Great Lakes Commercial Fisheries: Historical Overview and Prognoses for the Future

Travis O. Brenden*
Quantitative Fisheries Center
Department of Fisheries and Wildlife
Michigan State University
East Lansing, Michigan 48824

Russell W. Brown
Ecosystems Surveys Branch
Northeast Fisheries Science Center
National Marine Fisheries Service
Woods Hole, Massachusetts 02543

Mark P. Ebener
Inter-Tribal Fisheries and Assessment Program
Chippewa Ottawa Resource Authority
Sault Ste. Marie, Michigan 49783

Kevin Reid
Ontario Commercial Fisheries' Association
Blenheim, Ontario N0P 1A0

Tammy J. Newcomb
Fisheries Division
Michigan Department of Natural Resources
Lansing, Michigan 48909

*Corresponding author: brenden@msu.edu

Introduction

Commercial fishing played an important role in the settlement of the Great Lakes region of North America and continues to be an important industry in the area. Abundant fishery resources were a key factor in the establishment of early settlements in many areas around the Great Lakes. Along with timber, trapping, and mining, commercial fishing was one of the key natural resource extraction industries that generated economic wealth to stimulate settlement and development of many Great Lake ports.

The commercial fishing industry has had to respond to near continuous change in their technology, the Great Lakes ecosystem, and the regulations imposed by fisheries management agencies. The fact that a Great Lakes commercial fishing industry still exists is to some extent a testament to the adaptability, perseverance, and dedication of commercial fishers. Although the dynamic history of the commercial fishing industry in the Great Lakes can be partly explained by examination of fishery yields, one cannot gain a full appreciation of the dynamics of the industry without understanding the many factors that have affected and continue to affect the industry. These include changes in gear, processing and distribution of commercial products, economics, and regulation and management of the fisheries. In this chapter, we provide an overview of these factors along with an assessment of the history and current status of the commercial fisheries in each of the Great Lakes. More detailed analyses in the form of case studies for Great Lakes percids (Rosemen et al. 2008, *this volume*), salmonids (Claramunt and Madenjian *this volume*), lake sturgeon (Boase *this volume*), lake trout (Krueger *this volume*), and lake whitefish (Ebener et al. 2008b) can be found elsewhere.

Technological Developments

The continual technological development of fishing equipment, processing methods, and transportation/marketing has had profound effects on the efficiency of commercial fishers and the status of Great Lakes fish stocks. Early commercial fisheries were relatively primitive, near shore operations that harvested fish to be sold locally because means to transport products to distant markets were lacking. As fishing gear developed, commercial fishers were able to harvest fish from deeper waters, extending both the length of the fishing season and the number of species that could be harvested. Advances in boat and vessel designs allowed fishers to spend more days on the water, fish with more and larger gear, and transport their catch to more distant markets. These technological developments in some cases have resulted in overexploitation of fish stocks and contributed to an overall reduction in the number of commercial fishers that can be supported by Great Lakes fisheries. In this section, we review some of the changes in fishing gear, boat configurations, electronic equipment, and processing, marketing, and distribution of commercial fishery harvest, which have had the largest effects on the Great Lakes commercial fishing industry.

Fishing gear

Several types of fishing gear were used at one time or another by commercial fishers on the Great Lakes, including trotlines, dip nets, haul seines, pound nets, gill nets, trap nets, fyke and hoop nets, and trawls. Reliance on particular gear types has changed substantially as fishing effort has shifted to target different species and moved to areas located further offshore. Since the 1960s, concerns about bycatch have resulted in some states regulating the use of certain gears to protect particular species (Ebener et al. 2008b).

Trotlines, which are also referred to as set hooks, consist of hooks suspended by dropper lines from a main line. Trotlines were routinely used to catch lake trout in the upper Great Lakes from the mid 1800s until about the 1940s. Fishers often deployed as many as 2,000 to 3,000 hooks per set baited with bloaters, ciscoes, and rainbow smelt that floated off the bottom. The entire gang of hooks were floated at any desired depth through the use of float and anchor lines. Trotlines continue to be used by commercial fishers to harvest species such as brown bullhead, burbot, channel catfish, common carp, freshwater drum, quillback, rainbow smelt, white bass, white perch, white bass, and yellow perch in lakes Erie and Superior.

Haul or beach seines are walls of netting consisting of two wings and a bunt midsection. In some configurations, a bag is included at the bunt section to help capture fish. During operation, a section of shore waters is surrounded by the net and the wings of the net are drawn to shore. As the wings are drawn in, fish encompassed in the net are forced into the bunt section and bag of the net. Haul seines vary in size from a few meters to a few hundred meters in length. Haul seines used for commercial fishing can be as long as 700 m. Historically, seines were retrieved by hand or by horses. Presently, retrieval of seines is by hand or with automated winches.

Haul seine usage is generally limited to shallow areas where netting extends from the lake bottom to the lake surface. Seines are considered to be most effective for nearshore species or those that concentrate near shore seasonally (Hayes et al. 1996). In the Great Lakes, haul seines were used extensively in the 1800s to harvest spawning aggregations of lake whitefish, but their use declined as nearshore stocks of lake whitefish were depleted. Haul seines continue to be used by commercial fishers in Lakes Erie and Huron to harvest bigmouth buffalo, brown bullheads, channel catfish, common carp, freshwater drum, northern pike, yellow perch, and various species of minnows, suckers, and sunfish.

Pound nets, which were once widely fished along Great Lakes shorelines, are a passive type of entrapment gear, whereby fish encounter the net during normal movements. Pound nets consist of vertical walls of netting maintained in position by stakes that have been driven into the lake substrate (Figure 1). Netting is deployed to form three parts: the lead, the hearts, and the pot. Fish swimming near the shoreline encounter the lead, follow it into deeper water, and eventually get funneled into the pot of the net. One advantage of fishing with pound nets is that captured fish can be kept alive for several days, resulting in a fresher product for market. Use of pound nets is limited to shallow areas because of the need to use stakes to secure the nets. Additionally, because pound nets are fairly immobile, they are vulnerable to storm and ice damage and need to be removed each fall. Pound nets were in use on lakes Ontario and Erie by 1850 and were extensively used in Lake Erie, Saginaw Bay, southern Lake Michigan, and Green Bay (Van Oosten 1938). Only a few commercial fishers continue to use pound nets, primarily in Lake Michigan to harvest rainbow smelt, lake whitefish, and various sucker species.

Gill nets were among the first types of gears used by commercial fishing operations, and their use continues to present day. Gill nets consist of a vertical wall of netting or twine strung between a floated line and a sinker (leaded) line (Figure 1). Nets are normally set in a straight line and anchored at both ends. Fish are captured when they become wedged, gilled, or entangled in the netting. Gill nets can be fished from the lake surface, suspended at mid-depths, or set on the bottom. Gill nets gained popularity in the late 1800s because they required less labor and capital investment than pound nets, could be easily moved, and could be fished in deeper waters. The use of floats to fish gill nets at mid-depths greatly improved the efficiency of capturing ciscoes circa 1900 (Koelz 1926). In 1905, the introduction of the bull net, a very deep gill net that fished effectively in mid-depths, drastically increased fishing efficiency for cisco in Lake

Erie. Bull nets were subsequently outlawed by Ohio in 1929, and by New York and Pennsylvania in 1934 (Regier et al. 1969).

Mesh size of gill nets fished by Great Lakes commercial fishers has ranged from 3.18- to 35.56-cm stretched mesh. Bait nets (< 5.08-cm stretched mesh) are used to catch small bloaters, ciscoes, and rainbow smelt, while small mesh nets (5.08- to 7.62-cm stretched mesh) are used for adult deepwater chubs, ciscoes, round whitefish and yellow perch (Hile 1962). Larger mesh gill nets (10.16- to 30.48-cm stretched mesh) are used to target lake trout, lake whitefish, common carp, lake sturgeon, and suckers (Hile 1962). Mesh size is one of the most frequently regulated aspects of gill net fisheries. In 1972, Michigan banned the use of small-mesh gill nets in its jurisdictional waters of the Great Lakes to prevent bycatch of juvenile fish. Bans on large-mesh gill nets as part of the lake whitefish commercial fishery in Michigan waters of the Great Lakes were instituted in 1977 (Rybicki and Schneeberger 1990).

Configuration of gill nets fished by Great Lakes commercial fishers has changed substantially over the last several decades. These changes have affected commercial fish catch statistics for this gear, which makes it difficult to compare historical and present-day catch rates. Historically, gill nets were made from crude twine, but net makers later switched to netting made from linen. During the 1930s, softer, more elastic cotton thread replaced linen in most major fisheries, resulting in greatly improved capture efficiency. The conversion from cotton to multifilament gill nets occurred between 1949 and 1952 for the lake trout fishery (Pycha 1962) and between 1951 and 1961 for the cisco fishery (Selgeby 1982). Multifilament nylon net materials were superior to linen and cotton twine because of durability, elasticity, and reduced visibility to fish (Jester 1977). Unlike cotton and linen nets, multifilament nylon nets do not rot, and can be reset multiple times without the need to remove the nets for drying and treatment. As a result, the length of nets that could be fished per vessel and total number of days nets that could be deployed increased (Christie 1978). Published information on the relative efficiency of nylon and cotton nets suggested that nylon nets were two to three times more efficient than cotton (Lawler 1950; Hewson 1951; Atton 1955; Pycha 1962). During the 1960s, commercial fishers began to switch from multifilament to monofilament gill net mesh, and this change resulted in nearly a two-fold increase in efficiency for several species (Collins 1979; Henderson and Nepszy 1992). The conversion from multifilament to monofilament mesh was complete by the late 1970s.

