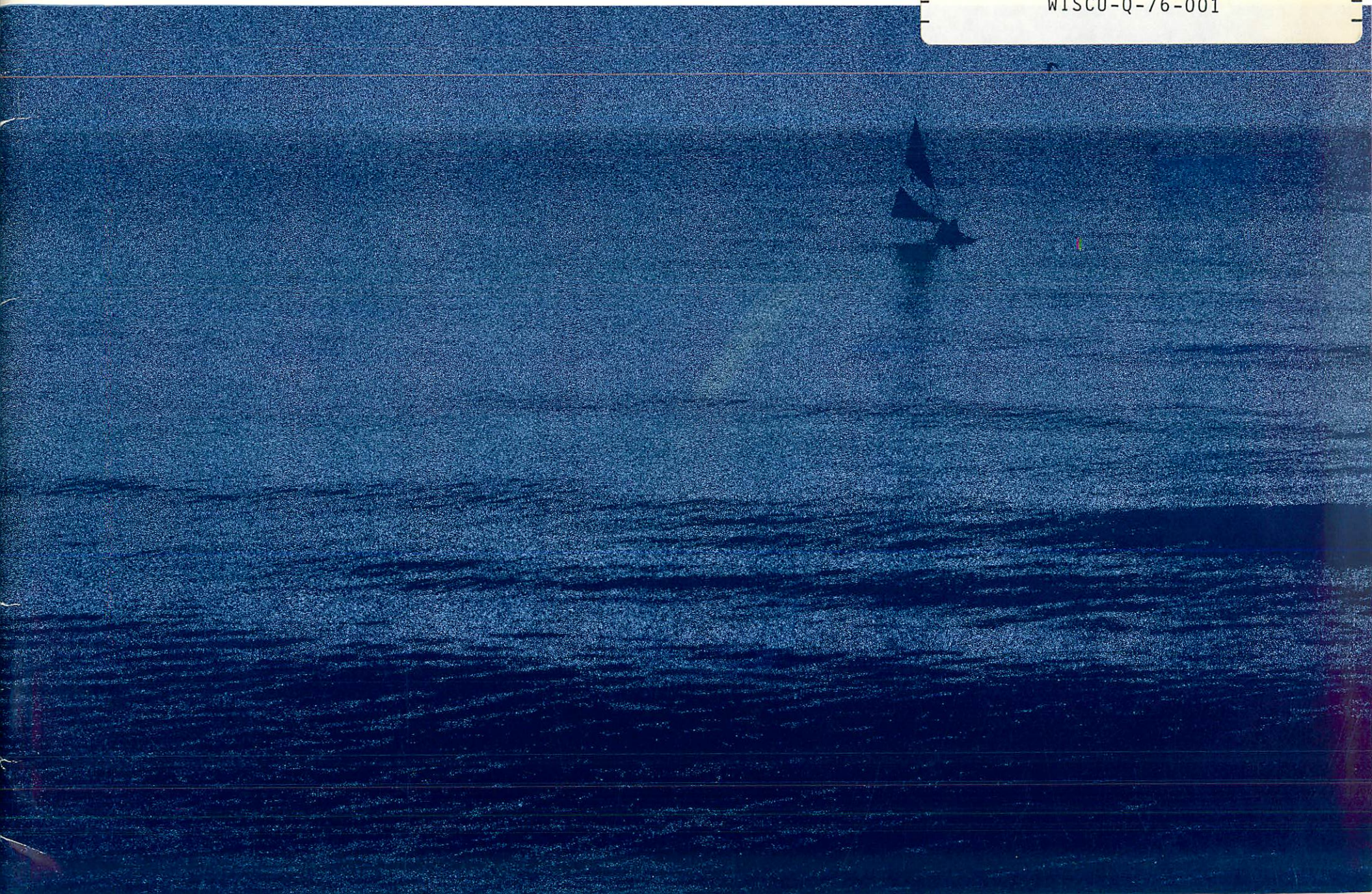
UNIVERSITY OF WISCONSIN SEA GRANT COLLEGE PROGRAM



TO THE READER:

Now in its tenth year the Wisconsin Sea Grant College Program is devoted to the development, use and conservation of the marine resources of the Great Lakes and oceans. The Sea Grant Program is a unique partnership between the university and the state and federal government. Federal support provided by the National Oceanic and Atmospheric Administration, U.S. Department of Commerce is matched by direct support from the state of Wisconsin and from industry and other nongovernmental users of the program.

The Wisconsin Sea Grant College Program is truly statewide. It includes participation by faculty and students from seven campuses of the University of Wisconsin System, the Medical College of Wisconsin, and the Wisconsin Departments of Natural Resources and Administration.

As an expression of the "Wisconsin Idea" the program effectively combines research, education and public service. Research programs are directly responsive to expressed needs by government, industry and the user public, and research results are widely publicized both to the users and to the scientific community. Students participate directly in this process. Sea Grant sponsors many formal education activities for university students, as well as for specialized public and industry groups.

Sea Grant is a people program. The creation, organization and operation of its activities are the products of the ideas and commitment of people. And the success of the program is measured by its service to people. This report, which covers the period of 1974 to 1976, tells about some of these people.

Robert A. Ragotzkie

ROBERT A. RAGOTZKIE, DIRECTOR
University of Wisconsin Sea Grant
College Program

CONTENTS

A report on the activities of the University of Wisconsin Sea Grant College Program from September 1, 1974 to August 31, 1976.

LIVING RESOURCES

In that bay, there is a channel where we took stores of fishes, sturgeons of vast biggness, and Pycks seven feet long.

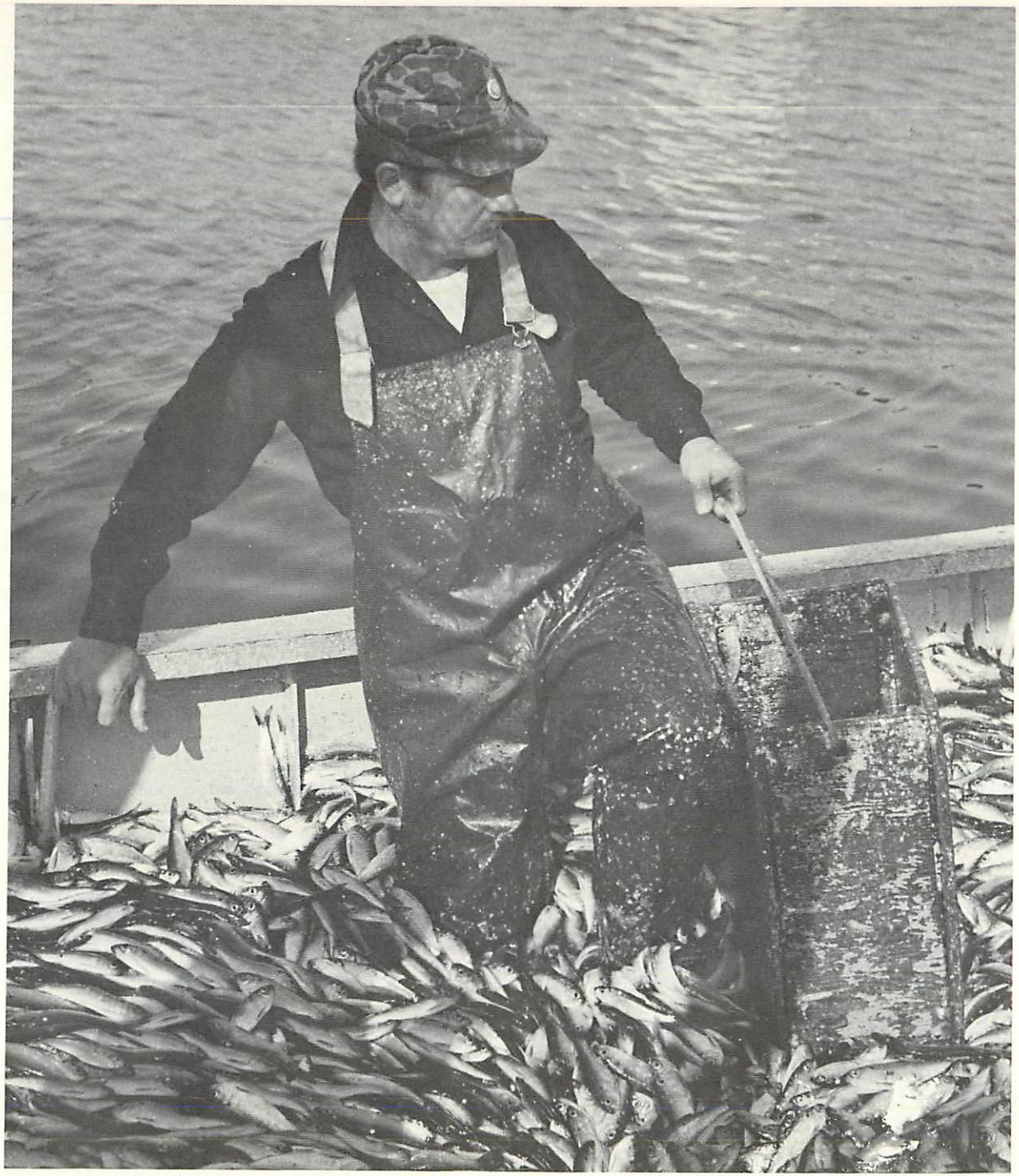
–P. Radisson

Early French explorer Pierre Radisson, impressed by Lake Superior's early abundance, could not have foreseen the future upheavals in the ecology of the Great Lakes. In the centuries to follow, overfishing, pollution and the invasion of exotic species of fish took their toll. Native whitefish and trout have declined. And the once teeming lake herring and chub are nearly gone.

In contrast, sea lamprey and alewives—ocean invaders of the 20th century—have adapted all too well to the freshwater Great Lakes. Vigilant chemical treatment of sea lamprey spawning streams has been necessary to keep this ruthless predator in check. With these controls in effect, the United States and Canada have been restocking the lakes with native fish and such exotic imports as coho, Chinook and Atlantic salmon.

But effective and lasting restoration of a fishery requires knowledge and an understanding of the total lake ecosystem. The University of Wisconsin Sea Grant College Program has sought to provide some of this basic information—particularly with respect to the Lake Michigan aquatic food chain and its important fish species.

In its Living Resources Subprogram, Sea Grant research is directed toward four goals: to assess the basic biological productivity of Lake Michigan; to better understand the reproduction and life cycles of its more important fish species as a basis for improved fisheries management; to evaluate and promote the commercial use of sucker, alewife and other underutilized species; and to explore fisheries economic issues and how government regulation affects these vital considerations.



LAKE PRODUCTIVITY

In a productive lake, small plants and animals convert dissolved nutrients and particulate matter to the essential building blocks for the aquatic food chain. In Lake Michigan, one of these vital organisms is the *Pontoporeia affinis*—a tiny crustacean that grubs for nourishment in the lake's bottom sediments.

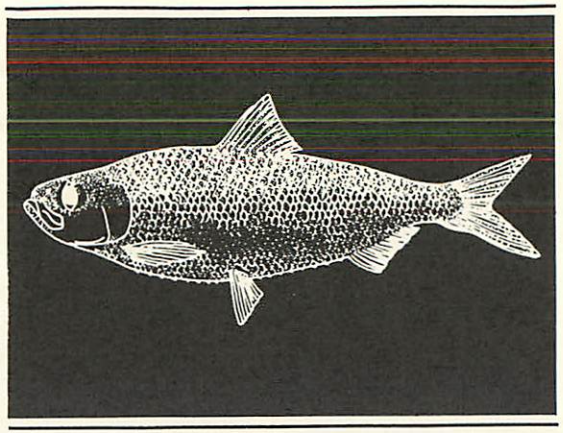
Zoologist Arthur Brooks of the University of Wisconsin-Milwaukee Center for Great Lakes Studies investigated the depths, water temperature and lake sediments that *Pontoporeia* in Lake Michigan seem to prefer. Brooks and his assistants also cultured these shrimp-like creatures in the laboratory to discover at what size they molt and shed their skeletal shell to grow a new one. Such data provide an understanding of the life cycle and growth rates of an animal that is itself an important food for whitefish, young lake trout, alewives and chub. [R/LR-1]

Sea Grant biologists have also probed Lake Michigan to study yet another key ingredient of fish diets. These minute planktonic animals—*Mysis relicta*—are sometimes called "fairy shrimp." At a site a few miles northeast of Milwaukee, the scientists retrieved *Mysis* from the lake bed 115 meters below the surface during the day and from the water column at night. This sampling over time has revealed much about the animal's size, movements, life cycles and reproductive capacity. [R/LR-2]

The fact that *Mysis* are so available may account for their popularity with the lake's hungry fish. Zoologist Brooks found that *Mysis* migrate up from the lake bed each summer night to feed on phytoplankton, concentrated in a layer of water just below Lake Michigan's thermocline.

Mysis and other small organisms gathering in this region of the water column in turn attract fish, particularly Lake Michigan's abundant alewives. Brooks concluded that most previous estimates of the lake's primary productivity—its minute life-supporting animal and plant life—have not adequately considered the contribution of this nutrient-rich zone with its "chlorophyll peak" of phytoplankton. [R/WQ-3]

Higher on the Lake Michigan food chain, alewives comprise the predominant staple food of the



valued predator fish. Unfortunately, in the absence of a well established alewife fishery accurate estimates of alewife populations are not easily derived. And experimental trawling to gain this information is expensive and of doubtful reliability.

To locate and assess alewife populations, a team headed by University of Wisconsin-Madison limnologist John Magnuson and geophysicist Clayton Clay has been refining a sonar technique. Their acoustical sensing system probes the entire water column beneath a moving vessel to detect any fish that lie below. Using four different vessels, the researchers have spent over 50 days on Lake Michigan since May 1975, taking periodic soundings on transects across much of the lake's southern basin. Other cruises during this period took them to Green Bay, northern Lake Michigan and Lake Huron.

Nighttime forays proved more successful in tracking alewives, the principal target. At dusk, hordes of these small silver fish move from near the bottom to mid water. There they spread in layers, easily detected by sonar. Techniques are now being developed that will interpret the sonar data so as to determine the actual fish poundage in the water. This information is necessary to those agencies stocking and managing the Great Lakes. [R/FA-1]

Plugging in the data they have so far collected, scientists are using a computerized model to get an overall picture of the Lake Michigan ecosystem. Expected to serve as a framework for assembling much Sea Grant research on the Great Lakes into a coherent and useful package, the model was developed and tested on a small inland lake in Madison, Wisconsin under an International Biological Program project. Ecologist James Kitchell and his associates at the University of Wisconsin-Madison are thus able to predict the growth and other dynamic changes in the lake. With this model, for example, they calculated theoretical concentrations of polychlorinated biphenyls (PCBs) in five-year-old yellow perch in southern Lake Michigan. These calculations proved to be within eight percent of measured concentrations—a good indicator of the model's accuracy.

Analytical tools like this also help to explain the manner in which fish concentrate water contaminants—whether, for instance, fish take up more PCBs from their diet or from the water passing over their gills. Knowing this, scientists hope to predict PCB concentrations in fish more closely as the use and release of these industrial compounds to the environment is curtailed.

The model can address additional questions. Given a commercial harvest of alewives, will there be enought left to support a desirable stock of predator fish? Or, in the case of aquaculture, at what temperatures do tank-grown yellow perch grow best as they mature from the fry stage? [R/FA-2]

FISH FOR MAN

To the sport commercial fisherman, Great Lakes' productivity is perhaps valued most in light of its support of trout, salmon and whitefish. In 1976 the dockside value of the commercial whitefish catch reached about $1.6 million. Just where different populations of whitefish reside and migrate in Lake Michigan is not precisely known, despite their historic importance to the commerical fisher.

Directed by biologist Henry Booke at the University of Wisconsin-Stevens Point, enzyme studies of sample whitefish have revealed several distinct genetic populations in Green Bay. Recovery of tagged fish has further indicated that whitefish populations move seasonably throughout Green Bay and northern Lake Michigan. Such information

about whitefish numbers, growth and migrations may allow improved fisheries management that, for one, can take into account the extremely variable spawning populations typical of this species. [R/LR-3]

Sport fisheries also fall within Wisconsin Sea Grant research interest. One of the most notable and widely adapted research achievements has been the artificial odor imprinting of migratory fish. After years of experimentation, a research team headed by Dr. Arthur Hasler, zoologist at the University of Wisconsin-Madison, has discovered that certain chemical odors can be used to imprint fingerlings prior to their downstream migration. Later these same compounds can lure them back as adults to desirable fishing or spawning sites.

The Wisconsin Department of Natural Resources has cooperated with this research and is now using the imprinting procedure in its planting programs. In 1977, the DNR stocked 40,000 imprinted coho salmon at each of several sites along Lake Michigan—including Kenosha, Racine, Oak Creek (South Milwaukee), Milwaukee and Port Washington. They are also experimenting with two other species—Chinook salmon and steelhead trout.

