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Maryland Sea Grant On The Chesapeake

The University of Maryland Sea Grant Program

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A Message From the Director

The great fish harvests of the Chesapeake have long been crucial to the people of Maryland, where nearly one-fifth of the state lies beneath the tributaries and tidal waters of the world's most productive estuary. These harvests are crucial because only a few biological systems—fisheries, forests, grasslands and croplands—form the basis of human life and social stability. Husbanded wisely, these biological systems provide renewable sources of food or energy; harvested or harmed beyond their regenerative powers, they become lost resources.

In Maryland, the future of those great fisheries is uncertain. During the last decade, harvests for oysters and striped bass declined, and harvests for blue crabs continued a history of dramatic population fluctuations. During the same years, the waters of the Bay altered in little-understood ways under the impact of hurricanes and herbicides, heavy metals and petroleum, sediment and sewage. And the seagrasses beneath those darkening waters began a mysterious decline in many parts of the estuary.

Understanding these biological systems, identifying the causes of these declines and fluctuations, rehabilitating these fisheries where possible, helping the people who depend on the Chesapeake for their daily earnings or seasonal recreation: these are the goals of the University of Maryland Sea Grant Program.

Because the Chesapeake is so large, so resilient and still so richly productive, these are workable goals. Because the estuary means so much to our sense of a regional history and destiny, these are important goals.

For over a century, several generations of Bayshore residents have learned and passed on a tradition of "following the water," choosing to work the Bay as independent, self-employed watermen, much as ranchers or farmers work a piece of range or cropland. And thousands of other residents still earn part or most of their living from processing, shipping or selling what the watermen catch. For these watermen and workers, for the families they raise and the communities they support, further fall-offs in the fish harvests could be a calamitous crop failure.

Maryland Sea Grant, born in 1977, is part of the National Sea Grant College Program, a federal-state effort aimed at applying science and technology to the wise management and development of this country's oceans, estuaries, rivers and lakes. A division of the U.S. Department of Commerce's National Oceanic and Atmospheric Administration, Sea Grant follows a decentralized management approach, asking local institutions and residents to identify regional problems and asking local universities to respond with research projects, education programs and advisory services designed to solve those problems. Sea Grant programs are targeted programs.

What progress have we made in responding to those problems, in reaching those goals? This booklet presents an overview of our efforts, an accounting of the people and projects, the activities and achievements of the University of Maryland Sea Grant Program.

DR. RITA R. COLWELL — *Director*
University of Maryland Sea Grant Program

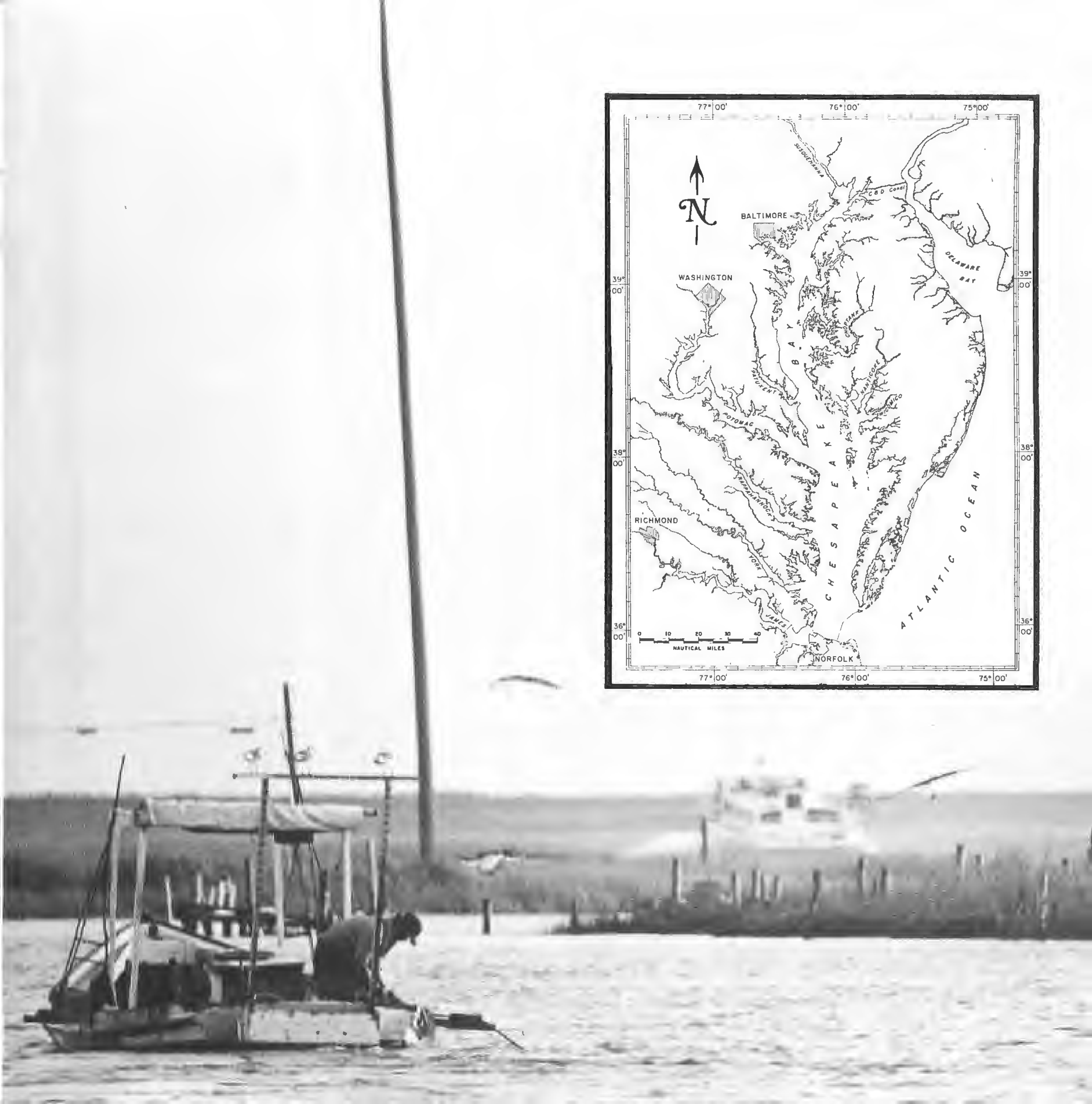
The Chesapeake's Great, Uncertain Seasons

For those who work the Chesapeake for a living, the estuary offers three great seasons: crabbing in the summer, oystering in the winter and fishing in the spring, especially for rockfish and especially when the annual spawning run floods the major rivers of the upper estuary with surging, silvergreen fish, many of them home from thousand-mile migrations to Maine and back.

The size of those seasons has, for centuries, made the Chesapeake the richest seafood-bearing estuary in the world. During the early 1970's in fact, the Bay was yielding an annual seafood harvest of 125 pounds per acre to watermen and sportsmen, 54 pounds per acre more than its nearest rival, the Sea of Azov in the Soviet Union. Recently, the Chesapeake was producing nearly one-fourth the total U.S. oyster catch and nearly half the blue crab catch, while spawning 90 per cent of the rockfish caught along the entire northeast coast.

For watermen, there is something eternal about those seasons, some long-range regularity that will eventually overcome the slumps that have beleaguered those fisheries for the past five years. Many learned their trade from their fathers and grandfathers. They have seen oysters and crabs and rockfish come and go and come back again enough times and in enough strength to help them raise their families on the basis of their baywork earnings. For men who have seen half a century of harvests, the declines of half a decade hardly matter.

Many scientists who study the Chesapeake, however, do get alarmed. They see beyond the slumping harvests to spat set trends, fingerling surveys, ongoing declines in underwater grasses, and increasing counts of chlorine and herbicides and heavy metals in the water. They say the blue crab has probably adapted to the changing Bay, but oysters and rockfish have stopped reproducing as prolifically as they did in the past. According to their calculations, two of the Bay's great seasons may soon be smaller.



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The First Season

OYSTERS

Crassostrea virginica

The Chesapeake Bay oyster harvest is the first great season in crisis. And not for the first time: Its history is a record of booms and slumps and partial recoveries, a record that sheds light on the problems and potential of the contemporary fishery.

That harvest, say the historians, began thousands of years ago with the Indians who roamed the Bay shore on foot and in canoes. Though these first Americans quickly converted the early colonists to the pleasures of corn and tobacco—especially tobacco—it took several centuries for the immigrants and their offspring to learn that oysters were healthy and tasty and catchable in profitable quantities.

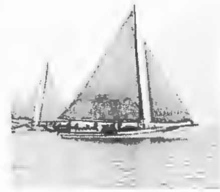
When Connecticut watermen early in the 19th century began plundering the northern Chesapeake for oysters to replenish their own overfished waters, Marylanders started taking their most plentiful shellfish seriously. From an annual catch of half a million bushels, the state harvest grew gradually to a mid-century total of 1.2 million bushels.

Then came railroads and steam canning and the opening of new markets in the restaurants of Philadelphia, New York, Pittsburgh, Wheeling and points west. From 1870 to 1900, Maryland watermen sailing slant-masted log canoes, pungys, bugeyes and skipjacks dredged and tonged oysters out of the Maryland Chesapeake at better than 10 million bushels a year. In 1875, they hauled home 14 million bushels; in 1885, 15 million. The Chesapeake Bay, in good years, was producing more meat than all the cattle-farms of Maryland, Delaware and Virginia. The great oyster hunt was on.

