as tiny dots to the feather. After several minutes he transferred the mixture into a high cylindrical McDonald hatching jar filled with stream water.

Periodically, Klauda agitated the eggs back into suspension with a rotating paddle that is part of the jar's design. He also monitored water temperature in the jar. When it rose by a degree, he siphoned off some water and replaced it with fresh-dipped river water. The parenting continued during the 2-hour return across the Bay Bridge to Shady Side, using a battery-operated aerator to pump air bubbles through the water and stopping occasionally to freshen the water from a thermos bucket.

Klauda monitored the eggs for 48 hours, after which they began to hatch. However, within 4 hours of the operation he had performed streamside, he examined the eggs for evidence of the expected cell division and determined that they had been successfully fertilized.

The project then switched to the Shady Side area. At Lyons Creek, where blueback herring had once been abundant, some of the hatched larvae continued their growth. They were contained in traps through which the water bearing ambient nutrients flowed naturally. Mike Jepson and others collected samples of the larvae periodically and tested them for reactions, working close by the creek in a shack equipped as a field lab. The rest of the herring larvae (and some shad larvae from another source) occupied aquariums and big circular holding tanks at the Shady Side laboratory. Here, under the direction of Bob Palmer, a controlled diluter system maintained the water in the various containers at four different pH (acid) levels—5.0, 5.7, 6.5, and 7.8 (near-neutral)—and at four aluminum concentrations—0.05, 0.1, 0.2, and 0.4 milligrams per liter (i.e., parts per million).

Aluminum occurs naturally in the soil, and its effect on the larvae appears to differ not only in relation to its own concentrations but to pH levels as well. A low pH chemically mobilizes aluminum in the water column to produce a potentially toxic condition. According to Palmer, a pH of 5 is 100 percent fatal to young larvae,



The control diluter system at Shady Side feeds potential toxicants to fish larvae in strictly controlled quantities. The water in various containers is maintained at four different pH levels and at four aluminum concentrations. Bob Palmer is senior technician in charge of the laboratory work.

but little mortality occurs at 7.8. In another experiment, the conditions of a rain storm are simulated in an "episodic" study. Palmer explained: "We drastically change the pH, and in addition change the aluminum concentration, so that the fishes experience the drop in pH associated with an acid rain event."

A related study at Shady Side, directed by Lenwood Hall and sponsored by the U.S. Fish and Wildlife Service, has examined several striped bass spawning and nursery areas in the Bay. The researchers monitored the organic and inorganic pollutants and water quality conditions that may contribute to the bass's devastating decline. They worked first in the Nanticoke River and last spring in the upper Bay and the C&D Canal. Hall was one of the first scientists to suggest, as a result of his work, that acidic conditions might be a prime contributor to the decrease in the populations of anadromous fish that spend their earliest stages of growth in estuarine waters. "We have shown," said Hall, "that acidic conditions and associated aluminum concentrations were factors responsible for striped bass larval mortality in one softwater system (the Nanticoke River) in one year. But we can't just extrapolate these data to other river systems in the Chesapeake Bay. We're now getting a perspective by being able to examine more than one system, each of them different." The project combines readings on acid rain, aluminum, and pH, and an assessment of inorganic contaminants and 21 organic contaminants, with studies of striped bass at two life stages, larval and yearling. Each spring, the researchers also evaluate the water quality and contaminant conditions in 10 different striped bass spawning habitats along the East Coast.

