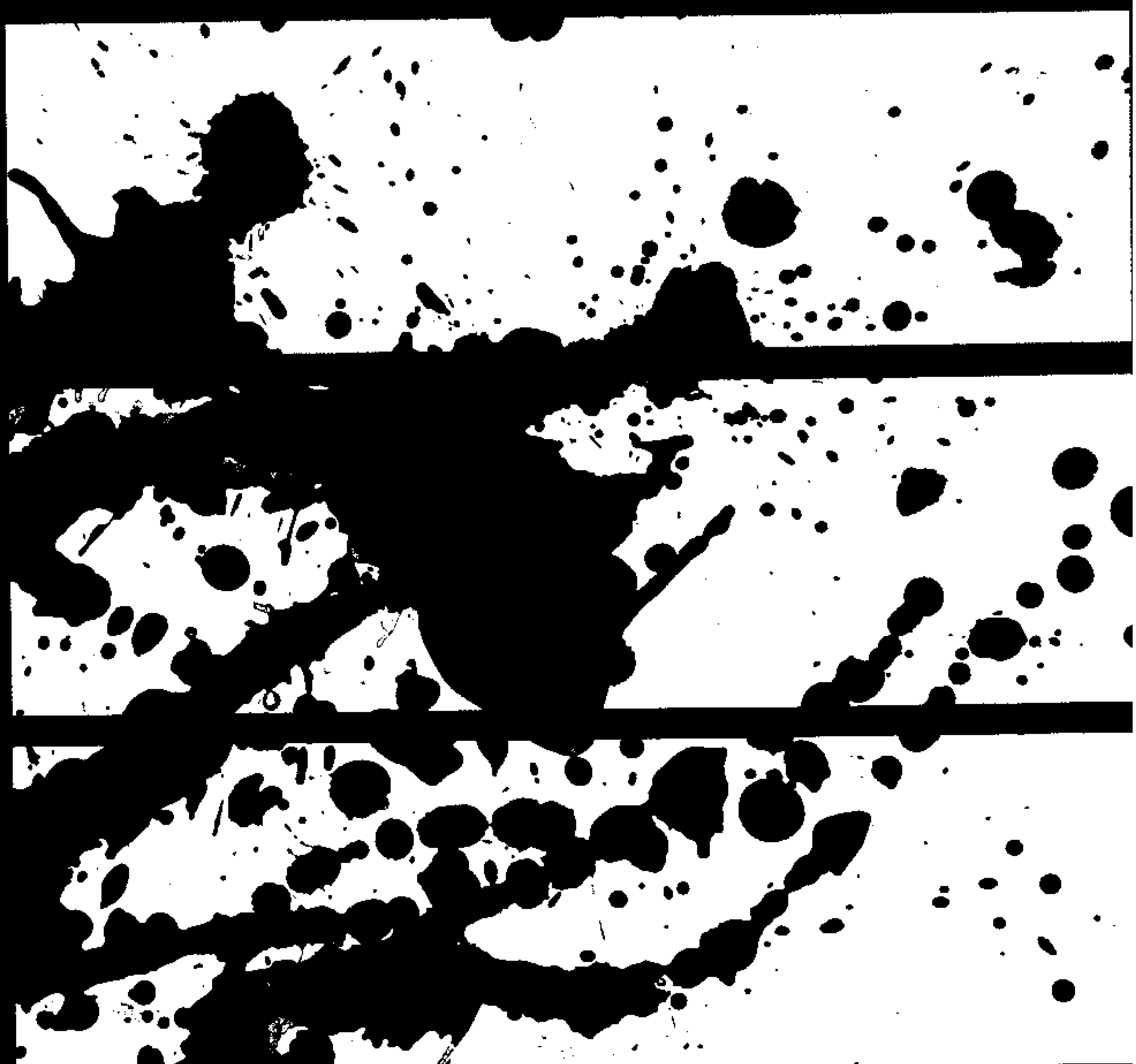
THE INVISIBLE MENACE

CONTAMINANTS IN THE GREAT LAKES



THE UNIVERSITY OF WISCONSIN SEA GRANT COLLEGE PROGRAM

THE INVISIBLE MENACE

■ CONTAMINANTS IN THE GREAT LAKES ■

A REPORT ON THE ACTIVITIES OF
THE UNIVERSITY OF WISCONSIN
SEA GRANT COLLEGE PROGRAM

■

WIS-SG-80-133; MARCH, 1980

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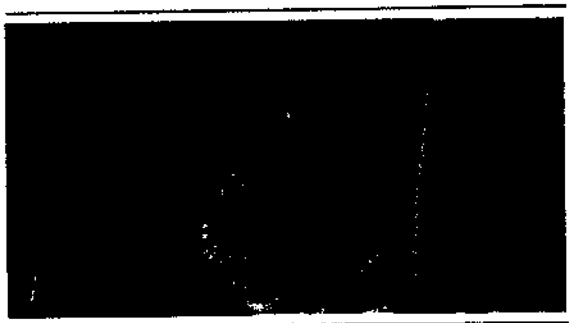
CONTENTS



TO THE READER:

The Laurentian Great Lakes form the nation's fourth sea coast, a chain of beautiful, enormous lakes linking the heartland of America with the Atlantic Ocean. In addition to recreation and transportation uses, these geological marvels could provide an everlasting supply of freshwater and food fish. Instead, the lakes' water, plants and animal life are being contaminated by a variety of man-made toxic substances. Ultimately, these substances pose a threat to the health and economic well-being of the region's people.

The primary mission of the University of Wisconsin Sea Grant College Program is to explore the potentials of and seek solutions to the problems of the Great Lakes and other marine resources. Because of the urgency and importance presently attached to the Great Lakes contaminants problem, this overview of Sea Grant achievements during the past three years gives special attention to our activities related to toxic substances. Sea Grant's many other programs and research projects – ranging from aquaculture and policy studies to diving physiology and ocean engineering – are profiled later in this report.

The goals and priorities of the Sea Grant mission shift and change to meet the needs of the time, but its three key functions remain the same: research, education and outreach. Only by tying together all three functions can real progress be made toward realizing the benefits and solving the problems of marine resources. The lakes' resources, if preserved and used wisely, will continue to benefit future generations of Americans and our Canadian neighbors.

Robert A. Ragotzkie

ROBERT A. RAGOTZKIE , DIRECTOR

THE INVISIBLE MENACE

On November 22, 1978, U.S. Secretary of State Cyrus Vance and Canadian Minister of External Affairs Don Jamieson lifted their glasses of champagne and toasted one of their most important joint possessions—the Great Lakes.

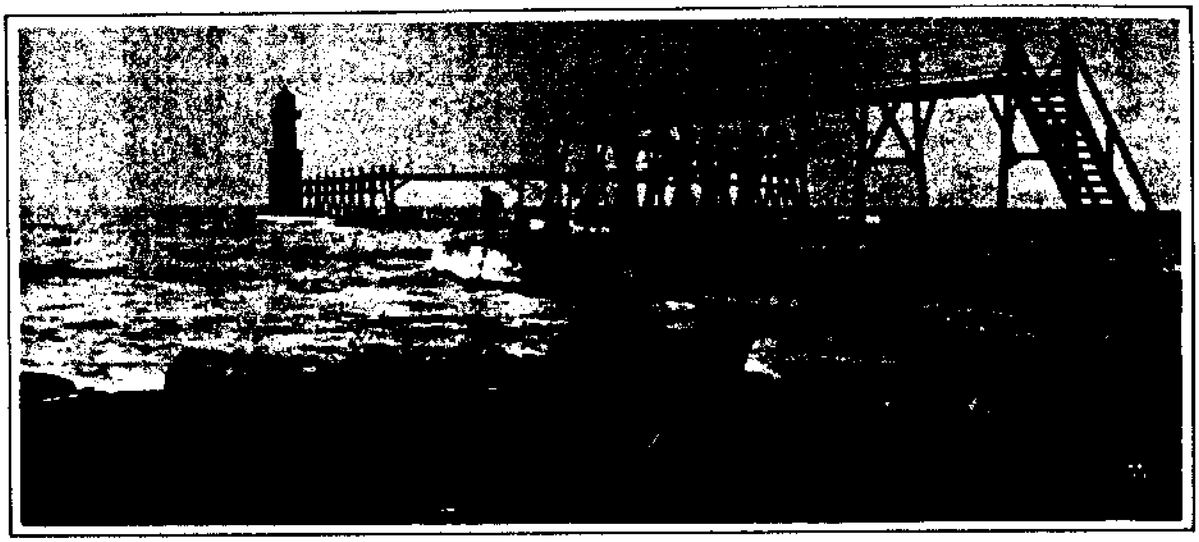
The occasion was the signing of a new international Great Lakes Water Quality Agreement in Ottawa, Canada. Containing 15 articles and 12 annexes, the new agreement updates, strengthens and builds upon the 1972 water quality agreement between the two countries. The intent of the agreement remains the same: to preserve and protect the largest reserve of freshwater on the face of the earth.

Over 40 million people—15 percent of the U.S. population and 25 percent of the Canadian population—live and work along the shores of the Great Lakes. They rely on the lakes for drinking water, recreation, fish, and water for industrial processes. All of these uses demand clean water.

The rapid development and settlement of the region in the earlier part of this century took its toll on water quality. By the 1960s, Lake Erie was being widely touted as the "dead" Great Lake, and algae blooms and fish kills were reported throughout the lower lakes.

Today, thanks to government action in both countries to control pollution and to the efforts of university and government scientists, the lakes' water quality is vastly improved. Fish are making a comeback in many areas, and beaches closed since the early 1940s are open to swimmers again.

Nonetheless, problems remain. A recent ruling by the U.S. Food and Drug Administration called attention to the seriousness of PCB pollution in the lakes. And the International Joint Commission, the body that oversees water quality control, has said that the control and monitoring of toxic substances is the most urgent problem facing the lakes.



Since the University of Wisconsin Sea Grant Program began in 1968, research aimed at solving Great Lakes water quality problems has been a high priority. So far, over 50 such projects have been supported.

In the late 1960s and early 70s, Wisconsin Sea Grant investigators focused on such questions as pesticide contamination of ducks in Lake Michigan, eutrophication in Green Bay and the effects on fish of chemicals used to control populations of the parasitic sea lamprey.

As the program has grown and knowledge of Great Lakes contaminants has become more sophisticated, the field of topics has expanded to include the sources, fates and effects of many problem chemicals in the lakes. These include organic compounds like PCBs and DDT; heavy metals like zinc, cadmium and arsenic; petroleum, and phosphorous. Scientists have studied, in particular, where these substances can be found, how they affect the aquatic environment and their public health implications.

In addition to this research, the University of Wisconsin Sea Grant Program has also supported economic and policy studies related to lake management and public service projects meant to enhance public understanding of Great Lakes water quality issues.

This report describes many of these Sea Grant activities over the past five years and puts them into the broad context of water quality problems related to the Great Lakes. It is meant only to be a glimpse of the program as it existed in 1979. This part of the Wisconsin Sea Grant College Program will continue to evolve and grow as long as water quality problems plague the people of the U.S. and Canada who live along the shores of the Great Lakes.

PCBs: A THREAT TO THE FISHERIES

Polychlorinated biphenyls. PCBs. Fifty years ago, they didn't exist. Today, they are found almost everywhere on earth, even in the most remote regions of the Arctic and Amazon.

These colorless, odorless chemicals are found in minute quantities in the environment and have become detectable only as a result of recent advances in analytical chemistry. And yet they have made newspaper headlines, inspired acts of Congress, worried the public, beleaguered the fishing industry and spawned a wide range of research projects.

Since PCBs were first manufactured in 1929, 1.4 billion pounds of these compounds have been produced. They had been used in many products because of their stability and low conductivity of electricity. For a time, they could be found in adhesives, plastics, paints, electrical components and carbonless carbon papers.

But research over the past 15 years has shown that these chemicals can be harmful to animals and humans if ingested in sufficient quantities.

When this information first came to light, the manufacture and use of PCBs were widely curtailed. Now they are used only in closed systems like electrical transformers or capacitors. And the U.S. government – in response to an act of Congress – is attempting to strictly control their disposal.

Nevertheless, almost half of the PCBs used in the past have ended up in our nation's dumping grounds – some 500 million pounds. As a result, PCBs are widespread in the environment.

In the Upper Midwest, the Great Lakes and the Mississippi River have borne the brunt of PCB pollution because most PCBs ultimately end up in aquatic systems. Once there, they sink to the bottom, where they lie in the sediments and are picked up by bottom-feeding organisms. These organisms are eaten by larger organisms and fish, which are, in turn, eaten by still larger fish. The PCBs become progressively more concentrated at each step up this food chain, and people are at the top of this chain.

Since PCBs were first recognized as a problem in the Great Lakes, scientists associated with the University of Wisconsin Sea Grant Program have been studying them.

The researchers are trying to answer the questions being asked by government agencies, lawmakers, fishermen and the public: Where are PCBs coming from? Where do they go? How do they affect fish? Can we get rid of them? What do they do to people who eat fish?

PCBs are still widely used in "closed" systems like these electrical transformers along a Door County road.

Sea Grant research in answer to that last question prompted the Federal Food and Drug Administration in June 1979 to take legal action to lower the amounts of PCBs permitted in fish sold for human consumption from five to two parts per million (ppm). This action has raised some new questions: How will the PCB ruling affect the Great Lakes sport and commercial fisheries? What fish in the lakes will meet the new standards? How long will the fish remain contaminated with PCBs? New Sea Grant research will attempt to answer these questions, too.

PCBs in the Great Lakes — Where do they come from?

At first, it was thought that most of the PCBs coming into Lake Michigan and the other Great Lakes were carried in runoff or were dumped with municipal and industrial wastes.

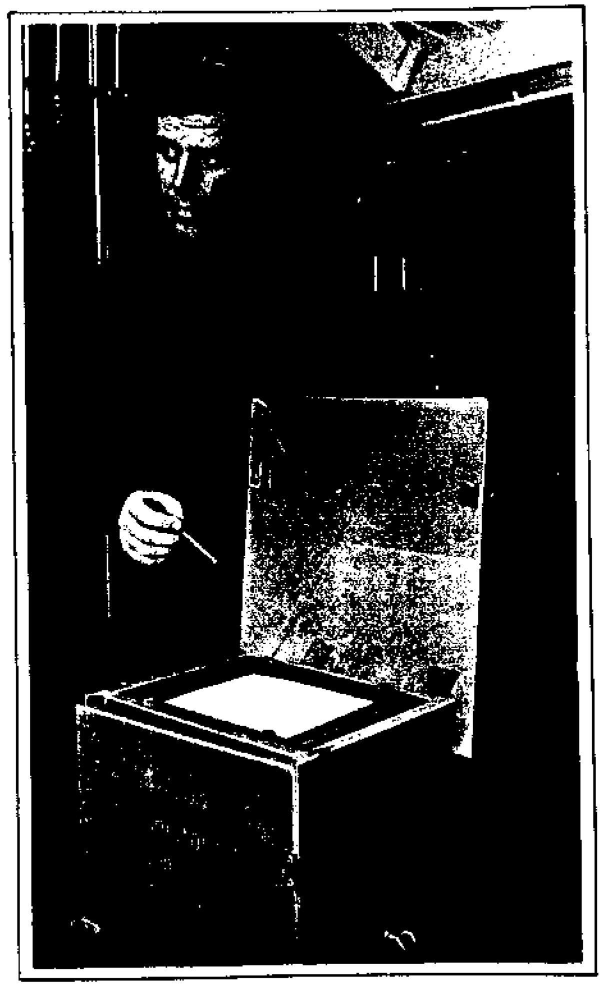
However, UW-Madison water chemist Anders Andren has shown that the atmosphere is perhaps the most important source of PCBs in the lakes. After collecting air samples around the southern basin of Lake Michigan, he and his students found that as much as 70 percent of the PCBs entering the lake may come from the atmosphere. This amounts to some 8600 kilograms or nearly 19,000 pounds per year.

"It's hard to pinpoint the sources of these airborne PCBs because they are so diffuse," says Andren. "Large cities with a lot of industrial activity always have elevated levels of PCBs in their air. They come out of landfills, incinerators, hydraulic fluids and leaking transformers."

Related research at the University of Minnesota has found PCBs in the sediments of Lake Superior, generally regarded as the purest of the five Great Lakes. Because of the scarcity of industry around that lake, Andren believes these findings underscore the importance of atmospheric inputs of PCBs.

Nonetheless, "point sources" of these chemicals remain important. One of the major contributors of PCBs to Lake Michigan is an area just offshore Waukegan, Illinois, where Outboard Marine Corporation had been dumping wastes for years. In Wisconsin, the prime PCB hot spot is the Sheboygan River. Here, a company inadvertently dumped large amounts of PCBs in a landfill site, where they leached into the river and contaminated the fish.

David Armstrong, also a UW-Madison water chemist, has been working extensively on the PCB problem. He says that because airborne sources are so difficult to control, it is all the more critical to track down the easier-to-manage discharges from specific sites.



UW-Madison water chemist Anders Andren shows visitors one of the air monitoring stations used to determine how much of Lake Michigan's PCB load comes from the atmosphere.

The Fate of PCBs

Armstrong and his colleagues have been studying the fate of PCBs in Lake Michigan by collecting samples of bottom sediments from the lake and studying how organisms take up PCBs in the water and from the lake bottom.

Once PCBs get into the lake — by whatever means — they normally become attached to particles in the water and settle to the bottom within two years, says Armstrong. From there, he notes, they are often recycled into the lake's food chain by tiny bottom-feeding organisms known as benthic invertebrates.

Previous studies of DDT, a chemical cousin of PCBs, showed that once its use had been banned, DDT decreased but did not disappear completely in Great Lakes fish. This led to the theory that DDT was being reintroduced into the food chain by bottom-feeding organisms long after the chemical was absent from the water.

Armstrong says a similar phenomenon may be occurring with PCBs. According to present information, he says, the burial of PCBs in bottom sediments is the chief way in which these contaminants are removed from the water. How long this takes depends on the amount of sediment carried into the lakes, the topography of the lake bottom and lake currents. If tiny organisms that burrow in the silt in search of food are present, they will stir up these sediments and consume PCB-contaminated particles, which are then passed up through the lake's food chain.

This combination of factors, says Armstrong, makes it hard to predict how long PCBs will remain a problem in the lakes, even after all new inputs of the chemicals have stopped.

"Depending on the area of Lake Michigan," he says, "it could be ten or as many as fifty years before the PCBs would be safely buried in the sediments."

PCBs in Fish

The Great Lakes resources most threatened by the presence of PCBs are fish. The level of PCBs in the water itself is so low as to be harmless when ingested. However, PCBs do concentrate in the fish, especially large, fatty fish like lake trout, carp, coho and chinook salmon. PCB levels of ten parts per million are not uncommon in these species in some parts of Lake Michigan.

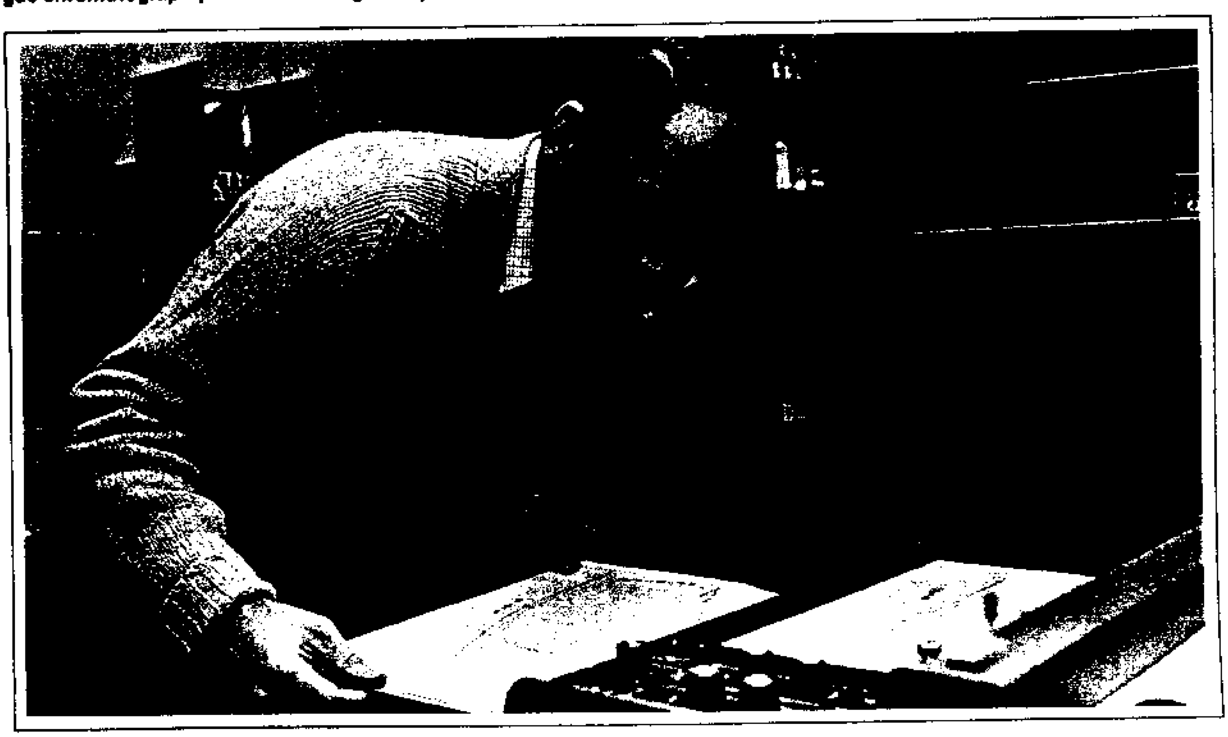
For nearly ten years, John Lech and Mark Melancon, scientists at the Medical College of Wisconsin, have been studying how fish take in and metabolize toxic substances like PCBs.

Lech says fish can take up PCBs directly from the water as well as through the food chain. Some fish have been found to contain concentrations of PCBs that are 100,000 to a million times greater than the concentrations in surrounding waters.

Lech says earlier research showed that fish can chemically alter such foreign substances when they are taken with food and digested.

"A compound could be changed to a form that is less harmful," he explains, "or it may attach itself to another molecule or particle that makes it easier for the fish to excrete it."

David Armstrong, co-coordinator of Sea Grant Microcontaminants and Water Quality Subprogram, examines a gas chromatograph printout showing PCB peaks.



John Lech, co-coordinator of the Water Quality Program, injects a chemical into the aquarium to see how it affects the fish.

On the other hand, he notes, some chemicals may become more toxic once they come in contact with the fish's enzymes.

According to Lech, PCBs apparently do not become more toxic once in a fish's system. He said adult fish seem to be able to carry fairly high levels in their bodies without ill effects. But the fish are slow to eliminate PCBs.

Lech and Melancon found that rainbow trout, exposed to one type of PCBs in the laboratory, eliminated 30 percent of the chemical after two weeks but took another 13 weeks to rid their systems of an additional six percent.

Studies by UW-Madison pharmacologist Richard Peterson have shown that spawning can help to speed up the elimination of PCBs from adult fish, since some of the chemical gets transferred to developing eggs and sperm. Overall, spawning has been found to reduce PCB levels in hatchery-reared adult trout by six to ten percent.

But this may have other repercussions. Former UW-Milwaukee biochemist Robert Broyles, now at the University of Oklahoma, has reported that in the early developmental stages, baby trout and chinook salmon can take up PCBs directly from the water – in addition to the PCBs already passed on from the parent fish. These tiny fish can thus accumulate lethal doses. Some scientists have speculated that this contamination may be one factor in the failure of lake trout, once native to Lake Michigan, to reproduce successfully there now.

Controlling PCBs

The most obvious place to control PCBs is at the source. For that reason, Congress and several states – including Wisconsin – have banned the manufacture and purchase of PCBs with few exemptions, such as use in electrical transformers and other closed systems.

In addition, the federal Toxic Substances Control Act, passed by Congress in October 1976, requires the government to enforce strict controls on the disposal of PCBs.