The imprinting techniques developed by Hasler's team have received widespread recognition. The National Marine Fisheries Service is using imprinting to guide hatchery-reared salmon to suitable spawning grounds on the Columbia River. Imprinting is also being tried on shad in the Connecticut River, Atlantic salmon in Scotland and on pelagic fish of British Columbia and New Zealand [R/BR-6]

Another sport fish being restocked in the Great Lakes is lake trout. Natural reproduction of these reintroduced native fish has so far failed to occur in Lake Michigan. Research biologist Ross Horrall of the Univeristy of Wisconsin-Madison has studied historic as well as current records of conditions influencing the natural reproduction of lake trout and whitefish. He observed that the Lake Superior and Canadian lake trout being used to restock Lake Michigan tend to spawn in shallow water and so may never reproduce successfully on Lake Michigan's deep reefs and shoals. These pockmarked underwater ridges were the traditional spawning grounds for the once populous deepwater strain of lake trout found in Lake Michigan.

In his research, Horrall fortuitously discovered 800,000 fingerlings in a Marquette, Michigan hatchery that were descendants of Lake Michigan's long-vanished deepwater lake trout. At his urging, the Great Lakes Fishery Commission planted 280,000 of these special little fish in Lake Michigan over the Milwaukee-Sheboygan reef complex, probably the ancestral spawning ground of these fish.

This coordinated effort involved state fisheries agencies, the Chesapeake and Ohio Railroad which operates the Ludington-Milwaukee car ferry, the U. S. Fish and Wildlife Service, the U. S. Coast Guard and the Wisconsin Sea Grant Program. Several years will elapse before it will be known whether or not these newly introduced lake trout, true to their genetic heritage, accept these reefs as "home" and return to spawn.

In general, Horrall believes, lake trout should be planted as eyed eggs rather than hatched fingerlings if they are to develop a homing instinct and return to those regions where they are introduced to the lake. He suggests there may be a critical imprinting phase even in the egg or early fry stage. [R/FA-5]

While Great Lakes catches of some traditional commercial fish species like chubs and perch have declined in recent years, other abundant species have gone almost unnoticed. White suckers in Lake Michigan and longnose suckers in Lake Superior are now considered by Sea Grant food scientists and others to be a promising new source of high quality protein.

Biologists John Magnuson and Horrall and their students at the University of Wisconsin-Madison are studying growth and mortality rates of white suckers in certain streams in the Green Bay and Door County regions of Lake Michigan. A practical aim is to determine the number of these fish that could be harvested without diminishing populations unduly.

Because suckers are most easily harvested during their spawning runs, the biologists are trying to learn what conditions induce the onset of these reproductive migrations. Magnuson and Horrall believe spawning may be triggered by increased stream flow—resulting from spring rain and melting snow. [R/LR-5]

Another underutilized fish is the alewife. Alewives comprise almost 85 percent of Lake Michigan's biomass. Small, localized operators have been harvesting alewives for fertilizer and cat and mink food.

But can and will *people* eat alewives? A Wisconsin Sea Grant research team believes the American consumer may come to relish it in a variety of forms. Over the past two years, food scientists led by David Stuiber and Robert Lindsay of the University of Wisconsin-Madison Food Sciences Department have developed a tasty, sardine-like product from this Great Lakes forage fish. In

the process, they have overcome problems with bones, bad flavor and watery texture, and have found better ways to handle and store the fish. Taste panels have approved of the results, rating the canned silvery fish superior to commercially available sardines.

Stuiber and Lindsay have also concocted canned and frozen food products from the sucker. Sucker patties made from minced, deboned sucker flesh, as well as alewife sardines, were devoured at a Sea Grant reception at the National Press Club in Washington, D. C. in June 1976.

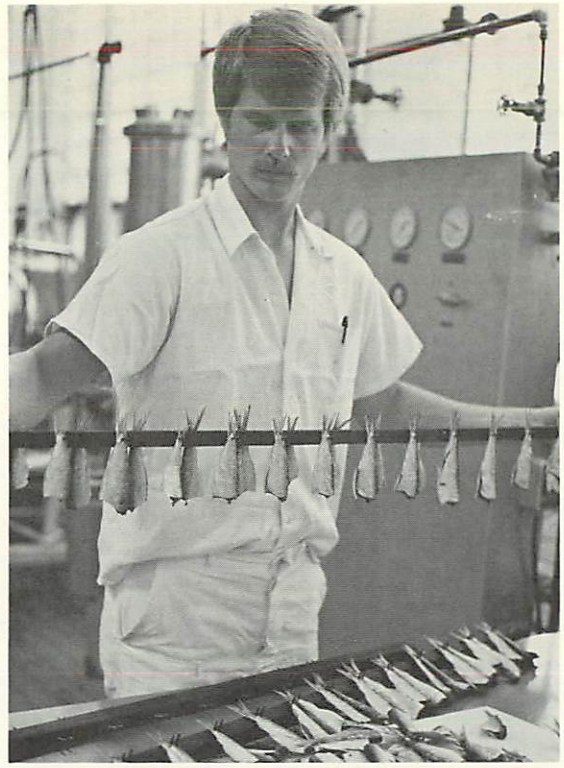
As a result of this research, one Wisconsin canning company is interested in processing alewife and sucker for human consumption. And a Wisconsin fishing firm on Lake Superior has begun to sell blocks of frozen minced sucker to a Minnesota processor.

The food scientists and economists on this "underutilized fish" project believe that alewife and sucker food products could boost Wisconsin's commercial fishery and provide the Midwest with an additional source of protein. [R/BR-11]

Scientific research can solve some problems confronting the commercial fisheries—such as developing new market products for underutilized fish species. But other problems relate more to economic and social questions. What are the social costs of programs designed to manage the Great Lakes fisheries? How will the fisherman, the consumer and the state in general each fare under alternative regulations?

Economist Richard Bishop, University of Wisconsin-Madison, has been studying the economic status of the fishing industry. At present he is using data from the DNR and plans to interview holders of commercial fishing licenses. From his work to date, he estimates that a proposed $200 commercial fishing license fee would eliminate a large proportion of fishermen in the trade in Wisconsin—many of them part-time fishermen. He notes that approximately 20 percent of Wisconsin's 300 licensed fishermen grossed less than $200 in 1976 and 37 percent grossed less than $1,000.

Bishop suggests it might be better to issue licenses with limited fishing privileges for a low fee, with a higher fee charged for a general license required of fishermen taking large catches. This would remove the economic burden for marginal fishermen who nevertheless may depend on this income.



A technician in UW-Madison's Food Science Laboratory prepares Lake Michigan alewives for canning.

The resource economist further suggests that we must at least anticipate the economic consequences of other hard policy decisions. For example, lowering the permissible PCB levels in fish from five to two parts per million (ppm), if strictly enforced, could set back many fishing operations. Ronald Poff, Great Lakes fisheries biologist of the DNR, points out that: "It is a safe assumption that more than half of the present whitefish catch exceeds the two ppm limit." Whitefish is the most important commercial species in Wisconsin and Poff bases his estimate on results of May 1977 samplings from Lake Michigan.

Still to be forecast are the economic results of various plans to limit entry into the Lake Michigan commercial fishery and other proposals being considered by the DNR to reduce the conflicts between commercial and sport fishermen. [R/LR-4]

This economic analysis has been a new dimension in the Living Resources Subprogram in the last few years and has strengthened the interdisciplinary approach of the program. This coordinated growth is helping to enhance our understanding and management of the Great Lakes ecosystem. The findings and skills developed in this subprogram find an immediate audience among Department of Natural Resources fisheries managers, sport and commercial fishermen, legislators and others with special lake-related interests within the state. But in promoting the biological health of the lakes through knowledge of the ecosystem, Sea Grant scientists are benefiting the general public as well.

AQUACULTURE

We can say from personal experience that a diet of whitefish alone, with no other food, can be eaten for days without losing its appeal.

–1836

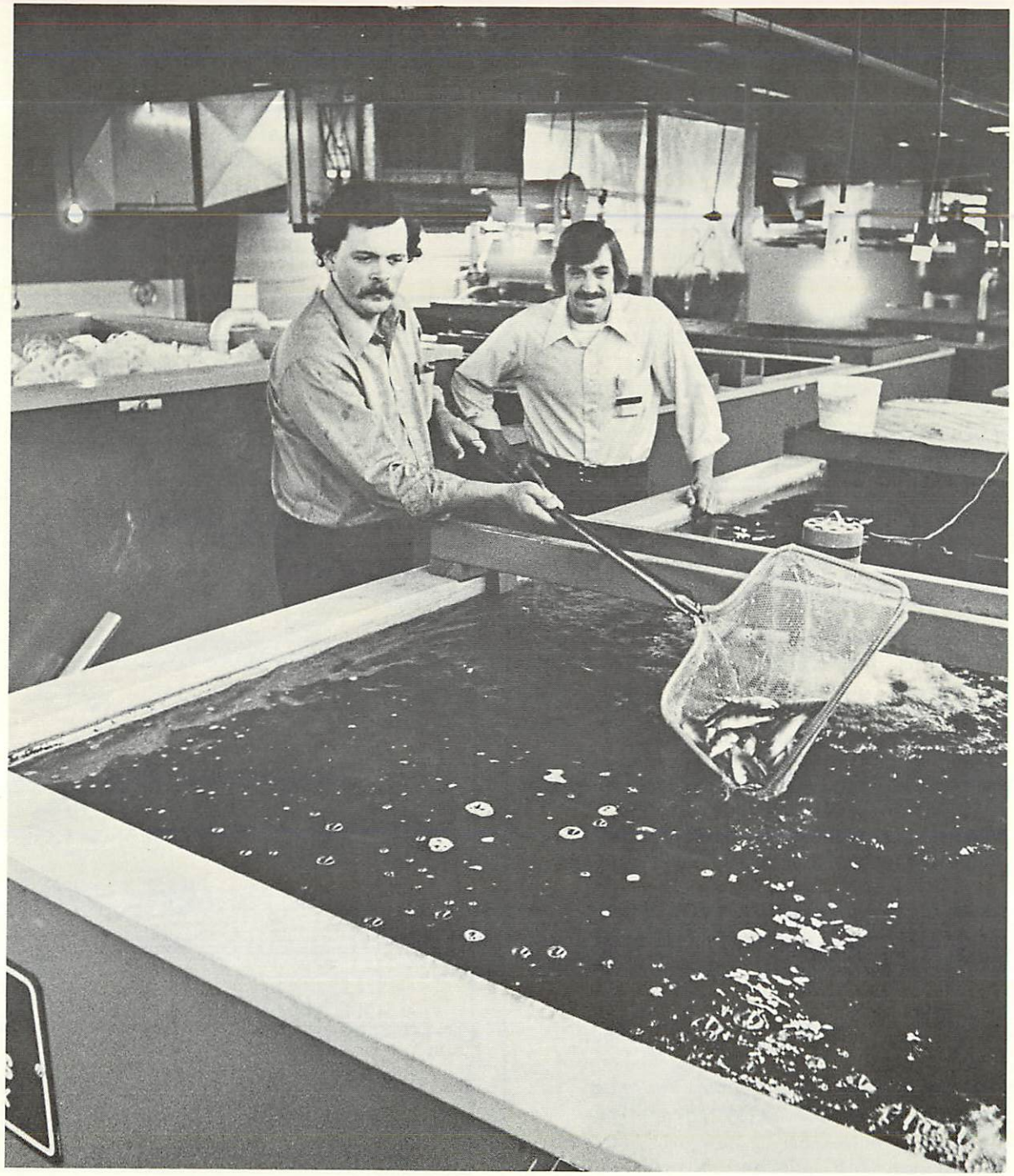
This enthusiastic endorsement set down by an anonymous 19th century scientist testifies to the quality of a fish once so abundant in the Great Lakes. Since those early days, other species besides whitefish have gained widespread popularity. One of these, yellow perch, has become the traditional fare at Friday night fish fries throughout Wisconsin.

In recent years, the catch of yellow perch in the Great Lakes has steadily declined due to a combination of factors—pollution, overfishing and competition for food with the overabundant alewife.

In response to a demonstrable need for new sources of perch, Sea Grant scientists, led by Professor Harold Calbert of the University of Wisconsin-Madison Food Science Department, have been raising yellow perch in tanks under controlled environmental conditions. These included such critical influences as light, heat, water quality, diet and population density.

The research team's biologists and engineers have made encouraging progress in meeting problems of perch aquaculture. These problems for the most part lie in the supply of fingerlings, the high cost of fish feed and utilities (heat, electricity and water). Together these costs make up about 60 percent of the budget for an aquaculture operation.

Perhaps the most critical prerequisite for the fish farmer is a reliable and economical source of perch fingerlings. Wild fish are hard to work with because they refuse to take artificial feed and often carry disease. And no supply of domesticated perch has yet been developed. To carry out their work the research



team biologists have developed a brood stock with good characteristics for perch farming. They plan to continue improving this brood stock through genetic selection. In this phase of research, they are learning about the environmental and physiological conditions that trigger the onset and duration of spawning. This understanding may someday enable aquaculturists to manipulate brook fish—assuring year-round spawning and a steady supply of fingerlings. [R/AQ-2]

A second crucial factor is diet. Perch apparently grow best on a three-part diet consisting of a starter ration followed by growing and finishing rations. As the fish mature, the biologists found that protein in the fish diet could be reduced. This saved about $50 to $75 per ton of feed, depending on prevailing prices. The researchers were able to save an additional $10 to $20 per ton by substituting animal fat for the soy oil most often used in fish feeds.

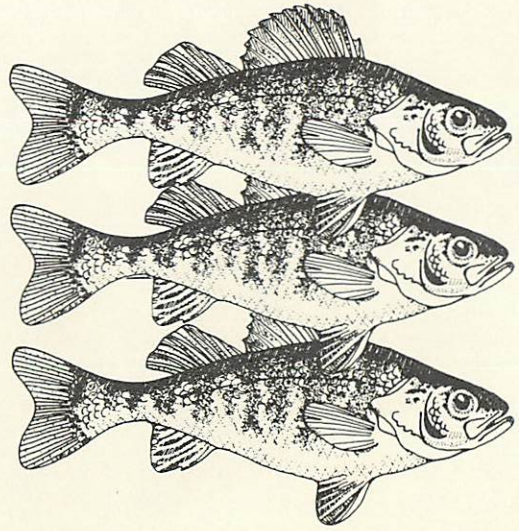
Utilities could drain a would-be perch farmer's bank account further. Electricity is required to pump water through the tanks and filters, and heat is needed to maintain an optimum water temperature for perch growth. The most feasible answer is to recycle the water through the system as many times as possible. By using a unique combination of three types of filters to remove fish wastes from the water, University of Wisconsin-Extension chemical engineer John Quigley found that the water in the system could be reused up to 20 times and still retain sufficient heat. Purifying systems can include a pressurized sand filter to remove suspended particles, followed by a biological filter to oxidize and mineralize dissolved organic wastes. [R/AQ-3]

The aquaculture team's economists have been analyzing the production costs and market potential of perch farming in the Midwest. Under the direction of agriculture economist Richard Vilstrup of the University of Wisconsin-Madison, marketing specialists have developed a computer program to predict expected profits based on current market prices for perch, initial investment and the costs of fingerlings, feed and utilities.

The economists generally view perch aquaculture as promising. Their optimism is strengthened by the 1976 enforcement of the minimum size limit for yellow perch taken from Lake Erie. This restriction reduced the perch supply by about 25 percent. As a result, the price of perch caught by Wisconsin fishermen in Lake Michigan rose in the fall of 1976 to $1.00 per pound in the round.

According to the economists, this was, at that time, the price that a perch farmer producing 100,000 pounds of fish per year had to receive for his product in order to break even. If, on the other hand, the natural harvest of perch increases, new markets and perch products may need to be developed to keep perch farming profitable. [R/AQ-1]

Aquaculture Research Program



While economic factors remain uncertain, the theory and practice of perch aquaculture is being proved by the aquaculture research team. Tank-grown perch fingerlings are reaching marketable size in ten months—a rate at least three times faster than fish in the wild. And taste panels at the University in Madison approve the aquacultured fish, finding the flesh tasty and of consistent quality.

A new and enlarged facility on the outskirts of Madison, opened in the summer of 1977, consolidates much of the research under one roof. In one area, three 16-foot demonstration tanks, each with its own unique system of regulating water quality, are used to demonstrate some of the design options available to the fish farmer. Each tank, made of fiberglass-coated plywood, contains some 4,000 perch.

Through these facilities and through the advisory work of the aquaculture specialists, widespread interest in perch farming has developed in Wisconsin and the Midwest.

Richard Gardipee, a recent graduate of the University of Wisconsin-Madison School of Business and now a Madison seafood retailer and wholesaler, sees aquaculture as a reliable source of fish. With advice from the Sea Grant aquaculture team, he has established his own fish farm near Madison, where several thousand perch and bluegill are being readied for harvest.

