Wisconsin Fishes and Fishery Management

Early Limnological and Fishery Research

The University of Wisconsin has long been a leader in the science of limnology, which deals with the physical, chemical, meteorological, and biological conditions of ponds and lakes. Many basic limnological studies were conducted by the team of E. A. Birge and Chancey Juday, who contributed a legacy of more than 400 publications produced over more than four decades, beginning in the last quarter of the nineteenth century. Their enormous impact on the science of limnology is described at length by Frey (1963).

The Birge-Juday research attracted scientists from many foreign countries to Madison, Wisconsin. Basic research from 1940 to 1961 in such areas as plankton, odor detection by fish, homing migrations in fish, sun orientation in fish, and the chemical composition of bottom muds, has been summarized by A. D. Hasler (1963). The identification, investigation, and control of biologically associated problems in freshwater environments, based on Wisconsin experience, are discussed by Mackenthun et al. (1964) and Mackenthun and Ingram (1967).

The earliest list of fishes from Wisconsin was provided by Lapham (1846:71):

> Among the fish afforded by our lakes and rivers are whitefish, salmon, sturgeon, perch, bass, suckers, herring, pickerel or muskellunge, trout, catfish, sheep's head, lawyers, and many others, nearly all valuable as articles of food for man. They are caught in large quantities, and some are exported. The Indians at the north, where game is scarce and where agriculture has not yet been introduced, live almost exclusively upon fish, which are caught in vast quantities at the mouths of the rivers. The excellent qualities of these fish for the table are too well known to need description here.

Between 1872 and 1877, P. R. Hoy published a series of articles on Wisconsin fishes, culminating in 1877 (Hoy 1883) with a list of over 100 species, the longest list of Wisconsin fishes compiled to that time. Other early papers dealing with Wisconsin fishes were those by Marshall and Gilbert (1905), Wagner (1908, 1910a, 1910b, 1911), and A. S. Pearse (1918, 1921a, 1921b, 1924a, 1924b). In 1927, C. W. Greene reported 141 species of fish known from Wisconsin, and A. R. Cahn recorded 90 species from the Waukesha County area. W. Koelz's monumental work on the coregonid fishes of the Great Lakes appeared in 1929; Koelz drew heavily from fish collected from Wisconsin's inland lakes and from Lakes Michigan and Superior.

To date, the most significant contribution to our overall knowledge of Wisconsin fishes and their distribution is Greene's *The Distribution of Wisconsin Fishes*, which appeared in 1935. His work, a joint effort of the Wisconsin Geological and Natural History Survey and the Museum of Zoology of the University of Michigan, was based on more than 1,441 collections of fishes made between 1925 and 1928. Greene recognized 149 species, 14 of these having 2 or more recognized subspecies. *The Distribution of Wisconsin Fishes* was originally planned to be only a section of a larger report which was being prepared under the direction of Dr. C. L. Hubbs. Unfortunately, because of the large expense anticipated in its printing, the Hubbs work was never published.

Fish Culture and Stocking

The account of early fish management in Wisconsin that follows is derived mostly from Cox (1939) and from the annual and biennial reports of the Commissioners of Fisheries of Wisconsin (1876–1910).

The first Wisconsin fish commissioners were appointed in 1874 in response to a sagging Great Lakes fishery. The same year, the Wisconsin legislature was attempting to regulate the take in order to preserve the industry. Year by year the industry was shrinking because more gear was used for catching fish, but the loss of fish stocks was not fully comprehended.

The artificial propagation of fish was looked upon as a cure-all for preventing the exhaustion of the fish supply. In 1875 the first fish hatchery (the present Nevin hatchery) was established at Nine Springs, about 5 km southwest of Madison. In Milwaukee a temporary hatchery for whitefish and lake trout eggs was set up in the engine house of the water works, and attempts were also made to hatch these species at Pensaukee (Wis. Conserv. Dep. 1963).

In early days, milk cans were used as containers for fish to be stocked. The cans were transported aboard railroad express cars, from which they were transferred to any available conveyance for distribution to streams and lakes. Often this was a horse-drawn wagon, and the cooperator frequently had difficulty directing his load through deep mud and slumping snow banks to the stream or lake of destination.

Early in the propagation program exotic Atlantic and Pacific salmon eggs were obtained by purchase and donation from the U.S. Fish Commissioner. Much emphasis was placed on propagating the coldwater salmonid fishes, but these were stocked indiscriminately in warmwater lakes and streams where survival was impossible. For instance, in 1875 43,000 landlocked salmon eggs were hatched in Wisconsin's state or private hatcheries, and 10,000 fry were planted in Lake Mendota at Madison and a like number in Oconomowoc Lake (Waukesha County). From 25,000 Penobscot salmon eggs, 10,000 fry were planted in Devil's Lake (Sauk County).

In 1876 Lake Geneva (Walworth County) was planted with 250,000 lake trout, 100,000 whitefish, 50,000 brook trout, 10,000 landlocked salmon, 25,000 king salmon, and 1,000,000 walleyes. During 1877 lake trout were stocked in Browns Lake (Racine County); Delavan, Troy, Lauderdale, and Lake Pleasant (Walworth County); Oconomowoc, Pine, Pewaukee, North, Nagawicka, and Okauchee (Waukesha County); Lake Ripley (Jefferson County); Fox Lake (Dodge County); and Swan and Silver lakes (Columbia County).

In 1878, 20 graylings were held in Madison ponds; this was the first of a series of attempts to propagate the grayling in sufficient numbers to establish it in Wisconsin. In the same year plans were laid to take eggs from Lake Mendota ciscoes and to transport them to the Milwaukee hatchery for later stocking of inland lakes of Wisconsin.

Also in 1878, chinook salmon were stocked in Lakes Mendota and Monona (Dane County), in tributaries to the Mississippi River (Grant County), in Silver and Spring lakes (Columbia County), and in the Wisconsin River at Portage. In 1878, the Wisconsin hatchery superintendent wrote:

> I assert without any fear of contradiction, that the water selected by your commission for the planting of young fry [is] in every way suited for their welfare and growth, and that in a few years the people will enjoy the benefits accruing from our labors in pisciculture (5th Annu. Rep., Commnrs. Fish. Wis. 1878:28).

In 1879 the chinook salmon stocking program no longer seemed secure, and, although 1,100 salmon grew well at the Madison ponds, the Commissioners of Fisheries of Wisconsin (1879:16) noted that "it is still an unsolved problem whether they are adapted to our waters and can be successfully raised there or not." Extensive salmon culture ended in 1879 (except for the program of the late 1960s), though sporadic attempts were made to introduce exotic salmonids—e.g., the landlocked strain of the Atlantic salmon, which was stocked in Trout Lake (Vilas County) during the 1907–1908 period.

Millions of brook trout, whitefish, and lake trout were propagated from the beginning of the fish culture program. Successful yields from the stocking of lake trout were reported in 1901–1902 from Hammil Lake (Bayfield County), and Bass and St. Croix lakes (Douglas County). From 1901 to 1902, lake trout fry were distributed to Green Lake (Green Lake County), Lake Mendota (Dane County), Pine, Minocqua, and Tomahawk lakes (Vilas County), and others. As a result of the widespread stocking of lake trout, the distribution of native lake trout in the inland lakes of Wisconsin is not clear.