During the 1970s and 1980s, commercial fishers experimented with deeper gill nets as a way to increase catch efficiency. Prior to the 1970s, commercial gill nets used on the Great Lakes were typically 28- or 36-meshes deep. During the late 1970s, commercial gill net fisheries for lake whitefish began changing to nets that were 50-meshes deep. Comparisons of catches from Lake Huron indicated that 50-mesh deep gill nets were 1.7 times more efficient at capturing lake whitefish than 36-mesh deep nets (Collins 1987). During the early 1990s, Tribal commercial fishers in Michigan waters began converting from 50-mesh deep gill nets to 60- and 75-mesh deep nets. Initial comparisons of lake whitefish catches found that 75-mesh deep nets were 1.4 times more efficient than the 50-mesh deep nets in lakes Superior, Huron, and Michigan (Chippewa-Ottawa Resource Authority, unpublished data).

Water clarity in some areas of the Great Lakes has increased substantially since the invasion of dreissenid mussels during the late 1980s and early 1990s (Fahnenstiel et al. 1995; Binding et al. 2007). Increased water clarity means that there is less dissolved material in the lakes, which allows different wavelengths of light to penetrate farther in the water column (Cole 1994). As a result, netting that was once relatively inconspicuous to fish may now be readily visible, which can have large effects on gill net catchability (Jester 1973, 1977). Great Lakes commercial fishers have a long history of responding to changing ecological conditions and markets by experimenting with different fishing times, areas and methods including the sizes, diameters, colors and hang ratios of gill net twine. In response to increased water clarity, the color of gill net twine has been changed to a green or white color to make nets more or less conspicuous to certain species fish. Green colored twine with high hang ratios is often used to target walleye whereas white twine with lower hang ratios is often used to avoid walleye bycatch while targeting white bass and white perch. Also in response to increased water clarity, the size of the monofilament twine in the lake whitefish gill net fisheries of Lake Erie, Lake Huron and Lake Ontario has been reduced from 0.2 mm to 0.15 mm (Larry Jackson, Lake Erie commercial fisher, personal communication).

Fish caught in gill nets often die and thus can have lower flesh quality and bring a lower market price if nets are not tended regularly. Concerns about bycatch and mortality of non-target species in gill-net fisheries has emerged as an important issue for fishery management agencies. Johnson et al. (2004b) estimated that a 100 mt commercial gill-net fishery for lake whitefish could kill in excess of 10 mt of lake trout through bycatch. Between 1985 and 1998, 71% of the

300 mt of lake trout that was harvested by large-mesh gill-net fisheries in northern lakes Huron and Michigan was taken as bycatch in fisheries targeting other species (Johnson et al. 2004a).

Trap and fyke nets were first used on the Great Lakes during the late 1800s. These nets operate on the same principles as a pound net, except that the hearts and pot are enclosed on all sides so that the entire net can be submerged. Additionally, trap and fyke nets are held in position by anchors rather than stakes (Figure 1); as a result, trap nets can be fished in deeper areas than pound nets. Trap nets were widely used in U.S. waters to target lake whitefish and walleye. Because of fears concerning their high capture efficiencies, trap nets were prohibited in Michigan and Ontario waters during the early 1900s. Deep trap nets, extremely tall trap nets fished in deeper waters of the upper Great Lakes, were introduced during the late 1920s (Van Oosten et al. 1946). The deep trap net was quickly prohibited by many management agencies because it was believed these nets caused depletion of lake whitefish stocks and excessive mortality of undersized fish in Lake Huron (Van Oosten et al. 1946; Berst and Spangler 1972). Since the 1990s, U.S. fishery management agencies in the Great Lakes have preferred the use of trap nets over other types of fishing gear because of reduced bycatch mortality on non-target species and because of persistent conflicts between gill netters and recreational anglers. In Ontario, the use of gill nets for commercial fishing continues to be permitted, except in areas where conflicts between commercial fishers and recreational anglers have lead the Ontario Ministry of Natural Resources to restrict the use of gill nets in favor of live-capture gear (e.g., Bay of Quinte on Lake Ontario, Inner Long Point Bay on Lake Erie).

Fewer trap-net operations can exist in a given area compared to gill-net operations because the capital investment to operate large trap nets is high (>$15,000 [USD] per net) and because the volume of fish that can be caught by trap nets is large. For example, in the main basin of Lake Huron and outer Saginaw Bay, there are only four large-mesh trap-net operations for lake whitefish, with each license authorized to operate 9 to 10 large-mesh trap nets. These four operations individually harvest between 90 and 200 mt of lake whitefish annually. The areas that can be fished by trap nets also is limited, as it is difficult to set and maintain the nets over rocky bottoms, steep banks, in strong currents, and in depths greater than 40 m. Because captured fish are kept alive in trap nets, trap-net fisheries generally produce a fresher and more premium product that is often more valuable per unit harvested than gill net-caught fish (Ebener et al. 2008b).

Otter trawls are bag-shaped nets that are towed along the bottom or in the water column by a boat. As the net is towed through the water, fish are sieved from the water column and eventually funneled into the cod end of the trawl. The term “otter” refers to the doors or boards that are attached to the wing leads of the trawl, which function to hold the trawl open. The headrope of the trawl is usually suspended with floats, and the bottom line is weighted to maintain contact with the bottom when trawled at bottom depths. Otter trawls were first used as a commercial fishing gear on the Great Lakes during the 1950s. Development of trawling has been limited because many areas of the Great Lakes lack the clean bottom needed to fish this gear, the required capital investment and operating costs for trawls are high, and some management agencies have discouraged or regulated against their use because bycatch can exceed acceptable levels. For example, in Wisconsin waters of Lake Michigan, the commercial trawl fishery for rainbow smelt harvested nearly 39 mt of chubs in 2007, which was approximately one-fifth of the yield taken by the Wisconsin gill-net chub fishery (Lake Michigan Fisheries Team 2008). Otter trawls continue to be extensively used to commercially harvest rainbow smelt in both lakes Erie and Michigan.

Boat configurations

Although early commercial fisheries were shore-based operations that used haul seines and pound nets as the primary fishing gear, advances in boat design allowed for the expansion of the commercial fishing industry to offshore fisheries. During the last century, fishing boats have progressed from row and sail- and steam-powered vessels to gas- and diesel-powered boats.

During the early 1870s, Mackinaw, Huron (a.k.a. square stern), Norwegian, and pound-net were four types of sailing vessels used in U.S. waters (Milner 1874). Milner (1874) described the Mackinaw as:

> “bow and stern sharp, a great deal of sheer, the greatest beam forward of amidships and taper with little curves to the stern. She is either schooner-rig, or with a lugsail forward, is fairly fast, the greatest surf-boat known, and with an experienced boatman will ride out any storm, or, if necessary, beach with greater safety then any other boat…They have been longer and more extensively used on the upper lakes than any other boats, and with less loss of life or accident”

The Huron was usually 8.2 to 11.0 m in length and was preferred by large gill-net operators fishing far from shore. The Norwegian was described as a “huge, unwieldy thing, with flaring bows, great sheer, high sides, and is sloop rigged” (Milner 1874). This vessel was preferred by Scandinavian fishers, but was known to be slow and difficult to row in calm winds. Pound-net boats generally had flat bottoms and wide beams, and were well suited for the task of driving pound net stakes into the lake bottom because of the boat’s stability.

Commercial fishery operations began converting from early sailboats to steam-powered tugs and gasoline-powered launches by the late 1880s (Koelz 1926; Kennedy 1970). This conversion was gradual; by 1919, there were 119 tugs, 626 gasoline launches, and 984 sail and rowboats fishing on the Great Lakes (McCullough 1989). Most gasoline powered boats were small launches, 7.6 to 15.2 m in length, used by nearshore pound- and gill-net fishing operations. Most early steam tugs in use were less then 20 m in length so that they could be operated by unlicensed pilots and engineers (Koelz 1926). The introduction of steam tugs resulted in increased fishing intensity because they allowed operators to fish up to five times more net than what previously was fished using sails and oars (Toner 1939). The addition of mechanical gill-net lifters on tugs during the early 1900s also increased the amount of netting that commercial fishers could deploy and retrieve. Gill-net lifters consist of a mechanized drum with fingers on the outside that grasp and retrieve the net as the drum is rotated. The net rotates partway around the drum before falling to the boat deck (Cobb 1914). Net lifters can be run either from a separate generator or directly from the boat engine.

During the 1920s and 1930s, commercial fishing fleets began converting to steel-hulled, diesel-powered boats. Steel-hulled gill-net boats evolved to the entire deck being enclosed with a high, box-like super structure known as the turtle deck (Figure 2). Initially developed by Lake Erie fishers, these enclosures were gradually upgraded from canvas to wood structure, and the design spread to other areas of the Great Lakes (Thompson 1978). Deployment and lifting of gill nets and unloading of harvested fish is accomplished through large, sliding doors located on the sides of the boat (Figure 3). Trap-net vessels also have evolved to having large open decks and small wheel houses (Figure 2) to accommodate bulky nets (Figure 4), which can be as large as 15.2 m in height and have leads as long as 300 m. Small steel and aluminum boats equipped with gasoline-powered outboards and, in some instances, mechanical net lifters, are still used by some commercial fishers, primarily in small-scale gill-net operations.

Early two-cycle diesel engines on commercial fishing boats have been largely replaced with four-cycle diesel engines on newer models. Although four-cycle engines are less powerful and more expensive to operate, durability of four-cycle engines is generally greater than that of two-cycle engines because of reduced engine loads. Four-cycle engines are also more thermally efficient than two-cycle engines and have lower fuel consumption and exhaust pollution (Calder 2007).