The problem of what to do about PCBs already loose in the environment still remains. Armstrong suggests, for example, that PCB dump sites, once identified, could be capped with soil that would prevent the chemicals from escaping to the water or air.

Another, somewhat novel suggestion for reducing PCBs in Lake Michigan fish has come from Armstrong and his former student David Weininger, now with the Environmental Protection Agency in Duluth, Minnesota. They note that the critical point of PCB transfer in the lake's food chain lies with the alewife, the chief food source for the large lake fish. Because alewives eat a lot and grow slowly, they tend to concentrate significant amounts of PCBs. Weininger has suggested that one way to reduce PCB levels in the large fish would be to harvest alewives on a massive scale.

In effect, this would remove that lake trout and salmon's contaminated food source. Weininger theorizes that these fish would then switch to eating smelt and sculpin – two species with low PCB levels. Weininger believes that, if this were done, PCB concentrations in adult salmon could decline by a factor of four within five years. Ron Poff, Great Lakes Fish Manager for the Wisconsin Department of Natural Resources, is intrigued by Weininger's suggestion, though he feels that a large-scale alewife harvest might be costly for the state.

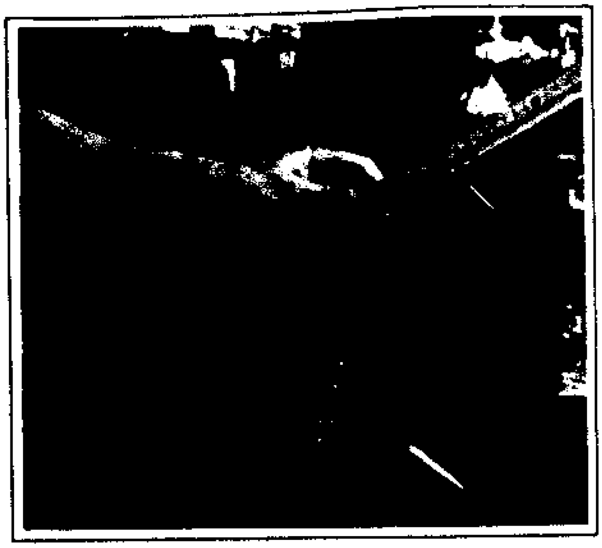
In any case, there is some evidence that PCB levels in Lake Michigan fish are declining naturally, albeit very slowly. Evidence for this has come from Michigan and Illinois, but Wisconsin officials say they don't see these trends in their state waters. The Wisconsin DNR is now conducting a comprehensive monitoring program to look closely at PCB levels in fish from throughout the state. The purpose is to advise both commercial and sport fishermen of where in the state certain fish contain levels of PCBs lower than the proposed FDA standard of two ppm.

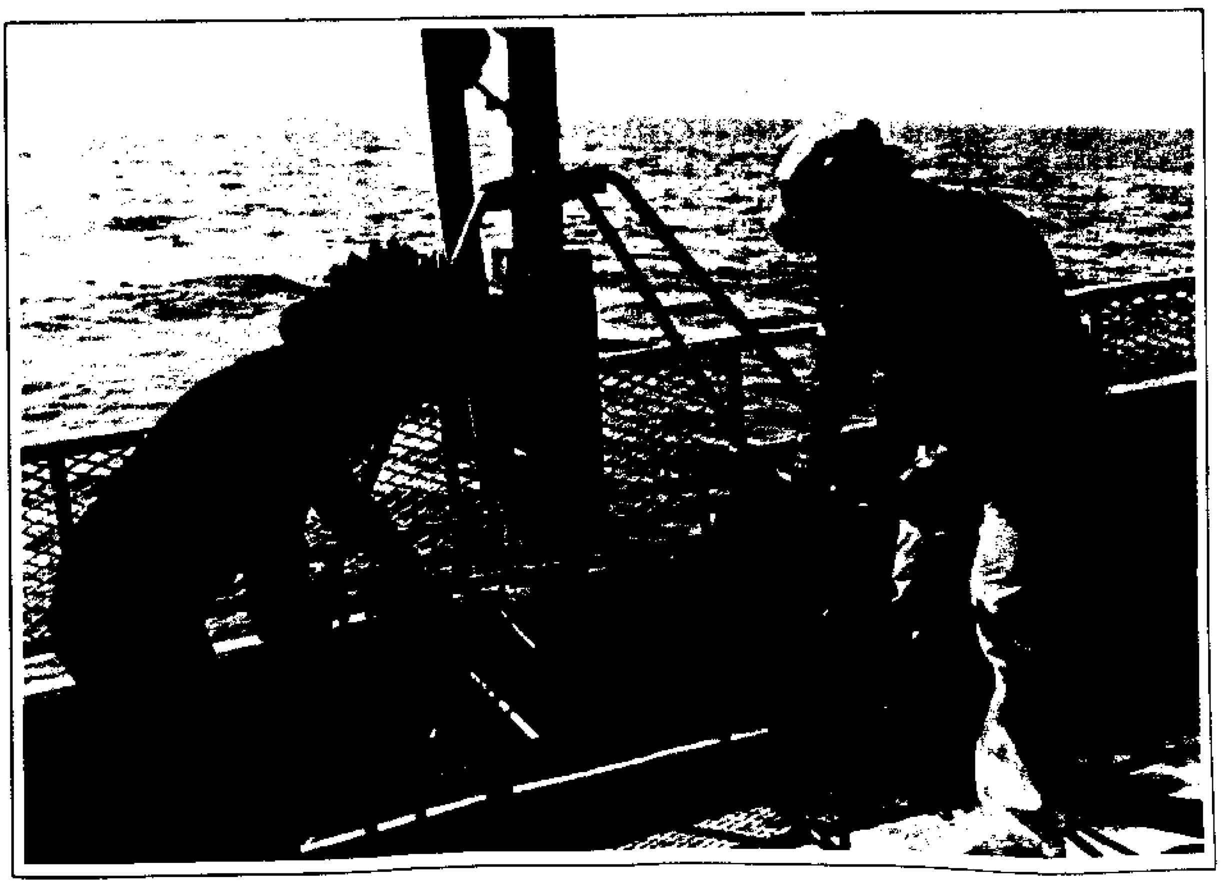
Indications are that many fish, particularly those in Lake Michigan and the Mississippi River, are still well above this standard. But when and how fast PCB levels will decline remains unknown.

UW-Madison biologist James Kitchell has been working with Armstrong, Weininger and UW-Milwaukee biologist Fred Binkowski to develop a bioenergetics model of the lake's fish species. The model incorporates knowledge of fish diets, growth rates and predator-prey relationships, all based on ongoing University of Wisconsin Sea Grant fisheries research. With the model, the scientists can use a computer to predict what PCB levels in fish would be, given a certain set of environmental circumstances.

For example, they have predicted that if PCB inputs to the lake were to stop immediately, PCB levels in coho salmon would decline 60-80 percent within six years. After that, they say, the remaining amount would decrease very slowly.

Sediment samples taken from Lake Michigan (bottom) are measured in a shipboard laboratory (top). Scientists are studying these samples to determine how much PCBs are in lake sediments and how long they are likely to remain there.





PCBs and Human Health

The overriding concern relative to PCB-contaminated fish is human health. There is controversy over whether PCBs can harm humans when consumed at the levels found in Great Lakes fish. But the evidence that PCBs can be toxic to humans has been compelling enough to prompt the FDA to tighten its standards on food containing these compounds. Some of that evidence has come from the research of James Allen, a UW-Madison pathologist.

Since a 1968 accident in Japan in which 15,000 people ate PCB-laden rice oil, scientists and physicians have known that large doses of PCBs could kill or sicken people.

In 1972, with UW Sea Grant support, Allen began to investigate what effects much lower doses of PCBs might have on rhesus monkeys, whose metabolism closely resembles that of humans.

In his initial work, Allen fed the monkeys diets containing high levels of PCBs (300 and 100 ppm) for a month. The animals suffered overt symptoms of poisoning. Within three months, they were dead.

Allen subsequently lowered levels to 5 and 2.5 ppm and showed these could affect the health and reproductive abilities of monkeys fed a steady diet of PCBs in the laboratory.

Infants born to these experimental animals received PCBs through their mothers' milk and suffered hair loss and acne. They were also more susceptible than normal infants to infection and stress-related diseases. Follow-up studies on these animals, done by UW-Madison psychologist Robert Bowman, revealed that these young monkeys also suffered from behavioral and learning disabilities.

Even after adult monkeys were removed from a PCB diet for three years, infants born during the "recovery" period also showed some of these ill effects.

More recently, Allen and research assistant Deborah Barsotti have been feeding monkeys PCB levels as low as .5 and 1 ppm three times a week in an attempt to more closely approximate human exposure to the compounds.

The adult monkeys have suffered no obvious ill-effects. But, as in earlier experiments, the mothers have produced smaller-than-average infants with the hyperpigmentation typical of PCB poisoning. Preliminary findings indicate these infants, too, suffer from behavioral problems.

How all these experiments may apply to the human situation, Allen can't say.

"There's no question that PCBs are harmful to humans; the question is at what level they are harmful," he says, adding that "there has been no work on humans to date that has yielded conclusive results on this."

The pathologist is particularly concerned that long-term, low-level PCB exposure may be causing subtle forms of health damage. But, as Barsotti notes, "In real life, people are exposed to so many

Psychologists with Wisconsin's Primate Research Center have studied the behavior of young monkeys exposed to PCBs through their mothers. They find such monkeys to be hyperactive and have learning disabilities.

contaminants that it would be hard to prove that PCBs were the cause of a particular disorder."

Nevertheless, Allen says some of the symptoms his research team has encountered with the monkeys bear investigating in men, women and children. These include slight alterations in immune responses, alterations in menstrual cycles, increased incidence of abortions, decreases in infant birth weights, and learning and behavioral disabilities.

Several University of Wisconsin Sea Grant projects addressing PCB effects on humans are now getting under way. Edward Kendrick of the UW-Madison Department of Preventive Medicine has begun a study of thirty mothers in the Sheboygan area who have a history of eating fish from the PCB-contaminated Sheboygan River.

He plans to analyze the breast milk and blood of these mothers and compare the PCB levels he finds to those found in mothers who have not eaten fish from the area.

"We'll also look at the infants and assess their development and growth rates," explains Kendrick.

Meanwhile, further north on Washington Island, Jill Smith is investigating levels of PCBs in adults. Smith, a UW-Madison graduate student in epidemiology and anthropology, is working with the island's registered nurse to collect information about local residents' dietary habits and to analyze the PCB levels in their blood. Commercial fishing has long been an important enterprise on the island, and many residents consume large amounts of fish.

Depending on the outcome of this pilot project, a larger study may be undertaken to see whether fish consumption can be linked with high levels of PCBs in the blood and whether this, in turn, can be linked with any of the symptoms of PCB intoxication uncovered by Allen and Barsotti.

Given the present state of knowledge about PCBs and human health, the Wisconsin DNR advises pregnant women, nursing mothers and children under six years old not to eat fish known to contain high levels of PCBs. All others are advised to limit their meals of these fish—especially carp, lake trout and salmon—to once a week.

UW-Madison food scientist David Stuiber is among those advising consumers on how to reduce PCB levels in their fish. He notes that PCBs are stored in the fat, and so fat and skin should be removed in cleaning, especially the fat around the fish's back and belly. Stuiber, a Sea Grant Advisory Services specialist, also recommends broiling, baking or barbecuing the fish so that it doesn't cook in its own juices.

Wisconsin's Lake Michigan commercial fishermen are among those hardest hit by the PCB problem.

Stuiber works closely with sportsmen, fish consumers and commercial fishermen. He says that if the new PCB ruling from the FDA goes into effect, it could have a serious impact on Wisconsin's commercial fishing industry, the largest of any Great Lakes state.

Economists have estimated that Wisconsin's fishery could lose some $1 million a year because of fish—primarily in Lake Michigan—that are off limits as a result of the proposed 2 ppm standard. Sport fishing activity in the lakes could also decrease, says Stuiber, through negative publicity or, possibly, reductions in fish stocking programs. The Lake Michigan sport fishery in Wisconsin is valued at more than $10 million a year.

These figures dramatically emphasize the importance of resolving the PCB issue in Wisconsin. Questions about PCB sources, fates and effects remain, and the University of Wisconsin Sea Grant Institute will continue to probe for answers in the laboratory and in the field. In addition, the Institute will make a special effort to keep government agencies, other universities, fishermen and the public apprised of the information its investigators are uncovering.

PESTICIDES: DANGEROUS ALLIES

The problem of toxic substances in the Great Lakes first came to light in the late 1960s, when high levels of DDT, a persistent pesticide, turned up in the lakes' larger fish species. Trout and salmon in Lake Michigan were contaminated with DDT at levels as high as 25 parts per million—greatly in excess of the federal standard of 5 ppm in food fish. As a result, some of these fish could not be marketed.

Concern also resulted from studies linking DDT to declines in the populations of eagles and other birds of prey. The pesticide disrupted the birds' calcium-producing mechanism, causing them to lay eggs that had precariously thin shells and were subject to premature breakage.

In 1972, DDT was banned nationally. One heartening result has been that levels of the pesticide in Great Lakes fish have dropped by about 80 percent in recent years, according to research by UW-Madison water chemist David Armstrong. Levels of dieldrin, another restricted pesticide, have also declined.

"DDT residues in fish began to decline faster than we thought they would after many of these chemicals were banned," Armstrong notes. "We saw an initial rapid drop when their input to the environment was stopped. Now DDT levels in fish are remaining fairly constant."

Eagles (top) and other birds of prey were adversely affected by DDT spraying in the 1950s and 60s. The green hydra (bottom) has given scientists new insights into the effects that low-level exposure to pesticides can have on organisms.

The chemicals haven't disappeared entirely because pesticides entering the lakes settle to the bottom and are buried in sediment. Bottom-feeding organisms pick up the pesticides from the sediments and cycle them back into the lakes' food web. This explains why concentrations of DDT dropped to about 20 percent of their original levels and then stayed about the same. Eventually, however, the DDT in the surface sediments becomes buried by uncontaminated muds, according to Armstrong. His research has also shown that some degradation of DDT occurs in the sediments.

Past Sea Grant work has also shed light on the way in which pesticides affect the small organisms that are food sources for fish. In one study, UW-Madison entomologists Fumio Matsumura (now at the University of Michigan) and Mallory Boush found that low levels of DDT, dieldrin, toxaphene and other persistent pesticides can impair the reproduction of the green hydra *(Chlorohydra viridissima)*, a zooplankton.

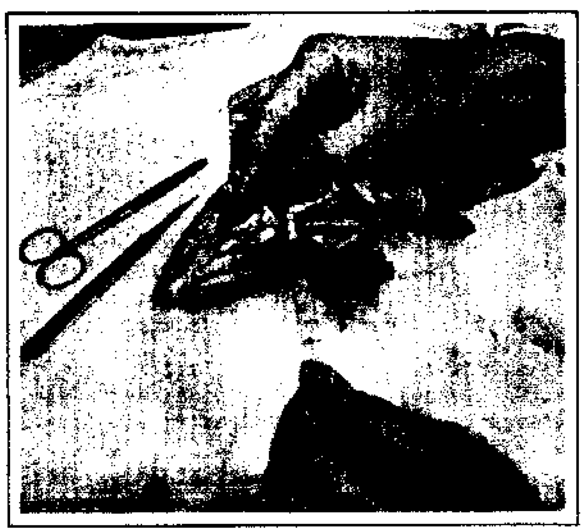
Levels of these compounds ranging from one to five parts per billion (ppb) significantly reduced the green hydra's ability to produce buds. When grown in the laboratory in pesticide-contaminated water, the tiny animal had to use 50 percent more energy to produce a bud.

Over the years, another pair of scientists – John Lech and Mark Melancon of the Medical College of Wisconsin in Milwaukee – have examined how various pesticides and other toxic chemicals are taken up, metabolized and eliminated by fish.

Among the compounds they have examined are Bayer 73 and TFM, two chemicals used to control sea lamprey populations in the Great Lakes. Lech and Melancon found that rainbow trout exposed to Bayer 73 over a 24-hour period concentrated it in their bile at levels up to 10,000 times greater than those in the surrounding water; TFM was concentrated over 1,000 times. As a result of this work, the researchers have suggested that fish might be effective monitors of pollutants that are nearly undetectable in the water itself.

In other work, Lech and Melancon explored the effects of chemical interactions in an aquatic system. The pharmacologists found, for example, that carbaryl – a DDT substitute widely used on corn and other crops – can react in combination with other chemicals to harm aquatic organisms. In the laboratory, carbaryl significantly increased the toxicity of 2,4-D, an herbicide; dieldrin, an insecticide; rotenone, a carp poison; and pentachlorophenol, a wood preservative.

Chemicals like these have been used widely throughout the Great Lakes basin. Through runoff and other sources, they eventually reach the lakes. The implications of that process underscore the need for a better understanding of the toxicity and interactions of various chemicals released to the environment.



Mark Melancon, Medical College of Wisconsin, extracts fish tissues for analysis of PCB residues and metabolites. Such tests reveal how fish concentrate PCBs and how they eliminate PCBs from their tissues.

DIOXINS:
OF MONKEYS AND MISCARRIAGES

Crop dusting with chemical pesticides remains a widespread practice.

On July 10, 1976, an industrial explosion at a chemical factory in Seveso, a town in northern Italy, released a poisonous cloud that drifted over some 4,000 acres of land. The cloud contained high levels of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) —one of the most toxic and persistent organic chemicals known.

Within days, hundreds of birds and small animals died, leaves began to drop from trees and residents of the area suffered from nausea and skin ailments. More than 700 people were evacuated from the town. Because past incidents of accidental TCDD contamination were known to have affected unborn babies, more than 90 pregnant women obtained clinical abortions.

But the now-famous Seveso incident was a large-scale industrial accident involving large amounts of dioxin. Scientific attention in the U.S. is beginning to focus on the possible human health implications of very low levels of dioxin contamination.

Dioxin is an unwanted minor byproduct in the manufacture of several chemicals, including 2,4,5-T, a widely-used herbicide. Each year, about seven million pounds of 2,4,5-T are sprayed over nearly five million acres of land in this country. The chemical has been used to kill weeds and woody shrubs along the right-of-ways for powerlines, highways, pipelines and railroads, and on rangelands, pasturelands and forestlands.

Many of these uses were halted as the result of a March 1979 order by the Environmental Protection Agency. Citing a possible link between 2,4,5-T exposure and miscarriages among women in Oregon, the EPA issued an emergency suspension ruling that banned all uses of 2,4,5-T and one of its derivatives, Silvex, except on rice crops and livestock grazing land.

The order reflected growing concern about dioxin contaminants in 2,4,5-T. Although these contaminants can break down into less harmful materials under ideal conditions, scientists believe most TCDD remains in the environment. Unknown quantities of this toxic substance are carried into waterways via the air, surface runoff and industrial discharges.

Waterways where TCDD has turned up include Michigan's Tittabawassee River and Lake Huron's Saginaw Bay. The compound has also been found in sediments and leachates from landfill sites near the Niagara River in New York State.

TCDD is known to cause tumors and birth defects in laboratory animals, and one study has found an increased incidence of liver cancer among Vietnamese people in the wake of the U.S. military's extensive use in 1961-62 of Agent Orange, a defoliant containing relatively high levels of TCDD.

In the U.S., dioxin has already turned up in the breast milk of nursing women living near 2,4,5-T-sprayed lands. Cattle grazing on treated rangelands have also shown TCDD in their fat, where the chemical has a tendency to build up.

UW-Madison pathologist James Allen, a consultant to the Italian government in the Seveso incident, has been looking at the health effects of long-term, low-level exposure to dioxin—exposure that, in humans, could result from diet or proximity to areas sprayed with 2,4,5-T.

To find out if there is a "safe" level of TCDD, Allen has been placing small amounts of the chemical in the diet of rhesus monkeys, whose metabolism closely resembles that of humans.

"We have yet to find a 'no effect' level of dioxin," the Sea Grant investigator reports. "In the rhesus monkey, we know that TCDD is extremely toxic. Even at low levels, it produces blood abnormalities, reproductive failures and an increase in liver functions."

In his first tests, begun in 1975, Allen fed eight female monkeys a diet containing 500 parts per trillion (ppt) of TCDD for nine months. Five of the eight animals died three months later.

"We didn't expect to see that. We thought this amount of dioxin was so small that it wouldn't kill the monkeys," says Allen's assistant, graduate student Deborah Barsotti. The surviving animals, like the monkeys that died, experienced a drop in red and white blood cells and lost body hair. In addition, they suffered swollen eyelids and reproductive failure. Only one of the monkeys was able to give birth.

The scientists later lowered the level of dioxin in the diet of a second group of monkeys to 50 ppt. None of the animals have died but they have experienced problems, including a number of spontaneous abortions and one stillbirth. Only two monkeys produced offspring.

Allen and Barsotti recently began feeding another group of monkeys a diet containing 25 ppt of dioxin. The results are not yet in, but Barsotti believes this group may produce enough offspring to permit an evaluation of the physical and behavioral effects of TCDD on infant development. Another group of monkeys will also be tested after being fed a diet containing 5 ppt of dioxin.

A rhesus monkey, exposed to only 500 parts per trillion (ppt) of dioxin, suffers dramatic effects, including swelling around the eyes, loss of hair and skin problems.

In nature, TCDD levels generally remain low. But Allen is quick to point out that low-level, long-term exposure may be as serious as a one-time, high-dose exposure. For example, Allen's work has shown that only two to three micrograms of TCDD per kilogram of body weight were enough to kill most of one group of monkeys over a nine-month period.

"These results should be sufficient to warrant further investigations into the health effects of dioxin on humans," warns Allen. "The 'no effect' level of TCDD may be below our detectable limits."

Allen believes the U.S. government should study Vietnam veterans who came into contact with Agent Orange—the 2,4,5-T-based herbicide used extensively in Vietnam. Many vets have complained of health problems that they claim have resulted from their exposure to Agent Orange.

But herbicides may not be the only source of dioxins. The Dow Chemical Company, one of the three major producers of 2,4,5-T in the U.S., contends that minute quantities of TCDD are also formed during combustion in refuse incinerators, fossil fuel plants, automobiles and even in the smoking of cigarettes.

Dow made this claim after high dioxin levels turned up in fish taken from the Tittabawassee River, which flows past the chemical company's Midland, Michigan, plant. While critics point to Dow as the likely source of the TCDD, the company has suggested other sources are to blame.

Until recently, there was some fear that traces of dioxin might also be formed during the chlorine bleaching of pulp in paper mills. UW-Madison soil scientist John Harkin believed that the right combination of chemicals and conditions might exist in pulp processing to create dioxin-type compounds as a byproduct.

To find out if this was happening, Harkin analyzed effluents from Wisconsin paper mills and also simulated effluent bleaching procedures in the laboratory.