The facility consists of a renovated barn in which eight 3,000-gallon tanks are installed. A purification system biologically filters the water through a large bin of styrofoam pellets. The water for the tanks will be partially heated by solar panels placed on a southern sloping roof.

The aquaculture team stresses that much work remains to perfect the technology and improve the economics of the fledging perch aquaculture industry. However, the achievements of Gardipee and of a growing number of Midwest entrepreneurs are a gratifying measure of University of Wisconsin Sea Grant research progress. [R/BR-12]

MICROCONTAMINANTS & WATER QUALITY

By the shores of Gitchee Gumee. . .Beat the clear and sunny water, Beat the shining Big-Sea-Water.

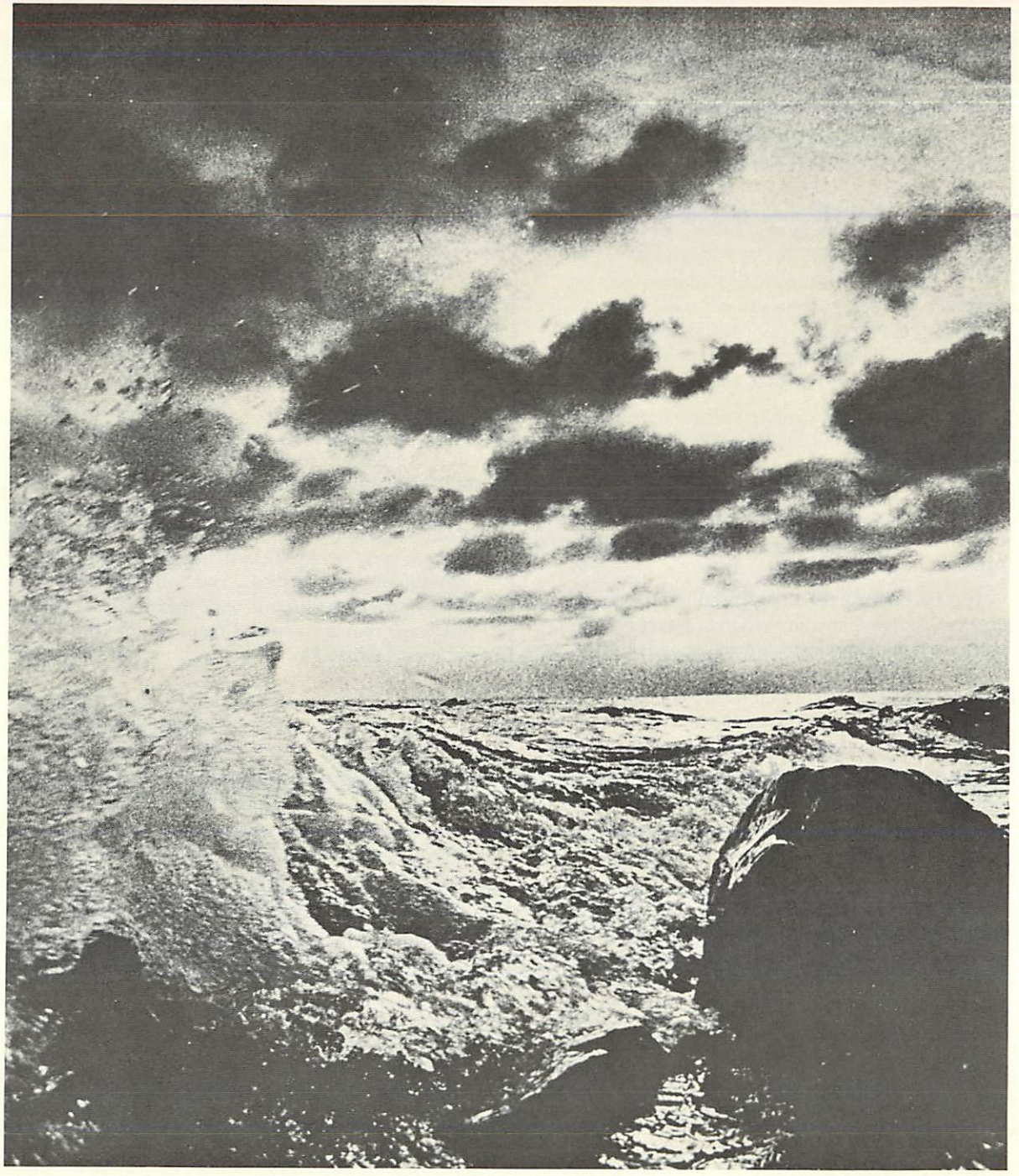
—H. Longfellow

Since the legendary days of Hiawatha, the "shining Big-Sea-Water" has lost little of its pristine quality. Lake Superior remains cold, clear and remarkably pure in all but its few industrial harbors. In contrast, Lake Michigan shows early signs of eutrophication, and a crescent of polluted water rims its southern basin from Milwaukee to the Indiana-Michigan border.

These freshwater seas are a major responsibility of the University of Wisconsin Sea Grant College Program. A Microcontaminants and Water Quality Subprogram is devoted to identifying the presence and pathways of various contaminants in the lakes. A second and more critical objective is to determine how these contaminants affect the lake environment and human health. Certainly the physical condition of the water both subtly and directly affects Great Lakes fisheries, recreational uses and municipal water supplies.

Eclipsing the now waning threat of DDT is that of PCBs (polychlorinated biphenyls)—a set of industrial compounds proving to be even more persistent and widespread in the environment than DDT. PCB molecules, borne through the air and coursing through waterways, concentrate in the Great Lakes and other natural "sinks" around the country. The economic liability of this contaminant to commercial and sports fisheries and its potential harm to human health are seen as both real and urgent.

How enduring is this threat to the Great Lakes? How long will PCBs and DDT continue to contaminate the fish? University of Wisconsin-Madison water chemist David Armstrong and zoologist James



Kitchell are testing and refining a mathematical model designed to predict the uptake of PCBs in Lake Michigan fish under both actual and theoretical conditions.

In tests with yellow perch, the investigators found that what the fish eats accounts for 75 percent of its PCB uptake. This would indicate that even though water contamination may be slight, PCBs in bottom sediments are likely to be taken up by bottom-dwelling organisms and introduced into the food chain. In this manner, pollutants are effectively recycled in the aquatic ecosystem. A model of PCB movements in the lakes will better equip authorities to cope with a public health problem that may be chronic for years to come.

The investigators' sampling of southern Lake Michigan fish also indicates a 60-80 percent decline in levels of DDT and its derivative compounds. However, levels of dieldrin, a highly toxic pesticide ingredient, have not subsided and remain near maximum tolerance levels set by the Food and Drug Administration. [R/MW-2]

It is becoming clear that preventing the arrival of these contaminants in the Great Lakes will require something more than cleaning up lake tributaries and controlling runoff from cities and farms. Recent studies estimate that a high percentage of some pollutants arrives via the air, either as fallout of dry particulate matter or in precipitation.

A research team, directed by University of Wisconsin-Madison water chemist Anders Andren, has extensively traversed Lake Michigan by boat—sampling aerosols, rainwater and lake water to detect both organic and inorganic pollutants. These comparative measurements can reveal how airborne substances alter the lake's chemistry. In addition, the sampling may indicate whether the foreign substances stem from natural sources or from human activities. [R/MW-6]

Whatever their source, airborne pollutants often settle on the water's surface, forming a microscopic film. These sometimes visible slicks may last days or weeks. By laying a wire screen over the surface, David Armstrong and his assistants have sampled the material in these films. This surface water, sampled to a depth of 0.3 millimeter, typically reveals zinc, cadmium, lead and copper concentrations many thousandfold higher in this microlayer "skin" than in the main body of the water.

Fly ash and other man-made particulates are common in surface films. However, dissolved and particulate organic carbon, nitrogen and phosphorus from varied and often undetermined sources are important ingredients in this surface enrichment.

Also on the lake surface are foams—a diverse mixture of trace metals, nutrients and chlorinated hydrocarbons, similar in composition to the surface films. They may simply be the compressed layering of film materials, according to Armstrong.

Contaminated foams and films may pose some threat to lake ecology. The water chemists believe that exposure of these surface materials to sunlight and other conditions could cause unusual interactions among the concentrated chemicals. Microscopic organisms, many of which live at the water's surface, can take up these pollutants and then be ingested by fish and birds. Thus what happens to these airborne pollutants once they settle on the water may be a critical factor in the lake's ecology. [R/BR-4]

The more apparent route for foreign substances reaching the Great Lakes is through tributaries and harbors. Less clear is the actual fate of trace metals, such as lead, zinc, copper and cadmium, after they are transported into harbors and open waters. Armstrong has been testing river-harbor systems in Lake Michigan to see how trace metals are concentrated in the water and in bottom sediments.

Trace metal concentrations were found to decline as a function of time and distance from the mouth of the tributary river. While this was expected, Armstrong and his associates determined that the pattern of declining concentrations was primarily influenced by dilution and not deposition in bottom sediments or uptake by organisms in the water. This conclusion is not encouraging since it indicates a continuing buildup of contaminants in the water over the whole lake as water circulates throughout the basin. [R/MW-1]

HEALTH EFFECTS OF CONTAMINANTS

How do aquatic organisms and fish react when exposed to contaminants? Reactions are varied, subtle and often deleterious. Most important is "biomagnefication," the process in which contaminants are concentrated and altered in aquatic food chains. Toxic substances taken up by one-celled plankton may be concentrated many thousandfold by the time they are lodged in large salmon and trout.

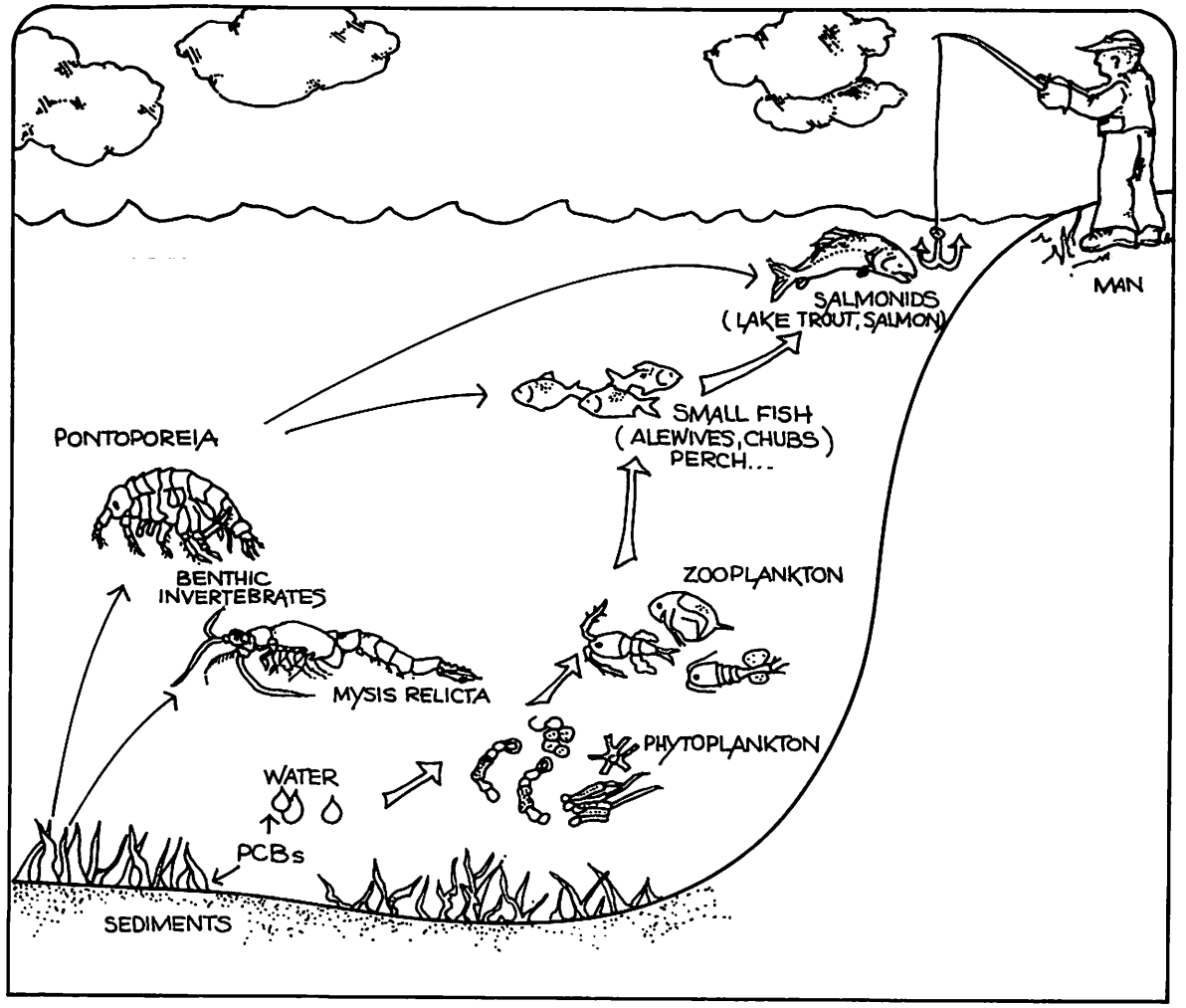
Fumio Matsumura and G. Mallory Boush, entomologists at the University of Wicsconsin-Madison, are studying a wide range of contaminants, including DDT and related compounds, and the way in which these toxic substances are transported through the aquatic food chain. From this kind of analysis, the degree of success of pollution, control programs may be more reliably predicted.

The two entomologists believe that the body of research on DDT offers a model for the study of PCBs. At the same time, they say, PCBs are more complex and troublesome than DDT. Whereas DDT is injurious to small organisms but relatively harmless to humans, PCBs are fairly harmless to lower form organisms and so are easily passed along the food chain to higher forms. Unlike DDT, the PCB compounds are especially toxic to higher animals, including humans.

In their research, Boush and Matsumura have developed bacteria that can degrade the PCB compounds by feeding on the carbon component. Although such biodegradation has certain industrial applications, they believe concentrations in natural environments are too low for such treatment. "Our super bug will go there and not find enough PCB molecules to survive," says Matsumura. [R/MW-3]

Chief among Great Lakes predator fish at the top of the food chain are the salmonids—coho and Chinook salmon, rainbow, brown and lake trout. How these widely sought game fish react to contaminants in the lakes can be critical to the health of these fish and those who eat them.

Because of the use of TFM and Bayer 73 in Great Lakes sea lamprey control programs, pharmacologists John Lech and Mark Melacon of the Medical College of Wisconsin have examined the manner in



The route by which PCBs are passed through the Lake Michigan food chain.

which these toxins are taken up, successfully metabolized and excreted by rainbow trout. They found that in a 24-hour exposure to Bayer 73, rainbow trout concentrated levels of this compound over 10,000 times in their bile; TFM over a thousand times; and certain crude oil elements several thousandfold. This being so, they believe fish might serve to monitor the presence of many pollutants, including petroleum products, that are otherwise at near undetectable levels in the water.

In addition, the pharmacologists observed certain synergistic effects that call for caution in the release of various chemicals to the environment. They found that carbaryl, a recent pesticide substitute, triples the lethal effect of the pesticide 2,4-D on exposed fish. Carbaryl, like other such pesticides and herbicides used in the Great Lakes basin, eventually reaches the lakes. And residues of 2,4-D, though its use is now limited, are widespread in the environment. [R/BR-5]

Just how toxic to fish are PCBs and other chlorinated hydrocarbons now found in the Great Lakes? Are PCBs and other contaminants contributing to the general failure of lake trout to reproduce in Lake Michigan?

To find out, zoologist Robert Broyles of the University of Wisconsin-Milwaukee has been exposing lake trout, Chinook and coho salmon eggs and fry to concentrations of PCBs in their water. With carbon-14 as a radioactive tracer to identify these compounds, he was able to measure their uptake in the eggs and fry. The results were dramatic. Exposed to a PCB concentration of 500 ppb (parts per billion) in water for four hours, the eggs and fish at sac fry stage achieved PCB levels of 30 ppm—a 60-fold concentration.

Broyles estimates that this concentrating process could continue under repeated exposure to the contaminants. However, experiments so far reveal little effect from the PCB levels on the red cell production, hatching, body structure (morphology) or mortality of his young subjects. Further research will seek to find what kinds (isomers) of PCBs are less readily taken up, and at what concentration levels harmful effects begin to appear in the fish. [R/MW-5]

In view of the evident PCB contamination of Great Lakes fish, Lech has pursued another question: how do salmonids, particularly rainbow and lake trout, metabolize and otherwise eliminate these toxic substances?