In another project, Hall has been studying the possible environmental effects resulting from the use of organotin-based antifouling paints. These paints, which have been used more and more widely on the hulls of recreational and commercial boats, contain components

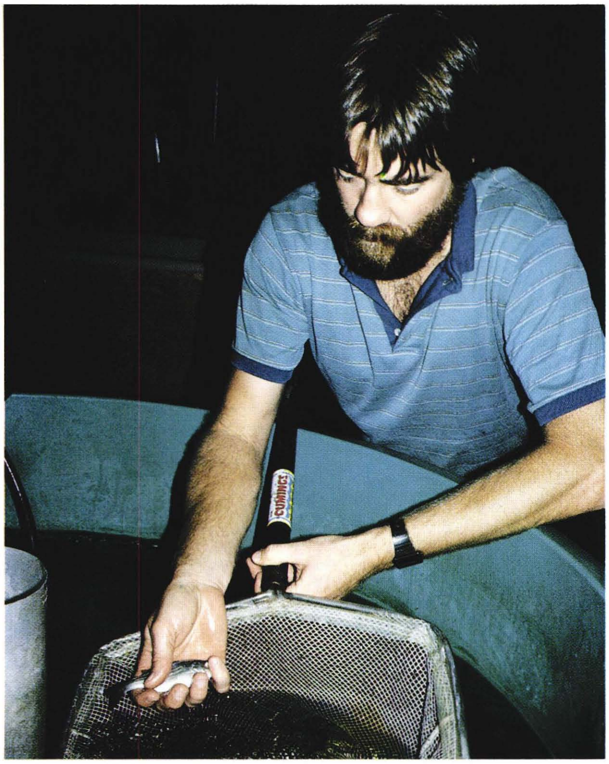
Sperm being extracted from a male blueback herring by Ronald Klauda of APL, Shady Side, Md. The white paste-like sperm fertilizes the female roe already in the container, to grow larvae for laboratory experiments exploring the effects of toxicity on young anadromous fish.

such as tributyltin oxide or tributyltin fluoride that appear to be extremely toxic to aquatic life. The focus of the present study is to determine the risk to aquatic life of organotin concentrations in the Chesapeake Bay.

Projects under Dennis Burton at APL's Shady Side facility include one in bioluminescence from single cell organisms that live in the ocean. Another deals with determining the minimum amount of chlorine needed to prevent biofouling in nuclear power plants.

SMITHSONIAN ENVIRONMENTAL RESEARCH CENTER

The Smithsonian Environmental Research Center (SERC) is a single administrative unit formed in 1983 by the merger of the Chesapeake Bay Center for Environmental Studies and the Smithsonian Radiation Bi-



Lenwood Hall of APL Shady Side examines a small striped bass that has been tank-raised from the larval stage. Experiments by Hall in the upper Chesapeake Bay where anadromous fish spend their earliest growth stages suggest that acidic conditions may be a prime contributor to the decrease in population of the popular commercial and sport fish.

ology Laboratory. The director of the newly formed organization, William Klein, has his headquarters at the radiation laboratory in Rockville, Md.

The Chesapeake Bay Center for Environmental Studies (CBCES, hereafter called the Center) was established in 1965 on the site of a farm south of Annapolis that had been bequeathed to the Smithsonian Institution. It is a Smithsonian Research Bureau, receiving approximately 60 percent of its funding from the federal government and the rest from grants and private sources. The area that the Center occupies, now grown through further acquisition to 2600 acres, encompasses the drainage basin of the Rhode River, a 2-mile tributary that empties directly into Chesapeake Bay. Rhode River is a small but complete estuary with tidal marshes, tidal mud flats, and open water surrounded by forests and fields.

Emphasizing land use, the Center's work concerns primarily the interrelationships between land and water and between the plants and animals found in a specific watershed, as well as the effects humans can have on this ecosystem. Research focuses on long-term ecological monitoring. Records of the area since Colonial times allow a land use perspective of 3 centuries. The Center's researchers can measure the land's current runoff and study its effects on the receiving estuary.

The Center is reached on a spur off the main highway that winds past cornfields and through woods. The

A raised walkway at the Smithsonian Environmental Research Center allows scientists and visitors to traverse a salt marsh of the nearby Rhode River without disturbing the delicate ecology of the march grasses.

road dead-ends at an unprepossessing set of buildings dominated by an old silo. On a hill to the right stands a new visitors' center. Inside the main building, a receptionist offers a cheerful greeting. Corridors lead to laboratories, offices, and a library. A message chalked on a lab blackboard gives a clue to the general dearth of people at mid-morning: "We're all out taking plankton."