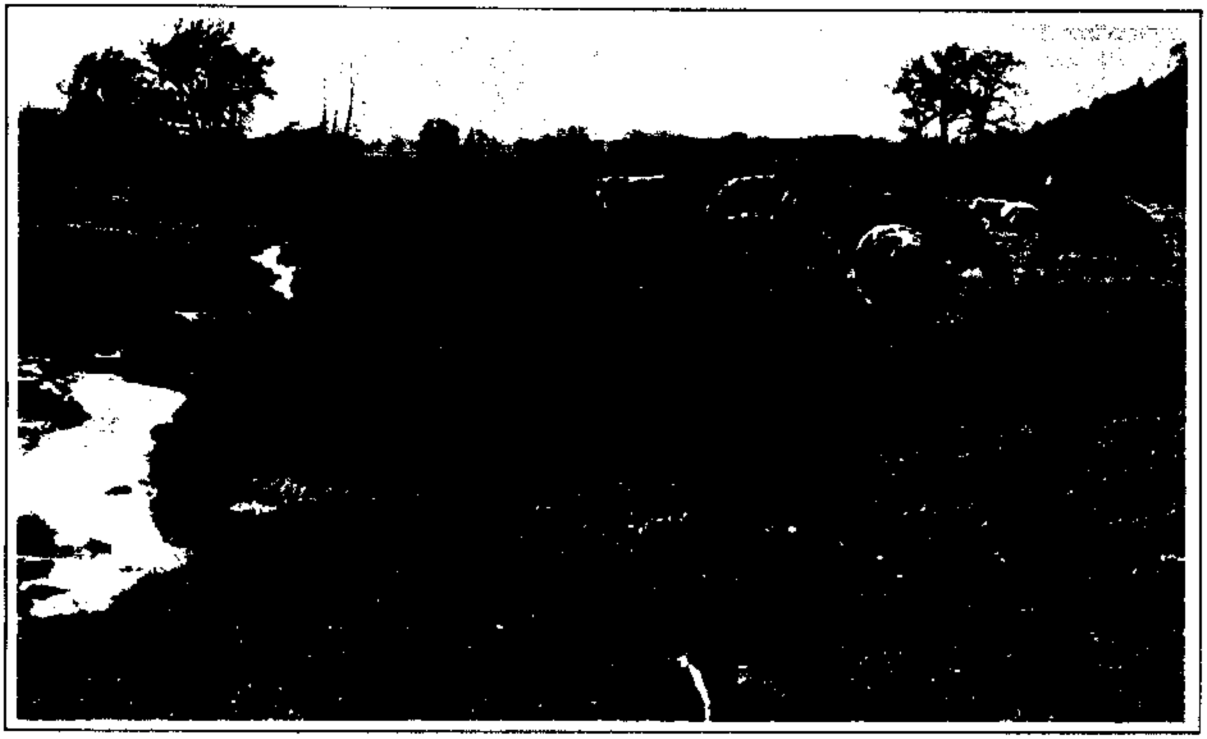
Fortunately, he found that the bleaching of paper pulp does *not* produce dioxins.

"This is probably due to the fact that the temperatures generated in the mills are not high enough to create these compounds," Harkin explains.

Had the reverse been true, he says, "it would have wreaked havoc on the paper industry, since there are some 47 pulp and paper mills in Wisconsin, and many use chlorine to bleach their pulp and alternate bleaching compounds are very expensive."

Sea Grant research has shown that dioxins are not produced as a by-product of the paper-making process as had once been suspected (top), but other discharges, like those from fossil fuel power plants (bottom), remain under suspicion as sources of minute amounts of dioxin.

PHOSPHORUS: BANNED, ON THE RUN



Phosphorus—one of the elements vital to life on earth. And yet its extensive use in products ranging from fertilizer to detergents has caused environmental concern. Phosphorus in farm runoff and municipal sewage enters lakes and streams and stimulates the growth of weeds and algae—causing waterways to become eutrophic, or nutrient-rich and oxygen-depleted.

Concern about the fertilizing effect of phosphorus on Wisconsin's lakes led the state legislature in 1978 to sharply reduce the levels of phosphorus allowed in commercial cleaning compounds. Similar controls were already in effect in Canada, New York, Vermont, Maine, Connecticut, Indiana, Michigan, Minnesota and the city of Chicago.

Biologists say that Lake Michigan's Green Bay in particular will benefit from reduced discharges of phosphorus. Farms, factories and towns have dumped a heavy load of phosphorus into this shallow cul-de-sac. Each year the resulting algae blooms caused by phosphorus extend north some 15 to 20 miles from the eutrophic southern end of the bay.

From 1970 to 1972, University of Wisconsin-Green Bay limnologist Paul Sager investigated the influx of phosphorus from its various sources into Green Bay. He sampled the water at 24 stations in the bay and 10 stations on the lower Fox River, which flows into the bay's southern end. He also checked the effluent of 11 municipal sewage treatment plants along the river, as well as the water quality in tributary streams.

Sager estimated that 38 percent of the phosphorus entering the bay was draining off rural land. He concluded that the Environmental Protection Agency's goals at the time for upgraded municipal sewage treatment would reduce the phosphorus loading to lower Green Bay by only 30 percent.

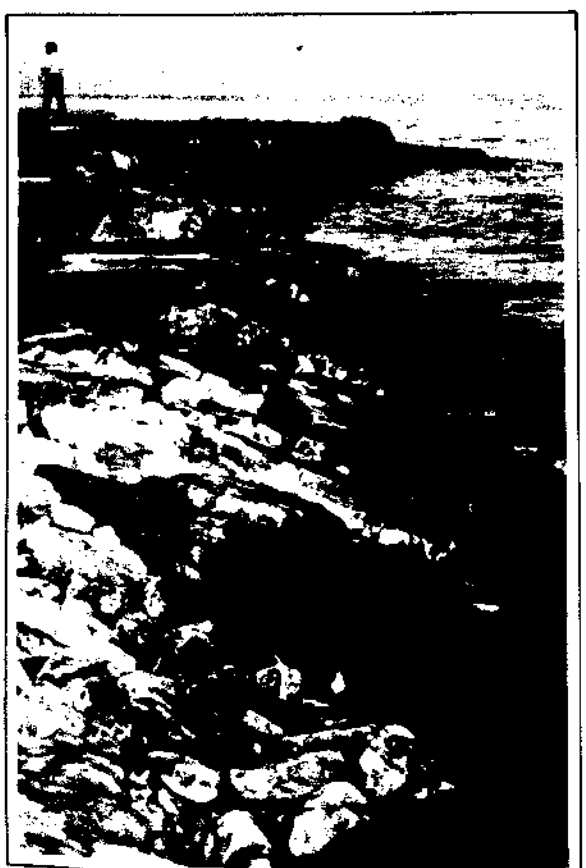
Nevertheless, the states ringing Lake Michigan had agreed in 1969 to reduce the phosphorus in treatment plant discharges to the lake basin by 80 percent. To reach this goal, Wisconsin ordered the 53 sanitary treatment plants serving districts of 2,500 or more residents in the Lake Michigan-Green Bay watershed to remove 85 percent of the phosphorus from their effluents by 1972. The date of compliance has since been pushed ahead to 1985.

This "uniform treatment" approach, though seeming to be fair, tends to be inefficient and costly, according to UW-Madison engineer Erhard Joeres and economist David Martin. They found that the cost of removing phosphorus can vary widely from one treatment plant to another, depending on such factors as the plant's age and size and the particular waste mixture being handled. Why not, they asked, allow industries and municipalities to voluntarily buy and sell pollution "rights"? Under this system, a company which finds it difficult to meet its permitted effluent standards would pay a company with more efficient waste treatment facilities on the same river or lake to remove an additional share of phosphorus. Thus the total amount of phosphorus being added to the waterway would remain the same while overall treatment costs would be less.

This general scheme has been variously termed Marketable Pollution Rights, Marketable Effluent Permits and Transferable Discharge Permits (TDP). The Wisconsin Department of Natural Resources prefers the latter designation—which avoids the implication that polluting is either "a right," or that, being "marketable," phosphorus removal may be a desirable source of profit.

Joeres and David suggest that a TDP system would be appropriate for a city like Milwaukee, which has

The growth of green algae along Green Bay's shores is one symptom of the high phosphorus content of the bay's waters.



large and efficient facilities for removing pollutants. Milwaukee's treatment plants receive "pickling liquor," a by-product of the local tool and die industry. These acid chemicals remove the phosphorus in Milwaukee wastes that would otherwise be contaminating Lake Michigan. The Wisconsin Sea Grant researchers believe that nearby sanitation districts could pay Milwaukee to remove those amounts of phosphorus that the smaller, outlying plants cannot economically eliminate.

In 1977, Joeres and David estimated this trading of phosphorus removal obligations could save Wisconsin taxpayers almost $750,000 a year in sewage plant operating and maintenance costs. A system of TDPs also avoids the political problem of imposing a uniform treatment standard on dischargers along a river that has sections with significantly different levels of pollution and treatment requirements.

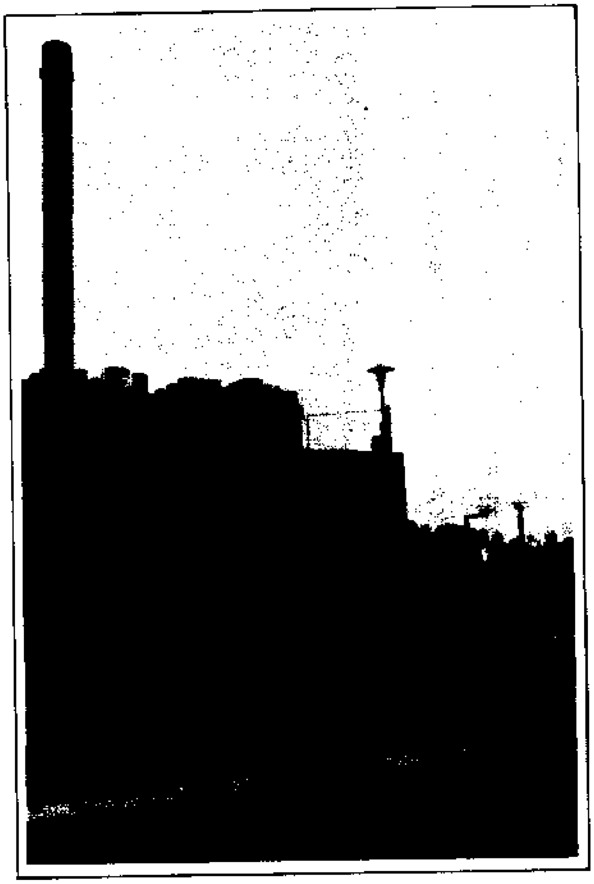
In effect, instead of achieving the required standards themselves, the smaller plants would pay nearby dischargers with more treatment capability or those located on cleaner stretches of the waterway upstream to do more than their share. On balance, then, the waterway would successfully meet federal water standards. The DNR would record these transactions and monitor water quality by computer and act as broker between the two dischargers.

While not yet ready to endorse the concept of transferable discharge permits, the DNR has encouraged the research team to look at ways such a system might be implemented to control organic pollutants that use up dissolved oxygen in the water. This biochemical oxygen demand is particularly heavy on the industrialized upper Wisconsin and lower Fox rivers.

According to DNR water quality planning official Donald Theiler, transferable discharge permits would work best in regions where city and industrial dischargers are clustered and have a cumulative effect on a river.

Of equal concern and more difficult to control is the phosphorus draining off the land, referred to as nonpoint source pollution. Two projects, recently incorporated in the Wisconsin Sea Grant subprogram on Green Bay, deal in large part with these diffuse sources of phosphorus.

To better understand and monitor such nonpoint source contamination, UW-Madison environmental engineer Frank Scarpace is developing techniques for mapping large watershed areas in the Green Bay region from the air. The data that result from aerial reconnaissance can then be plugged into computer models to predict water runoff and its impact on the quality of receiving waters.



Phosphorus in municipal and industrial wastes can be removed in treatment plants (top), but other sources of the element, like runoff from suburban lands (bottom), are not as easy to control.

Taking a different approach to the same problem, UW-Madison resource economists Daniel Bromley and Basil Sharp are examining land use practices that contribute to nonpoint source pollution of Green Bay area waterways. In particular, the research team is assessing the impact of livestock wastes on water in the Lower Fox-Green Bay region.

From these observations they will compare alternative policies designed to lessen the polluting effects of various agricultural practices. And, on a more comprehensive level, they will simulate alternative watershed management policies and evaluate effects on water quality.

These various Sea Grant projects are aimed at controlling the influx of phosphorus to Wisconsin's rivers and lakes and the Great Lakes in particular. The approaches to the problem cut across several academic disciplines—aquatic biology, engineering, sociology and economics. Success in integrating these efforts will go far toward helping to prevent the waste of a valuable nutrient and the further eutrophication of areas like Lake Michigan's Green Bay.

HEAVY METALS: MATTER OF CONSEQUENCE

Metals drift through the air in small particles and descend into the lakes. Others trickle in from tributary streams and rivers. No matter how they arrive, heavy metals can cause serious problems in the Great Lakes.

Relatively small concentrations of some metals—such as mercury, cadmium, zinc and copper—can kill aquatic organisms. Much lower concentrations still can have subtle yet harmful effects.

The metals come from a variety of sources, including industrial discharges, waste dumps, automobile exhaust and the burning of fossil fuels. Among the list of problem metals in the Great Lakes are:

MERCURY

Until 1970, industries discharged mercury into the St. Clair and Detroit rivers, whose waters empty into Lake Erie. Mercury contamination of fish and sediments led to commercial fishing bans on the lake in 1976. Some bans are still in effect, and Lake Erie commercial fishermen have been badly hurt as a result.

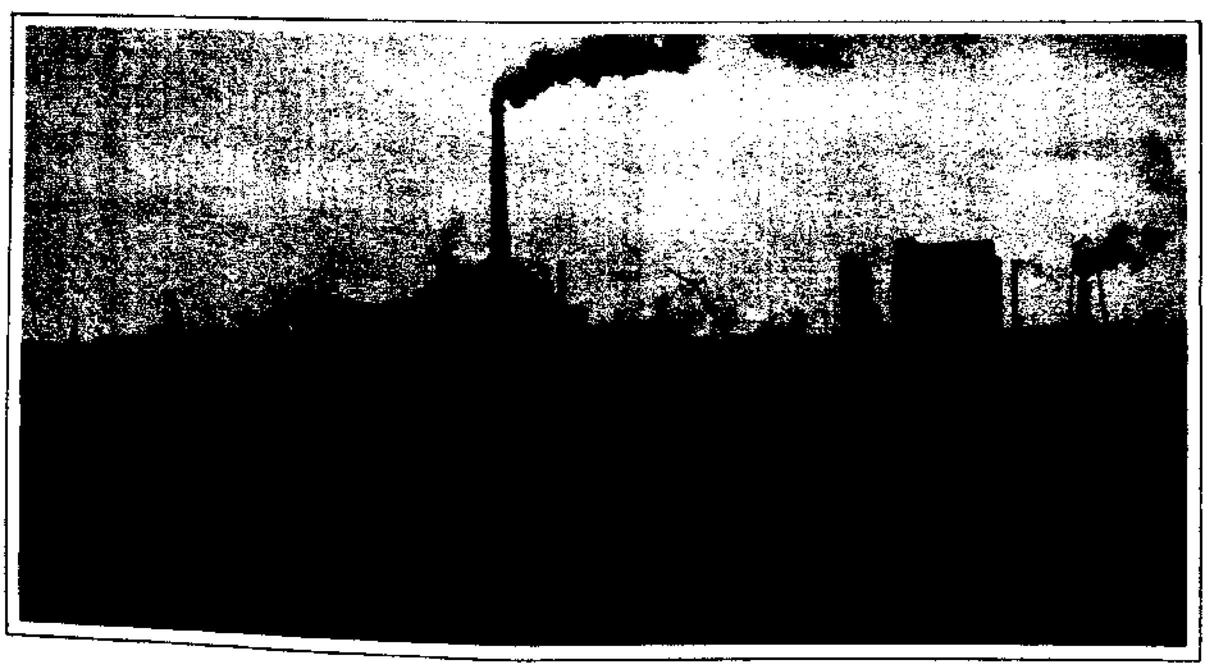
The hazard of mercury in waterways is due to a process called methylation by which microorganisms in lake sediments convert inorganic mercury into methyl mercury. In high concentrations, methyl mercury can affect the human nervous system and even cause death. Methylation is common in the aquatic environment, and scientists say other metals besides mercury also undergo the process.

ARSENIC

Another metal that undergoes methylation is arsenic. For many years the Ansul Chemical Company of Marinette, Wisconsin, used arsenic in the production of herbicides. Ansul disposed of wastes from its manufacturing process along the shore of the Menominee River. The arsenic leached out into soil and groundwater and eventually made its way into the Menominee River. From there it flowed into Green Bay at the rate of about 35 tons a year. Although the company has abandoned its herbicide operation and removed its wastes from the dump site, arsenic is expected to continue flowing into Green Bay for another 20 years.

University of Wisconsin-Madison water chemist Marc Anderson is trying to determine what happens to the chemical once it reaches the waterway. He notes that arsenic can exist in several different

Industrialized and heavily settled waterways like the Fox River are pollution problem areas because of heavy metals contamination.



UW-Madison water chemist Marc Anderson (left) studies a sample under a laser microscope, while his student Dennis Iverson (right) measures out a water sample containing arsenic.

physical and chemical states. Furthermore, it can cycle through these states many times as it moves through the water.

Unlike mercury, there is no evidence that arsenic can build up in the food chain and endanger human health. But Anderson is concerned about the possibility that arsenic might change the composition of algae or other organisms in the water. If so, it could affect the rest of the aquatic system.

Anderson's Sea Grant research so far suggests that the arsenic is diluted soon after it enters the bay. It then appears to follow the bay's counterclockwise flow pattern, drifting to the south.

He finds the highest concentrations of arsenic in muddy sediments. These muds are rich in clay, iron and aluminum oxides, which take up arsenic easily.

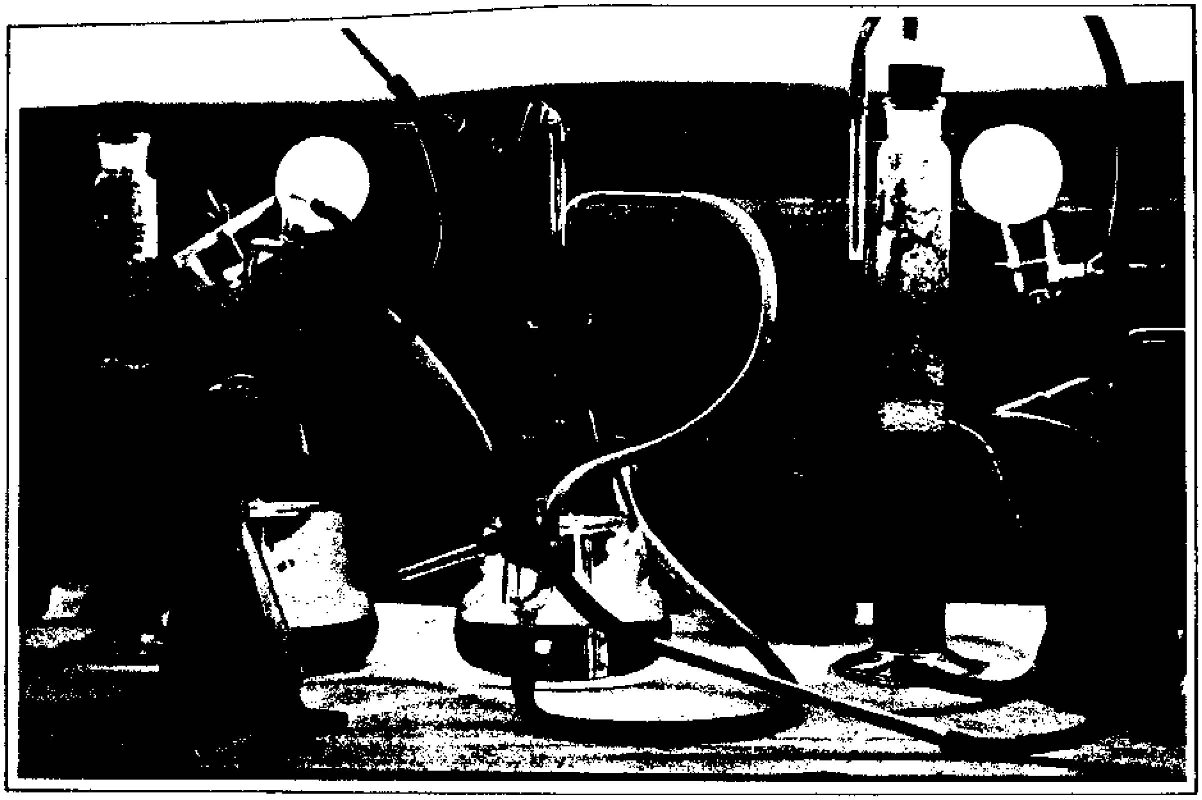
A phenomenon not yet explained is the occurrence of large amounts of arsenic in the northern part of the bay. Anderson says this may be due to the presence of iron-manganese nodules in that area. He says the arsenic could occur naturally with the nodules, or may concentrate there for some unknown reason.

CADMIUM

Cadmium is another metal suspected of adversely affecting aquatic life in the Great Lakes. The cadmium in Lake Michigan comes primarily from two sources: rubber tires and electroplating. Car and truck tires contain small amounts of cadmium. As tire rubber wears off on the pavement, rainfall washes the cadmium into the waterways. The metal is also discharged by the electroplating industry, in which cadmium is used to make other metals more durable and corrosion-resistant.

Two biologists at UW-Milwaukee—Arthur Brooks and Paul Bertram—are studying the effects of cadmium on a zooplankton called *Daphnia*. So far they have successfully grown two species of Lake Michigan *Daphnia* in the laboratory. The next step will be to subject the tiny animals to long-term cadmium exposure over the course of several generations.

Brooks and Bertram already found that one *Daphnia* strain suffered reproductive failures in the laboratory when exposed to cadmium levels as low as one part per billion. The biologists worry that if



this happens in nature, it could have serious implications for the aquatic organisms that rely on *Daphnia* for food. They are also concerned about the *Daphnia*'s proven ability to accumulate and concentrate the metal. This could mean that cadmium concentrates in organisms as it is passed on up the aquatic food chain.

In related work, the Milwaukee researchers are exploring the possibility that, over time, a strain of *Daphnia* resistant to cadmium may develop.

The human health implications of cadmium pollution are also a matter of concern. This metal concentrates in the kidneys and liver of humans, and high levels are known to cause kidney disease and birth defects under some conditions. Fortunately, says Bertram, the human body seems to be able to tolerate low levels of cadmium.

LEAD & TRACE METALS

Exploring another piece of the heavy metals picture is UW-Madison water chemist Anders Andren. He is attempting to find out precisely how metals enter the lake from the atmosphere and what the magnitude of this source is in Lake Michigan.

The question of magnitude involves calculation of a "mass balance." Measurements of the amount of a metal entering the lake from all sources are compared with the amount that settles out into the

The animal above is a young *Daphnia* – a zooplankton very important in the Great Lakes food chain – as seen through a microscope. These organisms have been shown to be sensitive to low levels of cadmium in the water.

sediments. If the sediment figure is lower than the input figure, it is an indication that the metal is building up in the water.

In analyzing sources of metals in the atmosphere, Andren has found that much of it comes from industrial areas – Gary, Chicago, Milwaukee and even as far away as St. Louis.

Most of the lead in the atmosphere comes from automobiles, which contribute heavily to the 0.5 to 3.0 ppm lead concentrations in the air over Lake Michigan. This compares to lead concentrations of .02 to .05 ppm in air a century ago. The sediments in southern Lake Michigan contain 46 times more lead than they did approximately 100 years ago, before the use of leaded gasoline.

Andren is trying to determine how much of that lead enters the water and how much gets carried to the lake bottom. Among other things, he wants to know, can the lake effectively rid itself of all the lead it receives, or could lead concentrations reach a level toxic to aquatic organisms and perhaps even humans?

Andren is working with another UW-Madison water chemist, David Armstrong, to determine how heavy metals move through water from the lake sediments.

"If we find metal concentrations are building up in the water, then controlling these materials at their sources is even more important," says Armstrong. "If the metals aren't building up in the water, it would indicate the lake is taking care of the problem by itself. That's what we're trying to find out."

