U N I V E R S I T Y   O F   W I S C O N S I N

The Fisheries of the Great Lakes

1984–86 BIENNIAL REPORT

S E A   G R A N T   I N S T I T U T E

WIS-SG-86-148: May 1986

Published by the University of Wisconsin Sea Grant Institute under grants from the National Sea Grant College Program, National Oceanic and Atmospheric Administration, U.S. Department of Commere, and from the State of Wisconsin. Federal grant NA80AA–D–00086.

From Robert A. Ragotzkie

Director, University of Wisconsin Sea Grant Institute

May 1, 1986

Had a cartographer visited the Great Lakes region shortly after the glaciers retreated several millenia ago, he would have been able to draw a map of the lakes not substantially different from those drawn today. But the lakes are not the same, by any means.

During the last 200 years, human uses and pressures on the lakes have caused many changes, and, like the changes in people, the important ones often occurred beneath the surface. In many cases, we did not even know that changes were occurring, and when we did recognize them, it was often too late to prevent lasting damage to the ecosystem.

Through research undertaken first by federal and state agencies and more recently by universities, we have begun to understand how the lakes function and where we as people fit in. With the advent of the National Sea Grant College Program, a remarkable and highly effective partnership of federal, state, university and private interests has developed for marine and Great Lakes study. As a part of this partnership, the University of Wisconsin Sea Grant Institute has helped to focus the resources of the entire University of Wisconsin System on the Great Lakes and their resources.

Wisconsin is a coastal state. Its "oceans" are the Great Lakes, and the Sea Grant program here focuses most of its attention on these inland seas. The UW Sea Grant Institute is an embodiment of "The Wisconsin Idea"—the idea that the boundaries of the university are the boundaries of the state. As the research arm of the state, the University of Wisconsin provided fertile ground for the Sea Grant model to develop and flourish.

In just 18 years, the UW Sea Grant Program has fostered a new understanding and appreciation for the Great Lakes. Sea Grant researchers, specialists and field agents have brought forth new information useful both for developing and protecting this magnificent international resource. More than 270 UW Sea Grant students have received Master's and Ph.D. degrees and have gone on to jobs in the private and public sectors, where they continue to apply the results of Sea Grant research.

The Great Lakes are finite in size and their resources are limited, yet they are subject to the same array of uses and pressures as the oceans. As closed bodies of water with relatively shallow basins, the lakes have a much smaller capacity to absorb and resist these pressures. The exploitation of their resources has had a much greater and more immediate effect on these inland seas than on the oceans.

When compared to the world ocean, however, the problem of establishing a management framework for the Great Lakes is relatively straightforward. Unlike the complexity of bringing some 150 nations to agreement on how to preserve the marine environment and manage ocean resources, the Great Lakes are shared by two friendly nations which have a common interest in safeguarding the resources and quality of their boundary waters. Beyond the favorable political and cultural climate between the U.S. and Canada, the more rapid response of the lakes to human impacts has forced the governments of both nations to move sooner and more quickly to create institutions and methods to deal with such situations than for the oceans.

The U.S. and Canada have agreed to manage the entire Great Lakes Basin as an ecosystem—the land surrounding the lakes and the streams flowing into them as well as the lakes themselves. The 1978 Water Quality Agreement between the two nations calls for restoring the integrity of the entire ecosystem: water, land, air and living things, including man.

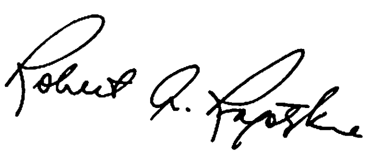
As a microcosm of the world ocean, the Great Lakes constitute a scientific, resource and management model from which much can be learned. This is especially true in the case of fishery research and management. In keeping with our practice of presenting biennial reports with a theme, it is particularly fitting that the UW Sea Grant's 1984–86 biennial report examines the history of the Great Lakes fishery in terms of our present knowledge and understanding of how the ecosystem functions.

Nearly destroyed by overexploitation, the invasion of alien species and pollution in the first half of this century, the Great Lakes fishery has undergone a remarkable rebirth. Virtually nonexistent just 20 years ago, the Great Lakes sport fishery today attracts some five million anglers, with a regional economic benefit of about $1.1 billion annually. The Great Lakes also support about 600 commercial fishermen, whose catch has a dockside value of about $48 million a year and a regional economic impact more than four times that. The rebirth of the fishery has been responsible for the economic revival of hundreds of Great Lakes coastal communities.

However, not all efforts to rejuvenate the fishery have been successful. Many native species have been lost forever, and others, like the lake trout, are barely surviving in one or two of the lakes. The carrying capacity of the forage base is in danger of being exceeded. Balancing the commercial and sport fishery harvest remains a difficult policy question.

Despite these continuing problems, our understanding of the Great Lakes ecosystem, particularly the fisheries, has reached the stage now where scientists are asking the right questions and management of the fisheries is entering a new and enlightened phase. Fishery management policies are being coordinated on both interstate and international levels. Stocking policies are being determined more by the lakes' carrying capacity than by political and short-term economic pressures.

Through its research program as well as its interaction with both state and federal management agencies, the UW Sea Grant Institute has made significant contributions to these advances. The recognition of these contributions has earned the program continuous strong support from the Congress, the State of Wisconsin, the University of Wisconsin and industry. The Sea Grant partnership has paid off handsomely in terms of Great Lakes resource management. Its continuing stream of well-trained and educated students will also pay dividends to the nation for decades to come.



The Fisheries of the Great Lakes

A Report on the Activities of the University of Wisconsin Sea Grant Institute 1984–86

The Fisheries of the Great Lakes

University of Wisconsin Sea Grant Institute

DAWN OF THE FISHERIES

THE GREAT LAKES PRIMEVAL

Most the world's large lakes have had many thousands of years to develop their individual complexes of fish species. But the North American Great Lakes had a scant number of years—scant by geological and evolutionary scales—to develop their unique fisheries. Only 16,000 years ago, the Great Lakes Basin was still buried under the two-mile-thick ice sheet of the Wisconsin Stage—the last major advance of the continental glaciers of the Ice Ages.

Before it completely withdrew from the Great Lakes Basin about 9,500 years ago, the Wisconsin glacier made several short advances and retreats. This forced the emerging Great Lakes at various times to drain southwestward to the Mississippi and Ohio rivers and eastward out the Ottawa River as well as through the St. Lawrence River—the routes by which most of the estimated 125 species of fish that originally inhabited the lakes arrived. Freed of the glacier's weight, the land slowly rebounded, and about 3,000 years ago this caused all five of the Great Lakes to begin draining exclusively out the St. Lawrence River. Only then did the 193-foot-high barrier of Niagara Falls prevent any other species of fish from colonizing the four upper lakes.

The pristine Great Lakes were an Eden for fish. They were highly oligotrophic—meaning the water was low in nutrients and high in life-supporting dissolved oxygen. Even the deepest waters of the lakes contained oxygen year-round. The lakes' numerous tributaries were clear-running and cool with deep-cut banks, and they were full most of the year, fed by a profusion of post-glacial inland lakes, springs and swamps. The canopy of the region's dense primeval forests also helped keep the tributaries brimming by preserving soil moisture and slowing the melting of the winter snow cover into late spring.

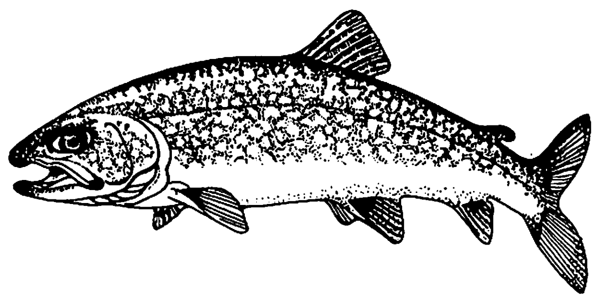
Vast wetlands and marshes lined many parts of the Great Lakes coast—most notably around Green Bay and the southern tip of Lake Michigan, the western tip of Lake Superior, and the western tip of Lake Erie. These wetlands, the rocky reefs of the lakes, and the clean gravel beds of their tributaries offered ideal spawning habitat for a variety of fish.

THE EARLY FISHERIES

The Great Lakes evolved five major endemic species—fish found only in these lakes. These were all members of the whitefish subfamily (*coregonae*) of the salmon family (*salmonidae*). Largest to smallest, they were the deepwater cisco, longjaw cisco, shortjaw cisco, kiyi and bloater. Commonly called chubs, all five lived in Lakes Huron and Michigan, four in Lake Superior and three in Lake Ontario. Perhaps because ciscoes prefer deep cold water, only one species, the longjaw cisco, inhabited Lake Erie, the southernmost and shallowest of the Great Lakes. Two other notable endemic species were the blue pike, a subspecies of walleye, and Michigan grayling trout.

Lake Trout

Salvelinus namaycush



By the time Europeans arrived on the scene about 350 years ago, stable communities of fish occupied almost every ecological niche in the Great Lakes, from the shallow bays and marshes of Lake Erie to the deepest waters of frigid Lake Superior. The lakes' dominant predator fish were the lake trout and burbot. These predators fed on an abundance of deepwater and slimy sculpins in the open waters of the lakes, and on a profusion of emerald and spottail shiners in nearshore waters. Besides the endemic ciscoes, the lakes also contained lake herring, lake whitefish and round whitefish. And the lakes' shallow bays and nearshore waters teemed with lake sturgeon, northern pike, suckers, channel catfish, white bass, freshwater drum, walleye, sauger and yellow perch. Lake Ontario also held a large indigenous population of Atlantic salmon.

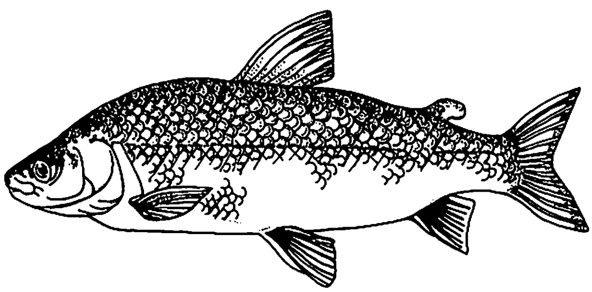
Scientists today estimate that about half of the entire biomass—half of all life in the lakes—consisted of fish weighing more than 10 pounds. Individuals among almost all large predator species reached sizes of more than 20 pounds. Though not a predator, the lake sturgeon reached a ponderous 200 or even 300 pounds. Like the huge old trees that dominated the surrounding forests, these massive fish—some of them well over 50 years old—dominated the community of fish in the lakes.

The first European explorers continually expressed astonishment at both the abundance and size of the fish in the Great Lakes. After a visit to Lake Superior's Chequamegon Bay in 1659, French explorer Pierre Esprit Radisson wrote, "In that bay there is a channel where we take stores of fishes, sturgeons of vast bigness, and Pycks seven feet long." French explorer Sieur Antoine de la Mothe Cadillac said he saw Native American fishermen "bring up in one net as many as a hundred whitefish" and that they caught large numbers of lake trout that "weighed up to 50 livres" (about 50 pounds).

Most of the Native Americans living in the region when the first Europeans arrived depended to one degree or another on the lakes' fish. The whitefish in particular was a central part of the diet of Lake Superior's Native Americans, and its annual autumn spawning run up the rapids of the St. Mary's River between Lakes Superior and Huron attracted tribes from far and wide. While dip-netting from a bobbing canoe was a favorite method, they also caught the fish by spearing and, much like modern anglers, with baited bone hooks and lines.

Lake Whitefish

Coregonus clupeaformis



The Native Americans generally did not venture very far out on the lakes to fish. They didn't need to—like the St. Mary's River, many Great Lakes tributaries were regular highways for migrating or spawning fish, and some tribes simply built stake-and-brush weirs to route these fish into their waiting nets, made of knotted fibers from the bark of young willow trees.

While fishing had long been an important occupation for the region's Native Americans—as is evidenced by mussel shell spoons and bone fish hooks left by the region's ancient Mound Builders—the fishing pressure exerted by Native Americans is believed to have been rather light, as their scattered and relatively small populations lived in a land that was also teeming in big game, waterfowl and other wildlife.

As fishing was good almost everywhere around the Great Lakes, fish soon became one of the mainstays in the diets of the early European fur traders, missionaries and settlers. Lake whitefish and lake trout were a regular part of the diet of those manning the first forts and trading posts, who also harvested and packed the fish for those at inland posts. In its heyday, the North West Company—which dominated the North American fur trade from 1784 to 1821—annually harvested and packed 500 to 1,000 barrels of Lake Superior fish to supply its far-flung outposts.

The first true commercial fishing on the Great Lakes probably began in the early 1800s with John Jacob Astor's American Fur Company, which established several fishing stations on Lake Superior. Most of the men fishing for the company were French or French-Indians, who, using gill nets and small boats, mainly harvested lake trout, whitefish and lake herring.

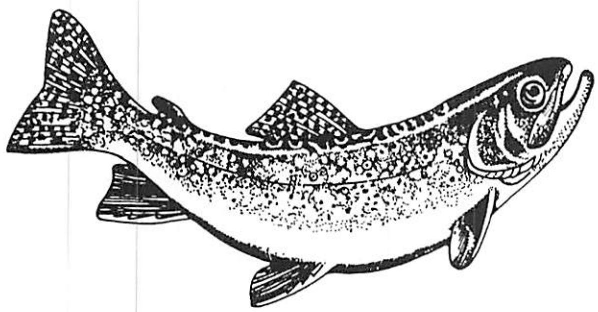
After two centuries of relentless exploitation, the region's supply of fur-bearing animals was nearly exhausted, but Astor was making so much money from Lake Superior fish that in 1835 the company launched a 112-ton schooner, aptly named the *John Jacob Astor,* for hauling fish and furs to its main post at Sault Ste. Marie. The company soon added a scow and several more schooners to its fleet, and by 1839 these ships were bringing in 5,000 barrels of lake trout and whitefish a year—almost a million pounds of fish. Fortunately for the beaver—and perhaps for the fish—the beaver hat was out of style by 1840, and the American Fur Company was bankrupt by 1842.

After the American Fur Company failed, independent fishermen took over many of its facilities, and commercial fishing on the Great Lakes soon grew into an important regionwide industry, providing both food and employment for the thousands of immigrants that poured into the region during the 1800s. The industry was also bolstered by the arrival of immigrants experienced in commercial fishing, like those from Norway, Denmark, Iceland and Sweden who formed fishing communities on the islands at the mouth of Lake Michigan's Green Bay.

PARADISE LOST

Despite the ever-increasing numbers of fish being harvested from the lakes, a far more ominous development was the simultaneous growth of another important regional industry—lumbering. Abetted by gargantuan federal and state land giveaways and a policy of clear-cutting the land for settlement, the vast primeval pineries of Michigan, Wisconsin and Minnesota were virtually reduced to stumps in less than 100 years.

The deforestation of the land was especially devastating to the region's fish populations. Without the shade of the forest canopy, the temperatures of many tributaries became too hot for brook trout and other coldwater species of fish. Wind and water eroded the unprotected soil, filling many streams and bays with silt, ruining spawning grounds and smothering the incubating eggs. Streamflows fluctuated from destructive flooding in spring to a trickle in autumn. Low stream levels caused so-called "anchor ice" to form along the bottom during the winter, which scoured the streambed and destroyed fish eggs when it began to move in the spring.



Brook Trout
Salvelinus fontinalis

The destruction of the forests—and its effect on the region's fish populations—was further aggravated by fires that often consumed the debris left behind by the lumberjacks. During the height of the logging era, as many as 25 million acres of forest a year went up in flames. In 1899, the U.S. Department of Agriculture reported that nearly all of northern Wisconsin had been logged over and that nearly half the territory had been burned over at least once.

The infamous Peshtigo fire, a raging six-day blaze that swept both sides of Green Bay during October 8–14, 1871, perhaps best illustrates the effects of these blazes on fish in the lakes' tributaries. In terms of lives lost, it was one of the worst single disasters in U.S. history—far worse than the more celebrated two-day Chicago fire that began the same day. Some 1,200 to 1,300 people perished in the Peshtigo fire, which consumed more than a million acres of stumps and the debris of fallen trees left by lumberjacks. As for the fish, according to one account:

"The Peshtigo River had been alive with pickerel, bass, sturgeon, suckers and other fish. Each spring before the fire, farmers had driven down to the banks with poles and nets. By evening they had a wagonload of fish to take home, where it was salted or smoked for use the following winter. But that fall of 1871, after the Great Fire had passed, the streams in the burned-over area were full of dead fish and for weeks afterward the water tasted of lye."