In contrast to the work of the other members of the Chesapeake Research Consortium, that of the Smithsonian Center appears to be a big single project. The land and water are the laboratory itself. In the woods, "leaf-litter" boxes collect tree fallout that is sorted and tabulated, season by season. A sluice collects rainwater and measures its volume. A wooden walkway bridges acres of saltwater marsh where spiked reed canary grasses stretch to the distant water. In a thickly vegetated tidal marsh, a raised railway allows researchers to go out for samples without damaging the delicate ecology. Beyond the marshes, a hill leads to open water and the pilings of a weir. The weir controls and documents the movement of fish and crustaceans from the river to one of its creeks. Boxes with monitoring equipment seem to be everywhere, their readings recorded by technicians on periodic rounds: weather stations to measure temperature, wind velocity, and sunlight; gauging stations to measure water flow and to collect river samples. In the laboratory, the samples are analyzed for nutrients, salinity, sediments, metals, bacteria, and nearly 30 other components. Researchers continually take biological samples from the area's multiple environments for other analyses.

"When you walk around," says David Correll, associate director of SERC and head of the Center, "it appears you're viewing undisturbed nature, but it's far from that. For example, the water is so impacted by land runoff that the spawning fish have almost been wiped out. The fact is, ironically, that if you can see something that's obviously wrong, it's probably not a pollution problem. The real pollutants are hidden and more insidious." Correll confirmed that the Center is oriented to the field. "We're a bit leery of trying to duplicate nature in the laboratory. Labs are for analysis after we've investigated on the water, marshes, and land."

The Center's environmental research program considers the three major elements of the Rhode River ecosystem: the uplands, the watershed, and the estuary. The uplands, or terrestrial communities, include a wide range of land uses: forests, abandoned fields, pastures, croplands, and residential land. Records date back to the 1600s, and local residents have supplied more extensive recent detail. Nutrient cycling, primary productivity, species diversity, and secondary succession are among the natural processes being investigated. By comparing the ecology of managed and unmanaged lands, the Center's researchers hope to develop a better understanding of how human activity affects this and similar environments.

The watershed of the Rhode River is composed of small basins that drain directly or through creeks into the estuary. The Center has mapped the basins according to land use and has constructed the instrumented sampling stations noted above to monitor the runoff from each basin. While the Rhode River is relatively small, it is large enough to show many properties of a typical estuary. By dividing the river into a series of "reaches," the Center's researchers have begun to develop a model that can predict mixing within the segments and between them.

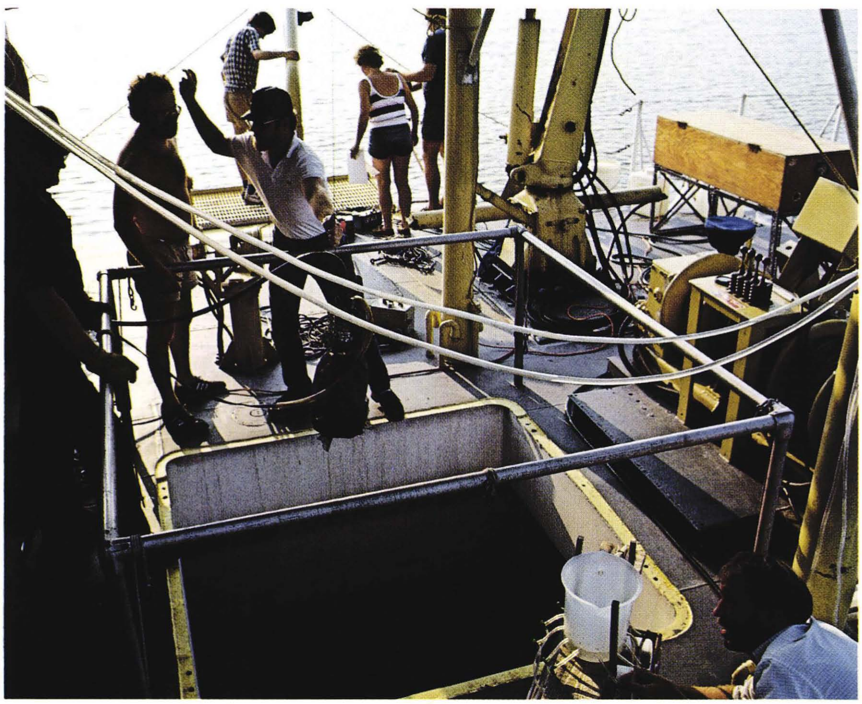
To sum it up, Correll said: "The Rhode River estuary is very much like a little Chesapeake Bay, with upper Bay conditions, except that in a small system you can't find everything represented. We do watershed research, looking at the impact of land use on water quality and land runoff. We try to relate that to downstream water quality in the receiving waters in various places, and the impact on biological populations. But all within this system. If you look at a map of the Chesapeake Bay, we're just a pinpoint. But we're geographically focused."