For 36 hours he exposed rainbow trout to a PCB isomer typically found in Great Lakes fish. At the end of this test period, the fish were examined and the scientists found that 88 percent of the resulting PCB contamination was in the fish's carcass, muscle, skin, lower intestinal tract and fat. Within two weeks, the fish eliminated almost 30 percent of the PCB contamination. This rapid decontamination then slowed radically. It took 126 more days to decline another six percent. Because of the slow, second-phase elimination, PCB contamination is expected to linger for many years in the larger fish of the Great Lakes. [R/BR-8]

Authorities have warned people to limit their diet of Great Lakes trout and salmon. And the sale

of lake trout from Lake Michigan has been banned in Wisconsin. But just how harmful to human health are small amounts of PCBs and other environmental contaminants, in the long run? Pathologist James R. Allen of the University of Wisconsin-Madison Primate Center is addressing this question by feeding rhesus monkeys steady diets containing small amounts of PCBs. Because the monkeys' metabolism closely resembles that of humans, such experiments have strong implications.

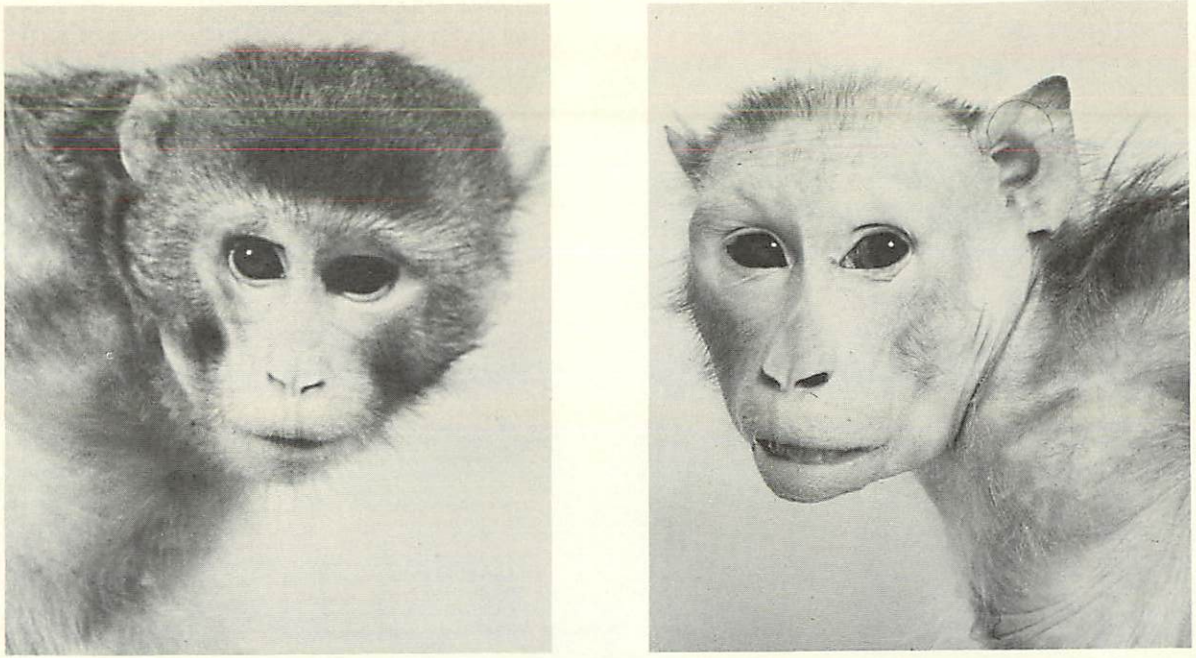
Allen discovered that PCB levels which the U. S. Food and Drug Administration have long regarded as safe caused serious health problems in the monkeys within two or three months when fed to them continuously. Monkeys fed 5 ppm PCBs daily (the official tolerance standard for food) developed persistent acne, hormone imbalances and other serious problems. He observed similar effects even with a diet of 2.5 ppm.

The PCB diet proved especially harmful to the mothers and infants. The monkeys had a lower rate of conception and aborted more often than is normal. Infants born to mothers kept on a PCB diet during pregnancy were small, unusually susceptible to infection and suffered learning disabilities. The offspring continued to develop symptoms after birth as they consumed their mothers' PCB contaminated milk.

The effects of PCB intoxication persisted even after the mothers had been off the contaminated diet for a year. Although the mothers' health improved, their body tissues and milk still contained PCBs, as did the tissues of infants born to them at this time. [R/BR-9]

Another pollutant of concern is TCDD (tetrachlorodibenzo-*p*-dioxin), one of the most potent toxins known. One major source is the defoliant 2,4,5-T, a weed killer that has been used extensively in Wisconsin and other states. Although concentrations of TCDD are almost undetectable in the Great Lakes, Allen sees evidence that concentrations of TCDD in fish are high enough to produce edema and twisted beaks in fish-eating seagulls. Chickens exposed to dioxins exhibit similar abnormalities.

Again through experiments with monkeys, Allen has found that dioxins caused long-term effects more severe than those caused by PCBs. Even at extremely low levels in the monkeys' diet (500 parts per trillion), dioxins seriously impaired the health, especially of the reproductive and immunity system. When bred, the animals had trouble conceiving and most aborted in the second month of pregnancy. After nine months, five out of eight animals died from almost complete lack of red and white blood cells. In continuing experiments, the amount of dioxin in the experiments has been lowered to levels which more closely approximate the levels in fish or other food consumed by man. [R/MW-8]



Rhesus monkey in UW-Madison's Wisconsin Regional Primate Research Center before (left) and after (right) being fed a diet containing 500 parts per trillion (ppt) dioxin for nine months.

A disturbing possibility is that dioxins are inadvertently being formed in the effluent of paper mills, of which there are many in Wisconsin. These discharges are known to kill fish and, even at low concentrations, to affect aquatic life in receiving waters.

Chemist John Harkin of the University of Wisconsin-Madison speculates that the chlorine bleaching of pulp might be creating compounds closely analogous to typical dioxins. He is analyzing bleach plant effluents for their possible dioxin content. In the laboratory he is using model compounds to study dioxin formation, particularly under conditions existing in bleach plants. If dioxins are discovered to be an ingredient of bleach plant effluents, he hopes to find a treatment process for removing dioxin contaminants. The Environmental Protection Agency has expressed interest in his findings. [R/MW-7]

Harkin's efforts to pinpoint and deal with yet another possible Great Lakes pollutant typify the design of the Microcontaminants and Water Quality Subprogram as a whole: to meet the nearly overwhelming challenge of Great Lakes pollution. In this confrontation, the enlisted scientists not only must meet project objectives, but direct their reserach to anticipate new problems that could arise in the dynamic Great Lakes environment.

COASTAL MANAGEMENT

PEOPLE & PROCESSES

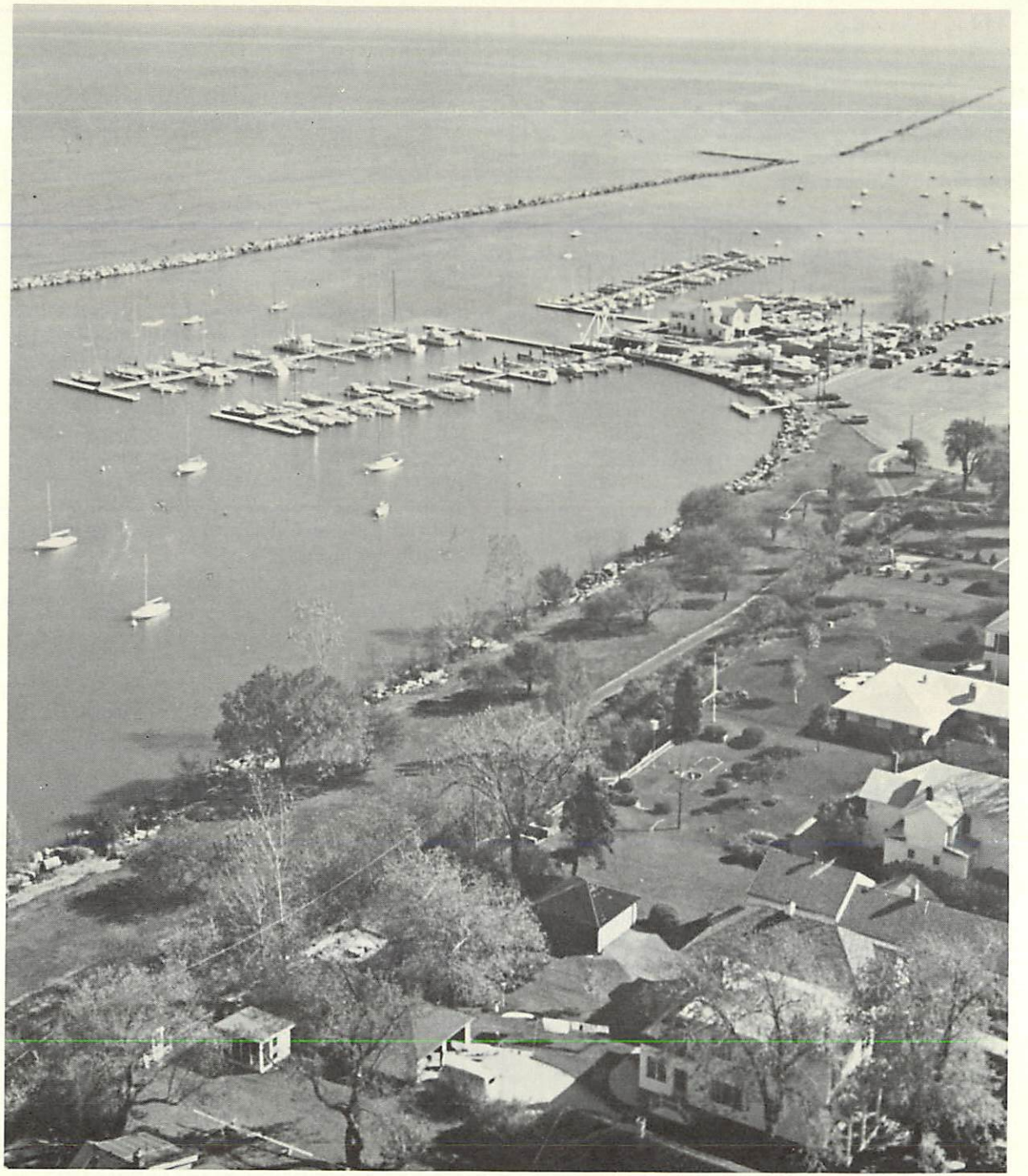
It were easy to build on the sides of these great lakes an infinite number of considerable towns which might have communication one with another by navigation. . .and by an inconceivable commerce that would establish itself among them.

—Fr. Hennepin

Since the prophetic vision of Father Louis Hennepin in 1630, a long tradition of Great Lakes shipping has developed. A maritime commerce, certainly inconceivable in the wilderness days of the early Jesuit explorers, today links the port cities of the five lakes—not only with one another but through the St. Lawrence Seaway to the world.

Along much of the 4,039 miles of U. S. coastline in the Great Lakes, large cities, power plants, marinas and "second homes" vie for space with towns, farms and swimming beaches. This "multiple use" of the coastal land and water embodies both promise and conflict.

In the fragile shoreland of the oceans and Great Lakes, it is increasingly important to know which uses and developments are desirable, even essential, and which are harmful and to be discouraged. The oft conflicting public goals both to preserve and yet develop coastal resources make Sea Grant's independent research and policy studies especially important. The University of Wisconsin Sea Grant College Program has apportioned this area of concern among two subprograms—Policy Studies and Shoreline Property and Resources.



POLICY STUDIES

Nearly half of Wisconsin's residents live and own property in coastal regions of the state's two Great Lakes. Unfortunately, systems for recording property ownership and institutions supporting that tenure are holdovers from simpler social and economic times.

Civil engineers James Clapp and Eldon Wagner and science policy expert John Steinhart at the University of Wisconsin-Madison are developing a modern cadastre suitable for the Wisconsin coastal area, which, it is hoped, can eventually be applied to other geographical areas. As a comprehensive record of interests in land holdings, a modern cadastre codifies the geodetic and topographic information about all land parcels in a region, as well as identifies their financial and legal features. Such up-to-date and complete records, it is felt, would provide conveniently centralized information and protection to shoreline property owners and a broad, factual basis for administrative programs to protect the coastal environment.

Racine County officials cooperated with the investigators in a test of their cadastral concepts as they applied to this industrial coastal county. The research, which actively involved citizens and public officials, was designed to modify the scientists' cadastre theories and practices to respond to a real life situation. [R/PS-18]

The existence of a modern land information system by itself, however, is not enough to promote the quality of a coastal region or river basin. In Wisconsin, the heavy loading of pollutants in the Fox River Basin which are carried into Green Bay has been a long-standing problem. Paper mills and other industries along the Fox River and the maze of town, county, regional and state jurisdictions make basinwide water resource management as imperative as it is difficult.

Resource economist Daniel Bromley, University of Wisconsin-Madison, has examined various institutional arrangements in the Fox River-lower Green Bay watershed that bear on the question of the region's water quality. From these studies, the research team, assisted by several federal and state commissions and agencies, made recommendations pertaining to proposed legislation which would establish a regional environmental quality authority in the Fox River Basin. Bromley's research team has also consulted extensively with the staff of the Fox River Water Quality Planning Agency. [R/PS-15]

Under the federal Coastal Zone Management Act of 1972, states fronting the oceans and Great Lakes are encouraged to manage and preserve these fragile frontiers. But what is a coastal region? How do you define its boundaries?

In 1975, the Wisconsin Sea Grant College Program took on the task of advising the Wisconsin Coastal Management Program on how to establish the boundaries of the state's coastal lands. Eight faculty members from three University campuses and a state administrative official met under Sea Grant and Wisconsin Coastal Management Program auspices. These specialists in such diverse fields as land use, meteorology and water chemistry met with task force chairman James Clapp biweekly throughout the year.

A principal task group recommendation was that the "coastal zone" not simply extend landward some fixed distance but that it extend far enough to encompass all of certain critical geographical areas. These would include wetlands, game refuges, remnants of prairies, geologic outcrops, dunes and fish refuges. The actual coastal boundary would then be defined by the nearest land use feature further inland—such as road or railbed, major transmission line or political boundary.

These and other recommendations and findings were of material assistance to the Coastal Management Program's Advisory Council in developing its policy statements. A secondary but important purpose of the Sea Grant task force was to suggest how the Wisconsin Sea Grant Program, in its research, advisory services and policies, might most effectively serve the public and the state in this area.

At the workaday level, tough problems are developing in the coastal region. An example is how to prevent phosphorus from reaching our lakes and contributing to their eutrophication. Federal law requires that Wisconsin and other Great Lakes states remove 80 percent of the phosphorus at treatment plants before effluents are released. In pursuing this goal, the Wisconsin Department of Natural Resources has met with resistance by many small communities. Ironically, the cost of litigation and resulting fines can almost equal the cost of installing the necessary equipment to remove the phosphorus.

But phosphorus concentrations at any given site, the pollution controls appropriate to handle them and the financial capacity of the local government to establish these controls all vary widely. Engineer Erhard Joeres and economist Martin David at the University of Wisconsin-Madison have evaluated the cost effectiveness of various enforcement policies in order to determine how the state can most equitably and efficiently meet the federal standards.

Significantly, they found that Milwaukee and a few other large communities are almost carrying the state in reaching the 80 percent phosphorus removal standard. Milwaukee now removes 90-92 percent of the phosphorus in its considerable sewage effluent, enabling the state to average 70-75 percent of phosphorus removal.

With this achievement in mind, as well as the political and technical difficulties in compliance among the myriad smaller offenders, Joeres and David believe the Department of Natural Resources should concentrate on the larger urban sanitation districts. They suggest that statewide financing of this effort should forestall resistance in the metropolitan areas that otherwise would be bearing an unfair load in the phosphorus cleanup campaign. [R/PS-8]

Other coastal issues by their nature may claim more direct public attention. Multiple uses of the coastal region can stir controversy, such as the siting of power plants along the Great Lakes and inland waters.

Science policy expert John Steinhart and energy specialist Thomas Smith, University of Wisconsin-Madison, approached the public decision-making process by studying the criteria used in the siting of power plants and transmission lines. "The Household Energy Game"—a 20-page booklet

The Ontonagon Lighthouse, built in 1866, remained in active service on Lake Superior until 1964.

in which the player can graphically chart his family's home energy budget—was invented early in this project. The game is now in its sixth printing, with over 60,000 copies widely distributed.

At the request of the Wisconsin Public Service Commission, the research team adapted these energy use concepts, as well as the economic-environmental factors in siting a power plant, to devise another "game." This one was designed to simulate the actual decision-making process.

Although gaming can be an effective educational tool, the investigators found that power plant siting, unlike water quality problems for example, was too emotional an issue to be an easy subject of structured interplay. Essentially the question of the fueling source (i.e., coal vs. nuclear fission) almost overrode consideration of the plant siting issue. However, when completed the game is expected to be useful to scientists, industry regulators, industrialists, environmentalists and members of the public concerned with power plant siting. [R/PS-3]

If power plants are not always desirable along the shore, what features are? For many, this region of land and water and historic settlements has a special attraction.