The exotic rainbow trout was secured from the U.S. Commissioner of Fisheries in 1880. The fish arrived in Wisconsin as eggs; about 2,000 young hatched from this initial shipment. In 1885, 600,000 rainbow trout were stocked in Wisconsin waters; in 1886, 620,000.

The first carp, 75 in number, were shipped to Wisconsin in 1880. They were bred upon arrival and produced 350 young the first year. Of these, 163 were distributed in 1881 to individuals in Rock, Columbia, Fond du Lac, Sauk, and Manitowoc counties. The commissioners, apparently little understanding the habits of the carp, reported (1884:15): "It is useless to undertake to grow carp where there are other fish. The carp must be cultivated in ponds expressly built for them and those of different ages must be kept by themselves." In 1891–1892, carp were distributed in Barron, Douglas, Eau Claire, Langlade, Marathon, St. Croix, Washburn, Bayfield, Chippewa, Marinette, Polk, Price, Sawyer, Shawano, and Taylor counties. In 1893, 8,050 carp were distributed in 37 counties; and in 1894, 8,125 in 36 counties. In all, between 1881 and 1895, over 131,000 carp fingerlings were distributed throughout Wisconsin. The last planting occurred in 1895, at which time this fish was well established in the state. By 1907 and 1908 it was the principal fish caught in the Mississippi River, and the superintendent of fisheries noted that fishermen were making more money catching and marketing "the despised carp" than they had made in past years from all other species.

Wisconsin initiated its walleye propagation program in 1883 and during that year produced 8 million fingerlings. Over a million Wisconsin muskellunge were propagated and planted in 1897. In 1887 Wisconsin imported 1,000 European brown trout eggs, which were hatched at the Bayfield Fish Hatchery at Bayfield (O. M. Brynildson et al. 1973). Exotic goldfish were received during the 1907–1908 period from the Nebraska Fish Commission in exchange for 100,000 eyed lake trout eggs; some goldfish were furnished to aquariums in Wisconsin, but the disposition of the remainder is unknown.

Lake sturgeon propagation plans were discussed in the Commissioners of Fisheries report for 1911–1912. At that time lake sturgeon were bringing the highest price of any freshwater fish, although in earlier days they had been caught in large numbers "and piled on the shores like so much cordwood." It was anticipated that lake sturgeon brood stock would be taken from the Wolf River; however, the plans never materialized. The problems associated with propagating the sturgeon have been discussed by Eddy and Surber (1947) and Eddy and Underhill (1974).

To improve the lake trout stocks in Lakes Michigan and Superior, the Wisconsin Commissioners allowed commercial fishermen, under permits, to catch lake trout during the closed season for the purpose of securing and fertilizing eggs (Bienn. Rep., Commnrs. Fish. Wis. 1909–1910). All expenses were incurred by the fishermen, who supplied as many eggs as were needed for the state hatcheries; those not needed were to be planted back on the lake trout reefs or spawning beds. During the 1909 season, 25 million eggs were sent to the hatcheries, and 15 million were planted back on the spawning beds.

In 1937, Wisconsin established a national record for state propagation and distribution of fish of all kinds, when over 1 billion fish were reared and planted in the state (Wis. Conserv. Dep. 1963).

Currently the Wisconsin Department of Natural Resources distributes fish from its own hatcheries, as well as from cooperative ponds, federal hatcheries, and private purchase. The program cultures mostly salmonids, largemouth bass, muskellunge, northern pike, and walleyes. In 1976, the department distributed over 436,000 brook trout, 1.1 million brown trout, 1.7 million rainbow trout, 1.1 million lake trout, 18,000 splake, 666,000 cohos, 1.1 million chinooks, 23,000 tiger trout, 609,000 largemouth bass, 12,000 smallmouth bass, 1.4 million muskellunge, 198,000 tiger muskellunge, 16 million northern pike, 54,000 perch, 62 million walleyes, 1.6 million whitefish, and lesser numbers of bluegills, catfish, crappies, sturgeon, sunfish, and rock bass (Wis. Dep. Nat. Resour. 1976a).

Fish Rescue and Transfer

From the late 1870s to the late 1930s, Iowa and Wisconsin Commissioners of Fisheries and the U.S. Fish Commission directed fish rescue and transfer programs to salvage Mississippi River fishes that were naturally imperiled.

In the June floodwaters on the Mississippi River, many fish that are ready to spawn seek the quiet backwaters to deposit their eggs. Conditions in the backwaters are favorable for the growth of the fish, and the young are often several centimeters long before the waters begin to subside. As the floods recede, the adult fish may return to the main channel, but many young fish are stranded in pools. Some pools become dry in a few days, others persist for weeks or months while the water slowly evaporates or seeps away, and a few remain until winter, when they freeze almost to the bottom. The landlocked fish die as the water diminishes or disappears, and as they are crowded, starved, and finally smothered when the pool freezes. A fish rescue and transfer program seeks to remove and distribute these fish before natural destruction occurs; the history and operational details of the program are given by Carlander (1954).

In 1898, the Wisconsin Commissioners of Fisheries reported that for several years they had collected small black bass from the sloughs and ponds along the Mississippi River for distribution to inland waters. In 1903–1904, over 117,000 bass rescued from Mississippi River sloughs were planted in inland waters. During the 1909–1910 period, of the almost 2 million fish taken from small Mississippi River ponds, approximately 600,000 were bass; over half of these were carried to the main river and the remainder were transported to inland lakes. In 1909, the Wisconsin legislature passed a law which directed that the license money paid by the commercial fishermen on the Mississippi River should create a separate fund to be used for the rescue of fish from the sloughs and bayous adjacent to the river (Carlander 1954).

In 1936, almost 10 million fish were transplanted in fish rescue operations conducted in the Mississippi, Wisconsin, Fox, and Wolf river bottoms, in flowages above power dams in some of the northern rivers, and in many lakes and streams where receding water or other conditions were detrimental to fish life (Wis. Conserv. *Bull.* 1937 2[1]:11). While the program was going on, private groups sent applications for rescued fish to be planted at their favorite fishing sites. When the fish cars made their trips inland, the applicants were notified where to meet the train to receive their quota of fish.

In the years for which it was possible to obtain records of the estimated numbers of fish caught, it appears that there were only 5 fish groups which in any year constituted more than 5% of the numbers of rescued fish:

> From 14 to 74 per cent of the fish were "catfish," including bullheads. "Sunfish" comprised 6 to 32 per cent of the annual catch and "crappies" varied from 3 to 37 per cent. Carp comprised from 0.6 to 39 per cent of the catch and "buffalo" from 0.6 to 16 per cent (Carlander 1954:38).

According to Carlander, the U.S. Fish Commission (Bureau of Fisheries) continued fish rescue operations on the Mississippi River until 1938 and retained crews for that purpose at Genoa and La Crosse. In the winter of 1939–1940, a crew of four men from the Wisconsin Conservation Department, working with local residents, seined Pool 10 near Cassville under the ice and rescued 100,000 fish. With this, the fish rescue and transfer program on the Mississippi River was nearing its end.

Although many regarded the fish rescue and transfer program as beneficial to fish stocks and to fishermen interested in exploiting these stocks, opposition to the program was growing for a number of reasons. Carlander (1954:35) noted:

> The sportsmen of the bordering states began to wonder if fish rightfully theirs were being sent to other parts of the country. . . . complaints that many game fish were being removed and the coarse fish returned to the river seem to have been somewhat justified since the records show that from twenty to ninety-three percent of the rescued "black bass" were transported to other waters.