Watermen went out in small boats, in log canoes, in anything that could float. The hunt, according to one observer, was "simply a scramble," carried on with "regard neither for the laws of God or man," with tongers battling dredgers and both battling the Oyster Police—a scramble complete with night poaching, daylight rustling, running gun battles, and massive overfishing of the oyster grounds.

Those boom times faded with the century. The catch records of the 20th century show a sharp drop during the first decades, followed by a long decline during which the annual harvest averaged only 2.5 million bushels over half a century.

Interrupting this decline have been occasional, short-lived jumps in the harvest, the result of little-understood natural cycles or—more recently—of active oyster management efforts by the Maryland Department of Natural Resources. From 1965 to 1975 those oyster seeding and shell planting programs boosted landings to a 10-year average of 2.7 million bushels a year, helping the Bay produce 27 percent of the U.S. harvest and outproduce the harvest of any other country.



With dockside values running between $10 million and $15 million annually, the oyster fishery still outranks all other Maryland catches combined, including crabs, clams, menhaden, striped bass, bluefish, white perch and any of a dozen other species regularly fished from the Bay. Chesapeake Bay oysters—despite decades of decline—remain one of the state's and the country's most valuable sea catches.

The oyster catch helps support more than 4,000 watermen and nearly 5,000 other Marylanders who work in shellfish shucking, processing and shipping.

At present, hand tongers, patent tongers and dredgers take oysters off nearly 1,000 public oyster bars spread over 215,000 underwater acres. Most watermen work as hand tongers, using small outboards and long, low-sided tongboats equipped with a small cabin forward and a long cockpit aft for dumping and culling each day's catch. To earn that catch they spend their days anchored over public bars, wrestling with long-shafted tongs made of wooden poles with metal baskets at the end for scooping oysters off the bottom.

A growing number of watermen have equipped their boats with patent-tonging rigs that feature power-driven winches for dropping and hauling up tong baskets, a system that cuts down hand labor but requires greater capital investment.

Only a handful of watermen still sail their skipjacks. Reading the wind and the tides and the currents, they glide these graceful, wide-beamed workboats back and forth across the oyster bars, dragging dredges, large iron claws used for scraping up oysters. The 30 aging skipjacks that still work the Bay are the last survivors of a commercial sailing fleet that once numbered in the hundreds.

Not all Maryland oysters come off the public bars. A few private planters lease plots of Bay bottom from the state, line their sections with old shell or other cultch material, and then seed periodically with young oysters. As a result of this kind of close management, those 10,000 private acres produce more bushels per acre than do the public bars. Despite the commercial potential, most watermen oppose private leasing, fearing eventual control of the fishery by large corporations rather than by independent, self-employed watermen.

What now threatens the oyster harvest and the way of life it supports is a series of oyster reproductive failures that could negate the oyster repletion effort and extend the fishery's historical decline. After significantly poor natural sets of new oysters in 1966, 1967, 1970 and 1971, Hurricane Agnes struck the Bay in 1972, causing enormous freshwater run-off, silting up oyster beds in the northern waters and diluting salinities. From 1965 through 1976, natural oyster reproduction was 72 percent lower than the average rates for the previous 27 years. If the supply of new oysters is not replenished soon, either by nature or by man, and if watermen continue to fish off the remaining oysters, the Bay harvest will soon decline again as it did during the early decades of this century.

Since 1977, many of the projects of the Maryland Sea Grant program have focused on three related goals:

- identifying the causes of the current decline,
- improving management of the contemporary fishery, and
- increasing future harvests.

Identifying the causes of the oyster shortage requires patient, basic research on the biology of the American oyster, on the environmental conditions that encourage or discourage growth and reproduction, and on the little-understood microbiology and chemistry of water quality. Among the conditions that could be causing the decline are:

- overfishing,
- declines in the sexual health of oysters,
- changes in food supplies,
- increases in chemical pollutants that hinder larval survival and spat set,
- decreasing salinities resulting from greater freshwater run-off, and
- increasing turbidity that fouls oyster beds with sediment.

The Search For Causes

The search for causes of the oyster decline starts with basic biology. Vic Kennedy's two-year study examined oyster reproduction in the central Chesapeake, searching for possible biological causes for poor spat sets in recent years. His results show that Maryland's oysters are sexually healthy and are spawning on schedule every summer. Kennedy's findings suggest that environmental rather than biological problems could be causing current declines. Those problems could include increases in chemical pollution and changes in natural food supplies and salinities.

Kennedy collected oysters from areas with good spat set and poor, from bars as far north as Tilghman Island, as far south as Tangier Sound. He checked on sexual health, counted male-female ratios, verified spawning periods and compared spat set in productive and non-productive rivers. After studying 6,300 oysters dredged off 18 oyster bars, he found no evidence for a widely suspected shortage of males and plenty of evidence for vigorous seasonal spawning.

Before his study, scientists worried that oysters were not spawning because of unbalanced sex ratios. Since most American oysters begin life as males, switch sex later on and remain females, several poor spat sets could interrupt the supply of young, primarily male oysters, leaving the oyster grounds overstocked with aging females. A poor male-female ratio could mean not enough male hormones or sperm in the water to encourage female spawning.

Kennedy found:

- Sex ratios vary around the Bay, but not greatly.
- Those ratios showed no clear relation to spat sets. Good spat-set areas like Broad Creek and Chicken Cock showed male populations of 41 and 38 percent. Some poor spat-set areas like Tred Avon and Herring Bay showed even higher male counts of 43 and 45 percent.

- On good bars and poor ones, oysters have been spawning in a similar pattern across the Bay during the last two decades.

"Ripening (of gonads) came in early spring, generally in May and was very rapid," Kennedy says. "And spawning would begin in late May or June and would continue through August and sometimes September." Though Kennedy took samples only in 1977 and 1978, he compared his oysters with similar studies done during the early 1960s when spat sets were much higher than in recent years. He found no evidence for a change in oyster spawning.

If sex ratios are fairly balanced and oysters are sexually healthy, then something unhealthy must be happening in the water between spawning and spat set to cause the current drops in the survival of new oysters in the Chesapeake. Kennedy suggests chemicals in the water or changes in the food supply.

Following the Water

Howard Seliger is studying how water flow patterns affect the distribution of oyster larvae and the oxygen and food those larvae need to survive. He has been adapting the techniques of physical hydrography to develop a more detailed description of the biological systems of the Bay's interior tributary estuaries. The end result should be a better understanding of where oyster food is and where we should focus future oyster repletion and aquaculture efforts.

The action of salt and fresh water in the Bay and its tributaries is well-known: Fresh water, entering the esturary from the watershed, moves south on top of the denser salt water coming up the Bay from the ocean. This upper layer of fresh water forms a "plume front" at the mouths of tributary estuaries like the Chester. When two such fronts meet, a layer of saltier water may become trapped between them, forming an area known as an "interfrontal" region. This region exchanges water with the rest of the Bay very slowly, and becomes an ideal area for organisms to grow, since nutrients tend to collect there.

Using specially designed equipment for making rapid measurements in shallow water, Seliger has identified the interfrontal region formed by the meeting of the plume fronts of the Chester and Susquehanna Rivers. There he found concentrations of phytoplankton and oyster larval food. This may be very important he says, because this interfrontal region "appears to overlap the locations of the major oyster beds in the Chester River."

Another type of front, the "shear" front, has also been observed in conjunction with oyster beds. In a shear front, the layers of fresh and salt water flow diagonally, allowing a layer of water to circulate between the surface and the bottom where young oysters are setting.

Though the mix of the waters creates conditions and areas favorable to oyster growth, the actual movement of the layers also presents something of a dilemma: Even in an interfrontal region, there is a net flow of water out of the estuary. Why aren't oyster larvae therefore washed out to the sea? How can they—or do they—stay in those nourishing areas?

Water flow patterns again provide a possible answer. As the two layers of water move in opposite directions, an organism might be able to overcome the natural down-Bay flow if it is able to swim up and down from one layer to the other, moving back and forth like an all-day subway rider, so that it remains in the area most beneficial to its growth. This, of course, presumes the existence of a mechanism which alerts the larvae to swim up or down, a mechanism which is yet to be identified. But Seliger found some indications that such a mechanism may be at work when he applied his hypothetical model to two rivers.

A Tale of Two Rivers

Though natural spat sets of new oysters have been declining around the Chesapeake, some areas continue to have good spatfall. One of these productive areas, Broad Creek, runs roughly parallel to the nearby Tred Avon River, an unproductive area. By studying these two rivers in detail, biologist Vic Kennedy and oceanographer William Boicourt are trying to develop a better explanation of the interwoven biological and physical factors affecting spat set.

Their hypothesis: certain rivers like Broad Creek may have tidal and current patterns that retain and cluster oyster larvae near oyster beds until they can set. Other rivers like the Tred Avon may be scattering larvae across poor setting areas.

Their technique: to use dye dispersal and water current meters to identify the flow regimes in both rivers and to correlate these water patterns with spat set, both on natural bars and on asbestos spat collectors.