The lumbering itself also took a toll on the fish. The practice of "driving" logs downstream inevitably scoured the stream bottom, destroying spawning grounds and incubating eggs alike. Dams constructed to help control water levels for floating the logs prevented fish from reaching upstream spawning grounds. Once downstream, the logs were usually gathered together in sheltered bays and towed along the shore in large rafts to lakeside sawmills, producing an accumulation of rotting bark and waterlogged wood in these critical nearshore habitats.

The sawmill operations also hurt the lakes' fish populations. An 1874 report on Great Lakes fisheries noted that "the refuse from the sawmills . . . is thrown into the streams in immense quantities to float out and sink in the lake. It is having a very injurious effect on the fisheries. The waterlogged slabs . . . tear and carry away the nets. The sawdust covers the feeding and spawning grounds of the fish." A later report described a similar situation on the Menominee River, a major tributary to Green Bay:

"The establishment of sawmills upon the Menominee River and the consequent deposition of great quantities of sawdust in the water has effected the ruin of the fisheries in the vicinity . . . the spawning grounds of the whitefish for a long distance outside the mouth of the river and on either shore, north and south, have been completely ruined. It is not unusual for vessels to meet portions of the mass of sawdust 20 to 30 miles from Menominee, and the water at the entrance of the bay is often covered with it. It is said to have accumulated at the mouth of the river, forming masses in some places eight feet deep."

Not only were fishing grounds damaged, but the once-extensive stocks of river whitefish, like those in the lower reaches of the Menominee, were destroyed by logging dams and debris. Today, however, the sawmills and the practice of dumping sawdust into the lakes and streams have largely disappeared and so, apparently, have their damaging effects on fish habitats.

Meanwhile, the mouths of major tributaries quite naturally had become the sites of many of the region's major cities and ports—Duluth-Superior, Green Bay, Milwaukee, Chicago, Toledo, Cleveland. Besides the disruption caused by such harbor activities as dredging and shipping, the formerly common practice of discharging untreated human and industrial wastes into these waterways in effect created "pollution plugs" that barred fish from entering many streams they had once used extensively for spawning.

Many coastal marshes were drained to accommodate the region's burgeoning human population. Since the mid-1800s, about 60 percent of the 15 square miles of marsh that originally skirted Green Bay has been lost to development. The huge marshy area at the mouth of the Chicago River, which was once used as a spawning and nursery area by numerous Lake Michigan fish, is now downtown Chicago, and the river itself no longer even empties into the lake, as its waters are now diverted through the South Branch and Chicago Sanitary & Ship Canal into the Des Plaines River. Much of the wetlands around the western tip of Lake Erie, like the Black Swamp around the Maumee River inland from Toledo, were drained and converted to agricultural use.

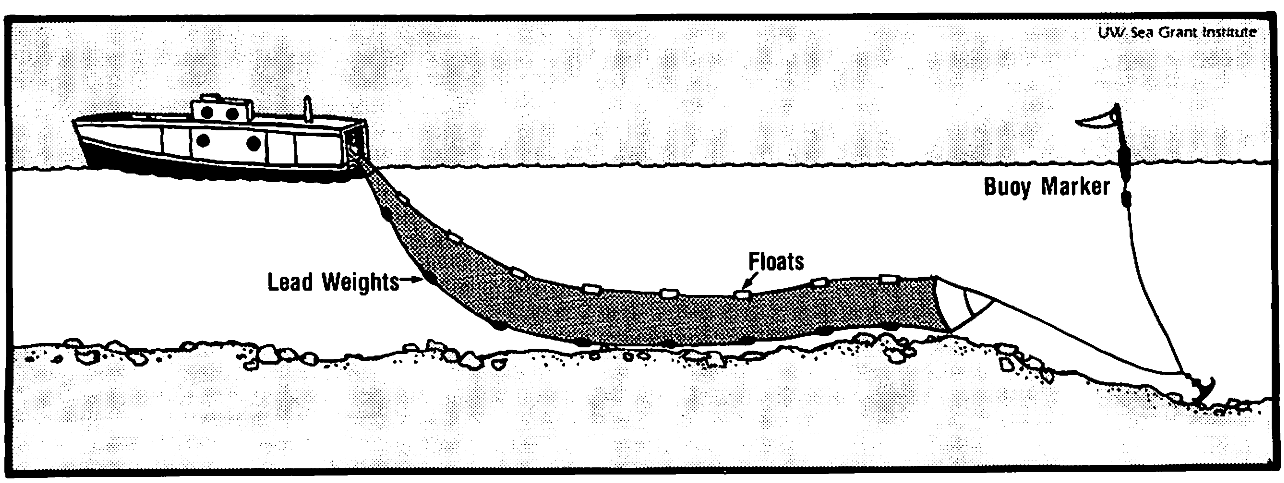
The effects of these developments—the deforestation, the sawmills, the damming of tributaries, the growth of cities and agriculture, the loss of coastal marshland—all helped set the stage on which the disasters that later befell the fish populations of the Great Lakes were to be played out.

FISHING TECHNOLOGY IMPROVES

Commercial fishing on the Great Lakes was at first conducted close to shore—where whitefish in particular were extremely abundant—with haul seines. Introduced on Lake Superior by the American Fur Company, gill nets were commonly used on the Great Lakes by the mid-1840s. Pound nets were introduced some 10 years later, by which time haul seines had been abandoned altogether.

Still used today, gill nets were reportedly being used by Native Americans on the upper Great Lakes as early as 1781. These nets are fairly simple in design: A net made of thin thread is attached between two heavy cords, and weights are attached to one side and floats to the other so that when the net is laid in the water it forms a curtain. Fish smaller than the net's mesh size swim through the net, but larger ones get only partway through the net and are caught by the gills when they try to back out. The mesh size can be increased to catch large fish like whitefish, trout, walleye, suckers and carp, or reduced to catch small fish like lake herring, deepwater ciscoes, perch and round whitefish.

The first commercial fishing gill nets were all made by hand from the threads of unraveled linen from Europe. Stones were used as sinkers, and strips of cedar were used as floats. Later, the nets were made from strong twine imported from Scotland. The gill nets used today are made from a fine synthetic twine, the floats are made of aluminum or plastic, and the weights are made



Setting the gill net. Like an anchored curtain, this net traps fish that swim into it by tangling them around the gills.

of lead. A fishermen must own a large number of gill nets, since the fragile mesh is frequently damaged by rough water and oversized fish. Ranging from 250 to 800 feet in length, these nets were once strung end-to-end in "gangs" that sometimes stretched for miles. Though they can be longer, gangs even a half mile long are rare today.

Introduced from Scotland, the pound net was first used on Lake Ontario around 1836 and was used throughout the Great Lakes during the 1850s. It consists of a "lead net"—a long strip of coarse netting that stretches fence-like from near shore to a depth of 40 or 45 feet—that steers fish out into deep water, through a narrow opening between two "wing nets" and into a large net-and-pole impoundment.

The trap net, introduced a short time later, also came into extensive use on the Great Lakes. It is much like the pound net but smaller, and it is held in place by anchors rather than poles embedded in the lake bottom, which makes it much easier to set and move.

Blessed with a large resource, the Great Lakes fishing industry prospered as these and other improvements in fishing technology—like the use of large, steam-powered fishing boats—continued apace through the 19th century. Not only did fishermen become more efficient as the century progressed, but they were able to go farther afield. One major advance was the introduction around 1890 of steam-powered drums for hauling in gill nets, which previously had to be pulled up by hand.

Long before the first regular surveys of the U.S. catch of Great Lakes fish began in 1879, it had become apparent that a once-enormous resource was in decline. This was one reason the federal government had created the U.S. Fish Commission in 1871, and the State of Wisconsin created its own fisheries commission three years later. The second annual report of the Wisconsin Commissioners of Fisheries, in making a case for stocking fish in Lakes Superior and Michigan, observed:

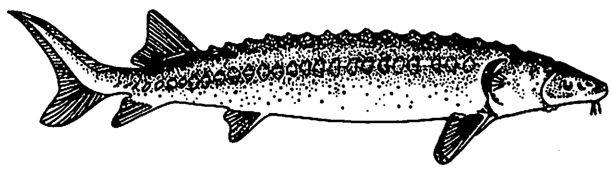
> ***"During the year 1875 there has been great complaints of scarcity of fish, and there has been a falling off of at least one-fourth; so that it is evident to all that the waters of Lake Michigan are being gradually depleted of fish."***

But as the fish became scarcer, instead of easing up, Great Lakes fishermen only tried harder, employing more boats, working longer hours, going further afield. Whitefish stocks in Lake Michigan, for example, were already in decline by the 1860s. The scarcity had become a common complaint among fishermen by the 1870s, yet the harvest remained high—totaling some 12 million pounds in 1879—as fishermen increased their fishing effort, shifted to new fishing grounds and used more efficient gear, including smaller meshes and finer twine in the gill nets. The whitefish catch dropped abruptly after that, though the total catch of Great Lakes fish remained stable until 1892 because of increases in the harvest of other species.

With all the other events occurring in and around the lakes during this period, however, it is difficult to assign blame for the declines in whitefish and other fish populations. Most likely it was due to the combination of both environmental changes and overfishing rather than just one or the other. Perhaps some fish populations were destabilized by the loss of their eldest and largest members, who, like the old trees in the primeval forests, were the first to be harvested. Overfishing was clearly a factor, however, in the demise of the hulking grandfather of lake fish, the sturgeon.

Lake Sturgeon

Acipenser fulvescens



Early Great Lakes fishermen largely regarded the big lake sturgeons as a nuisance because they were constantly fouling and damaging their nets. Up to 1875, commercial fishermen tried their best to exterminate the sturgeon. Sturgeon caught in fishing nets were usually removed, fatally wounded and tossed back into the water. Huge numbers of them were piled into offal heaps on shore, doused with kerosene and burned. They were so despised as a fish that they were even used as fuel under the boilers of early Great Lakes steamers.

Once the sturgeon became appreciated for its eggs (caviar), oil and a gelatin used for making isinglass, it was almost fished to extinction. More than three million pounds of sturgeon were harvested from Lake Michigan in 1880; by 1903, however, the catch had declined to only 65,000 pounds.

A BOUNTIFUL HARVEST

Capable of living 100 years or more, a sturgeon does not spawn until well into its teens or early twenties. Even then, the female will only spawn every four to six years. This slow reproductive cycle made the sturgeon highly vulnerable to overexploitation, and it has never fully recovered. Lake sturgeon still cannot be fished commercially today.

REACHING THE PEAK

In 1899, the U.S. Great Lakes commercial fish harvest hit its peak with a total catch topping 119 million pounds. The increasing catch only reflected greater fishing effort, however, as it was clear by then that the lakes' fish populations were declining and had been for decades.

Great Lakes fishermen were spending more and more time and money to catch fish—and the proceeds were being divided among more and more people. In 1880, for example, about 5,000 people were employed in the Great Lakes fishing industry. By 1885, there were twice as many people in the industry, twice as many vessels and twice as many pound nets, gill nets and seines, yet the catch of fish increased only 45 percent.

Even so, Great Lakes commercial fishermen today have reason to look back fondly on the first decades of the 20th century. In those days, it was still possible to go into business with a boat as small as 17 feet and a single pound net, and, despite the thousands of commercial fishermen on the lakes, there still seemed to be enough herring, lake trout and whitefish to go around. In winter, some fishermen even went out on the ice to continue fishing, living in little shanties where local farmers brought them supplies and fish buyers collected the catch on horse-drawn sleighs.

Again, it is difficult to measure precisely, but no doubt the swelling number of people living in the region and the attendant increase in municipal and industrial wastes going into the lakes were also having an increasingly adverse effect on fish populations at this time. The human population jumped 28 percent in the Great Lakes Basin between 1900 and 1925, mostly around Lakes Erie and Ontario. Over the next 25 years, the population in the basin spiraled upward another 40 percent to some 18 million people.

The water of Lake Michigan's Green Bay, for example, deteriorated rapidly under a continuous heavy dose of paper mill wastes delivered by the Lower Fox River. In 1927, the Wisconsin Conservation Commission and State Board of Health issued a special report with the following lament:

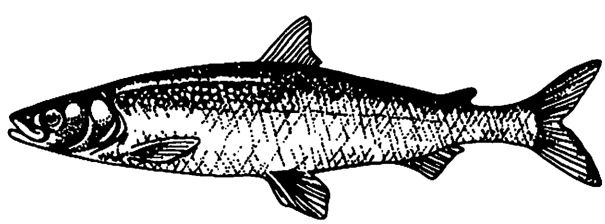
"Even the more resistant fishes, which inhabit the lower regions of the river, cannot withstand the combined effects of extensive pollution, low stream flow and high water temperatures which frequently exist during the latter part of the summer and early fall. The death of a large number of fish in the section of the river from Wrightstown to Green Bay has become almost an annual occurrence."

The report blamed the fish kills on low dissolved oxygen levels caused by untreated pulp and papermill wastes. The reduced streamflow caused by the proliferation of dams on Green Bay tributaries apparently was also a factor.

Like Green Bay, the nearshore waters of Lake Erie were also undergoing visible deterioration due to the increasing amounts of nitrogen, phosphorus and other nutrients entering the lake. These nutrients stimulated aquatic plant growth, the decomposition of which reduced the amount of dissolved oxygen in the water. This became a major problem in Lake Erie largely because the shallowest Great Lake was least able to absorb the increase in nutrients and silting due to agricultural activities in the basin and the destruction of coastal wetlands. The loss of coastal marshland was considered by some to also be a major factor in the loss of the lake's populations of northern pike, an important commercial fish species that preferred nearshore waters.

The collapse of Lake Erie's lake herring population in the mid-1920s was the first collapse of a major fishery and a dramatic indication that the whole Great Lakes fishery was in trouble. The lake herring had always been an important catch in all the Great Lakes, with the Lake Erie catch alone ranging from 20 million to 49 million pounds annually. But in a matter of years, the catch dropped to almost nothing, apparently due to both overfishing and environmental factors.

Lake Herring
Coregonus artedii



Events in Lake Huron in the 1930s were just as ominous. At that time, the deep trap net—a more versatile version of the pound net—was introduced and quickly adopted throughout the U.S. waters of the lake. Its widespread use soon depleted local fish stocks, which in turn forced many fishing operations to close. In 1931, more than 4.1 million pounds of whitefish were taken from Lake Huron. By 1942, the catch had declined to less than 100,000 pounds. But by then, it was clear that a far more devastating and unmanageable problem than overfishing and pollution had struck the Great Lakes fisheries.

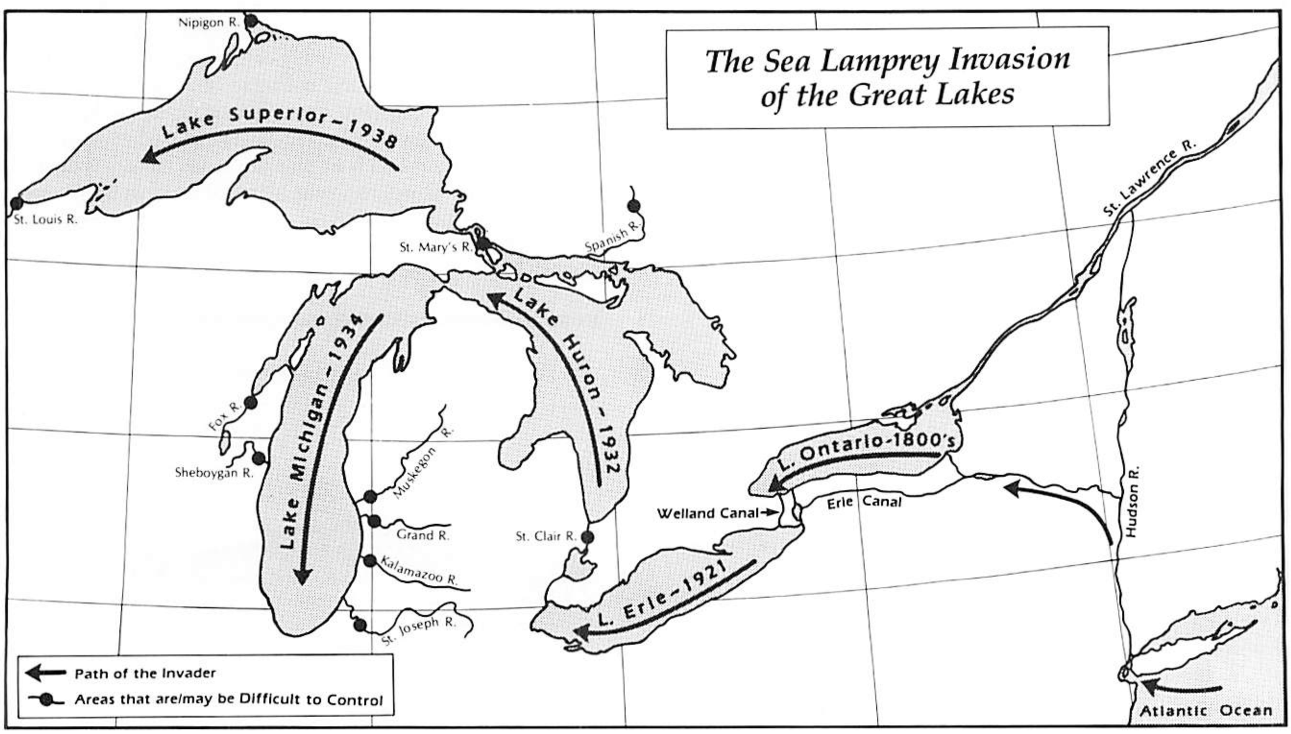
ALIEN INVASION

For 3,000 years, the great wall between Lake Erie and Lake Ontario—Niagara Falls—had barred new species of fish from entering the upper four Great Lakes. However, the falls also prevented ships from entering or leaving these inland seas, and in 1829 the Welland Ship Canal was built around the falls. In 1919, the canal was enlarged and improved for the fourth time, and within two years a grisly new type of fish had appeared in Lake Erie—the sea lamprey.