The Wisconsin Conservation Commission (1949:89) noted that between 1920 and 1925 large numbers of rescued fish, mostly black crappies, were distributed to many northern Wisconsin lakes where they became extremely abundant. These "carp of the north" came into competition with and displaced sport fishes like walleyes and bass, and as a result of crowding often became stunted themselves. Thus the indiscriminate stocking of species outside their normal range may result in the reduction or loss of more desirable native fishes.

In retrospect, most fishery biologists now question the value of fish rescue for maintaining desired fish populations in Wisconsin waters. Stocking rescued fish in lakes, ponds, and rivers is also of doubtful value, since such stocking does not necessarily improve fishing. Most warmwater lakes and ponds are already overrun by large numbers of stunted fish, and any additional stocking merely aggravates this condition. Fish stocking is seldom needed except in new ponds and new artificial lakes.

The fish rescue and transfer program was undoubtedly responsible for the "discovery," years later, of isolated individuals far removed from the known distribution of their species. Attention is called to such perplexing cases in the species accounts.

Fishkills

Fishkills are by no means a recent phenomenon in Wisconsin, where they have occurred every year for as long as records have been kept. Today, many fishkills occur yearly, and in some waters, partial fishkills have become an anticipated yearly event. Some fishkills are traceable to fish diseases, but most are caused in late winter and late summer by oxygen depletion in heavily vegetated waters which are high in nutrients.

During July and August 1884, a die-off of an estimated 136 kilotons of fish occurred in Lake Mendota (Dane County). The cause was unknown, but an infestation of the protozoan *Myxobolus* was suspected. During the hot, dry summer of 1910, thousands of fish perished in the waters of Lake Winnebago and Green Bay, and from the latter part of July to the middle of August walleyes and perch were found floating over the surface of Green Bay. In 1925, a large number of fish were killed in the Flambeau River, probably as a result of industrial pollution.

In the early spring of 1967, over 50 large lake sturgeon perished in Lake Wisconsin (Columbia County); the suggested cause of death was industrial pollution. In 1968, there was a complete kill of brook trout along a 3.2-km stretch of the Little Wolf River (Marathon and Waupaca counties), which was traced to poison flushed from a potato-spray tank.

In 1974, heavy fishkills were reported from the lower Rock River (Rock County), Luxemburg Creek (Kewaunee County), Six Mile Creek (Dane County), and the Wisconsin River (Oneida and Wood counties); wastes from food and paper industries were partly responsible (U.S. Off. Water Plan. and Stand. 1975). In 1975, fishkills in Wisconsin were attributed to municipal operations (40%), industrial operations (20%), agricultural operations (20%), and other operations (20%) (U.S. Off. Water Plan. and Stand. 1977). Heavy kills were reported in 1975 from Manitowoc River (Manitowoc County), Cedar Creek (Washington County), Willow River (St. Croix County), and Oconto River (Oconto County).

A severe fishkill occurred in the Wisconsin River below DuBay Dam (Portage County) during the winter of 1976–1977. Most fish killed were black bullheads. The following July several hundred dead yellow perch, carp, and young-of-year walleyes were observed in the same area. In both instances the die-offs were caused by a shortage of dissolved oxygen.

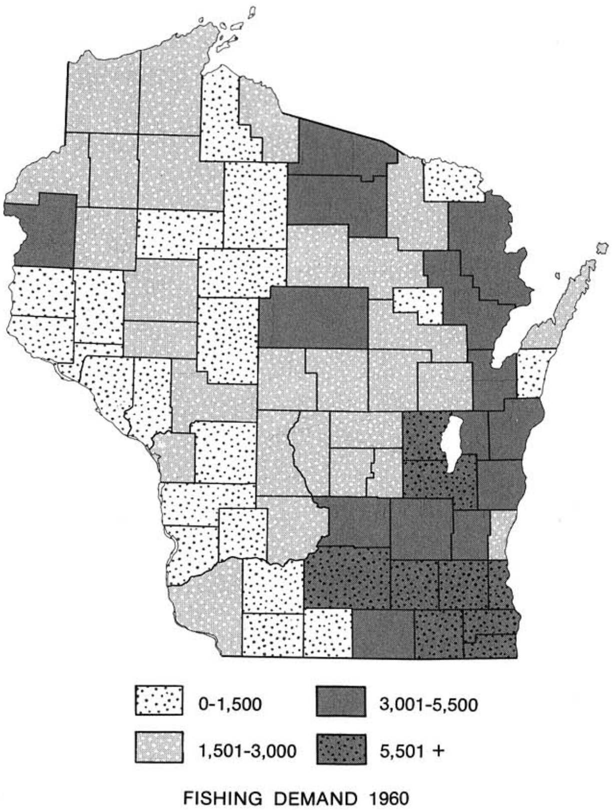
In the mid-1970s, after treatment of the Rock River with toxicants for the elimination of carp, the sport fishes that had been stocked were winterkilled. The nutrient-rich waters produced heavy crops of aquatic vegetation, which decomposed and depleted the water below the ice of its oxygen. Repeated attempts over several years to reintroduce sport fishes to the system resulted in failure.

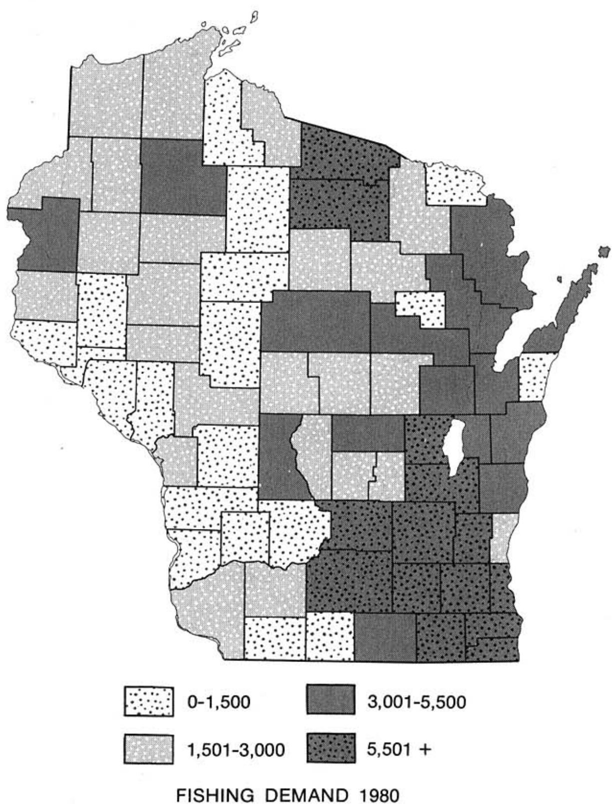
It is evident that the specific causes of fishkills are numerous. Some are natural, but municipal, agricultural, and industrial wastes introduced into our water systems are responsible for an increasing number of fishkills. Fishes stranded in overflow pools or in pools remaining after rapid drops in water level may die with the development of unfavorable conditions. Indeed, fishkills have become so commonplace that they seldom receive more than brief mention in local newspapers.