Electronic equipment

Perhaps the greatest change in commercial fishery operations in recent years has been in the area of electronics. Early electronic equipment used by commercial fishers included sounders and fathometers, which allowed fishers to locate specific depths needed to fish for deepwater species (Applegate and Van Meter 1970). By the 1950s, radio telephones were standard on most Great Lakes vessels. Echo sounders were first used by Lake Erie fishers in 1953 to locate concentrations of fish. By the 1970s, the Long Range Aid to Navigation (LORAN) system was in common use on the Great Lakes. First introduced during World War II, LORAN is a ground-based, radio-navigation system that uses low-frequency radio waves to determine vessel location. Differences in arrival time of signals emitted from several synchronized transmitters are used to determine location. Its development greatly improved navigational capabilities of commercial fishers.

Navigational capabilities of commercial fishers improved even more with the development of the Global Positioning System (GPS) by the U.S. Department of Defense (DOD), which first became fully operational during the early 1990s. Whereas LORAN is a ground-based navigational system, GPS is a satellite-based navigation system that uses a constellation of between 24 and 32 satellites to determine the location of a receiver based on differences in arrival time of microwave signals emitted from the satellites. GPS was originally developed for military applications, but its civilian use has increased rapidly and has largely replaced LORAN as a marine navigational system. Until 1 May 2000, intentional random errors of up to 100 m were introduced into the navigational system by the U.S. DOD to limit the accuracy of GPS locations, a practice referred to as selective availability. Even with selective availability, accuracy of GPS locations was better than that of the LORAN system. On 2 May 2000, the U.S. DOD turned off selective availability, which meant that even relatively inexpensive GPS receivers were capable of determining locations accurately to within several meters. Sub-meter accuracy of locations can be achieved through differential correction, which uses inaccuracies in GPS location estimates of fixed-site receivers to correct location estimates of other receivers.

Navigational capabilities of Great Lakes commercial fishers have also improved through the development of electronic navigational charts and advanced chart plotters. The use of nautical charts for navigation is certainly nothing new – mariners have used navigational charts for hundreds of years. However, the combination of GPS, electronic navigational charts, and chart plotters permit real-time plotting of vessel location in relation to navigational hazards. Electronic navigational charts are available in two formats: raster and vector. Raster navigational charts are digitized, geo-referenced copies of printed nautical charts. Because raster charts are exact replicas of printed charts, they have the exact same level of accuracy of printed charts. Vector electronic navigational charts on the other hand have been compiled from original chart source material that has been deemed navigationally significant. Vector electronic navigational charts come with added features that can be beneficial for navigation, such as zoom-in and rotation capabilities.

Technological advances in cell phones technology and the explosion in their use since the 1990s have also enhanced commercial fishery operations. During the late 1990s, there were estimated to be less then 400 million cell phone subscribers worldwide. By 2008, mobile cellular subscriptions were estimated to be in excess of 4 billion subscription (ITU 2009). Cell phones allow commercial fishers to communicate directly with buyers on shore and with large commercial lake whitefish markets such as those in New York, Chicago, and Detroit (Ebener et al. 2008b), informing them of the quantity and quality of each day's catch. This permits more direct marketing of Great Lakes commercial fishing products by both fishers and wholesalers.

Monitoring, control, and surveillance of Great Lakes commercial fishing have also been facilitated by advances in electronic devices. Electronic log books have been developed that allow data such as fishing effort, catch composition, vessel position, water temperature, and depth to be collected for individual hauls or net lifts. In some cases, there can be conflicts in terms of how much data can be collected from electronic systems and how much information commercial fishers are willing to share. From a fishery management perspective, biologists would like to have detailed and accurate information for determining the status of a fishery stock.

From a commercial fisher's perspective, this information can be viewed as proprietary, and the sharing and dissemination of the data may be seen as a threat to a fisher's livelihood. Fishery management agencies within the Great Lakes region have begun developing systems and regulations that implement electronic reporting of commercial fishing catch. In 2007 and 2008, the Ontario Ministry on Natural resources began a pilot project to assess the feasibility of implementing a combination of electronic catch reporting and real-time GPS monitoring of fishing tug position and activity. The pilot program, which was a cooperative project involving the Ontario Commercial Fisheries' Association and commercial fishers in lakes Erie and Huron, was considered a success. As a result, a commercial rollout of the electronic daily catch report is anticipated in the near future (John Johnson, Ontario Ministry of Natural Resources, personal communication). In 2006, the Wisconsin legislature enacted regulations that would have required commercial fishers to electronically record commercial catches and to transmit this information to a local office of the Wisconsin Department of Natural Resources daily (Ebener et al. 2008b). Although this provision was passed by the Wisconsin legislature, it has yet to be implemented.

In late 2008, the state of Ohio implemented an electronic monitoring system for the Lake Erie commercial trap-net industry and mandated that commercial harvest be reported electronically. With Ohio's monitoring system, commercial fishing vessels are required to be equipped with GPS receivers and transmitters that allow vessel tracks to be monitored by the Ohio Department of Natural Resources. Additionally, each commercial trap net is assigned a unique identifier code that must be scanned when a net is deployed and lifted. Commercial fishers are required to report the estimated yield per net of each quota species (only yellow perch as of late 2009) once nets are retrieved and the actual yield of all species per 10-minute grid once they have returned to the docks. Although Ohio's electronic monitoring system has been active for only a short while, it has already proven beneficial for obtaining more accurate measurements of commercial fishing effort and yellow perch harvest (Travis Hartman, Ohio Department of Natural Resources, personal communication).

Processing, marketing, and distribution

The initial development of Great Lakes commercial fisheries prior to 1850 was restricted by limitations in capabilities to preserve and transport landed fish. Fresh fish were sold in local markets, but could not be transported outside local areas without spoiling. Fish that were transported to more distant markets were typically gutted, beheaded, and packed in barrels of salt brine. Lake sailing vessels transported salt and barrels to the Great Lakes from the eastern United States and returned to the East Coast with brined fish. Salted fish were shipped as early as 1807, with shipments increasing greatly with the opening of the Erie Canal in 1825 (Ashworth 1987) and the Ohio Canal in 1832 (Mansfield 1899). The development of a salt-mining operation at Goderich, Ontario during the 1870s established a local supply of salt for fish preservation (Belden 1877). Fish were shipped by rail as early as the 1830s in the United States and the 1850s in Canada.

When adequate transportation became available, fish were transported on ice or in frozen form. Fish caught in the upper lakes during the late fall and winter could be frozen in the open air, bagged, and transported by ship or rail to distant markets. Ice cut from frozen ponds and lakes in the winter allowed the storage and transport of fish during warmer months. S.H. Davis of Detroit, Michigan introduced pan freezing to the Great Lakes in 1868. In his patented system, fish were placed in covered metal trays, packed in ice and salt, and frozen (Stansby 1963). Artificially-produced ice was available by 1870 with the invention of the Lowe Compression Ice Machine. Freezers were first used by fish wholesalers on the U.S. side of Lake Erie during the late 1800s. By 1885, Sandusky, Ohio processed 4,100 mt of fresh fish, 2,700 mt of salted fish, 1,500 mt of frozen fish, and 1,050 mt of smoked fish (Smith and Snell 1891). In 1892, an alternative method of freezing using chilled ammonia was introduced, and this method eventually replaced freezing with chilled brine systems (Stansby 1963). By 1900, shipments of salted fish were rare (McCullough 1989). Modern tunnel-type freezers and other types of blast freezers have led to the ability of Ontario fish processors to supply individual quick frozen (IQF) fillets to large food service and retail markets in the United States.

Prior to 1900, almost all fish were dressed by removing the head and entrails. Filleting of fish did not become common in the Great Lakes until the 1920s (Anonymous 1929). Filleting had several advantages, such as permitting the rapid freezing of fish and the reduction of shipping weight. In 1937, Grow Brothers Fishery (Painesville, Ohio) patented a machine capable of scaling and washing 1,200 fish per hour. In 1942, Kishman Fish Company (Huron, Ohio) developed a new scaler capable of processing 45 kg of fish every nine minutes. Previous electrical hand scalers took 30 minutes to process the same weight of fish. The invention of a machine for cleaning rainbow smelt by Omstead Fishery (Wheatley, Ontario) was a partial impetus for the development of a major trawl fishery for rainbow smelt in Lake Erie. Shrimp graders were used as early as 1960 to sort rainbow smelt during processing. The development of pin boning technology during the 1980s and advances since then have made it possible to reliably remove pin bones without damaging the integrity of the fillets and has helped improve marketability of commercial products.

Since 2005, many commercial fishers in Lake Erie and in southern Lake Huron have switched from landing fish in iced packers (usually containing up to 100 lbs of product) to large insulated plastic totes (usually containing up to 700 pounds of product) that are handled by lift trucks and can also be sealed and marked with a tamper-proof tag. This switch to landing in sealed totes has led to improved quality and reduced spoilage of commercial products. It has also allowed the Ontario Ministry of Natural Resources to verify the chain of custody of the totes and verify landed weights for the purpose of quota debiting.

Once a Great Lakes fish is landed, it traverses a complex distribution network before finally reaching consumers. Historically, the distribution was relatively simple: fish were landed, sold to a wholesale dealer, shipped to large metropolitan dealers, and then distributed to smaller retail markets for final sale. This distribution system still exists today, although on a somewhat larger scale. For example, in the Upper Peninsula and northern Lower Peninsula of Michigan, there are seven large wholesale buyers and many more small buyers now dealing in fish harvested in the Great Lakes. Prior to the 1980s, the number of wholesale buyers in the area was five or less. Wholesale buyers purchase and sell commercially-caught fish and also distribute fish to buyers in larger metropolitan areas like New York, Chicago, and Detroit, restaurants, grocery stores, large food processing companies, and directly to the consumer.

