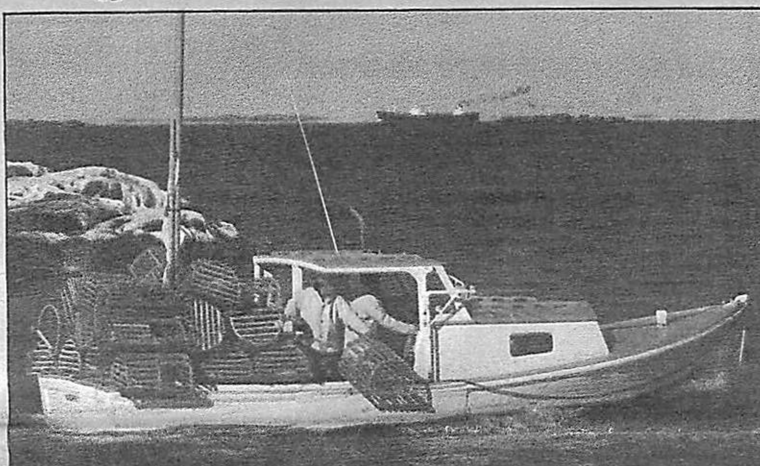
MEU-Q-86-001

INVESTING *in the* GULF OF MAINE



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New England's Own Ocean

Just beyond the reach of us is a land of plenty. The first explorers to cross the North Atlantic discovered its wealth, and 400 years later, fishermen are still harvesting its bounty. It is the Gulf of Maine, a 36,000 square-mile stretch of ocean New England can call its own.

Sheltered by the encircling arms of Cape Cod and Nova Scotia and their submarine extensions, Georges Bank and Browns Bank, the Gulf of Maine is almost entirely separated from the rest of the Atlantic Ocean. This sea beside a sea, with its indigenous organisms, circulation pattern, topography, salinity, and water temperatures constitutes a distinctive and complex ecosystem.

The Gulf of Maine was shaped by the Pleistocene ice sheet that covered much of North America until about 18,000 years ago. The glacier scoured rocks and soil from the land and transported them on a conveyor belt of ice to its leading edge. In eastern Maine, the ice left deep gouges that were to become the deepest water ports on the East Coast.

When the ice began to recede, rivers swollen by meltwater carved valleys through the glacial deposits and spread the finer materials far out onto the exposed shelf. As sea level rose, the hills and valleys of the continental margin became the basins, banks, and ridges of the Gulf of Maine.

Rivers still exert a powerful influence on our marginal sea. An average of 250 billion gallons of water a year, most of it as spring snowmelt, spills into the Gulf of Maine. Due to the earth's eastward rotation, it sets up a counterclockwise circulation. Incoming dense slope water from the Northeast Channel adds to this gyre, propelling nutrients, sediments, and marine life around the interior of the Gulf. A smaller clockwise gyre circulates over Georges Bank.

While the gyres promote horizontal mixing, it is the vertical mixing of seawater by strong tides and seasonal overturn that is most responsible for the productivity of the Gulf of Maine. Nutrients dredged from the bottom layers suffuse the sunlit surface waters to support huge blooms of phytoplankton.

Anyone who swims or dives in the frigid Gulf of Maine immediately encounters its fertility. Visibility underwater is commonly less than 20 feet, because of vast amounts of plankton and suspended particulates, forming a rich nutrient soup for organisms higher in the food chain.

Tiny animals called zooplankton graze on the minute algae phytoplankton. They, in turn, are consumed by carnivores of various sizes. Tapping a diversity of species rarely equalled in other seas, New England fishermen often haul a mixed trawl of several kinds of fish that school together.

Despite the present fertility of the Gulf there are problems on the horizon. Advances in fishing technology make it possible to deplete entire year classes of fish. Pollutants carried from the coast have been recently discovered in the sediments of the offshore basins. Alterations in shoreline habitats may be inhibiting the supply of nutrients to the Gulf.

While we profit now from the Gulf's youth and vitality, we need a deeper comprehension of its dynamic and complex character if we are to continue to reap its benefits in the future.

Lobsters With Wanderlust

Lobster has not always been the king of seafood, although it has been traditional New England fare from the time when the Penobscot and Narragansett Indians served it seasoned with sunflower oil.

In the 18th-century, the lobster was a poor man's food. It was a staple in the diet of indentured servants until they rebelled and refused to eat it more than three times a week. Lobsters were so abundant they were even used as fertilizer on colonial farms.

In 1850, lobsters cost 2-3¢ apiece. Today, they range from $2 to $20 a pound, depending on where you live.

In Maine, landings of 20 million pounds annually bring a wholesale price of $50 million. In fact, they are the highest value seafood product in Maine.

As a consequence, fishing effort has increased steadily over the century, even though landings have remained about the same. An estimated 90% of all inshore lobsters are caught the year they reach legal size (3¾ inches from eye socket to the beginning of the tail). Only 2% of those at or below legal size are sexually mature, which means that a small part of the population is sustaining a multimillion dollar industry.

Maine has taken unilateral measures to conserve the broodstock of lobsters. It is the only state that prohibits the landing of lobsters with a carapace-length above 5 inches. It also has a program to V-notch the tails of egg-bearing females, which then makes them off-limits to Maine lobstermen. These measures, lobstermen believe, protect the pool of larger lobsters which produce anywhere from 2-10 times the number of eggs of young females.

One reason that large lobsters (3½") may fare better than smaller ones is that they apparently move offshore, away from the highest concentration of lobster traps. An ongoing study jointly sponsored by Sea Grant, the Maine Department of Marine Resources, and the Maine Lobstermen's Association seems to indicate that the larger the lobster, the farther it moves.

In 1983 the Maine Lobstermen's Association asked researchers to help them learn more about the habits of these potentially important breeders by

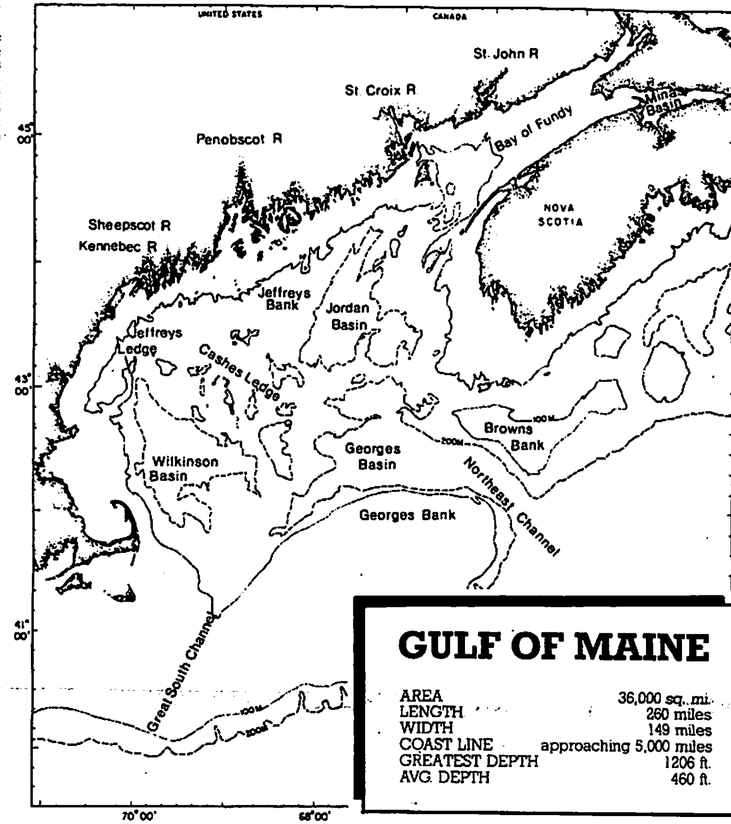
(Continued on Page 2)

tracking their movements over several years. In October 1983, Jay Krouse and co-workers of the Maine Department of Marine Resources tagged and V-notched 1,996 large female lobsters (3½-5"), and local lobstermen released them off Stonington and Boothbay Harbor. The next fall, they tagged another 1,923. Each lobster was surgically implanted with a long, red plastic tube bearing the inscription "UMO, Orono, Maine."

Lobstermen, through an extensive media campaign, were asked to record where they found the shellfish before returning them to the sea. On postcards distributed through the Maine Lobstermen's Association and lobster dealerships, they also recorded their observations concerning the presence of eggs, absence of claws, and whether the shell was soft, which indicates a recent molt.

All the data was sent to Robert Bayer, Professor of Animal and Veterinary Science at UMO. He and graduate student, Peter Daniel, plotted the lobsters' progress by computer.

Of 576 lobsters reported, 489, or 85%, had moved 20 miles or less. Usually these movements were offshore to deeper, warmer water in winter and onshore again in summer. Eighty-seven, 15%, moved more than 20 miles from where they had originally been released. Some lobsters were captured up to four times in different locations during the course of a year, revealing insights into annual lobster migration patterns that previous tagging projects had not provided. One lobster had journeyed from Stonington to 50 nautical miles south of Nantucket Island in 195 days, covering a distance of 238 nautical miles. At least six lobsters were observed to move 50-100 nautical miles south to the southwest, only to return to the initial release site within one year.



The long-distance lobsters trekked on average 60 miles to the southwest, following the counterclockwise currents of the Gulf of Maine. Several were found at Georges Bank, which is thought to be a breeding ground for lobsters.

The findings support the long-held belief of lobstermen that large lobsters leave the inshore fishery. Bayer explains, "If we know that the pattern is for larger, sexually mature lobsters to move to the offshore areas of Georges Bank and Browns Bank, then we might be able to optimize our recruitment (of new lobsters entering the fishery) by allowing these lobsters to make their migration and to give them some protection once they get there."

In the fall of 1985, lobstermen assumed an even larger role in the research program. Eight lobstermen from Cutler, Bucks Harbor, and New Harbor, caught, tagged, and released 900 lobsters that were larger than five inches to see if they match the wanderlust of their slightly smaller cousins.

What makes this study unique is that it is a cooperative effort between scientists and fishermen, two groups who are often in opposite camps when it comes to fisheries management. The university and the lobster industry recently formalized their partnership by creating the Maine Lobster Institute, an organization that will initiate and support lobster research projects.

Funding will come from the Maine Lobstermen's Association, the Maine Import/Export Association, and the University of Maine. Ed Blackmore, Executive Director of the Maine Lobstermen's Association, says the large lobster tagging study is just the beginning of joint industry-university research.

Investing In Investigating The Gulf Of Maine

Learning how to convert seaweed into energy, discovering cures for diseases in fish and shellfish, improving the return rate of Atlantic salmon and finding new alternatives for toxic waste disposal, are just some of the ways researchers at the University of Maine and the University of New Hampshire are recouping federal, state, and private investment in marine studies of the Gulf of Maine.

The joint Sea Grant College Program in Maine and New Hampshire is part of a national effort of research, education, and advisory services to accelerate the wise use and development of our marine resources.

Sea Grant, with its twin goals of research and outreach, was conceived in the 1960's by Athelstan Spilhaus, science popularizer and academician, who felt that the United States was devoting too much attention to the race for space and not enough to the exploration of the oceans. He and other Sea Grant proponents persuaded Congress to enact a national program for the study of the oceans. Twenty years later a $39 million Sea Grant Program at 300 academic and non-profit institutions around the U.S. and Puerto Rico now returns an estimated $230 million annually in gross revenues and savings to marine industries.

Through the National Oceanic and Atmospheric Administration, Sea Grant not only supports university research and education but also provides a mechanism for disseminating the information beyond the scientific community to decision makers and investors in public and private enterprises.

Science now pervades every aspect of modern life. Increasingly, science and technology are invoked to address issues in political, economic, and social policy. The general public is frequently asked to make scientific judgments. Decisions about pollution control, shoreline development, fisheries management, oil exploration, and even national boundaries rely on input from marine user groups and coastal residents. Those who live inland are equally involved in establishing marine policy by voting on bond issues for cargo ports and fish piers and deciding referendum questions on coastal uses. These responsibilities demand a scientifically literate constituency that bases its decisions on current knowledge.

The purpose of this publication is to share some of the current fund of knowledge about the Gulf of Maine, New England's "own" ocean, and to provide insight into why it is so productive and vital to the residents of northern New England.

Sea Grant researchers, both in the hard sciences and the social sciences, are assuming an active role in taking their work beyond the academic bastions. They participate in public lectures and public hearings, publish in popular journals, talk with students, and work one-on-one with marine resource users. They are eager to share their discoveries and their unanswered questions about the Gulf of Maine. Better knowledge of the Gulf, they conclude, is the key to protecting against shortsighted decisions.

This report is also about oceanography, an exacting, challenging, and exciting profession. The tools of the trade include nets, dredges, bottom cores, bathythermographs, diving gear, research vessels, submarines, and satellite sensors.

And the results are tantalizing glimpses into a new world that is frustratingly complex and intriguingly interconnected. When researchers find more questions than answers, they consider it a good day's work.

The Gulf of Maine is a living laboratory in our own backyard. Tapping its full potential is more than reaping profits from fish and oil. As Athelstan Spilhaus expressed it two decades ago, "The oceans offer us military, recreational, economical, artistic, and intellectual outlets of unlimited scope. They'll offer us more space than space in which to remain human."

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Investing in the Gulf of Maine

A Report on the Maine/New Hampshire Sea Grant College Program

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WHERE THEY WORK

. . . at public events
. . . in the classroom
. . . on the mudflats
. . . underwater
. . . in the lab
. . . onboard research vessels
. . . inside submersibles
. . . and even in schoolhouse basements converted to aquaculture hatcheries

FISHERIES

Seafood Quiz: Test Your Seafood Knowledge

Yes	No	
___	___	Have you eaten fresh seafood in the past week?
___	___	Do you know what port it came from?
___	___	Did you know that some fish caught off New Hampshire and Maine is shipped to Boston and back before it reaches the consumer?
___	___	Can you tell if your fresh fish is fresh?
___	___	If someone offered you sea urchin roe, hake, or eelpout would you eat it?
___	___	Would you let your cat/child eat it?
___	___	Did you know that groundfish is **not** the marine equivalent of hamburger?
___	___	Do you know what goes into bringing fresh seafood from the ocean to you?

From Sea to Supermarket

If you answered "No" to any of these questions, then you're probably not one of the 15,000 licensed, commercial fishermen who contribute $300 million annually to the economies of Maine and New Hampshire.

Even if you are not, you may be interested in recent strides in research and development that are helping the seafood industry to improve its productivity, product quality, and marketing strategies.

Seafood, long known as "brain food," is actually nearer and dearer to our hearts. Recent cardiovascular studies have concluded that eating more fish is an ideal way to cut back on heart-threatening cholesterol, fats, and calories. Fish is rich in oils that may actually help prevent heart attacks.

Education

Southern Maine Vocational Technical Institute, Washington County Vocational Technical Institute, and Sea Grant staff, with the assistance of the Massachusetts Maritime Academy, have sponsored technical training workshops for commercial fishermen.

Short courses in net mending, diesel engines, hydraulic and marine electronics attracted fishermen during their winter hiatus.

One young crewman signed up for every workshop. His rationale, "Anything you learn helps you do your job better. The more comprehensive knowledge you have, the more valuable you are to yourself and your boat. It translates immediately into dollars and cents."