Their findings could help oyster repletion efforts by identifying those river systems where oyster seeding and shell planting would be most effective in stimulating set.

The Oyster Food Scenario

Since oysters are spawning on schedule every summer, why are so few of their offspring surviving long enough to achieve successful spat set? A poor diet could be part of the problem, say some scientists. They suspect that changes in natural food supplies could be a major cause of the decline.

According to this scenario, lowered salinities and increased counts of pollution may have caused major shifts in phytoplankton stocks that oysters feed on, wiping out "good food" species and leaving "poor food" stocks. As a result, poorly fed oysters may still be spawning, but they may be generating offspring too weak to survive long. Those offspring, in turn, may not be finding the food they need to last until spat settlement.

To investigate this scenario, Glenn Patterson has been examining the sterol composition of oysters and some of the algae they feed on. Sterols are an essential ingredient in all but the most primitive life forms; for oysters they play a critical role in growth and reproduction. Patterson and Shin-ishi Teshima have already identified 40 sterols in oysters taken from the Choptank River, proving that the oyster's sterol makeup is among the most complex of any species. The researchers are also determining which sterols oysters may be able to synthesize and which they must take directly from plankton food stocks.

When a local aquaculturist transplanted Chesapeake Bay oysters to a creek on Hatteras Island off the coast of North Carolina, he found these Bay oysters grew more than twice as fast on Hatteras. Patterson and Teshima analyzed the transplants and discovered that the transplants had nearly three times the amount of sterols found in the stay-at-home oysters, startling evidence that food supplies may be a key problem.

Patterson now plans to compare sterol compostion of oysters and algae found in productive and unproductive areas of the Bay, an approach that should clarify the role of food in causing the current decline.

Competent Oysters

As with many molluscs, once oyster larvae become biologically ready, or competent, to begin growing their shells, they must find an environment which initiates and promotes this metamorphosis. For the oyster this means settling on hard surfaces on the Bay bottom, most often large patches of old shell.

But sometimes larvae are scattered by currents to areas where old shells are scarce. Like other species, the larvae of the oyster have the ability to sustain their competency and delay metamorphosis until suitable substrate is found.

Dale Bonar, a University of Maryland developmental biologist, studied the variable developmental rates of growth among sibling larvae and the rate and pattern of protein synthesis. This project may help us understand how the potential for growth and development of oyster larvae affects the eventual size of the total population.

He found that these sibling larvae grow at different rates. Most grew rapidly to competency, but a few simply stopped growing early in their development. Later on these late-bloomers resumed their growth—at a more rapid pace than their siblings—and reached competency in good health. Bonar suggests this stage of arrested development for a small portion of a single brood is a built-in mechanism for survival of the species.

Another such mechanism is the ability of both fast-growing and slow-growing oysters to sustain their period of competency. But the oyster, according to Bonar's research, does not enjoy an extended competency. Larvae can last without setting only three days, far less than the nearly 60 days other mollusc larvae enjoy.

Once ready, oyster larvae need only a substrate to begin growing shell. If the substrate is provided within the three-day period, growth begins with no adverse effects. If the substrate is introduced after that time, the larvae's growth will be slower, and they may die.

The Oyster Numbers Game

Forecasting the oyster harvest for the coming year has always been a favorite guessing game among Bay-area watermen, seafood processors and resource managers. Working with computers, mathematical formulas and 40 years worth of historical data, Robert Ulanowicz and his associates have been able to take a lot of the guesswork out of the game.

He developed a multiple regression formula capable of forecasting the oyster harvest up to four years ahead. The formula recently passed its first two tests with high marks, predicting the 1979 harvest with 98 percent accuracy. The formula achieved a precision unusual in mathematical modeling for an ecosystem as complex as the Chesapeake Bay.

1979 Prediction:	2,228,371 bushels
Harvest:	2,197,409
1980 Prediction:	1,954,290
Harvest:	2,081,875
1981 Prediction:	1,608,481
Harvest:	?
1982 Prediction:	1,616,452
Harvest:	?

The oyster formula is a lagged correlative model based primarily on two variables: spat set and seeding.

According to the model, the downward trend reflects two factors: declines in natural spat sets and a recent drop in the number of seed oysters planted annually under the shellfish management program of the Maryland Department of Natural Resources.

Before building their final model, Ulanowicz and computer programmer William Caplins collected 40 years of information on:

- oyster harvests,
- fishing effort,
- salinities,
- water temperatures,
- air temperatures,
- rainfall, and
- annual averages, extremes and stress episodes for all environmental variables.

They located and inserted into the computer more than 65,000 separate facts, developing a data bank that should prove useful for other researchers working on similar fishery projects. In the end, only spat set and seeding showed significant correlations with future harvests. The predictions for 1979, for example, depend on spat set and seeding data for 1975, 1974, 1973 and—surprisingly—1970.

Since spat set, as expected, proved the single most significant factor, they also worked on a model for predicting natural set. Good spat sets, they found, correlated with high salinities, low rainfall and low harvests the year before, but none of these correlations proved significant enough to give reliable correlations for future sets and, beyond that, for future harvests.

Besides generating accurate forecasts for future harvests, the model provides clear evidence of the importance of seeding in offsetting poor natural sets. "This study," says Ulanowicz, "shows we have moved from a 'wild harvest' to a 'put-and-take harvest' that is dependent on management efforts."

Understanding Spat Set

Microbiologists Rita Colwell and Ron Weiner are investigating two major suspects loosely implicated in the decline of oyster reproduction: biofouling of oyster beds and chemical pollution. In the process they are building better understanding of spat set—one of the most important and mysterious moments in the life cycle of the American oyster.

Once oyster larvae floating in the water are ready to set, they need to find good "cultch," hard surfaces like old shell, rocks, firm bay bottom, wire, wood, concrete—even rubber tires can make good cultch under the right conditions. Fouling of cultch can sometimes help, sometimes hinder that process. Fouling occurs because any surface that sits long in estuarine waters is soon covered by a film of microbial life, by communities of microorganisms, some of which attract larvae, some of which repel them. Chemical pollution could be hindering that process by weakening those microbial communities that speed up spat set.

By studying the role of microorganisms in the estuary, Colwell and Weiner have begun identifying those species that attract larvae and are now planning studies on specific pollutants that may disrupt spat set.

Their early work on this ongoing project developed the following findings:

- Oyster larvae preferentially set on surfaces first colonized by microorganisms.
- Two species which enhance spat-set attachment have been identified and isolated: one is a gram-negative rod and the other is a unique, filamentous, semi-spiral-shaped procaryote.
- A procaryote which is antagonistic to attachment has also been identified.
- Other conditions being equal, the invertebrate larvae were found to attach preferentially to oyster shell, as compared with glass, by a factor of 100 to one. Under proper conditions and in the presence of specific colonizing bacteria, spat attached readily to oyster shells in extremely high density.

Other kinds of substrates are being tested in continuing work, including bivalve shell and plastic and glass surfaces which are designed to elucidate the setting process of oyster larvae.

Improving Spat Set

To counter the prospect of falling harvests, the Maryland Department of Natural Resources every year dredges new oysters out of off-limits "seed areas" and plants them in public bars fished by watermen. One way to build up the number of seed oysters needed to sustain the fishery is to find better ways of catching spat around those off-limits bars with a history of high spat counts.

In an effort to determine the efficiency and cost effectiveness of various spat collection techniques, George Krantz and his associates rigged tests at four different locations in the Chesapeake Bay and at one site in Chincoteague Bay—all places where relatively large spatfall occurred over the previous five-year period.

Researchers tested a wide range of possible collection materials and ranked them according to observed efficiency in the following order: natural shell, concrete collectors, green shell, dredged shell, tire chips, slag, pine wood, oak wood.

The project identified several problem areas:

- Devices meant to attract oyster spat also drew large numbers of other organisms: tube worms, bryozoans and barnacles. Biofouling posed a major deterrent to efficient spat collection.
- Sediment, known to kill spat in hatchery environments, deposited on the surfaces of all collectors.
- Though placed in fairly protected waters, suspended collectors often fell prey to Bay storms; Tropical Storm David destroyed 60-70% of the collectors in a two-day period in 1979.
- Collection depended, of course, on availability of spat in the water. Since spat set proved low during the 1979 testing period, determinations of spat collector efficiency proved difficult in many cases.

Both the field tests and laboratory tests showed the oyster spat chose concrete about as often as oyster shell. The wire baskets coated with concrete proved attractive to spat and demonstrated the added advantage of less fouling due to the space between the wires, which allowed sediment and fouling organisms to pass through. Basket collectors weighed only 10 to 11 pounds at the end of the study, while shell bags—fouled with organisms and sediment—increased in weight from 35 to 80 pounds, making handling difficult.

The study's conclusion: of all the suspended collector systems, only the concrete-coated collector produced spat at a cost comparable to other sources of seed oysters. The most cost-effective system for collecting spat from the natural environment, though, remains the state's shell planting program, which does not rely on off-bottom collection devices.

Any spat collection device dependent on the natural environment suffers the whims of unpredictable production, and the study emphasizes that only hatchery technology, operating at a slightly higher spat production cost, can provide predictable yields of seed.