Recently, there has been an increasing trend toward using offshore processors in Asia to process Great Lakes fishes. Gutted lake whitefish are frozen and shipped to China where they are filleted, re-frozen, and shipped back to North American where they are sold at prices similar to fresh fillets (Ebener et al. 2008b). This is done primarily to reduce processing costs and increase profits. It remains to be seen, however, whether off-shore processing will continue to increase or whether increased shipping costs will reduce the profitability of this practice. During the summer of 2008, U.S. Regular Conventional Retail Gasoline Prices rose to over $4.00 (USD) per gallon and price per barrel of crude oil reached $147 (USD). Although gasoline and oil prices were substantially reduced by winter 2008, higher, rather then lower, oil and gasoline prices are likely to be the norm over the ensuing decades, which will affect transportation costs.

Great Lakes commercial fisheries are profoundly affected by marketing practices and the effect that they have on consumer demand. During the 1980s, marketing of roe for caviar from lake whitefish, deepwater chub, and Chinook salmon increased the demand and price for female fish of these species caught during fall. Cooperative ventures, in which groups of commercial fishers jointly market their product to receive higher prices are common. There are commercial fishery cooperatives in the Door County and Bayfield Peninsula areas of Wisconsin. The Ontario Fish Producers and Lake Erie Fish Packers and Processors Associations have operated much like fishery cooperatives, providing significant marketing advantages to fisheries in Ontario. The Great Lakes Indian Fish and Wildlife Commission (GLIFWC), which is an inter-tribal agency that assists member tribes and bands in the exercise of their off-reservation treaty fishing rights, is coordinating another Great Lakes lake whitefish marketing effort; the Lake Superior Chippewa Fish Marketing and Development initiative will assist tribally licensed fishers to process and sell high quality products made by member-tribes who fish in Lake Superior. Product demonstrations and promotions of products in target market communities is extensively being used by GLIFWC to build a Lake Superior lake whitefish market brand and encourage consumers to commit to making regular purchases at tribal-member owned and operated fish processing plants and grocery stores. The Great Lakes Indian Fish and Wildlife Commission is supporting tribal entrepreneurs in marketing fish through tribal bulk purchases for tribal enterprises, such as food services, restaurants, and casino dining facilities. They are also assisting tribal entrepreneurs in co-marketing with tourism promotion event organizers at the tribal, local, and regional level to promote Lake Superior lake whitefish sales. Michigan Sea Grant, which is part of the National Sea Grant Program administered by the National Oceanic and Atmospheric Administration, has also recently begun supporting the development of a new marketing strategy for Great Lakes lake whitefish to enhance product demand and ensure stock sustainability. One aspect of this marketing strategy has been the development of a “Legends of the Lakes” brand and a processing agreement among several commercial fishing operations to highlight the desirable attributes and uniqueness of Great Lakes lake whitefish

Since the 1980s, there has been an increasing trend for commercial fishers to market portions of their catch locally. The increasing trend toward local marketing is likely rooted in the increased popularity of green politics and the local food movement, which emphasizes the purchase of locally produced goods and services. What exactly constitutes "local" in the local food movement is somewhat ambiguous, but it is safe to say that off-shore Asian processing of Great Lakes harvest would violate the movement's principles. In many areas within the region, Great Lakes commercial fish products are available at local farmer's markets throughout the summer months.

Economics

Commercial fishing was an important industry during the settlement and development of the Great Lakes region. At its height, over 10,000 people were directly employed in the industry as fishers, processors, or marketing personnel. The importance of the fishing industry from an economic standpoint has declined over time. In Ontario, there are presently around 300 commercial fishers paying provincial commercial fishing royalty fees to the government (John Johnson, Ontario Ministry of Natural Resources, personal communication). Economic comparisons of commercial and recreational fisheries that include the landed value of commercial catches but ignore the processed and retail value of the catch will tend to underestimate the overall economic impact of commercial fisheries. In Lake Erie, the landed value of the commercial catch in 2002 was $30.5 million (CAD), which added $80.2 million (CAD) to the gross output of Canada. Commercial fish processing firms along Lake Erie in 2002 contributed an estimated $438 million (CAD) to Canada's gross domestic product (Charette and Morgan 2004).

From the late 1930s to the 1970s, total dockside value of both U.S. and Canadian commercial fisheries were relatively stable, with slight increases during the late 1940s and early 1950s due to increased yields of lake whitefish, ciscoes, walleyes, and blue pike stemming from strong year classes produced during the mid 1940s and the demand for food following World War II (Figure 5). Dockside value of fish increased steadily from the 1970s to the late 1980s and early 1990s due to the recovery of lake whitefish, walleye, and bloater stocks, development of fisheries for exotic species such as alewife and rainbow smelt, and worldwide increase in demand and prices for fishery products. Dockside value for Great Lakes commercial fisheries landed in the United States peaked in 1992 with an estimated value of approximately $24 million (USD). Dockside value for commercial fisheries landed in Canada peaked in 1988 with an estimated value of more than $57 million (CAD). Since these peaks occurred, however, dockside value for both U.S. and Canadian commercial fishery yields have generally declined. The annual declines averaged 3.5% in the United States and 1.7% in Canada. In 2006, dockside values of commercial yields were approximately $14 million (USD) in the United States and approximately $36 million (CAD) in Canada.

When adjusted for inflation, dockside values of U.S. commercial yields have declined steadily since the 1940s, while the dockside values of Canadian commercial yields have declined steadily since the late 1980s (Figure 5). When using 2006 as the reference point for inflationary adjustment, dockside value of U.S. commercial yields peaked in 1952 with an estimated inflation-adjusted value of $152 million (USD), which is more than 10 times the value of dockside yields in 2006 (Figure 5). Inflation-adjusted dockside value of Canadian commercial yields has averaged roughly $50 million (CAD) since the late 1930s. During this time span, the peak inflation-adjusted dockside value was $83 million (CAD) in 1988. The lowest inflation-adjusted dockside value was $31 million (CAD) in 2004

Management and Regulation of Commercial Fisheries

Management of the commercial fisheries in the Great Lakes has been fraught with conflict between state, provincial, federal, Native American tribal, and First Nation Aboriginal agencies and communities with management authority over various regions of the Great Lakes. Early on, conflicts stemmed from the economic importance of the commercial fishing industry to the Great Lakes region and involved the U.S. and Canadian federal governments and tariffs that were imposed on commercial fish harvests. More recently, conflicts have arisen between state/provincial governments and Native American tribes/First Nation communities regarding allocation of harvest and the different cultural and philosophical perspectives to fisheries management priorities. Most notably, Native American and First Nation governments view commercial and subsistence fishing as traditional means for its members to support themselves and their families and as a means for maintaining connections to spiritual and traditional pasts. In this section, we review how management and regulation of Great Lakes commercial fisheries by the various entities have evolved over time, and discuss the advent of international cooperation to coordinate fisheries management decision making in order to benefit the resource.

Management of state and provincial licensed fisheries

In the United States and Canada, primary authority to regulate commercial fisheries on the Great Lakes lies with state and provincial governments. In the United States, state authority to regulate fisheries stems from the U.S. Constitution making no explicit provision for the federal government to manage fish or wildlife populations. As a result, the power to preserve and regulate exploitation of fish and wildlife populations is automatically reserved to the states under Amendment 10 of the U.S. Constitution. That is not to say, however, that the U.S. federal government plays no role in Great Lakes commercial fisheries. The U.S. federal government is able to influence commercial fisheries through its powers to enter into treaties, to regulate commerce, and to manage federal properties. Presently, several U.S. federal agencies, including the National Oceanic and Atmospheric Administration, U.S. Fish and Wildlife Service, and the U.S. Geological Survey are actively engaged in research on the Great Lakes to provide scientific information to state fishery management agencies. The U.S. Fish and Wildlife Service has in particular played a pivotal role in efforts to reestablish lake trout in the Great Lakes by culturing lake trout in several national fish hatcheries and serving as agents, along with the Department of Fisheries and Oceans Canada, for the control of sea lamprey in the Great Lakes.

In Canada, the federal government assumed primary management authority for Canadian waters of the Great Lakes from 1867 to 1899. The Canadian federal government established the Department of Marine and Fisheries under the Fisheries Act of 1868 (McCullough 1989). In 1885, the Province of Ontario passed a fisheries act similar to the federal legislation in an effort to exert provincial control of the management of fisheries (Province of Ontario 1885). Enforcement responsibility, including licensure of commercial fisheries, was transferred from federal to provincial control in 1899. Responsibility for establishing regulations was disputed until the 1910s, when the federal government agreed to increased provincial input into the formulation of legislation. Currently, the federal Fisheries Act of Canada still provides legislation to protect and conserve fish stocks, but the provincial Fish and Wildlife Conservation Act provides for licensure of Great Lakes commercial fisheries. As in the United States, several agencies of the Canadian federal government are engaged in activities that affect Great Lakes commercial fisheries, including the Department of Fisheries and Oceans Canada and Environment Canada.

Since 1994, the Province of Ontario has contracted with the Ontario Commercial Fisheries' Association (OCFA) to maintain the database of daily catch reports for Ontario licensed commercial fishers. This agreement includes provisions for both data entry and collation. The partnership also includes an agreement that the OCFA will conduct a fall index assessment program for Lake Erie (Roseman et al. 2008) and develop and collect quarterly Royalty billings from commercial fishers. In 2005, approximately 21,500 catch reports were received by OCFA and entered into the Commercial Fisheries Harvest Information System. Maintenance of the database of catch reports by OCFA is considered beneficial to both the commercial fishing industry and the Ontario Ministry of Natural Resources. For the commercial fishing industry, OCFAs maintenance of the database helps keep the industry appraised of harvest in relation to enacted quotas, which helps optimize marketing of commercial fishing products.