Research and Development

The Maine/New Hampshire Sea Grant Program and its cooperative associations have instituted research, advisory, and education programs in direct response to industry needs and requests.

Basic research on individual fish species such as the work being done on yellowtail flounder and sea herring will eventually improve our ability to predict the size of fish stocks available to harvesters each year. Applied research, such as how to control sea urchin populations in the Gulf of Maine, is another area where Sea Grant scientists have taken the lead.

Research and development on fishing gear and product marketing have introduced new fisheries and enhanced traditional ones. The Fisheries Technology Service of the Sea Grant Marine Advisory Program recently developed a fishery for mahogany quahogs in Maine by analyzing population dynamics, designing hydraulic harvesting gear, and identifying marketing outlets for the underutilized shellfish. Thirty boats from downeast Maine are now landing a million dollars worth of ocean quahogs a year.

The Fisheries Technology Service (FTS) also perfected a shrimp-separator trawl which answered the shrimpers' problem of taking large amounts of juvenile flatfish. The unintentional harvesting of these small groundfish that share the ocean bottom with northern shrimp represented a $10 million annual loss in future groundfish revenues. By excluding juvenile flatfish from the net, the innovative shrimp gear preserves the quality of the delicate shellfish that would otherwise be crushed by the unwanted fish.

The FTS, the University of Maine Cooperative Extension Service, and the Sea Grant Marine Advisory Program have collaborated on sharing the research results of university scientists from New Hampshire and Maine. They work with shellfish committees, marine wardens, and 4-H club members to help improve the productivity of their clamflats. Several coastal communities owe the revitalization of their soft-shelled clam fisheries to the conservation and management practices and youth-organized hatchery projects introduced by the Sea Grant network.

Maine's sardine industry provides seasonal jobs for hundreds of workers and provides valuable dollars to Maine's economy, as it has for over a century.

Quality

Quality, rather than quantity, is seen as the solution for the fishing industry to attract a greater share of the consumer food dollar. Maintaining quality and extending shelflife are key factors in expanding to inland markets and gaining greater consumer acceptance for fresh fish. Quality, safety, and shelf life depend on factors such as the time between catching and processing, temperature, cleanliness, and the mysterious chemical processes that begin to operate as soon as a fish dies.

Despite what the commercials for air fresheners tell you, fresh fish does not smell. It is only fish that has passed its peak of freshness that gives off the "fishy odor" that offends one's nose and makes consumers leery of buying and preparing fresh fish themselves.

Bohdan Slabyj of the Department of Food Science at the University of Maine at Orono has been studying the factors responsible for quality loss in seafood for 23 years. His research has focused most recently on lipid peroxidation, the process that causes rancidity and the accompanying unappetizing odor in fish, chicken, lard, and other foods containing fatty acids.

Fatty fish, like herring, are more vulnerable to lipid peroxidation than leaner fish. Herring constitute a multimillion dollar fishery in northern New England. Juvenile herring — sardines — are caught in the summer months when warm air and water temperatures exacerbate spoiling (i.e. oxidation).

The fish are salted as soon as they are brought onboard herring carriers, but excess salt may result in a product that is not acceptable to the consumer. Both processors and fishermen are anxious to find an alternative way to retard spoilage.

Slabyj has observed that much of the action of lipid peroxidation takes place around the microsomes, parts of the cell membrane made up of proteins and lipids. The microsomes act in concert with other cofactors, energizing agents, that are normally found in fish tissue.

Slabyj separates the microsomes by homogenizing the fish tissue and centrifuging it at low speed to remove larger particles. Using ultracentrifuge, he isolates the cell membranes. When he uses very low concentrations of microsomes in his experiments, he obtains barely measurable levels of oxidation. Simply by adding fats to the solution, he can detect a dramatic increase in rancid products. Therefore, Slabyj reasons, the fats that are deposited outside the cell membrane somehow become oxidized. Oxidation thus affects both the lipids inside the cell membranes and the fatty tissues without.

His next step is to determine if membranes preferentially oxidize outside fats or if they oxidize themselves and then exchange materials with the surrounding lipids.

Paradoxically, unsaturated fats which are responsible for rancidity when oxidized, have been found to inhibit, rather than trigger, oxidation when added experimentally to lean fish. Slabyj's goal is to find out how these apparently conflicting facts mesh together. "Somehow free polyunsaturated fatty acids interfere with lipid oxidation, but how? We need to understand how oxidation of lipids works on the cellular level before we can

Why is this man smiling? Because he's seen his dream come true — North America's first display auction at the Portland Fish Pier.

Marketing

A revolution in fish marketing was quietly launched a decade ago by James Wilson, a soft-spoken fisheries economist at UMO. The idea he embraced — the first display auction in North America — became the rallying point for the $22 million Fish Pier in Portland, Maine.

The Portland Fish Exchange held its first auction on May 18, 1986 and is already changing the way the fishing industry does business. It puts all transactions out into the open, allows dealers to buy only as much fish as they need, stabilizes supply, and gives quality a position in the market place.

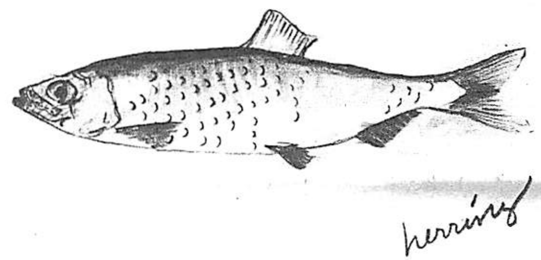
In traditional fish auctions, a buyer usually purchases an entire "trip," or boatload, sight unseen. Fish that were iced and boxed at sea usually command the same price as fish that were shoveled into the hold. In the display auction all the fish are exhibited in the refrigerated auction building, iced and boxed by size, species, and quality. In countries where display auctions are common, as in Japan and northern Europe, buyers consistently bid higher for the higher quality products.

"If the Portland auction works as planned," explains Wilson, "it's going to start to introduce a price premium for higher quality fish. Second, it should cut down the costs of buying and selling fish in general. If you're a buyer now buying fish directly from a boat, you'll find that maybe half aren't the species that you find useful for your customers. Then you have to turn around and sell the rest. That takes time and it takes money. Meanwhile the value and quality of the fish decreases. At the auction you'll simply be able to walk up and buy what you need. You won't face all those problems of reselling.

"The third principal advantage is that it will put each buyer in a position in which he is able to predict supplies in the market a lot more accurately than he can now. Say you're a buyer and rely on three, four, a half dozen boats. If one of these boats develops engine problems, if the weather is bad, if, if, if . . . all of a sudden you're without fish or have half as much as you expected. You'll have a hard time meeting contracts and operating your production line if you don't have the fish."

Wilson first proposed the concept of a display auction in a 1976 Sea Grant report on the potential impact of the 200-mile limit on the Maine fishing industry. He and Robin Peters, editor/publisher of *Commercial Fisheries News* and then a fisheries specialist with Sea Grant, developed the idea further in subsequent studies for the State Planning Office and the City of Portland. Wilson was later contracted by the city's Fish Pier Operations Committee to design the rules of operation for the fish auction and, more importantly, to strike a balance between the demands of the harvesters and the dealers/processors.

What they achieved is being viewed with anticipation by other fishing ports around the country. If the auction works, speculates Wilson, it could effect changes in traditional auctions like Boston and New Bedford. Already buyers and boat owners are saying that in Portland, at least, you have a fair chance to make quality pay.



begin to prevent it. We are trying to generate data that will lead to better handling and processing of fatty fish."

While Slabyj is experimenting on microsomes to improve fish quality, across campus Robert Bayer is working to improve the quality of New England's most famous seafood, lobster.

In his laboratory in the Animal and Veterinary Sciences Department at the University of Maine, Robert Bayer has concocted an artificial feed for pounded lobsters that are held for several months in fenced-in embayments until lobster prices reach their peak in late winter. The pelleted lobster feed, now available commercially, is a supplement to the scrap herring traditionally fed to penned lobsters. The feed helps to sustain muscle tissue, harden the shell, and reduce cannabalism. In time, Bayer hopes to produce feed that will help speed growth and maximize meat weight.

Bayer has also produced a medicated diet to control *gaffkemia* (also known as red-tail), a fatal and highly infectious bacterial disease responsible for over a million dollars in losses each year to lobster poundkeepers. Bayer has devised a simple test that poundowners can administer to detect the presence of the disease in their stock.

Still in use today, weirs were one of the earliest methods for capturing great schools of herring.

Consumer Education

A seafood sampling booth at Market Square Day in Portsmouth.

If improved quality and marketing create a bigger supply of fresh seafood, then there should be a corresponding effort to create more demand.

America has not traditionally been a nation of fish lovers. Annual per capita consumption of seafood reached an all-time high of 14.5 lbs. in 1985, up from slightly under 10 pounds at the end of World War II.

One person who is working to sustain the upswing is Sharon Meeker, docent coordinator for the Sea Grant Marine Advisory Program at the University of New Hampshire. In 1984 alone, she and her team of volunteer educators reached approximately 13,000 people through seafood sampler booths at community festivals in Portsmouth and Manchester and through programs for schools and community groups.

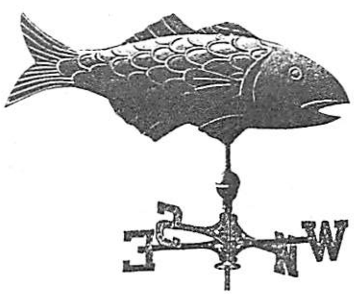
They provided samples of tasty concoctions like fish pate, fish puffs, and Irish moss pudding. Emphasizing the ease of preparation and the healthfulness of seafood, Meeker's docents (Greek for "teacher") also handed out recipes and journal reprints.

During COASTWEEK, 1984, the Marine Advisory Program under Meeker's planning sponsored an underutilized seafood supper. One hundred and ninety people devoured sea urchin roe, mussels, monkfish, shark, skate wings, seaweed pudding, and kelp cookies.

Meeker also has worked with home economists of the Cooperative Extension Service to develop a consumer education program that responds to the most common excuses for not buying fish: "I don't know how to tell if it's fresh. I don't know how to prepare it except by frying. I don't know where to buy it."

To help consumers locate fresh fish more easily, Meeker conducted a survey of fish retailers and wholesalers throughout New Hampshire, inquiring about their product lines, where they purchased their seafood, and what educational interest the group might have. She reported that out of 135 respondents, "Most purchased seafood directly from Boston, but about half of them also bought fish from local fishermen. Canada appeared to be making inroads into the market, as 25% reported buying fish from Canadian companies, particularly frozen fish."

The results of the survey were published as the "New Hampshire Seafood Directory." As a follow-up activity, a conference on seafood marketing and handling was held in March 1986 to address educational issues the respondents had identified. Working as a promoter and intermediary, Meeker may raise the national average for seafood consumption another notch or two.



Fish Forecasting

Fishing has often been compared to hunting. How successful the hunt will be depends on a skipper's familiarity with the fishing grounds, his knowledge of the fishery, and weather conditions. Chance, however, plays a large part in determining whether any particular trip will be a profitable one or a "broker."

On an annual basis, the abundance of commercially-important species can be predicted with more certainty. Fishery scientists estimate year class strength, the number of fish born in the same year that should eventually reach harvestable size. They base their figures on the number of adults available to spawn and the survival of eggs, larvae, and juvenile fish.

Though some species of fish may produce many thousands of eggs, few of these will survive to maturity. Very small changes in the mortality rate of eggs and larvae can have significant impact on the size of a particular year class.

Improving the accuracy of fish forecasts, then, depends on gaining a better understanding of the early life histories of Gulf of Maine species. These projects on yellowtail flounder and sea herring illustrate some of the factors which influence survival in the sea.

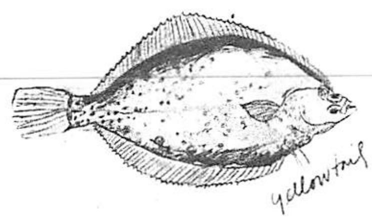
Along with cod and haddock, yellowtail flounder is one of the most important groundfish species in New England. Its landed value is $15 million annually. When the yellowtail population plummets, as it does frequently, it has an immediate impact on the fishing economy. Scientists are trying to understand why the yellowtail flounder year classes fluctuate so severely. Some are concentrating on the early life histories of the yellowtail and how well they cope with the double threat of predation and starvation.

Hunt Howell, a University of New Hampshire fisheries biologist, is studying the supply side issue: how the survival of the larval flounder may be related to their food supply. "We need to know a lot more about what yellowtail flounder are eating, how they select their food, and how much food is available to them in their early life history. My work is to put another piece in the puzzle of larval population dynamics so that someday we can understand the survivorship of that stage."

To get the data he needed for his study, Howell made four cruises in 1982 between the Isles of Shoals off New Hampshire and Stellwagen Bank north of Cape Cod. In six days of field work, he generated a year of laboratory studies in identifying, analyzing, and categorizing the yellowtail larvae and the zooplankton on which they feed. The yellowtail larvae ranged in size from 5-20mm and were about one to three months old. He dissected their tiny stomachs to discover what they ate. He learned that yellowtail larvae are surprisingly particular about their diet. Only three or four species of calanoid copepods accounted for more than 90% of their food.

Unlike other fish larvae, as the yellowtail grew, the size of their food did not. Three-month-old yellowtail still ate the same size prey that they had at one month.

Just-hatched yellowtail larvae can live off the stored food in an attached yolk for about seven days. Once the yolk sac is absorbed, they will start to starve unless they chance upon some zooplankton distributed in patches around the Gulf of Maine. If they do not, "After about four or five more days (after digesting their yolk sac), we think the larvae don't have much interest in eating. I think they're just too weak to catch food." Their chances of survival depend on the availability of the right food of the right size at the right time. Howell thinks that one contributing factor to a poor fishing year may be that most of a particular year class did not

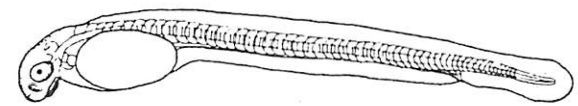


find that right combination.

Since the late 1800's, the harvesting of juvenile herring — sardines — has been a major fishery in Maine. On summer evenings, fishermen wait beside their weirs for the sardines to swim inshore and become entrapped in the semi-circular maze of suspended nets. Then the fishermen close off the entrance to the weirs and transfer the fish into boats sent by the canneries.

Sardines are a "boom or bust" fishery. Some years the weirs and seine nets collect so many fish that the canneries can't handle them all. Other years the fishermen wait in vain for the fish to arrive.

Knowing how many fish will be available, especially the two-year-olds which are the optimum size for canning, is important to fishermen and to processors alike. Making those predictions has been Joe Graham's lifework. For 24 years, Graham has been a herring population dynamicist with the Maine Department of Marine Resources. He bases his estimates on factors such as how many newly hatched larvae arrive in estuaries in the fall to winter over and how many herring hatch late in the breeding season. Whatever helps him better understand how many herring survive their first winter helps him improve his predictions of how many sardines will be available to the fishing industry two years later.



One of the mysteries of herring behavior Graham has noticed over the years is that larval herring arrive at the entrances of estuaries in waves, not in a continuous procession, between September and December. Why do they do this? Where do they come from? How old are they when they arrive? What routes do they take from where they hatch to where they overwinter? These are some of the questions Graham and fellow researchers, David Townsend and David Stevenson, have been trying to answer. It is a cooperative effort by the private Bigelow Laboratory for Ocean Sciences, the University of Maine, and the Maine Department of Marine Resources.