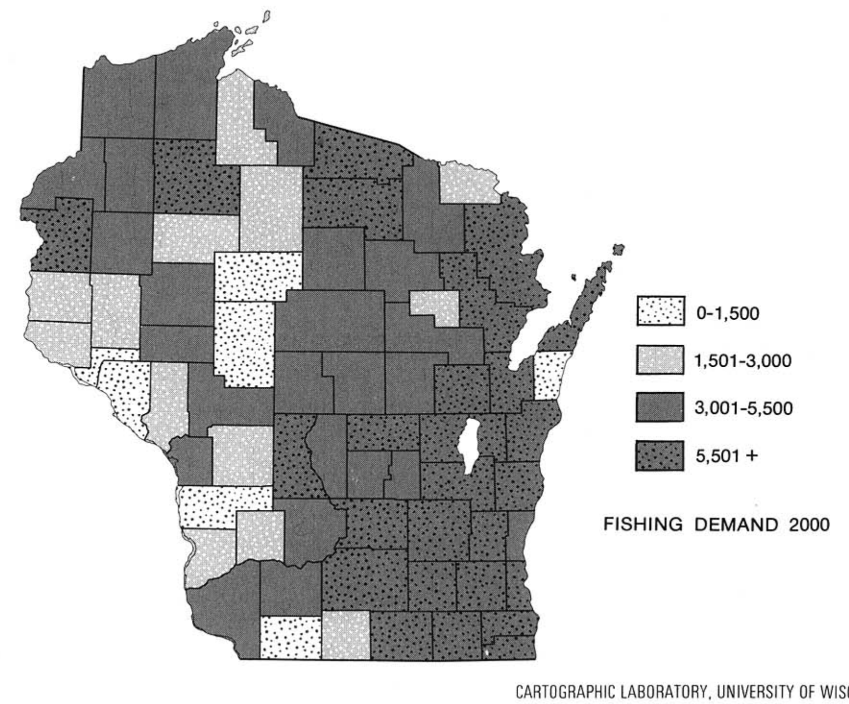
Fishing Demand and the Fish Resource

In Wisconsin sport fishing is the second most popular use of surface water resources. Only swimming attracts more water enthusiasts. Approximately 1 million anglers fished 18.5 million times and caught about 110 million fish in Wisconsin during the winter of 1970 and the summer of 1971 (Churchill 1971, 1972). Fishing, like other water-based activities, is concentrated most heavily on waters in the southeastern part of the state. Fortunately, these waters have the greatest capacity to produce fish pounds, although the population balance tilts toward nongame fish rather than sport fish.

It has been estimated that in 1960 only 9 Wisconsin counties could have exceeded 5,500 fishermen per summer Sunday; the estimate for 1980 was 14 counties. (In two of these counties, Oneida and Vilas, almost 40% of the projected 5,500+ fishermen per summer Sunday in 1980 were expected to be from Illinois.) (Wis. Dep. Resour. Dev. 1966.)







Numbers represent average number of fishermen per summer Sunday (after Wis. Dep. Resour. Dev. 1966:46–47).

In the year 2000, all but 20 counties should have over 3,000 fishermen on an average summer Sunday, and 27 of the counties, or more than one-third, may expect 5,500 fishermen; only 7 counties in Wisconsin might expect less than 1,500 fishing visits on the average summer Sunday. The increased fishing demand projected for the northwest sector is in part a reflection of increased demand by Twin Cities fishermen. The above data, however, do not reflect the increased fishing in those counties lying along the Great Lakes which resulted from the unanticipated salmon and trout bonanza that began in the late 1960s.

Statewide, Wisconsin fishing license sales continue to grow. Estimates indicate that about 25% of the public engages in fishing (Threinen 1964). Total sales of all Wisconsin fishing licenses were 1,374,531 in 1968, 1,386,208 in 1969, and 1,431,409 in 1970 (Kleinert and Degurse 1972). In 1970, the estimated fish taken included 4,579,000 trout, 204,000 salmon, 115,000 muskellunge, 3,282,000 northern pike, 4,651,000 walleyes, and 69,307,000 bass, perch, and other panfish (Wis. Legis. Ref. Bur. 1973).

Currently Lake Michigan sport fishing is an estimated $30-million-a-year business in Wisconsin. If state and federal agencies continue to stock trout and salmon in the lake, people will probably continue to fish for them.

Today there is a growing demand for food fish in the United States. Per capita fish consumption has increased from 4.8 kg in 1967 to 5.5 kg in 1975—a 14% increase over an 8-year period (Vilstrup 1975). The value of fish as a diet food and as a variety item in the menu has increased demand, and this trend is expected to continue.

The natural supply of fish has continued to decline as a result of increased commercial fishing pressure and environmental problems. Vilstrup (1975:46) stated:

> The yellow perch comes from Lake Erie with the bulk imported from Canada. Commercial catches from Lake Erie dwindled from a high of 15 million kg in 1969 to 6.8 million kg in 1974. It has been estimated that nearly 75% of the yellow perch are consumed in Wisconsin, and leading processors and distributors warn that prospects for an increased natural harvest appear limited.

In Lake Michigan's ecosystem the far-reaching effects of man's activities have included changes in water chemistry, benthos, plankton, and native fish populations. The changes in native fish stocks (mostly decreases in abundance) are primarily attributable to exploitation, the introduction of exotic fish species, and accelerated eutrophication and other effects of pollution (Wells and McLain 1973).

Although Lake Superior has not greatly changed from its pristine state, stocks of every fish species of commercial importance have been severely depleted (Lawrie and Rahrer 1973). The histories of all species suggest extensive overfishing long before the sea lamprey, known to have parasitized and reduced valuable fish populations, entered the lake. Recovery from these declines has been limited, but measures to control the sea lamprey, coupled with modern hatchery technology, clearly provide prospects for rejuvenating some existing stocks (e.g., lake trout) or developing entirely new ones (e.g., salmon spp.).

The fish resource is a matter of considerable complexity and is discussed in greater detail in the species accounts.

Fishery Management: Trends and New Developments

The goal of fishery management is to produce a sustainable yield of sport and commercial fishes. In Wisconsin, the Department of Natural Resources endeavors to sustain fish populations in waters where environmental deterioration has reduced the numbers of desirable fish species and where the fish have been overharvested. Managing water quality and fish populations is not an easy task. Early Wisconsin fish management activity is summarized in the "Fish Culture and Stocking" section, above. In the following paragraphs I bring together some recent management findings along with suggestions for the maintenance and rehabilitation of our waters.

Escanaba Lake in Vilas County has been an experimental lake since 1946, during which period fishing regulations have imposed no bag limits, no size limits, and no closed seasons for any sport fishes in its waters (Kempinger et al. 1975). Analysis of catch data from Escanaba Lake suggests that throughout Wisconsin the emphasis should be changed from managing the fish through fishing regulations to managing their habitat. Accordingly, for a number of species Wisconsin fishing regulations in recent years have been liberalized by reducing size limits and increasing bag limits. This trend is apt to continue.

The use of fish toxicants will undoubtedly be curtailed in the future (the negative effects of such treatment programs, discussed above, are also detailed in the species accounts). Dr. Willis King (Sport Fishing Inst. *Bull.* No. 262, March 1975, p. 7) commented that the pendulum has recently swung away from use of toxicants of all kinds in fresh waters, and has indicated that if new chemicals or new uses for old chemicals are wanted, the fish managers who want to use them are going to have to work for the money and personnel to do the basic environmental impact studies required. All new fish management projects should be highly coordinated by the Wisconsin Department of Natural Resources and should include the participation of all appropriate agencies (U.S. Soil Conservation Service, U.S. Environmental Protection Agency, U.S. Forest Service, state and local planning agencies, etc.) to promote the most comprehensive and effective effort for resolving fish management and water quality problems and managing aquatic systems.