The foot-long, snake-like sea lamprey is one of only two survivors of an ancient family of fish that existed before the dinosaurs, one that has survived 250 million years—the jawless fishes. Since it has no jaws, the lamprey feeds by attaching itself to the sides of large fish, rasping a hole in the skin, and sucking their blood and body fluids. The parasite remains attached to its victim for hours, days, even weeks—until it is no longer hungry, or its victim dies.

The sea lamprey is actually a saltwater fish, native to the Atlantic Ocean from the Maritime Provinces of Canada to Florida. Like salmon, it is an anadromous fish—one that normally spends its adult life in the open sea but runs up freshwater streams to spawn. Like many anadromous species, however, it can live its entire life in freshwater.

Some scientists believe that a few sea lamprey had always existed in Lake Ontario, colonizing it via the St. Lawrence River, while others believe it first arrived there via the Hudson River after the Erie Canal was completed in 1825. In either event, the clearing of the surrounding land and the resultant warming of Lake Ontario's cold-running tributaries apparently created a much more favorable spawning environment for the



The Sea Lamprey Invasion of the Great Lakes lamprey, enabling it to greatly increase in number. The presence of sea lampreys in Lake Ontario was first noted in 1835, yet the parasite did not become firmly established there until the 1880s—which perhaps also explains why it had not previously used the Welland Canal to reach Lake Erie. About the same time, Lake Ontario's fish stocks declined precipitously. Whether the sea lamprey played a major role in these events is unclear, but by 1900 the lake's largest predator, the Atlantic salmon, had disappeared.

Sea Lamprey
Petromyzon marinus

Lake Erie and its tributaries, on the other hand, were apparently *too* warm—or too polluted—to suit the sea lamprey, and it never became a serious problem there. The three big upper lakes were more inviting kettles of fish, however, and within 20 years of its appearance in Lake Erie, it had colonized them all. The first sea lampreys were spotted in Lake Huron in 1932 and in Lake Michigan in 1934. By 1938, they had arrived in Lake Superior as well.

With no natural predators in the lakes to control it, the parasite wreaked havoc among the Great Lakes fish populations, particularly lake trout and whitefish. The annual commercial catch of lake trout from Lakes Michigan and Huron dropped from a total of more than 11 million pounds in the early 1940s to less than 200,000 pounds just 15 years later. The lake trout populations collapsed in all the lakes but Lake Superior, and even there the lake trout harvest plummeted from an average of 4.5 million pounds a year in the late 1940s to only 500,000 pounds by 1960.

The burbot and whitefish populations in the upper Great Lakes were similarly devastated, and then the lampreys attacked the lakes' walleyes and suckers. Perhaps aided by overfishing, the lamprey wiped out many of the large cisco species in the three upper Great Lakes. Of the Great Lakes' five unique species of ciscoes, only the smallest—the shortjaw cisco, kiyi and bloater—survived. Hundreds of commercial fishing operations also became extinct.

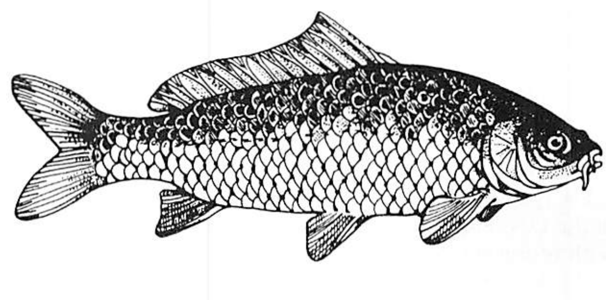
Following the sea lamprey through the Welland Canal from Lake Ontario into the upper lakes was another ocean fish that wreaked its own special form of havoc in the Great Lakes ecosystem—the alewife. Thanks to the sea lamprey, this small, sardine-like fish found a Great Lakes devoid of large predators, and in a short time alewives exploded in number in each of the upper four lakes except Superior, which is apparently too cold for it.

First reported in Lake Michigan in 1949, for example, the alewife was already being harvested commercially in 1956. A year later, the catch exceeded 100,000 pounds, and by 1958 it totaled more than a million pounds. As the numbers of valuable fish in the lake continued to decline, some fishermen could at least market the plentiful alewives for use in fishmeal, fertilizer and pet food. However, the alewife was not a commercial fish of first choice, and many commercial fishermen switched to fishing for perch, walleye and chubs.

By the 1960s, the alewife made up more than 80 percent of the lake's total number of fish and half of the total biomass. As its population expanded, it left less and less room for other species in the lake. Besides competing for food and habitat, the alewives also ate the eggs of other fish. Once the lake's most abundant commercial species, the lake herring completely disappeared from Lake Michigan under the combined pressure of alewives and commercial fishing. The emerald shiner—historically one of the most abundant species of fish in the lake—was reduced to small, isolated populations around the mouths of rivers.

Besides the sea lamprey and alewife, numerous other alien species of fish have also taken up residence in the Great Lakes, and each produced its own destabilizing effect on the ecosystem. First imported as a farm pond food fish in the 1800s, the German carp soon found its way into the Great Lakes, where it competed with the

Carp
Cyprinus carpio



native lake sturgeon for nearshore bottom habitat. Rainbow smelt, which feed on the fry of lake herring and whitefish, likewise originally escaped from inland lakes in Michigan, where they were being used in the early 1900s to feed stocked salmon. Rainbow trout and the brown trout, a European relative of the Atlantic salmon, were both first stocked in the Great Lakes by state fishery agencies in the 1880s. In 1956, about 20,000 pink salmon from the Pacific Ocean were accidentally released into a tributary to Lake Superior's Thunder Bay, and the fish has since spread to all five Great Lakes—the only saltwater salmon to reproduce naturally in substantial numbers so far. White perch and goldfish are two other exotic fish that now call the Great Lakes home. With the notable exception of the smelt, most of these invading fish had little commercial value—and they displaced many native species that did.

The invasion of these alien species and extinction of native species, coupled with the various human changes to the surrounding landscape, forever destroyed the original fish community structure of the Great Lakes. By the 1960s, the Great Lakes ecosystem was in shambles. Perhaps the lowpoint was reached in spring 1967, when a mass die-off of alewives occurred in Lake Michigan, apparently caused by a combination of starvation due to overpopulation and unusually cold weather. Hundreds of millions of rotting silvery carcasses washed up on Lake Michigan's beaches—pungent notice to everyone that the Great Lakes fishery was in serious trouble.

UNITED BY AN ENEMY

Prior to the sea lamprey invasion, management of the Great Lakes fishery was uncoordinated and largely ineffective. Most early attempts to stock whitefish and other declining species of fish in the lakes failed, while the introduction of exotic species to rejuvenate the fisheries too often succeeded—with precisely the opposite effect. Other management approaches—like restrictions on commercial fishing gear—were usually imposed too late and with too little information to be effective.

The need for comprehensive management of the Great Lakes fishery first became apparent in the late 1800s, when the lakes' fish stocks began declining. One of the first efforts at interstate cooperation on Great Lakes fisheries issues occurred in 1883, when members of the U.S. Fish and Game Commission met in Detroit with representatives from Minnesota, Wisconsin, Ohio and Michigan. Not one of the state legislatures approved any of the 13 recommendations adopted by the representatives, however. Twenty-six other interstate and international conferences on the Great Lakes fishery held between 1883 and 1941 were equally unproductive.

By the 1940s, however, the sea lamprey had made it clear that cooperation was the only alternative to the eventual demise of commercial fishing in both Canadian and U.S. waters of the Great Lakes. In 1946, the two nations created the Great Lakes Sea Lamprey Committee, which later merged with the Great Lakes Lake Trout Committee. That group was replaced in 1955 with the Great Lakes Fishery Commission, created by a treaty between the U.S. and Canada. A primary mission of the new commission was to find a way to control the sea lamprey.

The first attempts to control the lamprey with mechanical and electrical barriers in the streams where they spawned were relatively unsuccessful. U.S. and Canadian scientists soon determined that the best way to drive a stake into the heart of this "vampire" was to kill its larvae, thousands of which spent anywhere from three to 14 years in the streambeds where they were spawned before going back into the lakes as parasitic adults. After searching five years and testing some 6,000 different chemicals, U.S. Fish and Wildlife Service biologists in 1958 found an obscure chemical called TFM that selectively killed lamprey larvae without apparent harm to other aquatic life.

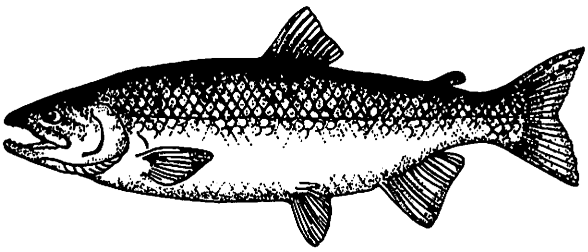
Because Lake Superior still had small surviving stocks of lake trout, it became the first lake to receive intensive TFM treatments. By 1962—just two years after the U.S. and Canada had completed treating all infested tributaries to the lake—the number of adult lamprey returning to spawn had dropped a spectacular 85 percent. Regular lampricide treatments began on Lake Michigan in 1963, on Lake Huron in 1970 and on Lake Ontario in 1972—all with similar results.

Assisted by vigorous stocking, the lake trout populations in Lake Superior soon rebounded. The native whitefish and burbot populations also made dramatic comebacks. By the early 1970s, the average annual commercial catch of whitefish was more than double what it was in 1960.

With the lamprey under control at last, the U.S. Fish and Wildlife Service and Great Lakes provincial and state agencies began a massive predator fish planting program both to bolster the fisheries and to bring the alewife under control. In the first 20 years after TFM treatments began, an average of about four million lake trout a year were planted in the Great Lakes. To the disappointment of the agencies and commercial fishermen alike, however, the stocked lake trout—produced from hatchery brood stock—largely failed to reproduce successfully in the lakes.

Coho Salmon

Oncorhynchus kisutch



After the massive alewife die-off in Lake Michigan in 1967, the State of Michigan and later Wisconsin began also stocking the lake with hundreds of thousands of coho salmon and then with millions of chinook salmon—predators imported from the Pacific Ocean to prey on alewives.

A MAJOR SETBACK

In 1965—just as it seemed lamprey control would save the Great Lakes commercial fishery—residues of DDT and another agricultural pesticide, dieldrin, were found to be contaminating Great Lakes fish. Fatty fish, including commercially harvested fish like chubs, lake trout, carp and salmon, were found to be accumulating relatively high levels of these persistent pesticides—levels deemed unsafe for human consumption by the U.S. Food and Drug Administration (FDA).

The "contaminated" label caused severe economic hardships on the already hard-pressed Great Lakes commercial fishing industry. In Lake Michigan, for example, the FDA shut down the fledgling commercial salmon industry in 1969 because of high levels of DDT in its canned salmon. The chub harvest was also curtailed. A once-thriving commercial carp fishery practically folded.

After use of DDT was banned in 1972, the levels of contamination dropped quickly. The amount of DDT in Lake Michigan bloater chubs, for instance, dropped from an average of 10 parts per million (ppm) in 1972 to less than 3 ppm just two years later. Similar reductions were recorded in fish from Lake Erie and Lake St. Clair near Detroit, two of the most heavily contaminated areas of the Great Lakes.

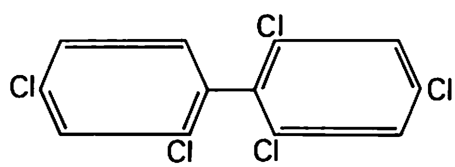
Then, about the time the DDT problem seemed to be fading away, another group of toxic compounds—PCBs—were found to be contaminating the lakes' fish. Used in the U.S. since the 1930s in adhesives, plastics, paints, electrical components and carbonless copy paper, PCBs are suspected of contributing to a variety of health problems, including developmental problems in children, liver damage and cancer. Because they do not break down easily into less harmful chemicals, PCBs persist for a long time in the environment. Being mobile compounds, they both leach out of landfills into groundwater, rivers and lakes, and evaporate into the air. Recent scientific studies have shown that atmospheric fallout accounts for 50 to 80 percent of the PCBs entering the Great Lakes today.

Once in the lakes, PCBs become concentrated in the fat of large fish through a process called "biomagnification," whereby they become attached to particles in the water and phytoplankton eaten by the lakes' zooplankton, vast numbers of which which are eaten by small fish, huge numbers of which are eaten by the large fish preferred by people. In the end, large fatty fish like lake trout, carp and chinook salmon may contain PCB concentrations 100,000 to one million times higher than the concentrations in surrounding waters.

The manufacture of PCBs was curtailed in 1970, and in 1976 PCB use was restricted to closed systems like electrical transformers and capacitors. The use of PCBs is now being phased out completely. Like DDT, the levels of PCBs in Great Lakes fish have since fallen dramatically, but they remain high enough in certain fish—particularly in some of the larger lake trout, chinook salmon and brown trout in Lake Michigan—that state agencies still issue yearly health advisories about eating the fish.

Concerned by these discoveries, government and university scientists began testing for other contaminants. They found that the fish, water and sediments of the Great Lakes contain varying amounts of a host of toxic compounds—including mercury, lead, dioxin, mirex and toxaphene—which come from a variety of human sources, such as industrial waste discharges, power plant emissions, automobile exhausts and runoff from cities and farms.

Thanks largely to federal, state and private efforts to curb water and air pollution since the early 1970s, the input of many of these toxics has been reduced. Today, though PCBs continue to be a major concern, most contaminants appear to be a problem only in local pollution "hot spots."



A PCB Molecule (pentachlorobiphenyl)

SPORT FISHING REVIVAL

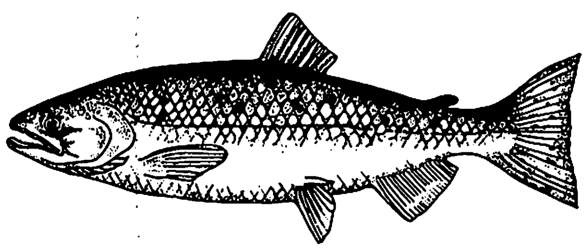
A WHOLE NEW GAME

Despite the contaminants problem, the predator stocking programs proceeded full ahead—and in a very brief time had the somewhat unanticipated effect of causing a regionwide epidemic of "coho fever," a condition of extreme excitement previously unknown among Great Lakes sport fishermen.

Largely to satisfy the increasing numbers of sport anglers, huge numbers of salmon have been stocked in the Great Lakes since the late 1960s. As of 1983, the accumulated plantings of coho salmon totaled nearly 46.7 million for Lake Michigan, 6.7 million for Lake Superior, 7.8 million for Lake Huron, 15.7 million for Lake Erie and 7 million for Lake Ontario. The accumulated plantings of chinook salmon by 1983 totaled 7.3 million for Lake Superior, 59.8 million for Lake Michigan, 17.4 million for Lake Huron, 10.9 million for Lake Erie and 12.6 million for Lake Ontario.

Chinook Salmon

Oncorhynchus tshawytscha



Virtually nonexistent just 20 years ago, the Great Lakes sport fishery today has a regional economic worth estimated at more than $1.1 billion and has been responsible for the economic revival of hundreds of coastal communities. By comparison, the Great Lakes commercial catch today has a dockside value totaling about $48 million a year, though its regional economic impact is about four times that amount.