The research has focused on the herring spawning ground in eastern Maine between Jonesport and West Quoddy Head, where large tides churn up nutrient-rich water. This region supplies many of the sardines caught in Maine and is one of the few locations where herring presently spawn in the Gulf of Maine. Graham, Stevenson, and Townsend have been able to trace herring hatched from this spawning ground as far south as Boothbay.

In order to pinpoint the exact location of the egg beds in eastern Maine, Stevenson interviewed lobstermen who reported eggs adhering to their lobster pots.

In the summer of 1985, Stevenson explored one spawning location by submarine. As part of a $10,000-day operation funded by the National Underwater Research Program (NURP) at the University of Connecticut, Stevenson descended into the Gulf of Maine in the Johnson Sea Link to see for himself what bottom type, topography, and water currents spawning herring prefer.

Stevenson returned to the same spawning ground in September during the spawning season. Using a small, unmanned remotely-operated vehicle (also supplied by NURP) mounted with an underwater video camera, he observed an area of ground bottom covered with a huge expanse of herring eggs. Stevenson says, "For 800 feet along an east-west axis we saw nothing but eggs. It was an absolute carpet of herring eggs an inch thick on a flat bottom . . . It was like looking down at a pine forest from a thousand feet up in the air."

In earlier cruises to the eastern Maine spawning ground, Townsend had found that there was almost no food available for the just-hatched herring larvae to eat. Although there were plenty of nutrients stirred up by the strong currents, the water was too turbulent to allow phytoplankton to grow.

Newly-hatched herring larvae can sustain themselves for about seven days on food stored in their attached yolk sacs. Meanwhile, they are swept down the coast, suspended in water rich in dissolved nutrients but poor in food. As the water becomes less turbulent and more stratified, phytoplankton begin to bloom in response to the increased amount of time spent near the surface waters. This in turn triggers a bloom of zooplankton, the microscopic animals that feed on phytoplankton. Just about the time the larval herring have absorbed their yolk sacs and are on the prowl for food, the zooplankton hatch. Zooplankton, as it happens, are what larval herring love to eat.

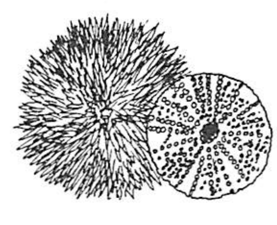
Whether this is good planning on the part of the adult herring or just coincidence, the researchers cannot say. But current measurements have shown that there is non-tidal coastal current that is responsible for moving the larvae and their potential food supply westward down the coast. "It's almost like a conveyor belt," explains Townsend. "The water, the fish larvae, and the dissolved nutrients all move downstream together."

What Graham, Stevenson, and Townsend are learning about larval herring survival will someday improve Joe Graham's annual fish forecast for the sardine industry.

Underwater Maneuvers

Just offshore in the Gulf of Maine, an army of pincushions is laying waste to a swath of ocean bottom between Atlantic Canada and northern Massachusetts.

Hordes of green sea urchins (*Strongylocentrotus droebachiensis*), marching spine to spine devour shallow water kelp beds that were once the refuge of lobsters, crabs, and other bottom dwellers.



The urchins live below the reach of the waves at a depth of 5 to 20 meters. After they have stripped an area of algae, they can adjust their metabolism to subsist on the drifting seaweeds and a film of microscopic algae that continues to develop in spite of the steady cropping.

Once established, sea urchin barrens can persist indefinitely. Only where divers meticulously remove urchins for several months or longer do kelps and Irish moss begin to reappear.

Larry Harris, a University of New Hampshire zoologist, and Robert Vadas, a botanist at the University of Maine, have studied the sea urchin onslaught and its impact on the interdependence of lobsters, kelp beds, and urchins. In Nova Scotia it had been reported that lobster catches seemed to decline when sea urchin populations increased.

They were particularly interested in the mechanism which introduced urchins to unexploited areas. Harris examined the problem from the juvenile prospective: What factors determine settlement, growth, and survival for the first year or two of life? Vadas focused on the mass of migration patterns of the adults. Harris also came up with a novel solution to the overpopulation problem.

Before Harris began his study, very little was known about juvenile urchins. Harris and his graduate students have spent many hours underwater observing where larval urchins settled. During the month of June, hundreds of thousands of small white dots would suddenly appear on any firm substrate, metamorphosing within 24 hours into miniature sea urchins.

While urchins were settling the researchers found no clear preferences between kelp beds and new or old urchin barrens. Harris frequently counted up to several thousand newly-settled urchins per square meter in all these areas. The kelp beds seemed to be the least hospitable to urchin survival, however.

By the time they are a year old, young urchins will have grown to about 4 mm. across. Though it takes several more years to reach adult size, sea urchins develop functioning gonads after two years. "Some urchins have been found to live fifteen years," notes Harris, "so they can do a lot of reproducing in their lifetime." In a large urchin, 20% of its weight may be devoted to gonads. This productivity, in fact, may be the key to its destruction.

The gonads of the sea urchins, known as "roe," are delicacies eaten raw in Japan and southern Europe. With the rising popularity of sushi bars in New York, Boston, and now Portland, there might just be a local market for the green sea urchins ripening off our coast. Harris and lobsterman Robert Bryant of Portsmouth have developed a technique for harvesting up to a ton of sea urchins a day. They envision a limited winter roe fishery from November to March during the off-season for lobster fishing and the on-season for sea urchin reproduction.

Harris believes there is no natural solution to the problem of sea urchin overpopulation. Although lobsters, crabs, wolf eels, and eelpouts will eat urchins, none seems to prefer them as its primary food. Harris contends that predators are just not effective in halting the sea urchin invasion he has seen overtake much of coastal New Hampshire and Maine.

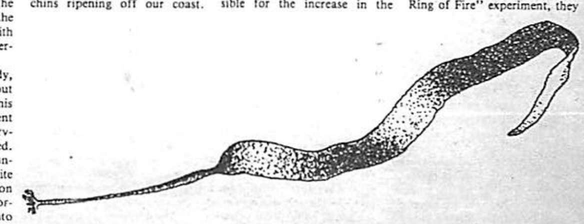
That is also the conclusion of Robert Vadas' research which has focused on the relationship among organisms in kelp communities. Earlier Canadian studies had proclaimed that lobsters were the "keystone" predators of sea urchins, that is, their presence was crucial in containing the urchin population. Overfishing of lobsters, the theory maintained, was responsible for the increase in the number of urchins.

Vadas' observations in Maine did not fit that theory. Even where there was no fishing pressure on lobsters, the urchin population continued to flourish.

Vadas wondered what mechanism triggered sea urchins to aggregate in "fronts" and advance across the ocean floor like an invading army. Capable of progressing several meters a day, these masses of urchins wreak havoc as their small ventral mouths nibble away at the kelp and Irish moss under their feet. When Napoleon said that an army travels on its stomach, he could well have been describing sea urchins.

The Canadian study held that urchins formed aggregations as a defensive response to the presence of lobsters, much as fish form schools and other animals flock. Vadas, on the other hand, had only observed sea urchins aggregate around their preferred food, the laminaria kelps.

He and Dr. Robert Elner, a Canadian biologist, put the urchins to the test with a series of ingenious ocean experiments. First, in what they term "The Ring of Fire" experiment, they

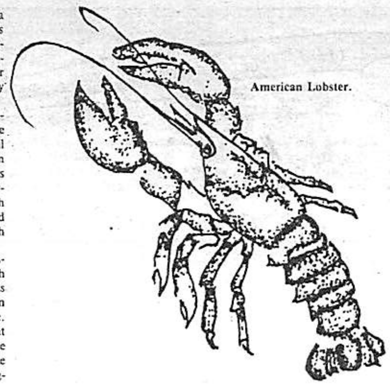


surrounded sea urchins with a ring of lobsters and crabs tethered to a metal frame to insure their cooperation. The urchins neither aggregated inside or outside the ring. They simply fled.

Then in "The Hotel Fire" experiment, Vadas and his graduate students, Ivar Babb and Phil Garwood, put fifty urchins in large cages. In the various cages they placed urchins alone, urchins with lobsters, urchins with kelp, urchins with less preferred algae and, finally, urchins with algae and lobsters.

All the experiments were conducted with both small-mesh cages which retained the urchins and with large-mesh cages from which the urchins could escape.

The researchers assumed that with a continuously available signal from the lobsters, the urchins would form defensive aggregations in the center or along the sides of the cages.



American Lobster.

In the small-mesh cages (except where food was present), the urchins piled up at the exits without forming any organized aggregation.

In the large-mesh cage containing lobsters but no food, 75% of the urchins fled within 24 hours. Where both lobsters and rockweed were present, the number of urchins more than doubled within 24 hours. Hardly an appropriate response to a fearsome predator. "These findings seriously compromised the notion that lobsters are a keystone predator," observes Vadas.

When the divers crushed an urchin upstream, other urchins fled in all directions making no attempt to group together in a defensive aggregation.

As a result of these experiments, researchers are reexamining their views on the interdependence of sea urchins, lobsters, and lobster fishermen. The shallow-water kelp communities of which sea urchins and lobsters are members are more complex than was previously believed. Vadas intends to expand his experiments on sea urchin behavior to other predators.

Bob Vadas epitomizes the trend among marine scientists to take a holistic approach to studying the complex ecosystems of the Gulf of Maine. He holds a joint appointment at the University of Maine in the departments of zoology, botany, and oceanography. He explains, "I'm really a hybrid. In other times I would have been called a naturalist. It allows you to look at questions with a broader, more flexible approach."

AQUACULTURE

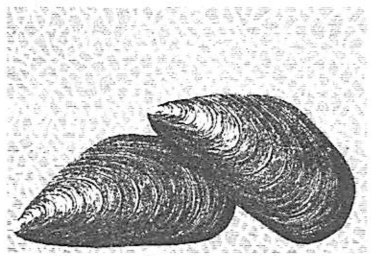
Farming the Sea

Fifteen years ago if you asked someone to define "aquaculture," the response might have been that it was knowing when to use your fingerbowl at a formal dinner.

Today, aquaculture — *fish farming*, as it's also known — is a burgeoning industry in New England, from a salmon ranching operation in Eastport, Maine, to mussel farms along the Damariscotta estuary, to trout and salmon hatcheries in Milford, New Hampshire. As of 1985, there were seven commercial aquaculture operations in New Hampshire and more than 50 in Maine.

Although the volume of aquaculture production in New England is still insignificant compared to commercial fishing, it accounts for 10% of the worldwide aquatic produce of seaweeds, fish, and shellfish. The practice has flourished in China for 4,000 years, but it was introduced to northern New England primarily through the efforts of the Maine/New Hampshire Sea Grant Program to cultivate blue mussels and European oysters in the early 1970's. The University of Maine's Ira C. Darling Center in Walpole literally hatched some of the first cultivated shellfish operations in the region.

Early Sea Grant research projects focused on environmental evaluations of culture sites, growth rates, and growout techniques. Later, supplying broodstock and innovations in harvesting and processing equipment helped to nurture nascent commercial ventures.



Through aquaculture techniques, Maine's mussel industry has grown to supply expanding markets with a high quality product.

Mussel Power

In the not too distant past, only the most adventuresome gourmet would dare to dine on mussels. Now, mussels are chic cuisine at bargain prices, still selling for around 50¢ a pound.

In Maine, which supplies 90% of all the mussels harvested in New England, the value of mussel landings has risen from almost nothing to $3.5 million annually.

In the 1970's Sea Grant through its two universities stimulated public acceptance of mussels by providing training, literature, and free samples to retailers and restauranteurs.

At the same time they gained valuable knowledge about growth rates, the development of pearl-free mussels, and culture techniques which built the foundation for private commercial operations.

Cultured mussels comprise about one-third of the total Maine harvest, growing from seed to market size in about a year and a half. Wild mussels, usually crowded into densely populated beds, take two to 11 years to reach harvestable size. Because the annoying pearls that grow inside every mussel take at least three years to become noticeable, most cultured mussels don't have discernible pearls.

The growth of the mussel culture industry is dependent on the availability of seed mussels which are taken from natural beds along the coast and spread out over leased areas in densities of 5-25 mussels per square foot. In Maine alone, 300,000 bushels of mussel seed a year are required in order to meet projected annual demands of 4-5 million pounds of market-size mussels.

University of Maine Professors Herbert Hidu and John Riley decided to try to help enhance seed mussel procurement. An alternative to dragging natural mussel beds would help reduce friction between aquaculturists and commercial mussel harvesters exploiting the same stocks, as well as reduce the mussel farmers' dependence on an uncertain source of supply.

Biologist Herb Hidu believes that more than chance should determine where a collector should look for mussel seed. Despite 15 years of research on blue mussels, no one had investigated where and when free-swimming mussel larvae were likely to convert to their sessile lifestyle. Hidu explains, "The focus of our part of the project is to learn more about the biology of mussel setting so eventually we can get a handle on optimizing seed collection."

He and Master's candidate Greg Podniesinski have described the distribution of swimming larvae and accompanying settlement patterns for estuarine systems in Maine.

To generate their data, they placed settlement traps (fibrous mesh pads) at 3-foot intervals in the water column at Deer Isle on lower Penobscot Bay and in the Damariscotta River. Settlement on the traps was examined throughout 1984 at each site. What they discovered was that settlement in the fall, winter, and early spring was almost entirely due to a secondary dispersal of juvenile mussels. Larval settlement was restricted to the summer months, primarily June and July. In addition, at the Deer Isle site, Podniesinski examined settlement over consecutive tide cycles at two-hour intervals. He found that both setting larvae and juvenile mussels were swept off the bottom during periods of increased current velocity, resulting in a significant redistribution of mussel set.

By analyzing preserved plankton samples collected at two-week intervals for eight consecutive years on Damariscotta estuaries, the researchers concluded that the water temperature and spring tides were critical factors in mussel spawning. By correlating these physical factors with spawning time, it is possible to fairly accurately predict when the greatest abundance of mussel larvae will be available.

The drudgery of observing larval settlement around the clock in the field and tabulating mussel abundance from hundreds of preserved samples has paid off. "Now we know," concludes Hidu, "that recruitment of mussel seed is more complex than we had originally believed."

While Hidu and Podniesinski were researching when and where mussel larvae would settle, Engineering Professor John Riley was trying to determine what substrates mussel larvae would prefer. The criteria for a mussel seed collector was that it had to attract and retain mussel seed and either be reusable or cheap enough to throw away at the end of a season.

Riley hung strips of burlap, jute, nylon netting, and polypropylene off Stonington and in the Damariscotta estuary, sampling every two weeks throughout the summer.

The burlap attracted a staggering amount of setup to 20,000 mussels per square foot. "To put it facetiously," comments Riley, "you could grow enough mussels to supply the whole state of Maine on your living room carpet."

But at such densities, mussels soon stopped growing for lack of nutrients, and the weight of the mussels and accumulated silt and algae ripped the burlap off the frame. Although all the materials readily attracted seed, Riley found that polypropylene strips were the most durable and practical.