Regulatory efforts by Canadian management agencies were initiated earlier, and were generally more restrictive than regulatory efforts by U.S. agencies. The Ontario legislature passed legislation providing for fish passage over mill dams and regulation of fishing methods, seasons, and locations for Atlantic salmon in Lake Ontario tributaries as early as 1828. Additional legislation between 1823 and 1843 regulated cisco fisheries in Burlington Bay, lake whitefish fisheries in the Niagara, St. Clair, and Detroit rivers, and lake trout fisheries in Kent and Essex counties in Lake Erie (McCullough 1989). The passage of the Fisheries Inspection Act of 1840 regulated the quality of fish products packed in Canada. These acts also established a network consisting of a superintendent, fishery overseers, and guardians to enforce fishing regulations.

Management regulations in U.S. waters were not initiated until the mid 1800s. Ohio instituted regulations in 1857 to prevent disruption of natural fish movements in rivers (Woner 1961), while Michigan enacted initial commercial fishing laws in 1865. Initial efforts to coordinate management efforts between U.S. states were made at a meeting of the U.S. Fish and Game Commission in 1883 (Truce 1887). Although the commission meeting resulted in 13 specific recommendations, none of the state legislatures adopted the resulting recommendations.

Licensing and permitting have been used historically to regulate the amount and distribution of commercial fishing activity. The Province of Ontario passed fishery legislation in 1885 that formally instituted a licensing system in Great Lakes waters (Province of Ontario

1885). Before the 1900s, pound net sites were assigned and leased on both the Canadian and U.S. shores of Lake Erie. Michigan began licensing nonresident commercial fishers in 1865 and resident fishers in 1907 (Brege and Kevern 1978), while Ohio initiated licensing in 1906 (Woner 1961). Licensing allowed managers to collect information about commercial landings through mandatory reporting programs and to enforce fishing regulations.

Management agencies have enacted size limits to prevent exploitation of fish prior to the time they reach sexual maturity. Michigan enacted minimum size limits on a regional basis for yellow perch and white suckers as early as 1893, and on a statewide basis in 1897 (Brege and Kevern 1978). In 1922, Ontario instituted minimum size limits on ciscoes, lake sturgeon, blue pike, yellow perch, white bass, freshwater drum, lake whitefish, and lake trout. With the recent shift from gill nets to impoundment gear in many U.S. fisheries, size limits continue to be an important regulatory tool because with impoundment gear undersized fish can be released alive. Size limits are of little utility in regulating fisheries conducted with gear that can cause direct mortality of captured fish (e.g., gill nets, trawls), unless they are accompanied by corresponding gear restrictions (e.g., regulations on mesh sizes, fishing locations, and seasons) and adequate enforcement.

Gear restrictions have been enacted by management agencies to reduce mortality of undersized or unintended species, to reduce competition between fishers and gear types, to reduce the efficiency of the fishery, or to reduce physical damage to habitat by active gear (e.g., seines, trawls). Mesh size was regulated to reduce mortality of undersized fish in seine, pound, gill, and trap-net fisheries as early as 1889 in Michigan (Brege and Kevern 1978) and by 1906 in Ohio (Woner 1961). In Lake Erie, where fishing intensity was greatest, shoreline areas were assigned to specific pound net operations, and regulations limited the distance gill nets could be set from shore (Keyes 1894). Several types of gear, including trap nets, deep trap nets, and bull nets have been prohibited for periods of time because of fears that their efficiency could result in stock depletion. Michigan banned trap nets in 1905, but reinstated their use during the 1920s (Brege and Kevern 1978). Deep trap nets were outlawed in Michigan and Wisconsin waters of Lake Michigan in 1935, Indiana waters of Lake Michigan and Michigan waters of Lake Superior in 1936 (Van Oosten et al. 1946). Trap-net fishing was not permitted in Canadian waters during the early years, but illegal use of trap nets in Georgian Bay was widespread (McCullough 1989).

Trap nets were finally legalized in Canadian waters in 1950, and have since replaced most pound nets on Great Lakes waters (Kennedy 1970).

Gill nets have been banned as commercial gear by some U.S. states as recently as the mid 1990s. Although small-mesh gill nets are still used in some fisheries (e.g., deepwater chub and yellow perch), only Wisconsin and Ontario currently allow the use of large-mesh gill nets. Presently, trap nets are the preferred fishing gear in U.S. fisheries because unintended bycatch can be released alive, and the market value of fish landed with trap nets is greater than for those taken by gill nets. Gill nets are still widely used by Canadian commercial fishers in many areas of the Great Lakes. Gill nets are also widely used by Native Americans and First Nation Aboriginals, because of their efficiency and the low cost to purchase, deploy, retrieve, and maintain this gear.

Management agencies have also instituted closed seasons and refuges for many species to protect spawning aggregations of fish from exploitation. The Canadian government established closed seasons for lake whitefish and lake trout in 1868, although early enforcement of these regulations was lacking. Michigan enacted closed seasons during the winter for lake whitefish to protect spawning populations in the Detroit and St. Clair rivers in 1875, and statewide closures by 1897 (Brege and Kevern 1978). Currently, closed fishing seasons center on the spawning seasons for lake trout and lake whitefish. For example, commercial fisheries for lake whitefish in northern lakes Michigan and Huron are closed for roughly a three-week period during November to protect fish while on their spawning grounds. More recently, a system of refuges was established in lakes Michigan, Huron, and Superior to protect lake trout in known spawning areas from commercial and recreational fishing (Ebener et al. 2008b).

Outright closure of commercial fisheries has occurred occasionally in the Great Lakes. Reasons for such closures have included perceived declines in stock abundance, concerns about possible health effects from commercial fish products, and to reserve harvest for recreational fisheries. Michigan has prohibited commercial harvest of most game species, including black bass, crappie, brook trout, brown trout, rainbow trout, rock bass, bluegill, muskellunge, sturgeon, coho salmon, northern pike, Chinook salmon, blue pike, walleye, sauger, and Atlantic salmon in order to protect recreational harvests (Brege and Kevern 1978). In 1922, Ontario banned the commercial harvest of largemouth bass, smallmouth bass, muskellunge, brook trout, brown trout, and rainbow trout. The Lake Erie walleye commercial fishery was closed during the early 1970s because of mercury contamination in fish. Although this fishery was reopened in 1977, in 1984 the Ohio legislature removed walleye as a commercial species because of its recreational fishery value. In 1962, the commercial fishery for lake trout in U.S. waters of Lake Superior was closed because of low population levels. In 2004, Ontario closed the commercial fishery for American eel in Lake Ontario and the St. Lawrence River because of perceived declines in eel abundance. In 2009, the Ontario Ministry of Natural Resources announced that recreational daily catch limits and commercial quotas for lake sturgeon in Ontario waters of Lake Huron would be reduced to zero on January 1 and July 1, 2009, respectively, because of concerns about the status of some populations, the effects of poaching, and the apparent commercialization of angler-caught and poached fish and roe.

During the early 1970s, many fishery management agencies, particularly in the United States, began to carry out management actions that favored recreational fishing over commercial fishing interests. Closures of commercial fisheries and/or reallocation of fish resources toward recreational fisheries was driven by a number of factors, one of which was the perception that larger economic returns came from recreational fisheries compared to commercial ones. Also, there were stakeholder complaints about bycatch of introduced salmonids in commercial gill nets, and perceived conflicts between commercial fisheries and the effort by international agencies to create recreational fisheries for lake trout, while trying to restore naturally reproducing stocks. In Michigan, limited-entry policies were enacted to limit commercial fishing effort. Wisconsin pursued a similar course of action until the mid 1970s when fisheries managers were redirected to maintain viable commercial fisheries (University of Wisconsin Sea Grant Institute 1988). Michigan and Wisconsin also reduced the areas in which commercial fishing was allowed (Brege and Kevern 1978). During this same period, the Province of Ontario continued to manage resources to promote both recreational and commercial fisheries in most Canadian waters

Recognition and reassertion of tribal fishing rights

Native American tribes and First Nation communities of the Great Lakes basin have been involved in some sort of commercial fishing as early as the 1700s. Kinietz (1940) noted that local tribes and communities would travel to the Straits of Mackinaw to sell or trade freshly caught fish with European traders. At the time of European settlement in North America, tribal and Aboriginal fishers were using gill nets, spears, weirs, and hook-and-line gear to harvest Great Lakes fish (Kinietz 1940). Species harvested for commercial or subsistence use included lake whitefish, lake trout, lake sturgeon, ciscoes, walleyes, and several species of suckers.

Between 1781 and 1854, Native American tribes and First Nation communities in the United States and Canada signed 10 treaties or agreements that ceded lands and Great Lakes waters to U.S., British, and Canadian governments (Minnesota Historical Society 1973). The treaties of 1836, 1842, and 1854 ceded lands and waters of the Great Lakes region to the U.S. federal government, while establishing tribal fishing rights in large areas of the U.S. Great Lakes waters. Among the treaties that were signed between the British and Canadian governments and First Nation communities in what is now the Province of Ontario are the 1836 Surrender of Southern Saugeen and Nawash Territories and the 1854 Surrender of the Saugeen (Bruce) Peninsula. These treaties essentially sold the land and water of the Great Lakes basin to the U.S. and Canadian governments. However, integral to most of the treaties was the guarantee that signatory Native American tribes and First Nation communities could continue to hunt, fish, trap, and gather resources on lands and water ceded to the various governments until the land was required for settlement.

An end result of the treaty process was that Native American tribes and First Nation communities and their associated activities were restricted to reservations created by the treaties. Settlement of the Great Lakes basin after signing of the treaties also severely restricted resource use by tribal and Aboriginal members. Non-tribal and non-Aboriginal commercial fishing operations quickly developed during the mid to late 1800s, and out-competed tribal and Aboriginal subsistence fisheries for available near-shore fish stocks. The Canada Fisheries Act of 1857 was created to manage the expanding non-Aboriginal Great Lakes commercial fishing industry by establishing regulations to protect fish populations. However, the Canada Fisheries Act did not recognize or accommodate Aboriginal fishing rights, subjected Aboriginal fishing activity to licensing, implemented closed seasons and other regulations, and restricted Aboriginal fishing activities to those conducted for domestic consumption. Tribal fishing rights were also restricted in the United States, but there were no federal laws that specifically mandated control over tribal fishing activities. Instead, regulations adopted by state fishery management agencies were imposed on tribal fisheries. Although some tribal members were fishing commercially under state licenses by the mid 1960s, the use of Great Lakes fishing by tribal members was limited.