One impediment to solving the fishery problems of the Great Lakes is conflict among approaches to fishery problems taken by the various management agencies having jurisdiction in different areas of the same lake (S. H. Smith 1973). Coordination of activities would contribute to attaining a common goal, once the goal has been defined.

Drastic measures must be taken to restore the Great Lakes (particularly Lake Michigan) to their original condition and to ensure that their native fish populations are not entirely extirpated. Ron Poff, Wisconsin DNR Great Lakes fisheries specialist, has suggested that PCBs be purged from the Great Lakes through the wholesale removal of alewives. Alewives contain up to 13 ppm of PCBs in their body tissues; and more than 100 million kg of alewives are available to bottom trawling in Lake Michigan.

Stanford Smith proposed making lake trout the primary planting fish for the Great Lakes, and converting all hatcheries to the rearing of trout instead of the salmon now propagated (R. C. Kienitz, *The Milwaukee Journal* 18 December 1977). Smith predicted that large concentrations of lake trout would depress and control the superabundance of alewives in the lakes, and that trout saturation would lead to natural reproduction of lake trout. In time, the hatcheries could be converted from lake trout reproduction to the propagation of whitefish, perch, chubs, and herring; stocking these native fishes would "drive the system further back to nature."

Our sport fishing culture in North America has been built around trophy rewards. Traditionally, the goal of a fishing vacation has been to bring home a large bass, muskellunge, or trout. However, times have changed, and there are now not enough large trophy-sized fish to go around. Recently nationwide sentiment has been supporting catch-and-release fishing as a management tool. Muskies, Inc., a Midwest-based organization interested in promoting conservation and fishing of the muskellunge, has strongly endorsed a catch-and-release program. In 1970, 19% of the total muskellunge caught by members were released back to the water; in 1976, 87%.

The spectacle represented by fishing tournaments has come under sharp criticism in recent years. Objections have been raised against promoters and others interested in financial gain through the abuse of the fish resource; fishing tournaments have also been viewed as putting a price on a fish's head or "killing fish for pay." Growing sentiment condemns the unnatural exploitation of fish and emphasizes the concept that fishing is a quiet, enjoyable, and private outdoor recreation.

More money and research will undoubtedly be directed toward solving the serious problems affecting some fish species. The stunting of panfishes has long been of concern to fish managers; however, remedies involving chemical treatments or predatory sport fishes have seldom been satisfactory. A new approach being explored is the introduction of native nongame predators, such as the burbot, bowfin, and gar, into waters with stunted panfish populations; these are the traditional top predators in many waters where stunting is seldom a problem.

A breakthrough in carp control is imminent. Recently it was discovered that carp move in tight schools under the ice. By outfitting a few "Judas" carp with transmitters, it may be possible to encircle and capture entire schools with nets, thus gaining valuable protein for man and effecting carp control at the same time. Such an example suggests that intensive research into fish behavior—an area in which we have little knowledge for many species—may pay dividends for future fish management.

Preserving Ecosystem Integrity: The Role of Nongame Fishes

In the "Report of Governor's Study Committee on the Use of Fish Toxicants for Fish Management," Cook et al. (1972) declared:

> The primary goal in the management of all our living resources must be to protect and enhance the integrity of ecosystems. A diversity of aquatic habitats and natural communities must be preserved to provide for education, research and esthetic enjoyment. It should be recognized that other generations will follow ours, and that we have a responsibility to maintain a suitable number of untampered ecosystems in representative habitats throughout the State and to place them "in trust" for the future.

Nongame fish (e.g., suckers, drums, gars, bowfins, minnows, and darters) constitute a large portion of our fishery resource, an important part that is often overlooked by sportsmen, resource managers, and research biologists. The management emphasis to date has been to establish sport fisheries, often for only a single species in a system. In Wisconsin, trout, muskellunge, northern pike, walleye, and bass have received most research emphasis. These species, at the tip of the food pyramid, constitute only a small part of the total fish volume in a given body of water; the nongame fishes outrank the sport species in total numbers of individuals, in combined weight, and in number of species present.

There are two arguments for the importance of every species of fish, regardless of how attractive or repulsive it may be. First, in terms of direct benefit to humans, there is no way to predict in advance which species may hold secrets useful in solving many kinds of problems. Koch (1975) quotes Joshua Lederberg:

> The variety of species is a great library of information literally encoded in the specific DNA molecules that characterize each type. It is paradoxical that, in this era of most rapid elimination of natural variety, we have begun to learn the keys to that code and to appreciate the subtleties of the evolutionary mechanism that it drives. Each different species is a unique adaptation to its own way of life, a lesson in 'how to live' that we never properly understand after we extinguish it.

It would be wrong to argue that every species has locked up inside its tissues a new food source or a cure for cancer. It is right to say, however, that every time we eliminate a species we eliminate the possibility of identifying its unique feature(s) and its possible value to humanity (Williams 1977). Second, all fish species are important as members of whole communities. It may seem, while you are fishing for walleyes or panfish, that gars, burbots, and bowfins are creatures with absolutely no redeeming virtues, but the quality of the walleyes and perch you catch may be directly dependent on the presence or absence of these predators. The lake fly (*Chironomus plumosus*) in the Lake Winnebago region may be a nuisance to the human population for a few days of the year, but to the lake sturgeon it is a prime food source throughout the year. Thus the strength of the lake sturgeon population is directly correlated with the "nuisance" level of the *Chironomus* larvae living in the lake muds.

Not enough effort has been made by fishery biologists to understand interspecific relationships, perhaps because the philosophy persists that nongame fishes are natural competitors with sport or other economically important fish species. According to Pister (1976), "management" has been manifested in nongame species destruction, often with virtually no biological justification.

Li (1975) has observed that (1) the evidence used to demonstrate interspecific competition is circumstantial in nature; (2) comparative dietary analysis of sport and nongame fish is inadequate; (3) sport fish territories, rather than food sources, may be limited in streams (sport fish are frequently the most aggressive fish in streams and unlikely to be displaced); and (4) predation (including fishing, a special form of predation) may be an important process governing community interactions. Li suggested that the concept of managing ecosystems should be promoted to replace single species management policies.

Probably the sucker is an example of a fish unfairly despised by many sportsmen, biologists, and fish managers. For decades it has been accused of depleting sport fish populations; yet a recent literature review (Holey et al. 1979) turned up no convincing evidence that sport fish populations were adversely affected by suckers. Although suckers eat the eggs and fry of some sport fishes, no evidence could be found that such predation was harmful. P. B. Moyle (1975) noted that trout and nongame fish can coexist in streams that support substantial trout populations.

Chemical treatment to control nongame fish in our streams is a management concept which must be reevaluated. In recent years the Wisconsin Department of Natural Resources has engaged in large-scale chemical treatment projects on lakes, reservoirs, and streams for the purpose of carp and "rough fish" control. According to Hasler (1973:214), although aquatic ecologists have decried the rising dangers of pollution,

> some are now supporting projects which may lead to the extermination of species or local populations of species under the justification of carp control. Entire drainage basins (e.g., Rock River, Wisconsin, 2,802 miles of streams and 100,400 acres of marshland) are poisoned with toxins, and such programs are labelled good conservation. I consider projects of this type contrary to the ecological ethic.

