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ENVIRONMENT, CULTURE, AND THE GREAT LAKES FISHERIES*

JOHN C. HUDSON and SUSY S. ZIEGLER

ABSTRACT. The commercial fisheries of the United States and Canadian Great Lakes are in a long period of decline. Detailed statistics kept for well over a century document a fluctuating pattern of harvests of the major commercial species. In the 1940s, sea lamprey began to devastate the fisheries, an effect that has not been fully countered. Overfishing, nonnative species, declining nutrient levels, and chemical pollution have contributed to reduced catches. Court decisions in the United States and Canada during the past thirty years have awarded a sizable share of commercial fishing rights to Native North Americans for their own support and sustenance. The Lake Erie yellow perch and walleye fishery, based mainly in Ontario, is the most successful commercial fishing operation in the region. Despite the many environmental and cultural challenges, the Great Lakes fisheries live on. *Keywords: Canada, fisheries, Great Lakes, United States.*

The United States and Canadian Great Lakes fisheries are experiencing a long-term decline. Annual harvests in U.S. waters dropped from around 23,000 metric tons per year in 1980 to 9,000 metric tons per year in 2011. The Canadian harvest, which is larger, has shown a similar trend. Recreational fishing is worth billions of dollars a year to the Great Lakes regional economy, mainly through tourism revenues, but Great Lakes commercial fishing contributes less than 1 percent of that amount (NOAA 2012).

Statistics on Great Lakes commercial fisheries in both the United States and Canada are some of the most detailed kept for any industry (Baldwin and others 2009; National Oceanic and Atmospheric Administration (NOAA) 2010; Fisheries and Oceans Canada 1990–2012). Annual total catches classified by species, states, lakes, and portions of lakes, have been tabulated from the 1860s to the present time.

In the 1800s, fish harvests in the Great Lakes were greater than they are today, and the long record suggests that the industry has experienced a continued pattern of fluctuations in harvests, species abundance, and demand for the product. A series of environmental changes unfolded over the past seventy-five years, beginning with the sea lamprey invasion of the 1940s (Ashworth 1986; Bogue 2000). In the past forty years, fishing as a business has been reorganized in the western Great Lakes as a result of court decisions in both countries that have specified the treaty rights of Native North Americans (Ferguson 1989; Doherty 1990).

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Great Lakes History

The modern Great Lakes originated at the end of the Pleistocene epoch when ice sheets that had covered the midcontinent region began wasting northward (Figure 1). Eleven thousand years ago a predecessor lake, known as Lake Algonquin, bordered the ice sheet's retreating southern margin roughly at the latitude of present-day Sault Ste. Marie. Lake Erie discharged into Lake Ontario at that time, but all the lakes to the north drained directly eastward through a North Bay outlet into the Ottawa River valley. The land surface rose as the weight of the glacial ice was removed, and as the North Bay outlet rose it ceased to be a drainage course. Lakes Michigan, Huron, and Superior then filled to their current levels and the St. Clair River became the only outlet for the three western lakes. This last, major adjustment took place about 4,000 years ago (Larsen 1987).

The flows of water down through the Great Lakes are constant and substantial, beginning with the flow out of Lake Superior, which is the largest of the lakes. Its average surface height is about 183 meters above sea level, which is about 7 meters higher than Lakes Michigan and Huron. Lake Huron is only 2 meters higher than Lake St. Clair, the small intermediate body of water separating it from Lake Erie. Lake Huron's volume of discharge into the St. Clair River is approximately the same as the flow of the Mississippi River at St. Louis. The

Fig. 1—The North American Great Lakes region, with 1836 and 1842 treaty waters indicated. (Cartography by John Hudson).

final plunge is the largest, at Niagara Falls, where Lake Erie's waters descend nearly 100 meters, into Lake Ontario. It is this constant flow that gives the Great Lakes their freshwater character. Without it they would experience salinity similar to other landlocked water bodies. As freshwater bodies, the Great Lakes are less productive than the oceans if climate is held constant. The recirculation of waters that keeps them "fresh" results in a loss of nutrients. The Great Lakes also are in a cool climate region, which curbs biomass production and slows the recycling of nutrients. Middle-latitude freshwater lakes are by no means nutrient poor, but they typically rank low in primary productivity compared with oceanic and tropical environments (Lieth and Whittaker 1975).

Native North Americans made extensive use of the Great Lakes as a source of food and as an avenue of transportation. Fishing and hunting were essential to the aboriginal way of life. The first Europeans who came to this part of North America were the French and they quickly learned the pattern of lakes and rivers from various groups of natives, especially the Hurons who lived in what is now Ontario. Within ten years after he founded Quebec City in 1608, Samuel de Champlain, along with his interpreter, Etienne Brule, passed through the portage at North Bay, crossed Lac Nipissing, and followed the French River down to Georgian Bay (Butterfield 1898). Within another five years the French had visited all of the Great Lakes.

Fishing Industry

Although the freshwater fishery has always depended on manual labor, it did not employ large numbers of people even in historic times. Detailed statistics of occupation published in the 1880 and 1890 U.S. Censuses indicate only about 6500 "fishermen" and 3000 "shoremen" were involved in Great Lakes fishing, about half of whom were employed in the state of Michigan and most of the rest in Ohio (Eleventh U.S. Census, 1890, *Report on Statistics of Fisheries*, 5–6). The 1881 Census of Canada shows that less than 0.1 percent of Ontario's labor force was engaged in fishing (McCullough 1989, 118). It was a small industry, scattered over numerous ports.

The binational statistics on fisheries reflect an industry that was almost constantly changing. The major species taken in Lake Huron, for example, fluctuated substantially from year to year, but showed fairly little overall trend from the end of the 1800s until the middle of the 20th century (Figure 2). One of the Great Lakes' most productive species had been the lake whitefish (*Coregonus clupeaformis*) until overfishing and poor recruitment led to a collapse of the whitefish harvest in the 1890s. Searching for an alternative, fishermen then turned to chubs, which they had not bothered to take when whitefish were abundant (Koelz 1926). Substitutions of this sort seem to have been fairly common historically.