Fishery management policies of U.S. state agencies began changing during the 1960s, providing the impetus for reassertion of treaty-protected fishing rights in the Great Lakes. Large areas of the Great Lakes were closed to commercial fishing, the number of licenses was reduced, and the use of gill nets was banned by several state agencies. At the same time that restrictions were being placed on state and provincial-licensed commercial fisheries, there was an increased awareness among Native American tribal members of their inherent sovereign rights, and many used the judicial system to reaffirm treaty-reserved fishing rights that were being restricted by changing state management policies. Of key importance to their efforts were the basic canons of construction established by the U.S. Supreme Court in cases dating back to the 1800s, which stated that treaties must be liberally interpreted in favor of Native American tribes (Worcester v. Georgia 1832; Chocktaw Nation v. United States 1886).

Three major court decisions had profound implications for Native American and First Nation Aboriginal commercial and subsistence fishing in the Great Lakes: United States v. Michigan (1979), Lac Court Oreilles Band v. Voight (1983), and Sparrow v. The Queen (1990). These three court decisions facilitated implementation of Native American and First Nation Aboriginal commercial fishing by recognizing tribal and Aboriginal rights to fish free of state or provincial regulation throughout areas ceded to the U.S. and Canadian governments. In United States v. Michigan (1979), which is referred to as the Fox Decision, the federal district court ruled that the Bay Mills, Sault Ste. Marie, and Grand Traverse Band of Ottawa and Chippewa Indians retained rights to fish free of state regulations in waters of lakes Superior, Huron, and Michigan ceded in the Treaty of 1836 (Figure 6). After the Fox Decision, the 6^{th} Circuit Court of Appeals further stipulated that the State of Michigan retained the right to regulate the tribal fishery in the event the State could prove tribal fishing activities were depleting the resource. In Lac Court Oreilles Band v. Voight (1983), the federal district court ruled that tribes signatory to the treaties of 1837 and 1842 retained the right to hunt, fish, trap, and gather resources outside of reservation boundaries in areas that now encompass parts of Minnesota, Wisconsin, and Michigan. In Sparrow v. The Queen (1990), the Canadian Supreme Court recognized the right of First Nation communities to fish for food and ceremonial purposes. Although the Sparrow Decision did not directly take up the issue whether Aboriginals had a right to fish commercially, the principles laid out in the Sparrow Decision were directly applicable to commercial fishing (Allain and Fréchette 1993). The Sparrow Decision also reminded the governments that they are held to a high standard in their dealings with Aboriginals and must be liberal and generous; it also provided a two-part test for ensuring that laws have due regard for Aboriginal rights. The two-part test of the Sparrow Decision asked, “Does the legislation infringe on an Aboriginal right, and is the infringement as reasonable and limited as possible?”

Prior to the Fox and Voight decisions, there were lower court rulings in the United States that also reaffirmed the existence of treaty-reserved fishing rights in the Great Lakes. However, these decisions addressed treaty rights in areas within or adjacent to reservation boundaries, and not the much broader off-reservation rights addressed in the Fox and Voight decisions. In People v. Jondreau (1971), the Michigan Supreme Court held that treaty fishing rights existed in Lake Superior waters in Michigan within the boundaries of the Keweenaw Bay Indian Community Reservation. In State v. Gunroe (1972), the Wisconsin Supreme Court found that the Red Cliff Band of Lake Superior Chippewas retained the right to fish commercially and for subsistence in Lake Superior waters adjacent to the band’s reservation. In People v. LeBlanc (1976), the Michigan Supreme Court supported the existence of treaty fishing rights in Michigan water of Lake Superior near the Bay Mills Indian community reservation.

Management of Tribal and First Nation Fisheries in the United States and Canada

Central to the exercise of treaty rights by Native American tribes and First Nation communities is the premise that along with the right to harvest the resource comes the responsibility of protection and management of the resource. Both U.S. and Canadian courts have recognized the authority of state, provincial, and federal governments to regulate the exercise of treaty fishing rights, and have generally required tribes and communities to show that commercial fishing activities were taking place at the time of the treaty for the commercial fishing rights to exist (Jannetta 1991). Regulation of treaty fishing rights by non-tribal and Aboriginal governments is permitted if the regulations do not discriminate against tribal and Aboriginal fisheries and are in the best interest of protecting the fishery resource. Since the basic philosophy of using Great Lakes fishery resources differs between state/provincial and tribal/Aboriginal governments, it is in the best interest of Native American tribes and First Nation communities to regulate their commercial fisheries.

Management of tribal commercial and subsistence fisheries in U.S. waters of the Great Lakes has been promulgated through inter-tribal agreements, state and tribal governments, federal governments, and court-sanctioned agreements or decrees. After the Fox Decision in 1979, regulations governing the tribal fisheries in the 1836 treaty-ceded waters of lakes Superior, Huron, and Michigan (Figure 6) were adopted by the U.S. Department of Interior. In 1981, the Secretary of the Interior allowed the federal rules to expire, which otherwise would have resulted in tribal commercial and subsistence fishing activities being regulated by the State of Michigan. In response, three Native American tribes, the Bay Mills Indian Community, Sault Ste. Marie Tribe of Chippewa Indians, and the Grand Traverse Band of Ottawa and Chippewa Indians, created the Chippewa/Ottawa Treaty Fishery Management Authority (COFTMA) to regulate commercial and subsistence fishing activities by tribal members in 1836 treaty-ceded waters. COFTMA regulations were approved by federal District Court in 1981.

The question of how fishery harvest should be allocated between COFTMA member tribes and the State of Michigan came to a head during the early 1980s. During this period, confrontations between tribal commercial fishers, state licensed commercial fishers, and recreational anglers were common (Ebener et al. 2008b). In 1985, COFTMA member tribes, the State of Michigan, and the U.S. government negotiated a 15-year agreement that addressed the allocation of fishery resources within the 1836 treaty-ceded waters. The agreement provided for tribal-managed commercial fisheries within portions of the treaty-ceded waters of lakes Michigan, Huron, and Superior. The negotiations resulted in the implementation of a comprehensive Consent Decree in 1985, which was instituted by U.S. Federal District Court despite objections by one of the tribes (United States v. Michigan 1985). As part of the 1985 Consent Decree, 1836 treaty-ceded waters were divided into state-commercial, tribal-commercial, and recreational fishing zones. As a result of this agreement, it was necessary for some state-licensed commercial fisheries to be bought out by the state to accommodate tribal-commercial fishing. Other state-licensed operations were relocated to other areas of the lakes. Additionally, a Technical Fishery Review Committee (TFRC) was established that was composed of representatives from COFTMA, U.S. Fish and Wildlife Service, and Michigan Department of Natural Resources. The TFRC was tasked with compiling an annual report outlining the status of fish stocks in 1836 treaty-ceded waters and establishing total allowable catch (TAC) levels for lake whitefish in each management unit of the ceded area. Although

TACs were estimated annually from 1986 to 1991, they were never enforced (TFRC 1992; Ebener et al. 2008b).

In May 2000, the 1985 Consent Decree expired. Renegotiation of the Consent Decree had begun several years prior to the expiration, and in August 2000 a new Consent Decree was signed by COFTMA, U.S. Fish and Wildlife Service, and Michigan Department of Natural Resources representatives (United States v. Michigan 2000). The new decree was set to be in force for 20 years. As part of the 2000 Consent Decree, the TFRC was reorganized into a Technical Fisheries Committee (TFC) that was to be the primary body for consultation and collaboration on biological issues within 1836 treaty-ceded waters. The TFC was tasked with updating fish population models to be used for setting harvest limits and to act as a forum for development and review of harvest limits and effort-based management issues. The 2000 Consent Decree additionally stipulated explicit data sharing avenues and timelines for submitting annual harvest limits and the exchange of fishery yield, effort, and biological data among biologists charged with estimating annual harvest limits (Ebener et al. 2008b). As part of the 2000 Consent Decree, COFTMA was reorganized into the Chippewa-Ottawa Resource Authority (CORA) as a result of two newly recognized tribal governments (Little Traverse Bay and Little River Bands of Chippewa Indians) being added to the agreement. The 2000 Consent Decree differed from the 1985 Decree in that it mandated an allocation of fish resources between the tribes and the State of Michigan. Parties to the Decree agreed that total available fish harvest from the 1836-ceded waters was to be divided equally between the tribes and state, but that the allocation did not have to be divided equally among species (Ebener et al. 2008b).

Management of tribal fisheries in the 1842 treaty-ceded waters of Lake Superior (Figure 6) has been less organized than management in the 1836 treaty-ceded waters. Following the Voight Decision in 1983, three Native American tribes developed annual inter-tribal agreements which were designed to govern commercial fishing activities by members of the tribes in Michigan waters of the 1842-ceded territory of Lake Superior. The State of Michigan was not included in the development of the inter-tribal agreements in the 1842 treaty-ceded waters, and there has been no specific judicial resolution or allocation of resources between tribal and non-tribal fisheries in the 1842 treaty-ceded waters. Michigan attempted to gain management authority over tribal fisheries in the 1842 treaty-ceded waters during the mid 1980s by petitioning the U.S. Federal government to impose state promulgated regulations over treaty fisheries. This attempt was unsuccessful as the federal government supported the contention of the three tribes that the inter-tribal agreement contained sufficient regulations to protect the fishery resources.