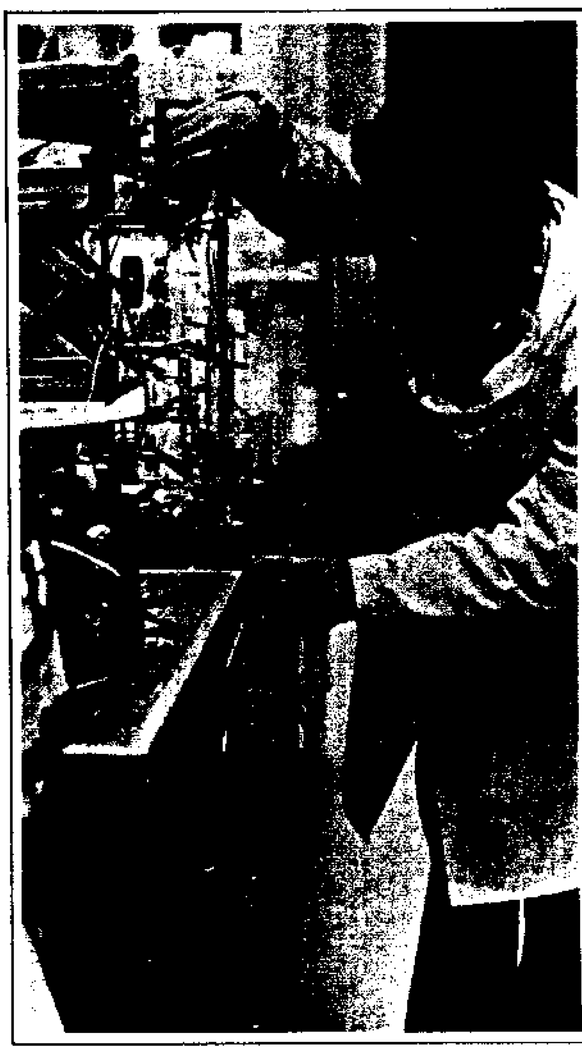
Armstrong and Andren have discovered that metals adhere to aquatic organisms like algae and plankton and are carried by these organisms to the bottom of the lake. But if there is more metal in the water than the organisms or other particles can carry, the metal will accumulate and become more concentrated in the water. An understanding of this process can help in evaluating the impact of trace metal pollution, says Armstrong.

Since heavy metals are toxic but difficult to measure at very low concentrations, sensitive methods are needed to detect them. One of these methods is Anodic Stripping Voltammetry (ASV) – a process by which trace metals are collected and concentrated on an electrode (usually a mercury drop) and then eventually released at concentrations that are higher and easier to measure. This process has limitations, however, since researchers must carry samples back to the laboratory for analysis, and contamination of the samples is a constant risk.

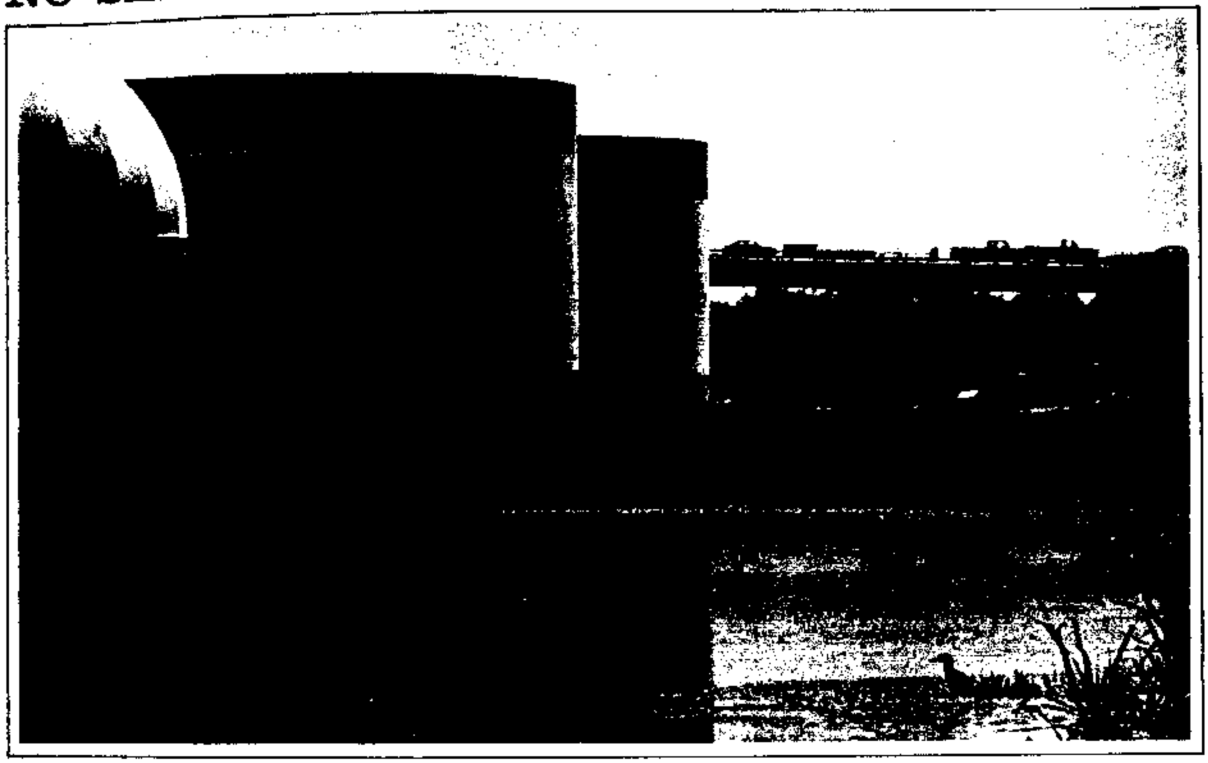
UW-Madison chemist Walter Blaedel is working on a new ASV technique that could be used by researchers in the field. Instead of mercury, Blaedel's technique involves using an electrode made of porous, sponge-like carbon material that is formed into small plugs. These fit into a portable, battery-powered apparatus that scientists can carry with them on research trips. Eventually, Blaedel would like to see his system refined so that it could be placed in the water and left there to record heavy metal contaminant levels automatically.

These Wisconsin Sea Grant projects are providing information on the increasingly important problem of heavy metal contamination of the Great Lakes.

Joseph Wang of the UW-Madison Chemistry Department makes adjustments on a new ASV instrument he and Walter Blaedel have developed. The device is meant to enable scientists to analyze water samples in the field for low concentrations of heavy metals.



OIL: NO SLICK SOLUTION



Oil spills and petroleum pollution are generally considered to be a problem of the world's oceans, not the Great Lakes. But oil traffic on the Great Lakes, as in the rest of the world, has grown dramatically in recent years. The Great Lakes ports at Toronto, Detroit, Indiana Harbor and Sarnia have become centers for a thriving commerce in crude and refined petroleum products.

There have not been any oil tanker accidents on the Great Lakes to compare to the 1976 breakup of the *Argo Merchant*, which spilled nearly 24,000 metric tons of oil off the coast of Massachusetts, or the *Amoco Cadiz*, which dumped almost 205,000 metric tons of petroleum into the waters off France's Brittany coast in 1978. And no incident in the Great Lakes compares to the oil drilling rig accident in Mexico's Bay of Campeche, that sent 20,000 to 30,000 barrels of oil a day into the Gulf of Mexico throughout the summer of 1979.

And yet there may be *1,400* times as much oil per unit of water in the Great Lakes as in the world's oceans. Furthermore, these freshwater seas may be especially sensitive to oil pollution, according to Wisconsin Sea Grant specialist J. Philip Keillor.

Keillor estimates that more than 134,000 metric tons of oil reach the Great Lakes each year—most of it from urban runoff and in municipal wastewater. He says such chronic discharges of oil into the Great Lakes pose significant ecological risks.

In Keillor's view, the Great Lakes may be particularly vulnerable to oil pollution because the lakes' bays and channels are like big bathtubs and offer little room for the gradual dispersal of oil before it affects the shorelines. In addition, the cold temperatures of the Great Lakes slow the degradation of petroleum compounds and prolong their toxic effects. Also, the cleanup of wintertime spills can be hampered by ice.

From government and industry records, Keillor found that in tonnage, petroleum is the fourth largest commodity shipped to and from U.S. Great Lakes ports (more than 6 million tons are shipped between U.S. ports each year), and Canadian shipments slightly exceed the U.S. level.

Keillor believes some new developments in petroleum commerce on the lakes could have long-range pollution potential. Small tankers in the 30,000-barrel range are being scrapped in favor of tankers which carry up to 100,000 barrels of oil. These larger tankers present the possibility of larger, more catastrophic spills. On the other hand, Keillor has found that, to date, most oil spills occur in the form of small, chronic spillage in harbor operations —which suggests that the fewer loadings required by large tankers may result in less harbor contamination. Yet spills from tankships and tank barges for 1976 and 1977 were up significantly (52 in 1976, 28 in 1977) over those of the previous three years, during which the average was 21 spills per year.

Keillor is also concerned about a trend to tanker barges. High winds and waves can easily break lines from tugboats, leaving barges adrift and at the mercy of a storm. Tanker barge spills off the Cleveland and Milwaukee harbors in 1975 and 1976 graphically demonstrated this risk.

The Sea Grant researcher has made his research information available to Michigan and Wisconsin officials, the U.S. Coast Guard, Canada's Environmental Emergency Branch, and the U.S. Fish and Wildlife Service. The latter agency is especially interested in the potential number and effects of oil spills that might occur if Great Lakes navigation becomes a year-round operation—a possibility now under study by U.S. and Canadian authorities.

In related research, UW-Madison water chemists Anders Andren and David Armstrong are investigating the extent to which petroleum hydrocarbons have contaminated Lake Michigan's southern basin.

"We know for sure this is happening near Indiana Harbor," says Andren, "but we want to see if we can detect it further out."

Basic to this quest is the need to distinguish between naturally-occurring hydrocarbons and those introduced by human activity. Andren notes that there is no standard way to analyze hydrocarbons in sediments. With graduate student Paul Doskey, he set about establishing ways to sample and analyze sediments in Lake Michigan. In August 1978, Doskey and other researchers collected lake bed samples from five locations in the southern lake basin.

"Our first objective will be to see whether petroleum hydrocarbons have contaminated sediments in areas other than the industrial ports of Chicago and Indiana and nearby regions of the lake," says Andren.

The research team brought back box-shaped "cores" about one quart in volume. Preserved by refrigeration, these cores will be sliced into horizontal layers and analyzed. The lower strata will represent the older sedimentary deposits in the lake bed.

"We are far from identifying the thousands of compounds in petroleum," says Andren. But in the last

A U.S. Coast Guardsman uses a suction hose to vacuum up oil spilled from a barge that went aground in Lake Michigan near the Milwaukee shore.

few years, he notes, researchers have developed gas chromatographic techniques for detecting polynucleated aromatic hydrocarbons (PAHs).

Because many are carcinogenic, PAHs are an important class of compounds. They may also be good indicators of oil pollution because they are constituents of many refined oil products, Andren says.

The relative abundance of Carbon-14 and Carbon-13 in samples can reveal the age of a petroleum deposit. The ratio of such hydrocarbons as pristane and phytane can also indicate the relative age of the petroleum deposits. Phytane, for example, is known to be abundant in ancient sediments; pristane is generally associated with more recent deposits.

Oil may be a significant Great Lakes pollutant, at least in and near harbors, and both Andren and Keillor regret the lack of research on how it affects Great Lakes fauna. Research on ocean oil spills indicates that petroleum compounds can interfere with fish spawning and kill bottom-dwelling organisms. In the Great Lakes, aquatic animals are already contending with eutrophic conditions and microcontaminants in the lower lakes and with cold, nutrient-poor waters in the upper lakes. In these stressed environments, petroleum contamination may represent an excessive burden.

John Lech, toxicologist at the Medical College of Wisconsin in Milwaukee, has examined how fish take up and transform two hydrocarbons characteristically found in fuel and lubricating oil—naphthalene and 2-methylnaphthalene. These and other hydrocarbons have been found in lake trout caught in the open waters of Lake Superior and Lake Huron.

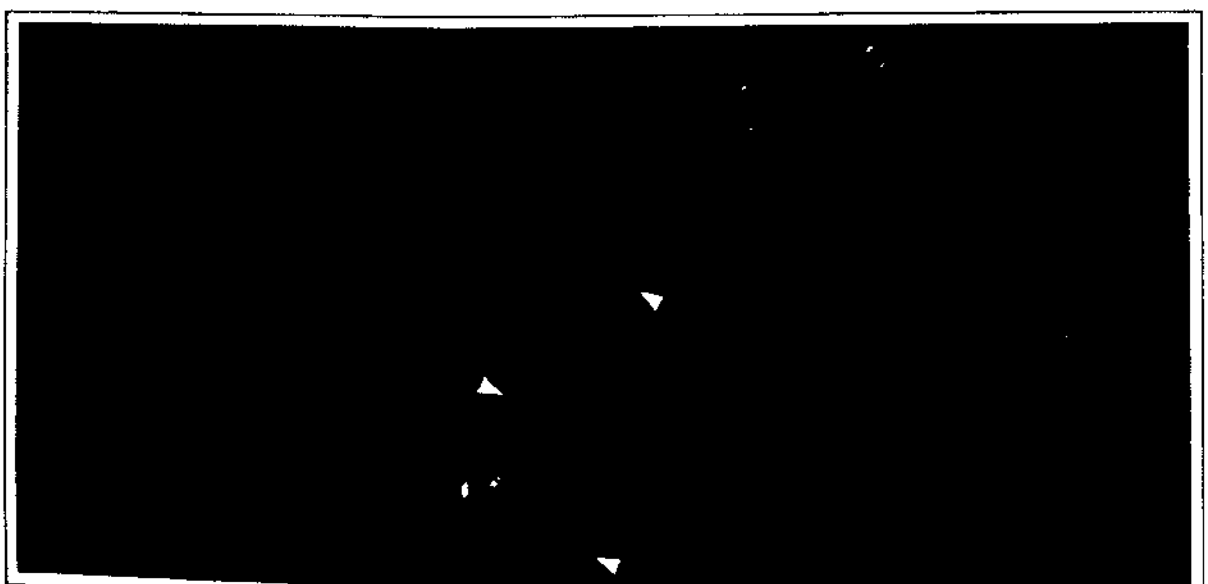
Lech exposed young rainbow trout to naphthalene for eight hours in the laboratory. He found that they concentrated the compound in their tissues at levels 20 to 100 times higher than those in the water and concentrations in fat and bile were several hundred times higher. These concentrations declined rapidly, however, once the contaminant was removed. The fish eliminated half of the dosage in less than 24 hours, and the remaining levels declined by half over ensuing 24-hour periods.

Longer exposure to these substances resulted in even greater uptake. Following four weeks of exposure, concentrations in bile were 13,000 times for naphthalene and 23,500 times for 2-methylnaphthalene the concentration of surrounding waters.

While the Great Lakes may never experience an oil spill anywhere near the magnitude of large ocean spills, smaller spills in the lakes are constantly exposing aquatic life to chronic contamination from petroleum compounds.

Keillor and other researchers believe the potential for serious environmental damage illustrates the need for improved oil recovery equipment as well as more research on the effects of chronic low-level exposure on lake organisms.

An oil boom curves around the barge in an only partially successful effort to keep the leaking oil (lighter areas) from drifting out into Lake Michigan.



RECENT RESEARCH PUBLICATIONS

Listed below are recent journal articles, papers, Master's theses and Ph.D. dissertations resulting from water quality research conducted by investigators funded by the University of Wisconsin Sea Grant College Program.

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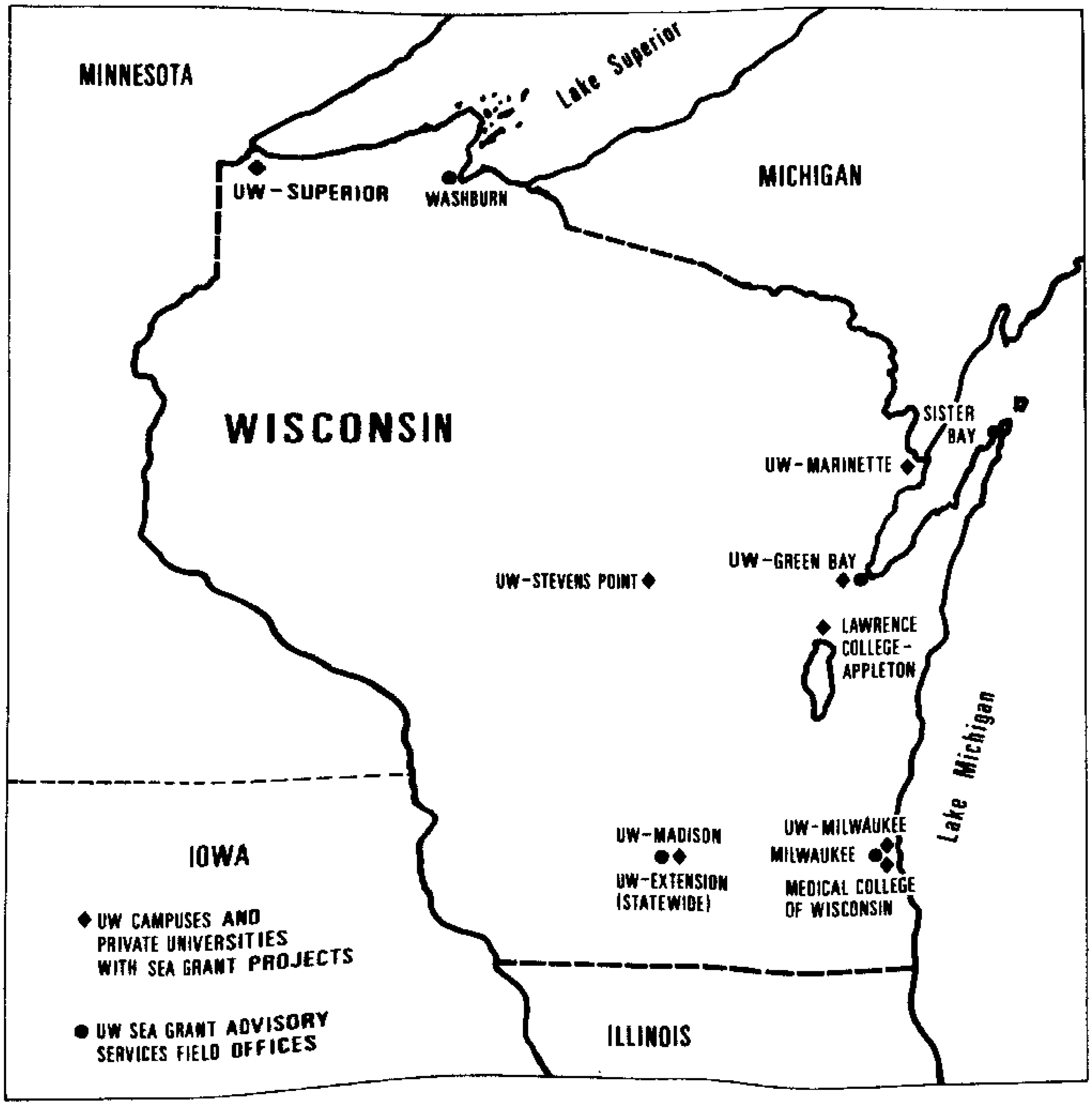
THE UNIVERSITY OF WISCONSIN SEA GRANT COLLEGE PROGRAM

While the University of Wisconsin Sea Grant Program is widely recognized for its work on contaminants, these studies make up only one of several major program research areas. Other subprograms include Living Resources, Aquaculture, Green Bay, Policy Studies, Coastal Structures and Erosion, Diving Physiology, Ocean Engineering, Advisory Services and Education. Here is a brief description of each subprogram, followed by an individual listing of current and recently completed projects. The map below shows the campuses involved in Wisconsin's Sea Grant Program and the location of the program's field offices.



LIVING RESOURCES

The chartered carferry maneuvers into position. At a signal, thousands of lake trout yearlings are shot over the side through large hoses and into Green Bay. Three SCUBA divers bobbing in the cold, choppy water disappear as they follow the stunned young fish to the bottom.

In this watery undertaking, Sea Grant scientists, in cooperation with government agencies and fish hatcheries, are trying to get to the bottom of a vexing mystery: Why aren't once-abundant lake trout successfully spawning in Lake Michigan?

The researchers were hoping to find a partial answer 30 feet down on Horseshoe Reef, a historic trout spawning ground in central Green Bay. The biologists and divers thought the fingerlings might remain long enough on the reef to pick up sensory cues of sight, smell and currents that would lure them back to that site to spawn in four or five years. If successful, this and similar plantings at other sites could help to reestablish natural spawning by this valued sport fish.

Lake trout are not the only native fish that once knew better days. In the last century, Lake Superior's whitefish were caught in large numbers with a standard six-inch mesh net. Today, the fish are generally smaller and so are the catches – due to the mid-century onslaught of the parasitic sea lamprey.

With the lamprey now under control, the harvest of whitefish shows occasional rebounds. But with such unpredictable boom and bust cycles, where is the fishery headed?

UW-Stevens Point biologists have been probing for the answer, recently tagging and analyzing over 6,000 fish over a three-year period. To encourage the cooperation of fishermen, the researchers offered bounties of $1 to $10 for each tag returned. The response was tremendous, with tag returns topping 1,500 in the third year alone. Personal contact and a growing appreciation for the research also helped, the scientists feel.

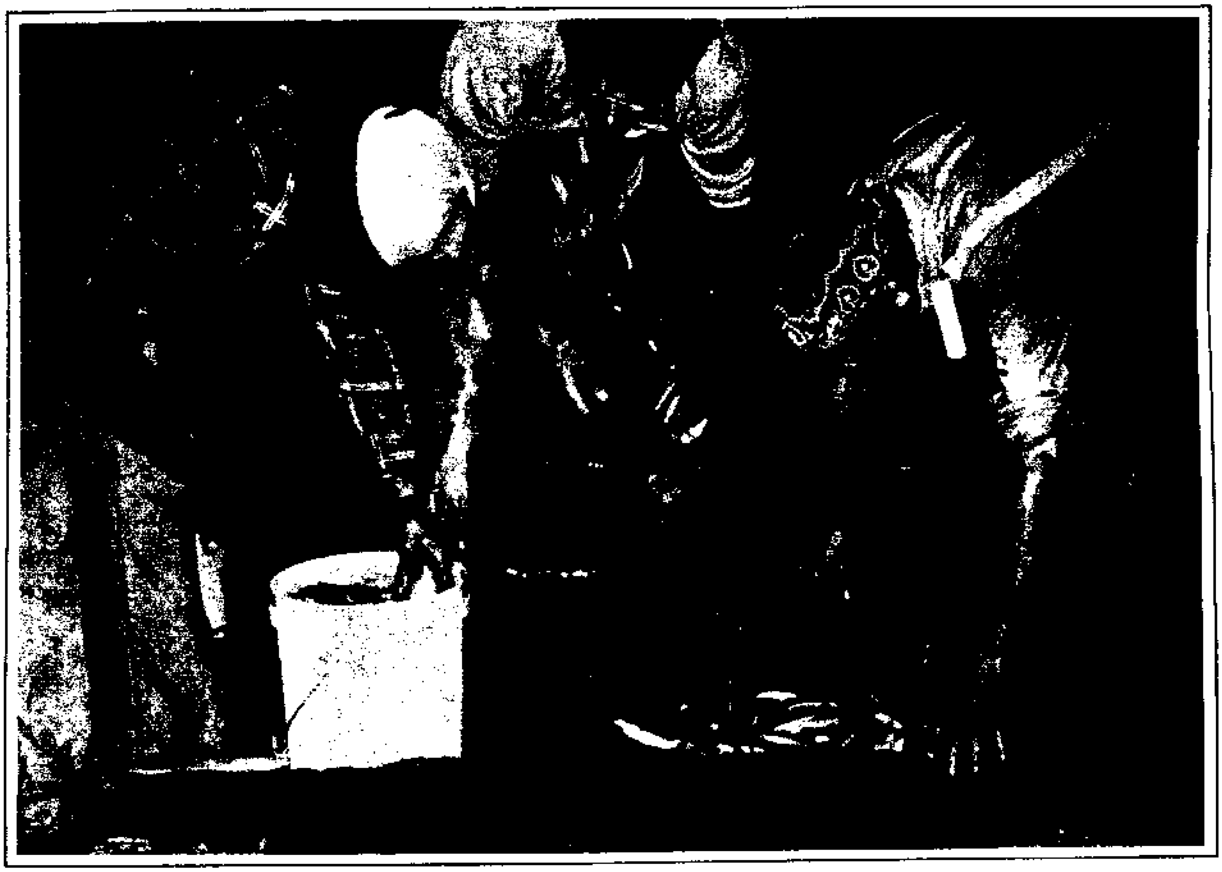
While fishermen earned a few extra dollars, the biologists believe they gained useful information on two population strains of whitefish in Green Bay and northern Lake Michigan. They found that the more important strain spawns in North Bay and Moonlight Bay, which are adjacent bays on Door Peninsula's eastern shore. The tagging revealed that this one population contributes more than 75 percent to Wisconsin's whitefish catch. The biologists believe it is essential, therefore, to protect these fertile coastal waters from pollution, dredging or other harmful developments.