A COOPERATIVE MULTIDISCIPLINARY LOOK AT THE OYSTER AND ITS NUTRITION

The R/V *Ridgely Warfield* left Annapolis at 4 A.M. under its captain, former Navy submariner Jim Wimsatt, to arrive at the mouth of the Choptank River by daylight. Most of the team members, from Johns Hopkins' CBI and the University of Maryland's CEES Horn Point, had come aboard with their equipment the night before. One of the three principal investigators, Roger Newell, joined the ship in a Boston whaler from the Horn Point facility a few miles down-Bay, first stopping to hand-dredge a batch of oysters as the initial step of his day's work.

There followed 2 days of sampling and testing, divided on location equally between Broad Creek and the adjacent Tred Avon River. Both are subestuaries that feed into the Choptank River. Both sustain oyster populations. However, the oysters in Broad Creek, while relatively small, are abundant in commercial quantities, while those in the Tred Avon are large but sparse.

The Horn Point-CBI project is funded by the University of Maryland Sea Grant College. Its purpose is to understand how environmental factors affect the recruitment, spatfall, and growth of oysters in the Chesapeake Bay, by conducting comparative studies of



Orderly bustle aboard R/V *Ridgely Warfield* during the joint CBI-CEES multidisciplinary study of the oyster and its nutrition. Crewmen around the enclosed central bay raise a pump that has been supplying ambient river water for on-deck experiments. Behind them, Roger Newell of CEES Horn Point (checked shirt), one of the principal investigators, raises a Niskin bottle to collect phytoplankton samples. The long box at right, called the coffin, enables inoculated water samples to incubate under various controlled light intensities. At right in the foreground, a header tank provides river water in controlled quantities to several trays of freshly dredged oysters (not shown) whose digestion of phytoplankton is being monitored.

oysters in the two subestuaries and of the phytoplankton (or plant algae) on which they feed.

Phytoplankton ecologists Larry Harding of the Chesapeake Bay Institute and Tom Jones of Salisbury State College and the CEES Horn Point Environmental Laboratory are examining the nutritional quality of the phytoplankton in each of the subestuaries. Jones concentrates on phytoplankton biochemistry and on how changes in environmental parameters influence the biochemical makeup of the algal cells. Harding studies the products of algal photosynthesis produced by changes in light and nutrients. Roger Newell of Horn Point, a bivalve physiologist, complements the phytoplankton studies by examining the ability of oysters in the two areas to digest the available nutrients in them—measuring the oysters' feeding efficiency and the particles of phytoplankton they ingest.

The project covers a 3-year span, of which 1985 is the last. The teams go on the water every 4 to 6 weeks from March through November to monitor and collect samples and then continue with an extensive examination of sample material in their home laboratories. On site, this translates into a 12- to 15-hour round of activity, on deck and in the wet laboratory aboard *Warfield*, and aboard skiffs in the surrounding subestuaries.