All of the species had population cycles on the order of five to ten years each, with harvests varying about 25 percent from year to year. The fluctuations

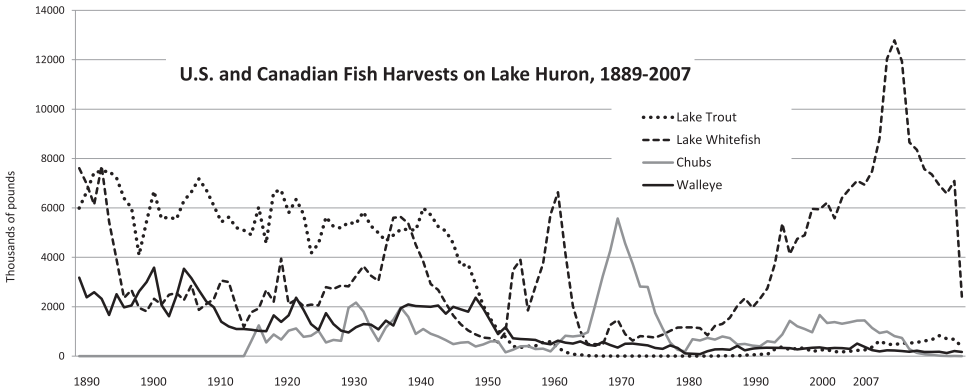

FIG. 2—U.S. and Canadian fish harvests on Lake Huron, 1889–2007.
Source: Baldwin and others 2009. (Graph by John Hudson).

presumably reflect recruitment within each species, competition for food between sympatric species, and the size of the annual harvests. Imposition of quotas on the number of fish taken and a restriction of the fishing season to portions of the year when fish were not spawning, while once thought unnecessary, eventually became the rule in both the United States and Canada (Bogue 2000).

Other fish also enjoyed markets both local and distant. Northern European ethnic groups, who made up a substantial share of the Wisconsin and Michigan population, were reliable consumers of lake herring, also known as chub (*Coregonus artedi*). Long-distance refrigerated transportation was employed to reach more distant markets. Rough fish, such as carp, seined from the lakes, were packed in ice and shipped in railroad cars to New York for manufacturing gefilte fish and other pickled fish products consumed by the city's Jewish population. Smoked chubs and whitefish were a Great Lakes delicacy that enjoyed local markets wherever fish were brought in. Smelt, an introduced species that Europeans favored, was caught in northern Michigan's lakes and eventually spread into Lake Michigan where it was fished commercially. These specialty-fish businesses still exist in the 21st century.

The Sea Lamprey

The old pattern of cycles changed abruptly in the 1940s when the sea lamprey (*Petromyzon marinus*) arrived. Of all the problems the Great Lakes fishery has faced over the years, none has been more vexing than that of the sea lamprey. In an early paper, Carl L. Hubbs and T. E. B. Pope vividly described the lamprey as an "eel-like creature, averaging about fifteen inches long, [that] clings to the larger food fishes with a round sucker-mouth, beset with rows of strong, horney teeth; then rasps open a hole in the skin of its victim by means of its serrated tongue plates, and injects an anticoagulating substance into the wound, to insure the free flow of the victim's blood, with which the parasite gorges itself" (1937, 172).

Usually included under the heading "invasive species," the sea lamprey may not even deserve that status. It was a known predator in the waters of Lake Ontario and New York's Cayuga Lake in the late-19th century. The western Great Lakes presumably were protected by the Niagara Escarpment because it was an insurmountable barrier for a creature of the lamprey's size. Introduction of the species above Niagara Falls has been regarded as an inadvertent development that followed construction of the Welland Canal between lakes Ontario and Erie (Lawrie 1970). The first Welland Canal, opened in the late 1820s, was enlarged during the 1870s, again in the early 1930s, and became part of the St. Lawrence Seaway in 1959 (Jackson 1975). At some point, probably between 1921 and 1936, the sea lamprey migrated into Lake Erie. The "invasive species" label has been challenged by mitochondrial DNA analyses, which suggest that Atlantic coast and Lake Ontario sea lamprey populations are genetically different, whereas samples from Lake Ontario are very similar to others taken from Lake Superior tributaries (Waldman and others 2004).

Whether the sea lamprey was a post-Pleistocene natural colonizer of Lake Ontario, and thus can be regarded as indigenous, or an invasive species in the entire Great Lakes system, the damage it has caused has been massive. Although the sea lamprey never has become well established in Lake Erie, it moved rapidly into the western Great Lakes. The lake trout (*Salvelinus namaycush*), probably the most prized fish of the Great Lakes, was its favorite target. Lake Huron's lake trout population declined in the early 1940s, Lake Michigan's in the late 1940s, and Lake Superior's in the 1950s (Figure 3). Officers of the Michigan Department of Conservation questioned commercial fisherman about the problem in 1946 and discovered sixty-eight streams where spawning

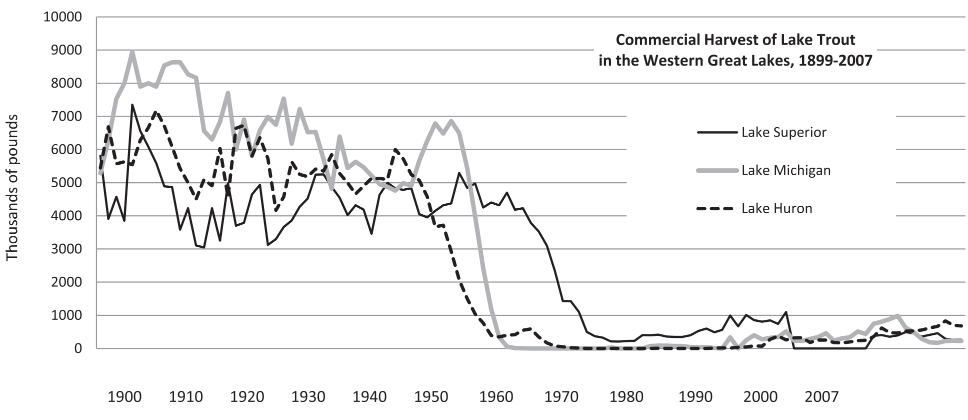

Fig. 3—Commercial harvest of lake trout in the western Great Lakes, 1899–2007. *Source:* Baldwin and others 2009. (Graph by John Hudson).

populations of sea lampreys were known. Nearly 100 percent of the commercial fish taken at that time bore lamprey scars (Shetter 1949).