Building A Better Hatchery

Another way to get more seed oysters is to grow them in a hatchery. Hatchery-spawned oysters have been widely suggested as one solution to the problem of declining natural spat sets in the Chesapeake Bay. If seed oysters can be economically spawned, set, and grown on land, and then planted in the Bay, then an extensive seeding program could help sustain Maryland's most valuable fish crop. For that reason, the shellfish program managers of the Maryland Department of Natural Resources have considered plans for building a production-size hatchery to supply those seed oysters. Before committing state funds, they are waiting on technical, economic and biological data now being developed at a pilot-scale hatchery at the Horn Point Environmental Laboratory with funding from the DNR and the Maryland Sea Grant Program.

George Krantz's work at the pilot hatchery concentrated first on confronting and solving the biological and technical problems of spawning, feeding, setting and planting seed oysters while keeping close track of all costs and potential revenues. Major problems encountered stemmed from the relatively low salinity of the Choptank River, a problem that meant longer production schedules, higher water flow rates and higher costs than previously estimated. The data compiled during the first two years' work was then scaled up to evaluate production hatcheries, either commercially operated or state-operated hatcheries.

To analyze the production dynamics and economics of a large-scale hatchery, Krantz and Fred Lipschultz used a series of linear programming models. Based on a 42-week annual production schedule, their model identified production bottlenecks, predicted problem areas and evaluated economic feasibility for both commercial harvesting and for seed production. Their findings:

- A commercial hatchery growing oysters to scale size would have little chance of succeeding, primarily because of possible crop failures and a three-year start-up period.
- Seed hatcheries, because they can turn out spat and generate income after only one year, have a better chance of economic survival, according to the model.
- Spat grown in the hatchery for 13 weeks suffered 90 percent mortality when planted in the Bay and produced profits of $.005 per oyster.
- Spat grown for 26 weeks suffered only 20 percent mortality after planting and yielded profits of $.04 per oyster.

As Krantz and his staff develop more data on hatchery production techniques, they will modify the model further.

Building A Better Oyster

Better oysters, oysters that grow faster and fatter, that don't get sick, and all have the same size shell. That's one of the goals of an oyster hatchery and one of the keys to a long-range oyster seeding effort. And it may not be as impossible as it sounds.

Agricultural scientists have learned better ways to breed bigger cows, pigs, chickens, and food plants of all kinds. Aquacultural researchers are now trying to do the same with oysters.

To develop some of the initial information needed for building a better oyster, Brian Bradley, George Krantz and Joseph Wutoh are studying variability in growth and survival of two oyster populations, research that applies directly to growing better brood stocks in shellfish hatcheries.

An Oyster Cell Line

Several times during recent history, epidemics caused by protozoan or fungal agents have wiped out large numbers of oysters, endangering Chesapeake Bay oyster harvests. To better understand molluscan pathology, Frank Hetrick and Nancy Lomax have been working on developing a molluscan cell line that could help scientists determine how disease-causing viruses interact with cells of oysters and clams.

The results of their work on oysters include:

- Establishing primary cultures of oyster cells, largely with tissues of the oyster heart, mantle and gonad. Their experimental procedure involved decontaminating oyster tissue, mincing it into small fragments, and either using the tissue directly in explant culture or dissociating the tissue further by trypsinization.
- Maintaining viable first-generation cells in culture for extended periods of time.
- Adapting a virus assay system and using it to test Chesapeake Bay oysters for evidence of enteroviruses—viruses that could cause intestinal infections in humans. By testing oysters from 11 oyster bars around the Bay, they were able to show that the Maryland oyster fishery has no problem of enterovirus contamination at the present time, a finding important to consumers, seafood processors and public health officials.

To date, however, they have not been able to achieve in their primary cell culture the kind of successful cell replication that would lead to second-generation cells and the establishment of a cell line.

With their clam culture work the results were similar: first-generation cells—both normal and neoplastic cells—were maintained in culture for extended periods, but no cell division occurred.

The Second Season
ROCKFISH

Morone saxatilis

The springtime rockfish run is the second great season in crisis.

In a good year, rockfish are the major commercial finfish catch in the Bay. For watermen stranded between slow, late-season oystering and erratic, early-season crabbing, that short rockfish spawning run can put their books in the black for the year.

In almost any year, rockfish, also known as striped bass, are the most popular sportfish in the estuary and one of the great coastal gamefish hunted by charter captains, private boatmen and surfcasters from North Carolina to Maine.

The rockfish may be on its way out as a great commercial and sports catch, but it is not going quietly. The fish became so profitable and popular because of its size and fighting spirit that its decline during this decade has sparked controversies among watermen, sportsmen, scientists and legislators from Maryland to Maine. Sportsmen have launched major lobbying efforts asking for commercial fishing bans and emergency research programs. Maryland watermen, in turn, have resisted fishing bans and started their own hatchery in hopes of restocking the depleted estuary. In the sudden decline of this once-prolific species, many people see a poignant symbol for man's abuse of the natural environment.

The signs of crisis are clear:

- Commercial harvests in Maryland waters declined from 4.9 million pounds as recently as 1973 to a catch of less than a million in 1979.
- In 1976, the sports catch had dropped to *one tenth* what it was in 1962, according to a survey by the Maryland Department of Natural Resources.

The causes of that decline are as murky as the rivers where the rockfish spawn, rivers that grow darker every year with more chemicals, heavy metals and sewage, rivers that may not hold enough food for the millions of rockfish larvae still born there every spring.

Research on rockfish has centered on the dynamics of dominant year classes, those sudden, outsize populations usually followed by a string of smaller classes. For several decades, dominant year classes arrived every six years or so, triggered by harsh winters followed by late thaws. That combination scours marsh grass and underwater vegetation, enriching the spawning waters with detritus that feed small organisms and build a dense food base for rockfish fry. This decade produced three cold winters but no large year classes since 1970, spurring research and debate on the problems of disappearing baygrasses, dwindling food supplies, competing species and increasing amounts of chemical pollution in the water.

Food For Fish

Two Sea Grant projects have been investigating the food supply for rockfish larvae, one of the key factors that determines survival past the larval stage and the eventual strength of each year class. Eileen Setzler-Hamilton is studying the competition for food between rockfish larvae and white perch larvae, many of which are spawned at the same time and in the same rivers. She is finding that white perch begin feeding earlier, as soon as they reach 3 mm in size, while rockfish start feeding later, when they reach 6 mm in size, around the sixth day. By analyzing stomach contents, she hopes to document whether both species feed on the same organisms and to evaluate the effect of this competition on rockfish survival.

Finding the Food

Working with funds raised by a New England sportsmen's group called Save the Bass, Douglas Martin is examining the effects of low food supplies on rockfish larvae. He reports that the effects of starvation can develop after a single day without food. One of the first effects, he found, is deterioration of eye tissues. Since the rockfish is a visual feeder, even partial loss of vision increases the probability of starvation unless the waters are dense with microscopic food.

Spawning Problems

Another suspect in the decline of striped bass populations is chemical pollution, and research supported by discretionary funds from Maryland Sea Grant has turned up preliminary evidence suggesting the power of toxic pollutants to disrupt rockfish spawning. In 1979, George Krantz took rockfish from the Choptank River and tried to induce spawning in land-based waterways at the Horn Point Environmental Laboratories. After inducing ovulation in 29 females, he found that only one female produced offspring capable of living more than four days. Most of the eggs proved infertile or produced fry with gross deformities. Though rockfish eggs are normally protective sacs, the color of pearls, the eggs from Horn Point proved so enfeebled they could be popped between two fingers.

The Economics of Decline

The depletion of the striped bass fishery affects thousands of people: watermen, recreational fishermen, food processors and the manufacturers, retailers and mechanics who supply, sell and service boats and fishing equipment. This complex structure is currently the focus of two University of Maryland resource economists, Virgil Norton and Ivar Strand.

Assessing the motivation of recreational fishermen—determining how much they will spend to go after striped bass, and what they may do if the bass aren't biting—may prove to be difficult, they report, since the number of bass available in the Bay has not been great. In assessing data collected in 1977 and 1979, they will establish values for recreationally caught striped bass which will incorporate intangibles not easily measured by economic models: values like being outdoors; boating on the Bay; being satisfied with casting for other fish.

In the commercial sector the pattern is much clearer. Rising retail prices for striped bass have not inhibited demand for the fish. Consequently, the costs of catching the striped bass for commercial fishermen have not been great enough to deter them from "searching out every striped bass." The striped bass is thus roasting over a dilemma: commercial fishermen are able to continue to earn their living harvesting the fish, which is good for them; but the cost is the further depletion of the species. "Current price trends and current regulatory approaches," Norton and Strand grimly suggest, "could lead to a complete elimination of this species."

The Third Season

CRABS

Callinectes sapidus

The Offshore Odyssey of the Atlantic Blue Crab

Summertime may be the most uncertain season of all for those who make their living off the fisheries of the Chesapeake.

The great summer harvest is the Atlantic blue crab. That hardy crustacean is not suffering the reproductive failure afflicting species like the oyster and the striped bass. Blue crabs, as far as scientists can tell, are still reproducing in prodigious numbers every year in the southern reaches of the Bay. But the great question for those who study and hunt this voracious animal is: where in the Bay or elsewhere do all these new crabs go?