Landscape architect William Tishler and his assistants at the University of Wisconsin-Madison have looked at 23 shoreline communities on Lakes Michigan and Superior. They found that public interest centers on the simple beauty of the white frame homes, picturesque churches, fishing wharves and warehouses. Also noted were fish restaurants, museums and other amenities.

The research team developed a system by which local citizens could evaluate these historic, cultural and aesthetic resources of their communities. The team will soon publish a booklet for developers and city planners suggesting guidelines for new construction in coastal areas and ways to recycle older buildings and "manage" open landscapes.

An historic preservation plan has already been prepared for Bayfield, Wisconsin—a gracious community of Queen Anne style homes, fishing restaurants and warehouses overlooking Lake Superior. Tishler believes this plan can serve as a model of what can be done in other coastal communities. [R/PS-9]

For Bayfield and nearby coastal towns, the need for some kind of planning is already clear. Better transportation services will be required as the Apostle Islands National Lakeshore, a new federal park, begins to draw tourists to the region. Alternative modes of travel in the area have been examined by University of Wisconsin-Madison civil and environmental engineers William Berg and Robert Smith. They concluded that automobiles are best suited for getting to points of embarkation to the islands. For those traveling a considerable distance, passenger trains with piggyback conveyance of private automobiles would save time and fuel. The transportation specialists also predicted that the present lack of garages, parking lots and other facilities for motorists will strain community resources near the national park. Berg and Smith noted that a great proportion of residents in this sparsely settled, rural region of Wisconsin depend on public transportation and suggested ways to improve the rural bus systems. These findings are being used by a consultant for the Northwest Wisconsin Regional Planning Commission. [R/PS-14]

A more immediate Great Lakes transportation issue is the future of the Lake Michigan ferries. For decades these sturdy old boats have carried boxcars and motorists back and forth between Wisconsin and Michigan, saving industrial shippers time and money and providing the tourist with the additional enjoyment and convenience of a Great Lakes "cruise." Unfortunately, the ferries have steadily lost money and the railroad companies owning the lines have been negotiating to discontinue service.

Harold Mayer, geographer and transportation specialist with the University of Wisconsin-Milwaukee and Harry C. Brockel, former Milwaukee port director and now specialist in the Center for Great Lakes Studies, have examined alternative modes of Lake Michigan transport and schemes for their management. Although the ferries have performed admirably in the past, the two specialists suggested that ferry boats can be upgraded to carry not only trains, private automobiles and passengers, but also truck-trailers. This would save the trucking industry money. Just as important, trucks would be able to save time in short hauls between Wisconsin and Michigan by avoiding the

long way around the lake through the crowded Chicago-Gary region.

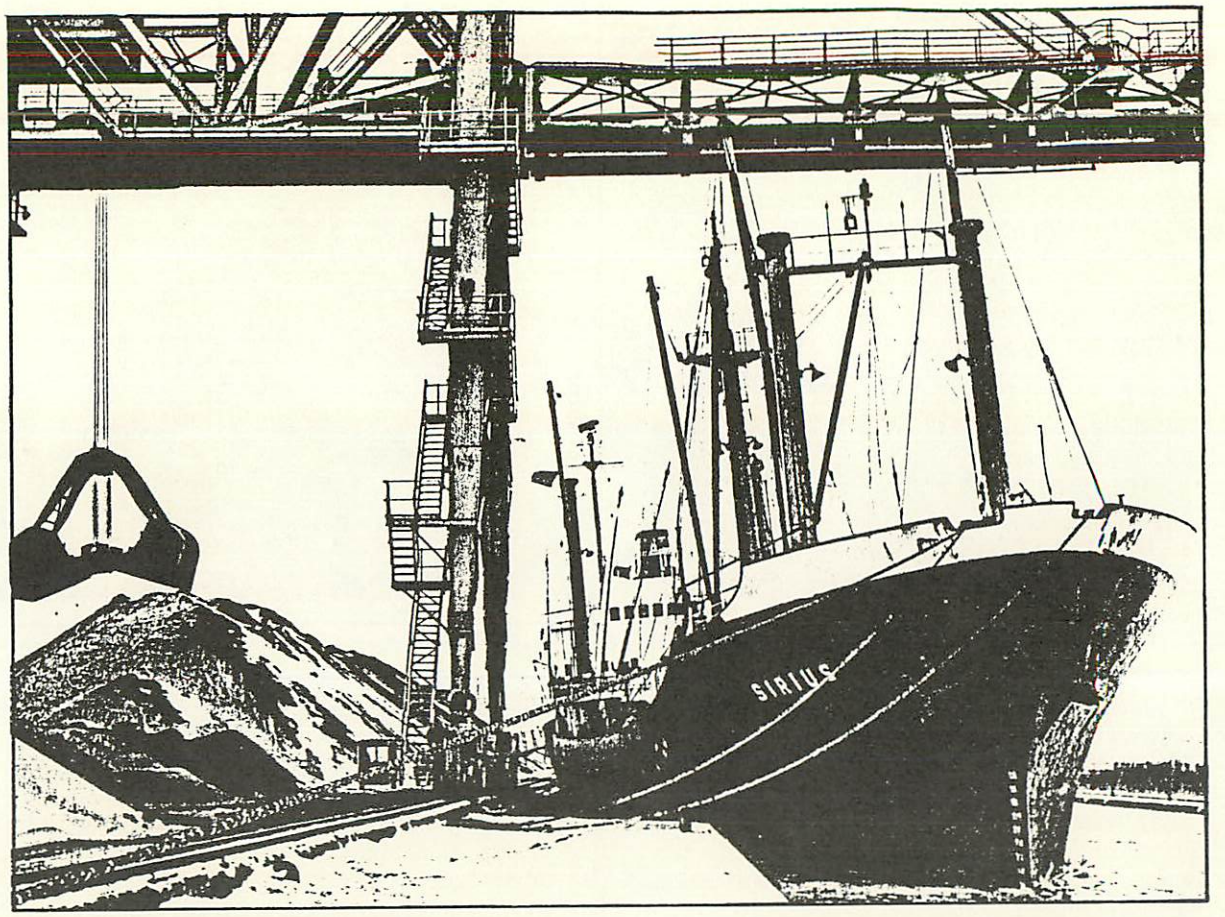
In documenting the value of ferries, Mayer and Brockel concluded that government subsidies would be justified. This could insure operating expenses and provide for improved docking facilities and environmentally improved engines. Mayer and Brockel also believe that three-decker ferries, accommodating trains, trucks and private autos, would come closest to breaking even financially. On the basis of these findings, the State Coastal Coordinating and Advisory Council has urged that the ferries be retained. Their policy recommendation to this effect helped stimulate Governor Lucey of Wisconsin and Governor Millikan of Michigan to work together on a plan to maintain ferry service.

Mayer and Brockel are having a further impact on transportation users and policies in the Great Lakes through their interaction with several organizations concerned with Lake Michigan transportation issues. [R/PS-16]

Another form of Great Lakes transportation—cargo shipping—continues to serve the industrial heart of the United States and Canada, despite storms and shipwrecks, winter ice and narrow locks. Such essential bulk commodities as iron ore, coal, grain and oil have become the biggest cargoes on the Great Lakes-St. Lawrence Seaway. Ships at the twin ports of Duluth and Superior on Lake Superior may soon be loading large consignments of oil from western Canada and coal from Montana and Wyoming.

Yet, Great Lakes shipping faces competition from other modes of transport. General cargo—manufactured, packaged goods and other industrial products—is being sent increasingly by truck and train to eastern ports for domestic or overseas shipment.

Economist Eric Schenker and Harry Brockel have co-authored a comprehensive book which is the culmination of several years of Sea Grant research on the ports and commerce of the Great Lakes system. This research was undertaken through the University of Wisconsin-Milwaukee Center for Great Lakes Studies. The book, *The Great Lakes Transportation System*, covers all facets of port operations and lake shipping—from ice floes to commodity flows, labor relations to port authority policies. Particularly timely is a chapter on the energy crisis as it affects Great Lakes shipping. Much of this research benefited from the use of the 1970 U. S. Foreign Trade Tapes. This data, the most recent since 1956, includes the origin-destination of each ship entering the St. Lawrence-Great Lakes complex, plus its number, size, type and national flag; the cargo and its valuation; and the ship's duration in each port.



While the United States and Canada share in regulation of the Great Lakes, no binding authority rules the high seas. Nevertheless, "freedom of the seas" is no longer an unassailable standard among nations. Mining the ocean bed awaits international agreement. And oil tanker spills and the difficulty in fixing not only responsibility, but even vessel ownership, dramatize an even more urgent need for international oceanic accords.

Richard Bilder, University of Wisconsin-Madison professor of law and former State Department specialist in international law, is analyzing these and other international issues and the processes of cooperation that can perhaps resolve them. From this, he hopes to suggest ways in which nations can overcome the risks of collaboration and construct successful multilateral institutions governing the seas. His findings would suggest measures supplementary or alternative to Law of the Sea negotiations. Much of Bilder's research was presented in a series of invited lectures at the Hague Academy of International Law. [R/PS-1]

SHORELINE PROPERTY AND RESOURCES

As one of the most productive but fragile biological zones, shorelands need to be carefully observed if they are to be protected from human activity. Erosion is a natural geological process that can be aggravated by shoreline development and even by erosion defense structures themselves. Also vulnerable are plant communities on land and aquatic life in nearshore waters. Several Sea Grant projects have either surveyed these various impacts directly or sought better ways to record what is physically happening along the shore.

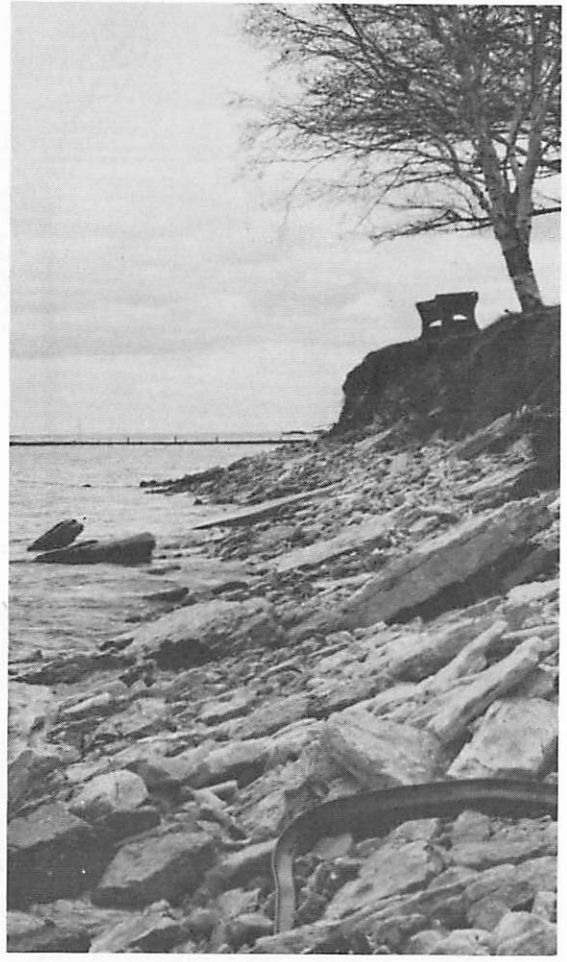
In two projects, special aerial surveillance techniques to monitor the shoreline have been developed. Civil and environmental engineer Theodore Green and physicist Robert Madding, both of the University of Wisconsin-Madison Marine Studies Center, adapted a "thermal scanner" to detect power plant effluents as these heated waters flow into Lake Michigan. The scanner, a 25-inch cigar-shaped instrument attached to the belly of a plane, registers infrared radiation from below. Recorded on tape, these "heat" measurements create a thermal profile or "picture" of ground level objects, each emitting a different degree of longwave intensity.

In more than 100 overflights along Wisconsin's Lake Michigan coastline, the investigators measured the relative temperature and dimensions of these plumes of heated water fanning into the lake. Their surveillance revealed that power plants in this region were exceeding the maximum allowed by the state. (To meet this standard, the effluent must cool to no more than 3 degrees Fahrenheit above ambient water temperature at a 1,000 foot distance from the outfall. This distance may be further as long as the total mixing zone [i.e., the thermal plume] does not exceed 72 acres.)

The investigators recommended that regulation of thermal effluents can and should be simplified by setting standards that can be more easily measured. One suggestion has been to legally limit the size of the mixing zone as the sole standard—a feature that can easily be monitored by the airborne thermal scanner.

With Wisconsin Department of Natural Resources funding, the research team has more recently been examining the heated effluents from paper mills on the Fox River and power plants throughout the state. [R/EP-1]

In the second aerial surveillance project, civil and environmental engineer Paul Wolf and physicist Frank Scarpace, University of Wisconsin-Madison, have developed an improved system of shoreline mapping. Sophisticated photographic measuring techniques were used to extract data from aerial photographs related to shoreline position. This technique enables scientists to ascertain from photographs of the same area, taken at two different times, the erosion that took place during the intervening period. [R/SP-3]



Another pair of Sea Grant research projects has taken a closer look at the Lake Michigan shoreline. From Rock Island off the tip of Door County to the Wisconsin-Illinois state line, University of Wisconsin-Green Bay geologist John Pezzetta and University of Wisconsin-Madison marine geologist J. Robert Moore conducted an aerial reconnaissance. At 76 shoreline sites deemed prone to erosion, the investigators followed up with ground level analysis of soil, slope, beach protection and other land characteristics along the shore. A detailed inventory of shoreline geology will be published, giving rates of recession in areas where development is considered especially hazardous. [R/SP-1]

In addition to geologic features, vegetation can typify coastal environments, such as marshes and estuaries, sand dunes or sloping bluffs. Botantists Peter Salamun and Forest Stearns, of the University of Wisconsin-Milwaukee, have examined plant communities along the full extent of Wisconsin's Lake Michigan coastline. They found that human impacts in this region have greatly reduced the amount of original vegetation. And in adjacent uplands, farming and coastal development have eliminated many plants which might have revegetated the coastal slopes. Erosion has resulted, particularly in areas with unstable clay banks. In addition, many marshes and unspoiled estuaries have been lost to commercial development in protected bays and river mouths.

In documenting the composition and condition of the state's coastal vegetation, the researchers urge the protection and further study of wetlands as nurseries and havens for waterfowl, fish and other aquatic animals. [R/SP-6]

These recommendations, along with the recommendations and research efforts of the rest of the Shoreline Property and Resources and Policy Studies projects, are as wide-ranging as the Great Lakes coastal environments themselves. Problems and issues change as scientific understanding grows and public attitudes shift. Thus the monitoring of erosion, water quality and man's uses of the lakes and their coastal regions and flexibility of Sea Grant research in these areas will be continuing needs.

MINERAL RESOURCES

There were rumors of great masses of pure copper and large veins full of copper. . .but they were all on the North Shore and that was Indian territory.
–R. B. Mclean, Superior City, 1854

Inflated claims of rich mineral deposits were part and parcel of early mining in the Lake Superior basin. But copper mining did flourish for many years on the Keweenaw Peninsula—a rocky, copper-veined thumb poking more than 50 miles into the lake.

Today the University of Wisconsin Sea Grant College Program has developed a Mineral Resources Subprogram that recognizes the continuing mineral potential in the upper Great Lakes region. Research within the subprogram seeks to improve underwater minerals exploration techniques and to further the environmentally-sound exploitation of marine and Great Lakes mineral deposits.

For several years, research teams under University of Wisconsin-Madison marine geologist J. Robert Moore (now at the University of Alaska) and geophysicist Robert P. Meyer have investigated the presence of copper veins extending offshore into Lake Superior. In the process, they have employed and refined various techniques, including seismic probes, magnetometry and dredge sampling.

The geologists found significant *underwater* copper lodes on both sides of the Keweenaw Peninsula with smaller amounts of zinc, cobalt and nickel also present. The presence of copper in Lake Superior and northern Wisconsin has long attracted mining firms such as American Copper and Nickel Company. If legal and environmental problems can be resolved, these lake bed deposits may become important reserves as land sources of these minerals are exhausted.

From the coring barge, WYNN, UW-Madison geologists and students collected underwater mineral samples off the coast of Alaska.