The Great Lakes Fisheries Commission

Recognizing that the sea lamprey was an international problem, the governments of Canada and the United States signed the Convention on Great Lakes Fisheries in 1954, which established the Great Lakes Fisheries Commission (GLFC). Headquartered in Ann Arbor, Michigan, the GLFC's major responsibility is lamprey control. Nearly five-dozen streams entering the Great Lakes have been outfitted with sea lamprey barriers that can be raised or lowered as the seasonally migrating lamprey enter or exit their spawning areas (GLFC 2012). The U.S. Fish and Wildlife Service and the Ministry of Fisheries and Oceans in Canada oversee operation of the barriers in their respective countries.

The greatest expenditure of money and effort by the GLFC is the application of lampricides. TFM (3-Trifluoromethyl-4-nitrophenol) and Bayluscide/niclosamide are lamprey-specific poisons placed in the tributary streams where the anadromous lamprey spawns (Gilderhus and Johnson 1980). Lampricide use is monitored by the United States Environmental Protection Agency (EPA) under amendments to the 1990 Insecticide, Fungicide, and Rodenticide Act (Hubert 2003). Because these various efforts also involve the status and operation of the inland waterways over which it has jurisdiction, the United States Army Corps of Engineers also takes part in lamprey control strategies (Adair and Sullivan 2013). Many agencies have a vested interest in the creature.

While early GLFC statements sometimes mentioned "lamprey eradication," that goal was seen as unattainable by 1979 when the first international conference on the lamprey problem was convened (Smith 1980). Another approach, developed in the 1980s and 1990s, involved the capture, sterilization, and release of adult lamprey males that are returned to the breeding population but are unable to reproduce (Twohey and others 2003). All three approaches—lampricides, stream barriers, and male-sterile-release—were used repeatedly and met with success by the late 1980s. Although the goal has changed from eradicating the species, to controlling it, to simply reducing its abundance, the overall sea lamprey program is generally regarded as a qualified success (Heinrich 2003).

Sea lamprey control is also expensive. Each year tens of millions of dollars are appropriated by the U.S. and Canadian governments to operate the sea lamprey programs that now employ more than 100 research scientists and technicians in the two countries. In an effort to control government expenditures on the lamprey, efforts have turned to assessing the effectiveness of various control strategies (Stewart and others 2003). Eradication activities now focus on the St. Marys River, the connecting channel through which Lake Superior's waters flow into Lake Huron, where lamprey populations have continued to grow despite massive efforts to control them. More than half of the streams receiving lampricide treatments are found within 100 miles of Sault Ste. Marie. But with an emphasis on the cost effectiveness of each abatement strategy, and given the number of separate efforts at control by the two countries, it has become difficult to know whether a given strategy has succeeded or not, even in a confined environment like the St. Marys River (Adams and others 2003).

The sterile-male-release program itself fell victim to uncertainty about its effectiveness and was discontinued in 2012 (Adair and Sullivan 2013). Although it had the advantage of being more "environmentally friendly" than either the stream barriers that also discourage fish migration, or the lampricide treatments that come close to violating EPA rules, there was inadequate evidence that the reduced lamprey numbers were worth the money spent on capture, sterilization, and release of adult males.

A lingering question is how much of the decline in commercial fish harvests can be ascribed just to the lamprey's presence (Egerton 1985). A massive reduction in fish harvests took place on Lake Huron around 1950, coinciding with the lamprey's period of unchecked growth, but it has also been suggested that the lake had been overfished prior to the lamprey's arrival (Wells and McLain 1973). Lake trout numbers had been reduced in Lake Superior, as well, just prior to the lamprey's appearance (Coble and others 1990). Fitted logistic population models indicate that lake whitefish were likely overexploited and their numbers significantly reduced before the lamprey became a factor (Jensen 1976). Both lamprey predation and overfishing probably caused the decline in Great Lakes fish stocks in the mid-20th century.

Alewife, Chinook, and Coho

The sea lamprey was an unwanted predator that became the target of a massive international program of elimination. A second invasive species, the alewife (*Alosa pseudoharengus*), arrived in the western Great Lakes during the 1940s and began to multiply in numbers soon thereafter, but it received a different treatment. The alewife became a commercial species, with thousands of tons sold to pet food processors and as bait to the Atlantic Coast lobster industry. Still, alewife abundance grew to shocking proportions by the mid-1960s, when billions of the small fish washed up on the shores of Lake Michigan where they fouled swimming beaches.

The method of alewife control was not eradication of the species, but rather the deliberate introduction of other fish known to be its natural predators. Although the lake trout had become almost extinct due to lamprey predation and overfishing, Pacific salmonine species, introduced after lamprey control had begun, proved to be eager consumers of the alewife (Crawford 2001). Chinook salmon, coho salmon, and rainbow trout (*Onchorhynchus* spp.) were produced in state fish hatcheries and released into the lake beginning in 1965. The three Pacific species were not introduced for the commercial fishery, but rather as a means for stimulating sport fishing. Coho fishing on Lakes Michigan and

Huron grew in popularity among sport anglers during the 1970s and 1980s as the fish fed on the ample supply of alewives (Bench and Smith 1999). Natural recruitment soon began to supplement the released fish hatchery stocks and hatchery contributions were reduced. By the mid-1980s the chinook harvest on Lake Michigan exceeded ten million pounds per year, but the inevitable soon happened. Decimated by chinook predation, alewife stocks declined, then recovered, and finally collapsed in the early 1990s. With their food source gone, the chinook declined as well (Figure 4).