The migrations of the blue crabs are closely watched along the Chesapeake shoretowns and islands, north and south. In Dominion and Crisfield, on Tilghman Island and Tangier, crabbing is still for thousands of watermen their warm weather work. After winter oystering, it is their major means of making a living. For nearly half the year from May well into October, the work, play and talk in these towns keeps time to those silent, unseen migrations along the bottom of the Bay. Watermen know there'll be crabs every year as sure as there'll be summer, but they don't know—they never know—how many crabs will be crawling north each season.

On the Chesapeake, good crabbing years and bad follow each other in wildly fluctuating cycles. Since 1966, the Bay-wide harvest has bounced up and down between a high of 94 million pounds and a low of 45 million. Similar jumps and drops punctuate the blue crab catch records of the last half century. Neither watermen nor resource managers nor marine biologists have been able to explain why these harvests fluctuate so dramatically.

Though most crabs head north in the spring, female blues pregnant from last summer's matings prefer to linger in the higher salinities to the south, turning the lower Bay into a giant crab hatchery. Carrying orange and brown egg masses, these females—called sooks—hatch their eggs from early spring to mid-summer, releasing millions of crab larvae into the water. Each female probably spawns two to three million larvae.

Tiny and barely visible, these larvae begin a different kind of migration. About their travels, however, little is known, either by biologists or watermen. What happens to these would-be crabs as they grow and molt, grow and molt, shedding their shells no less than 20 times in their passage to adulthood? More importantly, where in the Bay do these larvae go?

That's a major mystery in the well-studied life cycle of the Atlantic blue crab. Some biologists believe those larval migrations could cause harvest fluctuations the following years. If they could prove that larvae migrate and then track their migrations, biologists might predict those jumps and drops in the harvest. They might be able to tell when good years and bad years were coming. They might finally explain why the blue crab is such a variable feast.

Describing these migrations in greater detail has been a major project for Sea Grant researchers in Maryland, Delaware and Virginia. At the University of Maryland's Horn Point Environmental Laboratories, marine biologist Steve Sulkin has developed laboratory experiments that are revealing the ways in which blue crab larvae respond to light, gravity and pressure. His findings suggest that the blue crab through millennia of evolution has

developed adaptive mechanisms that insure wide dispersal of its offspring—dispersal in many years reaching far beyond the boundaries of the Chesapeake Bay.

His findings indicate:

- First-stage larvae, most of which seem to hatch in the upper waters of the Bay, tend to rise to the surface, swimming towards the light and against the pull of gravity and the pressure of deeper waters. In some years those larvae may be lost from the estuary, swept out by the ocean-flowing, upper waters of the Bay.
- Those first-stage larvae hatched in lower waters are probably trapped there. Though they also swim upwards, they are unable to cross the pycnocline, that sharp discontinuity in pressure that separates the inward Bay-flowing water from the upper, outward-flowing surface waters.
- Later-stage crabs, called megalopae, tend to sink downwards, seeking the darker, denser, saltier waters below.

From those findings and from field sampling surveys organized by Charles Epifanio of the University of Delaware and Anthony Provenzano of Old Dominion University, researchers are developing a new scenario describing the blue crab life cycle.

That scenario reads something like this: Those larvae born in the lower levels of the estuary remain in the Bay and form the base level of annual blue crab populations. Those larvae hatched in the upper, seaward-flowing waters, however, are usually swept out of the estuary and south along the Atlantic coast, sped along by the prevailing northwesterly winds and south-flowing currents. They are "recruited" to an offshore nursery, a large mixing and growing ground fed also by larvae washed out of Delaware Bay and Chincoteague and the Carolina sounds. Above the continental shelf, these larvae continue to float and feed and grow and molt, their numbers constantly cut by ocean-feeding fish.

The critical question is whether seagoing larvae are a lost part of each year's crop. Or do they return in some years? Are there frequent reversals in prevailing winds and currents? Do episodes of southerly winds, north-flowing currents, low freshwater run-offs help keep those larvae nearby until they metamorphose and seek deeper waters? Do they then re-enter the estuary, entrained by the inward-flowing bottom waters that feed into the Bay. That offshore recruitment, or the lack of it in some years, could clearly cause those huge fluctuations in the Baywide harvests.

Answering those questions is an ongoing goal of Sea Grant programs at three universities. Historical records suggest that reversals in prevailing winds and currents do occur during certain years, sometimes during crucial spawning months. Those currents, combined with low freshwater run-offs, could hold many of those upper-level larvae near the mouth of the Chesapeake, making offshore recruitment a significant source of new crabs during those years.

If that offshore hypothesis tests out, scientists should soon be able to come up with better predictions of how many crabs will be coming north through the Chesapeake each year.

The Bay's Big Blue Crabs

Blue crabs have always grown faster and larger in the Chesapeake Bay than in the saltier waters of Chincoteague Bay, leading scientists to speculate that either salinities or subtle genetic shifts accounted for the great differences in crab growth. Marjorie Reaka completed one of the first controlled experiments designed to test these competing hypotheses. Her results suggest other factors are at work.

She collected crabs from the Chesapeake and the Chincoteague and in controlled laboratory environments measured their growth responses under three different temperature regimes and three different salinity regimes. Her objectives were to find out how fast molting takes place and how much growth occurs during each molt.

Her findings:

- Chesapeake crabs molt more frequently than Chincoteague crabs and grow more quickly during each molt, when tested immediately after collection in laboratory conditions matching those in their original environments.
- Chesapeake and Chincoteague crabs, however, do not grow differently when tested under identical environments, a finding which means genetic differences do *not* determine the different growth rates for these populations.
- Salinity does *not* significantly affect frequency of molting or rate of growth during each molt.
- Warmer temperatures—up to 25º—do increase frequency of molting and rate of growth per molt.
- Larger crabs spawn many more eggs than smaller crabs, a finding which documents the hunch that estuarine rather than coastal crabs produce most of the larvae in the mid-Atlantic region.

At first glance, her discovery that warmer temperatures speed molting and growth presents a paradox: temperatures in the two regions are usually similar, with higher temperatures more often found in the Chincoteague, the site of smaller crabs.

To resolve the paradox, Reaka suggests two possibilities: crabs may grow quicker up to 24 degrees centigrade, the highest temperature tested, but warmer waters may stunt growth. A second, more likely explanation for faster growth in the Chesapeake is that blue crabs may find more food and nutrition in an estuary than in ocean coastal waters.

Red Crab Studies

The deep-sea red crab is the target of a rapidly developing commercial fishery along the eastern United States. Landings in southern New England in 1977 increased by 97 percent over the previous year, and in 1978 Virginia reportedly landed 4.8 million pounds. Some estimates predicted that landings in 1979 would approach 10 million

pounds. These estimates and earlier population projections make it clear that the potential for overexploitation of the fishery is increasing.

Biological and ecological information about the red crab is sketchy, however. William Van Heukelem and Steve Sulkin are studying growth rates of larval and juvenile stages and documenting behavioral responses of the larval stages which influence dispersal and hence recruitment of new individuals to the population.

Understanding the movement of the larvae can tell us which forces may encourage or inhibit their eventual recruitment.

Water Quality Studies

Underlying the success of any fishery is the health of the whole ecosystem; underlying that health is water quality. Major pollutants now entering the Chesapeake Bay include agricultural pesticides, petroleum, heavy metals, sewage and the chlorine used to treat it. With so many substances flowing into the water from cities, farms and industries, the Maryland Sea Grant Program has focused research on:

- developing more accurate indicators of water quality;
- building a better understanding of the interactions, degradations, and fates of the various pollutants in the estuary; and
- compiling base-line data on the little-understood microbial populations that recycle some of these pollutants and participate in important ways to the major food chains of the estuary.

The Problem With Water Quality Tests

Health tests widely used to monitor water quality in Maryland rivers and estuaries may be consistently inaccurate, the result of errors identified by microbiologists Rita Colwell and Brian Austin.

To guard against typhoid, paratyphoid and dysentery, the classic water-borne diseases, health officials have long used the coliform index, a classic sampling procedure for testing water and seafood products scheduled for human consumption. The index is an indirect test: it samples not for disease agents, but for coliforms, harmless "indicator" organisms. The key assumptions behind the test are two: positive readings imply coliforms; coliforms, in turn, imply disease-causing bacteria.

Those time-worn assumptions may be incorrect, according to Colwell and Austin. They discovered that many other bacteria typical to the Bay can also cause positive coliform counts. That finding supports a widely held hunch that traditional water quality tests need to be re-evaluated. A positive reading on a coliform test may not indicate a health hazard, say the microbiologists, and a negative reading may not imply healthy conditions.

What causes a positive result, says Austin, is bacteria with the ability to ferment lactose in the test broth. Some harmless bacteria, it is now clear, possess that ability and others may be able to acquire it via plasmids—pieces of extracellular DNA that can be passed among and picked up by a variety of bacterial species. "With a completed coliform test, we really don't know what the organisms are that cause a positive result," he explains.