"If you want to describe the lab work in one word," says CBI technician Mike Mallonee, "you can say we filter water." Water samples gathered periodically throughout the day from a variety of locations are filtered under vacuum through an array of glass tubes and bottles where removable filters collect the minute particles of phytoplankton. The filters, each about the size of a quarter, are meticulously removed with tweezers, labeled, wrapped in foil, and stored frozen by the hundreds. Later, back at the Shady Side and Horn Point laboratories, the phytoplankton and other particles on the filters will be subjected to a variety of analyses to assess their biochemical composition and other properties. As a break from filtering, graduate student Mike Crosby and technician Linda Franklin of the Horn Point lab made a "transect" of the subestuaries by boat each afternoon. They stopped at numerous stations over a several mile stretch (in quick succession to ensure the same conditions of tide and sunlight at each) to collect water samples and to make instrument readings in the water. The readings documented light penetration, oxygen content, salinity, and temperature at various depths.

One of the major experimental regimens involved recording the exposure of phytoplankton to the light that occurs at various depths in the water. Light exposure determines algal growth patterns and patterns of carbon metabolism. Turbidity and light losses caused by suspended particles in turn influence these aspects of phytoplankton physiology. Early each morning, Jones of CEES and CBI technician Kelly Henderson used the boat to anchor arrays of water samples in the open water. The samples, containing known quantities and types of phytoplankton, had been inoculated with radioactive carbon 14. The algae in the sealed bottles of inoculated water take up carbon dioxide (the source of nutrition) by photosynthesis, much as land plants do. The resulting fixation patterns, determined by laboratory measurements of radioactive carbon in the protein, lipid, polysaccharide, and metabolites of the samples, indicate where the carbon goes within the phytoplankton cells at various levels of turbidity.

Water samples, containing known quantities and types of phytoplankton, are inoculated with radioactive carbon 14 before being lowered into the Choptank River. The immersion will produce patterns of algal growth and carbon metabolism under various conditions of light exposure. Tom Jones of CEES Horn Point, one of three principal investigators, steadies the bottles as CBI's Kelly Henderson does the inoculation. The experiment was part of a joint effort of the University of Maryland and Johns Hopkins institutions to study environmental factors affecting oysters.

Aboard ship the researchers performed the same inoculation process on other samples that they incubated on deck in the "coffin"—a closed box with fluorescent lights. In the coffin, different light intensities were simulated when bottled samples placed inside were wrapped in varied layers of heavy black mesh to block from 50 to 99 percent of the light. In a third aspect of the same study, samples were incubated in a shipboard environmental chamber, essentially a refrigerator with fluorescent lights. Back at the CBI laboratory at Shady Side, Harding and his technicians have designed a further light-control device, a structure resembling a huge black aspirin tablet. The "wheel" is fitted with wedge-like compartments to represent segments of time. The biological rhythms of the phytoplankton can be studied by simulating day and night without, as Harding puts it, "requiring us to stay up all night."

Newell's work started with dredging oysters in the morning. He cleaned them of mud and fouling organisms, then placed them in individual compartments fed by a controlled flow of river water. The oysters, which Newell terms "functioning animals," feed on phytoplankton by filtering it from the water. During the day, the oysters digest some of the algae and produce excreta from the waste, and also eject some as unassimilated "pseudo-feces." After establishing his oysters in flowing water, Newell spent much of the day "particle counting"—recording with a Coulter counter the number of algal particles in both the ambient water and the water in which the oysters lay, in order to determine the rate and extent of the oysters' feeding. At the end of the day, he collected the feces and pseudo-feces that each oyster had produced. Chemical analysis of this material determines what the oysters have assimilated from the phytoplankton available to them.