The absence of alewives had the opposite effect on walleye populations. The walleyed pike (*Stizostedion vitreum*), often called pickerel or yellow pickerel in Canada, is a member of the perch (*Percidae*) family. A highly desirable game fish, it has been reproduced in fish hatcheries of the Great Lakes states for many years. The walleye became a substitute for the chinook salmon in Great Lakes waters after the alewife collapse. With the adult alewives that ate walleye fry eliminated, walleye populations boomed. Nearly one million pounds of walleye were taken by sport anglers in Lake Huron's Saginaw Bay in 2009 (Michigan DNR 2010). Walleye, lake trout, and chinook thus all help to keep alewife numbers in check (Figure 4).

The cycles evident in Lake Michigan fish harvests begin with the lake trout's decline due to lamprey predation. Fishermen then turned to lake whitefish, but those stocks, too, became depleted by the lamprey. Lake herring and chubs, both smaller fish suited mainly to smoking, became a productive harvest in the 1950s, but various conditions eventually reduced their numbers as well. The reign of the alewife, from 1960 to 1980, was brought under control by the chinook until it, too, declined as its alewife prey declined. Harvests of the desirable species recovered in the 1990s to levels slightly lower than before the lamprey arrived in the 1940s (Figure 4).

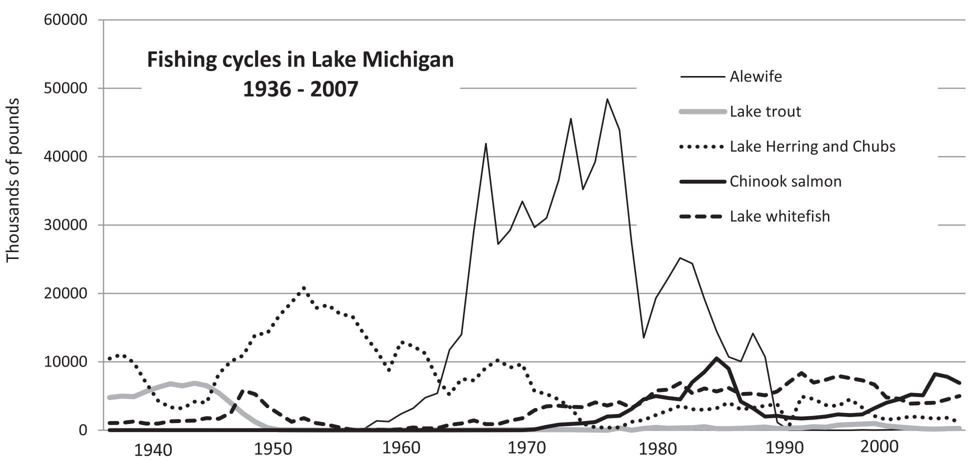

FIG. 4—Fishing cycles in Lake Michigan, 1936–2007.
Source: Baldwin and others 2009. (Graph by John Hudson).

More Invaders

Zebra mussels (*Dreissena polymorpha*) originated in the lakes of southern Russia and Ukraine and in the Black and Caspian seas. They are small, averaging no more than a few centimeters in length and have tiny "zebra stripes" on their shells. They are thought to have entered the Great Lakes in the ballast water of ships (Michigan Department of Natural Resources, 2010). Two other species from the south Russian lakes and oceans, the quagga (*D. rostriformis bugensis*), which is a mussel slightly larger than the zebra species, and the goby (*Neogobius melanostomus*), a round, soft-bodied fish, also seem to have entered the Great Lakes in ocean-going ships (Jude and DeBoe 1996). Zebra mussels began to cause alarm by the late 1980s in part because they attached themselves to solid objects such as water-intake pipes in the lake waters, and were difficult to remove (Nalepa and others 2000; Clapp and others 2001; Reed and others 2004).

All three species dwell on the lake bottom—or, in food-web terms, in the benthic zone. The mussel actually clears lake water by filtering it and absorbing its nutrients. The result is water that is clearer at a given depth, permitting greater sunlight penetration, which produces the undesirable result of additional algae growth. The bottom-dwellers sequester the available nutrients in lake water at the lowest levels, making the pelagic zone above—where fish typically reside—relatively poorer in nutrients. The goby is a food source for fish, but the mussels provide little of nutritive value (Michigan Department of Natural Resources, 2010).

An example of a species adversely affected by mussel invasion is diporeia, which are small, shrimplike crustaceans that feed on plankton in the bottom waters, but migrate up into the pelagic zone where they become food for the lake whitefish. Diporeia were once abundant and were associated with the great increases in Lake Huron's whitefish population from the 1970s through 2000. The recent decline in whitefish in Lake Huron has been linked to the disappearance of the diporeia, which appear to be negatively impacted by the presence of zebra and quagga mussels (Herbst and others 2013).

The evolution of new problems in the Great Lakes fishery is a function of the objective conditions causing those problems, of course, but it also reflects the ways in which scientists conceptualize the problem. Each added problem shifts attention away from the older ones, which sometimes remain unsolved. "Cleaning up" the Great Lakes is no longer viewed as a one-time-only task. Restoring the ecosystem has become an ongoing effort that grows more complex the longer it is carried on. The most recent legislation, the Great Lakes Fish and Wildlife Restoration Act, was launched in 1990 and subsequently has been funded by Congress several times, most recently in 2012 (16 U.S. Code § 941). This legislation has the continuing goal of revitalizing the Great Lakes ecosystem through habitat restoration and protection, and it makes millions of dollars available annually to groups who would engage in cooperative conservation (EPA 2010a).

Water-Quality Concerns

Not only overfishing and species interactions, but also chemical pollution has led to closures of fisheries on each of the Great Lakes at various times over the past century. One of the first species to be protected was the lake sturgeon (*Acipenser fulvescens*), a large bottom-feeding fish prized for its roe (caviar), which has long brought a high market price. All commercial sturgeon fishing was prohibited in United States waters of the Great Lakes from 1928 to 1956 because the population had crashed (Baldwin and others 2009), in part because contaminants in the water impeded reproductive success (Michigan DNR 2014a). The sturgeon recovered from its near disappearance and recently has been championed by the Environmental Protection Agency as part of its Great Lakes Restoration Initiative (U.S. Environmental Protection Agency (EPA) 2010a). The EPA plans to stock 25,000 fingerling sturgeon and create rearing facilities on more than a dozen streams to help sturgeon populations reach sustainable levels.