Management of tribal commercial and subsistence fisheries within Wisconsin waters of Lake Superior has been established through tribal initiatives and negotiated settlements. Subsequent to the Gunroe Decision in 1972, the Red Cliff Band held informal discussions with staff members of the Wisconsin Department of Natural Resources regarding tribal commercial and subsistence fishing activities in Lake Superior waters adjacent to the reservation. Tribal members were generally adhering to fishing regulations already governing the state-licensed commercial fishery during the time. The informal discussions broke down during the late 1970s after a tribal member was arrested for harvesting walleyes in a tributary to Lake Superior. As a result, in 1979 the Red Cliff Band developed the first fishery regulations and court system to govern tribal member fishing rights in the Great Lakes. The tribe subsequently negotiated a 5-year fishery management agreement with the Wisconsin Department of Natural Resources in 1981. In 1986, the Red Cliff Band, along with the Bad River Tribe, negotiated a 10-year fishery management agreement with the State of Wisconsin, which allocated lake trout populations and fisheries in the Apostle Islands area of Lake Superior to the tribes. The management agreement was modified in 1993 to address issues related to limiting the amount of gill net that could be set and the harvest of lake trout. A third agreement among the three governments was reached in 1996, which maintained the lake trout refuges and restricted areas from the earlier agreements, but which also addressed enforcement and joint monitoring of commercial catches. The 1996 agreement additionally laid out an approach for ensuring that lake trout quotas were not exceeded and also called for the establishment of a biological committee, whose primary responsibility was to estimate harvest limits for lake trout for the Lake Superior management unit surrounding the Apostle Islands. In 2006, a fourth agreement among the three governments was reached. As part of the 2006 agreement, the biological committee was asked to develop statistical catch-at-age models for lake whitefish stocks to help in determining health of lake whitefish populations and the sustainability of current harvest levels (Ebener et al. 2008b).

In 1988, tribal fishing rights in Minnesota under the 1854 treaty were reaffirmed by agreement between the Grand Portage Bay of Chippewa Indian and the State of Minnesota (Hansen et al. 1995). The agreement defined the on-reservation fishing zone in Lake Superior, allocated 12.25 mt of lake trout annually to the Grand Portage tribe, created a season when harvest of lake trout was prohibited, and called for mandatory reporting of catches and licensing of the fishery. In exchange, non-tribal commercial fishing was prohibited in Grand Portage Bay, and tribal members were allowed to take lake trout from the bay with any gear and at any depth (Hansen et al. 1995).

Currently, management of tribal commercial and subsistence fisheries within U.S. waters of the Great Lakes is facilitated through two inter-tribal agencies: CORA and GLIFWC. As previously discussed, CORA directly manages the tribal fishery in the 1836 treaty-ceded waters of lakes Superior, Michigan, and Huron. GLIFWC is an organization of 11 Ojibway tribes, but has no direct management control over Great Lakes fisheries. Instead, GLIFWC serves as an advisory organization providing technical, legal, and enforcement capabilities to tribes involved in fishing issues. Both CORA and GLIFWC have administrative, biological, enforcement, and public information branches. CORA also supports a judicial system for adjudicating regulation violators.

Despite the formation of inter-tribal regulatory bodies, nearly all fishery management decisions are made by individual tribes. Every tribe involved with fishing on the Great Lakes possesses an internal structure for managing the fisheries. The Grand Portage, Red Cliff, Bad River, Keweenaw Bay, Bay Mills, Sault Ste. Marie, Grand Traverse, Little Traverse Bay, and Little River tribes have all formed conservation committees where fishing-related issues are first discussed and generally approved or denied. Ultimate regulatory authority, however, lies with the individual tribal governments. Fishery management recommendations are typically passed on from the conservation committees to the respective tribal government that posses the ultimate regulatory authority over its members. In the case of CORA, issues pass from the conservation committees to the tribal government, and finally to CORA, which may or may not adopt a joint regulation or management strategy. CORA member tribes can adopt more stringent regulations that govern only members of their particular tribe, but they cannot adopt more lenient regulations.

Although the existence of treaty fishing rights in Canadian waters of the Great Lakes was only recently acknowledged through the Sparrow Decision, during the 1970s and 1980s, unsuccessful negotiations occurred between the federal and provincial governments and First Nation communities concerning fishing rights (Notzke 1994). Following the Sparrow Decision, an Ontario Court in 1993 ruled in that members of the Saugeen Ojibway, which is composed of the Chippewas of Nawash Unceded First Nation and Saugeen First Nation, had a well-established right to fish commercially under the treaties of 1836, 1854, and 1862 along the eastern shores of the main basin of Lake Huron on the Bruce Peninsula (R. v. Jones 1993). This court ruling further stipulated that fishing rights of the Saugeen Ojibway were higher in priority than rights of provincial licensed fisheries. As a result, the court stipulated that the Saugeen Ojibway should be allowed to participate in developing a fisheries resource allocation plan (Allain and Fréchette 1993).

Following the Jones decision, the Saugeen Ojibway and the Province of Ontario attempted to reach an agreement over allocation of fishery harvest around the Bruce Peninsula and co-management of fishery stocks. In June 2000, an interim 5-year allocation and co-management agreement was achieved. The agreement included provisions for how data should be exchanged between Saugeen Ojibway and the Ontario Ministry of Natural Resources, mechanisms to calculate TACSs, and how breaches in the agreement should be addressed. A second 5-year agreement between the Saugeen Ojibway and the Province of Ontario was reached in 2005. As part of the 2005 agreement, all lake whitefish in the area around the Bruce Peninsula were allocated to the Saugeen Ojibway, with Saugeen Ojibway also being responsible for monitoring harvest through commercial catch sampling. As a result, quotas for lake whitefish from non-Aboriginal fishers were bought out by the Province of Ontario and reallocated to the Saugeen Ojibway.

The Province of Ontario has developed several formal partnerships with First Nation communities to foster interest in ensuring sustainable commercial or subsistence fishery resources. For example, in 1993 Ontario entered into an agreement with the Union of Ontario Indians, which is a political organization that represents 42 First Nations throughout Ontario. This agreement between the Province of Ontario and Union of Ontario Indians resulted in the creation of the Anishinabek/Ontario Fisheries Resource Center (AOFRC), which acts as an independent center for fisheries assessment and management, and reports on such things as stock status, and stresses to fish populations. The AOFRC also offers management recommendations and facilitates information sharing among Ontario First Nations and the Ontario Ministry of Natural Resources.

International Coordination

Early attempts to coordinate fisheries management in the Great Lakes failed to produce tangible results. The first initiative occurred as early as 1892, when Canada and the United States established an international fishery commission to investigate overfishing, pollution, the establishment of closed seasons for the fisheries, and the stocking of fish in border waters. This committee recommended establishment of a joint commission with the authority to regulate the international fisheries in the Great Lakes by establishing uniform regulations for both U.S. and Canadian waters. Although a draft treaty was signed in 1908, the U.S. House of Representatives refused to approve the treaty (Piper 1967). During the early 1940s, the United States and Canada convened a Board of Inquiry to investigate the current state of fisheries management on the Great Lakes (Gallagher and Van Oosten 1943). Recommendations from this board produced a treaty signed in 1946 that established an international commission to formulate common fishery regulations for the Great Lakes (Great Lakes Fisheries 1946). The states of Wisconsin and Ohio passed resolutions in objection to the treaty, and the treaty was never ratified.

Finally, in 1954, as a result of severe declines in lake trout and lake whitefish stock abundance, the United States–Canada convention on Great Lakes fisheries led to a ratified agreement for bilateral collaboration on the protection and perpetuation of the Great Lakes' fisheries resources. The key to the success of this agreement was that the regulatory authorities were retained within the state management agencies as opposed to delegating those authorities to an international body (Dochoda and Jones 2002). As part of this agreement, the United States and Canada agreed to establish the Great Lakes Fishery Commission (GLFC). The duties of the GLFC included the developing coordinated programs of research in the Great Lakes, and, on the basis of the findings, recommending measures that would permit the maximum sustained productivity of stocks of fish of common concern. The GLFC also was tasked with forming and implementing a program to eradicate or minimize sea lamprey populations in the Great Lakes.

As part of a "study and advise" mandate in the convention, the commission was also encouraged to play a coordinating role for the agencies (Dochoda and Jones 2002). In 1981, fishery management agencies in the Great Lakes basin and the GLFC adopted a Joint Strategic Plan for the Management of Great Lakes Fisheries as a mechanism for facilitating cooperative management of Great Lakes fisheries (GLFC 1994). This Joint Strategic Plan has been renewed twice, most recently in 1997. Current signatories of the plan include all state (Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, Wisconsin) and provincial fishery management agencies (Ontario) bordering the Great Lakes, CORA, GLIFWC, U.S. National Oceanic and Atmospheric Association, U.S. Fish and Wildlife Service, U.S. Geological Survey, and Fisheries and Oceans Canada.

Management decisions are made on a consensus basis through separate Lake Committees for each of the Great Lakes The Lake Committees consist of representatives from each state, provincial, and inter-tribal fishery management agency surrounding the respective lakes. While Lake Committees were developed prior to the Joint Strategic Plan, their roles in identifying and resolving management problems were formalized and strengthened as part of the plan. Lake Committee tasks include the consideration of issues and problems of common concern to member agencies; the development and coordination of joint programs and research projects; and the consideration of issues pertinent to, or referred by, the GLFC. To address basin-wide issues or initiatives and for setting priorities regarding research and sea lamprey control issues, the Lake Committee representatives from all the lakes combined form the Council of Lake Committees, which is a unifying body for all Great Lakes Fisheries management (Dochoda and Jones 2002). The Joint Strategic Plan also provides for mechanisms of dispute resolution when consensus is unachievable (Dochoda and Jones 2002).