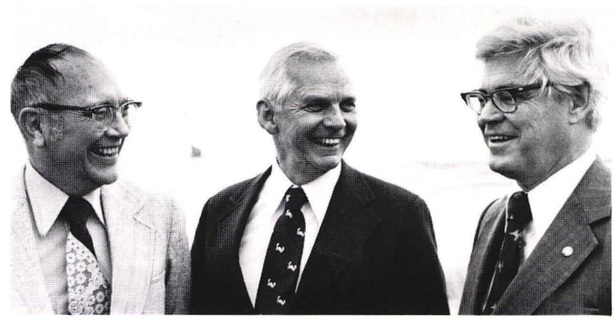
Once a day, Newell also went by boat to gather a series of "spat plates" that he kept anchored throughout the subestuaries near known oyster bars. He changed these 10-centimeter-square asbestos plates every week (the Horn Point facility is only a half-hour away by high-speed boat) and then counted under a microscope the number of floating oyster larvae that had attached to the plate to become spat—baby oysters. "On one plate 3 weeks ago," he declared, "I had the misfortune to find 4200 spat. Phenomenal! You can imagine the counting it involved." The count may indicate the number of surviving larvae but does not promise that all these will grow into mature, harvestable oysters.

What the CBI and Horn Point researchers hope to gain from the project is a knowledge of the nutritional links between the oyster and its environment that man can control, in order to increase the survivability and abundance of oysters in the Bay.

ONGOING THOUGHTS FROM A PROGRAM WITHOUT CONCLUSIONS

Ian Morris of CEES voiced what runs like a *leitmotiv* through all the interviews I conducted with members of the Chesapeake Bay research community: the only way to deal adequately with the problems of the great estuary is with facts gained through disciplined scientific investigation. Regarding the increase of low-oxygen water in the Bay, for example (a problem that has occupied researchers from both the Johns Hopkins and University of Maryland laboratories during 1985), Morris said: "The only real way of understanding it will be to do good physical and chemical and biological oceanography."

Morris particularly defends the practices of monitoring, as he worries that the present monitoring programs of the Bay are being defined by "the people who need to take management actions" without considering input from the scientific community. "Monitoring Chesapeake Bay is in essence a large multidisciplinary oceanography program." Morris also frets over the opportunities to monitor that are being missed. "There is so much that could be done without much additional cost that isn't being done. Beautiful remote sensing techniques that could be developed aboard the large freighters that travel the Bay, for example."



Second-generation pioneers of Chesapeake Bay research. This photograph, taken a decade ago, shows (left to right) Donald W. Pritchard, then-director of The Johns Hopkins University Chesapeake Bay Institute, L. Eugene Cronin, then-director of the University of Maryland Chesapeake Biological Laboratory, and William J. Hargis, then-director of the Virginia Institute of Marine Science of the College of William and Mary. (Photo by Hal Willard.)

L. Eugene Cronin, formerly director of CBL and later of the Consortium but now retired, has been involved in Bay research since 1940 when he began under the Bay pioneer, Truitt. (See below for more on Dr. Truitt.) Much of Cronin's mission in recent years has been to place the needs of Chesapeake Bay research in perspective. "This estuarine system is at once the largest, the most valuable, and the most complex in the nation," he declares. "It is so located that every pressure from human activities will continue to increase rapidly. Yet our investment so far in new learning to cope with this increase is very small—a fraction of 1 percent of the Bay's annual benefits. We need a greater comprehension of this magnificent system, not just a series of quick fixes, so that the huge expenditures now being made in water quality protection will be efficiently used, and so that fisheries can be restored and the biological health of the system improved and sustained. There must be larger scale and longer term research programs, as carefully designed and coordinated as a trip to the moon. There must also be plenty of research by highly competent but free-thinking scientists, since these are the great potential source of new concepts."