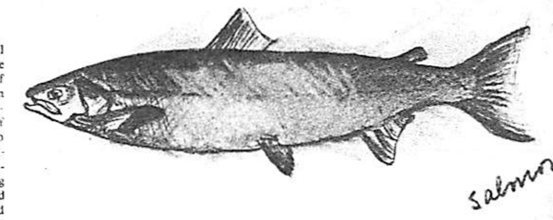
With the recent discovery of extensive mussel beds about 50 miles offshore, it is still cheaper for mussel culture business to drag for natural seed then to use Riley's method. When the mussel seed glut disappears, as it did suddenly in 1982, Riley will have an advisory bulletin ready for those who want to help Mother Nature along.

Riley views his recent research in seed collection not as pure aquaculture, but as "sea ranching," interfering in part of an organism's life cycle to maximize growth or abundance, and then letting the environment nurture the product to harvestable size.

He predicts that sea ranching is the next logical stage for shellfish aquaculture in northern New England. "Ranching is the convergence of aquaculture and fisheries. We started out trying to raise the young in hatcheries in concentrated production onshore, and this didn't pan out too well. We've had a lot more success working within the natural life cycle of shellfish by exercising some control over just a portion of their lives. This seems to work a lot better in Maine."

SOS: Saving Our Salmon

The Tale of the Spinning Salmon



An aquaculturist gazes in dismay at a tankful of young salmon spinning around a pool like animated corkscrews. These gyrations are the only outward sign of a highly contagious, fatal disease known as infectious pancreatic necrosis which is caused by the virus IPNV. Chances are that up to 90-100% of the fish in the hatchery may succumb to the disease, and with them a hefty investment of time and money.

IPN most commonly infects hatchery-bred fish such as salmon and trout, but it has also been found in menhaden (pogies), striped bass, eels, summer flounder, and shellfish. It is amazingly widespread for a malady that was not even observed until the 1940's and only identified as a disease in 1958. Since then, 175 "isolates" or variations of nine broad groups or serotypes have been found worldwide. It now occurs in fresh and saltwater everywhere but in Australia.

Because IPN's spread is rapid, its symptoms not apparent until shortly before death, and its cure still unknown, the disease poses a formidable challenge to fish pathologists. UMO microbiologists Bruce Nicholson and Paul Reno have taken on the challenge to try to unravel the mysteries of the disease. Reno and Nicholson are pioneers in marine biotechnology, the application of engineering principles to biological processes. By adapting a biomedical technique invented in 1975 for diagnosing and treating human viruses and cancers, they have created monoclonal antibodies to IPNV, which help diagnose IPN and may eventually lead to a vaccine to prevent it.

Reno and Nicholson are analyzing a local strain of IPNV that is representative of all the U.S. occurrences of the disease. The UMO researchers inject the "West Buxton isolate" virus into a mouse which will develop antibodies against the disease. They then remove the lymphocytes from its spleen and fuse them with cancer cells from another mouse. These hybrid cells, called hybridomas, have the characteristics of both parent cells: they produce antibodies to the IPNV and they continue to grow and divide indefinitely. The solution of hybridomas is diluted further and further until each solution contains only a single cell producing purified IPNV antibody. From one hybridoma the researchers can produce large volumes of antibodies with the exact same genetic makeup: monoclonal antibodies.

So far Reno and Nicholson have cultured five monoclonal antibodies that attack the local variety of IPNV, as well as seven others against other IPNV isolates. Only about 30 hybridomas have been produced worldwide, and they are shared by research laboratories to test their effects on local strains of IPNV.

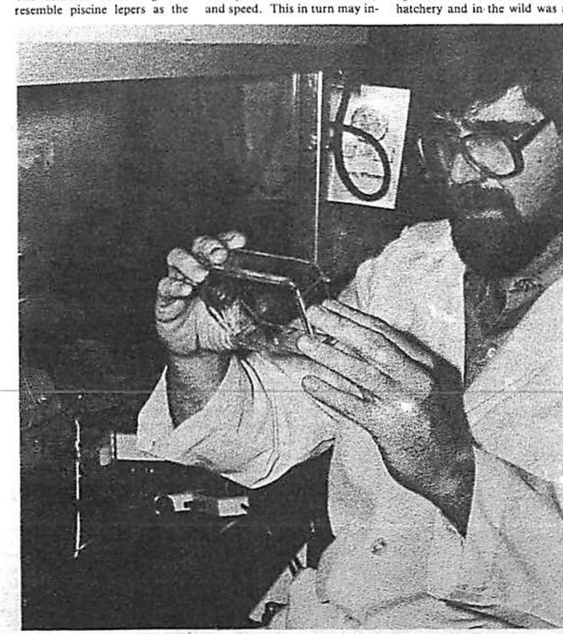
Because each hybridoma produces monoclonal antibodies which are always identical, experiments done by different laboratories will be replicable and reliable, essential characteristics for scientific research. These monoclonal antibodies have led researchers to identify similarities among various strains of the disease and have helped track down the origin of local infections. Two of the five monoclonal antibodies that were manufactured in the UMO labs have been found to inhibit infectious sites on the IPN virus. How many more infectious sites are left to discover? "Perhaps 25-30," surmises Reno.

Although they can't yet cure it, monoclonal antibodies have helped improve the accuracy of detecting IPNV.

Reno has recently established a fish health clinic for aquaculturists at UMO. With the help of ELISA (enzyme-linked immunosorbent assay), he can detect IPNV in fish, eggs, and sperm. By exposing a suspected virus to various combinations of monoclonal antibodies, he is able to pinpoint the strain and guess at how the disease entered the hatchery. Reno observes, "Each isolate reacts differently with several monoclonal antibodies. They are very precise in what they'll bind to, so you can detect small changes in a virus. Before, all you could determine was whether the virus was present or not. Now you can say where the virus may have come from."

The Story of the Rotting Fin

An ailment that aquaculturists can spot more easily than IPN is fin rot disease (*Salmo salar*). The afflicted fishes begin to resemble piscine lepers as the disease gnaws away part or all of their fins. Fin rot does not usually kill the animals, but it seems to impair their maneuverability and speed. This in turn may influence their ability to survive in the open ocean.



Laboratory studies focusing on fish diseases such as IPNV can lead to a decreased incidence of the disease in salmon hatcheries.

How Atlantic salmon fare against fin rot disease both in the hatchery and in the wild was a Sea Grant project by Paul Reno and Darrell Pratt and their graduate students, S. Maheshkumar and C. Giray, all of the University of Maine. For over two years, 200 fish from the Green Lake National Fish Hatchery, Ellsworth Falls, Maine, and 200 more from the Craig Brook Fish Hatchery, East Orland, Maine — a total of 10,000 fish — were monitored biweekly for fin rot disease.

The scientists examined how rearing density, food supply, age, and water temperature affected the incidence of the disease. They found that these factors affected the level of stress in the fish and, consequently, their susceptibility to becoming ill. Rearing density was the most important factor in controlling the progress of the disease.

They found evidence of fin rot in young salmon as early as July when they were about six months old, although the disease did not become readily detected by hatchery personnel until September or October.

The disease starts in the dorsal (top) fin and progresses to the pectoral (side) and caudal (tail) fins later in the summer. The infection is at its worst in September, when water temperatures have peaked. The active erosion of fins subsides and continues at a chronic level throughout the winter; however, no fin regeneration occurs in the hatchery. By late winter some healing of the open wounds occurs. If the fish are kept in the hatchery through another summer, the fins degenerate even further.

What happens to the fish once they are released into the ocean? Ninety percent of those that were released had fin rot on their pectoral fins (which control turnings and stopping), and 35-50% on their caudal fin (which aids propulsion). Most also had fin rot on their dorsal fin.

Only 10% of those that returned to the hatchery had fin rot on their pectoral fins, although the condition of the dorsal fins appeared to be unchanged. Either the pectoral fins had regenerated, or most of those with pectoral fin rot died at sea. Even more striking was the return rate of fish with caudal fin rot — less than 1% returned. The scientists believe that they lacked the speed and maneuverability to escape predators and capture prey.

To investigate how loss of various fins affect salmon movement, fish were placed in a round tank and a video camera mounted above to record their fright response when an object was thrown into the tank.

Non-diseased fish would simply make a swift U-turn away from the object. Fish with pectoral fin rot, however, showed a lack of maneuverability to one side or the other depending on which fin was diseased. They also could not move as quickly as normal fish.

On the basis of this study, Reno would suggest to hatchery managers that fish with pectoral and/or caudal fin rot are likely not to survive in the wild. It is estimated that if fin rot, with its high morbidity — approaching 100% — were eliminated, the return rate for released salmon would double.

Restoring the Atlantic Salmon

New England rivers once glistened with the silver bodies of Atlantic salmon battling their way upstream to spawn, until dams, pollution, and overfishing virtually eliminated them. In the past twenty years, $150 million has been spent to restore Atlantic salmon to New England waterways.

The construction of fish ladders over dams, the restoration of natural habitats, and large-scale fish hatcheries are slowly returning Atlantic salmon to their native streams. A continuing problem for hatcheries, however, is a chronic shortage of Atlantic salmon eggs.

Stacia Sower, an endocrinologist at the University of New Hampshire, is using biotechnology to help provide a consistent supply of eggs for salmon culture in New England. She is adapting a method pioneered in the Northwest to speed up ovulation and spawning in salmon through the injection of natural protein hormones. Sower administers a combination of hormones which duplicate those found in the fish's brain and pituitary gland. These trigger ovulation.

Stacia Sower holds a salmon that is about to become the subject of a UNH experiment in accelerating ovulation.

By stimulating and regulating reproduction, aquaculturists can obtain eggs from their own stock and reduce their dependence on eggs supplied by public hatcheries. This also allows hatchery operators to establish a schedule for spawning so they can move the fish in manageable batches rather than waiting for the salmon to spawn over several months. Young salmon spawned three or four weeks earlier than normal have a headstart on growth before the cold weather arrives.

This treatment is being used in hatcheries on the West Coast on 50,000 salmon a year. The cost of the treatment at one commercial sea ranch was calculated to be about 3¢ per fish. Where a single adult salmon can bring up to $50, that is a significant return on investment.

Sniffing Out the Acid Rain

What does a smokestack in Ohio have to do with an Atlantic salmon searching for its home stream in northern New England? Possibly quite a lot, according to UNH zoologists Winsor Watson and Carl Royce-Malmgren. They are investigating the effect of acid rain on salmon's sense of smell.

Researchers worldwide have documented a decrease in salmon populations in acidified streams, that is, where the pH is less than 6 (neutral = 7.0). PH levels low enough to kill fish outright are relatively rare, but chronic levels have been found to reduce the fitness of fish for spawning and migration. Watson and Royce-Malmgren believe that acid water may alter salmon's ability to recognize the olfactory cues of their home streams.

Watson explains the importance of salmon returning to where they were spawned: "Only small parts of rivers are suitable for spawning. There may be other spots where the fish may be able to lay their eggs, but a few months later the streams may dry up or freeze down into the gravel."

Some researchers believe they follow the chemical cues of organic compounds such as amino acids present in the water or the scent from offspring of the same breeding stock now living in their home stream.

Using a Y-shaped stream model Royce-Malmgren studied the response of juvenile salmon to olfactory stimulants. With fresh water flowing into the two inlets of the model, young salmon were placed in the downstream area and allowed to swim about freely. Stimulus compounds, such as amino acids, were infused into one or the other arm of the chamber, following a control period. Various concentrations of these stimulus compounds were tested. The behavior was recorded on videotape and analyzed using an interactive computer-video system Royce-Malmgren designed and developed. The salmon would indicate a preference by either swimming toward the source of the stimulus or, if repelled, away from the source into the arm of the model with "clean" water only.

Royce-Malmgren found that in cases where juvenile salmon were attracted to a particular amino acid (glycine) at a near-neutral pH, they became indifferent to it at a low pH. However, when the pH of the chamber's water was returned to near-neutral, the salmon's response also reverted back to its original behavior.

His experiments suggest that changes in acidity modify the salmon's behavioral response to the amino acid in the water, and that the effect is reversible. Although much more work needs to be done on adult fish and in the natural environment, Royce-Malmgren believes "that as the pH of the rivers and streams of New England change, possibly the salmon are no longer recognizing the smells that they've come to know."

Over the past two decades a substantial effort has been made to restock the rivers of New England primarily by rearing Atlantic salmon to the parr or smolt stages in hatcheries and releasing them for their migration to sea. The proportion of returning hatchery-bred salmon is now estimated at about 1% of the nearly one million released. Any factor such as acid rain that may reduce the return rate could have a substantial economic impact on the reintroduction of Atlantic salmon to New England rivers.

Stress on Salmon

The New Hampshire Fish and Game Department (NHFG) is working to supplement Atlantic salmon populations by introducing its West Coast cousin, the coho salmon, to New Hampshire rivers. The coho are raised from eggs and imprinted on the waters of the Milford hatchery. They are released at about a year and a half of age.

Although the number of young salmon raised in the hatchery has increased over the past several years, there has been no corresponding increase in the number of adults returning after a two-year hiatus at sea.

Fish and Game biologists wondered if overcrowding of the young in the hatchery might lessen their ability to survive in the wild. UNH endocrinologist Stacia Sower and NHFG biologist Robert Fawcett designed a cooperative research project to evaluate the effects of rearing densities. They measured the level of hormones that affect smoltification, the ability to adapt from freshwater to saltwater, in salmon reared at high densities and at low densities.

"These hormones may be indicators of the overall fitness of the salmon to survive in the ocean," explains Sower. "Thus far it appears that high-rearing densities (and greater stress) seem to suppress hormones."

In 1983, tagged salmon reared in pens containing 30,000 and 15,000 fish were released into the Lamprey River. In fall, 1985, 0.18% of the first group and 0.23% of the second group returned from sea. Thus, a higher percentage of the salmon reared at low density returned.

In the fall of 1986 some of the 65,000 fish reared at three different densities and released in 1984 should return to the Milford hatchery, adding more information on what constitutes optimal rearing densities.

If the returns validate her theory that less crowding lowers stress, Sower could save the New Hampshire Fish and Game Department considerable expense. "If you can show that lower density is better, we can lower the cost of stocking salmon, because you don't have to release as many fish to get a better return."

A Guide to Microscopic Mollusks

You would think that by now all the animals along the Atlantic Coast would have been collected, catalogued, and keyed, especially such common creatures as clams, mussels, oysters, and scallops. However, until recently there was no reliable "field guide" for the earliest developmental stages of these bivalve mollusks.

From the time they hatch to about two weeks of age, bivalve larvae are carried along by waves and currents as part of the rich planktonic soup of the North Atlantic Ocean. No larger than the period at the end of this sentence, one bivalve larva looks almost identical to any other. Without being able to distinguish among them, scientists cannot document year to year fluctuations in their abundance or assess what damage a chemical discharge or an oil spill might have done to a particular species of young shellfish.

In a three-year project led by Rutgers University, thirteen institutions cooperated in creating a reliable key to 25 species of bivalve larvae.

The project was initiated by Richard Lutz, a former graduate student in Oceanography at the University of Maine who is now the director of the Rutgers Shellfish Research Laboratory in Bivalve, New Jersey. Lutz gives an example of why a key was needed. "At the University of Maine Darling Center we used to do studies of the plankton found in the intake and effluent waters of nuclear power plants to see if they were still alive after going through the plant. In the census reports, the bivalve larvae were all lumped in one group, but it's important to know if the dead bivalve larvae are commercially-important species like blue mussels, hardshell clams, or oysters, or if they're non-commercial species."