The Colwell-Austin project also had other goals and other findings. After collecting and analyzing water, sediment and oysters at monthly intervals from four locations in the upper Chesapeake, they have:

- evaluated the coliform index and identified sources of error;
- established that extra-chromosomal elements were responsible for lactose-fermenting abilities in *Pseudomonas aeruginosa;*
- named a wide range of *Enterobacteriaceae* that occur in oysters, sediment and water;
- found no seasonal variations in coliform counts in oysters; and
- discovered that oyster bacteria resemble sediment bacteria.

That last finding suggests that testing sediment rather than water may give more accurate readings on the health of shellfish beds.

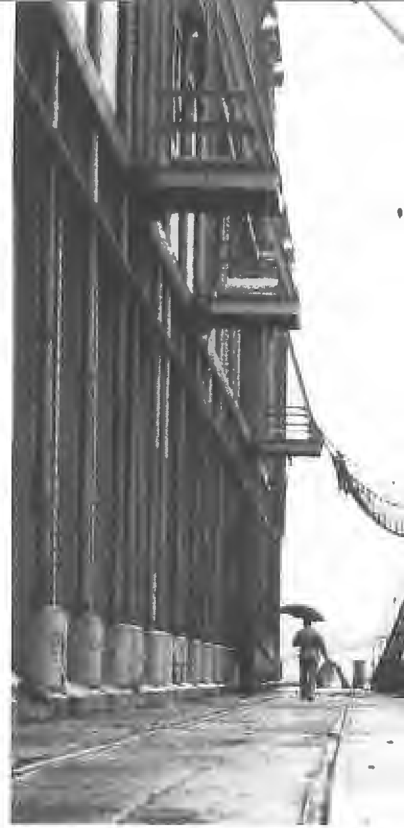
Monitoring Petroleum Pollution

Oil spills now rank right behind nuclear accidents as one of the major environmental nightmares of the modern age, thanks to headlines about the wreck of the supertanker *Amoco Cadiz* and the blowout of oil wells like the Ixtoc 1 that ran out of control in the Gulf of Mexico last year. Most oil pollution, however, occurs through leakage during shipping and offloading, and the major damage—as with nuclear wastes—may not show up until years later.

Two Maryland Sea Grant scientists have developed laboratory techniques for monitoring a subtle form of oil pollution found in many harbor and river shipping areas. Chemist Howard DeVoe, after working out a quicker system for extracting oil compounds from sediment and oysters, identified several polycyclic aromatic hydrocarbons (PAH's) in water and sediment samples taken from Baltimore Harbor. And microbiologist Mary Voll adapted the Ames test—a standard test for cell mutation—to show that some of those PAH's may be carcinogenic. The researchers found no evidence that oysters were taking up the cancer-causing compounds.

The Maryland scientists were studying PAH's because these compounds are one of the most subtle, long-lasting and difficult-to-detect forms of oil pollution. When spilled in water, most petroleum compounds begin to break apart, with some hydrocarbons evaporating quickly and others degrading slowly through microbial action. Because PAH's may last for centuries, they could be building up in the bottoms of harbors, rivers and estuaries where they can mix with other materials and possibly contaminate shellfish and other marine life.

Detecting PAH's causes special problems for researchers because of the difficulty of separating the compound from bottom sediment and animal tissue. "The sediment we looked at had the consistency of black mayonnaise," says DeVoe, "and nearly all of it had a variety of industrial chemicals in it." Working with oysters and sediment from the



Colgate Creek section of Baltimore Harbor, DeVoe devised techniques for preparing samples that proved quicker than the time-consuming methods previously described in the scientific literature. Using high-pressure liquid chromatography, he identified several four-ring hydrocarbon compounds and benzo(a)pyrene, a five-ring hydrocarbon compound.

By adapting the Ames test, Voll found evidence that some of those PAH's and other unidentified materials in the harbor are probably carcinogenic. The Ames test showed that the harbor compounds caused mutations in bacteria, a trait common to most cancer-causing agents. That discovery shows "nothing alarming," says Voll, since the harbor floor, heavily enriched by hydrocarbons over the years, is not a typical Chesapeake Bay environment. What would be alarming, she says, would be massive dredging of harbor sediment and the dumping of spoil disposal in other, biologically productive areas.

The researchers found no evidence of PAH uptake in oysters taken from the Choptank River, a relatively clean environment, or from other oysters kept in an aquarium lined with contaminated sediments.

Co-oxidation of Petroleum

Co-oxidation is a little-understood means of microbial degradation of petroleum hydrocarbons. In co-oxidation, microbes growing on one compound, the growth substrate, are able to oxidize a second compound, the cosubstrate. Joseph Cooney and Michael Shiaris are trying to discover whether co-oxidation plays an important ecological role in the degradation of polycyclic aromatic hydrocarbons (PAH's).

They first developed an assay procedure for detecting bacteria and fungi that degrade PAH's in the presence or absence of organic substrates. Using this assay, they found preliminary evidence that co-oxidation may be occurring among complex hydrocarbon mixtures such as those found in the sediments of the estuary.

Tracking Trace Metals

Heavy industry means jobs and paychecks and food on the table for hundreds of thousands of people in the Chesapeake Bay area.

Heavy industry also means heavy metals in the waters of the world's largest tidal estuary, metals like mercury, tin and arsenic. Add to that mixture metals entering from other sources—lead from automobile exhausts, cadmium from brake linings, tin from anitfouling paints—and the result is an interlinked economic and environmental problem.

In an estuary, heavy metals may undergo chemical and microbial transformations that help them penetrate the seafood chain at several levels. Trace metals often enter the food chain at the microbial level and then work their way up through the links, moving through bacteria, phytoplankton, zooplankton and fish larvae, sometimes invading the blood and tissue of oysters and crabs and finfish. In large concentrations, trace metals are probably toxic.

Since the links in that food chain are many and tangled, understanding *how* metals move along the chain still calls for a lot of complicated guesswork. Chemist J. M. Bellama studied the interactions of metals and microbes, trying to clarify the means by which microorganisms transform tin and mercury into organometal compounds and trying to identify the role of those compounds in the estuarine ecology.

Cadmium Studies

Yen-Wan Hung studied the potential of using oysters as a possible biological indicator of cadmium pollution in different areas of the Chesapeake Bay. The scope of the research was restricted to developing data on rates of cadmium uptake under varied laboratory environments.

Hung tested oysters for 40 days in four water samples with cadmium concentrations ranging from 8 parts per billion (ppb) to 105 ppb. Her findings to date:

- Oysters take up cadmium from water.
- The rate of uptake increases with the amount of cadmium contamination.
- Temperature affects the rate of uptake.

The Greening of the American Oyster

Oysters aren't supposed to turn green. When they do, it usually means they have been growing in copper-saturated water. Although the Chesapeake does not yet have green oysters in the numbers reported elsewhere, it does have increasing counts of copper, chitin and pesticides. Microbiologists Richard Smucker and Joseph Cooney are tracing out one of the ways in which those three elements can cause the greening of oysters.

Chitin is in the estuary because crabs are in the estuary. Chitin forms part of the outer skeleton for crabs and for some species of marine zooplankton. When these animals shed their shells or die, certain microorganisms break down their skeletons and recycle the chitin into carbon and nitrogen that are important to the natural energy flows of the Bay.

Copper is in the estuary because it leaks in from heavy industry and urban run-offs; pesticides are there because they wash off farmlands. When other researchers began reporting that some of the new pesticides can kill off chitin-degrading microorganisms, Smucker and Cooney realized that would leave a lot of free-floating chitin fibers. They also realized all that chitin could be hooking up with copper, making it easier for that metal to penetrate oyster flesh.

To test their hypothesis, they kept one set of oysters in water laced with copper and chitin and compared them with a second set placed in water spiked only with copper. They found that oysters retain much more chitin-bound copper than unbound copper.

Their findings are preliminary, but suggestive. Further evidence could come from testing oysters over longer periods at lower copper levels similar to those found in some areas of the estuary. The goal of their research is to develop data needed for determining permissible levels for pesticides and heavy metals in estuarine waters.

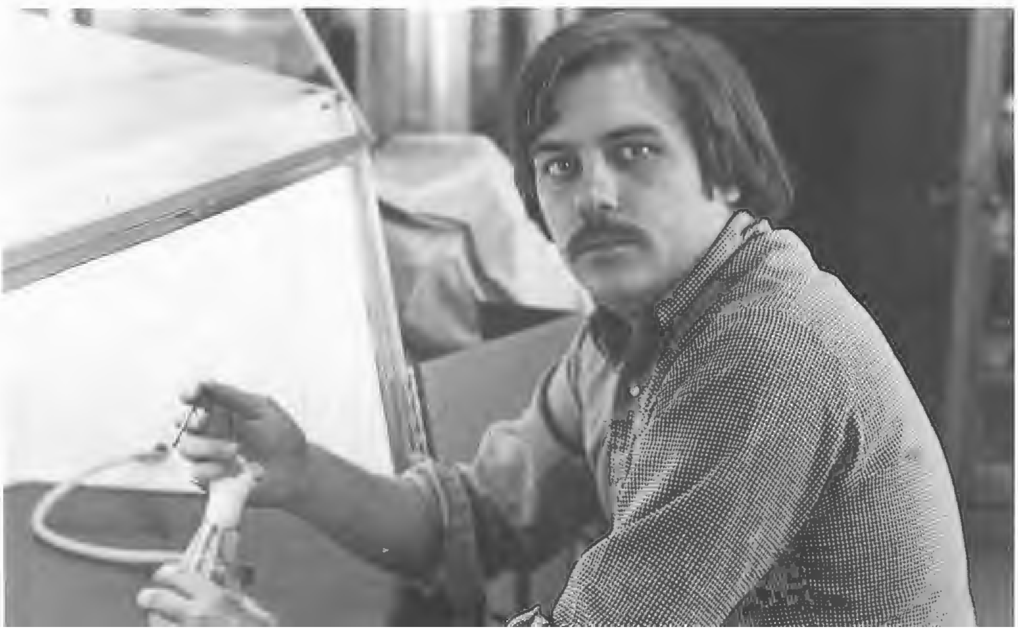
Baygrass Studies

One of the most disturbing trends of recent years has been the ongoing decline of underwater grasses around the Chesapeake Bay. Since these rooted aquatic plants help stabilize sediment, reduce turbidity and provide food and shelter for many waterfowl, finfish and shellfish, the current die-off could be damaging the ecosystem in several subtle and important ways. Scientists from a variety of institutions are studying possible causes such as increases in turbidity, nutrients and herbicides. Two Sea Grant projects are investigating the possible effects of atrazine, a powerful herbicide widely used by farmers to reduce weeds.