The sport fishing boom also caused a large charter fishing industry to develop throughout the region. In Wisconsin, for example, only a handful of charter boats plied Wisconsin's Great Lakes waters in the early 1970s; by 1985, there were about 560 of them. The story is much the same in Minnesota, Michigan, Ohio, New York and the Chicago area.

"I think you can almost look on the charter boat industry as a 'new wave' commercial fishery," Carlos Fetterolf, executive secretary of the Great Lakes Fishery Commission, said recently, noting that the charter fishing industry is already being regulated in much the same way as the traditional commercial fishery.

The tremendous growth in sport fishing soon created fishery allocation conflicts between commercial fishermen and anglers in almost every Great Lakes state, as the regulation of the fisheries within their borders is a state prerogative. Some fish, like whitefish and chubs, are only harvested commercially. Others, like most species of salmon and trout—which are grown in hatcheries and stocked with the financial support of anglers—are mainly reserved for sport fishermen. And some, like yellow perch, are shared by both groups.

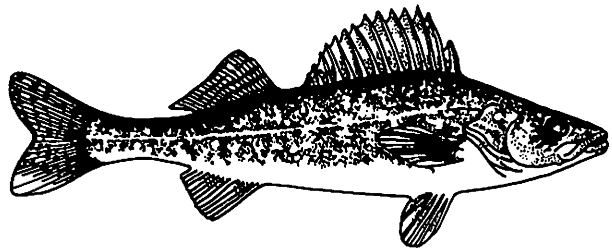
After weighing both sport and commercial fishing, several economists have concluded that a fish caught for sport generates a greater economic benefit than one brought in commercially. Given the greater economic returns of the sport fishery, most state policymakers in the 1960s lined up on the side of sport fishing. Fish management programs in some states continue to favor sport fishing in conflicts between the two interests. Most Great Lakes states also put an emphasis on stocking salmon, trout and walleye, which are designated almost entirely for sport fishermen.

Michigan and Ohio's departments of natural resources in particular have taken actions to ensure that commercial fishing does not endanger their sport fisheries. Partly to prevent depletion of game fish, the Michigan DNR has imposed strict size limits, catch quotas, season limits, area regulations, gear regulations and limits on the number of licensed fishermen in an attempt to control the size of the commercial fishing industry. Ohio eliminated a large share of the commercial fishing in Lake Erie in favor of sport fishing.

Wisconsin also gave preferential treatment to sport fishing from 1968 to the mid-1970s, when the state reconsidered and decided it was also important to maintain a "viable" commercial fishery.

Walleye

Stizostedion vitreum vitreum

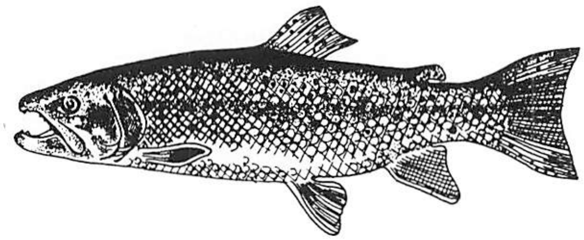


The fisheries allocation problem has been further complicated by the issue of Native American fishing rights. Many Great Lakes tribes, the Chippewa in particular, ceded their lands to the U.S. in exchange for perpetual hunting and fishing rights. In Wisconsin, for instance, the Bad River and Red Cliff bands of Chippewas have claimed their treaty rights to fish anywhere in Lake Superior at any time—a claim that has been upheld by the Wisconsin Supreme Court. State fish wardens thus have no authority over tribal fishermen, and state fishing regulations cannot be used to control their activities. This has caused considerable concern among fisheries managers and raised the ire of some commercial and sport fishermen.

Even though the State of Michigan has gone to court on virtually every issue regarding Native American fishing rights, an agreement between the state and tribal fishermen has recently been reached. In Wisconsin, a workable agreement also was struck recently between the state and tribal fishermen in which the annual quota on lake trout is to be divided equally between tribal fishermen and sport and commercial fishermen. Though their whitefish catch remains unrestricted, the Chippewa fishermen are now respecting the state's Lake Superior fish refuges and closed seasons.

Rainbow Trout

Salmo gairdneri



THE FISHERY TODAY

Most observers agree that the Great Lakes fishery, both commercial and sport, is better off today than it has been for a long time. One reason is that more is known today about fish biology—how they reproduce, live and interact with their environment and each other—than ever before.

"The overall outlook is excellent, especially for Lake Michigan. We think we now know how to manipulate the Lake Michigan fishery, and that we can fine-tune it to get even more out of it than we do now," according to Lee Kernen, chief of the Great Lakes and Boundary Waters section of the Wisconsin DNR's Bureau of Fish Management.

But opinions differ as to the direction such manipulation will—or should—take. Until basin-wide management plans can be laid out that include long-range goals as well as more immediate objectives, opinions will continue to differ. Presently, the Lake Michigan sport fishery (lake trout and salmon) is largely a put-and-take fishery. This gives management agencies greater flexibility in managing the system, though at greater cost, than would a self-sustaining natural predator-prey system.

Some scientists, fisheries officials and commercial fishermen, however, have qualms about continuing to stock Pacific salmon in some Great Lakes waters. U.S. Fish and Wildlife Service biologists have reported that coho salmon are now spawning successfully in most of Lake Superior's tributaries—meaning they are on the brink of becoming self-sustaining, with the possibility that they might interfere with the spawning runs of other valued fish, like rainbow trout. While Michigan continues to stock cohos in Lake Superior today, Minnesota discontinued its coho plantings in 1974, and Wisconsin never planted cohos in Lake Superior.

Also, as anyone who fishes the Great Lakes knows, the sea lamprey has not disappeared. Many large fish still bear lamprey scars—mute evidence that eradication of the parasite is simply not possible. Without continuous lamprey control, today's billion-dollar sport fishery could not exist. And as the water quality of many rivers and streams continues to improve, the number of potential spawning sites for lamprey is increasing.

Scientists worry that TFM and a strengthening compound, Bayer 73, will one day lose their potency against the lamprey, or that some yet-undetected environmental damage will emerge. Some scientists believe it is simply best not to rely on chemicals to control such exotics if possible.

Alternative controls currently being explored include the use of lamprey attractants and repellants and mechanical and electrical barriers to thwart lamprey spawning runs. Biological controls—including introduction of natural predators, if one can be found, and genetic manipulation—are also being considered.

Despite massive stocking programs in both Lakes Michigan and Superior, natural reproduction of the once-abundant native lake trout has remained modest in Lake Superior and negligible in Lake Michigan. This failure has been particularly frustrating in view of the ease with which so many unwelcome species of fish have colonized the Great Lakes.

According to University of Wisconsin–Madison Sea Grant zoologist Ross Horrall, who has spent almost a decade working on the problem, some of the factors that may be interfering with the natural reproduction of lake trout include:

- **Contaminants like PCBs and DDT;**
- **Yet-unidentified changes in the lake trout's natural habitat, especially on spawning grounds;**
- **Their early life history in a hatchery disrupts important factors needed for successful reproduction;**
- **The fish are perhaps being stocked at the wrong sites;**
- **They are perhaps being stocked at too old an age to imprint to suitable spawning sites;**
- **The strains of lake trout being stocked may have the wrong genetic makeup to reproduce in the areas where they are stocked;**
- **The number of older mature spawners may be too low; and/or**
- **Spawning usually does not occur on traditional spawning sites.**

Consequently, Horrall and other Great Lakes fisheries scientists are conducting various experiments with lake trout, testing different spawning sites, genetic strains, stocking times and other variables that may have an effect on natural reproduction. Horrall has even interviewed retired commercial fishermen—men who were working when the lake trout were naturally abundant—for help in locating the lake trout's traditional spawning areas. Recently, Horrall has experimentally planted millions of lake trout sac fry over these historic spawning reefs in the hope that they would remember those sites as adults and return to spawn. The results are due to come in soon.

The Wisconsin DNR has also been experimenting with similar types of stocking during the lake trout's early life stages. In the Apostle Islands region of Lake Superior, the DNR has been planting lake trout eggs in specially designed Astroturf sandwiches.

It may take several more years of stocking, study and experimentation to unravel the mystery. Or, at some point in the future, "the right fish might just meet at the right place at the right time, and they'll do it all by themselves," Horrall said. In either event, after years of continuous stocking, it seems the odds should be improving, since thousands of stocked lake trout now live in Lake Michigan and the other Great Lakes.

The history of the Great Lakes fishery has largely been one of disasters and surprises—most of them unpleasant. One pleasant surprise in recent years has been the comeback of the bloater chub in Lake Michigan.

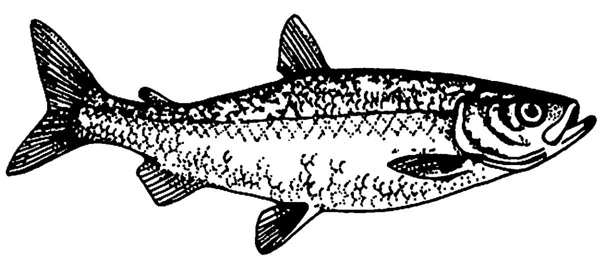
The bloater—small, oily and slow-growing—was never popular as a fresh fish, but it was quite popular as a smoked fish. When the alewife population in Lake Michigan exploded during the 1960s, bloater populations fell rapidly. To help stem the decline, the Wisconsin DNR banned chub fishing in Wisconsin Great Lakes waters between January and March, when most chubs spawn.

Despite the ban, the commercial catch dropped to almost nothing by the mid-1970s. Many biologists predicted the chub was doomed to extinction, and the states of Wisconsin, Michigan, Indiana and Illinois agreed to close the chub fishery in 1976.

Sampling by the Wisconsin DNR indicated that the 1977 year-class of bloater had shown a slight increase. Then the bloater's population exploded. The 1978 year-class was six times larger than in any of the previous 10 year-classes. The chub's comeback was so strong that the commercial bloater fishery was reopened in 1979. The annual commercial quota has increased from 900,000 pounds in 1979 to three million pounds in 1985. As the bloater continues to multiply, the Wisconsin DNR has recommended a 3.5 million pound quota for 1986.

Bloater

Coregonus hoyi



Scientists are not sure why the bloater rebounded in such a brief time, nor are they convinced that the event was due entirely to the lakewide ban on chub fishing.

"That's one of the questions," said John Magnuson, director of the UW-Madison Center for Limnology. "In fact, we think they came back in part because the alewives and smelt were becoming less abundant than they were at the time the chubs were declining. The response of the chubs was perhaps partly due to the closing of the fishery, but also partly due, we think, to reduced interactions with the alewives and smelt."

Scientists know it is possible, if conditions are right, for very small numbers of adult spawners to produce very large numbers of young. Apparently, conditions were just right for the bloater chub.

A SILVER LINING

The Great Lakes supported some 10,000 commercial fishermen at the turn of the century. Today, only about 600 part- and full-time commercial fishermen wrest a living from the Great Lakes, and the number continues to decline.

While such factors as fluctuating catches, higher operating costs and marketing problems due to contaminants have all played a role, the declining number of commercial fishermen in recent years reflects the policy of limiting commercial fishing in favor of sport fishing adopted by Ohio and Michigan, formerly two of the biggest commercial fishing states on the Great Lakes. Even in Wisconsin, where commercial fishing is still endorsed, only 230 licensed commercial fishermen worked Lakes Michigan and Superior in 1984—down about 100 from five years earlier—and their numbers are expected to drop further.

Consequently, the Great Lakes commercial fishing industry of the future is likely to be both smaller and more strictly managed, yet the overall prospects for commercial fishing appear good, especially on Lake Michigan, and the commercial and tribal fishery on Lake Superior is as good as its been in 50 years.

In its early years, 90 percent of the Great Lakes commercial catch consisted of lake herring, chubs, whitefish, yellow perch, sturgeon and lake trout. Though the sturgeon still cannot be harvested commercially, the populations of the other traditional commercial species have—like the bloater chub—shown notable improvement in recent years.

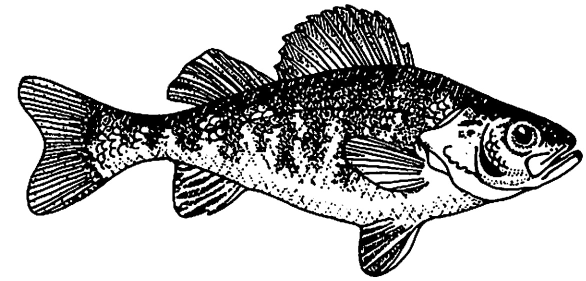
Historically one of the most valuable species of fish netted by commercial fishermen on northern Lake Michigan and Green Bay, the whitefish there have greatly increased in number since the lamprey was brought under control in the 1960s. By the 1970s, the commercial whitefish harvest from these waters averaged more than 2 million pounds a year. In recent years, the average has been closer to 3 million pounds annually, and the fishery "appears to be in good health," according to UW-Stevens Point Sea Grant biologist Frederick Copes. Whitefish stocks are also strong in Lake Superior, where Wisconsin fishermen alone now harvest an average of 300,000 to 340,000 pounds per year.

One of the most productive perch fisheries on the Great Lakes, the Green Bay yellow perch harvest from 1952 to 1964 averaged more than a million pounds a year. Competition from alewives and overfishing by commercial operators, however, caused the bay's perch population to collapse in 1965. In 1966, the commercial harvest was only 162,000 pounds and has averaged less than a half-million pounds since then.

However, the bay's perch population has shown improvement since 1983, when the commercial perch quota was cut to 200,000 pounds under a Wisconsin DNR plan to achieve a 600,000-pound commercial harvest and a 400,000-pound sport catch by 1991. As a result, the quota was raised to 350,000 pounds in 1984, and the DNR has recommended that the commercial catch quota be raised to 400,000 pounds in 1986.

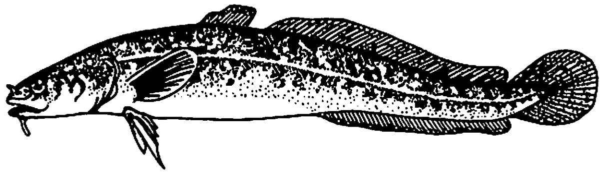
Up until the 1980s, lake herring continued to be rare except in Lake Superior, and even there the herring populations were depressed. In the last seven years, however, Lake Superior herring stocks have made an extremely good comeback. Wisconsin commercial harvests today total about 150,000 pounds each year.

Except by Native American fishermen, lake trout can be harvested commercially only on Lake Superior, the only Great Lake where some stocks of lake trout survived the lamprey invasion. Today, the lake trout harvest by commercial and tribal fishermen in Wisconsin waters of the lake averages more than 240,000 pounds annually.



Yellow Perch
Perca flavescens

Burbot
Lota lota



In addition to these traditional commercial species, scientists and commercial fishermen alike believe the future may lie in harvesting other species of fish—the so-called "underutilized species," such as carp, suckers and burbot.

Small commercial fisheries already exist for some of these fish. Great Lakes suckers are being marketed as bait to Southern fishermen. In some areas, burbot are sold on the local restaurant market. During the last five years, the commercial burbot harvest from Green Bay and northern Lake Michigan has increased nearly five-fold and now totals about 100,000 pounds annually.

However, because consumers are unfamiliar with these fish and are reluctant to buy them, all such species are difficult to market, and most fishermen cannot profit enough to make it worth harvesting these fish. In addition, not enough is known about the biology of these species to adequately manage their harvest were a market to develop.

AIDING AN ALIEN

Recognizing that fisheries everywhere, including the Great Lakes, are historically unstable, Great Lakes fishery biologists believe it is in everyone's best interests to keep the sport and commercial fisheries on solid ground by establishing quotas and other limitations designed to produce long-term sustainable yields.

Consider the alewife. In addition to providing forage for millions of trout and salmon, alewives continue to be harvested commercially for use in animal feeds and fertilizer. Commercial fishermen each year net some 23 million pounds of alewives from Lake Michigan alone. Sport fishermen as well as biologists worry that the alewife is perhaps being overharvested.

"Sport fishermen are becoming increasingly concerned about the forage base," UW-Madison fisheries biologist James Kitchell said. "The continued viability of the alewife is the key to that magnificent sport fishery we see out there."

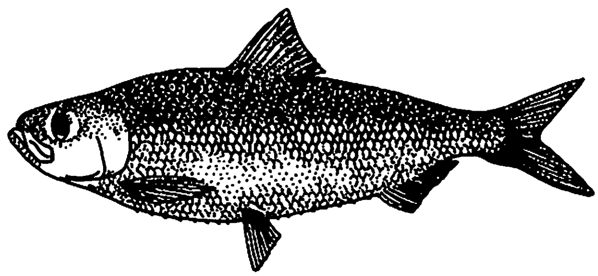
For several years now, Kitchell and his team of UW Sea Grant scientists have been analyzing the predator-prey interactions in the Great Lakes through computer models and fish sampling programs. Their research has indicated that, although the numbers of alewives declined 86 percent between 1981 and 1985, alewives continue to make up more than 70 percent of the diet of Lake Michigan salmon and trout. As a result, there is concern about reduced growth rates in salmon and trout.