Herb Hidu, who directed the University of Maine's participation in the study, adds: "Just to describe a life cycle of a species you need to know what you've got. For example, it's almost impossible to distinguish the blue mussel larvae from horse mussel larvae. The real differentiating feature is the hinge teeth that keep the two shells together."

UMO researchers contributed the larvae of 11 northern species of mollusks which were spawned and reared at the Ira C. Darling Center's aquaculture facility. These were photographed at various stages of development under a scanning electron microscope.

Armed with this key and a routine compound microscope, a shellfish researcher can now look at newly-hatched bivalve and recognize it by its teeth.

Seaweed Solutions

Think of eating seaweeds and you usually think of lacquered bowls of Nori soup or raw fish rolled in seaweed. One might not think of puddings, chocolate milk shakes, beer, gravy, or ice cream in the same context, but they also contain algae. Carrageenan, an extract from red seaweeds, is used as a thickener or to maintain liquids in suspension.

The largest producer of carrageenan in the world is Marine Colloids in Rockland, Maine. At one time the company was supplied with Irish moss by local seaweed harvesters who raked the algae from the intertidal zones. Today their raw materials, *Chondrus, Eucheuma*, and *Iridaea*, primarily come from the coasts of Atlantic Canada, Chile, and the Philippines.

Carrageenan is one of three major extracts from seaweeds: carrageenan and agars are derived from red algae; alginic acids come from brown seaweeds, such as kelp and rockweed.

Rich in vitamins and minerals such as vitamin C, iodine, and potassium, seaweeds have been used in traditional folk remedies since 3000 B.C.

New uses for the extracts of seaweeds will take advantage of the abundance of algae along our coast.

Today seaweeds play another role in medicine. Hospitals and biomedical laboratories create a great demand for agar, the seaweed gel that is a medium for culturing bacteria. It is one of the most expensive extracts to produce and is in short supply, especially the high-quality, low-sulfate agar prized by the medical community.

Presently, the only viable domestic source of agar is a slow-growing species (*Geledium robustum*) that occurs in southern California. In order to meet the U.S. demand for agars, this species and other agarophytes are also imported from Mexico, South America, and Japan.

Dr. Arthur Mathieson, UNH professor of botany and faculty member at the Jackson Estuarine Laboratory on Great Bay, has discovered another source of agar in his own backyard. It is a local algae that thrives in Northeastern estuaries like Great Bay, New Hampshire, and the Damariscotta River estuary in Maine.

Gracilaria tikvahiae (it has no common name) is a "relic" in the Gulf of Maine. It prefers the warmer waters from the Caribbean to Cape Cod. It probably extended north of Cape Cod during a warmer climatic period and now is restricted to sheltered bays of northern New England where it grows, quips Mathieson, "like a weed."

The one drawback of using *Gracilaria* to make agar is that the naturally occurring alga contains too much sulfate, which can affect its viscosity and gelling properties and even cause it to precipitate out of solution.

Dr. Mathieson and his research team of Eleanor Tveter-Gallagher and Clayton Penniman were able to reduce the sulfur content in the *Gracilaria* by cultivating it in artificial seawater with reduced amounts of sulfur. They also were able to precipitate out sulfur from *Gracilaria* growing in natural seawater, a method that could be duplicated in large-scale commercial projects.

Mathieson foresees that this local "weed" may someday be an alternative to our current limited, unstable supplies of agar. "Only about 100 miles of our coastline supports the natural growth of our domestic agar source. During World War II, when the supply of agar from Japan was cut off, we really scrambled to come up with adequate agar material. If the foreign sources of agar are ever cut off again, then the U.S. will have to do something to enhance its domestic production. Either we have to manipulate an underutilized agar-producing seaweed with a relatively high sulfur content, or we will have to find another material that we don't even know about yet."

A Maine researcher is looking at other ways to use the abundance of seaweeds along our coasts. Gary King, a microbiologist at UMO's Ira C. Darling Center, asserts, "There is a substantial population of seaweeds along our coast which, if it could be harvested and fermented economically, could be a cheap source of renewable energy."

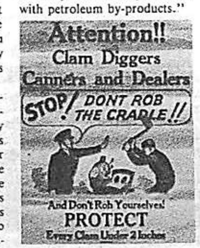
King once calculated that methane gas made from the rockweed (Ascophyllum nodosum) growing along Maine's 3,500 miles of shoreline could meet the total annual energy needs of a city of 30,000-40,000 people. Unfortunately, the costs of harvesting the rockweed, transporting it to processing facilities, and distributing the natural gas to homeowners would far outstrip any savings over using more conventional fuels.

There are more economical sources of biomass for producing methane, which makes up about 70% of natural gas. Wastes from rum distilleries, sugar cane harvesting, fish processing, and sewage treatment are just a few. King, though skeptical, holds out the hope that "perhaps in some places on the Maine coast you might find a significant, very local impact of using seaweeds as an energy source."

King is interested in the nitty-gritty details of seaweed fermentation (breaking down sugars by bacteria or by yeasts) that yields methane, alcohol, and other organic compounds. How are the large, complex sugars that are stored in the seaweed's cell walls broken down into simpler sugars which in turn are reduced to methane (CH_4) and carbon dioxide (CO_2)? What by-products are generated at each step of the process?

The by-products of seaweed fermentation are potentially much more valuable than the end product of methane. They include industrial solvents, such as butanol, acetone, and butane diol, as well as fine chemicals such as butyric acid and ethanol. Eventually several different commercially-important by-products could be made from fermenting one species of algae.

Presently, industrial solvents and fine chemicals are derived from petroleum. Dr. King questions the wisdom of using a nonrenewable fuel for this purpose. "Even though the price of petroleum is low today, that won't always be so. Society has to consider what petroleum is being used for now and what alternatives could be produced. The future of seaweeds is to produce chemicals that don't occur naturally and can compete in cost with petroleum by-products."



Saltwater Beer and Other Brews

For hundreds of years Caribbean molasses has been made into rum. Now, UNH microbiologist William Chesbro sees it as a potential source of gasohol, a mixture of methane and gasoline that was touted as an alternative to gasoline during the oil crisis. Chesbro has discovered a relatively low-cost process to ferment molasses into alcohol using seawater instead of freshwater, which has always been used in the past.

Until now no one had thought to use seawater as a growth medium for yeasts and other bacteria because they usually died in saltwater. Chesbro found that it was only because the bacteria were starving to death. While looking for indicators of pollution from human wastes in shellfish, Chesbro discovered that bacteria would grow "quite happily" in seawater if food was added to the medium. The advantages of seawater over freshwater for large-scale production of fermentation alcohol are an unlimited supply of water, lower production costs, and low-cost waste disposal.

Although gasohol has been the main focus of Chesbro's experiments, he is quick to point out that seawater fermentation would be equally useful for the large-scale production of antibiotics or commercial solvents such as acetone and butanol. The United States uses synthetic alcohol, a petroleum by-product, for most of its industrial uses because it is purer than alcohol derived from fermentation. The Japanese, on the other hand, use fermentation alcohol for making almost anything: perfumes, lacquers and paints, as well as Scotch and beer. Chesbro's saltwater process also makes potable beer, although he acknowledges, "It tastes like beer to which you've added a handful of salt."

Gasohol from seawater has been produced with Sea Grant funding on a small scale using New Hampshire coastal waters in a UNH-patented fermentation apparatus on campus. The next step is to secure funding for a demonstration plant to make gasohol on a commercial scale.

Chesbro hopes to find a Caribbean country willing to invest \$6-\$8 million for a 5-10 million gallons/year gasohol plant. It could be located on the coast or on a ship. He envisions ponderous barges plying the waters of the Caribbean, buying molasses from the sugar cane harvest, processing it enroute, and selling the gasohol to industrial buyers in the Northeast.

With the current world oil glut, interest in gasohol is low. At present Dr. Chesbro is experimenting with fermenting other alcohols, but when oil prices begin to rise again, more than one patron may turn to Dr. Chesbro to see what he can brew from seawater.

COASTAL CONFLICTS

Managing for Change

Field trips which inform the public about the natural limits of coastal resources give them a better basis for making decisions about future use.

The tradition of town meetings and home rule, coupled with pride in the natural beaüty of their coast, have made New Englanders equal partners with government and developers in defining the future character of their seacoast communities.

The coastal towns of Maine and New Hampshire are the fastest growing regions in their states. Although much of New Hampshire's 18 miles of coast is already developed, a surprising 77% of its shoreline and tidal wetlands is publicly owned or managed. The little remaining undeveloped, privately-held coastal land is disappearing fast.

Only 3% of the coast of Maine is publicly owned, but the 3500-mile coastline would seem to have enough room to accommodate all the competing demands for its use. Yet intensive development has already overwhelmed parts of southern Maine, and several towns have imposed a moratorium on new construction until they can find a way to harness rapid growth. State goverment is working to preserve water-dependent uses of the harbors, increase public access, and protect natural, historic, and flood-prone areas of the coast from further development.

In both states new homes, condominiums, tourist support services, and expanding industries compete with natural areas for a place along the coast. Fishermen and residents of modest means are being squeezed out of the coastal scene by high taxes and property values.

Public access for beachgoers, boaters, and clammers is diminishing along many parts of the coast. Traditional rights of way are giving way to "no trespassing" signs.

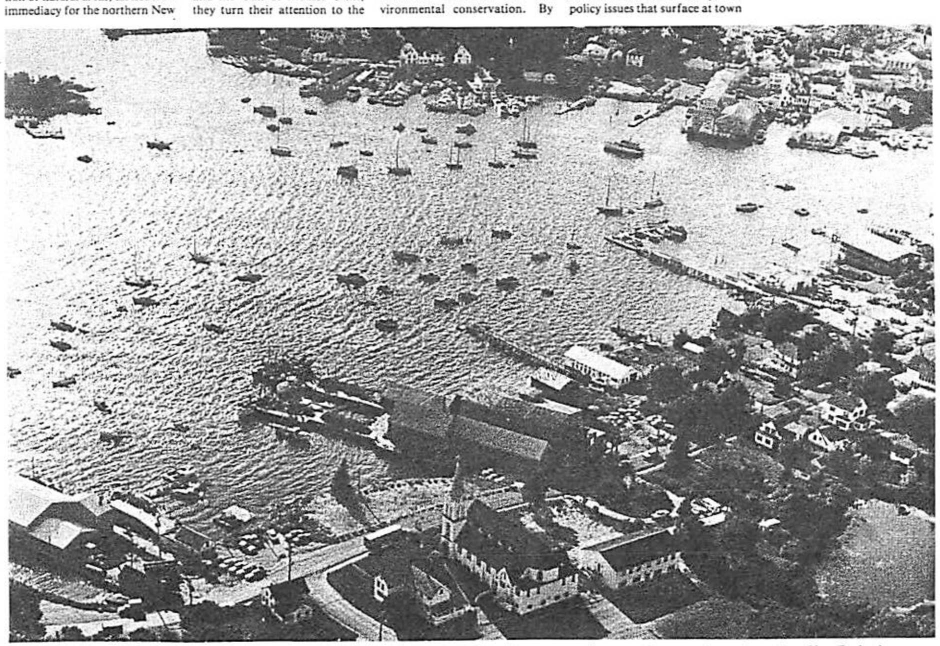
Julia Steed Mawson, the director of Odiorne Point State Park in Rye, New Hampshire, and marine education specialist for the Sea Grant Program, has developed a Coastal Issues curriculum for high school students and adults. She focuses on water quality and quantity, coastal access, industrial and commercial development, and the preservation of natural areas, all issues of immediacy for the northern New England coast.

She believes that only an informed citizenry who cares about the future of the coast can help to maintain the delicate balance between encouraging economic growth and preserving environmental quality.

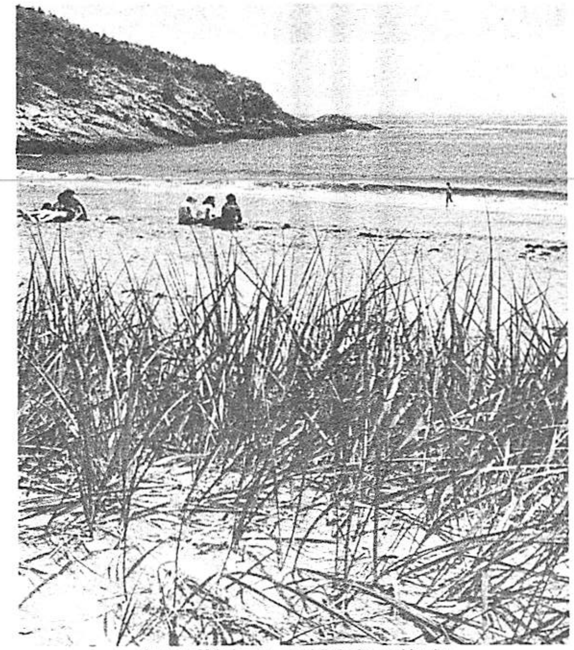
In the Coastal Issues high school curriculum, students first study the coastal environments and the Gulf of Maine. Next, they turn their attention to the critical thinking skills they will need as adult decision makers. They learn what decision-making is all about, who makes land use decisions, and how the private citizen fits into the process. Then, the students take on the roles of special interest groups and cooperate in creating a simulated development plan for Odiorne Point that maximizes economic benefits and environmental conservation. By working together, the students come to realize that "In good knowledgeable decision-making there are going to be compromises on all sides. There are no easy answers."

Through a permanent exhibit at the Nature Center, a Coastal Issues tour, and discussion of the changes taking place along the Northeast coast, visitors become sensitized to some of the public policy issues that surface at town meetings and on bond issues and referendum ballots.

After one Coastal Issues tour, stopping at shorefront sites from Seabrook to Portsmouth, a participant observed wryly, "It's becoming obvious that it's getting harder even to see the ocean because of all the development taking place along the coast."



The cumulative impact of coastal development and the need to manage it is one of the most pressing natural resource issues in northern New England.



Access to Maine's coast, especially its few sand beaches, is a public policy issue of growing concern.

Public access is an issue of growing importance to all coastal states. Carolyn Baldwin, a New Hampshire attorney and formerly on the faculty of the Franklin Pierce Law Center, was one of the first people locally to examine the issue in a report on the "Legal Aspects of Providing and Controlling Access to New Hampshire's Coastal Resources." Her 1984 report for the Sea Grant College Program helped to point the direction for further research on cumulative impact and municipal and state responsibility for providing coastal access.

Videotape was the method John Butzow, formerly of the University of Maine's School of Education, chose to teach the general public about marine issues and conflicts. "Why video? Videotape used for both broadcast television and for private groups and individual viewing makes our message much more available to the public than the print media."

As their contribution to the Northern New England Marine Education Project, Butzow's graduate students, Phillip Kane and Jay Calkins, produced "The Gulf of Maine: A Sea Beside the Sea" and "Not Just Another Fish Story."

The first film has reached over 50,000 people, including high school and college students and adults. According to Butzow, it is primarily aimed at "those of voting age."

The videotapes give visual impact to the themes of the unique resources and conflicting uses of the Gulf of Maine and its boundaries.