Roy Sjoblad is examining the ways in which atrazine interacts with sediments, suspended particles and microorganisms in the Bay. Working with new techniques for detecting the transformation of atrazine, he is documenting the ways in which atrazine might be degrading or altering to less harmful forms.

Marilyn Speedie is looking at the ways in which atrazine interacts with fungi, at the by-products of that interaction and at the effects of atrazine on the cellulolytic activity of fungi, microorganisms which play a key role in the detrital food chain and in the nutrition of filter-feeding shellfish.

These projects will accumulate hard data helpful in determining just how harmful or harmless these agricultural herbicides are.



Cholera Studies

The outbreak of cholera in Louisiana several years ago has emphasized the importance of developing a better basic understanding of the prevalence of this naturally occurring organism in those estuaries and coastal waters that are heavily harvested for shellfish. As part of an ongoing, three-year national study of cholera organisms in Maryland, Louisiana and Oregon—major shellfish-producing states—Rita Colwell will be developing basic information on the prevalence of *Vibrio cholera* and *Vibrio parahaemolyticus* in the Chesapeake Bay. One goal of the project is a better understanding of how these vibrios multiply in raw or processed shellfish; another is developing a Vibrio Index that could be used for determining the public health safety of shellfish.

The Ecology of *Bdellovibrio bacteriovorus*

The predatory nature of the microbial parasite *Bdellovibrio bacteriovorus* aroused the curiosity of William Falkler and Henry Williams when they observed that the most-favored prey of the little-understood *Bdellovibrio* were gram-negative bacteria, the kind of pathogenic fecal organisms responsible for infecting people who eat crabs and oysters taken from the Bay.

Falkler and Williams thought this predatory relationship important. *Bdellovibrio* could be acting as an ecological purifier, naturally controlling the population of pathogenic organisms. By determining the numbers and location of the *Bdellovibrio*, they might be able to come up with a guide to the extent and toxicity of the biological pollution which is becoming more and more prevalent in the Bay.

They sampled the water at eleven Bay sites, from Tolchester Beach to Cape Henry. They found, for example:

- The greatest number of *Bdellovibrios* occur in the middle and lower regions of the Bay; the fewest in the north where salinity is less than one percent. The York and Rappahannock rivers hold the highest concentrations.
- The number of *Bdellovibrios* is one to three thousand times greater on oyster shells than in the water. Most of the scant research on these bacteria had focused on their presence in the water. These findings suggest that *Bdellovibrios* are finding their pathogenic prey not in the water but along the bottom.

Special Projects

The ability to respond quickly to problems and opportunities is one of the great strengths of a program such as Maryland Sea Grant. In recent years, the program has participated in a variety of special projects including:

- supporting in cooperation with the Maryland Department of Natural Resources an annual Spat Set Cruise that surveys oyster reproduction on natural oyster bars around the Maryland portion of the Chesapeake;
- starting research to test the economic and technical feasibility of composting blue crab processing wastes;
- improving the capabilities of the Seafood Technology Laboratory of the University of Maryland Center for Environmental and Estuarine Studies, a necessary step towards addressing the special needs of the state's seafood processors;
- purchasing a water-quality auto-analyzer that is currently being used for studies on nutrient loading in the Chesapeake and its major tributaries;
- funding a preliminary study of the problems of spawning rockfish in hatcheries;
- providing partial support for research that identified the virus responsible for many menhaden fish kills;
- developing three educational workbooks on estuarine topics for use in the state's public school system in cooperation with the University of Maryland Science Teaching Center and organizing marine science workshops for science teachers in the state; and
- supporting and developing a special graduate-level course in microbial ecology.

What Do the People Think?

What do citizens of Maryland think about pollution in the Chesapeake Bay? About the possibilities of more nuclear power plants? About the problems of watermen and seafood processors? About the future of the estuary? What do the Bay's many environmental, professional and special-interest groups have to say about these issues?

These are the kinds of questions addressed by Pat Florestano and Patricia Rathbun, who studied the relationship between

resource users and the interest groups that represent them. Since interest groups form an important part of the American democratic process, the researchers used several methods to determine exactly who these groups are, how they react to specific issues and what general attitudes they have.

After identifying three kinds of interest groups—environmental, recreational and occupational—they found a fair consistency between interest-group positions on major issues and the opinions of the public.

Of the twelve issues addressed only three sparked significant differences of opinion:

- On land use control, the citizens felt more strongly that a landowner should determine the use of private lands.
- On government regulation of waterfront construction, a full three-quarters of the groups supported government regulation, while only two-thirds of the citizens agreed.
- On oil spills, again, three-quarters of the interest groups demonstrated a conservationist approach, saying that they did not feel that the public overreacted to oil spills. Slightly fewer citizens—two-thirds—shared this belief.

On nine major issues, special interest groups and the general citizenry responded with what was essentially one voice. For example, the interest groups and the individual citizens both agreed that the state should protect and give preferential treatment to the seafood industry: two-thirds of each group supported the idea. Likewise, neither citizens nor interest groups thought that government regulations should limit recreational boating. The special interest groups and the citizens agreed, too, that they did not want to see any more nuclear power in the Bay.

There are three important conclusions which can be drawn from this study:

- Interest group policies are generally in harmony with citizens' views.
- Very few citizen users of the Chesapeake are aware of the activities of, or even the existence of, Bay interest groups.
- Many interest groups exist on low budgets and are quite small, composed of only a few people who designed a letterhead.

How do citizens feel about the Bay's future? According to this study, they are mildly optimistic. Forty-three percent said that the Bay will improve within the next five years, 34 percent said that it will worsen, 22 percent that it will remain pretty much the same.

At the top of the list of concerns: pollution. Some 69 percent of the citizens named pollution as the most important issue, and an overwhelming 96 percent thought that those convicted of dumping toxins into the Bay should be held legally and financially responsible. Further, 94 percent of the respondents wanted a commission established to keep track of all the substances that get dumped into the estuary.

Marine Advisory Program

A long road leads from university laboratories and classrooms to the docks that line the shores of the Chesapeake Bay. Down that road travel the marine advisory agents and specialists, equipped with facts and figures given them by researchers and experts and well aware of the hard-earned perceptions watermen have of their environment. Important middlemen, these agents and specialists take with them a broad sense of problems and solutions as they go. To those who work the Bay, they bring new techniques in harvesting, processing and business management. To the researchers they bring accurate descriptions of on-the-water difficulties, sharing the basic knowledge they learn from those who live and labor on the Bay.

To tackle a wide range of problems, the Marine Advisory Program, under the administration of the University of Maryland Cooperative Extension Service, has set up several areas of concentration, with Dr. Tony Mazzaccaro as coordinator: marine economics, marine engineering and technology, marine safety and survival, marine recreation and seafood technology.

Here are some specific concerns and functions of the various program areas:

- A marine economist, working in conjunction with other agents and other specialists, stages seminars focused on aiding the marine community—especially commercial fishermen and marina operators—helping them deal with such issues as small business management, income taxes, retirement and insurance. Publications—in the form of easy-to-read Fact Sheets—help communicate this information to a wide target audience. Some topics have been: *Applying for a Fishing Loan*, *How Watermen Can Minimize Business Risks*, and *Leasing: An Alternative to Buying*.
- A marine engineer, working with a marine technology specialist and other experts in the field, organizes workshops for watermen and boat

owners on such topics as marine hydraulics, marine electrical systems, marine maintenance and repair, navigational systems and corrosion. Publications such as *Hydraulics in Commercial Fishing* and *Workboat DC Electrical Systems* make this information readily available to a range of readers, as do technical articles written for widely circulated periodicals like *National Fisherman*.