A diver inventories aquatic animals found within a sampling ring on a reef near Lake Michigan's Door Peninsula where lake trout once spawned.

In Lake Superior, a research team works even more closely with local fishermen. The target for both is the lake's under-harvested, yet abundant, populations of smelt.

Because smelt feed after dark and near the surface, scientists in their research vessel – an old, converted tug – often meet fishermen on the lake at night. Both the research vessel and the fishing boats use sonar equipment to locate smelt concentrations, and such information is frequently shared, to the benefit of both parties.

Through these experiments, as well as more basic studies of the smelt and their habitats in the western half of Lake Superior, the scientists intend to prove that a neglected fishery can be tapped to produce more food and provide more jobs.



Scientists check a trawl net for smelt during a nighttime research expedition on Lake Superior.

Other Sea Grant researchers are assessing alewife populations in Lake Michigan, examining the potential of white suckers as a food source, studying the feeding behavior and growth of yellow perch in Green Bay, and documenting the biological role of plankton – the microscopic plants and animals that are a vital source of food for fish.

Much of this information is being assimilated in a mathematical model, which researchers developed in an effort to approximate the dynamics of fish growth and predation in the lakes. In one application, the model reliably predicted the uptake and retention of PCBs by yellow perch over a period of years.

PCBs have been a chronic problem for Great Lakes fishermen, a problem aggravated by a recent decision by the U.S. Food and Drug Administration to reduce by more than half the maximum level of PCBs allowed in fish sold commercially. Those standards could reduce the marketable fish harvest in Wisconsin's Great Lakes waters from 48 million to two million pounds annually. Sport fishing might also be adversely affected by the negative publicity of unsafe fish.

In response to the toxic substances issue, Sea Grant researchers are developing a model to assess different strategies to manage the Lake Michigan fishery while minimizing the problem of PCB contamination. That project, as well as another project concerned with assessing the benefits and costs of sea lamprey control and salmonid stocking, are intended to help restore the fishery ecosystem while rehabilitating the commercial fishing industry on the lake.

Focusing on the human aspects of the fisheries, Sea Grant economists are developing an economic profile of Wisconsin's commercial fishermen. This information is being made available to agencies charged with regulating many conditions of the fishing trade.

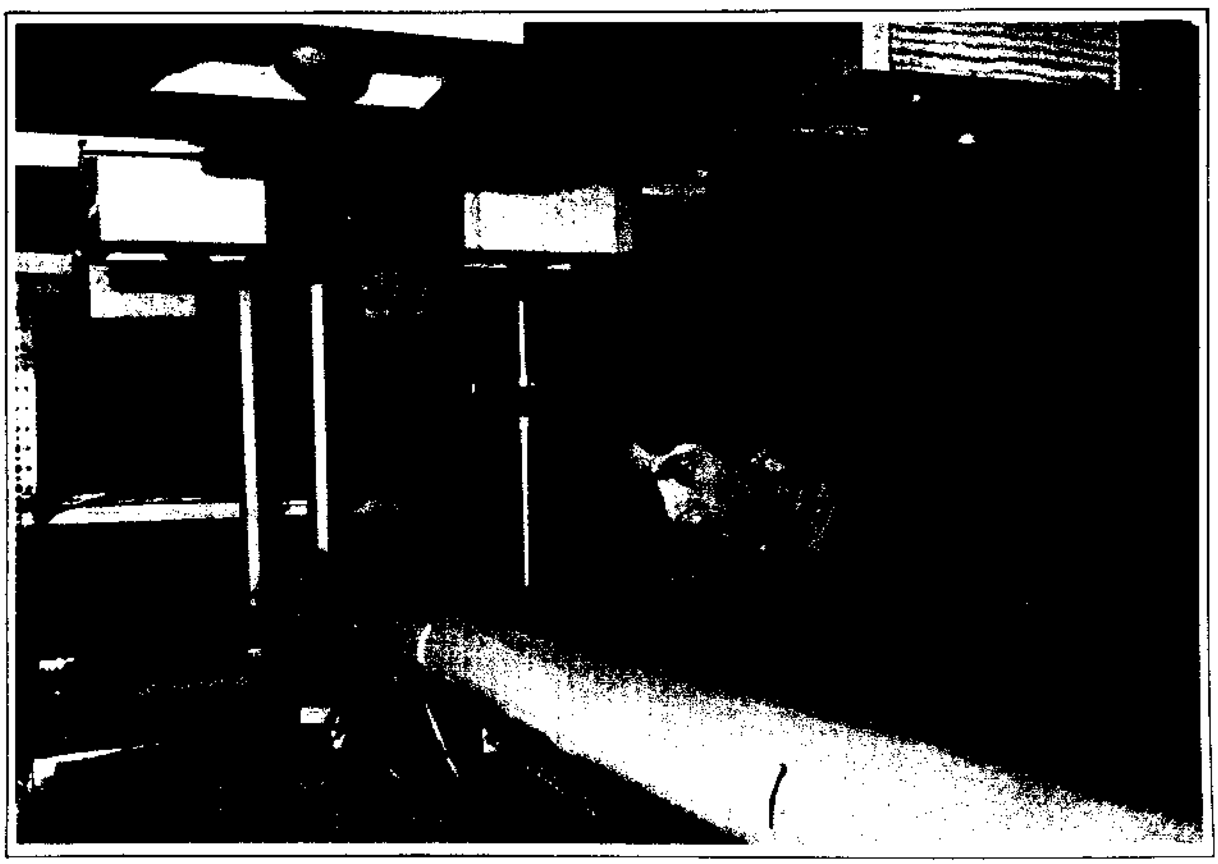
Although the financial outlook for Great Lakes fishermen has not been bright, it is getting better. The reopening of the Lake Michigan chub fishery in 1979, for example, was encouraging – suddenly, it seems, the issue has become not what other work is available to the chub fishermen, but how they would divide the 900,000-pound chub quota.

Experimental filtration system at UW-Madison's Aquaculture Research Laboratory (top). Laboratory technician Bill Manci feeds perch fingerlings small amounts of ammonia and nitrites to see how they affect growth (bottom).

The Great Lakes once held what was thought to be an inexhaustible supply of fish. In Wisconsin, the tradition of Friday night fish fries—with yellow perch the usual entree—grew out of this abundance. But overfishing, pollution and competition for food with invading alewives took their tool on the perch population, and today the demand for perch greatly exceeds the supply.

To help ease this shortage, University of Wisconsin researchers are developing techniques for raising yellow perch in tanks under controlled environmental conditions—a system called aquaculture. They are also looking at freshwater aquaculture in a broader sense—to see what role it might play in the future of the Great Lakes fisheries.

In one form or another, aquaculture has been practiced for centuries. But growing perch in an artificial environment presents many problems. One is the water itself. The most practical approach seems to be to recycle water continuously through an aquaculture system. But the electrical and heating costs of recycling are high, so chemical engineers are working to develop a more economical system.



Water in present recirculating systems also picks up small amounts of ammonia and nitrite from waste filters. These toxic chemicals retard the growth rate of fish and could, in concentrations high enough, be lethal. Researchers are exploring how much ammonia and nitrite water can contain and still support healthy, fast-growing fish. The next step will be to design filters to maintain water quality within those levels.

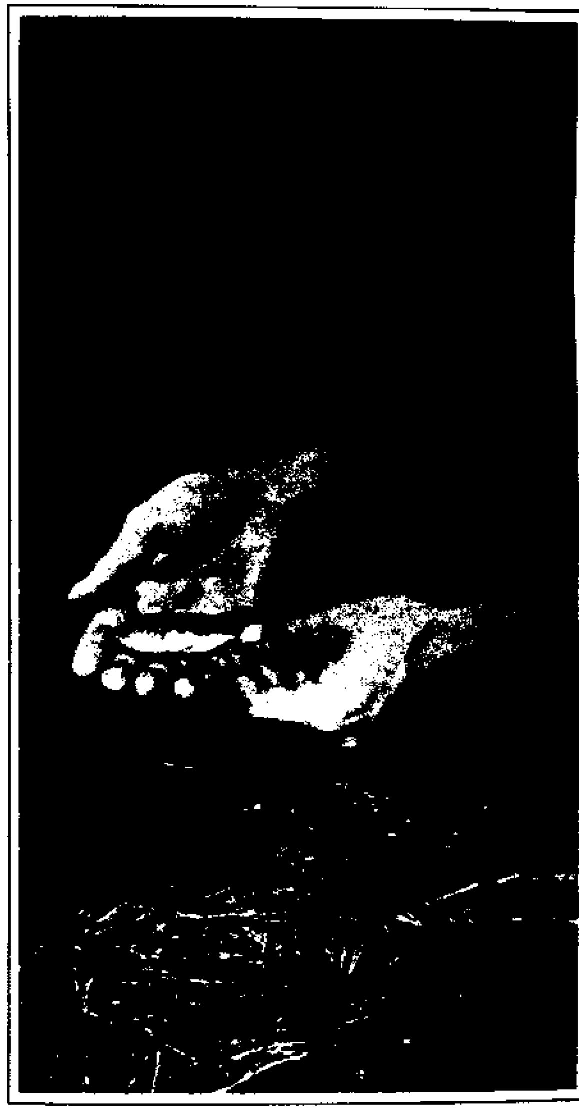
Another problem is what to feed the fish. Perch seem to fare best on a formulated diet composed mainly of fish meal. But this diet is becoming expensive and difficult to obtain, so scientists are searching for a diet that will produce rapid growth at the least cost. To do this, investigators are determining the energy requirements of perch and experimenting with different diets to find out how much energy the fish use to digest various feeds. Among other things, they hope to develop a feed that will approximate the perch's diet in nature.

Securing a reliable supply of brood stock is another challenge. While techniques for the artificial insemination of warm-blooded animals have been used for a long time, they are new to the fish world. Two UW-Madison scientists, however, have succeeded in freezing fish sperm for as long as six weeks. They expect to eventually be able to preserve the sperm for even longer periods. With artificial insemination, aquaculturists will need a smaller supply of brood stock and will be able to breed the fish at any time of the year.

Through cross-breeding and selection, researchers are also working to develop a strain of perch that is suited to aquacultural conditions. A critical phase of perch aquaculture is the period of growth from the larva to the fingerling. Young perch transferred from the wild don't fare well in tanks, and raising perch from larvae isn't practical because no artificial food source can compare with natural sources.

The present alternative—now used at the UW Aquaculture Research Laboratory—is to grow perch in ponds during this critical larval stage. The ponds are fertilized and then stocked with fish eggs in the spring. After the eggs hatch and grow to fingerling size, the ponds are drained and the fish are transferred to tanks.

Although perch aquaculture is still a borderline operation economically, some pioneers are now raising perch in tanks. Most of these operations are small and experimental, but the product is good. Taste tests show that aquaculture-raised perch taste as good as—or better than—wild perch. Nevertheless, the successful development of a large-scale aquaculture industry in the region will depend on the collaboration of private enterprise, government agencies and university researchers.



Perch fingerling reared in fingerling production pond at one of the UW-Madison's agricultural experimental farms.

GREEN BAY

Fishing ground, transportation artery, industrial workhorse, recreation area—Lake Michigan's Green Bay is one of the nation's most heavily used and most productive waterways.

At the same time, this resource suffers from a familiar list of ailments: pollution from municipal and industrial waste, eutrophication, the pressures of shoreline development.

In line with a renewed effort to clean up the waterway and restore its fisheries, the University of Wisconsin Sea Grant Program in 1978 launched a major, 10-year research program on the bay and its watershed. The program aims to fill in gaps in current knowledge about the bay's physical, chemical and biological systems, and to translate the results of that research into a form useful for making decisions about the bay's future.

Involved in the effort are biologists, chemists, geologists, oceanographers, economists, engineers and social scientists from UW campuses in Madison, Green Bay, Stevens Point and Milwaukee, and from Lawrence University in Appleton.

A key part of the research program is to study the ecology of Green Bay's west shore marshes, which represent an estimated 80 percent of all of Wisconsin's Great Lakes wetlands.

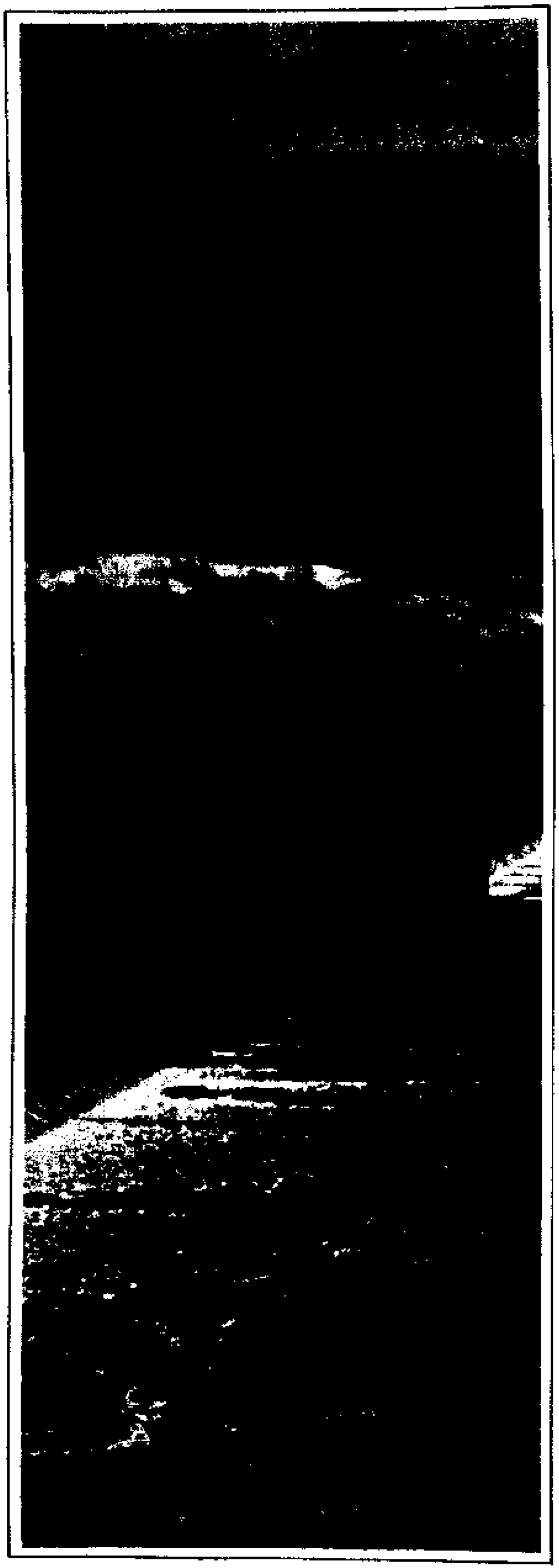
Among other things, these marshes are important as fish spawning grounds and as habitat for rare bird life. Researchers are studying the relationship between vegetation, bird life and changing water levels in the hope their work will help government agencies design better ways to manage and protect these critical wetland resources.

Other researchers are looking for ways to improve the management of the bay's fishery—the most productive on Lake Michigan. Projects focus on the growth and distribution of various fish, including yellow perch, a staple of Green Bay's commercial fishing industry; whitefish, Wisconsin's most valuable commercial species; planted lake trout, which have failed to reproduce naturally in Lake Michigan, and sucker, a potential target for commercial fishermen.

Equally critical to the future of the bay is its water quality, which is imperiled by industrial discharges and runoff from rural lands in the watershed.

One Sea Grant investigator is examining land use practices in the bay area with an eye toward

Green Bay perch fisherman Everett Marks, heading for home.



Industrial clean-up of the Fox River is improving Green Bay's water quality (left). UW-Green Bay students use a seine net to capture perch fingerlings in one of the bay's fish nursery areas (below).

developing proposals for reducing the runoff of nutrient-rich sediment.

Another researcher is working to improve techniques for mapping land use in the bay's watershed with airborne cameras and remote sensing devices. These techniques, in turn, will be plugged into a Department of Natural Resources computer model to assess the impact of pollution from diverse "nonpoint" sources such as farmland runoff.

Yet another scientist is examining the fate of some 35 tons of arsenic seeping into the bay each year from an industrial waste dump on the Menominee River.

To provide a bridge between the research aspect of the program and the community, a planning workshop was held at the UW-Green Bay campus in the fall of 1978. The workshop drew together about 100 Wisconsin, Michigan and Illinois representatives from universities, industries and government, who explored research needs and opportunities on the bay. From this workshop came several recommended research priorities that are being incorporated into this year's Green Bay program — among them circulation patterns and water transport in the bay and a toxic substances inventory for the Fox River and Green Bay.

POLICY STUDIES

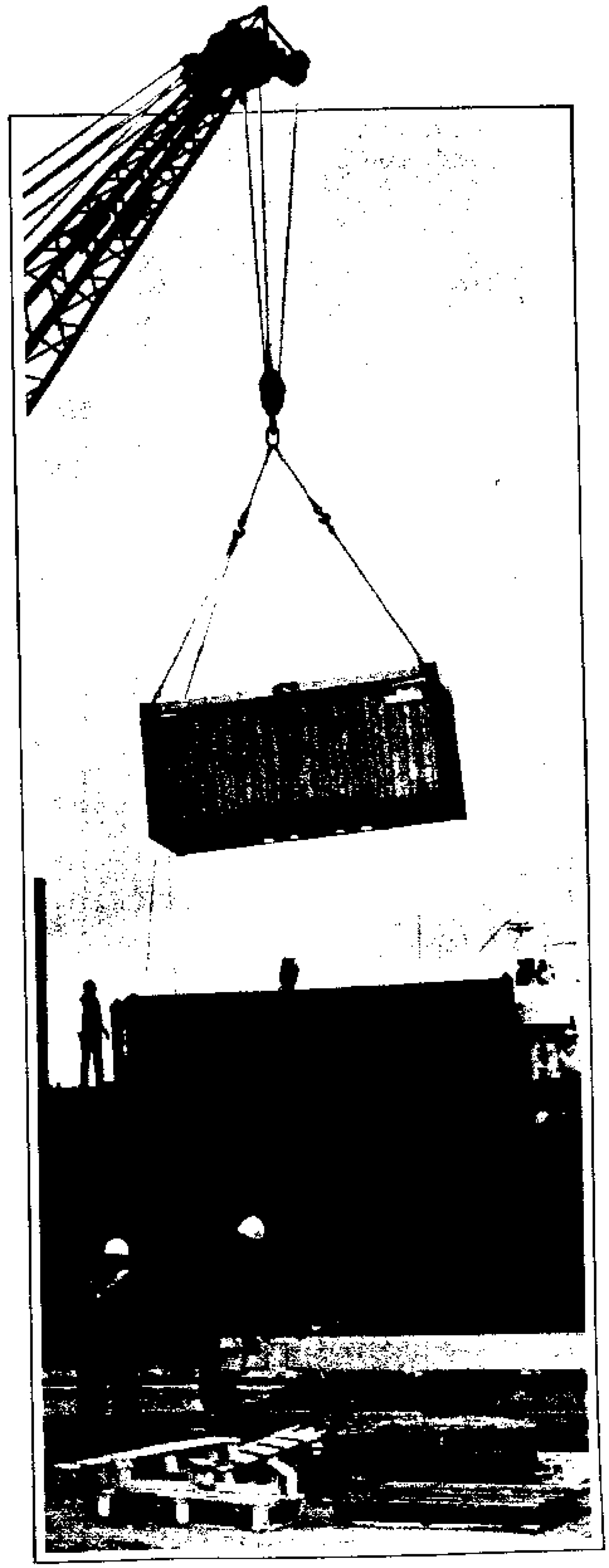
Protecting the Great Lakes is not simply a matter of controlling the discharge of polluting chemicals and wastes. It also means managing resources along the coastlines. Developing tools for effective coastal management has been a principal aim of several investigators in the Sea Grant Policy Studies area.

In one instance, researchers have pointed the way toward creation of a cadastre – a comprehensive record of land holdings. Designed to register such factors as land ownership, boundaries and environmental data, these records will be an invaluable help to agencies involved in coastal planning and an aid to shoreline property owners. Though applied initially to Racine County – which has taken preliminary steps to implement the idea – the cadastre concept is transferable to other areas as well.

Managing our coastal property effectively also depends on the participation of shoreline residents. In an effort to improve citizen involvement in coastal planning, Policy Studies investigators held a series of workshops in Kewaunee County. This is a predominantly rural area on the west shore of Lake Michigan that is under increasing development pressures. Several hundred citizens attended these workshops and responded to questionnaires developed by the investigators. They identified critical natural and cultural resources in the area and urged that the county become the focus for area-wide coastal planning. The techniques involved in this project are being used in several other counties as part of ongoing efforts to preserve farmland and coastal wetlands.

On another front, researchers have suggested that the state might be able to manage its Great Lakes resources more efficiently if it were to adopt innovative pollution control schemes. One proposal involves the buying and selling of pollution rights. Scientists have suggested, for example, that a system of transferable discharge permits could simplify the control of phosphorus entering Lake Michigan. They are now examining how this concept might be applied to water quality control along the Fox River.

Another water quality-related policy project focuses on the "Milwaukee Pollution Case." This 1977 court decision required metropolitan Milwaukee to comply with waste treatment standards much more stringent than those set by the federal government. The point of the study is to see what scientific evidence led the court to this conclusion.



The fate of the lakes' human resources has also concerned investigators. Along these lines, a group of Milwaukee researchers inventoried labor and management organizations in the Great Lakes-St. Lawrence Seaway system and found that larger ships and new technologies have made lakes sailors an aged, vanishing breed. In particular, the trend toward fewer, larger and more automated vessels has reduced the need for skilled crews.