Soon after its creation by President Nixon in 1969, the Environmental Protection Agency began issuing a series of directives aimed at improving water quality. In 1979, the EPA banned many household detergent products then in use because they increased phosphorous content in surface waters. High phosphorous loadings produced eutrophication and a decline in fish populations due to lack of dissolved oxygen in lakes and streams. Among the other negative consequences of excessive phosphorous loadings was the disappearance of large-bodied invertebrates (Tyson and Knight 2001). Caddis fly larvae were historically important in the diet of Lake Erie's yellow perch. Fish numbers declined as the invertebrates disappeared, but water-quality improvements erased part of the decline, and are credited for having produced the recovery (Bridgeman and others 2006). In all, billions of dollars have been spent to reduce phosphorous inputs to the Great Lakes (Johengen and others 1994).

Two pollutants linked to industrial sources—mercury and polychlorinated biphenyls (PCBs)—were responsible for several fishery closures during the 1970s. Only a few years after the new coho and chinook salmon began occupying the attention of sport anglers, high levels of PCBs were discovered in the fish and warnings were issued against their consumption by humans. Commercial fishing of Pacific salmon species was prohibited in lakes Erie, Huron, and Ontario in 1976 (Baldwin and others 2009). Mercury levels judged to be dangerous caused closure of the perch and walleye fisheries in lakes Erie, Huron, and Ontario in 1970. Levels of Mirex, a chlorinated hydrocarbon used as an insecticide, led to other fishery closures in 1976 and a ban on its use went into effect. Closures of fisheries and warnings against fish consumption in the 1970s led to a distrust of Great Lakes fish products that has lingered long after the bans were lifted (EPA 2010b, 2010c).

The Methods of Fishing

The first Europeans to write about the fishing practices of Great Lakes Native people were the Jesuit priests and their fellow travelers. The spearing of fish, the use of nets, and the generally industrious manner in which fishing was carried out interested these foreign observers who wrote about such matters in the journals they kept. Mackinac Island was described in 1674 as "that Island so noted for its fisheries" (Thwaites 1900, 131). Along Green Bay (Baie des Puans) the practice of diverting fish into a small section of a stream where they could be speared was described (Thwaites 1900, 131). Later, when Henry Schoolcraft, traveling under U.S. government auspices, visited the site of Sault Sainte Marie in 1824 he wrote, "no place in America has been so highly celebrated as a locality for taking this really fine and delicious [whitefish] as Saint Mary's Falls" (Schoolcraft 1851, 122). An industrial-scale fishery, commensurate, of course, with the times and technology, was in place by the time Euro-Americans arrived on the Great Lakes.

The taking of fish, whether in a subsistence, commercial, or sporting context, has been accomplished for centuries using only a limited number of techniques. The use of hooks and line, while usually associated with sport fishing, is also used in the lake trout fishery of the Great Lakes, for example (Koelz 1926). Fish provided a substantial share of the food gathered by Native North Americans for their sustenance and, given their dependence on this resource, it is not surprising that they invented various means for harvesting quantities of fish at a time rather than taking them individually. Great Lakes commercial fisheries of the Euro-American period tended to follow the Native North American practices, although with some technological differences.

Among the very old techniques was the gill net, which was in common use by Native North Americans at the time French explorers and missionaries first arrived in the 17th century (Anderson 1896). The gill net is a long net, suspended vertically in fairly shallow water below the waterline but above the bottom, that is held in place by floats at the top and weights at the bottom. Fish swim into the net and are trapped by their gills and thus cannot swim away. They are held in place with their gills open, which deprives them of oxygen and causes them to drown. The gill net's mesh size defines the size of fish that can be trapped in this manner.

The pound net (and the trap net, which is similar) is an alternative means of trapping fish that consists of a fixed arrangement of submerged nets (Michigan Department of Natural Resources, 2012). Pound nets gradually redirect fish from an arrangement of outer "wings" through smaller and smaller spaces, until the fish enter a small, boxlike arrangement of nets known as a pound or pot. Fish remain live in the pound until they are harvested. The gill net and the pound net are the two most common methods used in the Great Lakes fishery (Figure 5).

Along with the length, mesh size, and positioning of nets, state laws generally limit the catch, the minimum size of fish that can be taken, and calendar dates when fishing is prohibited. State governments also authorize licenses to fish and designate species that are not open to fishing. Laws about these

FIG. 5—Traditional Great Lakes gill-net fishing boat of the Red Cliff Band of Lake Superior Chippewa, Wisconsin. (Photograph by John Hudson, 1980).

matters in the United States are state laws that are enacted by state governments, enforced by state game and fish officials, and which vary from state to state.

Controversies over the use of gill nets versus pound nets have sometimes set Native Americans, who are credited with inventing the gill net, against non-Natives, many of whom favor the pound nets, which were probably a northern European invention (Koelz 1926). Gill nets need to be set in place each time they are pulled, whereas pound nets can remain in place over an entire season and require less work. Gill nets trap fish by their size—thereby without regard to species—whereas pound nets have the advantage that nontarget species can be thrown back. These arguments have been repeated many times during the past forty years of controversy over Native fishing rights in the Great Lakes which, in turn, have played out against the background of environmental problems that have characterized the same period.

The Basis of Native Treaty Rights in the Great Lakes Fishery

The Great Lakes states were carved out of the Northwest Territory following its establishment by the Continental Congress in 1787. The Northwest Ordinance states, in part: "The utmost good faith shall always be observed towards the Indians; their lands and property shall never be taken from them without their consent; and, in their property, rights, and liberty, they shall never be invaded or disturbed" (Section 14, Article 3). While it is easy to read this passage as having been violated many times in the years after it was written, the notion that the Natives' "property, rights, and liberty" will be respected was mentioned specifically.

The 1814 Treaty of Ghent, which ended the War of 1812 between Great Britain and the United States, stipulated that both countries restore to "all the Tribes or Nations of Indians with whom they may be at war. . . all the possessions, rights, and privileges which they may have enjoyed or been entitled to" prior to the hostilities (Article the Ninth, 8 Stat. 218). Nearly all Native people of the Great Lakes region would have come under this stipulation, given the location of the war and the tribes involved.