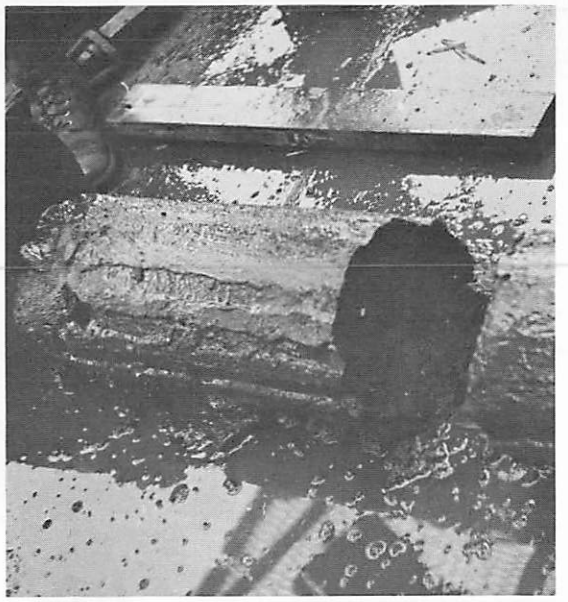
Moore observes, however, that customary technology in the mining industry is geared to dry land mining of high grade deposits. Commercial exploitation of underwater deposits will require new prospecting, mining and processing techniques. The following projects within the Mineral Resources Subprogram are designed to meet that need, both in the Great Lakes, and more significantly, in the oceans.

A regionally important resource, largely overlooked until recent years, is the large deposits of sand and gravel in Lake Michigan. Although the United States supplies two-thirds of the world's offshore sand and gravel, none is mined from offshore urban areas of Lake Michigan. Sand and gravel used in Milwaukee construction, for example, is quarried on land and trucked up to 30 miles. In 1971 this transport cost an average $1.20 a ton, more than double the cost of the material itself. Despite such costs, land mining of sand and gravel in Wisconsin has been doubling in this century every 12 years, slightly faster than the rate of increase nationwide.

A research team headed by Meyer is now in the process of locating and assessing these offshore deposits, using various sonic and electrical techniques as well as a physical sampling program. Three field sites were chosen—one with a known deposit of sand, another with gravel deposits and the third with a mixture of both. In these three geologically different environments, the researchers are testing methods that can be used to detect and distinguish among the single and mixed sediment types. [R/GM-10]

Other Sea Grant minerals research is sited in the remote Bering Sea of Alaska. Moore and his student team have been seeking improved methods of locating noble metals, especially gold and platinum. These minerals, along with osmium, palladium and iridium, are considered critical to modern industrial technology.

Building on the earlier Sea Grant research in Lake Superior, Moore's team concentrated on the presence and associated environments of mineral lodes in Alaskan coastal waters. They determined that promising exploration clues can be unearthed by mapping the location and relative concentrations of such geochemical parameters as nickel, cobalt, silver, barium and copper.



A twelve-inch core sample taken in 65 feet of water off the entrance to Goodnews Bay, Alaska.

They also investigated the likelihood that additional clues can be gleaned from the mineral grain revealed in thin-section petrography—the microscopic study of finely sliced rocks.

As evidence of industrial interest in this research, the Chromalloy Mining Corporation of southeastern Alaska generously provided vessels and research facilities for these field investigations. [R/GM-8]

Minerals are also found in placers—glacial or waterborne deposits that often settle at the mouths of rivers or in coastal waters. Moore and his young geologists included in their field work a study of mineral placers off the Alaskan coast. Essentially they looked for those relationships in sediment composition that might indicate the likely presence of gold and platinum.

In this research, they developed an "exploration window" concept that established the ratio of certain key metals in the sediments in relation to the presence of gold and platinum. This approach, which has favorably impressed several mining companies, was presented at a symposium of the Alaska Geological Society. A further refinement of the concept was presented in 1976 at the International Geological Congress held in Sidney, Australia. Several firms in the Alaskan area, American Placer Gold Company, Amuedo-Ivey and NOMECO among others, are now utilizing some of the research findings developed in this project. [R/GM-7]

One of the most remarkable achievements in the underwater mineral mining industry is the ability to retrieve manganese nodules from the deep ocean. An estimated 50 billion tons of these potato-sized lumps of mixed hard minerals lie in scattered locations on the ocean floor. Moore and his colleagues have even discovered a related, pea-sized form of manganese nodule in the Great Lakes.

With these achievements has come the challenge of processing and extracting the several metals intermixed in the manganese nodule. Chemical engineers Thomas Chapman and Dale Rudd, University of Wisconsin-Madison, are developing chemical solutions and designing processing equipment that can extract and sort out the desired minerals—especially copper, cobalt and nickel.

The two engineers have encountered unexpected interactions between copper and cobalt. Nevertheless they remain convinced that hydrometallurgical, rather than pyrometallurgical (firing), methods are the answer to refining the manganese nodule. In support of this conclusion, they have most recently designed an electrochemical cell that will recover single metals in a separate state.

This research into the processing of manganese nodules has also served to increase understanding between the underwater mining industry and government agencies seeking to influence the proper development of this new technology. [R/GM-9]

A strong feature of the Mineral Resources Subprogram has been the financial and logistic support extended to it by many marine mining companies—especially those operating in the Alaska region. This close interaction with industry was highlighted in 1976 by the seventh annual Underwater Mining Institute, hosted in Madison by the University of Wisconsin. These international meetings of academic, industry and government representatives testify to the research leadership of the University's underwater minerals program.

OCEAN ENGINEERING

They are swept by Borean and dismasting blasts as direful as any that lash the salted wave; they know what shipwrecks are, for out of sight of land, however inland, they have drowned full many a midnight ship with all its shrieking crew.

—H. Melville

Herman Melville, one of the great writers of the sea, understood and respected the forces of nature on the Great Lakes. Today, the relentless forces of wind, water and ice inspire not only great literature but new lines of scientific research.

The University of Wisconsin Sea Grant College Program has supported innovative approaches within its Ocean Engineering Subprogram. These projects fall within three broad research categories: diver assistive devices and physiology of underwater diving; underwater construction; and coastal processes and engineering.

DIVER ASSISTIVE DEVICES AND PHYSIOLOGY OF UNDERWATER DIVING

From monitoring fish plantings to the construction of offshore oil rigs, at some stage of research or construction the services of an underwater diver are often required. Whatever the nature of the activity, the scuba diver's life depends on his diving equipment and his expertise in its use.

With this in mind, a group of University of Wisconsin-Madison engineers and physiologists has been building prototypes of diving gear designed to be safer and more efficient. They have also been studying how the human body functions under the stress of submersion.

An engineering design class, taught by mechanical engineer Ali Seireg, built a "Sea Grant Underwater Habitat." Built from an old milk vat and

anchored in 28 feet of water just off the bottom of Madison's Lake Mendota, this submarine laboratory is used mainly to train divers, test underwater equipment and study the physical reactions of divers to underwater work. It is also a potential base for scientific research within the lake itself.

Another achievement has been a full-scale model of a platform, stabilized by computer-controlled propellors, which provides the working diver with increased stability and efficiency.

To increase diving safety, another student under Seireg's direction designed and built a full-size prototype of an underwater rescue capsule. This unique structure enables an injured diver to be brought directly to the water's surface from any depth, avoiding the slow ascent ordinarily required for decompression. On the surface the diver can be decompressed while simultaneously receiving medical treatment.

Normal ascent requires accurate decompression schedules. To avoid tedious and time-consuming computation, Seireg's design class invented and built a diver's life support system, which not only signals when the diver should surface, but computes the proper decompression schedule. This package unit can be strapped to the diver. A similar device developed by Seireg's class is a miniature decompression calculator that the diver can strap to his arm or waist.

To make these and other devices more appropriate to the diver's needs, it is well to know the physical and psychological stresses encountered by humans under water. Physicians Edward Lanphier and William Reddan and chemical engineer Edwin Lightfoot, all at the University of Wisconsin-Madison, built a special underwater exercise machine which measures how the heart and lungs respond to underwater exertion.

One of the greatest limitations on the diver is, of course, the recurrent need to replenish his air supply. Ali Seireg and Edwin Lightfoot hope to eliminate this dependence on tanks and surface air supplies by developing an artificial gill. They find certain types of gill systems more practical than others, and are now testing in the laboratory certain gill systems which use a special liquid with a high affinity for oxygen. Although designs for removing oxygen from water exist in principle, this would be the first system to make air available to divers under the pressures found at ordinary diving depths. [R/NA-1]

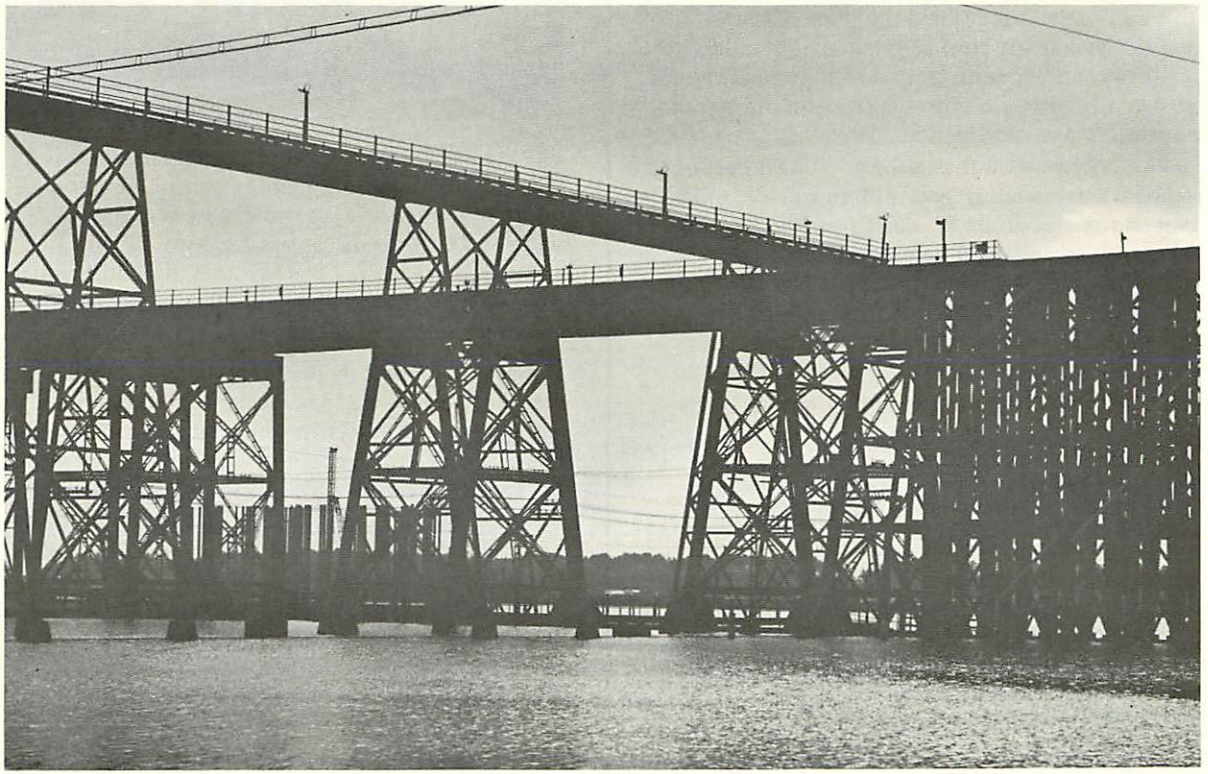
UNDERWATER CONSTRUCTION

In another area of study, Wisconsin Sea Grant scientists are trying to increase the reliability of materials used in submerged structures. Engineer Y. A. Chang, University of Wisconsin-Milwaukee, suspects that increasing concentrations of organic wastes in Milwaukee and other harbors may be accelerating the corrosion of pilings, thereby shortening their effective life. In the laboratory he has tested the corrosion properties of two types of steel commonly used in construction. He found that the most severe corrosion in these laboratory experiments occurred just *below* the mud line, while in field experiments it occurred just *above* the mud line.

Chang is now investigating reasons for this difference, in the belief that better understanding of the corrosion process will be applicable to a wide varity of underwater steel structures. [R/NA-2]

Submerged steel must not only resist corrosion, it must be structurally sound. In this regard, underwater welding can be critical, since underwater welds tend to be brittle and therefore weaker than those made on dry land. Carl Loper, University of Wisconsin-Madison engineer, has made a detailed laboratory analysis of the wet weld process to learn how to prevent this loss of strength. He has confirmed his suspicion that weld defects are caused by the entrapment of hydrogen from the surrounding water in the weld metal. [R/OE-3]

The ore docks in Superior, Wisconsin.



COASTAL PROCESSES AND ENGINEERING

The inland seas are characterized by many of the same natural processes and environmental challenges as are found in the oceans. These include erosion and ice damage, as well as the subtle but critical flow of pollutants through harbors into nearshore waters.

Perhaps the most visibly distressing event along any coastline—ocean or Great Lakes—is erosion. Last year, Wisconsin landowners suffered $15 million in property damage due to shoreline erosion along Lakes Michigan and Superior. Too often this erosion has proved to be either physically impossible or economically unfeasible to control.

Civil and environmental engineer Tuncer Edil, University of Wisconsin-Madison, has been analyzing the causes and dynamics of erosion. He hopes to learn how to predict whether a given section of shoreline is likely to erode, thereby making possible better planning of coastal development. For this purpose he has studied the slope of bluffs and the geology of bluff soils along both Lakes Michigan and Superior. With certain types of bluffs, he can now estimate both the rate and the amount of erosion over short periods. [R/SP-2]

Not only water but also the grinding power of ice in Great Lakes harbors and inshore waters can inflict damage on property. Each year hundreds of thousands of dollars of damage is done to docks, piers and other shoreline structures. Over the past two years, University of Wisconsin-Extension engineer Allen Wortley has organized three technical institutes where engineers and marina designers and operators can come together to discuss ice and marina problems.

Drawing from these technical meetings and from independent research in the Bayfield and Madeline Island area of Lake Superior, Wortley has written an ice engineering guide, useful in the design and construction of small craft harbors. Techniques discussed for preventing ice damage included the use of various ice-proof structures as well as bubbler systems to prevent ice formation around submerged structures. [R/NA-5]

Large, commercial-industrial ports such as Milwaukee and Duluth-Superior can absorb ice damage.

But the harbor waters of these ports face increasing difficulty in absorbing the stealthy, year-round influx of pollutants. Just how these pollutants travel through harbor waters and into the lake is a matter of increasing concern to harbor authorities, pollution control officials and others seeking to discover the fate of these water contaminants.

Because present methods for making measurements of harbor-open lake water exchange are tedious and costly, civil and environmental engineer Theodore Green and electrical engineer James Beyer are working at the University of Wisconsin-Madison to develop a system capable of providing continuous, easily analyzed information about water flows between harbors and nearshore areas.

So far they have designed a computer model of a system which relies on electromagnetic forces to detect the movements of different water layers. In a field test of these electromagnetic techniques, the engineers distributed electrodes across the bottom of a small river. By measuring conductivity and the electric fields produced by magnetic field and water flow, they were able to derive data on water velocities at different levels of the water column. With this data Green and Beyer believe that they can estimate where and how fast the currents may be carrying off certain pollutants—depending on whether the pollutants are floating at the surface, near the bottom or at some level in between. Instrumentation to take these measurements is being refined and may eventually be installed in Milwaukee and other Great Lakes ports. [R/OE-4]

Taken together, the projects within the Ocean Engineering Subprogram deal with some of man's strongest, most direct impacts on the Great Lakes. The research responds to the needs of underwater divers, the deterioration of man-made structures in the water and the aggravated effects of ice and erosion. And as further development is accommodated in the Great Lakes coastal region, this and related engineering research will find broader and increasingly critical applications.

ADVISORY SERVICES, COMMUNICATIONS, & EDUCATION

The boundaries of the University are the boundaries of the State.

—Charles Van Hise, President
University of Wisconsin, 1903-1918

The conviction that a state university has the responsibility to serve all the people who support it was originally expressed by one of the University of Wisconsin's early leaders and remains as a continuing philosophy of many university programs. In the Wisconsin Sea Grant College Program, Advisory Services, Communications and Education epitomize this philosophy. Through public meetings and conferences, publications, radio programs and films, courses, lectures and personal contacts, Sea Grant personnel are bridging the gap between university research and the public.

ADVISORY SERVICES

The Sea Grant Advisory Services Program is the link between those who study marine and Great Lakes resources and the resource users, be they from industry, government or the general public. The program operates in two ways—through the operation of specialists in particular areas like fisheries, aquaculture, water quality and recreation; and more recently through Sea Grant representatives located in coastal areas of the state.