Maurice Lynch of the Virginia Institute of Marine Science and the Consortium addressed the problem of communication between the people doing research and the people who are funding it (who thus dictate what can be done): "Over the time I've been in the profession, since 1971, I'd weigh the link between Chesapeake Bay researchers and management as positive. The only time it gets a little weak is when management feels it ought to be doing something, and science feels it ought to know for sure before it can give management a definitive answer. If there is miscommunication, it's usually an inability to communicate—management's inability to phrase a question that can get a definitive management-appropriate answer, the scientific community's inability to recognize that they have something to contribute to management when management doesn't phrase the question just right."

PERSPECTIVE FROM A PATRIARCH

Chesapeake Bay has a long enough natural and political history that research could be expected to have been a part of the scene for more than the present generation. However, there appears to have been little sustained support for Bay research until fairly recent times.

The acknowledged dean of Chesapeake Bay researchers is Reginald V. Truitt, founder of the University of Maryland Chesapeake Biological Laboratory. An historic marker outside what is now the executive office building of CBL in Solomons, Md., states:

> Founded by R. V. Truitt, 1925, sponsored by Maryland's Conservation Department since 1931, in cooperation with Carnegie Institution, Johns Hopkins and Maryland Universities, Goucher, St. John's Washington, and Western Maryland Colleges, "to afford a research and study center where facts tending toward a fuller appreciation of nature may be gathered and disseminated."

The pioneer of organized Chesapeake Bay research, Reginald V. Truitt. Now 95, Truitt established CBL in 1925, following several years of Bay research for the University of Maryland without a formal facility.

According to Dr. Truitt, in retirement at age 95 but acknowledged to remain "a valuable resource" by present CBL staff members, there was nothing casual about his effort. His memory dwells on struggles to have the need recognized for orderly research on the ecologies of Chesapeake Bay. He set up his first field station at Solomons, an effective midway point in the Bay between salt and fresh water sources, in 1919. At the time, he was a young instructor in marine entomology at the University of Maryland and wished to pursue his concern for the oyster and blue crab populations that had always been the livelihood of Bay watermen. The station remained a shack until the local Episcopal church let him use its parish hall in 1923. No official support, other than Truitt's salary at the University of Maryland, came until 1931 when Governor Albert Ritchie gave his support to build a laboratory at Solomons. In the following year, the Maryland Conservation Department (predecessor of the present Department of Natural Resources) voted an annual budget: $500. As Truitt continued his investigations into the habits of the oyster and blue crab populations, he was assisted by graduate students but often remained the only scientist-in-residence.

A problem that Truitt had to face was the opposition of Bay legislators and watermen. As far back as the mid-1920s, he recalls having urged the legislature to raise the legal catch size of oysters "to give the little oyster a chance to go through the winter and spawn the next spring." When he testified before a committee of the Annapolis legislature, "a senator from down in Culver [Calvert] County took me to task. 'Here's the man!' he shouted. 'Here's the man coming before us, pretends to be a friend of the watermen, and he's taking their livelihood away from them. Taking their very livelihood!' "

What about the watermen themselves, I asked. Did they give you a hard time? "No. . . ." We were sitting in the living room of the Truitt home on Kent Island fronting a creek of Eastern Bay, a major Chesapeake tributary. Within sight rode the anchored boats of present crabbers and oystermen. "Some watermen did think I was interfering with God's work, maybe, but no, I had no real trouble. . . ."

Before leaving, I asked Dr. Truitt what he felt had been his most important life's accomplishment. The question seemed so obvious that he looked at me surprised. "Well, establishing a research center. Focusing attention on it, on the needs of the Bay. The work led to a similar lab in every coastal state from the Rio Grande to Maine. I had the first one."

It had been an uphill fight. Many say it remains so.

REFERENCES and NOTE

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[3] C. C. Sarabun, A. Brandt, M. A. Tyler, and G. D. Smith, "Biological Transport, Internal Waves, and Mixing in the Chesapeake Bay," *Johns Hopkins APL Tech. Dig.* **6**, 227-236 (1985).

[4] A. J. Lippson and R. L. Lippson, *Life in the Chesapeake Bay,* The Johns Hopkins University Press, Baltimore (1984).