The major precedent for Native rights, however, is found in the treaties with the Ottawa and Chippewa tribes concluded at Washington, D.C., in 1836 (7 Stat. 491); and with the Chippewa concluded at La Pointe, Wisconsin, on Lake Superior, in 1842 (7 Stat. 591). Both treaties are sometimes called "removal treaties" because they detailed the boundaries of lands that would be ceded to the United States under terms of the treaty. The 1836 treaty involved lands of present day Michigan; the 1842 treaty applied to lands in the Upper Peninsula of Michigan and Wisconsin that bordered Lake Superior. In today's interpretation, the waters of the Great Lakes adjacent to these land cessions are referred to as "treaty waters." The 1836 treaty waters include portions of lakes Huron, Michigan, and Superior; the 1842 treaty waters lie within the Wisconsin and Michigan portions of Lake Superior west of the 1836 treaty line (Figure 1).

Article 13 of the 1836 treaty states that "the Indians stipulate for the right of hunting on the lands ceded, with the other usual privileges of occupancy, until the land is required for settlement." Article 2 of the 1842 treaty reads similarly: "The Indians stipulate for the right of hunting on the ceded territory, with the other usual privileges of occupancy, until required to remove by the President of the United States." The usual interpretation of these stipulations prior to the 1970s had been that the "rights" did not apply away from reservation lands. State game wardens did not enforce state laws about fishing and hunting on Native American reservations, where only tribal and federal laws were in force, but they did enforce those laws everywhere else, such as on the waters of the Great Lakes.

In 1971, Albert ("Big Abe") LeBlanc, a Chippewa Indian and an enrolled member of the Bay Mills Indian Community, was arrested for commercial fishing without a license and with using an illegal gill net on Whitefish Bay of Lake Superior, near Sault Ste. Marie, Michigan. He was convicted of both charges in district court. The case was appealed to the Michigan Supreme Court in 1976 where the lower court's decision was reversed (People of the State of Michigan v. A. B. LeBlanc, Supreme Court of Michigan, 1976. 248 N.W. 2d. 199).

The case was appealed to the western U.S. District Court of Michigan in 1979, where Judge Noel P. Fox confirmed the state Supreme Court decision (U.S. v. Michigan and others, No. M26-73 C.A). The "Fox decision" became the foundation of many more court opinions and consent decrees in the years that followed (Ferguson 1989). Judge Fox ruled that the tribes have a treaty right to fish in the Great Lakes and the state is without authority to regulate that right. Article 13 of the 1836 treaty was designed "to reassure the Indian people that they could continue living the way they had been living. While the Indians might have been willing to give up their right to hunt on various parcels of land as that land became occupied with settlers, the vital right to fish in the Great Lakes was something that the Indians understood would not be taken from them" (Fox decision, V, part B [27]).

Establishing the Tribal Fisheries

In the court cases that followed, judges in Michigan and Wisconsin broadened the interpretation of Native rights in matters of fishing, hunting, and gathering not just on reservations but on all lands and waters in the ceded territories not privately owned (Wilkinson 1991; GLIFWC n.d.). In 1980, a court-mandated settlement was issued that provided for the practical operation of the Great Lakes fishery. The Chippewa Ottawa Fishery Treaty Management Authority (COFTMA) was established to manage the Native fishery, a duty that included the issuing of licenses, enforcement of tribal laws, and monitoring of tribal fisheries. Tribe-licensed commercial fishing began in 1980 and was greatly aided by a 1985 consent decree issued by the Michigan District Court, which increased the number of tribal licenses (Figure 6). The consent decree was to operate for fifteen years, until 2000, by which time two more tribes had joined and the COFTMA name was changed to Chippewa Ottawa Resource Authority (CORA 2012). A second decree, extending to 2020, was enacted in 2000 (USFWS 2000).

A roughly parallel set of court decisions took place in Canada beginning in the 1970s (Allain 1996). Canadian Supreme Court decisions, which continue to be handed down in 2013, began as treaty fishing rights issues in British Columbia's salmon streams. In the Great Lakes region, most of the tribal licenses are held by the Saugeen Ojibway Nation, which has a substantial area of fishing rights on both sides of the Bruce Peninsula in Lake Huron. Other First Nations operating Great Lakes fisheries in Ontario are based near Thunder Bay, Wawa, Sault Ste. Marie, Manitoulin Island, Lac Nipissing, and Kingston.

The succession of court decisions led to splitting the western Great Lakes commercial fishery into two components, one privately owned and operated by non-Natives, the other tribally owned and operated by Native Americans (Seider and Schram 2010). The impracticalities of enforcing different fishing laws on different groups of people in the same waters led to a gridded zonation of the lakes whereby tribe-licensed commercial fishing takes place in some areas and state-licensed fishing in others (see maps in Michigan DNR 2006a, 2006b; Mattes 2011). Over time, the tribe-licensed areas were broadened to include most of the 1836 and 1842 treaty waters. Separate detachments of law-enforcement officers now police the Native and the non-Native fisheries. Both groups also have evolved their own separate networks of fisheries biologists, research labs, technicians, and fish hatcheries.