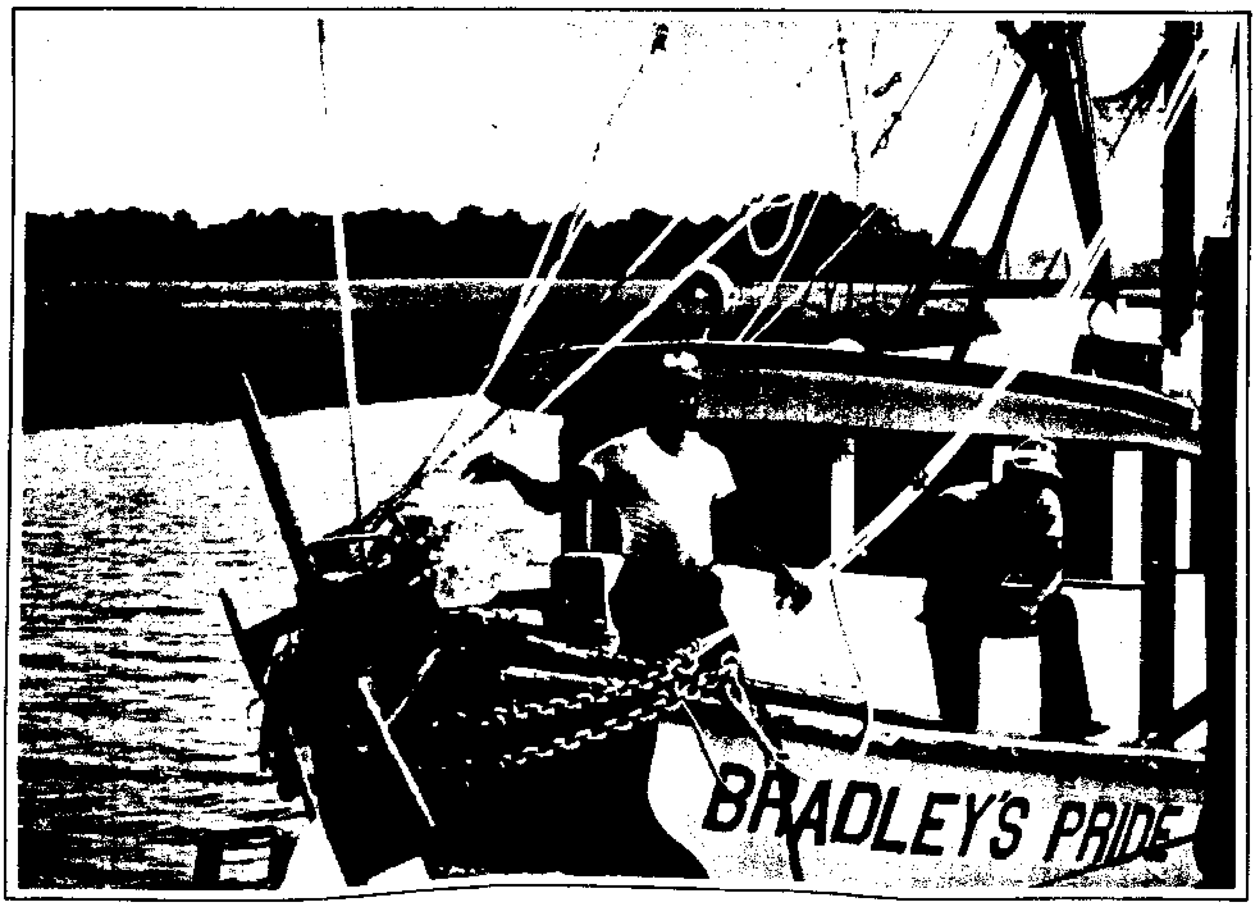
Partly in response to these findings, manpower planners are attempting to retrain and relocate displaced Great Lakes sailors. Other agencies, including the Coast Guard and the U.S. Department of Transportation, are also relying on the results of this study for their planning efforts.

Endangered resources of an unusual sort are the focus of two other projects. In one, an investigator is examining the relationship between the coastal environment and the people of the Sea Islands in South Carolina. This remarkably intact African culture is imperiled by changing technology and land development. Other researchers studying the relationship between cultural development and the ocean environment in waterfront communities should find this Sea Islands study both interesting and useful.

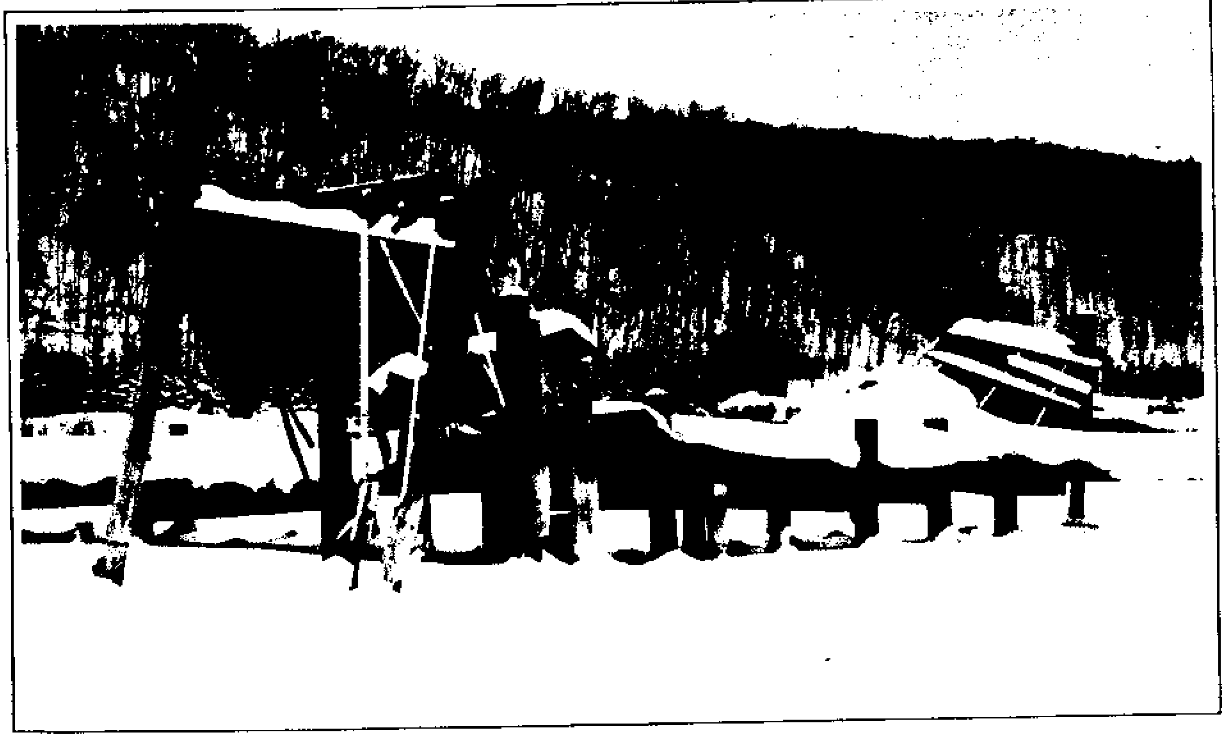
The second project is also designed to help protect a threatened cultural resource—Great Lakes shipwrecks. By looking at the resource itself, legal ownership patterns and what other states have done, investigators hope to make recommendations on alternative ways in which Wisconsin might preserve these invaluable archeological relics.

In the national/international arena, a noted legal scholar is exploring the implications of negotiations at the Third United Nations Law of the Sea Conference as they relate to global natural resources decisions. The investigator in this project, a UW-Madison law professor, has extensive experience in the study of international legal issues and has been asked to serve on an American Society of International Law panel studying nationalism and the marine environment.

Commercial fishermen on South Carolina's Sea Islands.



COASTAL STRUCTURES & EROSION



Ice damaged dock in Munising, Michigan.

Looking like a dilapidated roller coaster, the Munising marina dock stands twisted and distorted as a result of the awesome force of winter ice. Each year, shoreline ice bends iron railings, twists docks into crazy shapes and lifts pilings right up out of the lake bed, causing hundreds of thousands of dollars worth of damage along Great Lakes coastlines.

Allen Wortley, a University of Wisconsin-Extension engineer, has been trying to find solutions to this expensive problem. He has surveyed ice damage at nearly 100 Great Lakes marinas, including the one at Munising on Lake Superior, and has advised many marina owners on how to minimize ice damage.

As a result of his advice, some marina owners have installed bubbler systems that prevent ice from forming around their docks. These systems are expensive, however, each costing over $4,000 to install and more than $1,000 a year to operate.

Wortley has also prepared an ice engineering guidebook and sponsored conferences on ice and marina design for northern climates. One alternative he is investigating is a system used by the Scandinavians – floating docks. In Lake Superior's Bayfield Harbor, Wortley is testing three different types of commercially available floating docks to see how they hold up under severe ice conditions. So far, he says, these docks seem to withstand the stress and strain of Lake Superior ice.

Another problem plaguing those who live along the coast is the continual loss of coastal land and structures to erosion. The lakes have long demonstrated overpowering forces of erosion in this geologically young region. The red clay along the shores of Lake Superior and the glacial till along Lake Michigan are both vulnerable to runoff, seepage and to the clawing action of the surf.

In one project, UW-Madison geophysicists have explored the layers of glacial till that lie exposed in the clay-like bluffs along Wisconsin's Lake Michigan coastline. By examining soil properties in the laboratory, the researchers have been able to assess how vulnerable these bluffs are to erosion and to offer guidance to coastal planners.

Along Lake Superior, two UW-Superior botanists have catalogued plant life at 25 sites along the red clay bluffs from the western tip of the lake to the Bayfield Peninsula. Aerial pictures, old surveys and other historic records reveal that these bluffs have lost an average of two to three feet per year over the last three decades. The northern Wisconsin botanists seek to determine what plants provide the most effective anchors for the red clay soil.

Winter ice along the shore can cause shore erosion (below). A coastal resident uses concrete blocks and rubble to try and stop coastal erosion in Racine, Wisconsin (bottom right).

Although strong and deep root systems are desirable, the researchers conclude that to control erosion, roots must not extract too much water during dry periods. If the clay becomes too dry, it becomes brittle and fractures. When it rains, these cracks act as if they were greased, one face slipping against the other and exposing the soil to further erosion. The researchers hope to find vegetation that will not extract too much moisture and yet stabilize the bluffs, thus helping prevent the waters of Wisconsin's Lake Superior coast from turning blood red after a heavy rain as they do now.

In another project, researchers have analyzed eight sites along Lakes Michigan and Superior to assess factors influencing shoreline slope, vegetation, wave action and lake levels. Among other things, they have determined that rains and surface wash can be as important in causing bluffs to recede as other factors such as groundwater saturation.

Information from these projects will help coastal planners and engineers find the best erosion control techniques for various high bluff areas along the lakes.

In a related, retrospective look at the Great Lakes, UW-Madison climatologists are trying to correlate long-term climatic changes with water levels in Lake Superior. These historical trends offer possible insights into future lake levels and associated erosion in the lakes. Such information may also be of use in other research and in management policies that must consider the effects of different climate episodes.

To verify the region's climatic history, the researchers are examining published reports on tree rings based on corings from 122 sites in North America. They have also collected over 100 red and white pine corings at three sites in Michigan's Upper Peninsula. Many of these trees were over 250 years old.

The thickness of each ring indicates the annual precipitation in the region of the tree. From this evidence, the Madison scientists detect what appear to be sharp breaks in patterns of water supply to the Lake Superior basin in 1915, 1934 and 1953. An understanding of the characteristics of such climate episodes and causes will enable scientists to predict future lake levels more reliably.

None of these projects, of course, can hope to completely thwart the process of erosion. But Sea Grant research should help scientists to understand erosion's causes, enlist the natural defenses of shoreline vegetation and project the long-range effects of climate on lake levels and the resulting loss of shoreline.

DIVING PHYSIOLOGY & OCEAN ENGINEERING

Put a bicycle rider under water and you still have the same bicycle rider . . . Or do you?

Submergence affects the respiratory and circulatory systems of the human body. In such an alien environment, the body behaves differently. Even with a source of oxygen, it has to learn how to breathe differently to work at maximum efficiency and even to survive.

The changes the body undergoes under water are being tracked by Sea Grant scientists monitoring such things as air consumption, heart rate and blood pressure in human "guinea pigs" pedaling bicycles underwater.

This project at the university's Biotron is part of a major diving physiology program directed by Drs. Edward Lanphier and John Rankin of the Department of Preventive Medicine.

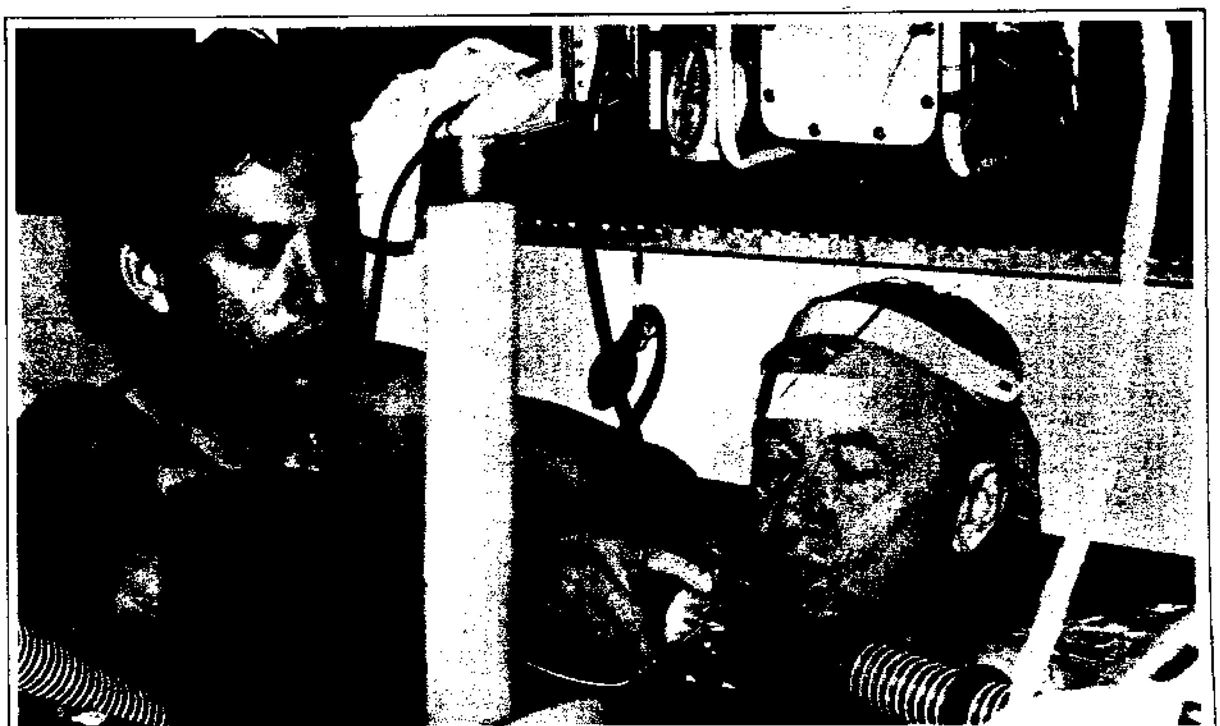
The information they develop may help determine the best position for the body in underwater work. It could also influence the design of diving emergency procedures and, as a side benefit, help medical researchers improve breathing techniques for chronic lung patients. Work is also progressing on how people retain carbon dioxide while diving underwater. Past research has shown that some people don't breathe enough air and thus tend to build up excess carbon dioxide, which sometimes results in fatal underwater accidents.

In addition, the researchers now have a pressure research chamber installed in the Biotron for use in animal and human studies on the effects of both high and low pressures. The investigators hope to develop new approaches to decompression and to determine how pressure can affect the fetus in pregnant women.

The whole program is aimed at making commercial and recreational diving safer and more productive. Other researchers have also been looking at ways to improve diving safety and performance.

In past work, Ali Seirig and a group of mechanical engineers developed a number of innovative

Volunteer Russell Stensrud (right) helps University of Wisconsin graduate student Shunsaku Koga determine how working underwater affects a person's heart rate and respiration.



devices for recreational divers, who now spend over $500 million a year on equipment. Patents have been applied for on new SCUBA equipment, diving regulators, rescue decompression chambers and other devices. The researchers have also developed a mobile underwater laboratory and a stable diving platform.

In current work, the investigators are creating equipment designed to minimize breathing resistance underwater and allow divers to re-breathe exhaled gases. And in a novel approach to recreational SCUBA diving equipment, new snorkel gear designed to work in deep and shallow water is being developed.

In a third ocean engineering project, UW-Madison engineer T. C. Huang is exploring ways to help Great Lakes freighters withstand the force of waves, vibrations, and other forms of stress.

The awesome power of these forces was illustrated by the 1975 sinking of the freighter *Edmund Fitzgerald* in Lake Superior. While the exact cause of this disaster remains a controversy, the ship's hull was found in two pieces on the lake bottom, suggesting that the ship broke up under stress.

Huang's correspondence with shipbuilders, naval architects and marine engineers indicates a need for better understanding of hull vibration under different wave conditions. With most new ships being designed by computers, Huang's three different computer models could lead to better design of Great Lakes freighters.

Pigmy goats (above) and pregnant sheep (below) are being used in decompression experiments at the UW-Madison Biotron's hyperbaric chamber.

ADVISORY SERVICES & COMMUNICATIONS

Col. Ben Chapla (right) and Robert Videkovich take measurements along a Racine County bluff as part of the Coastwatch project.

The dangers of chemical pollutants in water and fish . . . Ways to revitalize the Great Lakes fisheries and make better use of neglected species of fish . . . The feasibility of growing fish in man-made environments and of retrieving valuable metals from the ocean floor . . .

All such knowledge resulting from university research is of little value unless it reaches those people who need it. This is the function of Sea Grant Advisory Services and Communications.

With workshops, publications, personal contacts, radio programs and films, Advisory Services and Communications carry the information developed by Sea Grant researchers and other sources to a whole spectrum of audiences—industries, government agencies, schools, other universities, citizen groups and the general public.

The chief function of Advisory Services is to arrange and conduct technical assistance, conferences, workshops and public information programs on a local, regional, state and sometimes national level.

This program was recently expanded with the creation of field offices in four strategic locations on the Wisconsin coasts of Lakes Superior and Michigan. Sited at Washburn, Green Bay, Milwaukee and Sister Bay, Sea Grant representatives reach out to provide technical assistance to area fishermen and other Great Lakes user groups. They also supply marine-related information to local schools, civic groups and the general public.

Sea Grant Advisory Services also arranges for assistance to the public from university specialists in engineering, aquaculture, food science and fisheries. Through workshops on deep sea mining, toxic substances and fisheries research, the Advisory Services staff has acted as a switchboard channeling research and policy information to commerical fishermen, industry representatives, scientists and government officials.

A special project involving Advisory Services personnel is the Coastwatch project. Sponsored by the Wisconsin Coastal Management Program, a group of local citizen volunteers is monitoring shoreline processes in Racine County. This project is providing information to coastal planners who are developing criteria for regulating shoreline development and use in erosion-prone areas.

Aquaculture, or fish farming, is an area of Sea Grant research that has generated such widespread interest that, in the fall of 1977, Sea Grant opened a new Aquaculture Research Laboratory. Here yellow perch are grown in tanks in a controlled environment. More than 1,000 people have been taken on tours of this facility by Advisory Services personnel to see how a fish farm might be set up and operated in Wisconsin's environment.

Another example of assistance involves the fishing industry. Advisory Services food scientist David Stuiber has helped some fish processors modify their operations to correct sanitary problems and deal with fish wastes by converting those wastes into a liquid fertilizer for house plants. Now the wastes are disposed of safely while providing the processors with a new product line.

Door County Sea Grant specialist Lynn Frederick helps commercial fishermen Dennis and John Hickey make minced sucker patties using equipment borrowed from food science professor David Stuiber (top). Sea Grant coastal engineer Phil Keillor drives a marker stake into a Racine County bluff as part of the Coastwatchers shore erosion project (bottom).

Stuiber is also developing new uses for long-neglected species of Great Lakes fish. He has found that, with the help of smoking and spicy sauces, alewives can be made into a tasty product similar to sardines; with the aid of vegetable fat and sweet corn, suckers can be breaded and used as minced fish cutlets.

On a regional level, Sea Grant representatives participate in the Great Lakes Network, a coalition of Sea Grant people from the Great Lakes states. As part of this program, Advisory Services co-sponsored a fisheries conference in late 1977 to map out long-range policy considerations for managing the Great Lakes fisheries.

On the national level, the Wisconsin Advisory Services Division hosted a national workshop on toxic substances in aquatic environments in July 1979 and coordinated the ninth and tenth Underwater Mining Institutes in fall of 1978 and 1979. In recent years, this annual meeting has focused primarily on the legal, economic and technical challenges of mining the ocean floor for its golfball-size manganese nodules.

The Communications Office is another part of Advisory Services, producing and distributing a wide range of publications and public service programs based on Sea Grant work.

A total of 46 new publications were produced by the Communications Office in 1977-78 alone, and more than 100,000 copies of all Wisconsin Sea Grant publications were distributed. These publications range from technical reports for use by scientists and engineers to simplified, down-to-earth publications for school children and the general public.

UW-Sea Grant's newest publication is *Around the Shores of Lake Superior: A Guide to Historic Sites.* This 180-page book, written by two UW-Extension historians, takes its readers on a 1,000-mile journey around Lake Superior, identifying and describing 113 sites of historic or scenic interest along the way. The book is being distributed by University of Wisconsin Press.

In cooperation with the University of Wisconsin-Madison Institute for Environmental Studies, Sea Grant also continues to produce *Earthwatch,* a daily, two-minute radio program about the Great Lakes, science and environmental issues. The award-winning program is broadcast by about 100 stations in six Great Lakes states and is heard by an estimated four million people, making it the largest public service program produced in Wisconsin.

In addition, the Sea Grant Communications Office distributes films and slide shows, issues press releases and prepares pamphlets and brochures for the program. The staff's public relations role sometimes takes a more direct approach: At the 1979 Wisconsin State Fair, more than 100,000 people visited the Sea Grant staff's Great Lakes fisheries exhibit and examined materials about PCBs, smoking fish, fish recipes and the Sea Grant Program in general.

EDUCATION

People are the ultimate users and beneficiaries when marine resources are developed and utilized—and the ultimate losers when these resources are abused. Whether they are policymakers, resources managers, technicians, private entrepreneurs or simply members of the general public, people need to know about marine resources, how they are developed and what their limits are. This is the business of education.

An integral part of the University of Wisconsin Sea Grant College Program, marine education takes on many forms. Sea Grant supports education in several ways—through financial assistance to students, funding new courses and special lectures on the Great Lakes and oceans, providing educational publications, and supporting field research, educational travel and seminars on marine topics for college students.

About 50 graduate and scores of undergraduate students are financially supported, directly or indirectly, by the UW Sea Grant Program. Many more students are involved in Sea Grant work/study programs and Sea Grant-supported courses and other educational activities. With Sea Grant support, graduate students who have made significant research contributions participate in national scientific meetings and symposiums. Five exceptional graduate students are receiving special research assistantships.

Sea Grant education funds have also been used to support a "Problems in Oceanography" course at UW-Madison and to send students in the class to Sapelo Island, Georgia, for oceanic experience.

With partial support from Sea Grant, 17 Advanced Botany students were sent to San Salvador, Bahamas, for a field study of marine algae of the Caribbean Ocean in 1978.

Several lecture series and a few special lectures have been supported, too. Among them were a guest lecture seminar for the UW-Madison Water Chemistry Program and a nine-lecture series about Sea Grant research held on three UW campuses. One of the more recent special lectures was a discussion of the new 200-mile national fishing zone by Dr. Brian Rothchild of the National Oceanic and Atmospheric Administration.

Other Sea Grant education projects have introduced Milwaukee inner-city youth to Great Lakes issues, sent Sister Bay and Green Bay students out on the R/V "Aquarius" to witness Lake Michigan field research firsthand, and provided field trips to Lake Superior wetlands for Washburn area students.

In an effort to help teachers integrate environmental studies into their curricula, the Sea Grant communications staff produced and distributed *An Educator's Guide to Great Lakes Materials,* which describes Great Lakes-oriented books, films, maps and pamphlets available for classroom use.

In addition, Sea Grant has joined with the UW-Madison Institute for Environmental Studies in developing a tabloid called *Earthbeats* for junior and senior high school students. The first two issues, which focused on the Great Lakes and energy resources and conservation, are now in use in classrooms throughout Wisconsin.

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Total Mercury Residues in Livers and Eggs of Oldsquaws. Steven R. Peterson and Robert S. Ellarson. WIS-SG-77-375.

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Species Interactions in Percid Communities. James Maclean and John J. Magnuson. WIS-SG-78-390.

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Sardine-Like Products from Lake Michigan Alewives (Alosa pseudoharengus). L. H. Hicks, D. A. Stuiber, R. C. Lindsay and V. L. Carlson. WIS-SG-78-393.

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Homing of Rainbow Trout Translated in Lake Michigan: A Comparison of Three Procedures Used for Imprinting and Stocking. A. T. Scholz, C. K. Gosse, J. C. Cooper, R. M. Horrall, A. D. Hasler, R. I. Daly and R. J. Poff. WIS-SG-79-395.

Preliminary Observations on the Sperm of Yellow Perch. Steven D. Koenig, T. B. Kayes and H. E. Calbert. WIS-SG-79-396.