The decline in the number of alewives and the reluctance of game fish to switch to other forage fish may ultimately threaten Lake Michigan's trophy sport fishery.

Such research has directly influenced the way Lake Michigan's fishery is being managed. In recent years, both Wisconsin and Michigan have developed forecast schemes and stocking rates based on the carrying capacity of the lake's forage base, and stocking rates for salmon have been curtailed and reduced.

Alewife

Alosa pseudoharengus



For example, the State of Wisconsin has put a ceiling on the number of salmonids it stocks into Lake Michigan each year to maintain about the same pressure on the forage base as in 1982. The state DNR uses microcomputer models derived from Kitchell's bioenergetic models to determine the predator-prey interactions and appropriate stocking rates. Wisconsin uses the "chinook standard" to determine the impact of different salmonids on the forage base—one chinook eats as much as two coho, or 1.5 lake trout.

Likewise, the Michigan DNR stocked 10 percent fewer salmonids into Lake Michigan in 1985 than were stocked in 1984, which reflects its concern about the stability of the forage base. Michigan uses a "coho standard" to normalize the numbers of salmonid stocked, where two coho equal one chinook or 1.5 lake trout.

The carrying capacity of the forage base of the Great Lakes was also the focus of a Great Lakes Fishery Commission symposium in March 1985, and Kitchell received support in 1985-86 from the commission to develop and write an ecological rationale for managing predator-prey systems in the Great Lakes.

LAKE TROUT INCUBATOR EXPERIMENT

SEA GRANT AND THE GREAT LAKES

Though people have harvested fish since prehistoric times, not much was known about aquatic environments until recently. The scientific study of lakes and their ecosystems—limnology—came into being only in the 1800s and first began in the U.S. in the 1890s under Prof. E.A. Birge at the University of Wisconsin in Madison, where Lake Mendota became "the most studied lake in the world."

About the time the alewife die-off in Lake Michigan made the desperate condition of the Great Lakes fishery into national news, the federal government approved the National Sea Grant College and Program Act of 1966, a state and federally funded, university-based research and outreach program dedicated to the development and protection of the nation's ocean and Great Lakes resources.

With its long history in lake studies, the University of Wisconsin in 1968 became the site of the first Sea Grant program in the Great Lakes region. Since then, Sea Grant programs have also been established in Michigan, Minnesota, New York, Ohio and, most recently, in Illinois and Indiana. Together, these programs form the Great Lakes Sea Grant Network, whereby—for the first time—research on the Great Lakes is being coordinated so that duplications of effort are avoided, study methods are standardized and research results are widely disseminated.

Much of what is currently known about the fish, the ecosystem, the contaminants problem and the economic value of the Great Lakes has been produced during the last 17 years by these Sea Grant scientists. This growing body of scientific knowledge is providing state and federal agencies with a far better understanding of how the Great Lakes ecosystem functions—and with new and better tools for managing the fishery.

In addition, Sea Grant scientists and Advisory Services field agents are helping Great Lakes commercial fishermen find new markets and better ways to package their catch, and advising sport fishermen of the contaminants problem and of ways to prepare the fish so that the amount of toxics is reduced.

The Great Lakes can never be restored to their pristine, primeval condition. There is no return to Eden for the fishes of the Great Lakes—their future and fate now depends on the actions, understanding and wisdom of the people who live along the lakes' shores.

PUBLICATIONS, 1984–86

UNIVERSITY OF WISCONSIN SEA GRANT INSTITUTE

Public Information Reports

Home Pickling of Fish. David Stuiber and Mary Mennes. WIS-SG-84-143 (reprinted, 1985).

Home Smoking of Fish. David Stuiber, Mary Mennes and C.E. Johnson. WIS-SG-84-144 (reprinted, 1985).

The Future of Great Lakes Resources. Biennial Report for 1982-84. UW Sea Grant Communications staff. WIS-SG-84-145.

Home Canning of Fish. David Stuiber and Mary Mennes. WIS-SG-84-146 (reprinted 1985).

University of Wisconsin Sea Grant Institute Project Directory, 1984–86. Communications Office staff. WIS-SG-85-147.

The Fisheries of the Great Lakes. Biennial Report for 1984-86. Communications Office staff. WIS-SG-86-148.

Fish of Lake Superior. Warren Downs. WIS-SG-75-124 (revised, 1984).

The Sea Lamprey: Invader of the Great Lakes. Warren Downs. WIS-SG-82-138 (revised, 1985).

Advisory Reports

Great Lakes Small-Craft Harbor & Structure Design for Ice Conditions. C. Allen Wortley. WIS-SG-84-426 (reprinted, 1985).

1982 Charter Boat Operator Study. Jack Gray, Doug Link, Kim Peterson, Al Miller and Gene Woock. WIS-SG-85-427.

Eating Lake Michigan Fish. Fact Sheet. UW Sea Grant Institute. March 1985. (reprinted, 1986).

Cleaning Great Lakes Fish. Sign. UW Sea Grant Institute. March 1985.

How to Select Lure Colors for Successful Fishing. Pennants Series. Lynn Frederick. WIS-SG-85-428-1. (reprinted, 1986).

Hypothermia: Surviving in Cold Water. Pennants Series. James Lubner. WIS-SG-85-428-2. (reprinted, 1986).

How to Reduce Winter Ice Damage to Marinas. Pennants Series. C. Allen Wortley. WIS-SG-85-428-3.

Understanding Ice and Its Behavior in Marinas: Trouble and Intrigue. Pennants Series. C. Allen Wortley. WIS-SG-85-428-4.

Dioxin: A Cause for Concern? Thomas Stolzenburg and John Sullivan. WIS-SG-83-141 (revised, 1984).

Technical Reports

Toxaphene in the Great Lakes. John Sullivan and David Armstrong. WIS-SG-85-241.

Great Lakes Transportation in the Eighties. Ronald L. Heilmann, Harold M. Mayer and Eric Schenker. WIS-SG-86-242.

Reprints

Generator Column Determination of Octanol/Water Partition Coefficients for Selected Polychlorinated Biphenyl Congeners. Kent B. Woodburn, William J. Doucette and Anders W. Andren. WIS-SG-84-759.

Vapor Pressures for Biphenyl, 4-Chlorobiphenyl, 2,2′,3,3′,-5,5′,6,6′- Octachlorobiphenyl, and Decachlorobiphenyl. L. Burkhard, Dave Armstrong and Anders Andren. WIS-SG-84-760.

Identification of Volatile Aroma Compounds from Oxidized Frozen Whitefish. David B. Josephson, Robert C. Lindsay and David A. Stuiber. WIS-SG-84-761.

Reprints (continued)

Phytoplankton Standing Stock, Size Distribution, Species Composition and Productivity along a Trophic Gradient in Green Bay, Lake Michigan. Sumner Richman, Paul Sager, Gary Banta, T. Rodman Harvey and Bart Destasio. WIS-SG-84-762.

Zooplankton Standing Stock, Species Composition and Size Distribution along a Trophic Gradient in Green Bay, Lake Michigan. Sumner Richman, Megan Bailiff, Lawrence Mackey and David Bolgrien. WIS-SG-84-763.

Social Carrying Capacity for Boating at Apostle Islands National Lakeshore. Thomas A. Heberlein and Geraldine Alfano. WIS-SG-84-764.

Geomorphology and Stability of Southwestern Lake Superior Coastal Slopes. M.N. Schultz, T.B. Edil and A. Bagchi. WIS-SG-84-765.

Determination of the Hydrogeologic Properties of Lakebeds Using Offshore Geophysical Surveys. Kenneth R. Bradbury and Robert W. Taylor. WIS-SG-85-766.

Biogenesis of Lipid-Derived Volatile Aroma Compounds in the Emerald Shiner *(Notropis atherinoides)*. David B. Josephson, Robert C. Lindsay and David A. Stuiber. WIS-SG-85-767.

Variations in the Occurrences of Enzymically Derived Volatile Aroma Compounds in Salt- and Freshwater Fish. David B. Josephson, Robert C. Lindsay and David A. Stuiber. WIS-SG-85-768.

Character Displacement and Habitat Shift in a Native Cisco in Southeastern Lake Michigan: Evidence for Competition? Larry B. Crowder. WIS-SG-85-769.

Lake Michigan Fish: Are They Safe to Eat? *Wisconsin Sportsman Magazine* reprint, March 1985.

Ecological Shifts in Resource Use by Bloaters in Lake Michigan. Larry B. Crowder and Helen L. Crawford. WIS-SG-85-770.

Optimal Foraging and Feeding Mode Shifts in Fishes. Larry B. Crowder. WIS-SG-85-771.

Volatile Compounds Characterizing the Aroma of Fresh Atlantic and Pacific Oysters. David B. Josephson, Robert C. Lindsay and David A. Stuiber. WIS-SG-85-772.

Effect of Handling and Packaging on the Quality of Frozen Whitefish. David B. Josephson, Robert C. Lindsay and David A. Stuiber. WIS-SG-85-773.

The Relationship Between the Size of Some Salmonid Fishes and the Intensity of Their Acanthocephalan Infections. Omar M. Amin. WIS-SG-85-774.

Association Between Summer Temperature and Precipitation Patterns Over the Great Lakes Region and Water Supplies to the Great Lakes. W.A.R. Brinkmann. WIS-SG-85-775.

Estimation of Vapor Pressures for Polychlorinated Biphenyls: A Comparison of Eleven Predictive Methods. Lawrence P. Burkhard, Anders W. Andren and David E. Armstrong. WIS-SG-85-776.

Henry's Law Constants for the Polychlorinated Biphenyls. Lawrence P. Burkhard, David E. Armstrong and Anders W. Andren. WIS-SG-85-777.

Evaluating Otolith Analysis for Bloater *Coregonus hoyi*: Do Otoliths Ring True? James Rice, Larry Crowder and Fred Binkowski. WIS-SG-85-778.

Occurrence and Transport of Organic Microcontaminants in the Duluth-Superior Harbor. Donald Bahnick and Thomas Markee. WIS-SG-85-779.

Quantitative Performance of a Simple Tenax-GC Adsorption Method for Use in the Analysis of Aroma Volatiles. G. Olafsdottir, J.A. Steinke and R.C. Lindsay. WIS-SG-85-780.

Size-Selective Attack by Parasitic Lampreys: Consideration of Alternate Null Hypotheses. Philip A. Cochran. WIS-SG-85-781.

Hormonal Growth Promotion and Evidence for a Size-Related Difference in Response to Estradiol-17β in Yellow Perch *(Perca flavescens)*. Jeffrey Malison, Cody Best, Terrence Kayes, Clyde Amundson and Bernard Wentworth. WIS-SG-85-782.

Population Statistics, Yield Estimates, and Management Considerations for Two Lake Whitefish Stocks in Lake Michigan. Mark Ebener and Frederick A. Copes. WIS-SG-86-783.

Partitioning Behavior of Polycholorinated Biphenyls. Lawrence P. Burkhard, David E. Armstrong and Anders W. Andren. WIS-SG-86-784.

Pacific Salmon in the Great Lakes. Warren Downs. *Wisconsin Sportsman Magazine* reprint, March 1986.

Modeling Great Lakes Diversion Impacts. Eric D. Loucks and Erhard F. Joeres. WIS-SG-86-785.

Sexual Differentiation and Use of Hormones to Control Sex in Yellow Perch (*Perca flavescens*). Jeffrey A. Malison, Terrence B. Kayes, Cody D. Best, Clyde H. Amundson and Bernard C. Wentworth. WIS-SG-86-786.

The Effects of *Salmincola californiensis* (Copepoda: Lernaeopodidae) on the Gills of Farm-Raised Rainbow Trout, *Salmo gairdneri*. Daniel R. Sutherland and Darwin D. Wittrock. WIS-SG-86-787.

WORKING THE LAKES

PROJECTS PROFILE, 1984-86

UNIVERSITY OF WISCONSIN SEA GRANT INSTITUTE

LIVING RESOURCES

Coordinators: James Kitchell, Center for Limnology, UW-Madison
Ross Horrall, Marine Studies Center, UW-Madison

The UW Sea Grant Living Resources Subprogram deals with every aspect of life in the Great Lakes—how fish reproduce, survive and grow; what they eat; how different species of lake plants and animals compete for habitat, and how the lakes' predator-prey system works. One special objective of this research program is to determine the maximum numbers of predatory sport fish that can be stocked in the Great Lakes without overtaxing the forage fish populations. Another is to find out why the once-abundant native lake trout has failed to reestablish self-sustaining populations in Lake Michigan and the other Great Lakes.

▪ Competition for Resources Among Lake Michigan Forage Fishes: Consequences of an Alewife Decline (R/LR-30)

John Magnuson, Center for Limnology, UW-Madison

Thanks to the huge numbers of trout and salmon stocked in Lake Michigan, its once-overabundant alewife population has been dramatically reduced. This may lead to a significant increase in the number of bloater chubs, a commercially valuable forage fish in the lake, which must compete with the alewife for its food. But too few alewives may also cause the lake's trout and salmon to begin eating the chubs instead, causing ecological as well as economic problems. Through trawl samples, the researchers are comparing the current habitats of alewives and bloaters and looking for related changes in the sizes and numbers of various zooplankton, the tiny lake animals eaten by these fish. Such information will help state and federal fish management agencies make better-informed stocking decisions to protect both the commercial and sport fisheries of Lake Michigan.

▪ Predator-Prey Systems in the Great Lakes (R/LR-29)

James Kitchell, Center for Limnology, UW-Madison

Proper management of the multimillion-dollar Great Lakes fishery requires a thorough understanding of the interactions between the lakes' predator fish and the forage fish on which they prey. Through computer simulations, the researchers hope to accurately predict how Great Lakes salmonid and prey populations will behave under a variety of management scenarios. This widely-used computer bioenergetics model is also being refined to consider related changes in the plankton populations on which forage and young predator fish depend. Combined with the results of other studies, this research will help improve both short- and long-term fish management throughout the region.

▪ Daily Growth Rates and Variable Recruitment of Larval Fishes in Lake Michigan (R/LR-22)

Fred Binkowski, Center for Great Lakes Studies, UW-Milwaukee
James Kitchell, Center for Limnology, UW-Madison

A central problem in fisheries management is anticipating the growth and survival rates of young fish. The major aim of this study is to determine whether otoliths—the calcium deposits in the inner ear of fish—are a reliable means of assessing the age, daily growth, year class strength and survival of fish. In a related effort, the researchers are also studying the effect of zooplankton predation on the survival of bloater and alewife larvae, two key species in Lake Michigan's commercial and sport fisheries. If proven reliable, the otolith method will give fishery managers two more years of lead time than they now have for making harvest and stocking decisions based on the projected future strength of each year's new crop of forage fish. The researchers have so far concluded that application of otolith analysis to larval bloaters in the field is both feasible and promising.

▪ Salmonid Diet Survey (R/LR-28)

James Kitchell, Center for Limnology, UW-Madison

How will increased stocking of trout and salmon in the Great Lakes affect the forage fish? Will it cause an alewife population crash? Will the salmonids then shift to other prey? To answer these questions, Kitchell is studying the stomach contents of Lake Michigan salmonids as part of a cooperative effort involving the entire Great Lakes Sea Grant Network and state and federal agencies throughout the region. His project focuses on a recent decline in Lake Michigan's alewife population and whether this has caused shifts in the diets of the lake's salmonids. In sum, this regionwide research will help determine how many of which kinds of salmonids each of the Great Lakes can support without damaging the stocks of other valuable species of fish.

- **Fish Parasite Communities as Indicators of Predator-Prey Relationships in Lake Michigan (R/LR-27)**

Bruce Christensen, Veterinary Science, UW–Madison

In conjunction with the Salmonid Diet Survey, this study is examining whether various Lake Michigan forage fish contain specific types of parasites that can later be found in the predator fish that eat them. While the stomach content analysis of the diet survey reveals what a salmonid ate just before it was captured, the types of parasites in it may indicate the kinds of prey it was eating over much longer periods of time. Since many of the fish in the lake today are not native to it, the scientists will also examine whether this situation favors native parasites to the extent that they might adversely affect salmonid growth and reproduction.