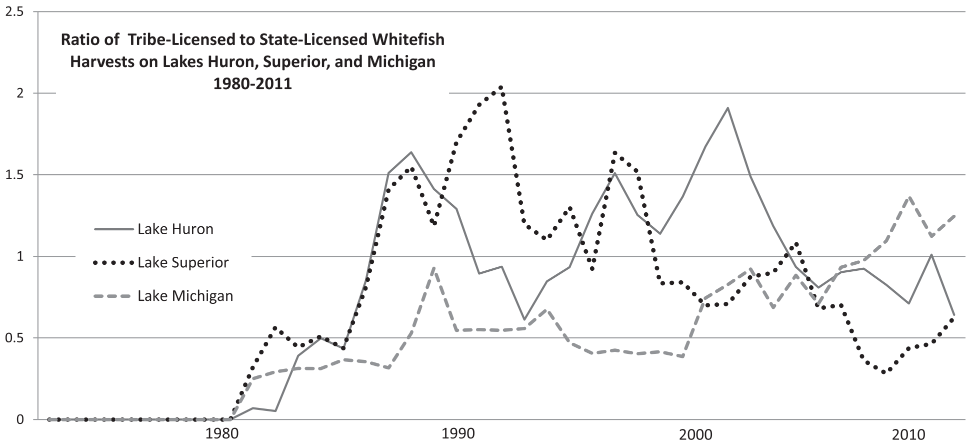

FIG. 6—Ratio of tribe-licensed to state-licensed whitefish harvests on lakes Huron, Superior, and Michigan, 1980–2011. Values above 1.0 indicate a greater quantity of fish harvested by the tribe-licensed fisheries.
Source: USGS 2013. (Graph by John Hudson).

Lake Michigan is divided north-south along the 1836 treaty line, which closely approximates the Wisconsin-Michigan state line (Figure 1). By the early 21st century there were 165 commercial fishing licenses in force on Lake Michigan; 81 were issued by the state of Wisconsin, where no 1836 treaty-rights waters have been recognized; 73 were Chippewa-Ottawa tribal licenses for the Michigan side of the lake; and 11 were issued by the state of Michigan (Table 1). The Native fishery thus strongly dominates on the Michigan side of Lake Michigan. Some Michigan fishermen moved their operations to Wisconsin where it was easier for non-Natives to obtain a license (Ebener and others 2008). Only small sections of Lake Michigan, near Muskegon, Leland, and Escanaba, now have state-of-Michigan-licensed commercial fisheries (Figure 6).

TABLE 1—AVERAGE NUMBER OF GREAT LAKES COMMERCIAL FISHING LICENSES ISSUED PER YEAR, 2000–2005

	STATE OR PROVINCIAL LICENSED				TRIBAL LICENSED		
	WISCONSIN	MICHIGAN	ONTARIO	OHIO, PA.	U.S. TRIBAL	CANADA TRIBAL	TOTAL
Lake Superior	10	8	35	0	109	16	178
Lake Huron	0	14	58	0	63	19	154
Lake Michigan	81	11	0	0	73	0	165
Lake Erie	0	0	103	3	0	0	106
Lake Ontario	0	0	24	0	0	0	24
Total	91	33	220	3	245	35	627
Gill net	62	2	169	0	212	30	475

Source: Compiled from Ebener and others 2008.

Lake Superior's pattern is even more strongly oriented toward tribe-licensed fishing, although Ontario provincial licenses dominate in the Canadian waters of Lake Superior. Of a total of 154 licenses in force on Lake Huron, 63 are tribal on the Michigan side of the lake, 14 are issued by the state of Michigan, and the remaining 77 are issued by the province of Ontario. No Michigan-licensed fisheries operate north of Alpena on Lake Huron, and most of the state-licensed activity takes place just south of Alpena or in Saginaw Bay (Michigan DNR 2012).

Continuing efforts to reestablish lake trout numbers led fishery managers to designate portions of Lake Huron and Lake Michigan waters off-limits to all commercial fishing, whether state-licensed or tribal, as areas essential for lake trout reproduction. Seasonal lake trout refuges also have been designated in Lake Superior. Lake trout harvests have grown slightly over the year although they have never again reached the levels known in the pre-lamprey era (Holey and others 1995). Tribe-licensed fisheries in Lake Superior harvest about ten pounds of lake trout for every 100 pounds of lake whitefish they bring in (Mattes 2011).

Despite buyout programs designed to replace gill net gear with pound nets in the tribe-licensed fisheries in the U.S., the use of large-mesh gill nets still dominates the Great Lakes fishery. Wisconsin never outlawed gill nets to the extent that Michigan did, Canada does not outlaw gill nets at all, and the tribes continue to adhere to their age-old practice of using gill nets. Three-fourths of the licensed commercial fishers on the Great Lakes use large-mesh gill nets (Table 1).

Making a Living

Buyout programs, reduced numbers of licenses, and reductions in allowable catch have contributed to a reduction in commercial fishing on the Great Lakes. While tribe-licensed fisheries have grown in number and expanded in production, they remain dedicated to the production of fish for tribal consumption. Fish caught by the tribe-licensed fisheries are available for sale, although the amount sold on the open market is not known.

The sale price of fish is relatively low. The three most important commercial species (whitefish, walleye, and yellow perch) seldom bring more than $2.00 per pound dockside (NOAA 2010, 2012), although increased demand for lake whitefish caused the wholesale price to increase 30 percent in 2013 (Michigan Department of Natural Resources, 2014b). The cost of fishing gear, boat, fuel, and labor must be subtracted from that amount, which leaves little hope for profit. Canadian prices, in Canadian dollars, tell a similar story for fish caught on the northern sides of the lakes (Fisheries and Oceans Canada 1990–2012). Periodic upswings in the size of the harvest potentially lead to oversupply and a depressed price.

In the Great Lakes fishing industry, limits are imposed on the catch that a license holder may sell. To expand, some fishermen purchase the entire operations of others in the same business, including the boat, gear, and license. Some fishing families have adapted to the changing fisheries and have continued in the business for several generations (Great Lakes Whitefish 2007–13; Figure 7).

The Lake Erie Yellow Perch Fishery

In all of the Great Lakes today, one fishery stands out as a success that is simultaneously environmentally sound, operates on a economically sustainable basis, and produces a large quantity of fish for local, national, and international markets (Nate and others 2011). It is the western Lake Erie yellow perch fishery, which also produces quantities of walleyed pike (yellow pickerel in Canadian terms of reference), sauger, and white bass. More than four-fifths of the industry is concentrated in two small Lake Erie ports, Kingsville and Wheatley, which are separated by the Pelee Peninsula about fifty miles southeast of Windsor, Ontario. The village of Wheatley claims to be the world's largest freshwater fishing port. The two towns are also the southernmost settlements in all of Canada and are surrounded by fruit orchards and fields of vegetables made possible by the benign climate.