After treatment of the Rock River with antimycin A in 1970 and again in 1973, the major fishery consisted of bullheads, primarily black bullheads (Baumann 1975). The sport fish and panfish catch and the catch per unit effort fell dramatically between the second and third years after treatment on the upper section of the river, leaving in doubt the possibility of establishing a large natural population of predatory sport fish. Baumann noted no overall recreational improvement resulting from the reclamation. The sport fishery return has not noticeably increased, and continual restocking may be necessary to replace the sport fishes lost to winterkills and summerkills caused by the large increase in aquatic plants. Baumann concluded that a large, eutrophic river system cannot be effectively managed simply by treatment with toxicants and restocking with fishes.

Surveys of several chemically treated waters in Wisconsin have shown a sharp decrease in the total number of fish species following treatment (Becker 1975). A follow-up study of 1965 and 1967 antimycin field tests showed the persistence even as late as 1972 of an impoverished variety of fish species and for many species a reduction in numbers. Initial data in one study show that clams are particularly sensitive to fish toxicants, and that some species may have been eradicated in treated waters (H. Mathiak, pers. comm.).

The mass poisoning of waters appears to work contrary to those biological and ecological principles which support the concept that great species diversity leads to the stability of the environment. Hasler (1973:215) explained:

> To reduce the number of species in man's environment, then, is to invite instability, to reduce man's freedom to choose new species for exploitation and to impoverish the quality of his life. Driving a species to extinction is a process which cannot be reversed. Unlike a mineral which, though exploited until it is scarce, will always be somewhere on the earth—in a scrap heap or in the depths of the ocean—a biological species is unique, and, once lost, cannot be recreated. Over millions of years, evolution has experimented with countless biological types and has preserved those which are successful and well-adapted to their environment. They are the world's living museum and, as such, belong to humanity. No local group is justified in depriving future generations of species and their potential use by causing their extinction.

Pister (1976:13) said it this way:

> We still have a long way to go in the fish and wildlife professions before we reach an acceptable level of philosophical maturity. History alone will judge the value of what we do today. In the year 2076, society will be far less interested in the 1976 catch per angler in Crowley Lake or the degree of hunter success on a certain wildlife management area than in what happened to our native fauna if we fail to appreciate it enough to preserve, manage, and utilize it. We have inherited so much from our predecessors that we automatically assume an enormous debt to the future.

The approximately 25% of the Wisconsin populace who engage in fishing obviously have a stake in the state's fish resource, but we should not overlook the equally important and legitimate interest of the remaining 75%. Pister (1976) predicted a great expansion of nonconsumptive uses of fish and wildlife, with "a major increase in photography, species identification, behavioral studies, and similar 'research' pursuits. We should prepare for this inevitable demand and structure our management programs accordingly" (p. 12).

According to Pister, the only logical way to meet this demand is to manage and utilize the total fish and wildlife resource. This total resource, including both sport and nongame species, is vastly greater than the resource we have heretofore been concerned with. The management of nongame species is still embryonic in both practice and philosophy (Miller and Pister 1971, Pister 1974). During the late 1970s, Wisconsin's acting governor, addressing the Board of the Wisconsin Department of Natural Resources, recommended the establishment of an office within the department that would be concerned with nongame species. The move is especially commendable since it points up political recognition of a vast resource which in the past has had little attention.

In Wisconsin, official agencies continue to refer to many large nongame fish as "rough fish." This derogatory epithet engenders public animosity toward such species as buffaloes, burbot, redhorse suckers, freshwater drum, goldeye, carpsuckers, and quillback, all of which are excellent food fishes. Although the Governor's Study Committee on the Use of Fish Toxicants for Fish Management (Cook et al. 1972) recommended the deletion in writing and speech of "rough fish," the term persists in current fishing regulations (1980). The still common use of the terms "rough fish" and "trash fish" by fish managers is some indication of the extent to which management policies continue to be dictated by the public's rather narrow demands. In fact, sport fish are only important because of their present social and economic value. Li (1975) recommended that we broaden our management perspectives by trying to change the societal values which have resulted in the narrow policies of the past, and that we recognize the increasing need for fish protein to feed human populations. Carlander (1955) has shown that the total productivity of an aquatic system increases with the number of fish species which inhabit it. Butler (1976) predicted that we will soon protect and manage our freshwater sheepshead, suckers, carp, and other species for their value as sources of high quality protein.

In Wisconsin during the late 1970s, the commercial use of some white and longnose suckers was tested. These fish from Lakes Michigan and Superior were deboned, minced, frozen into 11.3-kg (25-lb) blocks, and shipped east. Some of the product, in the form of "fish crispies," sold in supermarkets at $1.96 per kilo (89¢ per pound). Consumers used the minced fish as a substitute for more expensive crabmeat in stuffing, in place of tuna in casseroles and salads, and in place of salmon in salmon loaf. Sucker meat is sweet tasting, low in calories and cholesterol, and highly nutritious.

Undoubtedly Bardach (1964) described the most pungent way of preserving nongame fish bounty—turning the fish into "cheese." The practice is of ancient origin and is widespread throughout the Orient. The recipe calls for certain thumb-long, short-lived fishes which are found in large numbers. After being cleaned and mixed with salt, the fish are allowed to rot in a vat. After 6 months—or, for the best results, even longer—the action of various bacteria will have turned the mixture into a white paste compounded of proteins and amino acids and laced with calcium from the softened bones. The odor is very strong, but approached without prejudice—and bearing in mind that Western cheese is of comparable origin—this "cheese" can be delicious.

Wisconsin fish processors and University of Wisconsin scientists have demonstrated that disagreeable fish processing wastes make a nutritious plant food and are trying to expand the market for it (*The Milwaukee Journal* 15 September 1977). The fertilizer is made by adding acids to organic material which break it down into nitrogen, phosphorus, and potassium while preventing bacterial fermentation.

Number of Species, Their Distribution, and Future Entries

This study recognizes 157 species of fish from Wisconsin waters. Of these species, 137 are present in the Mississippi River basin, 131 in the Lake Michigan basin, and 74 in the Lake Superior basin. By comparison, Greene (1935) reported 148 species from Wisconsin of which 132 were known from the Mississippi River basin, 111 from the Lake Michigan basin, and 58 from the Lake Superior basin. Since Greene (1935), the blue catfish (*Ictalurus furcatus*) has been removed from the state list of fishes (see p. 694), and the following species have been added: sea lamprey (*Petromyzon marinus*), alewife (*Alosa pseudoharengus*), pink salmon (*Oncorhynchus gorbuscha*), coho salmon (*Oncorhynchus kisutch*), chinook salmon (*Oncorhynchus tshawytscha*), pygmy whitefish (*Prosopium coulteri*), ironcolor shiner (*Notropis chalybaeus*), red shiner (*Notropis lutrensis*), river redhorse (*Moxostoma carinatum*), and bluntnose darter (*Etheostoma chlorosomum*). In addition to the species accounts for all Wisconsin fishes, I have treated separately the siscowet (*Salvelinus namaycush siscowet*), a subspecies of the lake trout. This form is now widely recognized and is receiving increased attention in Lake Superior waters from commercial fishermen and personnel of the Wisconsin Department of Natural Resources.