- **Factors Influencing the Reestablishment of Self-Sustaining Stocks of Lake Trout in Lake Michigan (R/GB-7)**

Ross Horrall, Marine Studies Center, UW–Madison

Lake Michigan's native lake trout population disappeared about 1950 due to the combined effects of overfishing and the parasitic sea lamprey. The lamprey was brought under control in the 1960s, and millions of lake trout have been stocked in the lake since then, but the trout population has failed to become self-sustaining. To find out why, these researchers are studying the history of the native lake trout and comparing the characteristics of trout spawning reefs in Lake Michigan with those in Lake Superior, where remnant populations of native lake trout still survive. They are also studying the possible effects of lake contaminants on egg and sac fry survival and trying to find better ways to plant trout on their former spawning reefs. With this information, government agencies hope to establish reproducing lake trout populations and thereby eliminate the need for and considerable expense of continually stocking this prize sport fish. The state's Department of Natural Resources is also supporting this project.

- **Studies on the Early Life History and Recruitment of Feral and Native Lake Trout, with Special Emphasis on Experimentally Planted Eggs and Alevins (R/LR-32)**

Ross Horrall, Marine Studies Center, UW–Madison

More than 25 years and considerable expense have gone into trying to reestablish self-sustaining lake trout populations in the Great Lakes, with little success to date. One problem is that very little is known about the early life history of these fish. In laboratory and field research, Horrall is studying lake trout development from egg through the first year of life in an attempt to find out why hatchery-raised trout don't reproduce in the wild. The investigator is also studying site imprinting mechanisms in young fish. A solution to this problem would not only save the millions of dollars a year now spent stocking this popular sport fish, but would also restore the lake trout to its original role as the top predator of the Great Lakes. The state's Department of Natural Resources and the city of Ashland are also providing logistic support for the project.

G R E E N   B A Y

Coordinator: H.J. Harris, Science and Environmental Change, UW–Green Bay

Lake Michigan's Green Bay is a microcosm of the Great Lakes. Its waters range from warm, shallow and algae-rich to cold, deep and clear. It is surrounded by a heavily populated and industrialized area, which depends on it for water, recreation, shipping, and commercial and sport fishing. Consequently, the bay has suffered the familiar litany of interrelated problems common to the Great Lakes—declining fisheries, polluted waters, closed beaches, a stagnating shipping industry, dredging dilemmas, and management fragmented by a variety of sometimes conflicting political jurisdictions.

Accordingly, Green Bay is also the focus of a concentrated, international and multiagency effort to rehabilitate its ecosystem and enhance the value of its resources. UW Sea Grant has played a major role in that effort and since 1978 has sponsored this multidisciplinary research subprogram devoted entirely to solving Green Bay's problems.

- **Green Bay Subprogram Coordination (R/GB-5)**

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

Rehabilitation of the Green Bay ecosystem requires coordination of UW Sea Grant and other Green Bay research activities and cooperation among government and private agencies concerned with Green Bay's resources. This investigator works closely with the Wisconsin Department of Natural Resources, U.S. Environmental Protection Agency, U.S. Fish & Wildlife Service, and the U.S.-Canadian Great Lakes Fishery Commission and International Joint Commission, as well as city and county agencies. Largely as a result of the vast amount of data on Green Bay generated by Sea Grant research, the Great Lakes Fishery Commission selected the bay to be the focus of an ecosystem rehabilitation study, the results of which will be applied to solving similar problems throughout the region.

▪ Contribution of Marshlands to the Green Bay Pelagic Food Chain (R/GB-18)

H.J. Harris/Paul Sager, Science and Environmental Change, UW–Green Bay
Sumner Richman, Biology, Lawrence University

Coastal marshes may contribute significantly to the supplies of carbon, nitrogen, phosphorus and other nutrients in the bay's offshore waters, or, in some instances, may act as sinks for these nutrients. The investigators are studying the amount of marsh nutrients exported to open water and whether particulate marsh detritus is a source of food for the major types zooplankton in the bay. They are also comparing the nutrient loading from the marshes to those from industrial and municipal discharges to determine the extent to which each contributes to the bay's excessive biological productivity—information essential to determining whether further reductions in such discharges will effectively improve the bay's water quality.

▪ Fishery Models for Green Bay (R/GB-24)

James Kitchell, Center for Limnology, UW–Madison

Green Bay produces a large share of Lake Michigan's walleye, perch, whitefish, northern pike, alewife and smelt. In this project, a computer model of the Lake Michigan fishery is being adapted specifically for the management of Green Bay's yellow perch and walleye fisheries. The model offers fishery managers the means to quickly and thoroughly analyze how alternative management strategies will affect the bay's fisheries. The investigators are working closely with management agencies and other researchers to develop and test fish population and fishery management models that can be run on microcomputers.

▪ Population Modeling of Lake Whitefish in Green Bay and Wisconsin Waters of Lake Michigan and Model Verification (R/GB-23)

Frederick Copes, Biology, UW–Stevens Point
Daniel Coble, Wisconsin Cooperative Fishery Research Unit, UW–Stevens Point

More than two million pounds of whitefish are harvested from Green Bay and northern Lake Michigan each year. Sound management of this commercial fishery—one of the most important in the lake—requires vital statistics on the lake's whitefish population: Its birth and death rates, its overall size, and its growth rate. In addition to compiling such data, these UW–Stevens Point biologists are developing predictive computer models of the whitefish population and recruitment to determine optimal harvest rates. They are also experimenting with special trap nets and other methods to improve harvest efficiency and reduce the catch of undersize whitefish. This project was initiated in 1984 in direct response to requests from the Wisconsin and Michigan departments of natural resources and from commercial and Native American fishermen, who are already making extensive use of its findings.

▪ The Physical, Chemical and Biological Dynamics of the Benthic Boundary Layer in Green Bay, Lake Michigan (R/GB-22)

J. Val Klump, Center for Great Lakes Studies, UW–Milwaukee
David Edgington, Center for Great Lakes Studies, UW–Milwaukee

Any effort to improve Green Bay's water quality must take into account the role of bottom-dwelling organisms and sedimentation, which have a major effect on the amount of oxygen, nutrients and contaminants in the water. In field and laboratory experiments, these investigators are characterizing these benthic organisms and sediments and studying how sediment particles are transported throughout the bay. Such information is essential to the design of efficient strategies for effectively controlling pollution in the bay.

▪ Economic Analysis for Management of the Green Bay Fisheries and Other Great Lakes Fisheries of Wisconsin (R/PS-32)

Richard Bishop, Agricultural Economics, UW–Madison

The bottom line is the payback: Economic as well as biological factors must be considered in regulating the use of fish resources. Bishop, a resource economist, is using investment theory to analyze alternative management policies for Green Bay's depressed yellow perch fishery and its emerging walleye fishery. His analysis will compare the economics of the sport and commercial harvests of both fisheries and the trade-offs of stocking walleye in Wisconsin's Great Lakes versus its inland waters. This research will help ensure that Wisconsin taxpayers and fishermen alike continue to benefit from the Green Bay's valuable fishery.

CASCADING WATERS

MICROCONTAMINANTS AND WATER QUALITY

Coordinator: David Armstrong, Water Chemistry Laboratory, UW–Madison

Hundreds of factories, thousands of farms and millions of people surround the Great Lakes, with the almost unavoidable result that many of the waste products and byproducts of human activities end up in the lakes. Yet people continue to depend on the lakes for drinking water and for fish to eat, so protection of the lakes' water quality is a matter of special concern. Even very small amounts of chemicals like DDT, polychlorinated biphenyls (PCBs), toxaphene and dioxin in the water can accumulate to unsafe levels in fish.

UW Sea Grant scientists are national leaders in research on PCBs and other Great Lakes contaminants. This research subprogram brings together chemists, biologists, pathologists, toxicologists and medical scientists throughout the state to investigate the sources, pathways, fate and health effects of a variety of environmental contaminants—information essential to protecting the health and economic well-being of the region and people everywhere.

- **Atmospheric Concentrations and Transport of Organic Contaminants Across the Air/Water Interface in the Upper Great Lakes (R/MW-28)**

Anders Andren, Water Chemistry Laboratory, UW–Madison

Much of the PCBs, polyaromatic hydrocarbons (PAHs) and toxaphene entering the Great Lakes comes from the air. But how much? Is the amount decreasing or increasing? And how does this affect how much is in the water? This research team is sampling the concentrations of these and other compounds in the air and rain over Lake Michigan and studying how contaminants move between the air and water. They will compare this with data collected in 1977-78 to determine if atmospheric PCB and PAH levels have changed, which will indicate the effectiveness of efforts to control these contaminants so far.

- **Transport and Fractionation of Hydrophobic Organic Compounds by Suspended Particulate Matter in Lake Michigan (R/MW-33)**

David Armstrong, Water Chemistry Laboratory, UW–Madison

Because they don't mix with water, PCBs and other hydrophobic organic compounds (HOCs) that enter the Great Lakes become attached instead to various particles suspended in the water—so the fate of such compounds is tied to what happens to these particles. Armstrong is examining the accumulation of HOCs on specific kinds of lake particles and the role these particles play in suspending, distributing and removing the HOCs in the water. Such information is needed to determine how much and how long PCBs and other HOCs will remain in the Great Lakes before they are buried in the sediments and removed from the food chain.

- **Role of Particle-Mediated Processes in Controlling Metals and Silica in Lake Michigan (R/MW-37)**

David Armstrong, Water Chemistry Laboratory, UW–Madison

Suspended particles play a key role in the water quality of the Great Lakes. But how are these particles produced and what determines how long they remain suspended in the water? Focusing on toxic metals like lead, copper and cadmium and on essential nutrients like silica and phosphorus, these researchers are trying to discern the processes that control the behavior of particles, which in turn control the levels of these metals and nutrients in the water. In conjunction with other UW Sea Grant research, this information will provide a better understanding of the chemical composition of the lakes, including whether increased phosphorus loading will reduce silica levels and cause biological changes in the lakes.

- **Evaluating Eutrophication in Lake Michigan Using Data from Municipal Water Intakes (R/MW-32)**

David Edgington, Center for Great Lakes Studies, UW–Milwaukee
Arthur Brooks, Center for Great Lakes Studies, UW–Milwaukee

It is generally believed that increased inputs of phosphorus and other nutrients from human sources to the Great Lakes are causing the lakes to become overfertilized (eutrophic), which may lead to them being dominated by undesirable species of algae and fish. These scientists are evaluating whether historical data based on long-term monitoring at two Milwaukee water filtration plants can be used to accurately assess and monitor the past and present trophic status of the lake. The results of this research will be very important in evaluating the cost-effectiveness of increased waste treatment to avoid eutrophication of the Great Lakes.

- **Polychlorinated Dibenzo-p-Dioxins (PCDDs) and Dibenzofurans (PCDFs): Persistence and Toxicity in Freshwater Fish (R/MW-27)**

Richard Peterson, Pharmacy, UW–Madison

The chemical 2,3,7,8-tetrachloridibenzo-p-dioxin (TCDD) is the most toxic form of PCDDs found in freshwater fish, but little is known about what happens to TCDD once it is in the fish. These investigators are examining how TCDD is metabolized, accumulated, stored and excreted by fish. Their other objectives are to learn how TCDD affects the health, growth, disease resistance and reproduction of rainbow trout, yellow perch and other fish. This research will help determine how long it takes fish to become TCDD-free and what levels of dioxin contamination present a cause for concern. Such information can also be applied to assessing the dangers posed by all types of PCDDs, PCDFs and other halogenated aromatic hydrocarbons.

▪ Metallothionein as an Indicator in Fish of Exposure to Toxic Organic Chemicals (R/MW-36)

C. Frank Shaw III, Chemistry, UW–Milwaukee
David Petering, Chemistry/Center for Great Lakes Studies, UW–Milwaukee

These two chemists are testing the hypothesis that the concentration of an unusual protein, metallothionein, in a fish's liver is directly related to its exposure to toxic substances in its food and water. In tests with metals and PCBs, they are also examining whether metallothionein residues can be used to determine exactly which contaminants a fish was exposed to. If true, this knowledge will provide a quick and reliable way to monitor for contaminants in fish and in the water the fish came from. It will also provide important insights as to how a fish's body deals with contaminants.

▪ Fate Assessment of Organic Chemicals in Aqueous Environments (R/MW-31)

Anders Andren, Water Chemistry Laboratory, UW–Madison
David Armstrong, Water Chemistry Laboratory, UW–Madison

Representing a broad class of manufactured chemical compounds, many halogenated aromatic hydrocarbons (HAHs) are cancer-causing and all of them are persistent in the environment. In addition, almost all HAHs are on the federal "priority pollutants" list. The purpose of this project is to determine those physical and chemical properties of HAHs that determine their fate in the Great Lakes—for example, whether these compounds vaporize into the air or attach to particles in the water, how long they take to break down in the environment and whether the resulting chemicals are toxic or harmless. These data can also be applied to rivers and lakes nationwide and used by toxicologists, pharmacologists, oncologists and various regulatory agencies to assess and prescreen the health hazards of these compounds in the environment.

▪ Workshop on Methods for Analysis of Organic Compounds in the Great Lakes, II (R/MW-34)

William Sonzogni, Water Chemistry Laboratory, UW–Madison
Douglas Dube, State Laboratory of Hygiene, UW–Madison

Microcontaminants are difficult to detect and quantify, and the problem has been compounded by the different analytical techniques used by different Great Lakes researchers. In 1980, UW Sea Grant sponsored a workshop designed to standardize and improve such analysis. Since then, both new contaminants and new analytical techniques have emerged, so Sonzogni has organized a second workshop. The results of this workshop will help U.S. and Canadian Great Lakes scientists coordinate and improve their research, avoid duplication of effort and standardize measurements to ensure that the contaminants problem is accurately assessed and monitored and that research dollars are spent efficiently. Sea Grant is jointly supporting this project with the State Laboratory of Hygiene and the National Oceanic and Atmospheric Administration's National Marine Pollution Program Office.

▪ Measurement of the Interaction Between Lake Michigan and the Groundwater of Wisconsin (R/MW-35)

Mary Anderson, Geology and Geophysics, UW–Madison
Robert Taylor, Geological and Geophysical Sciences, UW–Milwaukee

Through a unique combination of geophysical and hydrogeological techniques, this team of hydrogeologists has developed a new technique for analyzing the interactions between Wisconsin's coastal groundwater aquifer and Lake Michigan. They have discovered that groundwater may be the source of 10 percent or more of Lake Michigan's water, and that lake water seeps inland in areas where the aquifer has been drawn down. These discoveries have many important implications with regard to the possible sources of contaminants in the lake, the location of coastal waste disposal sites and the extent to which lake water recharges coastal groundwater supplies. The scientists are now mapping the lakebed along the entire Lake Michigan shore of Wisconsin, which will help them determine both the present and potential rates of water exchange between the lake and coastal aquifers. This knowledge will be particularly valuable to local, state and federal agencies charged with managing water supplies, overseeing shoreline development and protecting the lake's water quality.

A Q U A C U L T U R E

Coordinator: Clyde Amundson, Food Science, UW–Madison

In the Great Lakes region, aquaculture plays a key role in the management of fishery resources and has significant potential as a method of food production. According to the U.S. Department of Agriculture, Wisconsin is the nation's fourth largest producer of rainbow trout. More than 50 licensed fish farmers in the state are also raising a variety of panfish, bait and cool- and warm-water game fish. Because of the climate, commercial aquaculture in this region will probably be restricted to coolwater species like perch and walleye and coldwater species like trout, salmon and whitefish.

The primary mission of the UW Sea Grant Aquaculture Subprogram is to develop and improve the technological and scientific data base necessary for the propagation and culture of these fish. Current research includes studies to determine the proper dietary needs of fish, prevent fish diseases and improve the growth of fish in ponds, raceways and closed-circulation tank systems. This research is carried out at the UW Aquaculture Research Laboratory, located at the Lake Mills Fish Hatchery in southeastern Wisconsin and also at the Great Lakes Research Facility at UW–Milwaukee.

This effort to develop aquaculture in the Midwest involves the help and cooperation of the UW–Madison College of Agricultural & Life Sciences, UW–Milwaukee Center for Great Lakes Studies, U.S. Fish & Wildlife Service, Wisconsin Fisheries Council, Wisconsin Department of Natural Resources and the Wisconsin Department of Agriculture, Trade and Consumer Protection. The subprogram also receives support from private industries interested in aquaculture development.