Lake Erie is the smallest of the Great Lakes, but it has long yielded the most fish (Koelz 1926). The lake's warmer waters and shallower depths are more productive than the cooler, deeper lakes such as Superior (Hayward and Margraf 1987). Yellow perch are a favorite of the "Friday night fish-fry" served at many restaurants in the Great Lakes region, and walleye is a favorite target of sport

Fig. 7—Thill's Fish House on Lake Superior, Marquette, Michigan. This multigeneration family business has adapted to changes in the fisheries to keep up with increasing consumer demand for local whitefish. (Photograph by Susy Ziegler, November 2013).

anglers. Lake Erie commercial harvests of the two species fluctuated until overfishing and poor recruitment led to a collapse in the walleye fishery in the 1960s (Nate and others 2011). Additional problems arrived in the early 1970s when mercury contamination led to fisheries closures. Bans on phosphate detergents and various efforts to control agricultural runoff greatly reduced phosphorous loadings in the lake and helped improved water quality.

A catch-quota management system was implemented on Lake Erie in 1976. United States and Canadian allocations, as well as both commercial and sportfishing interests, are managed by the Lake Erie Committee of the Great Lakes Fishery Commission (Lake Erie Committee 2013a). Fisheries biologists from various governmental agencies conduct research annually to determine the status of fish populations and then exchange their findings. A total allowable catch (TAC) for the following year is determined by the Lake Erie Percid Management Advisory Group in terms of what is regarded as a realistic harvest of walleye and yellow perch to keep the two fisheries operating on a sustainable basis (Lake Erie Committee 2013a, 2013b).

Lake Erie is roughly divided "down the middle" by the U.S.–Canadian border, although the dividing line is shifted north or south six times along the lake's long east-west axis (O'Kelly 2012). Each state and the province of Ontario receive a TAC allocation that is in proportion to the Lake Erie surface area under their respective jurisdictions. Ontario's yellow perch TAC for 2013 was 6.9 million pounds; Ohio's was 3.48 million pounds. The quantity of fish taken by sport anglers is monitored more closely in the United States than in Canada, but in both countries the sport and commercial harvests must respect the TAC levels. Annual variations in TAC target values fluctuate roughly 10 percent up and down for yellow perch. In the walleyed pike fishery some years see expansions or cuts of 50 percent or more with respect to the previous year's TAC (Lake Erie Committee 2003–2013).

Although phosphorous loadings posed a greater problem in western Lake Erie than in the rest of the lake, it is the lake's western basin that produces the most fish (Lake Erie Committee 2013b). Statistics on the location of fish harvested show a strong association with shallow waters at the western end of the lake, in both the U.S. and Canada. Large harvests of yellow perch continue eastward along Lake Erie's northern shore more than 70 kilometers east of Wheatley.

Only one commercial fishery (at Port Clinton, Ohio) accounts for much of the U.S. yellow perch catch, but a half-dozen firms in Wheatley and Kingsville, Ontario, help boost the annual total for the lake above five million pounds. Part of the perch and walleye harvest is sold fresh although most of it is frozen immediately after the fish are processed. Lake Erie fish are sold in markets in both countries and are exported around the world. Frozen-food processing companies operating near Kingsville and Wheatley also produce frozen fruit and vegetable entrees from products grown in the extensive outdoor and indoor hydroponic gardens found in that part of Ontario. Smoked fish and canned or frozen fish snack products also come from the cluster of food-processing factories in this area.

Yellow perch also can be produced on aquaculture farms, although there are problems associated with survival of the young fry (Hartleb and others 2012). A single aquaculture firm at Albany, Indiana, near Indianapolis, produces a large share of the yellow perch farmed in the U.S., but its level of output is still well below that of the Canadian Lake Erie fisheries. The Lake Erie product thus appears to have at least some future in the diet of North American consumers.

Conclusion

Given the variety of problems that the Great Lakes fishery has faced, it is little wonder that many people believe that the fisheries have collapsed, or that even if fish are caught it would be unsafe to eat them. The array of issues surrounding the fishery is so large that the level of interventionist management currently in force probably will have to continue indefinitely. About the only environmental issue that has not been linked directly to the decline in fish populations is climate change; thus far, at least, the Great Lakes fisheries show no discernible evidence of it (Madenjian and others 2002), although fish biologists are monitoring local effects of changing climate.

But new problems do appear from time to time, such as the "Asian carp invasion" of 2008–2009 (Kappen and others 2012). No Asian carp damage to Great Lakes fish populations has yet been recorded, nor indeed have any Asian carp been detected inhabiting the Great Lakes, but the prospect of yet another invasive species led to demands from various groups that "something be done" about the problem. Legal authority to intervene was established in the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (16 U.S. Code § 4702 (1)).

In January 2014, the United States Army Corps of Engineers released its comprehensive study of how to prevent the interbasin transfer of aquatic nuisance species (USACE 2014). Alternative Plan 5, the most comprehensive of the proposed courses of action, would sever the hydrologic connection between the Great Lakes and Mississippi River basins at the Lake Michigan lakefront. The project would take twenty-five years to complete and would cost more than $18.4 billion. Most of the expenditure would support flood-abatement measures that would be necessary if such a plan were implemented.

While it is easy to claim that today's Great Lakes fishery is overregulated, it is also easy to see how the situation came about. The fact that different states, different countries, and different groups of people have different laws is partially responsible. The earnest efforts of scientists in both countries to find a solution to environmental problems less often produces a solution to those problems than it does a continuation of research and monitoring activities and a call for more research aimed at ultimately finding a solution. The periodic appearance of new nonnative species has only made that situation worse. Efforts to clean up pollution have generally been a success, but scientists and fishermen alike will need to be vigilant. State-licensed and tribe-licensed fisheries in the western Great Lakes have amicable relations, although the public cost of maintaining the substantial programs of research, monitoring, and law enforcement that keep the two groups separate is rarely mentioned. The number of people employed in all of these activities has grown even while the fishery itself has shrunk. Despite the many environmental and cultural challenges, state-licensed commercial fishing increased in value from 2012 to 2013 (Michigan DNR 2014b). The Great Lakes fisheries live on.

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