Law and the Sea

The current emphasis in television news reporting is on analyzing the meaning behind the headlines. In-depth coverage, interviews with newsmakers, and identifying trends in news events are what make programs like the MacNeil Lehrer News Hour so successful. The *Territorial Sea* has been doing just that for four years in the legal field in the area of marine resource law.

The Marine Law Institute of Portland, Maine, publishes this quarterly research publication analyzing the legal developments in the management of interjurisdictional marine resources. It originally focused on interpreting case law and policy decisions concerning the Magnuson Fishery Conservation and Management Act, the 1976 law that established the framework for managing domestic and foreign fishing within 200 miles of the U.S. coast. More recently, *Territorial Sea* has broadened its focus to include management implications of the 1984 World Court decision establishing a maritime boundary between Atlantic Canada and the United States.

MARINE LAW INSTITUTE

Issues of the *Territorial Sea* on state vs. federal management authority, joint ventures between U.S. fishermen and foreign processors, and coastal zone management have become standard reading for state and federal fisheries managers, policy researchers, maritime lawyers, and Congressional staff.

Jill Bubier, attorney and associate editor of *Territorial Sea*, explains how the staff develops its topics. "We take a news item, research its background, interview the parties involved, and put it into a larger context of fisheries management or other areas of natural resource law. That provides a framework to then analyze the significance of the recent development for resource managers."

Bringing together the people who make the headlines is another way that the Marine Law Institute helps to clarify marine issues. Marine Law Institute director Alison Rieser organized the first East Coast Fisheries Law Conference in 1983 for maritime lawyers, representatives of the fishing industry, and state and federal fisheries managers. Response was uniformly enthusiastic, so a second Conference on East Coast Fisheries Law and Policy was scheduled for June 17-20, 1986. Particular attention was given to issues affecting Georges Bank and the Gulf of Maine, including the World Court boundary decision, tax laws, fishery regulations, joint ventures, marine insurance and fisheries development.

The legal advice of the Marine Law Institute is sought on so many "down-home" issues such as beach access and clamflat management that in 1986 it became the most recent addition to the cooperators' network of the Sea Grant Marine Advisory Program, which provides informal education concerning marine resources.

OCEAN POLLUTION UPDATE

Tracking a Carcinogen

If the old adage "oil and water don't mix" were really true, then cleaning up oil spills would simply be a matter of scooping puddles of petroleum off the water's surface. But some of the oil, including its most toxic components, does mix.

Crude oil is made up of thousands of compounds. Some compounds are volatile and evaporate in the first few hours after a spill occurs. Others persist for years, dissolved in the water or clinging to minute, suspended particles. One type that lingers in the marine environment is a particularly toxic group of compounds — *polynuclear aromatic hydrocarbons* — PAH's for short. Some PAH's are thought to cause cancer in humans. Relatively little is known about them, but they are rapidly replacing DDT and PCB's as the newest acronym to fear. Although they make up only a small fraction of an oil spill, they are, per unit, the most toxic and resilient chemicals released.

A team of scientists at the University of New Hampshire is working to fill some of the gaps in knowledge concerning polynuclear aromatic hydrocarbons. Clarence Grant, Barbaros Celikkol, Galen Jones, Rudolph Seitz, and M. Robinson Swift are tracking the fate of PAH's in Northern Atlantic estuaries: where they come from, where they go, and how they may be broken down into other substances.

PAH's enter the ocean primarily through auto exhaust and ash and smoke from the burning of oil, coal, gas, and wood. In comparison, pollution from oil spills contributes a much smaller amount of the total. In specific locations, however, as along industrialized coastlines, oil can be the dominant source.

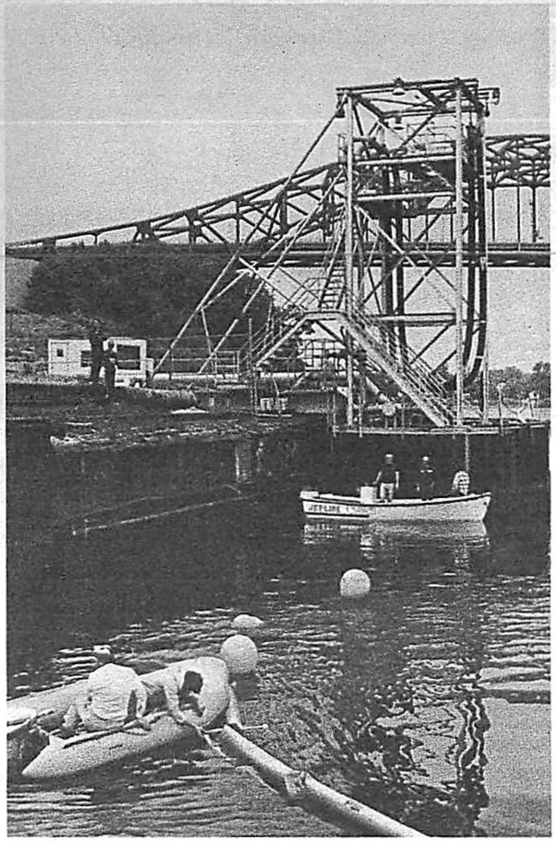
Galen Jones explains, "What motivated our project was concern over the number of oil spills in Great Bay. At that time almost no work had been done on the environmental impact of PAH's."

Analytical chemists Seitz and Grant, working with graduate students Tom Gauthier and Kathy Booth, have been tracking the distribution of PAH's in estuaries where low wave energy inhibits the dispersion of toxic wastes. PAH's can dissolve to a limited extent in water. Carried by currents, they may become susceptible to degradation by oil-eating bacteria or by sunlight. Most of the time, Seitz and Grant have found, PAH's adsorb or attach to organic particles suspended in the water. They may become heavy enough to sink to the bottom, which temporarily removes them from circulation. Because they persist in the sediments for such a long time, it is likely that these benthic PAH's will eventually be incorporated into the food chain.

Using ultraviolet light, the researchers are perfecting a rapid, accurate method for measuring minute quantities of these toxic substances in water. This information is helping mechanical engineers Celikkol and Swift to devise a computer model that predicts the pathways by which PAH's may disperse in an estuary.

Jones, a microbiologist, is examining ways that PAH's can be decomposed. He has identified a microorganism that "eats" phenanthrene, one type of PAH. His graduate student William Guerin has found that surfactants (substances like soap that reduce surface tension and increase solubility) can help speed the breakdown of PAH's. This work has long-term implications for oil spill cleanup technology.

PAH's are not particularly easy to trace in the marine environment or to break down by chemical or biological means. But as project coordinator Grant points out, "It's important to know the fate of these things, since some PAH's are known carcinogens."



Testing the oil deployment booms on the Piscataqua River (Jeff Savage's project).

Keeping Oil Pollution at Bay

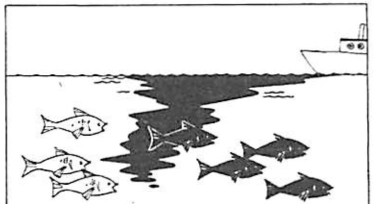
There are five privately-owned oil terminals along the banks of the Piscataqua River which empties into Portsmouth Harbor. Together they handle more than 11 million barrels of oil a year. The tidal currents run 3 to 4 knots past the terminals, and any oil spill from a tanker during unloading could quickly spread on the floodtide to the productive salt marshes and mud flats of Great and Little Bay.

The New Hampshire Water Supply and Pollution Control Commission turned to UNH for help in preventing a disaster. It asked UNH mechanical engineers to design an emergency oil spill containment and clean-up strategy that could be implemented within minutes after a spill at each oil terminal site. The system had to take into account the complex tidal currents and eddies of the Piscataqua River.

Professors Godfrey Savage, Barbaros Celikkol, and M. Robinson Swift studied current speeds and direction around each terminal in order to design computer simulations of site-specific configurations for laying out oil booms. The booms, sausage-shaped floats that project slightly above and below the waterline, would cut across the prevailing currents in order to minimize drag that could submerge the floats and allow oil to escape. The booms would hold the oil until terminal personnel could vacuum it into holding tanks. All this had to be accomplished within a few minutes after a spill, before professional clean-up crews had time to respond to the emergency.

When the Water Pollution Supply and Control Commission field tested the computer simulations, they found they could lay up to 1700 feet of oil boom in half an hour.

Project director Savage, who worked in oil exploration and deep sea drilling research before becoming a mechanical engineer, believes containing oil spills with carefully laid out booms is "the only conventional, reasonably cost-effective way of doing it." Oil terminal managers apparently agree. They and the state of New Hampshire have spent $100,000 on oil booms to keep on hand to implement UNH's oil containment strategy whenever the need may arise.



"I thought they said oil and water don't mix!"

Packaging Our Hazardous Wastes

Approximately 60 metric tons of hazardous wastes are generated annually in the United States. Probably less than 10% of that material finds its way into impermeable, secure disposal sites. The remainder is dumped into porous landfills or ponds or burned without proper controls. The eventual consequences of these practices surface in news stories about hazardous waste contamination in Love Canal, New York and closer to home, in Epping and Raymond, New Hampshire, and Grey, Maine.

Could the ocean be a safer repository for these materials if a method could be found to isolate hazardous wastes from the corrosive effects of seawater? UNH Civil Engineering professors Paul Bishop and David Gress are examining the potential for using a method of hazardous waste disposal that immobilizes heavy metals chemically as well as physically. The process, known as solidification/stabilization, incorporates hazardous material chemically and physically into the pore spaces of portland cement.

This process has been shown to be effective in neutralizing hazardous wastes destined for burial in landfills. Solidification converts hazardous sludge or liquid into solid, structurally sound material. Stabilization binds the hazardous chemicals into practically insoluble compounds.

An advantage of disposing of solidified/stabilized wastes in the ocean is that they would not be vulnerable to the freezing/thawing action of land-based disposal sites and the detrimental effect of acid rain.

Bishop and Gress are examining how seawater, the "universal solvent," reacts with various chemical combinations of portland cement containing different concentrations of the heavy metals — chromium, cadmium, and lead.

In order to understand how solidification/stabilization works on a molecular level they use a scanning electron microscope to examine the microstructure. They test for leaching of the contaminants by pulverizing the materials and then by flowing seawater around the particles. So far their tests in the laboratory have shown almost no leaching.

What if a block of portland cement on the ocean floor does not completely entrap the hazardous material? Gress predicts, "It would release heavy metals so slowly that the marine environment could absorb it gradually."

The amount of hazardous wastes are increasing at the same time that communities are becoming more reluctant to allow them within their boundaries. The ultimate value of Bishop's and Gress' research could be that, "We are taking something no one wants, that is extremely detrimental to life, and making use of it. We are trying to make a new material that's usable from a hazardous material, rather than create another plastic-lined pit that's going to be there forever."

Tracing Toxic Metals

Oil spills are not the only toxic threat to industrialized coastlines. Trace metals, like lead and tin, can become exceedingly toxic when they combine with organic compounds. They are found increasingly in rivers and estuaries, especially around boatyards where they occur in gasoline and marine paints.

James H. Weber of the University of New Hampshire is tracking the formation, movement, and decomposition of organotins in New England waters. Weber, who is an environmental chemist, observes that "Organotin compounds are virtually everywhere in the estuary . . . In some cases, the levels of organotins might be exceedingly toxic to marine life."

The marine paints used on boats to inhibit encrustation by algae and barnacles usually contain organotins. In France, contamination of oyster beds was traced to those antifouling boat paints, and their use is now banned.

One obstacle to tracing the distribution of organotin and other toxic materials is that they occur in such minute quantities that they are almost impossible to measure with existing instrumentation. Weber and co-workers developed a technique to measure concentrations of organotin compounds that had been too low to measure in the past.

In the United States, 20,000 tons of organotin compounds are produced each year, much of them as antifouling marine paints. Where these metals go and how they change in the ocean are of considerable significance to the health of the marine environment and to our own.

Water Quality

Charles Vorosmarty, Parker River Project.

Coastal water quality is the concern of two projects at the UNH Complex Systems Research Center, a think tank that encourages a multidisciplinary approach to research.

Judith Spiller, a policy analyst at Complex Systems, surveyed state water quality standards in Massachusetts, New Hampshire, and Maine to determine to what degree the states standardized and coordinated their regulations.

Spiller found that although the states' approaches to marine pollution control were similar, there were few mechanisms in place to inform or involve neighboring states of proposed developments that might affect their water quality as well. Spiller observes, "Ocean currents transport pollutants well beyond the site where the disposal takes place. This argues for a regional approach to policy control."

The principal concern along the coast is how much development can you allow without lowering water quality. What techniques can you use to make predictive judgments about development's effect on marine water quality?

A major problem stems from disagreement among scientists about questions like: What are safe levels of heavy metals in coastal waters? How much sewage waste can the ocean absorb and neutralize? Is secondary treatment sludge more dangerous to the marine environment than primary treatment effluents? This disagreement leaves policy makers to draw their own interpretations from the scientists' findings. "When a regulator is confronted with conflicting opinions in interpreting data, what policy does he or she develop?"

Spiller believes it is the researchers' responsibility to "bridge the gap between academic science and regulation." One of her goals is to bring together scientists, planners, and policy developers to help formulate research priorities in order to generate data for decision makers.

Existing water quality standards offer little guidance in predicting how growth will affect future water quality. Spiller says, "One promising technique is an interactive modeling approach to estuarine systems. Using computer simulations, you can see the effects of nutrient loading such as the addition of sewage wastes or rainwater runoff which may add bacteria or heavy metal contaminants to the system. It's a dynamic approach to planning because you can change the parameters and you can adapt the model from area to area. Scientists can use it as a research tool; planners can use it to explore the implications of different growth scenarios. Working together, both groups can better understand each other's information needs and constraints."

Not coincidentally, a similar model is being conceived in the office next to Spiller's by fellow Complex System researchers Berrien Moore and Charles Vorosmarty. They are collaborating with faculty members from microbiology, civil engineering, and earth sciences to construct a computer model that will incorporate how biological, chemical, and physical components interact in an estuary to influence water quality. Their ambition ultimately is to quantify the dynamics of this complex ecosystem which directly affects the vitality of our coastal fisheries. Their computer model could eventually be used in predicting the productivity of estuarine areas and the perturbations in water quality that might be caused by human development along their shores.

The first stage of their project is gathering field data from which to construct a computer model. Their study site is a relatively pristine stretch of the Parker River estuary in northern Massachusetts that evolves from a freshwater marsh into a typical New England salt marsh.

Their sampling reveals dramatic variations in the concentrations of nitrogen and phosphorus in the water column, changes that can be directly linked to tidal hydrodynamics. At neap tides, concentrations are typically high, while during spring tides, concentrations are greatly reduced.

An important component of their project is to quantify how different elements of the marsh system — plants and detritus, algae, suspended particles, and bottom sediments — take up and release nutrients over a season. A series of on-site experiments will provide this information. Another important component of the project is determining how water circulation affects the movement and exchange of nutrients. A computer simulation model of tidal flows is under construction, which will be linked to estimates of biological nutrient processing in order to simulate patterns of observed water quality.

Once the researchers understand what's happening in a particular ecosystem they will try to extrapolate it to other areas. Incorporating their field data on nutrient exchange and water circulation patterns into a computer program would save the time and expense of sampling every estuary.