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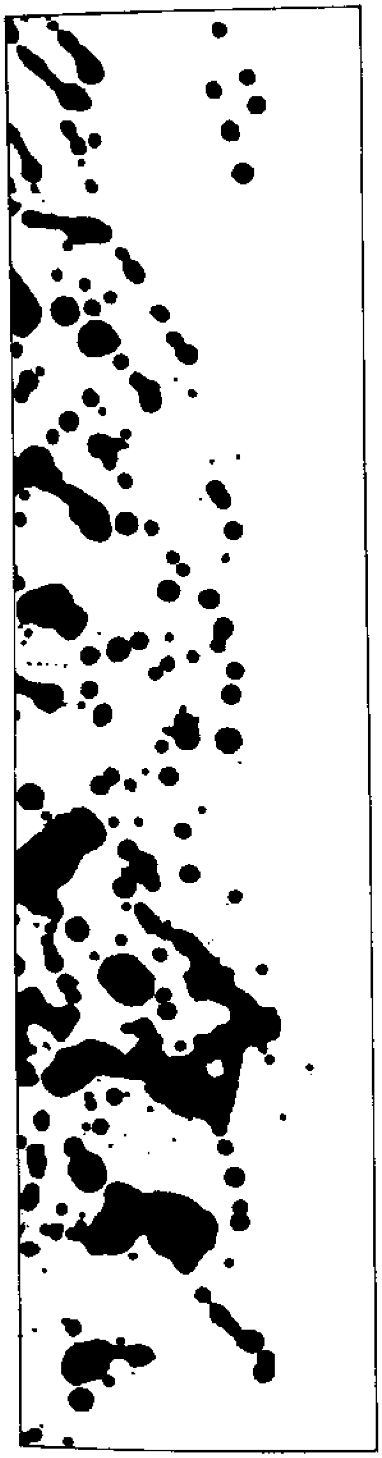
UNIVERSITY OF WISCONSIN SEA GRANT COLLEGE PROGRAM ■ 1979-80

PROJECT DIRECTORY



The largest reservoir of freshwater on the face of the earth, the Great Lakes are host to a remarkable diversity of living and mineral resources, and provide a unique oceanic shipping artery connecting the world with the agricultural and industrial heartlands of the United States and Canada. The lakes also provide graphic examples of ecosystems thrown into disarray and clean, clear waters despoiled by human use.

To explore the potentials of this extraordinary natural resource and to provide solutions to the problems it faces are the primary missions of the University of Wisconsin Sea Grant College Program.

Though less than 12 years old, the Program has already gained international recognition for its research on Great Lakes chemical pollutants, particularly PCBs (polychlorinated biphenyls). Sea Grant-supported PCB studies have been used by both state and federal policymakers as the basis for enacting controls on these toxic chemicals.

Another major area of Sea Grant research involves rehabilitation of the Great Lakes fisheries—enhancing fish production and utilization to restore a once-thriving food industry and foster a healthy recreational industry.

But the Wisconsin Sea Grant Program encompasses much more than fisheries and water quality. Other major Sea Grant subprograms include Aquaculture, Green Bay, Geological and Mineral Resources, Ocean Engineering, Diving Physiology, Policy Studies and New Applications. Within these subprograms are more than 50 research projects. Project goals range from determining what types of docks and piers can best withstand the lakes' destructive winter ice to finding new ways to detect and mine underwater minerals. Scientists in these subprograms are also developing electronic devices to locate and estimate lake fish populations, designing safer and more efficient diving equipment, tracing the fate of toxic chemicals after they enter the lakes, and examining international law with regard to ocean issues and national policies.

Solving "real-life" marine problems is the underlying goal of all Sea Grant research, and project proposals are carefully reviewed both at the local and federal level before they are approved and funded.

Of course, scientific research means little if the information it produces is not communicated to the individuals and industries that need it. This role is filled by the Sea Grant Advisory Services staff. Research results are widely disseminated through scientific, technical and general audience publications. Information is also shared at special workshops and conferences on Great Lakes issues, and Advisory Services field agents make direct contact with the public on the local level through speeches, exhibits, involvement in community activities and answering individual inquiries.

In cooperation with the Institute for Environmental Studies, the Sea Grant Program also produces *Earthwatch*, Wisconsin's largest public service radio program. The award-winning program is broadcast each weekday by about 100 radio stations and reaches an estimated four million people in six Great Lakes states.

Another major Sea Grant function is education. The Program supports many graduate and undergraduate students throughout the University of Wisconsin System and provides grants for developing new university courses, holding special lectures and film series, and creating opportunities for adults and students to do field studies on the Great Lakes and oceans.

Administered by the University of Wisconsin Sea Grant Institute, the Sea Grant Program brings a wide array of university talent to bear on Great Lakes problems and marine resources in general. Though headquartered on the UW-Madison campus, Sea Grant work involves nearly 100 faculty members and 150 graduate students on six other University of Wisconsin campuses—Green Bay, Milwaukee, Stevens Point, Marinette, Superior and UW-Extension—and at two private colleges—Lawrence University and the Medical College of Wisconsin.

One of a national network of Sea Grant institutions funded by the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce, the Wisconsin Sea Grant Program became the nation's fifth Sea Grant College in 1972 in recognition of its achievements. Sea Grant work is well regarded in Wisconsin, and the legislature recently increased the program's state budget to match increases in an annual federal grant that now stands at $1.7 million.

A list of 1978-80 Sea Grant subprograms and projects—and a brief description of each—follows.

LIVING RESOURCES

Biologists, ecologists and resource economists are seeking to understand and enhance the biological riches of the Great Lakes and promote their wise use. Research extends from investigation of nutrient recycling by microscopic zooplankton to an analysis of fish management strategies to minimize PCB contamination of the lakes' valued trout and salmon.

1) IMPACT OF NUTRIENT RECYCLING ON LAKE MICHIGAN'S NUTRIENT BUDGET (LR-10)

Arthur Brooks, Charles Remsen, Center for Great Lakes Studies, UW-Milwaukee

An important phase in the cycle of nutrients within a lake's ecosystem is the transport of such elements as nitrogen, phosphorus and carbon in the excretions of zooplankton and fish. Zoologists are sampling Lake Michigan waters to better understand the contribution of this phase to the lake's essential nutrient base as well as related interactions of aquatic life.

2) GREAT LAKES ZOOPLANKTON KEY AND MONOGRAPH (LR-12)

Stanley Dodson, Zoology, UW-Madison

A definitive list, or key, of the zooplankton in Lake Superior and the Great Lakes in general will include information on the history, abundance, trophic relationships and distribution of these minute aquatic animals. This information, plus detailed line drawings of each species, will provide basic knowledge helpful in managing fisheries.

3) FOOD REQUIREMENTS, GROWTH AND METABOLISM OF YOUNG ALEWIVES (LR-9)

Carroll Norden, Fred Binkowski, Zoology, UW-Milwaukee

Research is determining the amount of energy derived from food use in alewife growth over time and at controlled temperatures. This information is being incorporated in a model of biomass dynamics and fish predator-prey relationships in Lake Michigan—particularly that between salmonid species and their alewife prey.

4) OPTIMIZING YIELD FROM WESTERN LAKE SUPERIOR COMMERCIAL FISHERIES THROUGH SMELT STOCK ASSESSMENT (LR-8)

William Swenson, Biology, UW-Superior

Biologists are studying smelt populations and, in cooperation with commercial fishermen, developing suitable equipment and techniques for a year-round, offshore commercial smelt fishery. In addition, water sampling throughout western Lake Superior is revealing the effects of water turbidity, plankton concentrations and water temperatures on alewife abundance.

5) RECREATIONAL AND COMMERCIAL FISHING IN WISCONSIN'S LAKE MICHIGAN WATERS (LR-11)

Richard Bishop, Agricultural Economics, UW-Madison

Resource economists are monitoring the economics of commercial fishing and, through interviews and mail surveys, developing a social/economic profile of recreational fishermen. From this information, the economists will be able to clarify and perhaps resolve the economic issues that arise in conflicts between sport and commercial fishing in Lake Michigan and the Great Lakes in general.

6) ALTERNATIVE MANAGEMENT STRATEGIES FOR MINIMIZING PCBs IN LAKE MICHIGAN FISHES (LR-14)

James Kitchell, Zoology, UW-Madison

Building on previous Sea Grant work, this project is an investigation into the effectiveness, costs and benefits of various kinds of fish management practices aimed at minimizing the amounts of PCBs in Lake Michigan fish harvested for human consumption. It will result in a better understanding of the dynamics of and relationship between the lake biomass and the levels of PCBs in salmonids and their prey and how this might be manipulated to reduce the risk to human health. (Initiated September 1, 1979).

7) COMPETITION FOR RESOURCES AMONG PLANKTIVOROUS FISHES IN LAKE MICHIGAN (LR-15)

John Magnuson, Limnology Laboratory, UW-Madison

Decision on fish stocking programs and harvest quotas must be based, in part, on knowledge of the planktivorous fish population. This project will examine the seasonal divisions of habitat resources among planktivorous fishes and how this affects the distribution of the food fish that prey on them. (Initiated September 1, 1979).

8) ECONOMICS OF REHABILITATING THE LAKE MICHIGAN FISHERY: A CASE STUDY (LR-16)

Richard Bishop, Agricultural Economics, UW-Madison

This project will assess the benefits and costs of sea lamprey control and salmonid stocking programs for all of Lake Michigan. To be carried out jointly with Michigan State University Sea Grant researchers, the project will be especially important to future policy decisions on these programs if the chemicals currently used to control the sea lamprey run into problems with the EPA. (Initiated September 1, 1979).

9) APPLICATION OF FISH GROWTH MODELS (FA-2)

James Kitchell, Marine Studies Center, UW-Madison

To predict changes in the complex biological web in the Great Lakes, biologists developed a mathematical model useful in investigating the dynamics of fish growth and the rate at which predators consume their prey. While this work focused on lake trout, rainbow trout and alewife, other models were developed to estimate sea lamprey predation under various environmental influences and to estimate the route and persistence of PCBs in fish. (Completed August 31, 1979).

10) FISH POPULATION ESTIMATION IN LAKE MICHIGAN USING SONAR (FA-1)

John Magnuson, Zoology, UW-Madison

Biologists and engineers perfected new shipboard sonar techniques for detecting fish—their location, abundance and spatial distribution. This research focused particularly on Lake Michigan alewives, which constitute the lake's preponderant biomass and forage base. (Completed August 31,79).

GREEN BAY

Several interrelated projects, involving an array of scientific disciplines, are focused on Green Bay. Within this watershed lie the environmental and social problems of over-enriched waters, industrial pollution, urban and rural runoff, highly productive but dynamically changing fisheries—and the promise of a better future.

1) BIOLOGICAL PRODUCTION IN GREEN BAY COASTAL MARSHES (GB-6)

H. J. Harris, Science and Environmental Change, UW-Green Bay

Systematic sampling of the biota of three wetlands—Peters Marsh, Sensiba Wildlife Area and Peshtigo Marsh—is providing an understanding of these sensitive coastal environments. Data on rooted plants, small animal organisms and marsh birds should reveal the effects of natural changes in water level as well as human-caused perturbation, such as diking and the disposal of dredged materials in wetlands areas.

2) DYNAMICS OF HERBIVORE POPULATIONS AND FIRST-YEAR YELLOW PERCH IN LOWER GREEN BAY (LR-7)

Sumner Richman, Biology, Lawrence University; Paul Sager, Science and Environmental Change, UW-Green Bay

Biologists are examining the feeding interactions among phytoplankton, zooplankton and juvenile perch to better assess the growth and abundance of perch in the lower bay. Water sampling as well as examination of perch stomach contents will reveal specifically the role of zooplankton fluctuations in the energy flow of pelagic communities.

3) VITAL STATISTICS AND POPULATION STRUCTURE OF THE WISCONSIN WHITEFISH FISHERY OF LAKE MICHIGAN (LR-3)

Henry Booke, Wisconsin Cooperative Fisheries Research Unit, UW-Stevens Point

Whitefish tagging and enzyme studies are helping to locate genetically discrete whitefish stocks and to determine the age distribution, abundance and migrations of this commercial fish throughout Green Bay and northern Lake Michigan. Information on fish mortality and year class strength will enhance management of a more stable fishery. Drawing upon this research experience, the investigators are helping the Wisconsin Department of Natural Resources to design a whitefish sampling program for the future.

4) DYNAMICS OF SUCKER POPULATIONS OF GREEN BAY AND ADJACENT WATERS OF LAKE MICHIGAN (LR-5)

John Magnuson, Zoology, UW-Madison

Biologists are studying the population structure, growth and mortality rates of suckers in Green Bay tributaries and on the Lake Michigan side of the Door County Peninsula. In addition to biological information, the research will indicate how great a commercial harvest of suckers can be sustained.

5) FACTORS INFLUENCING THE REESTABLISHMENT OF SELF-SUSTAINING STOCKS OF LAKE TROUT IN LAKE MICHIGAN WITH SPECIAL REFERENCE TO GREEN BAY (GB-7)

John Magnuson, Zoology, UW-Madison; Ross Horrall, Marine Studies Center, UW-Madison

To help restore naturally reproducing lake trout in Lakes Michigan and Superior, biologists are studying the history of the lake trout populations, the genetic characteristics of three strains of trout, and the physical features of spawning reefs in Lake Superior and Green Bay. Federal and state agencies, with recommendations and assistance by the investigators, are planting lake trout fingerlings on these offshore sites to see if they will "remember" and return to spawn at these offshore sites where they have been planted.

6) FATE OF ARSENIC DEPOSITED IN GREEN BAY BY THE MENOMINEE RIVER (GB-11)

Marc Anderson, Water Chemistry, UW-Madison

Water chemists are investigating the movement and chemical cycling of arsenic that has leached from an industrial dump into a tributary of Green Bay. Field sampling of this massive contamination coupled with laboratory testing seeks to determine where and in what form the arsenic is "ending up"—whether it escapes to the atmosphere, concentrates in the bay's biota, or settles in bottom sediments.

7) REMOTE SENSING OF THE GREEN BAY WATERSHED TO ESTIMATE THE IMPACT OF LAND DEVELOPMENT ON THE BAY'S WATER QUALITY (GB-9)

Frank Scarpace, Institute for Environmental Studies, UW-Madison

Engineers are developing digitized (number-coded), multi-spectral aerial imagery—remote sensing that can "picture" land cover and water currents. These techniques will assess nonpoint source pollution in the Green Bay watershed in the form of urban and agricultural runoff.

8) NONPOINT SOURCE POLLUTION IN GREEN BAY AND ITS IMPLICATIONS FOR WATER QUALITY MANAGEMENT (GB-8)

Daniel Bromley, Agricultural Economics, UW-Madison

Focusing on the Lower Fox River and Green Bay watershed, resource economists are analyzing current land use practices and alternative policies for reducing sediment/nutrient runoff from rural hinterlands. By integrating the estimates of these and other nonpoint sources with known point source loadings, the investigators can better simulate and compare alternative water quality management policies.

9) WATER-MASS STRUCTURES AND EXCHANGES IN GREEN BAY, LAKE MICHIGAN (GB-10)

Clifford Mortimer, Center for Great Lakes Studies, UW-Milwaukee

Information does not exist about the dynamics of thermal stratification and water-mass exchange in Green Bay. This project will provide such information, which is urgently needed for the selection, testing and development of models of water quality, ecosystem dynamics and management strategies. This information will lead to a better-designed water quality monitoring network for obtaining realistic assessment of long-term effects on Green Bay of management strategies in the watershed. This project will have immediate, practical value in assessing water quality changes in the bay and providing real-world data for testing and improving various ecosystem models, and long-term value in improving water quality management with respect to the bay. (Initiated July 1, 1979).

10) PHYSICAL-CHEMICAL CHARACTERISTICS AND DYNAMICS OF GREEN BAY, LAKE MICHIGAN (GB-12)

James Wiersma, Science and Environmental Change, UW-Green Bay

This project will provide baseline data against which the actual impact of future activities on the bay can be assessed. This information can also be used to test predictive mathematical models of eutrophication and water-mass movement. The project will provide physical-chemical data about the bay, define major seasonal changes during the open water period, examine nutrient transfer processes and determine whether eutrophic conditions in the lower bay are causing oxygen depletion in the hypolimnion during the summer. (Initiated July 1, 1979).

AQUACULTURE

To extend and enhance the capacity of the Great Lakes for producing fish, a research team is developing techniques for growing fish under controlled conditions via aquaculture. Initially the emphasis has been on the culture of yellow perch including nutrition, reproductive biology and larvae production. The program will be extended to research on other species of cool water fish such as walleye, centrarchids (sunfishes) and whitefish.

1) EVALUATION OF WATER REUSE SYSTEMS FOR YELLOW PERCH AQUACULTURE (AQ-6)

John T. Quigley, Engineering, UW-Extension

By monitoring three water treatment and recycling systems, researchers are comparing their relative efficiency, testing energy-saving modifications in water circulation and identifying production-scale water quality needs of the fish from egg to marketable size. Specific factors being examined include water temperatures, dissolved oxygen levels, the water's pH (alkalinity vs. acidity) and the presence of such excretory products as ammonia, nitrate and nitrite.

2) PERCH AQUACULTURE SYSTEMS STUDY (AQ-7)

Erhard Joeres, Paul M. Berthouex, Civil and Environmental Engineering, UW-Madison

Perch aquaculture has been demonstrated to be technically feasible, but can it be made commercially feasible? That is what this project aims to find out. By building a fish growth model and a production cost model, the researchers will provide a realistic estimate of the costs and feasibility of developing a perch aquaculture operation.

3) DEVELOPMENT OF AQUACULTURE SYSTEMS FOR COOL WATER FISH SPECIES (AQ-4)

Harold Calbert, Food Science, UW-Madison

Food scientists, biologists and engineers are perfecting ways to grow yellow perch and other cool water fish in controlled environments. Research objectives include the development of year-round perch reproduction, optimum feeding regimes and analyses of the effects of water conditions in tanks and rearing ponds on perch growth.

4) ENERGY REQUIREMENTS OF YELLOW PERCH (AQ-5)

Clifford H. Mortimer, Fred Binkowski, Center for Great Lakes Studies, UW-Milwaukee

Biologists are determining the metabolism of yellow perch in relation to their weight and water temperature. Conversion-efficient fish diets that enable fish to grow with the least expenditure of energy will contribute to the success of perch aquaculture.

DIVING PHYSIOLOGY

Scientists are investigating how the human body functions underwater—knowledge that will help make SCUBA diving a safer and easier activity.

1) PHYSIOLOGY OF DIVING (NA-11)

John Rankin, Preventive Medicine, UW-Madison; Edward Lanphier, Biotron, UW-Madison

A medical research team is investigating the medical aspects and physiology of deep-sea diving and underwater work in order to increase underwater performance ability and diving safety. Research involves work with a hyperbaric chamber and immersion tanks in the UW-Madison's Biotron.

2) FETAL RESPONSES TO DECOMPRESSION (DP-1)

John H. G. Rankin, Physiology, UW-Madison

There are more than 40,000 registered female SCUBA divers in the U.S., but very little is known about the dangers of diving during pregnancy. The aim of this project is to determine whether standard decompression tables, designed for men, are suitable for use by pregnant women and to prove the limits of fetal resistance to decompression sickness so that recommendations to women who dive during pregnancy can be made. This will be accomplished by observing the effect of standard "no decompression" dives on sheep at various stages of gestation. (Initiated Oct. 1, 1979).

MICROCONTAMINANTS & WATER QUALITY

"The Commission believes that the control and monitoring of toxic substances within the Great Lakes ecosystem is the most urgent problem facing the Governments under the present Water Quality Agreement."— International Joint Commission Fifth Annual Report

This statement reflects the considered judgement of the scientific communities and government agencies in both the U.S. and Canada. Chemists, biologists, pathologists, toxicologists and medical scientists of the Wisconsin Sea Grant Program are engaged in research on the sources, ecosystem routes, effects on aquatic life and, ultimately, the consequences on human health of several of the more critical contaminants of the lakes. Research is also underway on methods to detect and anticipate new toxic chemicals entering the lakes.

1) AIR POLLUTION INPUT OF ORGANIC AND INORGANIC SUBSTANCES TO LAKE MICHIGAN WATER (MW-6)

Anders Andren, Civil and Environmental Engineering, UW-Madison

Water chemists are analyzing air and rainwater samples taken from Lake Michigan to determine what proportion of contaminants in the water arrive via the atmosphere. This knowledge—plus a determination as to whether airborne contaminants are coming from natural sources or from human activities—will indicate the usefulness of water quality programs based solely on controlling pollution from tributaries and coastal runoff.

2) PETROLEUM HYDROCARBONS IN THE SEDIMENTS AND BENTHOS OF LAKES MICHIGAN (INDIANA HARBOR) AND SUPERIOR (DULUTH HARBOR) (MW-13)

Anders Andren, Civil and Environmental Engineering, UW-Madison

Water chemists are measuring the levels of selected hydrocarbons in two petroleum-polluted harbors. Information derived from sediment cores, indicating the depth distribution of these hydrocarbons, and concentrations found in important benthic organisms will be useful in assessing and controlling Great Lakes oil pollution.

3) BIOTRANSFORMATION OF SUBSTITUTED PHENOLS BY FISH AND AQUATIC MICROORGANISMS (MW-17)

John Lech, Pharmacology, Medical College of Wisconsin

Pentachlorophenol (PCP) has been shown to be toxic to fish at low concentrations, and pentachloroanisole (PCA), its methyl ether form, has been found in several fish species, including Lake Michigan lake trout. This project will evaluate some of the possible sources of PCP in fish. This will be of value in predicting what situations might cause high PCP levels in fish and how these levels might be reduced if they become a problem. (Initiated September 1, 1979).

4) RESPONSE OF *DAPHNIA* POPULATIONS TO LONG-TERM CADMIUM EXPOSURE (MW-16)

Arthur Brooks, Center for Great Lakes Studies, UW-Milwaukee

By exposing *Daphnia* to controlled amounts of cadmium, biologists are testing zooplankton resistance to a toxic pollutant found in trace amounts in the Great Lakes. Determining how this industrial contaminant affects *Daphnia* reproduction, predator avoidance and other survival characteristics of this important aquatic animal will influence how water quality criteria in the Great Lakes are set.

5) RESPONSE OF PRIMATES TO PCBs (SR-9)

James R. Allen, Pathology, UW-Madison

Rhesus monkeys fed diets containing PCB levels comparable to those found in contaminated Great Lakes fish suffered ill health and impaired reproduction. Now subjects are being tested on diets of fish meal containing PCBs at one part per million—closely approximating human exposure to these compounds.

6) INVITATIONAL WORKSHOP ON THE ANALYSIS OF TOXIC ORGANIC COMPOUNDS IN THE GREAT LAKES (MW-19)

Joseph Delfino, Civil and Environmental Engineering, UW-Madison

Intercalibration of methodology and general agreement on analytical protocols are essential to the efficient diffusion of scientific knowledge. This workshop will provide an opportunity for scientists concerned with the analysis of toxic organic compounds in the Great Lakes to inspect firsthand the data of other scientists in the field and to exchange information face to face. A summary report on the consensus opinions reached regarding methods for toxics analyses in Great Lakes matrices will subsequently be prepared and widely distributed to appropriate university and agency laboratories. (Initiated September 1, 1979).

7) EVALUATION OF PROCESSES CONTROLLING THE TRACE METAL STATUS OF SOUTHERN LAKE MICHIGAN (MW-11)

David Armstrong, Water Chemistry, UW-Madison

Analyses of Lake Michigan sediments show increasing levels of such trace elements as lead, zinc, copper, chromium, tin, bromine and nickel. To understand the ecological effects, water chemists are studying trace metals input from lake tributaries, their pathways through the lake, movement in and out of bottom sediments, and interaction with plankton and other aquatic life.

8) ON-SITE HEAVY METAL ANALYSIS USING ANODIC STRIPPING VOLTAMMETRY (MW-15)

William Blaedel, Chemistry, UW-Madison

For on-site measurement of trace metals in various aquatic media, chemists are developing an improved electronic method for detecting trace metal ions in water. A prototype instrument, incorporating porous electrodes (of pyrolytic carbon) and other innovations, will be tested on water samples of increasing chemical complexity—distilled, tap, lake and sea water—as well as Lake Michigan itself.