Since the late 1920s, a number of fish species have appeared in major Wisconsin drainage basins from which they had not been reported previously. In the Mississippi River basin, these are the red shiner, longnose sucker, river redhorse, bluntnose darter, and slimy sculpin; in the Lake Michigan basin, they are the northern brook lamprey, American brook lamprey, sea lamprey, shortnose gar, alewife, gizzard shad, pink salmon, coho salmon, chinook salmon, goldfish, ironcolor shiner, pugnose minnow, bigmouth buffalo, black redhorse, flathead catfish, pirate perch, yellow bass, warmouth, western sand darter, and river darter; and in the Lake Superior basin, the northern brook lamprey, sea lamprey, American eel, alewife, pink salmon, coho salmon, chinook salmon, pygmy whitefish, rainbow smelt, carp, blackchin shiner, yellow bullhead, channel catfish, stonecat, tadpole madtom, and spoonhead sculpin. The distribution of the species in the three watersheds is in conformity with the hypothesis that the Mississippi drainage is the center of origin of the Great Lakes fishes (Greene 1935).

The criterion used to add a fish species to the state list generally implies the successful establishment of that species, either through its own movement into state waters (e.g., the red shiner and the pink salmon) or through direct introduction by man (e.g., the coho salmon). There is little question about the successful establishment of the coho and chinook salmon as sport species; however, self-propagation of these species is not certain at this time, although limited reproduction is suspected in Lake Superior tributaries.

Wisconsin waters are expected to yield new species in the future. In Illinois, a number of species occur that may appear in Wisconsin by natural means or as introductions; these include the blue catfish (*Ictalurus furcatus*), the spotted gar (*Lepisosteus oculatus*), the silverjaw minnow (*Ericymba buccata*), the bigeye chub (*Hybopsis amblops*), the bigeye shiner (*Notropis boops*), the silverband shiner (*Notropis shumardi*), the freckled madtom (*Noturus nocturnus*), the redear sunfish (*Lepomis microlophus*), the spotted bass (*Micropterus punctulatus*), the greenside darter (*Etheostoma blennioides*), the orangethroat darter (*Etheostoma spectabile*), and the dusky darter (*Percina sciera*).

Crossover Connections

Crossover connections are frequently perched swamps or low, drained areas which, during high water or flooding, are covered with a sheet of water that connects drainage basins normally separated from one another. In the last 150 years there have been intermittent connections between the Mississippi River and Lake Michigan drainage basins, and possibly between the Mississippi and Lake Superior basins.

The best known Wisconsin crossover connection is the low divide between the Fox and Wisconsin rivers at Portage (Columbia County). Accounts persisted through the 1830s of floodwaters at this crossover deep enough to float canoes, and even government barges; undoubtedly unrestricted passage was available to fishes at such times. Commercial interests in the early 1800s agitated strongly for the establishment by the government of a canal. The first canal was completed about 1837 with a channel deep enough to float a canoe (Wis. Hist. Coll. 1895 13:345–347). In 1876 the federal government completed a canal 21 m wide, about 1.5 m deep, and 4 km long, with upper locks at the Wisconsin River and lower locks at the Fox River end. This canal remained in operation until July 1951. In the early 1960s, the upper locks were closed permanently, but still allowing a water flow of some 0.3 cms (10 cfs) from the Wisconsin River through the canal and into the Fox River. Since the late 1950s, a number of Mississippi River fishes have appeared in the Lake Michigan basin; these include the shortnose gar, bullhead minnow, pugnose minnow, blackstripe topminnow, western sand darter, and river darter. The Fox-Wisconsin connection at Portage is suspected to be the crossover point.

Greene (1935) called attention to the low divide between the headwaters of the Menomonee and Bark rivers (Washington County), and another low divide between the headwaters of the Root and Des Plaines rivers (Racine County). Until recently these may have been connections, at least intermittent ones, between the Mississippi and Lake Michigan basins.

After examining topographic maps, W. McKee (pers. comm.) suggested that crossover connections linking the Mississippi River and Lake Michigan basins may at one time have occurred between the Fox River and Menomonee River drainages at T7N R20E Secs 14 and 28, and the Bark River and Menomonee River drainages at T9N R19E Secs 35 and 36 (Waukesha County); between the Oconomowoc River and Cedar Creek drainages at T9N R19E Sec 3, the Pike Lake and Cedar Lake drainages at T10N R19E Secs 5, 6, 7, and 18, and the East Branch of the Rock River and Milwaukee River drainages at T12N R18E Secs 23, 24, 25, and 26 (Washington County); between the West Branch of the Rock River and East Branch of the Fond du Lac River drainages at T14N R15E Sec 12, and the West Branch of the Rock River and West Branch of the Fond du Lac River drainages at T15N R15E Sec 17 (Fond du Lac County); and between the Kimball Creek and Furbush Creek drainages at T39N R12E Secs 33 and 34, and the White Deer Lake and Butternut Lake drainages at T40N R12E Sec 34 (Forest County). Recent crossover connections linking the Mississippi River and Lake Superior drainage basins may have occurred between the Weber Creek and Pine Lake drainages at T43N R3E Sec 4 (Iron County); between the Upper St. Croix Lake and West Fork of the Brule River drainages at T45N R11W Secs 7 and 8; and between the Spruce River and Black River drainages at T45N R15W Secs 24 and 25 (Douglas County).

Present and past Illinois crossover connections between the Mississippi River and Lake Michigan basins include the low divide, about 2 km wide, between the Chicago and Des Plaines rivers, over which the early Jesuit missionaries paddled their boats during spring flood stages (Hubbs and Lagler 1964); and the Chicago Drainage Canal, which was completed in 1840 and further developed at the turn of this century into the Chicago Sanitary and Ship Canal. The recent entry of the gizzard shad into southern Lake Michigan is believed to have occurred via the Chicago Sanitary and Ship Canal.

For additional information on fish movements and dispersal routes, see Greene (1935) and Hubbs and Lagler (1964).

Exotic Fishes

As we have seen, non-native (exotic) fishes reach Wisconsin waters through direct introduction by man and through manmade waterways that facilitate passage around barriers. Early introductions apparently were made with little forethought: there was little understanding of the ecological requirements of the fish being introduced, little expertise to assure that the stocked fish had a reasonable chance of establishing itself, and little knowledge of or concern about the probable negative impact of the introduced exotic on the native fish population. During the nineteenth century, management philosophy permitted indiscriminate stocking of native and non-native fishes into as many new waters as possible (see the sections "Fish Culture and Stocking" and "Fish Rescue and Transfer," above).

Exotic fishes have also moved successfully through manmade waterways which were constructed in the interest of economic expediency. Economic interests were responsible for the construction of the Welland Canal (by-pass to Niagara Falls), which opened the upper Great Lakes not only to Atlantic shipping but to the anadromous Atlantic fishes, several species of which have already become scourges to the endemic fish community of the upper Great Lakes. Such open waterways continue to allow free passage for additional exotic species, and fish managers are wondering whether exotics of the future will be as damaging as those of the past. Several short accounts of Wisconsin's exotic species follow. For more detail, see species accounts in the literature cited.