THE DYNAMIC SEA

Students of the history of the earth are resigned to the fact that geologic events like mountain building and sea floor spreading take millions of years to happen. During a lifetime, earth scientists rarely witness significant changes in mountains, seas, or climates. Small wonder then that they flock to any scientific arena where dramatic action is guaranteed. Where do some geologists go in search of proof of a dynamic earth? They go to the beach.

Dune Defenders

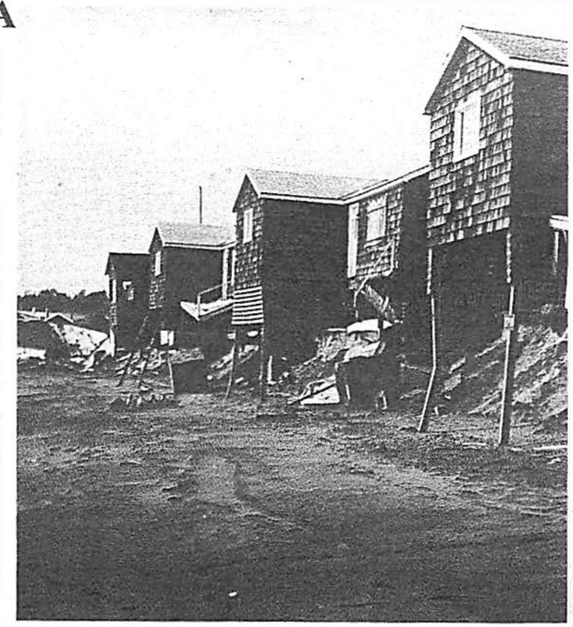
The beach, by definition, is constantly in motion. Tides, surf, and winds are responsible for daily changes in its appearance. Erosional storm waves in winter and constructive gentle waves in summer account for seasonal variations. Over a period of several years, longshore currents also transport sand along the coast. These interacting forces constantly reshape the beach, often making it unrecognizable from one season to another, or even from one day to the next.

Two of those drawn to the beach are L. Kenneth Fink, an oceanographer at the University of Maine's Ira C. Darling Center, and his colleague, Duncan F. FitzGerald, a geologist at Boston University. They study one of the most dynamic parts of a dynamic system: tidal inlets. "All of our Maine beaches are contained within rocky headlands. An inlet is usually adjacent to one of those bedrock projections. The tidal inlet itself migrates over time, back and forth like the wagging of a dog's tail. This migration of tidal inlets releases large volumes of sand." Fink is examining the role these tidal inlets play in reshaping the shoreline along the coast of southern and mid-coast Maine.

Classically, when a river meets the sea the result is a delta reaching out into the ocean. There, ebb tides deposit enormous quantities of sand onto a broad, flat coastal plain.

In Maine, however, in small to moderate size tidal inlets just the opposite is happening. Fink and FitzGerald discovered that the currents in these mesotidal inlets are flood-dominated, so that large volumes of sand are being transported into the intertidal areas behind the barrier beaches. The net result is a landward movement of sediment, with more infilling and less open water behind these inlets than elsewhere.

The implications of these findings bear directly on dredging and maintenance policies for



Erosion of sand beach systems by waves and storms pose a constant threat to structures built too near the water.

Maine harbors. To offset this continual shoaling in estuaries and salt marshes, dredging has to take place more frequently than in other parts of the country where ebb tide currents dominate. Dredging is expensive, poses the dilemma of where to dump the dredge spoils, and, ultimately, says Fink, is fated to be unsuccessful. He foresees that, "Our research will eventually mandate a completely new approach to dredging policies in Maine because there are places where it is not going to be cost effective."

Fink and FitzGerald have expanded their research to include the morphodynamics of larger tidal inlets, specifically the Scarborough River at Old Orchard Beach and the Kennebec River at Popham Beach. Here much greater volumes of freshwater draining large watersheds have created more typical ebb-dominant tidal deltas.

They are looking at how the sand in these deltas, within the reach of waves and longshore currents, affects the supply of sand to two of Maine's largest beaches.

The Kennebec River system is one of the most variable shorelines in the state, while the Scarborough-Old Orchard Beach area is one of the most stable. It has been accumulating sediment seaward for the last 60-70 years despite a continuous rise in sea level. The headland of Prout's Neck protects Pine Point from major storm waves, reducing their energy and converting them into constructive waves that move sand onto the beach instead of eroding it.

By comparing these two systems, Fink and FitzGerald hope to identify characteristics that would differentiate highly vulnerable coastal areas from those that could be developed with minimal impact.

Ken Fink's passionate concern for Maine beaches takes him not only to the shore but to town meetings and Board of Environmental Protection hearings. An article in *Downeast Magazine* stated that, "Many credit him with being the one person most responsible for educating the Maine public and government officials on the dynamics of sand beaches."

His research and his testimony figured in the passage of the Maine Sand Dunes Law, a 1978 amendment to the state's wetlands protection act. It severely limits new construction on beaches and dunes and the reconstruction of storm damaged buildings or seawalls.

William Beebe, a 19th century naturalist, once called beaches "the battleground of the sea." He was referring to the interaction of waves, wind, and sand. And today, there is another factor — *man*. Beachfront owners wage war against the forces of erosion with seawalls, groins, and breakwaters. Man-made structures interrupt the action of currents and waves for a while, but even the best-designed measures are only temporary.

Even in our brief lifetimes, the beach will change a thousand times. In our desperation to preserve what is "ours," to try to create stability where there is none, we sometimes lose sight of the overall scheme of nature. What she destroys in one place, she will recreate in another in her own good time, not ours.

Deep Drilling

As offshore oil exploration moves into deeper water, drilling technology is moving ahead to keep up with the new challenges. Down to a depth of 1000 feet, the conventional steel jacket platform, which looks a bit like an underwater Eiffel Tower, is still the drilling rig of choice. Beyond that depth the weight, rigidity, and expense of the steel jacket platform make it infeasible.

Compliant structures such as the tension leg platform which yield slightly to the dynamic forces of waves, wind, and earthquakes may be the answer for deep water drilling in heavy seas.

The tension leg platform is essentially a large barge anchored to the bottom by flexible tethers. The working position of the vessel is five to six feet below its normal flotation which limits the vertical motion of the vessel. The critical factor in the safety of such a vessel is the pullout resistance of the anchor to which the tethers are attached. The anchor itself consists of a grid structure on the sea bottom which in turn is pinned down by tension piles. UNH Civil Engineering Professor Pedro De Alba is working on a project that will help assess the safety of tension leg platforms.

Every wave that passes under the platform exerts a slight pull on the tension piles. Likewise, earthquake loading in sand will produce an increase in intergranular pore water and, consequently, a decrease in the stiffness and strength of the soil in which the tension pile rests. Earthquakes in sand eventually can produce liquefaction in which the sand no longer has the strength to support a structure.

Unlike the steel jacket platform which was introduced in the Gulf of Mexico just after World War II, the first tension leg platform was installed in the North Sea in 1983 and is a relatively untested technology. De Alba says, "The tension platform is a promising solution for deeper water. The question is how well the structure can withstand long term up and down movements and earthquakes. After a million waves, does the pile gradually work its way out of the seabed? The evidence now is somewhat contradictory. Some people say it's perfectly safe. It seems to depend on the type of soil the pile is resting in."

De Alba is using a cyclic loading simple shear machine developed at the UNH soil mechanics laboratory to test the effect of long term vertical stress on the stability and deformation of tension leg piles in sand. In 12 hours, the machine simulates 10,000 waves. The machine is on gliders so it can also experience sudden jolts sideways to simulate earthquakes.

De Alba believes that his work could someday have implications for the Gulf of Maine. "Our work was funded by Sea Grant in the possibility that some tension leg platforms could be built if the Georges Bank slope is ever opened for oil exploration. On Georges Bank you have a deep sand bottom, violent wave climate, and the possibility of earthquakes."

Waiting for the Big Wave

Fishermen and yachtsmen can tell you that it gets pretty rough in the Gulf of Maine. Bryan Pearce, Kewal Puri, and Vijay Panchang of the University of Maine can tell you just *how* rough. They are studying the wave climate of the Gulf of Maine and associated coastal regions.

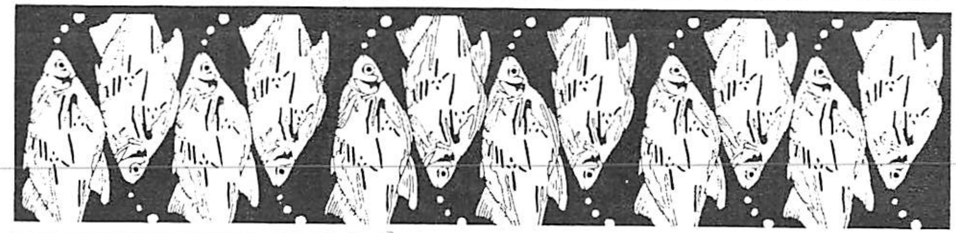
Being able to predict maximum wave heights through a computer model is imperative, they point out, if we are to fully understand coastal processes and establish design criteria for offshore oil rigs or shorefront structures.

Civil Engineering professor Pearce has always been interested in waves. He was surprised to find that prior to this project there were almost no wave data on the Gulf of Maine, despite its importance to the fishing industry and marine transportation and, potentially, for oil exploration.

He first focused on wave heights in the offshore regions of the Gulf of Maine. "When a ship's captain tells you those are eight-footers," explains Pearce, "he's usually referring to the average of the highest one-third of the waves. That's the significant wave height." What the researchers wanted to determine was the maximum design wave, i.e., the highest wave in a storm which, it turns out, is approximately twice the significant wave height. That means that a mariner tossing about in 20-foot waves may suddenly be confronted by a 40-foot wave.

"The next escalation of 'what's the highest wave,' " con-

Understanding wave height patterns over a long period of time can help engineers predict the best locations for sitting coastal and offshore structures.



CREDITS

Cover photo: Stephen Rubicam

Special thanks to: Mike McGuire of the Rockland Courier-Gazette for the use of several photographs and to Sara Hammond of the Portland Press Herald for the photo of the clam seed dredge.

Other photos: Bob Bayer, John Brooks, Mary Cerullo, Ken Fink, Leon Kouyomjian, Kathleen Lignell, Ted Loder, Jim Mullins, Alexander Nichols, Brenda Roth, "Buster" Towsend, Joanna Young.

tinues Pearce, "is the highest wave to go through here in, say, a hundred-year period? That's the 100-year wave."

Pearce and his graduate student Vijay Panchang from India used a numerical model to hindcast design wave heights. They extrapolated wind speeds from atmospheric pressure data records on 22 nor'easters over a 32-year period. Wind speeds were run through a wave model to estimate 50-year and 100-year wave heights in deep water. The 100-year wave generated in the interior Gulf of Maine, they calculated, was 75 feet high. The resulting publication, "Estimation of Design Wave Heights in the Gulf of Maine," won Panchang two national student awards.

As waves move closer to shore, the characterization of design wave height becomes much more complicated. In a bay or estuary the wave train becomes a jumble of local wind-generated waves and waves coming in from offshore, all altered by bottom topography. "The question we're looking at," says Pearce, "is how to figure out wave heights in shallow water incorporating a combined diffraction/refraction model and the local generation of waves."

The U.S. Army Corps of Engineers has developed broad-brush wave models for most of the coastal United States, most of which is relatively straight shoreline. Its computer program could not accommodate the deeply indented coastline and many islands of the Gulf of Maine. In order to build a breakwater inside a bay that can withstand design wave heights, cautions Pearce, one has to take into account the waves propagating around an island or a headland. Pearce's model does that.

A relationship that intrigues mathematician Kewal Puri is the interaction between breaking waves and the ocean bottom. Factors such as bottom type, its permeability, bottom turbulence, beach slope, and even ripples in the sand affect wave structures as they approach the shore. A little understood phenomenon that affects the behavior of waves as they touch bottom is the "boundary layer," a semi-fluid layer of fine particles a few centimeters wide that has an elastic quality that can dampen wave energy by powers of ten.

Puri admits his work is "futuristic," but he believes understanding how this elastic layer absorbs wave energy will be important in coastal modeling and calculating design wave heights for coastal construction.

Pearce and Puri's model for predicting design wave heights in the Gulf of Maine will help us understand the extremes of violence of which the ocean is capable — without our having to experience it firsthand.

Ocean Opportunities

How many colleges offer a course that promises both adventure and the opportunity to attempt something that's never been done before? Does it sound like a field trip to the Amazon with Indiana Jones? It is in reality an undergraduate course at the University of New Hampshire called *Ocean Projects*, and it presents students with real world challenges in ocean engineering and applied science.

For twenty years, University of New Hampshire seniors in engineering and the physical and biological sciences have been receiving hands-on experience in solving marine-related problems — from building a portable underwater diving habitat to laying the groundwork for an underwater camera that can transmit images in color.

Mechanical Engineering professor Jeff Savage, who directs the course with Fletch Blanchard of Electrical Engineering, explains, "We want the course to be fun, to introduce some adventure, but basically we try to have the students conceive of something that's never been done before. They design it, build it, and test it. Then they have to have the gumption to get up in front of a panel of external judges and defend their designs."

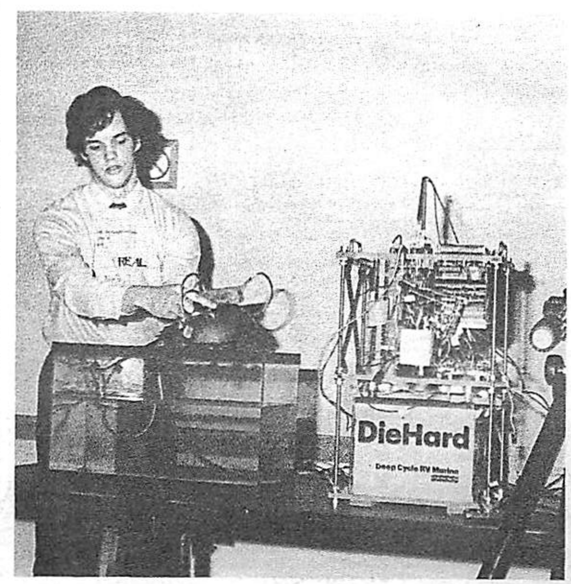
Students learn how to work together and how to deal with budgets, vendors, and other scientists. They are given a budget for materials, phone calls, and field trips which they manage to stretch by cajoling donations of equipment and expertise from manufacturers and industry advisors.

Although Ocean Projects students often devote a disproportionate amount of time to this course, many find that their overall grade-point average goes up. Savage attributes this to their gaining self-confidence from "learning to take risks, which is something people don't often do in academics."

Dozens of UNH faculty have served as project advisors to the Ocean Projects course over the years. Several of them have been rewarded with results leading to research proposals that were externally funded in subsequent years.

One student project that grew into a fully-funded research project was a study of how deeply raindrops penetrate water. Students designed a "rain-making machine" that could vary the speed and size of manufactured raindrops.

Their advisor, Franz Anderson, an oceanographer who specializes in estuarine research, is expanding on their work to determine how important rainfall may be in moving sediments in shallow water and in intertidal areas.