9) ACCUMULATION, DISTRIBUTION AND ELIMINATION OF PCBs IN YELLOW PERCH FED A CONTAMINATED RATION (MW-14)

Richard Peterson, Pharmacy, UW-Madison

Pharmacologists are feeding yellow perch PCB-contaminated fish meal (made from Lake Michigan alewives) and recording the accumulation, distribution and elimination of the compound in the test fish. These laboratory studies will indicate whether alewife fish meal can safely be used in perch aquaculture.

10) EFFECT OF SPAWNING ON DISTRIBUTION AND ELIMINATION OF PCBs IN LAKE MICHIGAN FISH (MW-9)

Richard Peterson, Pharmacy, UW-Madison

Pharmacologists are investigating the effect of egg and sperm formation and spawning in rainbow trout (fatty fish prototype) and yellow perch (nonfatty fish prototype) on the distribution and elimination of PCBs by the fish. In addition, the researchers are looking at the transfer of PCBs from the adult fish to the egg and then to the developing fry to better understand the effect of this widespread industrial contaminant on Great Lakes ecosystems.

11) PCB LEVELS IN HUMAN FLUIDS: SHEBOYGAN CASE STUDY (MW-18)

John Rankin, Preventive Medicine, UW-Madison

At the request of the state Departments of Natural Resources and of Health and Social

Services, and the City of Sheboygan, this project will examine PCB contamination of the breast milk and blood of Sheboygan residents, obtain preliminary data on the effect of PCBs on infant health, and determine the relationship between PCB levels and the ingestion of sport fish from Wisconsin waterways, specifically the Sheboygan River. (Initiated July 1, 1979).

12) RESPONSES OF PRIMATES FED DIOXIN-CONTAMINATED FISH OIL (MW-22)

James R. Allen, Pathology, UW-Madison

Game fish and water supplies in some areas of the U.S. are contaminated with levels of TCDD potentially injurious to humans. By feeding fish oil containing dioxin to an animal model that responds similarly to man, the project will provide an evaluation of the potential danger to the human population posed by the consumption of fish contaminated with this substance. This data will be of assistance to regulatory agencies in establishing safe levels of TCDD in the food chain.

13) AN ASSESSMENT OF SELECTED PRIORITY ORGANIC POLLUTANTS IN THE LOWER FOX RIVER AND GREEN BAY (MW-20)

Joseph Delfino, Civil and Environmental Engineering, UW-Madison

State and federal environmental policymakers need a broad base of accurate information by which to assess the organic pollutant problem. This project will investigate the types of chemicals that might be expected to appear in the lower Fox River aquatic environment, develop or improve methods of detecting such chemicals, and isolate and identify priority pollutants.

14) AN ASSESSMENT OF PATHWAYS OF CHEMICAL IN THE LOWER FOX RIVER/GREEN BAY (MW-21)

Anders Andren, Civil and Environmental Engineering, UW-Madison

What becomes of hazardous chemicals once they enter the aquatic environment? This project is aimed at improving and evaluating the present procedures used to predict the fate of selected chemicals in the Fox River and Green Bay area. State agencies can use this information to evaluate the impact of hazardous chemicals in this area and to evaluate the human health implications of these pollutants. (Initiated September 1, 1979).

15) BIOTRANSFORMATION AND DISPOSITION OF GREAT LAKES MICROCONTAMINANTS IN SALMONIDS (BR-5)

John Lech, Pharmacology, Medical College of Wisconsin

Toxicologists examined the manner in which rainbow trout take up, metabolize and excrete the lampricide Bayer 73—a toxic compound sometimes used as a synergist in the chemical control of lamprey reproduction. Other compounds similarly studied are PCBs and other known Great Lakes contaminants, whose observed concentrations in fish bile may provide a means of gauging contaminant concentrations not only in the fish but in the lakes. (Completed August 31, 1979).

16) ACCUMULATION AND BIOLOGICAL AVAILABILITY OF PCBs in LAKE MICHIGAN SEDIMENTS (MW-12)

David Armstrong, Water Chemistry, UW-Madison

Water chemists have investigated the rate at which PCBs are accumulating in Lake Michigan sediments and are now calculating the compounds' future movement via bottom-dwelling organisms to pelagic fish. This information will be used to estimate how long PCB concentrations will persist in Great Lakes fish as an environmental problem. (Completed August 31, 1979).

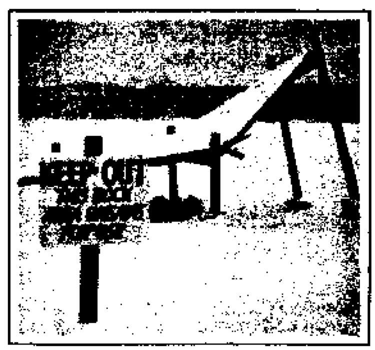
17) RESPONSE OF PRIMATES TO 2,3,7,8-TETRACHLORODIBENZO-p-DIOXIN (MW-8)

James R. Allen, Pathology, UW-Madison

Rhesus monkeys were fed diets containing trace amounts of a dioxin called TCDD, an extremely toxic compound thought to exist at very low concentrations in the Great Lakes. Steady diets containing TCDD at only 500 parts-per-trillion impaired the monkeys' reproductive system, lowered resistance to disease and killed five of the eight animals within nine months. Concentrations reduced tenfold produced similar results within two years—results considered quite significant, since the physiology of rhesus monkeys is similar to that of a human. (Completed August 31, 1979).

OCEAN ENGINEERING

Human activities in lakes and oceans involve risks to property and life itself. Research engineers are designing devices to make underwater diving safer and more efficient, ship hulls less prone to wave damage and small craft harbors safe from winter ice.



1) IMPULSIVE RESPONSE AND RESONANCE OF GREAT LAKES SHIPS (OE-6)

T. C. Huang, Engineering Mechanics, UW-Madison

To investigate a possible cause of Great Lakes shipwrecks, an engineer is mathematically modelling the responses of ship hulls to various types of wave action which create vibrations in long-bodied vessels. These vibrations cause the hull to resonate—an amplified motion that in some instances might lead to structural failure and loss of ship.

2) DEVELOPMENT OF UNDERWATER DEVICES (OE-8)

Ali Seireg, Mechanical Engineering, UW-Madison

Engineering research teams are designing safer and more efficient equipment to assist underwater divers in the strenuous and often disorienting realm beneath the surface. Their achievements include techniques for improving the design of standard snorkels; air regulators that allow easier breathing and the one-time reuse of exhaled gases, and lighter, stronger SCUBA tanks.

3) ICE ENGINEERING FOR SMALL CRAFT HARBORS (OE-9)

Allen Wortley, Engineering, UW-Extension

Dock failures and maintenance costs due to ice result in losses of millions of dollars annually. This project will prepare a "Design Manual for Northern Small-Craft Harbors," which will provide practical information about ice behavior and characteristics, and dockage systems to deal with them. Included will be specific dock design criteria and recommendations, and evaluations and comparisons of commercially-produced floating dock systems. (Initiated Sept. 1, 1979).

4) FLOATING DOCKAGE SYSTEMS SUBJECTED TO ICE LOADINGS (OE-7)

Allen Wortley, Engineering, UW-Extension

An engineer sought to improve the techniques for the design and construction of floating dockage systems in small craft harbors troubled by winter ice. In addition to comparisons of commercially available structures, the research included measurement of ice thickness, water temperatures and other winter conditions found in small craft harbors in the Upper Great Lakes. (Completed Aug. 31, 1979).

POLICY STUDIES

Many water resource questions, within the Great Lakes region and globally, require social, political and economic answers. Several projects, grouped as concerns of "policy," are developing managerial options and approaches to a variety of problems—from the decline of Great Lakes shipping to the preservation of historically important shipwrecks.

1) OCEAN POLICY AND NATURAL RESOURCE STRATEGY (PS-24)

Richard Bilder, Law School, UW-Madison

A former State Department specialist in international law is exploring the wide range of ocean resource issues confronting the world's nations and possible approaches to their resolution—both within and outside the framework of the Law of the Sea conference. Through a study of international policies and law, as well as consultations with authorities in the field, the research aims at "more management consistent policies for ocean and global resources."

2) ECONOMIC INCENTIVES AND BARRIERS TO COASTAL WETLANDS PROTECTION (PS-29)

Richard Barrows, Agricultural Economics, UW-Madison

Major opposition to attempts to preserve the state's wetlands appears to come from the agricultural sector. This project will attempt to provide information about the economic incentives to drain wetlands for agriculture and thus help resource managers and lawmakers develop innovative means to overcome these incentives through partial or full compensation to wetlands owners. This will include the development and application of a conceptual mathematical model of these economic incentives for typical Wisconsin farms. (Initiated Sept. 1, 1979).

3) ASSESSING AN UNDERWATER PARK PRESERVE FOR WISCONSIN'S GREAT LAKES WATERS (PS-26)

William Tishler, Landscape Architecture, UW-Madison

To preserve a regional heritage, investigators are making an inventory of the scores of shipwrecks along Wisconsin's Great Lakes shoreline. They are further researching the jurisdiction and ownership of these wrecks, and exploring ways to protect the most interesting and accessible wreck sites as underwater parks—to be managed as living museums of Great Lakes history.

4) CULTURAL CONTINUITY: THE SEA ISLANDS AFRO-AMERICANS (PS-27)

Tom Shick, Afro-American Studies, UW-Madison

A specialist in Afro-American history is documenting the evolution of Afro-American culture indigenous to the remote barrier Sea Islands off the South Carolina coast. An understanding of the manner in which the descendants of early island plantation slaves are adapting to modern farming and fishing may provide a model for studies of other insular communities while encouraging greater sensitivity in coastal development that may encroach upon ethnic populations.

5) TRANSFERABLE DISCHARGE PERMITS: IMPLEMENTATION STUDIES (PS-28)

Martin David, Economics, UW-Madison

Building on previous Sea Grant research, this study will create a simulation model of the industrial sector's reaction to the opportunity to purchase and sell pollution permits, and assess the effects of such action on water quality, the likelihood of violations of water quality standards, and the river's ability to withstand short-term pollution shocks. The thrust of this study is to provide a comprehensive report to the Wisconsin Department of Natural Resources on the design and implementation of a transferable discharge permit system for the Fox River. (Initiated Sept. 1, 1979).

6) GREAT LAKES INTERNATIONAL TRADE: HINTERLAND SERVED AND SHIPPER'S ROUTE OPTIONS (PS-25)

Eric Schenker, Business Administration, UW-Milwaukee

Economists and maritime trade specialists are studying recently released data on the origin/destination of Great Lakes' maritime trade. In a related effort, they are looking at shipping costs and market areas, and developing a model to define optimum cargo routing for Great Lakes shippers—an analysis that will identify the strengths and weaknesses of various Great Lake ports.

7) AN INVESTIGATION OF MARKETABLE POLLUTION RIGHTS FOR POLLUTION CONTROL (PS-22)

Martin David, Economics, UW-Madison; E. Joeres, Engineering, UW-Madison

An economics-engineering research team has proposed a system for controlling pollution by the issuance of "pollution rights"—preferably termed "transferable discharge permits" by Wisconsin Department of Natural Resources officials—to industries and municipalities discharging into river systems. The investigators analyzed the policy and operational aspects of the system, which they believe would strengthen DNR efforts to implement more fairly the Wisconsin Pollution Discharge Elimination System. (Completed Aug. 31,79).

8) LIMNOLOGICAL COMMENTARY ON THE MILWAUKEE POLLUTION CASE

Clifford Mortimer, Center for Great Lakes Studies, UW-Milwaukee

A protracted lawsuit, ending in 1977 in federal court, found that Milwaukee harbor effluents were polluting Illinois waters of Lake Michigan. A limnologist studied the legal controversy between Illinois as plaintiff and Milwaukee and its sanitation district as defendants to determine what scientific evidence weighed most heavily in the court's decision. An objective was to discover the implications for resolving future environmental disputes and how the legal process, as invoked in this case, might be improved. (Completed Aug. 31, 1979).

NEW APPLICATIONS

Some projects do not fall within the topical boundaries of other research subprograms. Currently, one such project is examining how Lake Superior water levels respond to long-term changes of climate.

1) RESPONSE OF LAKE SUPERIOR TO NET BASIN SUPPLIES AND GREAT LAKES WATER LEVELS TO CLIMATE VARIATIONS (NA-7)

Waltraud Brinkmann, Institute for Environmental Studies, UW-Madison

Climatologists are assessing the influence of climate on long-term fluctuations of Great Lakes water levels. In this effort, probability distributions and time series models of climate and net basis supplies for a 300-400-year period are being developed, based on historical records and climatic indicators, such as tree rings and pollen in lake sediments. These data will be used to develop scenarios of future net basin supplies and lake levels.

2) LAKE SUPERIOR SHORELINE VEGETATION AND EROSION: AN ECOLOGICAL SURVEY (NA-18)

Rudy Koch, Center for Lake Superior Studies, UW-Superior

To establish the influence of vegetation on coastal erosion, botanists catalogued plant life at 25 sites along Wisconsin's Lake Superior shore and studied aerial pictures and historical surveys of the receding coastline. Through field work and greenhouse studies of selected plant species, they looked for suitable trees and plant cover that would help stabilize the erosion-prone red clay bluffs of the region. (Completed Aug. 31, 1979).

GEOLOGICAL & MINERAL RESOURCES

Analysis of Lake Michigan and Lake Superior shorelines will lead to an understanding of the forces causing Great Lakes coastal erosion. Investigators are also concerned with long-range water supplies, considering the hydraulic connection between Lake Michigan and groundwater aquifers near its Wisconsin shoreline.

1) DETAILED ANALYSIS OF FACTORS INFLUENCING SHORELINE EROSION ON THE GREAT LAKES (MA-9)

Tuncer Edil, Civil and Environmental Engineering, UW-Madison
David Mickelson, Geology and Geophysics, UW-Madison

Factors influencing coastal erosion—among them, climate, soil type, groundwater, vegetation, wave action and lake levels—are being analyzed at several sites characterized by sloping contours along Lakes Michigan and Superior. This information is being compiled for the use of anyone involved in determining both structural and nonstructural remedies for erosion in high bluff areas.

GEOPHYSICAL ASSESSMENT OF THE HYDRAULIC CONNECTION BETWEEN LAKE MICHIGAN AND THE GROUNDWATER AQUIFERS ON ITS WESTERN BOUNDARY (MN-1)

Mary Anderson, Geology, UW-Madison

Information gained from this five-year project will enable scientists for the first time to assess how much groundwater flows into the lake, or, conversely, how much can be induced to flow from the lake into heavily pumped areas. This information will also be valuable in determining where contamination of the lake is possible as a result of surface waste disposal (e.g., landfills and sewage sludge) and in assessing the environmental impact of power plant and other construction sites. (Initiated Sept. 1, 1979).

3) STRATIGRAPHY AND GEOTECHNICAL PROPERTIES OF GLACIAL DEPOSITS ALONG THE SHORELINE OF LAKES MICHIGAN AND SUPERIOR (MN-2)

David Mickelson, Geology and Geophysics, UW-Madison

The variability of material along the shoreline must be tested before bluff retreat models can be developed to assess the slope failure process. This project will produce that information. In addition, it will provide a better knowledge of the glacial history of the Lake Superior regions. Cosponsored by the Wisconsin Coastal Management Program.

EDUCATION & ADVISORY SERVICES

Through personal contacts, meetings and media communication, the Advisory Services program within the Sea Grant Institute forges the information and service link between those who study marine and Great Lakes resources and those in industry, government and the public who use those resources.

1) ADVISORY SERVICES DIRECTOR'S OFFICE (A-1)

Gregory Hedden, Director, UW-Extension

Sea Grant specialists provide information and assistance to individuals and organizations interested in aquaculture, coastal erosion defenses, fisheries, underwater mining and other areas of Sea Grant expertise. Such contacts outside the institute program also identify public needs and influence the course of future Sea Grant research.

2) SEA GRANT ADVISORY SERVICES FIELD AGENTS AND ACTIVITIES (A-14)

Gene Woock, UW Sea Grant Office

UW Sea Grant Institute representatives—stationed at Washburn, Green Bay, Sister Bay and Milwaukee—provide information about the Institute program and carry out a variety of educational/informational projects ranging from meetings on fish cookery to short courses on lake biology.

3) SEA GRANT COMMUNICATIONS (A-2)

Linda Weimer, UW Sea Grant Office

Great Lakes and Sea Grant information is disseminated in many ways—through films, publications, news articles, radio programs and special exhibits. Publications designed for the public include, for instance, "ABCs of PCBs," "Fundamentals of Fish Farming," "Our Great Lakes," and "Fish of Lake Superior."

4) EARTHWATCH PUBLIC SERVICE RADIO PROGRAM AND NEWSPAPER COLUMN (A-3)

Linda Weimer, Peyton Smith, UW Sea Grant Office

Earthwatch—a daily, two-minute environmental radio program produced in cooperation with the UW-Madison Institute for Environmental Studies—is carried by over 100 stations in Wisconsin and the Midwest. *Earthwatch/Wisconsin*, a more regionally-focused news column, appears weekly in 80 newspapers, principally in Wisconsin.

5) FOOD SCIENCE AND FISH PROGRAM (A-8)

David Stuiber, Food Science, UW-Madison

A Sea Grant food scientist provides information and technical assistance to the fishing industry and advice on fish handling and preparation to sports fishermen and consumers. In addition, he is developing new food products from under-utilized fish like the sucker and alewife and working on better ways to use or dispose of fish processing wastes.

6) SPECIAL EDUCATION PROGRAMS

The Sea Grant Office underwrites several educational activities, including assistantships for students working on Sea Grant research, new courses in oceanography and limnology, and special lecture/film series on campuses around the state.

Sea Grant Institute
University of Wisconsin-Madison
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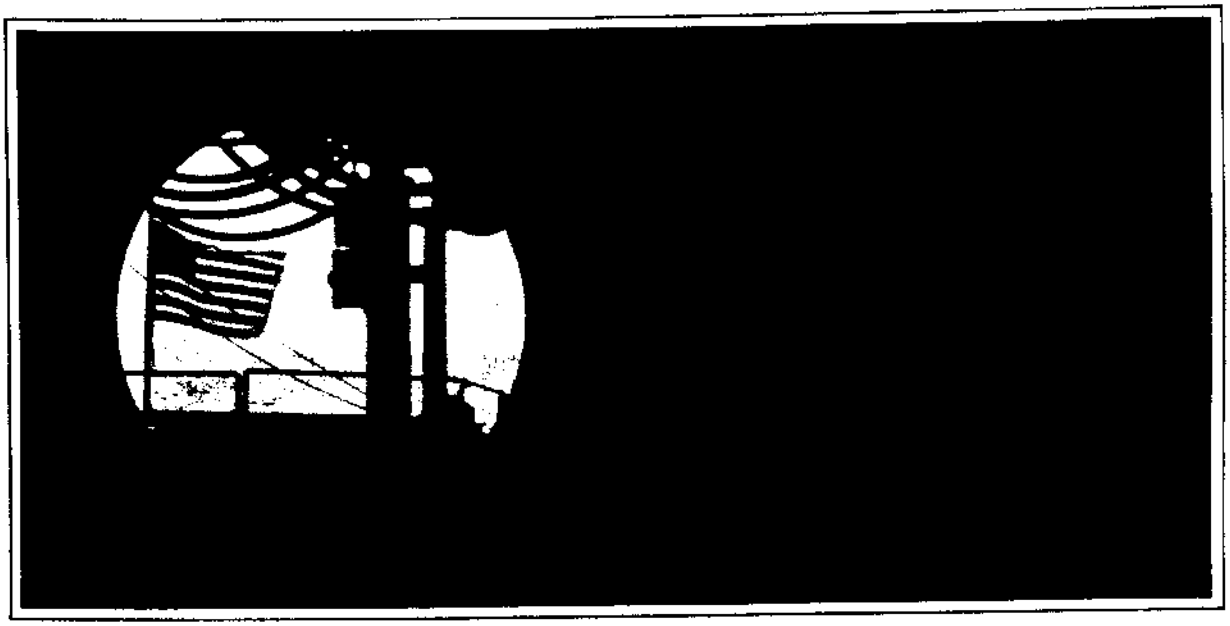
Madison, Wisconsin 53706

PROGRAM BUDGET ▪ 1977-79

University of Wisconsin Sea Grant College Program



	1977-78		1978-79	
	Federal	State	Federal	State
LIVING RESOURCES	170,759	131,705	129,883	58,943
AQUACULTURE	101,727	52,043	144,653	69,071
GREEN BAY	– –	– –	233,853	116,869
MICROCONTAMINANTS AND WATER QUALITY	168,000	105,315	215,225	100,707
POLICY STUDIES	116,874	50,297	122,643	57,219
MINERAL RESOURCES	58,894	35,537	– –	– –
OCEAN ENGINEERING	117,374	62,598	62,749	45,765
NEW APPLICATIONS	46,387	43,059	97,295	48,381
ADVISORY SERVICES	390,000	105,137	383,113	174,146
EDUCATION	43,516	28,734	16,722	12,193
PROGRAM DEVELOPMENT	74,939	10,061	44,791	30,097
SHIP TIME	–0–	60,000	–0–	60,000
PROGRAM ADMINISTRATION	111,530	40,514	115,073	54,609
TOTAL:	$1,400,000	$725,000	$1,546,000	$828,000

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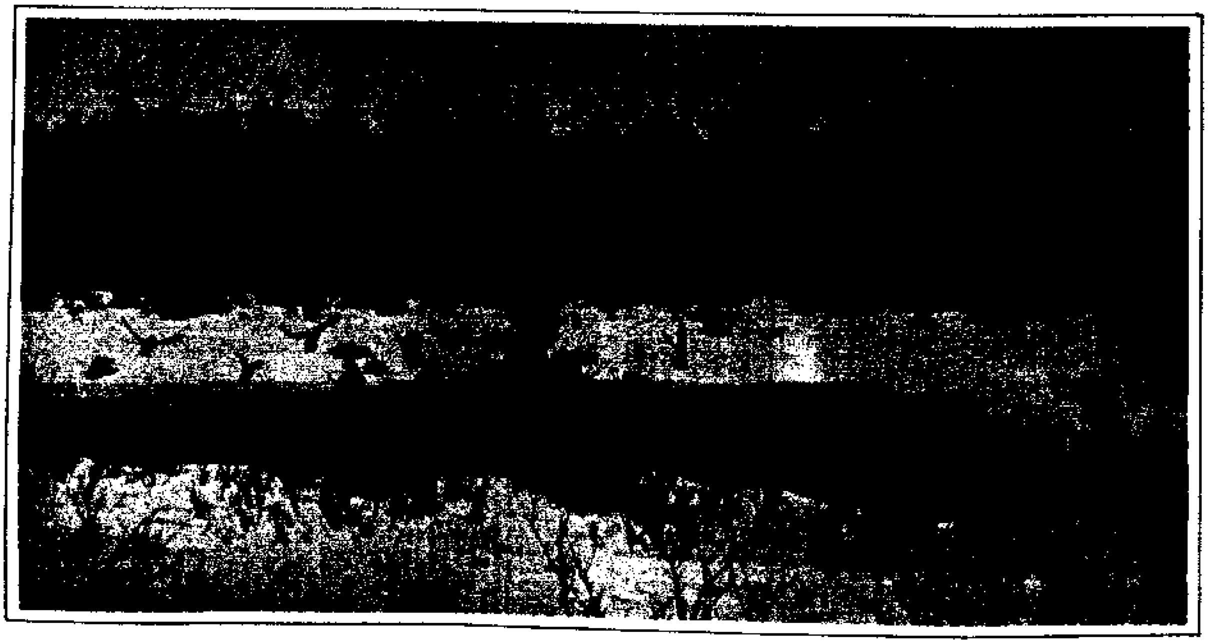

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