• Aquaculture Development and Subprogram Coordination (R/AQ-8)

Clyde Amundson, Food Science, UW–Madison
Terrence Kayes, Food Science, UW–Madison

In addition to coordinating UW Sea Grant aquaculture research, these scientists oversee the UW Aquaculture Research Laboratory at the Lake Mills Fish Hatchery. The laboratory is operated by the UW–Madison Sea Grant Institute and the College of Agricultural and Life Sciences in cooperation with the Wisconsin Department of Natural Resources. The laboratory furnishes "wet lab" space, aquaria, hatchery equipment, fish eggs, fish and feed to Sea Grant researchers and assists them with their fish husbandry needs. In addition to these duties, Amundson and Kayes are responsible for identifying the aquaculture-related needs of Great Lakes fisheries management agencies, commercial fishermen, fish farmers and related businesses. They are also the state's representatives in the national Sea Grant aquaculture research plan and are working with various state agencies to develop an aquaculture plan for Wisconsin.

• Comparative Studies on the Requirements of Selected Great Lakes Fishes for Protein and (Key) Amino Acids (R/AQ-13)

Clyde Amundson, Food Science, UW–Madison
Kyu-Il Kim, Food Science, UW–Madison

Fish feed makes up 15 to 30 percent of the production costs at government hatcheries and about twice that in private aquaculture operations. In an effort to reduce these costs, these Sea Grant scientists have been studying the dietary amino acid requirements of rainbow trout. They are now comparing how rainbow trout diet requirements differ from those of other cold- and coolwater fish like coho salmon and channel catfish. This information will help them determine the optimum diet for these and other fish and to develop less expensive feeds from local sources. The researchers have already been able to reduce the protein content in fish feed for rainbow trout from 35 to 25 percent and still achieve the same growth rates. In the Great Lakes region alone, reducing rainbow trout feed costs by just 5 percent would save an estimated $1.3 million to $1.7 million a year. Applied nationwide, a 5 to 10 percent reduction in feed costs could save U.S. aquaculturists from $6 million to $27 million a year.

• Genetic Manipulation of Growth and Production of Selected Great Lakes Coolwater Fishes (R/AQ-14)

Clyde Amundson, Food Science, UW–Madison
Terrence Kayes, Food Science, UW–Madison

In most coolwater fish, the females grow larger and faster than the males, so if the gender of these fish can be manipulated to produce mostly females, food fish aquaculturists could increase the average size of the adult fish they produce by 10 to 15 percent. And because such differences are hormonal, the use of artificial hormones in fish feeds could increase growth in both genders by 10 to 25 percent. In studies involving perch, walleye and sauger, these investigators are examining ways to genetically adapt fish to artificial feeds and intensive aquaculture techniques and, through cross-breeding and the use of hormones, to control the sex and improve the growth of slow-growing species.

• Effects of Environmental and Nutritional Stress on Resistance to Disease in Coolwater Fishes (R/AQ-11)

Cynthia Sommer, Zoology/Microbiology, UW–Milwaukee

Environmental stresses and poor diets can undermine the health of cultured fish by reducing their resistance to disease. Sommer is determining how stresses like extreme water temperatures, crowding, low oxygen levels, ammonia contamination and deficient diets affect the immune systems of coolwater and coldwater fish. An understanding of these effects is essential if aquaculture is to flourish. The methodologies developed by Sommer have already been requested by federal, state, university and private organizations for use in monitoring hatchery fish health and fish immunization research.

DIVING PHYSIOLOGY

Coordinator: Edward Lanphier, Preventive Medicine/Biotron, UW–Madison

An estimated 1.5 million Americans scuba dive for fun, and many others dive professionally at offshore drilling sites and other underwater marine operations. By learning more about how the human body functions under pressure, UW Sea Grant scientists are assembling the basic medical knowledge needed to help make diving safer and more efficient.

The UW Sea Grant Diving Physiology Subprogram has provided new insights on the nature and occurrence of decompression sickness. In 1984, the results of UW Sea Grant diving research were published nationwide when the scientists reported that laboratory experiments and a survey of U.S. diving accidents had revealed an unexpectedly high incidence of paralyzing "spinal cord hits" following the deep, short "bounce" dives that sport divers often make, and that "the chokes," a deadly congestion of the lungs, occurs if a diver goes from deep water to high altitude too quickly.

Diving physiology research has also resulted in major advances in knowledge about the effects of immersion on the heart and lungs, including the important medical discovery that immersion exercise is beneficial therapy for severe respiratory ailments.

▪ Pilot Study of the Psychobiologic Characterization of Divers Judged to Be at Risk (R/DP-2)

William Morgan, Sport Psychology Laboratory, UW–Madison

The diving community generally agrees that psychological factors often play a key role in diving mishaps and the some 140 sport diving fatalities that occur each year. Based on studies of firefighters that accurately identified 75 percent of those most likely to hyperventilate and panic while wearing breathing apparatuses in a fire, Morgan—a sport psychologist—is now developing a psychological profile of the type of individual who may be unable to handle difficult physical and mental work under water. This information will be especially useful to diver instructors and employers in screening divers at risk of panicking under water. Such screening could help people considering the sport to discover beforehand if they are among the 5 to 10 percent psychologically unsuited to the rigors of diving. So far, in tests with 29 diving students, Morgan's model was 86 percent accurate, correctly predicting the panic/non-panic performance of 25 students. Depending on the success of this pilot study, the scientists hope to next find ways to train such people to cope with the difficulties of breathing and working under water.

▪ Physiology of Diving (R/NA-11)

Edward Lanphier, Preventive Medicine/Biotron, UW–Madison

Knowledge of the physiological responses to underwater diving is critical in developing equipment and procedures for this growing sport and commercial activity. Through laboratory and pressure chamber experiments, a team of medical and chemical engineering researchers is continuing to study a variety of diving-related problems, including loss of consciousness due to carbon dioxide retention among certain divers, the effects of water temperature and underwater exertion on the heart and lungs, the benefits of immersion exercise for heart and lung patients, the dangers of and treatment for decompression sickness, and the risks of bone necrosis from frequent diving and decompression. Based on these interrelated studies, the research team is developing a series of recommendations designed to improve diving safety and efficiency. In addition to benefiting divers, such "extraterrestrial" research is second only to that of outer space missions in providing new insights to the functioning of the human body.

NEW INITIATIVES

Coordinator: Robert Ragotzkie, Sea Grant Institute, UW–Madison

The New Initiatives Subprogram is comprised of projects that do not fall logically into any of the other subprograms but that address important Great Lakes or marine-related issues. This grouping gives the UW Sea Grant program a degree of flexibility to support innovative proposals and research talent that do not fit standard program themes.

- **Multipurpose Assessment of Thematic Mapper Data for Coastal Resource Management (R/NI-9)**

Thomas Lillesand, Institute for Environmental Studies, UW–Madison

Satellites and state-of-the-art remote sensing and computer technology have enabled scientists to make a quantum leap in both general and detailed surveillance of the earth's surface and resources. This project focuses on analyzing marine and coastal resources from space via high resolution satellite data generated by a new experimental scanner, the Thematic Mapper (TM). The TM was integrated into the Landsat 4 and Landsat 5 satellites in an attempt to overcome the limitations of earlier satellite data on the earth's resources. By correlating satellite images with ground-level observations, Lillesand is evaluating both the technical feasibility and practical utility of using TM data for an array of coastal resource monitoring tasks, including land use mapping, aquatic vegetation mapping, chlorophyll *a* distribution, eutrophication assessment, analysis of sediment source and transport, and surface water temperatures. An Experimental Satellite Image Map of Sturgeon Bay, Wis., has already been produced from early project results. If successful, Lillesand may develop practical guidelines for integrating high resolution satellite data into coastal resource management for local, national and international agencies interested in land use and water resource monitoring.

- **The Pullout of Harbor Piles by Vertical Motions of Ice (R/NI-8)**

Tuncer Edil, Civil and Environmental Engineering, UW–Madison
Theodore Green III, Civil and Environmental Engineering/Meteorology, UW–Madison

Winter ice causes hundreds of thousands of dollars in damage to marinas and other harbor structures throughout the Great Lakes. "Ice jacking," a common problem in northern harbors, is the phenomenon whereby the continued, small vertical oscillation of the ice in a harbor can pull piles completely out of the bottom over the course of a winter. To help marina and harbor designers minimize such damage, these research engineers are conducting laboratory and field tests to analyze the characteristics of vertical motions of ice and the effect these motions have on piles. The researchers are also evaluating which types of structures and designs best withstand the vertical forces of ice. Such information will be useful anywhere that people must deal with ice, one of the most powerful forces of nature.

POLICY STUDIES

Coordinator: Richard Bishop, Agricultural Economics, UW–Madison

The UW Sea Grant Policy Studies Subprogram supports research that helps solve public policy problems related to Great Lakes and ocean resources, with high priority given to innovative projects that investigate theoretical and methodological issues as well.

Past projects have examined Great Lakes shipping, international law and natural resource policy issues affecting the oceans and Antarctica, a marketable discharge permit system to reduce the costs of pollution control, the economic costs and benefits in preserving coastal wetlands, and the feasibility of developing underwater parks in the Great Lakes for recreational divers.

- **Management of Great Lakes Waters (R/PS-30)**

Erhard Joeres, Civil and Environmental Engineering, UW–Madison

In this project, a team of engineers and economists is addressing the overall strategy of Great Lakes water management. Investigators are evaluating the hydrologic and economic consequences of diversions of Great Lakes water out of the basin, should such diversions ever be implemented. These researchers have developed a hydrologic and economic model that assigns values to the effects that different water levels will have on two important industries—shipping and hydropower. The researchers have concluded that a continuous large-scale diversion of water (10,000 cfs) from Lake Superior or Lakes Michigan-Huron out of the Great Lakes basin would cause water levels in Lakes Superior, Michigan and Huron to drop approximately six inches over 15 years after the water transfer began. Most of the drop would be felt within the first five years. These lower lake levels would cost regional shipping and hydropower industries up to $80 million a year. This model will help U.S., Canadian, state and provincial policymakers choose the best uses for Great Lakes water from among the competing demands for it.

GETTING AWAY FROM IT ALL

- **Recreational Boating and Rural Development: A Comparative Assessment of Boaters Across Time (1975–1985) and Location (Bayfield and Door Counties) (R/PS-34)**

Thomas Heberlein, Rural Sociology, UW–Madison

Better information on recreational boaters can enable coastal communities to more accurately assess the need for boating facilities and clientele services, and to plan for them. Through a series of questionnaires, Heberlein is developing data on the needs and preferences of boaters in the Bayfield area of Lake Superior and the Green Bay-Door County area of Lake Michigan. The data will then be compared with data from a 1975 survey on Bayfield area boaters to see how the numbers, preferences, economic impacts and general characteristics of boaters have changed in the past decade.

SEAFOOD TECHNOLOGY

Coordinator: David Stuiber, Food Science, UW–Madison

With their abundance of trout, salmon, whitefish, chubs, smelt and perch, the Great Lakes collectively support one of the largest freshwater fisheries in the world. In recent years, the Great Lakes commercial fishery catch has had a dockside value of $36 million annually. To assist this industry, UW Sea Grant has initiated the Seafood Technology Subprogram, which builds on past Sea Grant research on such industry problems as sanitation, disposal of fish processing wastes, and the need to improve fish processing and preservation techniques.

- **Role of Enzymically Derived Volatiles from Prostaglandins in Fish and Fishery Products (R/SF-1)**

David Stuiber, Food Science, UW–Madison
Robert Lindsay, Food Science, UW–Madison

The preservation of the flavor and aroma of fresh fish has long been a major problem for the seafood industry. These UW Sea Grant food scientists have identified many of the fresh-fish flavor compounds and their sources. Compounds that lead to off-flavors in seafood products have also been identified. The researchers are now investigating how these off-flavor compounds develop in both freshwater and saltwater species of fish, and how that process can be stopped or at least greatly slowed down. This research will help identify techniques that can be applied to prolong the shelf-life of fish and other seafoods—to the benefit of the seafood industry and consumers alike.

E D U C A T I O N

Coordinator: Robert Ragotzkie, Sea Grant Institute, UW–Madison

It is a tradition at the University of Wisconsin that research and graduate education go hand-in-hand. The majority of graduate education support provided by the UW Sea Grant College Program is through individual research projects in the form of research and project assistantships. About 50 graduate and 50 undergraduate students are receiving financial support from UW Sea Grant during 1984-86. UW Sea Grant also sponsors other educational activities, including special assistantships for students working on Sea Grant research, the development of Great Lakes and oceanography courses on University of Wisconsin campuses and special seminars and film/lecture series around the state.

- **Special Education Programs (E/E-1)**

Robert Ragotzkie, Sea Grant Institute, UW–Madison

One objective of this project is to enable project investigators to employ exceptional students to work on Sea Grant research subsequent to the proposal process and to support students while they complete their theses after the project has been completed. During 1984–86 four students working on projects in microcontaminants and water quality, aquaculture and policy studies are receiving support. This project also allows the program to respond to the need for new Great Lakes and oceanography course development and to update existing courses, to provide travel support for visiting lecturers and for students presenting papers at scientific conferences, and to provide students with shipboard and coastal research experience.

- **Great Lakes Seminar on Recent Advances in Limnology and Oceanography (E/E-11)**

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

Eminent scientists from the U.S., Canada and England were featured in this winter-spring 1985 series of public seminars at the UW Great Lakes Research Facility in Milwaukee. The fifth such series since 1973, these seminars enabled students, researchers and the public to learn more about current Great Lakes issues and related scientific research. Students and citizens from throughout Wisconsin talked directly with some of the nation's leading scientists and discussed the latest advances in Great Lakes research. Participating students were able to earn two graduate or undergraduate credits through the UW-Milwaukee Zoology Department. Support for the series was also provided by the UW-Milwaukee Urban Corridor Consortium.

ADVISORY SERVICES

Coordinator: Allen H. Miller, Sea Grant Institute, UW–Madison

Through one-on-one advice and assistance, training workshops, conferences, field research and the use of various media, the Advisory Services Subprogram is the service component of the UW Sea Grant program. Advisory Services is the link between the few who study the Great Lakes and the many who use and manage their resources.

Headquartered at UW–Madison, Advisory Services provides its services along Wisconsin's 820 miles of coast through four field offices with agents located at Superior, Sister Bay, Green Bay and Milwaukee. Five specialists in aquaculture, coastal engineering, food science, ice engineering and recreation also provide in-depth service to the Great Lakes community. The UW Sea Grant Communications Office helps disseminate results of Sea Grant-sponsored research and advisory efforts through publications, television, film and radio by producing both technical and public information materials.

▪ Advisory Services Field Agents Network (AS/A-14)

Coordinator: Allen H. Miller, Sea Grant Institute, UW–Madison

UW Sea Grant's four field agents help bring the resources of the university to coastal communities, government agencies, businesses and industries that use and depend on the Great Lakes. Agents teach, advise and conduct field research in support of four major client groups: the commercial and recreational fishing industries; marine recreational businesses; marine industries and engineering firms; and aquaculturists —those who practice fish farming. For example, during 1984–86, Sea Grant's field agents are working with both the charter and commercial fishing industries to strengthen their businesses. The field agents have initiated an extensive program to educate fishers and consumers on proper cleaning and preparation of Great Lakes fish to reduce quantities of the troublesome contaminants, such as PCBs. Agents are working with commercial fishers and the Department of Natural Resources, field testing net sizes to reduce the mortality of undersized perch in Green Bay. In addition, the agents are working to provide campgrounds and motels with an alternative to the costly disposal of fish wastes by developing effective methods for composting fish wastes. Through such efforts, field agents exemplify "The Wisconsin Idea" by bringing the resources of the university to people along the Great Lakes coast.

▪ Advisory Services Coordination and Specialist Activities (AS/A-1)

Allen H. Miller, Sea Grant Institute, UW–Madison

Coastal businesses and industries, communities and government agencies all have special concerns regarding Great Lakes resources. Five specialists in aquaculture, coastal engineering, food science, ice engineering and recreation provide services through workshops, one-on-one consultation, laboratory and field research and state, national and international conferences. The specialists work closely with the Great Lakes community to find solutions to problems ranging from business management of the growing charter fishing fleet, to fish husbandry for fledgling fish farmers, to advising shoreline owners and governmental agencies on how to combat erosion caused by current high water levels in the Great Lakes. UW Sea Grant Advisory Services also continues to sponsor the Underwater Mining Institute (UMI), now in its sixteenth year. The UMI is internationally recognized as one of the major conferences for interaction among the university community, governmental agencies and industry. Cosponsored in 1985 with Canada's Department of Energy, Mines and Resources, the 16th Annual UMI has attracted participants from western Europe, the U.S. and Canada.