- In marine safety and survival, the marine advisory agent cooperates with the specialists to determine the nature and extent of dangers which threaten those who work Maryland waters, especially the Chesapeake Bay. Information goes out to those who can benefit from it, information about hypothermia and drowning, about survival gear and safe boating practices.
- Marine recreation—a growing concern and a booming industry in Maryland—receives emphasis in publications like the Advisory Program's new marine leaflet series. These leaflets cover such basic concerns as lightning protection systems and the navigation of busy shipping channels. Workshops for marina owners help focus on the needs of those who provide services for the marine community, defining problems boaters face in the Bay.
- In the area of seafood technology, specialists and agents work on outlining problems faced by the Maryland seafood industry, those who process the oysters, clams, crabs and finfish we eat. A seafood technology specialist cooperates with the marine engineer to solve difficulties processors have in meeting federal guidelines for plant effluents. They also investigate new and more efficient means of processing and preparing seafood on a commercial scale. A conference held with the state of Virginia in 1980, for example, helped focus on the problem of handling large volumes of crab waste.

- To keep abreast of developments in the seafood industry, the advisory agent organizes an annual Oyster Culture Conference, where researchers join managers and watermen to discuss the problems and potentials of aquaculture in Maryland. The prospects of commercial aquaculture become increasingly important as natural oyster populations dwindle.
- Another annual event coordinated by the advisory agent, in conjunction with the university and the state Department of Natural Resources, is the Spat Survey Cruise, an examination of the new growth of oysters on Maryland oyster bars. This cruise allows scientists and oystermen, managers and environmentalists to share in the dredging and surveying of oysters, putting people directly in touch with the problems facing this fishery.
- As part of its outreach function, the advisory service produces newspaper articles and radio spots through a series entitled the Bay/Shore Report. These treatments, along with articles placed in relevant periodicals, reach a large audience with information about boating, seafood and science.

Through workshops, publications and face-to-face visits, the Marine Advisory Program—the agents and the specialists—continue to link the university community with the daily users of the state's marine and estuarine resources. It is a vital connection.

Education

Education takes many forms. From graduate study in the environmental sciences to public school curricula to how-to pamphlets for boaters, Maryland Sea Grant helps to generate involvement and interest, foundations for learning.

On the college level, fellowships encourage students to pursue careers in the marine sciences. Three Sea Grant fellowships channel funds from NOAA to undergraduates enrolled in the Environmental Sciences Program at the University of Maryland Eastern Shore. Three graduate fellowships go to degree-seeking students in the marine, estuarine and environmental sciences at participating campuses of the university. Graduate students construct schedules tailored to their special needs, either on the master's or doctoral level, drawing from fields like marine and estuarine ecology, environmental microbiology, environmental biology, and fisheries and wildlife management.

Maryland Sea Grant also offers traineeships for students working toward graduate degrees, allowing them to acquire practical work experience as they team up with researchers involved in Sea Grant projects. Robert Burke, for example, aided Dr. Dale Bonar in research on oyster larvae, as he studied the effects of environment and crowding on oyster growth and metamorphosis. And Hugh Reichardt, another graduate student receiving training funds, worked with Dr. Marjorie Reaka in her research on the blue crab. Among other things, Reichardt has collected data on growth rates, trying to determine why the Chincoteague crab matures at a smaller size than the Chesapeake crab, and whether crab molting corresponds in some way to lunar phases. These studies give trainees an opportunity to make specific contributions to our knowledge of commercially important species and to build valuable work experiences.

A Sea Grant social science project directed by Robert Bish and Pat Florestano

generated curricula which took an interdisciplinary approach to Bay problems. Here students participated in simulated problem-solving processes, discovering how management choices evolve.

The Bay provides a focus for Sea Grant's public education efforts as well. Dr. Ken Stibolt of Anne Arundel Community College has provided workshop experiences for science teachers interested in Bay-related curricula. Teachers, after experiences aboard the 26-foot, diesel-powered research vessel and in the college's laboratories, returned to the classroom well motivated and well equipped to teach students about the complexities of the Bay.

Interest in marine education continues to build in Maryland. William Talbott directs an in-service training program for teachers in the Baltimore area, and Dr. Robert Paul of St. Mary's College has put together a work-study program for high school and undergraduate students. The Sea Grant Program teamed up with the university's Science Teaching Center to produce three marine science mini-units: *The American Oyster, Food Webs in an Estuary*, and *Tides and Marshes*. Sea Grant and the Teaching Center sponsored a workshop introducing these materials and sharing their knowledge about marine education opportunities that exist in the Bay area. The emphasis: using the Chesapeake as a tool for teaching students the rudiments of biology, physics and chemistry, as well as social dynamics and economics. At the same time, these education projects aim at increasing a general awareness and appreciation of the Chesapeake as the nation's largest estuary.

Education at Sea Grant takes place on the professorial level as well. As part of an information exchange program, several university researchers traveled to France to visit facilities at the University of Marseilles during November of 1978. Microbiologist Joseph Cooney, virologist Frank Hetrick and benthic ecologist Victor Kennedy spent two weeks meeting with French scientists involved in such areas as marine microbiology; fish, clam, and shrimp aquaculture; virology and fish disease; and marine ecology. The three Sea Grant investigators shared progress they have made in their own fields: Hetrick, for example, presented a seminar on the cultivation of oyster cells *in vitro* and on the effects of heavy metals on viral disease in trout. Ties with French researchers have remained strong, especially in the field of aquaculture. Dr. John Adams visited French facilities in December of 1979 to examine economic issues involved in transferring French aquaculture techniques to Africa, and Dr. Sheldon Sommer and Dr. Steven Rebach journeyed to France in March of 1980 to continue the investigation into French aquaculture technology.

The exchange program, the teacher workshops, the curriculum materials and interdisciplinary courses, all these represent one of Sea Grant's prime objectives: educating the populace about the world's waters, spreading the knowledge of a few into the minds of many.

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Marine Advisory Publications

These publications are available from the Maryland Marine Advisory Program, Symons Hall, College Park, Maryland 20742.

Marine Leaflets

Keep Clear: Big Ships in the Bay. ML137.
Lightning: Grounding Your Boat. ML138.
The Maryland Marine Advisory Program. ML139.

Fact Sheets

Applying for a Fishing Loan. NORMAN K. BENDER. FS 225.
Budgeting in a Marine Business. NORMAN K. BENDER and BILLY V. LESSLEY. FS224.
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Financial Assistance for Watermen. NORMAN K. BENDER. Revised by DAVID SWARTZ, 1980. FS 222.
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How Watermen Can Minimize Business Risks. DAVID SWARTZ. FS 301.
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Retirement Plans: Preparing for the Future. NORMAN K. BENDER. FS 227.
Seafood Processing and the Clean Water Act. RUSSELL BRINSFIELD. FS 308.
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Bay/Shore Reports. JACK GREER. Vol. 1, Nos. 1 - 16.
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Budget Summary
Expenditures By Activity 1978*

		NOAA Grant Funds	Matching Funds
Marine Resources Development	**Aquaculture:**		
	Aquaculture – Molluscs	14,250	22,400
	Living Resources other than Aquaculture:		
	Commercial Fisheries – Biology	95,065	39,950
	Pathology of Marine Organisms	86,395	10,250
	Marine Law and Socio- Economics		
	Federal Regulation of the Seafood Industry	32,200	-0-
Marine Environmental Research	**Ecosystems Research:**		
	Ecosystems Research	6,080	4,550
	Pollution Studies:		
	Metals	18,000	7,300
	Organic Compounds	25,180	21,000
Marine Education and Training	**College Level:**		
	Course Development – Law Curriuclum	28,500	28,150
	Other Education:		
	Sea Grant Trainees	32,500	16,000
	Sea Grant Fellows	40,500	-0-
Advisory Services	**Extension Programs:**		
	Extension Agent Services	125,000	65,600
	Other Advisory Services:		
	Communications	11,680	30,950
Program Management and Development	**Program Administration:**		
	Program Administration	15,430	97,750
	Program Logistic Support	1,520	11,400
	Program Development		
	New Applications Development	30,400	14,600
	TOTAL	562,700	369,900

Budget Summary
Expenditures By Activity 1979*

	NOAA Grant Funds	Matching Funds	
Aquaculture:			**Marine Resources Development**
Aquaculture—Molluscs	10,000	8,900	
Living Resources other than Aquaculture:			
Commercial Fisheries—Biology	200,600	63,450	
Pathology of Marine Organisms	59,200	7,550	
Marine Law and Socio-Economics:			
Marine Economics	21,200	29,000	
Socio-Political Studies	17,650	10,500	
Pollution Studies:			**Marine Environmental Research**
Metals	29,000	15,350	
Chemical	15,450	8,250	
Industrial	11,000	15,900	
College Level:			**Marine Education and Training**
Course Development—Other Resource Use	5,250	11,000	
Other Education:			
Teacher Training	5,200	3,100	
Research Techniques	4,000	7,700	
Trainees	52,850	27,000	
Extension Programs:			**Advisory Service**
Extension Agent Services	144,000	98,240	
Other Advisory Services:			
Communications	36,000	24,560	
Program Administration:			**Program Management and Development**
Program Administration	18,350	76,950	
Program Logistic Support	74,750	42,800	
Program Development:			
New Applications Development	44,400	86,800	
TOTAL	**748,900**	**537,050**	

* These summaries are only approximate. In accordance with federal grant requirements, the official financial report will be submitted by the Office of Sponsored Programs, University of Maryland.

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