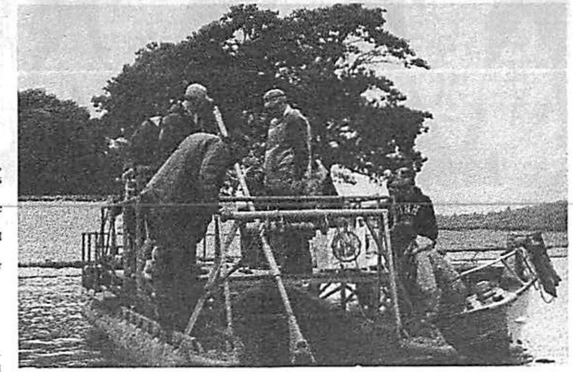
Senior engineering students at UNH work with industry to gain experience and present their projects at a year-end competition.

MARINE ADVISORY PROGRAM

By integrating the talents and resources of a variety of educational institutions and government agencies, the Sea Grant Marine Advisory Program (MAP) in Maine and New Hampshire extends the impact of its programs and responds more effectively to the needs of those dependent on marine resources.

Among the many projects supported by the Marine Advisory Program are:

- survival workshops and videotapes teaching boaters, fishermen, and emergency medical technicians how to deal with the dangers of hypothermia
- aquaculture programs to help towns and organizations revitalize their clamflats
- a workshop to help familiarize property owners with coastal erosion problems and potential solutions
- marine education program curriculum guides, and teacher training



A clam seed dredge developed by UMO engineers now makes it possible to transplant natural clam seed from overcrowded areas to depleted flats.

MARINE ADVISORY PROGRAM COOPERATORS

The Marine Advisory Program Cooperators form a cohesive network of organizations and institutions in northern New England working towards common goals and objectives.

SEA GRANT MARINE ADVISORY PROGRAM

David Dow, Program Leader
30 Coburn Hall
University of Maine
Orono, Maine 04469
(207) 581-1440

Brian Doyle, Program Leader
Marine Program Building
University of New Hampshire
Durham, New Hampshire 03824
(603) 862-3460

FISHERIES TECHNOLOGY SERVICE

The Fisheries Technology Service (FTS) is a division of Maine's Department of Marine Resources with offices in Hallowell, Addison, Ellsworth, and Yarmouth.

As a cooperator in the Marine Advisory Program, FTS maintains an important link to those university resources applicable to fishery development. Examples of FTS projects are:

- Shrimp separator trawl — a two codend trawl that sorts and retains shrimp and market fish, releasing the juvenile fish and trash;
- Mahogany quahog market and gear development-locating markets, demonstrating proper handling methods, evolving a hydraulic harvesting dredge;
- Lobster V-notcher-development and promotion of a tool for lobstermen;

Fisheries Technology Service
Department of Marine Resources
State House Station 21
Augusta, ME 04333
(207) 289-2291

COOPERATIVE EXTENSION SERVICE

As a MAP cooperator, the Cooperative Extension Service of the University of Maine at Orono provides programs such as:

- clam management workshops on the biology and management strategies of a soft-shelled clam;
- harbormasters' forums and the Maine Harbormasters Association concerned with the management of harbors and waterways;

Cooperative Extension Service
Winslow Hall
University of Maine
Orono, Maine 04469
(207) 581-3167

MARINE LAW INSTITUTE

The Marine Law Institute in Portland, Maine, is a jointly-sponsored program at the University of Maine School of Law and the Center for Research and Advanced Study at the University of Southern Maine.

As a new member of the Marine Advisory Program network, the Marine Law Institute provides education and legal analysis to policy makers, lawyers, and marine resource users through such means as:

- *Territorial Sea*, a quarterly publication examining developments in the management of interjurisdictional fishery resources;
- conference on East Coast Fisheries Law and Policy exploring recent changes in regional, national, and international fisheries law policy;

Marine Law Institute
246 Deering Avenue
Portland, ME 04102
(207) 780-4474

MAINE MARITIME ACADEMY

The Maine Maritime Academy (MMA) in Castine is a four-year residential college offering undergraduate and graduate training programs in marine careers. As an affiliate of the Marine Advisory Program, it provides non-credit continuing education for those already employed in marine industries.

Some of its recent programs include:

- Scuba diver safety conferences updating divers and rescue personnel on new equipment, safety techniques, and medical procedures;
- "Operation Sea Specimen," providing education and live marine specimens to public schoolteachers;

Maine Maritime Academy
Castine, Maine 04420
(207) 326-4311

SOUTHERN MAINE VOCATIONAL TECHNICAL INSTITUTE

The Southern Maine Vocational Technical Institute's Marine Science Department offers two-year training programs to prepare students for careers as oceanographic technicians or licensed ship officers.

Southern Maine Vocational Technical Institute
Fort Road
South Portland, ME 04106
(207) 799-7303

NORTHEAST MARINE EDUCATION PROGRAM

Through curriculum development and educational research, the Northeast Marine Education Program at the University of Maine at Orono helps to increase knowledge of the Gulf of Maine among teachers and extension educators.

Among its projects are:

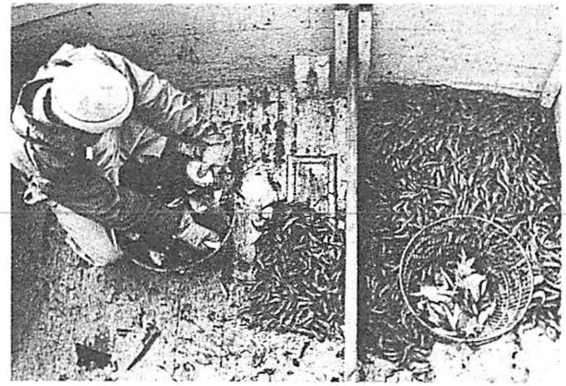
- curriculum guides on marine resources;
- videotapes on the Gulf of Maine;
- summer institutes for educators which combine field trips and classroom activities.

Northeast Marine Education Program
College of Education
206 Shibles Hall
University of Maine
Orono, Maine 04469
(207) 581-2434

MARINE TRADES CENTER

The Marine Trades Center in Eastport, Maine, is a division of the Washington County Vocational Technical Institute, which traditionally offers programs in wooden boatbuilding, marine fishing, marine mechanics, and commercial fishing.

Marine Trades Center
Deep Cove
Eastport, Maine 04631
(207) 853-2518



Development of a new shrimp separator trawl to eliminate fish of other species from the catch is just one of many gear projects sponsored by the MAP.

Safety at sea continues to be an important focus for the Marine Advisory Program and its network of cooperators.

Communicating in all kinds of weather using a variety of media is an essential part of Marine Advisory Program work.

Several MAP Cooperators offer practical courses for fishermen, often aboard aptly-names vessels such as this one.

COMMUNICATIONS

What is a Marine Communicator?

Someone who can talk with dolphins?

A sea chanty singer?

A radio operator on a ship to shore transmission?

None of the above. It's the support staff of the Sea Grant College Program who make sure that the knowledge of university researchers, marine advisory personnel, and educators reaches the people who can use it.

The communications staff produces the biennial report, educational and technical reports, magazine articles, news releases, exhibits, brochures and posters, and a quarterly newsletter, *WINDWARD*. They also assist in the production of books, films, radio/television programs, and regional conferences, lecture series, and workshops.

The communicators devote their energies to the audiences targeted by the Sea Grant Program: the general public, marine resource users and managers, the education community, and researchers. *WINDWARD*, with a circulation of 11,000, reaches the broadest audience, covering marine research and education in New Hampshire and Maine.

Eye-catching posters and brochures, exhibits at community events, and television and radio programs are the vehicles that reach the general public.

A bright-red lobster cut-out brochure featuring lobster anatomy, information on Sea Grant lobster research and little-known facts like "Most lobsters are right-handed" was introduced at an Audubon Wildlife Festival.

A television pilot on seafood purchase and preparation called, "A Different Kettle of Fish," aired on the Maine Public Broadcasting Network in 1984.

Promotion by the communications staff has helped to make COASTWEEK — a series of public events celebrating our coast — an annual event in New Hampshire and Maine.

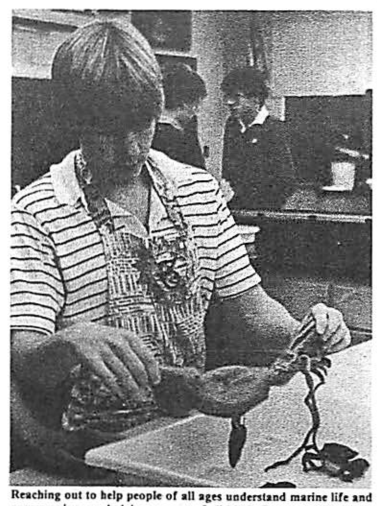
For our marine industries, the communicators have worked with scientific and extension staff to produce videotapes on hypothermia, bulletins on lobster diets and storing lobsters in live cars, a guide for harbor management, a handbook on increasing clam harvests, and an economic profile on Maine's marine service industries.

For students and teachers, the communications staff prepared *Ocean Opportunities*, an introduction to marine careers, and provided editorial support for the Marine Advisory Program's *Floating Lab Resource Manual*, *A Fine Kettle of Fish*, a curriculum unit, and *Tidepool Times*, a marine education newsletter that has been reproduced in a New Hampshire coastal newspaper.

The scientific community is supported by the publication of its research results in technical reports, bulletins, and press releases, a directory of research projects, and *Marine Program Notes*, a biweekly update on research advances, conferences, and professional opportunities, edited by the UNH communications office.

The communications staff has another audience: the news media itself. As a result of cultivating media contacts at newspapers, magazines, and television and radio stations, features on Sea Grant research and outreach programs have appeared in *The Boston Globe*, *The New York Times*, *Newsweek*, *Popular Science*, *Down East Magazine*, in local newspapers, and on radio and television in New Hampshire and Maine.

So what is a Marine Communicator? It's the voice of Sea Grant.



Reaching out to help people of all ages understand marine life and processes is an underlying concept of all MAP Cooperators' efforts.

GULF OF MAINE GUIDES

from the Sea Grant Bookshelf

The Maine/New Hampshire Sea Grant College Program has been investing its research, education, and public service efforts in the Gulf of Maine for over a decade.

To provide useful information about the Gulf of Maine and its resources for the public, Sea Grant has published many pamphlets and books during the past 10 years. Some of these publications are described below. If you would like to order one or more of them, just contact your nearest Sea Grant Communications Office at either (207) 581-1440 at the University of Maine at Orono or (603) 862-2994 at the University of New Hampshire in Durham.

THE SEASIDE NATURALIST: A GUIDE TO NATURE STUDY AT THE SEASHORE

by Deborah A. Coulombe

A popular, delightfully illustrated seashore nature guide for young people, **The Seaside Naturalist** was written and illustrated by Deborah A. Coulombe, as a by-product of her equally attractive hand-calligraphed and hand-drawn publication, **The Tidepool Times**.

A foreward by Julia Steed Mawson, Nature Center Director of the University of New Hampshire's Marine Program complements the fascinating contents, easy-to-read descriptions of northern New England's marine life, beach creatures, and tidal processes. Published by Spectrum Books but available through the UNH Sea Grant Communications Office in Durham. (1984; $12.95)

A TEACHERS' GUIDE TO THE WHALES OF THE GULF OF MAINE

by Catherine Kiorpes Elk

A "must" for teachers, whale watchers, and anyone interested in the world's largest creatures, this guide is an important addition to the growing literature on the 18 species of cetaceans in the Gulf of Maine.

Abundantly illustrated by MaJo Keleshian, the guide also offers innovative classroom activities developed through the popular Whales on Wheels program of the College of the Atlantic.

The guide not only prepares schools, museums, nature centers, and aquariums for the Whales on Wheels presentations but also offers detailed, up-to-date information on whale anatomy, diving physiology, whale intelligence, feeding and locomotion, sighting charts, and a plethora of activity suggestions about whales and other marine mammals for all age levels.

THE MAINE SEACOAST

by Sherman Hasbrouck and Kathleen Lignell

Not just another fish story, **The Maine Seacoast** tells the story of Maine's 3,500-mile coast, beginning with the forming of the Gulf of Maine 15,000 years ago and concluding with current research efforts and management issues.

In this 12-page digest, the authors describe and summarize basic information on Maine's coastal and marine resources; the Gulf of Maine; geology and natural history of the coast; Maine's commercial fisheries; the impact of urbanization and tourism; past and present conservation efforts; and public policy issues. (1986; $1.00, single copy. Bulk rates on request.)

WINDWARD

Edited by Brenda Joziatis

This attractive newsletter, prepared by the New Hampshire communications staff, reports on activities of the UNH Marine Program and the Maine/New Hampshire Sea Grant College Program.

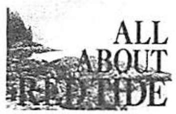
Published quarterly, *Windward* is available through the UNH Marine Program, Durham, NH 03824.

HOMARUS AMERICANUS: THE AMERICAN LOBSTER

by the Maine Sea Grant Communications Staff

Did you know that lobsters may live 100 years and grow to five feet? Do you know what lobsters eat and how they're caught? These and other fun facts are highlighted in this lobster cut-out brochure describing the American, or "Maine," Lobster.

The American lobster symbolizes the Maine coast more than any other animal, for its fine taste has made it world famous. Before 1800, lobsters were the most common large crustacean along the coast of Maine, but since the advent of commercial lobstering, they have become much more scarce. This brochure also reports what is being done to preserve the lobster fishery in the Gulf of Maine. (1984; free)



ALL ABOUT RED TIDE

by Kathleen Lignell

This colorful poster/brochure explains how the red tide "blooms"; how it is monitored; how the toxins work; and discusses Paralytic Shellfish Poisoning (PSP) and public health.

Marine animals directly affected by these microscopic plants are those that filter their food from the water — shellfish such as clams, mussels, and oysters. Lobsters, crabs, and finfish, however, are meateaters, and do not accumulate the poison, and may be eaten in safety. This brochure is chock-full of facts you should know about red tide and its effects on marine animals and human beings. (1981; free)

LOOKING AHEAD

The Long Range Plan of the Maine/New Hampshire Sea Grant College Program

This report identifies the key marine issues which will be important to the northern New England region over the next three to five years. To promote the wise use of our own marine resource — the Gulf of Maine — we need a full understanding of the issues which will affect these waters in the future. The purpose of the Long Range Plan is to communicate those issues and areas where the creative minds of marine researchers in Maine and New Hampshire can constructively influence the development of the resources of one of the world's richest marine environment. (1986; free)

In addition to these publications, the Maine/New Hampshire Sea Grant Communications staff prepare and circulate marine-related information through periodical newsletters, fact sheets, news releases, and videotape materials. The two communications offices in Durham, New Hampshire and Orono, Maine also keep close contact with other Sea Grant programs around the country and can answer a variety of questions on marine-related issues nationwide.

NEW HAMPSHIRE SEAFOOD DIRECTORY

by B. Sharon Meeker

What's what and what's where when it comes to New Hampshire seafood can be found in this handy directory listing the various retail and wholesale outlets for seafood in the state. The directory also provides information not only on types of seafood carried but also the forms such as "fresh," "frozen," or "smoked," in which it is available.

This multi-use directory also has a section on nutritional aspects of seafood and how to prepare it, including mouth-watering recipes for cod, cusk, flounder, haddock, hake, and pollock. (1985; $3.00)