In 1872, 25,000 American shad (*Alosa sapidissima*), native to the Atlantic Coast from Labrador to Florida, were introduced in the Mississippi River a few kilometers above St. Paul, Minnesota (Carlander 1954). In 1873, 70,000 young-of-year American shad were released into the Fox River at Appleton (Milner 1874b). The absence of progress reports following these records implies extirpation of the species in Wisconsin waters.

Rainbow trout (*Salmo gairdneri*) and brown trout (*Salmo trutta*) were introduced widely in Wisconsin waters during the late 1800s. Both are established and reproduce successfully; however, their numbers in lakes and rivers are augmented by an extensive stocking program.

Coho salmon (*Oncorhynchus kisutch*), chinook salmon (*Oncorhynchus tshawytscha*), and Atlantic salmon (*Salmo salar*) were widely stocked in Wisconsin waters during the 1870s. These introductions failed, and the program was discontinued except for occasional experimental plantings. With the use of new stocking techniques from the late 1960s to the present, coho and chinook introductions have provided a high rate of return to the angler. Atlantic salmon, stocked during the 1970s in Lake Michigan by the State of Michigan, have been caught along Wisconsin shores by Wisconsin anglers.

In 1959, the cutthroat trout (*Salmo clarki*) was introduced into a Washington County lake, and, in the 1970s, kokanee (*Oncorhynchus nerka*) were planted in a Langlade County lake. The success or failure of these plants has not been publicized; presumably self-propagation was nil. Hubbs and Lagler (1964) noted one record of the temporary establishment of the cutthroat trout in the State of Michigan.

The rainbow smelt (*Osmerus mordax*) appeared in the Wisconsin waters of Lake Michigan in the late 1920s and of Lake Superior in the 1930s. This strain was from a plant made in State of Michigan waters in 1912. The rainbow smelt reproduces successfully in the Great Lakes and in several inland lakes in Wisconsin where it has been introduced.

The alewife (*Alosa pseudoharengus*) and the sea lamprey (*Petromyzon marinus*) entered the upper Great Lakes via the Welland Canal and reached Wisconsin waters of Lakes Michigan and Superior in the 1930s and 1940s, respectively. Both species have reached pest numbers in Lake Michigan, and are undoubtedly responsible for the decline, if not the extirpation, of a number of endemic fish species in Wisconsin.

Four species of exotic minnows are known from Wisconsin. Best known is the carp (*Cyprinus carpio*), which was introduced successfully in 1881 and today is distributed in all but seven northern counties. The goldfish (*Carassius auratus*) has been introduced by man in a number of ponds, lakes, and streams of southeastern Wisconsin, where it has become successfully established, particularly in urban areas. The European rudd (*Scardinius erythrophthalmus*) was introduced into Oconomowoc Lake in 1917, and at least temporarily bred successfully. No recent records are known (Greene 1935). In the 1970s, Asiatic grass carp (*Ctenopharyngodon idella*) were illegally introduced into several private ponds in eastern and southern Wisconsin. The Wisconsin Department of Natural Resources has poisoned out these waters to prevent what may be another "carp problem."

Every year a number of tropical fishes from aquariums are illegally introduced into manmade warm water ponds. Occasionally these produce one or more broods during the summer of release. In the early 1960s I seined numerous guppies (*Poecilia reticulata*) and several unknown tropical fish from small ponds near Allenton (Washington County). Priegel (1967a) reported that a *Tilapia* species, a native of Africa, had been placed in Supple Marsh adjacent to Lake Winnebago, and that in August 1965 a 190-mm specimen was caught by an angler using worms as bait. Tropical fish are not known to survive Wisconsin's cold winters.

Although it is now unlawful to introduce exotic fishes into the waters of Wisconsin, the problem is a continuing one. More than 100 million fish were imported into the United States in 1972 alone, and some of these undoubtedly were released into public waters. The majority pose no danger to native fishes, but the probability exists that one or more species may become uncontrollable pests.

Extirpated and Endangered Fishes

Each species of fish has its evolutionary lifetime: infancy, when it is newly evolved from pre-existing forms; maturity, when it is expanding its range and becoming a part of the ecosystem; old age, when its numbers and range decrease; and ultimately death. Some species are like weeds. They are everywhere and successfully compete for space and food. Other species hang onto their identities by slim threads. They are vulnerable to fishing, to predators, and to slight changes in the environment.

The official Wisconsin Department of Natural Resources listings of fishes placed on endangered, threatened, and watch status are given in Wisconsin Department of Natural Resources Endangered Species Committee (1975) and Les (1979). I use these official listings for each troubled species in that part of the species account entitled "Distribution, Status, and Habitat." The following paragraphs give my personal listings of endangered species, which differ somewhat from those of the Wisconsin Department of Natural Resources, although they are based on the Department's definitions of endangered fish categories.

Extirpated Wisconsin species are the skipjack herring, blackfin cisco, deepwater cisco, longjaw cisco, shortnose cisco, ghost shiner, ironcolor shiner, creek chubsucker, and black redhorse. All were still present in Wisconsin waters in the late 1920s.

Endangered fishes are those in trouble. Their continued existence as a part of the state's wild fauna is in jeopardy, and without help they may become extirpated. They are officially protected by Wisconsin law (Chap. 29.415, Wis. Statutes). I consider the following species endangered: shortjaw cisco (Lake Michigan only; common in Lake Superior), kiyi (Lake Michigan only; abundant in Superior), gravel chub, striped shiner, and bluntnose darter.

Threatened fishes are those which appear likely to become endangered within the foreseeable future. Species I consider to be threatened are: paddlefish, blue sucker, river redhorse, goldeye, longear sunfish, pallid shiner, redfin shiner, Ozark minnow, pugnose shiner, starhead topminnow, crystal darter, western sand darter (Lake Michigan basin only; common in Mississippi River basin), mud darter, gilt darter, and slender madtom.

Fishes which may or may not be holding their own at the present time are given *watch* status. They are species suspected to have some problem which has not been identified or proved. They require special observation to identify conditions that might cause further decline, or factors that could help to ensure their survival in the state. I place the following under watch status: American eel, lake herring, bloater, pygmy whitefish, lake sturgeon, redside dace, speckled chub, pugnose minnow, red shiner, weed shiner, lake chubsucker, black buffalo, greater redhorse, pirate perch, and least darter.

The protection of fish species in trouble is a new concept in many states. How does one protect a lake or stream inhabited by an endangered species? What are the specific causes for its being endangered? How does one rally public support for preservation of endangered fishes? Fish species in trouble are mostly nongame fishes, often minnows and darters, which may be sensitive to the slightest alterations in their aquatic habitats. And man, the primary exploiter of and competitor for aquatic habitat with these species, is the only creature capable of restoring damaged habitat and its biotic treasures.

The Wisconsin Department of Natural Resources Endangered Species Committee (1975:1) observed that

> if wild creatures are disappearing, it is time to consider whether man too may be endangered. The survival of fish and wildlife and the survival of man are cut from the same fabric. Wild things are biological indicators of the health of our environment—barometers of the future of all life.
>
> What is really at stake is the well being of the total community of nature of which man is a part. We are concerned here with a remarkably interrelated whole, where each species has its place. If we eliminate one, we may lose another. Or we may cause the malfunctioning of the entire ecosystem. We don't know the complete role of many animals in the outdoor community. Until we do we cannot afford to lose any species.