▪ Lake Ice and Marina Design Advisory Services (AS/A-20)

C. Allen Wortley, Engineering Professional Development, UW–Madison

Each year ice causes hundreds of thousands of dollars in damage to navigation and harbor facilities throughout the Great Lakes. Based on a decade of research, Wortley wrote the first comprehensive manual on designing small-craft harbors and marina structures to better withstand ice conditions. Over 1,000 copies of this manual, published in 1984, have already been sold to designers, builders and operators of Great Lakes marinas and harbor facilities. Two conferences on marina design and ice engineering are held annually with audiences of more than 150 people each from throughout the U.S. and Canada. Wortley, who continues to observe ice conditions at more than 200 Great Lakes sites, provides invaluable advice and assistance to the operators of harbor and marina facilities.

▪ Sea Grant Communications (AS/A-2)

Peyton Smith, Sea Grant Institute, UW–Madison

The Communications Office disseminates information about Sea Grant and the Great Lakes in a variety of ways—through published reports, reprints of science and trade journal articles, news releases, radio programs and special exhibits. The Communications Office also responds to requests for information from the public and handles public information needs for Sea Grant scientists, agents and specialists. It also produces the UW Sea Grant Institute's newsletter, program reports and the biennial funding proposals to the National Sea Grant College Program.

- **Food Science and Fish Program (AS/A-8)**

Coordinator: David Stuiber, Food Science, UW–Madison

The Great Lakes provide one of the world's largest sources of freshwater fish. Stuiber's role is to advise and assist fish processors, governmental agencies and consumers on how to best use this resource. His work includes developing better methods of packaging fish, developing marketable products from underutilized species and improving sanitation practices in processing facilities. During this period, Stuiber has also co-authored three publications on how to properly can, smoke and pickle fish at home. Such activities directly serve the state's commercial fishing industry and consumers alike, and indirectly help increase the value of Wisconsin's Great Lakes resources.

- **Earthwatch Public Service Radio Program (AS/A-3)**

Peyton Smith, Sea Grant Institute, UW–Madison

"Earthwatch" is a weekly series of five two-minute public service radio programs dealing with current scientific and environmental issues. Produced jointly with the UW-Madison Institute for Environmental Studies, "Earthwatch" is aired over some 100 stations throughout Wisconsin and in adjacent states. The award-winning radio series focuses particularly on the Great Lakes and Sea Grant activities both in Wisconsin and around the nation. It also serves to provide professional experience to UW-Madison graduate and undergraduate students, which has helped many of them acquire successful positions in TV, radio, magazines and newspapers throughout the U.S.

PROGRAM ADMINISTRATION

Coordinator: Robert Ragotzkie, Sea Grant Institute, UW–Madison

UW Sea Grant began in 1968, and just four years later, reflecting its success in integrating a high quality research program with effective educational and advisory services programs, was the fifth program to be designated a Sea Grant College Program in the nation and the first in the Great Lakes. The overall management of the UW Sea Grant College Program includes program planning, project evaluation, proposal development, research coordination, program reporting, various administrative functions, and provides leadership for the program as a whole.

- **Program Development (SGA-1)**

Robert Ragotzkie, Sea Grant Institute, UW–Madison

This project allows the UW Sea Grant College Program to initiate projects that are proposed in the course of the grant period, solicit projects in areas of high program priority, and/or to augment existing projects or program areas. For example, funds are being used to support projects dealing with the occurrence of sterol oxides in seafood and consumer acceptance of fish products. Other projects include composting of fish wastes, developing a larval feed for aquacultured fish and the completion of a book on the Great Lakes transportation system.

- **Shiptime in Support of Sea Grant Research Projects (SGA-3)**

Robert Ragotzkie, Sea Grant Institute, UW–Madison

This project provides the ship time needed for projects requiring field work on Lakes Michigan and Superior, including research on the lakes' fisheries, sediments and water quality. To minimize expenses, several kinds of field work are usually conducted simultaneously on each cruise of the University of Wisconsin's two research vessels, the *R/V Aquarius* and *R/V Neeskay*, based at Sturgeon Bay and Milwaukee, respectively.

- **Program Management (SGA-2)**

Robert Ragotzkie, Sea Grant Institute, UW–Madison

This project provides the leadership for and the management of the University of Wisconsin Sea Grant College Program. Methods include sound management and fiscal practices, a high level of quality control of all program activities, and seeking out innovative and high-risk research initiatives. This project also fosters Great Lakes regional Sea Grant activities and maintains public awareness of the benefits of both the Wisconsin and the National Sea Grant College Program.

GREAT LAKES GATEWAY

PROJECT STANDING TABLE

N= New Project; C= Continuing Project; F= Completed Project; T=Terminated Project

Living Resources

		1984–85	1985–86
R/LR-30	Competition for Resources Among Lake Michigan Forage Fishes: Consequences of an Alewife Decline	N	F
R/LR-29	Predator-Prey Systems in the Great Lakes	N	C
R/LR-22	Daily Growth Rates and Variable Recruitment of Larval Fishes in Lake Michigan	C	F
R/LR-28	Salmonid Diet Survey	N	F
R/GB-7	Factors Influencing the Reestablishment of Self-Sustaining Stocks of Lake Trout in Lake Michigan	F	—
R/LR-32	Studies on the Early Life History and Recruitment of Feral and Native Lake Trout, with Special Emphasis on Experimentally Planted Eggs and Alevins	—	N
R/LR-27	Fish Parasite Communities as Indicators of Predator-Prey Relationships in Lake Michigan	N	C

Green Bay

R/GB-5	Green Bay Subprogram Coordination	C	C
R/GB-22	The Physical, Chemical and Biological Dynamics of the Benthic Boundary Layer in Green Bay, Lake Michigan	N	C
R/GB-18	Contribution of Marshlands to the Green Bay Pelagic Food Chain	F	—
R/GB-24	Fishery Models for Green Bay	N	F
R/GB-23	Population Modeling of Lake Whitefish in Green Bay and Wisconsin Waters of Lake Michigan and Model Verification	N	F
R/PS-32	Economic Analysis for Management of the Green Bay Fisheries and Other Great Lakes Fisheries of Wisconsin	C	F

Microcontaminants and Water Quality

R/MW-31	Fate Assessment of Organic Chemicals in Aqueous Environments	N	C
R/MW-28	Atmospheric Concentrations and Transport of Organic Contaminants Across the Air/Water Interface in the Upper Great Lakes	C	F
R/MW-33	Transport and Fractionation of Hydrophobic Organic Compounds by Suspended Particulate Matter in Lake Michigan	N	C
R/MW-37	Role of Particle-Mediated Processes in Controlling Metals and Silica in Lake Michigan	N	C
R/MW-32	Evaluating Eutrophication in Lake Michigan Using Data from Municipal Water Intakes	N	F
R/MW-27	Polychlorinated Dibenzo-p-Dioxins (PCDDs) and Dibenzofurans (PCDFs): Persistence and Toxicity in Freshwater Fish	C	C
R/MW-36	Metallothionein as an Indicator in Fish of Exposure to Toxic Organic Chemicals	N	C
R/MW-35	Measurement of the Interaction Between Lake Michigan and the Groundwater of Wisconsin	N	C
R/MW-34	Workshop on Methods for Analysis of Organic Compounds in the Great Lakes, II	—	N/F

Aquaculture

		1984–85	1985–86
R/AQ-13	Comparative Studies on the Requirements of Selected Great Lakes Fishes for Protein and (Key) Amino Acids	N	C
R/AQ-14	Genetic Manipulation of Growth and Production of Selected Great Lakes Coolwater Fishes	N	C
R/AQ-15	Development of a Fermentation Process for Mass Culturing Live Food Organisms for Feeding Larval Fishes	N/T	—
R/AQ-11	Effects of Environmental and Nutritional Stress on Resistance to Disease in Coolwater Fishes	F	—
R/AQ-8	Aquaculture Development and Subprogram Coordination	C	C

Seafood Technology

R/SF-1	Role of Enzymically-Derived Volatiles from Prostaglandins in Fish and Fishery Products	N	C

Policy Studies

R/PS-30	Management of Great Lakes Waters	F	—
R/PS-34	Recreational Boating and Rural Development: A Comparative Assessment of Boaters Across Time (1975–85) and Location (Bayfield and Door Counties)	N	F

Diving Physiology

R/NA-11	Physiology of Diving	C	C
R/DP-2	Pilot Study of the Psychobiologic Characterization of Divers Judged to Be at Risk	N/F	—

New Initiatives

R/NI-9	Multipurpose Assessment of Thematic Mapper Data for Coastal Resource Management	N	F
R/NI-8	The Pullout of Harbor Piles by Vertical Motions of Ice	N	F

Advisory Services

AS/A-14	Advisory Services Field Agents Network	C	C
AS/A-1	Advisory Services Coordination and Specialist Activities	C	C
AS/A-8	Food Science and Fish Program	C	C
AS/A-20	Lake Ice and Marina Design Advisory Services	C	C
AS/A-2	Sea Grant Communications	C	C
AS/A-3	Earthwatch Public Service Radio Program	C	C

Education

E/E-1	Special Education Programs	C	C
E/E-11	Great Lakes Seminar on Recent Advances in Limnology and Oceanography	N/F	—

Program Administration

SGA-1	Program Development	C	C
SGA-3	Shiptime in Support of Sea Grant Research Projects	C	C
SGA-2	Program Management	C	C

BUDGETS BY ACTIVITIES

	1984–85		1985–86	
	NOAA	UW	NOAA	UW
Marine Resources Development				
Aquaculture	$ 191,436	$ 69,128	$ 202,732	$ 76,417
Living Resources Other than Aquaculture	40,200	11,930	56,242	16,976
Socio-Economic and Legal Studies				
Marine Economics	39,183	16,135	52,208	19,585
Socio-Political Studies	79,798	27,254	19,045	4,719
Marine Technology Research and Development				
Ocean Engineering	68,743	23,339	71,801	26,012
Resources Recovery and Utilization	141,831	52,793	140,148	44,070
Marine Environmental Research				
Research and Studies in Direct Support of Coastal Management Decisions	57,950	55,298	69,502	60,782
Ecosystems Research	203,851	64,525	132,523	42,536
Pollution Studies	173,210	170,578	166,598	173,338
Environmental Models	243,232	109,413	263,492	111,622
Marine Education and Training				
Other Education	32,558	21,108	16,783	10,211
Advisory Services				
Extension Programs	198,276	71,439	248,510	76,498
Other Advisory Services	195,141	73,811	246,811	79,548
Program Management and Development				
Program Administration	155,401	212,578	168,262	246,188
Program Development	79,190	20,671	45,343	11,498
TOTAL	**$1,900,000**	**$1,000,000**	**$1,900,000**	**$1,000,000**

MEASURING MARSH NUTRIENTS

Advisory Council

Stephen M. Born
Chairman, Dept. of Urban & Regional Planning
UW-Madison

Gordon Chesters
Director, Water Resources Center
UW-Madison

Arnold L. Clement
Director, Planning & Development
Racine County Planning & Zoning Dept.
Sturtevant, Wisconsin

H. Jack Day
Professor, Science & Environmental Change
UW-Green Bay

David Edgington (chairman)
Director, Center for Great Lakes Studies
UW-Milwaukee

Joyce Erdman
Madison, Wisconsin

George Evenson
Sturgeon Bay, Wisconsin

Lee Kernen
Chief, Great Lakes & Boundary Waters Section
Bureau of Fish Management
Wisconsin Dept. of Natural Resources
Madison, Wisconsin

Reuben H. Lorenz
President, UW Credit Union
Madison, Wisconsin

John J. Magnuson
Director, Center for Limnology
UW-Madison

W. Robert Marshall
Director, University-Industry Research Program
UW-Madison

Dallas O. Peterson
Associate Vice President for Academic Affairs
UW System
Madison, Wisconsin

Robert A. Ragotzkie (ex officio)
Director, UW Sea Grant Institute
UW-Madison

Bert O. Smith
Smith Brothers Fisheries, Inc.
Port Washington, Wisconsin

Ayse C. Somersan
State Program Leader
UW-Extension
Madison, Wisconsin

Daniel O. Trainer
Dean, College of Natural Resources
UW-Stevens Point

Subprogram Coordinators

Living Resources

James Kitchell
Center for Limnology
UW-Madison

Ross Horrall
Marine Studies Center
UW-Madison

Green Bay

H.J. Harris
Science & Environmental Change
UW-Green Bay

Microcontaminants & Water Quality

David Armstrong
Water Chemistry Program
UW-Madison

Aquaculture

Clyde Amundson
Food Science
UW-Madison

Seafood Technology

David Stuiber
Food Science
UW-Madison

Policy Studies

Richard Bishop
Agricultural Economics
UW-Madison

Diving Physiology

Edward Lanphier
Preventive Medicine & Biotron
UW-Madison

New Initiatives

Robert A. Ragotzkie
Sea Grant Institute
UW-Madison

Advisory Services

Allen Miller
Sea Grant Institute
UW-Madison

SEA GRANT INSTITUTE STAFF

UNIVERSITY OF WISCONSIN

Institute Administration Offices
1800 University Avenue
Madison, WI 53705
Phone: (608) 262–0905

Robert A. Ragotzkie
Director

Anders Andren
Associate Director

Mary Lou Reeb
Assistant Director for Administration

Daniel Marklein
Financial Manager

J. Philip Keillor
Facilities Manager

Delphine Skinner
Secretary to the Director

Donna Ford
Fiscal Clerk

Gloria Gardner
Receptionist

Communications Office
1800 University Avenue
Madison, WI 53705
Phone: (608) 263–3259

Peyton Smith
Coordinator

Stephen Wittman
Publications Editor

Christine Kohler
Publication Production Coordinator

Marc Kennedy
Science Writer

Warren Downs
Science Writer

Linda Campbell
Program Assistant

Wendy Schorr
Artist (part-time)

Paul Rome
Graduate Assistant Writer

Jeanette Lytle
Student Writer

Advisory Services
1800 University Avenue
Madison, WI 53705
Phone: (608) 262–0645

Allen H. Miller
Coordinator

Pat Boyd
Program Assistant

Specialists

Fred Binkowski
Aquaculture
UW-Milwaukee
(414) 224-3026

J. Philip Keillor
Coastal Engineering
UW Sea Grant Institute
(608) 263-5133

David Stuiber
Fishery Development
UW-Madison
(608) 263-2087

C. Allen Wortley
Ice Engineering
UW-Madison
(608) 262-0577

Field Agents

Lynn Frederick
The Walkway Mall
522 Bay Shore Drive
Sister Bay, WI 54234
Phone: (414) 854-5329
Secretary: Nancy Smith

Clifford Kraft
Science & Environmental Change
University of Wisconsin
ES-105
Green Bay, WI 54301-7001
Phone: (414) 465-2795
Secretary: Cathi Hinricks

James Lubner
Great Lakes Research Facility
University of Wisconsin
600 E. Greenfield Avenue
Milwaukee, WI 53204
Phone: (414) 224-3024
Secretary: Helen Smentek

Karen Plass
230 Old Main
University of Wisconsin
1800 Grand Avenue
Superior, WI 54880
Phone: (715) 394-8472
Secretary: Diane Fox

Research Vessel Aquarius

John Eriksson
Captain, *R/V Aquarius*
4419 Walker Road
Sturgeon Bay, WI 54235
Phone: (414) 743-2968

Project Coordinator • Peyton Smith
Editing • Stephen Wittman and Peyton Smith
Contributing Writers • James Napoli, Warren Downs and Don Davenport
Cover Design • Christine Kohler
Production Assistance • Linda Campbell and Wendy Schorr

Illustrations:

Fish by Christine Kohler
Gill net by Jana Fothergill

Photographs:

Michael Brisson, pp. 26, 36; Rick Evans, pp. 6, 22; Lynn Frederick, p. 12; Jim Gill, p. 18; *Minneapolis Tribune*, p. iv; Paul Rome pp. 32, 40.

Acknowledgements:

For their help and assistance in reviewing the historical narrative, thanks are extended to: Richard Bishop, professor, Department of Agricultural Economics, UW–Madison; Frederick Copes, professor, Biology Department, UW–Stevens Point; Steven Hewett, project associate, Center for Limnology, UW–Madison; Ross Horrall, scientist, Marine Studies Center, UW–Madison; Barry Johnson, project associate, Center for Limnology, UW–Madison; Lee Kernen, chief, Great Lakes & Boundary Waters Section, Bureau of Fish Management, Wisconsin Department of Natural Resources; James Kitchell, associate director, Center for Limnology, and professor of zoology, UW–Madison; Clifford Kraft, UW Sea Grant Advisory Services field agent, Green Bay, Wis., and John Magnuson, director, Center for Limnology, and professor of zoology, UW–Madison.

WIS-SG-86-148

This publication is available from:

Communications Office
Sea Grant Institute
University of Wisconsin
1800 University Avenue
Madison, WI 53705

Phone (608) 263-3259

WIS-SG-86-148