Of all activities of the Sea Grant Program, none has generated quite the interest as perch aquaculture, or fish farming. Over 2,000 people have requested information about fish farming and many have personally visited the aquaculture demonstration facil-

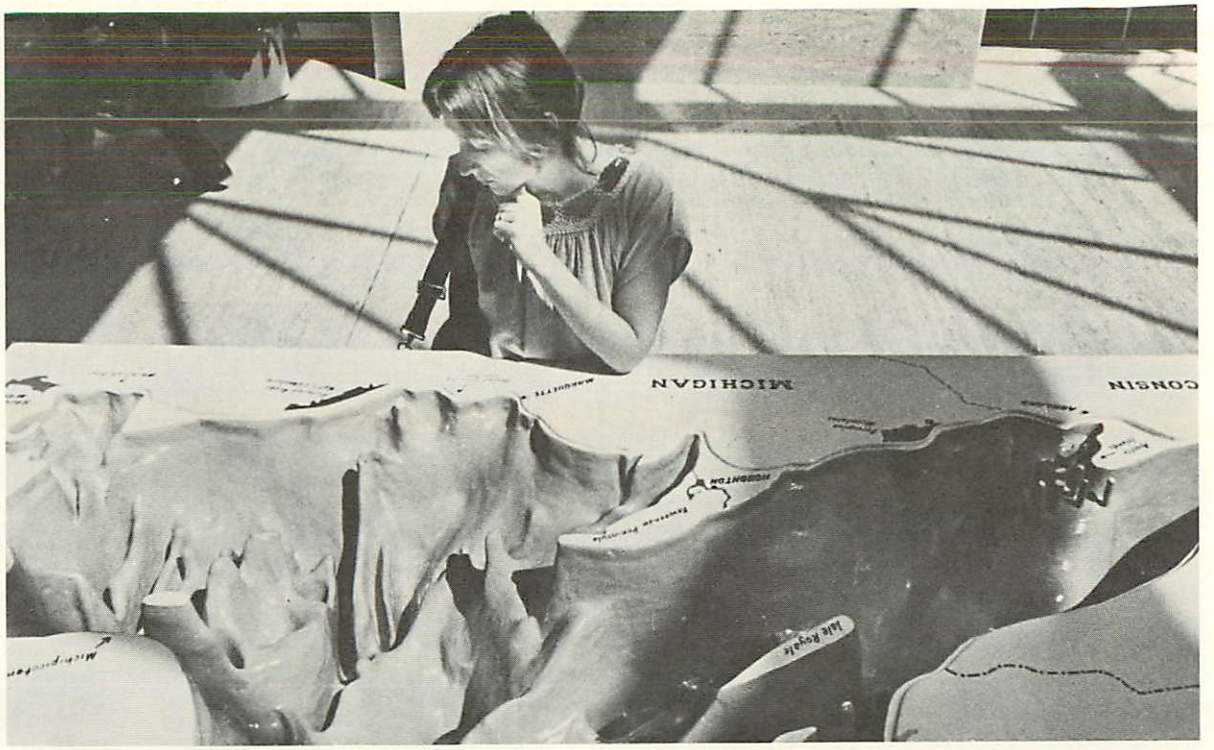
ity. Because of this interest, a full-time aquaculture specialist was recently added to the program through University of Wisconsin-Extension. Several entrepreneurs are already relying on his information and advice in starting their own perch farms.

The idea of using suckers and alewives for human food has not captured the public's imagination in quite the same way as aquaculture, but several Wisconsin industries have expressed interest in the idea. One Wisconsin company would like to process these underutilized Great Lakes fish for human consumption using methods devised by University of Wisconsin-Madison food scientist David Stuiber.

Stuiber, Sea Grant's Advisory Services fishery specialist, advised fish processors on how to upgrade their plant operations by improving their waste disposal practices and worked closely with the state's commercial fishing community. He also served on a Wisconsin Department of Agriculture committee to review sanitary regulations relating to the fish processing industry. [AS/A-8] Another specialist who worked on some of these problems was Jack Quigley, an engineer with University of Wisconsin-Extension. Quigley concentrated on water treatment problems related to the perch aquaculture studies. [AS/A-7]

A second major area of Sea Grant activity over the past several years has been shoreline processes and erosion. Advisory Service Director Gregory Hedden notes that erosion has cost Wisconsin shoreline property owners millions of dollars in recent years. Hedden is now preparing two informational booklets for the public—one describing the causes of lake level fluctuations and another outlining ways in which property owners can best combat shoreline erosion. [AS/A-13]

Most Great Lakes communities can physically cope with erosion. But economic survival may be problematic, depending to a large degree on recreation and tourism. John Powers, business and recreational specialist at the University of Wisconsin-Green Bay, has compiled information on recreation in the coastal regions of Lake Michigan and Green Bay. This information is designed to help property owners and coastal communities plan wisely for the development of marine recreation facilities. [AS/A-12]



In the fall of 1976, the Advisory Services division added a new dimension to its activities by establishing Sea Grant field representatives in the state's coastal areas. These people are working with local communities, small businesses, industry and education groups and the general public, providing them with information and assistance on Great Lakes-related problems. In providing these services, the specialists draw upon the talents and resources of the entire university. University of Wisconsin Sea Grant offices are now located in Sturgeon Bay, Washburn and Milwaukee. [AS/A-14]

COMMUNICATIONS

With more than 600 miles of Great Lakes coastline, many coastal residents in Wisconsin know the Great Lakes at close hand. However, general public awareness of the lakes is lacking. Over the past two years, the Sea Grant Communications Office has tried to heighten public knowledge and understanding of Lakes Michigan and Superior in the belief that this will lead to better appreciation and wiser use of their resources.

Over 50 new publications dealing with the Great Lakes have been produced and distributed, including reprints, technical reports, public information booklets and two 300-page books. Fifty-one thousand publications were distributed in 1976 alone. Some of the more popular publications included "The ABCs of PCBs," a pamphlet answering basic questions about a critical water pollution problem; "Fish of Lake Superior," a guide with drawings and descriptions of the fish; and "The Coasts of Wisconsin," the story of the people, resources and current problems of Wisconsin's Great Lakes coastal areas.

During the summer of 1976 members of the communications staff designed and built an exhibit, dealing with the Great Lakes and Sea Grant research, which was displayed for a week in the shopping mall of a downtown Milwaukee bank building. High-

lighting the exhibit was an aquarium with important Great Lakes fish and an eight-foot long scale model of Lake Superior showing its depths and contours. Many other groups have since requested the exhibit and parts of it have been displayed throughout the state.

A documentary film, "The Last Fishermen," was produced in 1974. The film depicts the culture and problems of the rapidly disappearing Great Lakes commercial fisherman. The film, booked through its first year by schools and community groups has been aired on nine television stations and placed in the Central Education Network Regional Library. Portions of it were also used on the NBC "Today" show in their bicentennial salute to Wisconsin.

With the University of Wisconsin-Madison Institute for Environmental Studies, the Sea Grant Program has sponsored Earthwatch, a daily, two-minute environmental radio program. The program received an award in 1975 from the U. S. Environmental Protection Agency. With a network of 110 stations in Wisconsin and neighboring states, Earthwatch now has an estimated listening audience of several million people per month. Programs deal with all sorts of environmental issues—from pollution of the oceans to growing plants in the desert. Of the 260 programs produced during 1976, 121 concerned the Great Lakes and other water resources.

Earthwatch/Wisconsin, a weekly newspaper column inspired by the success of the radio program, now appears in over 50 Wisconsin newspapers. The articles pertain to state environmental issues and research. [AS/A-3]

EDUCATION

Education—that broad panoply of academic courses and lectures, field trips and books—plays an integral part in the Sea Grant Program. Over the past two years University of Wisconsin Sea Grant research has directly supported over 300 graduate and undergraduate students. During the ten years the program has been at Wisconsin, Sea Grant-supported students have received over 36 Ph.D. and 60 Master's Degrees. Many more have benefited from an educational standpoint by participating in Sea Grant projects and courses.

In one course, SCUBA diving specialist David Engeseth has trained students and marine scientists to carry out their own underwater research more safely and efficiently. Over the years, these popular classes in SCUBA diving at the University of Wisconsin-Madison accommodated about 300 fledgling divers. [E/E-9]

On the Milwaukee campus, geographer Harold Mayer taught a course in maritime transportation to acquaint students with the economic importance, as well as the problems, of Great Lakes ports such as Milwaukee's. [E/E-11]

Through another special course—Problems in Oceanography—Sea Grant has given students an opportunity to actually experience being at sea. The class was conducted by a faculty team from University of Wisconsin-Madison's Institute for Environmental Studies, Marine Studies Center and the Limnology Laboratory. An annual highlight is a week of field work at Sapelo Island, a remote barrier island off the Georgia coast. Far from experiencing a vacation, the students worked hard in pursuit of marine research projects and interpretation of their data. This intensive experience was especially important to Wisconsin oceanography students, who otherwise would have little or no contact with saltwater environments. [E/E-8]

The Wisconsin Sea Grant Program has also sponsored several lecture series dealing with Great Lakes topics and broadcast over the Education Television Network. This network links all Wisconsin counties. A network outlet exists at each University of Wisconsin campus or county office. [E/E-1]

The program has also supported adult education courses dealing with Wisconsin's Great Lakes. Lynn Entine of the University of Wisconsin-Extension has worked with groups throughout the state to promote courses in sport fishing, beach ecology, water quality and natural history. Enrollment for these courses during 1976-77 numbered over 150.

Another way to enhance public concern for the Great Lakes is to convey some sense of their history and cultural importance. Certainly the Great Lakes played an early role in the settlement and growth of Wisconsin. For this reason, a portable exhibit of photographs depicting Wisconsin's Great Lakes heritage has been assembled for display at schools, fairs and other public places. So far it has been displayed at several locations in Milwaukee and Madison, as well as in Superior and Door County. [E/E-12] In addition, University of Wisconsin-Extension historians Margaret Bogue and Virginia Palmer are developing a guide to historic sites along the Lake Superior coast. [E/E-13]

Another kind of guidebook, but one which should prove equally popular, is a definitive guide to the state's fish being prepared by University of Wisconsin-Stevens Point biologist George Becker. This comprehensive, illustrated text should be invaluable to geologists, sport and commercial fishermen and the interested public. [E/E-5]

The usefulness of this guidebook-to-be, along with the many other materials and services provided by communications, advisory services and education efforts, is demonstrated by the many letters we receive from the public. A few excerpts go a long way in showing the meaningful exchange of information between the Wisconsin Sea Grant Program and the people it serves:

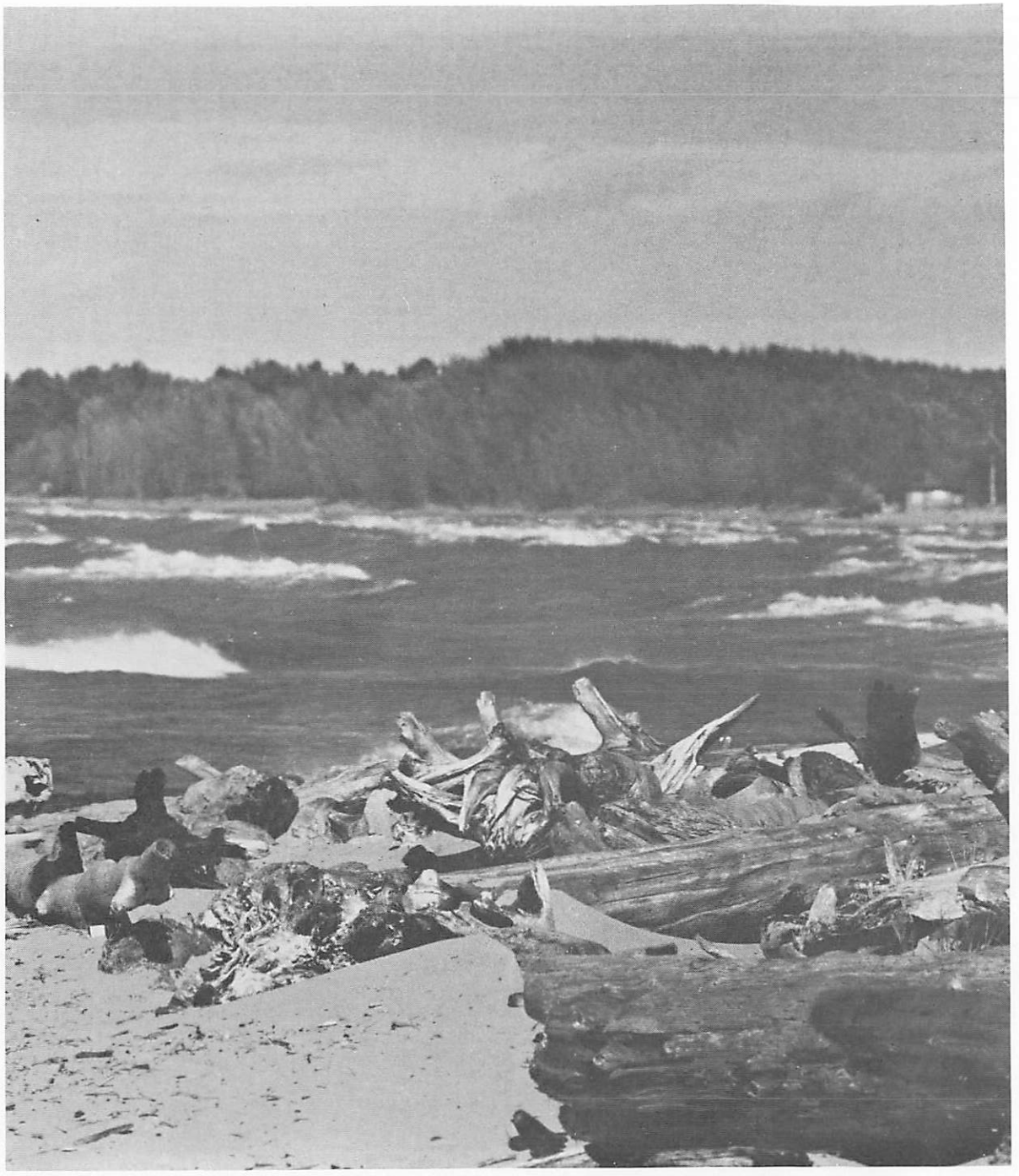
. . .from a regional planning commission
We would much appreciate receiving your information on shoreline erosion in the Great Lakes. We are in the process of developing guidelines for the use of local governmental units in regulating certain kinds of critical areas including shorelines and steep bluffs.

. . .from a potential fish farmer
I have asked the Department of Natural Resources about the feasibility of raising fish commercially. They suggested I write for your publication, "Fundamentals of Fish Farming." Any other information on the subject would be appreciated, also.

. . .from an Earthwatch/Radio listener
As announced on the program heard at 9:00 p.m. on the radio, please send me an "energy game." It appears to be a good way of helping to reach the goal of reducing energy consumption. I try never to miss the program—an excellent means of communication.

. . .from a fishermen's association director
Your books and films are of real help in establishing an awareness of the benefits of a well-managed and maintained Great Lakes System. . . Enclosed is a sample Class Agenda (incorporating your materials) for a ten-week class on Great Lakes fishing.

. . .and from a young reader
I like the articles in the newspaper that you have been writing. I like to go up north and see the beauty of the Great Lakes. To see the ships go by and the waves come up to the shore. I never would have known about them if I didn't read the paper. Please send me more information.



1974-76

PUBLICATIONS

PUBLIC INFORMATION

The Coasts of Wisconsin. James Napoli. WIS-SG-75-122.

Annual Report: 1972-74. U. W. Sea Grant College Program. WIS-SG-75-123.

Fish of Lake Superior. Warren Downs. WIS-SG-75-124.

ABCs of PCBs. Linda Weimer, Warren Downs, Cathy Manson, Peyton Smith. WIS-SG-76-126.

ADVISORY REPORTS

The Household Energy Game. T. W. Smith, J. Jenkins. WIS-SG-74-409.

Sources of Water Quality, Lake Level, Ice, Water Temperature and Meteorological Data for the St. Lawrence Great Lakes. A. M. Beeton, J. Strand. WIS-SG-75-410.

Wisconsin's Lake Michigan Charter Fishing Industry. R. B. Ditton, W. A. Strang. WIS-SG-75-411.

A Summary of Land and Water Use Trends and Related Research Needs in the Green Bay Region. G. Bertrand, J. Lang, J. Ross. WIS-SG-74-412.

Aquaculture: Raising Perch for the Midwest Market: Proceedings of a Conference. WIS-SG-75-413. ($1.50)

Artificial Imprinting of Salmon and Trout in Lake Michigan. A. T. Scholz, R. M. Horrall, J. C. Cooper, A. D. Hasler, D. M. Madison, R. Poff, R. Daly. WIS-SG-75-414.

Shoreline Erosion and Landslides in the Great Lakes. Tuncer B. Edil, Luis E. Vallejo. WIS-SG-76-415.

REPRINTS

Wastewater Treatment in Fish Processing. D. A. Stuiber, J. T. Quigley. WIS-SG-74-345.

Residual Effects of Short-Term, Low-Level Exposure of Nonhuman Primates to Polychlorinated Biphenyls. J. R. Allen, L. A. Carstens, D. A. Barsotti. WIS-SG-75-355.

Role of the Nucleus in Formation of Ferromanganese Nodules: Processing Guidelines for the Marine Miner. C. L. Morgan, J. R. Moore. WIS-SG-75-356.

Underwater Copper Exploration in Lake Superior II: Specific Targets Charted in 1974. R. P. Meyer, J. R. Moore, E. L. Nebrija. WIS-SG-75-357.

Comparison of Thermal Scanning and In Situ Techniques for Monitoring Thermal Discharges. Gary J. Marmer, John V. Tokar and Robert P. Madding. WIS-SG-76-358.

Electrical Prospecting for Copper Veins in Shallow Water. Edgardo L. Nebrija, Charles T. Young, Robert P. Meyer, J. Robert Moore. WIS-SG-76-359.

Sediment Dispersal Patterns as Clues to Placer-Like Platinum Accumulation in and Near Chagvan Bay, Alaska. Robert M. Owen and J. Robert Moore. WIS-SG-76-360.

How the Salmon Comes Home. Arthur D. Hasler. WIS-SG-76-361.

Scanning Thermal Plumes. F. L. Scarpace, R. P. Madding, T. Green III. WIS-SG-76-362.

Microbial Metabolism of Polychlorinated Biphenyls. Studies of the Relative Degradability of Polychlorinated Biphenyl Components by *Alkaligenes sp.* Kensuke Furukawa and Fumio Matsumura. WIS-SG-76-363.

Imprinting to Chemical Cues: The Basis for Home Stream Selection in Salmon. Allan T. Scholz, Ross M. Horrall, Jon C. Cooper, Arthur D. Hasler. WIS-SG-76-364.

Reproductive Dysfunction in Rhesus Monkeys Exposed to Low Levels of Polychlorinated Biphenyls (Aroclor 1248). D. A. Barsotti, R. J. Marlar and J. R. Allen. WIS-SG-76-365.

Effects of Temperature and Light on Growth of Yellow Perch and Walleye Using Formulated Feed. H. T. Huh, H. E. Calbert, and D. A. Stuiber. WIS-SG-76-366.

Acoustic Estimates of Fish Density and Scattering Function. Miles L. Peterson, Clarence S. Clay and Stephen B. Brandt. WIS-SG-76-367.

Automatic Orientation Control Device for Underwater Divers. A. Baz and A. Seireg. WIS-SG-76-368.

Electrical Prospecting Methods Applied to Shallow-Water Mineral Exploration. Edgardo L. Nebrija, Charles T. Young, Robert P. Meyer and J. Robert Moore. WIS-SG-76-369.

TECHNICAL REPORTS

Analysis of the Lake Michigan Basin Phosphorus Removal Policy in Wisconsin. D. A. Braasch, E. F. Joeres. WIS-SG-75-224.

The Role of Technical Information in Decisions on Nuclear Power Plants. M. Beane, J. Ross. WIS-SG-75-225.

Gulls and Terns as Indicators of Man's Impact Upon Lake Superior. James T. Harris, Sumner W. Matteson. WIS-SG-75-227.

A Computer Analysis of the Water Quality in the Lower Fox River and Lower Green Bay, Wisconsin. Robert W. Lanz. WIS-SG-75-228.

The Green Bay Watershed: Past/Present/Future. Gerard Bertrand, Jean Lang, John Ross. WIS-SG-76-229. ($3.00)

The Great Lakes Transportation System. Eric Schenker, Harold M. Mayer, Harry C. Brockel. WIS-SG-76-230. ($3.50)

The Settlement of International Environmental Disputes. Richard B. Bilder. WIS-SG-76-231.

PROJECT LIST • 1974-1977

Project, Project Code/Principal Investigator, Affiliation	Project Status: New (N), Continuing (C), Completed (X)		
● LIVING RESOURCES	74-75	75-76	76-77
Fish Population Estimation in Lake Michigan Using Sonar, R/FA-1. John J. Magnuson, UWMSN	N	C	C
Application of Fish Growth Model, R/FA-2. James F. Kitchell, UWMSN	N	C	C
Energy Requirements and Growth of Three Species of Lake Michigan Fishes: Alewife, Smelt and Bloater, R/BR-7. Carroll R. Norden, UWMKE.	C	C	X
An Investigation of the Deep-Living Phytoplankton of Lake Michigan, R/WQ-3. Arthur S. Brooks, UWMKE	C	C	C
Population Dynamics and Production of *Pontoporeia affinis* in Lake Michigan, R/LR-1. Arthur S. Brooks, UWMKE (formerly Alfred M. Beeton, UWMKE).		N	X
The Ecology of *Mysis relicta* (Loven) in Lake Michigan with Emphasis on Population Dynamics and Abundance, R/LR-2. Arthur S. Brooks, UWMKE (formerly Alfred M. Beeton, UWMKE).		N	X
Application of Odor Imprinting to Salmon Management in the Great Lakes, R/BR-6. Arthur D. Hasler. UWMSN	C	C	X
Factors Influencing the Success or Failure of Natural Reproduction in Populations of Lake Trout and Whitefish from Lakes Michigan and Superior, R/FA-5. Ross M. Horrall, UWMSN	N	X	
Some Environmental Requirements of Juvenile Whitefish of Northern Lake Michigan, R/FA-4. Alfred M. Beeton, UWMKE	N	C	X
Vital Statistics and Population Structure of the Wisconsin Whitefish Fishery of Lake Michigan, R/LR-3. Henry E. Booke, UWSTP.		N	X
Wisconsin's Great Lakes Commercial Fisheries: Current Economic Issues, R/LR-4. Richard C. Bishop. UWMSN.		N	C
Economic Analysis of Lake Michigan Sports Fisheries, R/FA-3. Douglas Booth, UWMKE.	N	X	
Quality Improvement of Food Products from Underutilized Fish Species, R/BR-11. David A. Stuiber, Robert Lindsay, UWMSN.	C	C	X
Dynamics of Sucker Populations of Green Bay and Adjacent Waters of Lake Michigan, R/LR-5. John J. Magnuson, Ross M. Horrall, UWMSN.		N	C
Helminth Parasites of Lake Michigan Fishes, R/LR-6. Omar Amin, UWPKS.			N

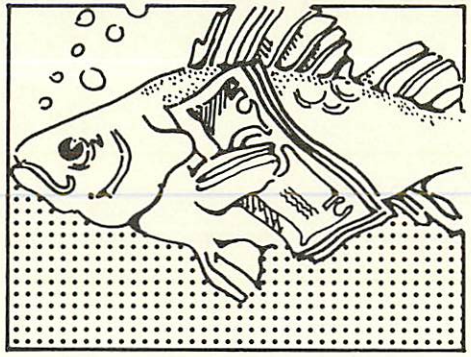
● POLICY STUDIES	74-75	75-76	76-77
Designing Institutions for International Oceanic Cooperation: The Cooperative Process, R/PS-1. Richard B. Bilder, UWMSN.	C	C	X
Phosphorus Removal in the Wisconsin Lake Michigan Watershed: Policy Implications, R/PS-8. Erhard F. Joeres, UWMSN.	C	X	
Water Management Institutions: Conceptual Problems and Practical Applications, R/PS-15. Daniel W. Bromley, UWMSN (formerly Melville McMillan, UWMSN).	N	X	
Identification, Evaluation and Utilization of Scenic, Cultural and Historic Resources in Coastal Communities, R/PS-9. William H. Tishler, UWMSN.	C	X	
Power Plant Siting and Energy Issues in the Great Lakes Coastal Zone, R/PS-3. John S. Steinhart, UWMSN.	N	X	
Alternate Transportation Planning Policies for the Apostle Islands National Lakeshore Region, R/PS-14. William Berg, UWMSN.	N	X	
Trans-Lake Michigan Transportation Services, R/PS-16. Harold M. Mayer, UWMKE.		N	X
An Investigation of a Cadastre (Land Interest Information System) for the Coastal Zone, R/PS-18. James L. Clapp, UWMSN.		N	C
Institutional Design for Resource Management in Wisconsin's Coastal Zone, R/PS-19. Daniel W. Bromley, UWMSN.			N
Labor Organizations and the Great Lakes-St. Lawrence Seaway System, R/PS-20. Eric Schenker, UWMKE.			N
● SHORELINE PROPERTY AND RESOURCES			
Remote Sensing in the Coastal Zone of Lake Michigan, R/EP-1. Theodore Green III, UWMSN.	C	X	
Shoreline Erosion in Lake Michigan—Rock Island to the Wisconsin-Illinois State Line, R/SP-1. John M. Pezzetta, UWGB.	N	X	
Computerized Shoreline Mapping from Aerial Photography, R/SP-3. Paul R. Wolf, UWMSN.	N	X	
Shore Ice and Erosion, R/SP-4. Theodore Green III, J. Robert Moore, UWMSN.	N	X	
Species Composition, Abundance and Stability of the Coastal Zone Plant Communities along Western Lake Michigan, R/SP-6. Peter J. Salamun, UWMKE.		N	X

PROJECT LIST-CONTINUED

● MICROCONTAMINANTS AND WATER QUALITY	74-75	75-76	76-77
Trace Metal Transport and Distribution in the River Mouth and Associated Nearshore Lake Michigan Areas for the Milwaukee and Fox Rivers, R/MW-1. David E. Armstrong, UWMSN.	N	X	
Identification, Distribution and Transport of Halogenated Organic Microcontaminants in Southern Lake Michigan, R/MW-2. David E. Armstrong, UWMSN.	N	C	X
Air Pollution Inputs of Organic and Inorganic Substances to Lake Michigan Water, R/MW-6. Anders W. Andren, UWMSN.		N	C
Surface Microlayer-Microcontaminant Interactions in Lake Michigan, R/BR-4. David E. Armstrong, UWMSN.	C	X	
Accumulation, Transport and Fate of Persistent Pesticides in Lake Michigan Food Chains, R/MW-3. Fumio Matsumura, G. Mallory Boush, UWMSN.	N	C	X
The Effects of PCBs and Other Chlorinated Hydrocarbons on the Early Development of Great Lakes Fishes, R/MW-5. Robert H. Broyles, UWMKE.		N	X
Elimination and Metabolism of PCBs by Lake Michigan Salmonids, R/BR-8. John J. Lech, Medical College of Wisconsin, Milwaukee.	C	X	
Biotransformation and Disposition of Great Lakes Microcontaminants in Salmonids, R/BR-5. John J. Lech, Medical College of Wisconsin, Milwaukee.	C	C	C
Responses of Primates to Polychlorinated Biphenyls, R/BR-9. James R. Allen, UWMSN.	C	C	C
Dioxin Involvement in Chemical Toxicity of Pulp and Paper Mill Bleachery Effluent, R/MW-7. John H. Harkin. UWMSN		N	C
Response of Primates to 2,3,7,8-Tetrachlorodibenzo-*p*-Dioxin, R/MW-8. James R. Allen, UWMSN.		N	C
Effect of Polychlorinated Biphenyls on Reproduction in Lake Michigan Salmonids, R/MW-9. Richard Peterson, UWMSN.			N
Petroleum in the Great Lakes Environment, R/MW-10. John S. Steinhart, UWMSN.			N
Evaluation of Processes Controlling the Trace Metal Status of Southern Lake Michigan, R/MW-11. David E. Armstrong, UWMSN.			N

● AQUACULTURE AQUACULTURE	74-75	75-76	76-77
Raising Yellow Perch and Walleye Pike for Human Food Use, R/BR-12. Harold E. Calbert, UWMSN.	C	C	C
Monitoring and Treating Wastewater from Food Fish Production, R/AQ-3. John T. Quigley, UWEXT.	C	C	C
Propagation of Perch and Walleye Pike Throughout the Year, R/AQ-2. W. B. Quay, UWMSN.	N	C	C
Economic Analysis of Income and Market Potential of Aquaculture Systems for Cold Water Fish, R/AQ-1. Richard H. Vilstrup, UWMSN.	N	C	X
● GEO-ENVIRONMENTAL AND MINERAL RESOURCES			
Marine Noble Metals Exploration, R/GM-7. J. Robert Moore, UWMSN.		N	X
Marine Lode Minerals Exploration, R/GM-8. J. Robert Moore, UWMSN.		N	X
Metal Extraction from Manganese Nodules, R/GM-9. Thomas W. Chapman, UWMSN.		N	C
Western Lake Michigan Sand and Gravel Assessment, R/GM-10. Robert P. Meyer, UWMSN.		N	C
Potential for New Minerals Resources, U. S. Trust Territory, R/GM-11. J. Robert Moore, UWMSN.			N
● OCEAN ENGINEERING			
Assistive Devices for Scuba Divers, R/NA-1. Ali Seireg, UWMSN.	C	C	C
Assistive Devices for Scuba Divers—Artificial Gill Systems, R/OE-1. Ali Seireg, UWMSN.	C	C	C
Assistive Devices for Scuba Divers—Physiological Evaluation for Diving Equipment, R/OE-2. Ali Seireg, UWMSN.	C	C	C
Corrosion of Metals in Marine Structures, R/NA-2. Y. Austin Chang, UWMKE.	C	C	C
The Underwater Welding of Steel, R/OE-3. Carl Loper, UWMSN.	C	C	X
Marina-Lake Ice, R/NA-5. C. Allen Wortley, UWEXT.	C	C	X
Mechanics of Coastal Slumps in the Great Lakes, R/SP-2. Tuncer B. Edil, UWMSN.	N	C	X
Electromagnetic Measurements of Harbor Flushing, R/OE-4. Theodore Green III, UWMSN.		N	C

ADVISORY SERVICES	74-75	75-76	76-77
Advisory Services Director's Office, AS/A-1. Gregory D. Hedden, UWEXT.	C	C	C
Sea Grant Communications, AS/A-2. Linda Weimer, Sea Grant Office.	C	C	C
Earthwatch Public Service Radio Program, AS/A-3. Linda Weimer, Sea Grant Office.	C	C	C
ERTS Data File, AS/A-4. Linda Weimer, Sea Grant Office.	C	X	
Water Quality, AS/A-7. John Quigley, UWEXT.	C	C	C
Food Science and Fish Program, AS/A-8. David Stuiber, UWMSN.	C	C	C
Recreation Development—Lake Michigan and Green Bay, AS/A-12. John E. Powers, UWGB.	N	X	
Shore Erosion, AS/A-13. Gregory D. Hedden, UWEXT.	C	X	
Sea Grant Advisory Services Field Agents and Activities, AS/A-14. Gene Woock, UWEXT.			N
EDUCATION EDUCATION			
Special Education Programs, E/E-1. Sea Grant Advisory Council.	C	C	C
Problems in Oceanography, E/E-8. James F. Kitchell, UWMSN.	C	C	X
Basic Scuba Instruction, E/E-9. David Engeseth, UWMSN.	N	X	
Maritime Transportation, E/E-11. Harold Mayer, UWMKE.		N	X
Marine Communications Training Program, E/E-3. Linda Weimer, Sea Grant Office.	C	C	X
Photo Exhibit of Wisconsin's Great Lakes Heritage, E/E-12. John Ross, UWMSN.		N	X
Bicentennial Guide to the Historic Sites and Museums of the Great Lakes, E/E-13. Margaret Bogue, UWEXT.		N	X
Great Lakes Continuing Education, E/E-14. Lynn Entine, UWEXT.		N	C
Book on the Fishes of Wisconsin, E/E-5. George C. Becker, UWSTP.			N



PROGRAM BUDGET

University of Wisconsin Sea Grant College Program

	1974-75		1975-76		1976-77	
	NOAA	UW	NOAA	UW	NOAA	UW
LIVING RESOURCES	83,026	79,185	151,043	144,089	125,828	107,461
AQUACULTURE	51,471	13,493	49,343	22,294	77,083	51,403
MICROCONTAMINANTS AND WATER QUALITY	132,769	61,173	137,725	64,650	149,909	94,501
POLICY STUDIES	122,623	102,199	109,636	72,828	75,588	49,889
SHORELINE PROPERTY AND RESOURCES	47,015	43,211	65,604	42,674		
PORTS AND COMMERCE	59,012	40,469				
GEO-ENVIRONMENTAL AND MINERAL RESOURCES	90,456	58,952	62,915	40,018	113,259	45,432
OCEAN ENGINEERING			118,696	69,134	94,130	81,117
ELECTRIC POWER	54,989	44,016				
NEW APPLICATIONS	82,362	72,407				
ADVISORY SERVICES	221,214	37,740	207,745	53,410	336,883	80,485
EDUCATION	30,443	61,079	49,732	49,939	43,154	33,023
ADMINISTRATION	149,620	62,076	172,561	40,964	209,166	131,689
TOTAL	1,125,000	675,000	1,125,000	600,000	1,225,000	675,000

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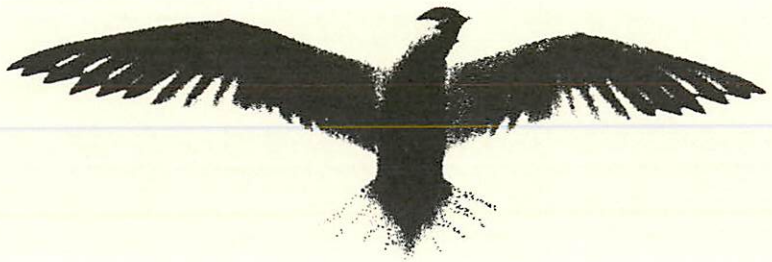

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