Each Lake Committee is supported by a Technical Committee that is composed of scientific experts. While formal membership is for personnel from those agencies signatory to the Joint Strategic Plan, informal members also contribute, including subject-area experts, who participate at the request of the Technical Committee. These committees provide the scientific basis for policy and management decision making for the Great Lakes fisheries (Dochoda and Jones 2002).

During the late 1980s and early 1990s, Lake Committees developed objectives for managing fish communities of each lake (Busiahn 1990; Kerr and LeTendre 1991; DesJardine et al. 1995; Eshenroder et al. 1995). The fish community objectives for lakes Ontario, Superior, and Erie have been updated once since then (Stewart et al. 1999; Horns et al. 2003; Ryan et al. 2003). Fish community objectives for the lakes address habitat management, sea lamprey control, introduced species, stocking of hatchery-reared fish, and establishment of goals for the structure of fish communities. Goals for each species, or groups of species, typically focus on harvest targets that incorporate some expectation of future yields based on historic harvests over a previous, stable time period (Bushian 1990; DesJardine et al. 1995; Eshenroder et al. 1995).

The Lake Erie Committee (LEC) is unique from other Lake Committees in that one of the tasks it performs annually is the determination of lakewide allowable harvests for walleye and yellow perch, which it accomplishes based on recommendations from its Walleye and Yellow Perch Task Groups. Achieving bi-national consensus on walleye and yellow perch status has been an LEC task since the early 1970s when the Scientific Protocol Committee (SPC) for Lake Erie was first established. In 1977, the SPC was succeeded by the Standing Technical Committee, which formed the Walleye and Yellow Perch Task groups for the purpose of refining TAC calculations (Knight 1997). Prior to 1977, the various Lake Erie jurisdictions set their own catch limits for walleye and yellow perch. Bi-national consensus-based TACs were first set for walleye in 1977 and for yellow perch in 1993. This unique aspect of the LEC evolved as a result of differences in focus between the U.S. and Ontario fishery management agencies on commercial and recreational fisheries and the desire to obtain consensus among the jurisdictions on responsible management strategies for the fisheries (Koonce et al. 1999; Roseman et al. 2008).

Decision Making Policies for Setting Commercial Fishing Allocations

Given the number of political jurisdictions and stakeholder types with vested interest in Great Lakes fish stocks, the potential for conflicts among competing interests is high. As a result, decision processes regarding allocation to different jurisdictions and stakeholders are important to prevent conflicts and to prevent overharvest from occurring. Across the lakes, there are several different approaches used to determine harvest levels and the different fractions of the catch to be allocated to commercial, recreational, state-licensed, provincial-licensed, or tribal-licensed fishers. In some cases, commercial harvest is limited simply by regulation of commercial fishing effort. In other cases, commercial harvest is evaluated based on statistical models that project stock abundance in the future and implement explicit harvest policies that govern fishing effort at certain population levels. Herein, we describe a few of the approaches that are used in making harvest allocation to provide a sense of how decisions are made that affect Great Lakes commercial fisheries.

Lake Whitefish and Lake Trout in 1836 Treaty-Ceded Waters

As part of the 2000 Consent Decree agreement between CORA, the Michigan Department of Natural Resources, and the U.S. Fish and Wildlife Service for 1836 Treaty-Ceded Waters in Michigan, the TFC was created and tasked with developing and updating fish population models to be used for setting harvest limits and harvest regulation guidelines for lake whitefish and lake trout (United States v. Michigan 2000). The actual job of developing and updating these population models falls to the Modeling Subcommittee (MSC), which was created under the auspices of the TFC. The MSC uses statistical catch-at-age (SCAA) models to estimate year- and age-specific population abundance and mortality rates for lake trout and lake whitefish in ceded areas (Woldt et al. 2007). SCAA modeling is a sophisticated, non-linear statistical modeling method for forward projection of age-specific abundances using fishery dependent and fishery independent data sources. SCAA models can be very complex, involving the estimation of more than 100 parameters. The MSC uses SCAA models to predict age-specific population abundances of lake whitefish and lake trout for the current year. These age-specific abundance levels are then projected into the future using recent estimates or future predictions of fishing, sea lamprey induced, and natural mortality rates (Sitar et al. 2007).

For lake trout stocks, harvest limits are based on a target annual mortality rate of either 40 or 45% depending on which management unit is being considered. That means that the combination of recreational fishing mortality, commercial fishing mortality, natural mortality, sea lamprey mortality, and bycatch mortality cannot exceed these values in any given year, unless all parties agree that the target mortality rate should be changed.

Within 1836 Treaty-Ceded Waters, lake trout are allocated approximately equally between the State of Michigan and the Tribes. However, the precise allocation varies from one management unit to the next. For example, in one management unit, the tribes are allocated 88% of the available harvest, while Michigan is allocated the remaining 12%. In another management unit, the tribes are allocated 5% of available harvest, while Michigan is allocated 95%. The 2000 Consent Decree includes a stipulation that harvest limits from one year to the next shall not be adjusted by more than fifteen percent (15%) in either direction unless all parties agree that a greater change is needed. This stipulation was intended to prevent large changes in allocated catches from year to year in order to provide some stability in harvests for the commercial and recreational fisheries.

Lake whitefish harvest in shared management units is also regulated with a target annual mortality rate; however, for lake whitefish harvest limits are based on allowing a maximum of 65% total annual mortality. Harvest limits for lake whitefish are determined on an annual basis using data that lag by 2 years from the upcoming quota year. For example, TACs for 2009 were determined using data collected through 2007. Tribal commercial fishers are allocated the majority of harvest in the shared management units of the 1836 Treaty-Ceded Waters. The amount allocated to state-licensed commercial fishers ranges from 10 to 45%. However, the 2000 Consent Decree additionally stipulates that if no state-licensed commercial fishery participates in the fishery in a shared management unit, then the entire harvest limit will be allocated to tribal fishers.

In shared management units, deviations between actual harvests and established limits are calculated each year for both state-licensed and tribal fishers. Enforcement actions would be triggered for a particular management unit if actual harvest for either party exceeded the established limit by 25%, either on the basis of a single year or for a running 5-year average. In these circumstances, the following year's allocation to the offending party would be reduced, and the allocation to the non-offending party would be increased by the number of pounds by which the harvest limit was exceeded. The offending party would also be required to initiate corrective management action to prevent future over harvest of stocks (Ebener et al. 2008b).

Walleye and Yellow Perch in Lake Erie

Walleye and yellow perch allowable harvests in Lake Erie are established by the LEC based on recommendations from the Lake Erie Standing Technical Committee and the Walleye (WTG) and Yellow Perch (YPTG) Task Groups. The WTG presently uses SCAA modeling to predict year- and age-specific population abundances and mortality rates for walleye primarily located in the western and central basins of Lake Erie. These are the primary populations of interest as they provide most of the benefits to users throughout Lake Erie. Presently, the SCAA model for western and central basin walleye stocks uses data from a number of sources to predict abundance, including recreational fishery data from Ohio and Michigan, commercial fishery data from Ontario, and fishery-independent assessment data from Ohio, Ontario, and Michigan (WTG 2008). Predictions of abundance from the SCAA model are combined with predictions of age-2 walleye recruitment levels, which are estimated from a linear regression model that uses estimates of age-2 walleye abundance from the SCAA model and catches of young-of-year walleye from Ontario and Ohio fishery independent surveys as independent variables (WTG 2008).

Allowable harvest for Lake Erie walleye is presently set using an abundance dependent fishing mortality control rule referred to as the "sliding-*F* harvest policy," which is a feedback approach that varies targeted fishing mortality rates in relation to projected population abundance of age-2 and older fish. The policy stipulates that when walleye abundance is below 15 million fish, targeted fishing mortality rate should be F=0.1. When walleye abundance is between 20 and 40 million fish, targeted fishing mortality rate ranges from F=0.20 to F=0.35. At abundances greater than 40 million fish, targeted fishing mortality is capped at F=0.35 (Locke et al. 2005). The primary advantages of using a feedback approach such as the sliding-*F* harvest policy are that it allows the fishery to safely exploit the resource when abundance is high and it reduces exploitation rates during periods of lower population abundance (Wright et al. 2005).

The sliding-*F* harvest policy was evaluated along with several policies using a walleye biological simulation model (Wright et al. 2005), that explicitly took into account key uncertainties regarding walleye stock and fishery dynamics. Key areas of uncertainty for the modeled fishery included catchability, selectivity at age, current abundance, stock size-recruitment relationship, and angler effort-abundance relationship (Wright et al. 2005). The simulation model used measured levels of uncertainty for these variables in evaluating the effects of the different harvest policies on long-term sustainability of the Lake Erie walleye by projecting their population status 50 years in the future (Wright et al. 2005). Performance measures used to evaluate the different policies included the average population abundance over time, percent of time the population was below target levels (15 million and 25 million walleyes were used as thresholds), percent of time the population remained below a target threshold for three or more years, and average commercial and recreational harvests over time. Based on this evaluation, the LEC ultimately selected the sliding-*F* harvest policy for setting allowable harvest of Lake Erie walleyes because simulations indicated that enacting this policy would enable older walleyes to survive and migrate in sufficient numbers to support central and eastern basin fisheries, and it also would create a broad and consistent distribution of benefits throughout the lake (Wright et al. 2005).

Allowable harvest recommendations for Lake Erie yellow perch follow similar procedures as for walleye. Statistical catch-at-age modeling is used to predict year- and age-specific abundances of yellow perch and regression modeling is used to predict future recruitment of age-2 yellow perch based on collection of young-of-year fish from fishery independent trawl surveys (Roseman et al. 2008). Whereas the WTG uses a sliding-*F* harvest policy to determine allowable harvest, the Lake YPTG presently has no pre-determined harvest policy for the four yellow perch management units. A yellow perch management plan that would include harvest control rules for each management unit is currently under development (YPTG 2006, 2007, 2008). Presently, the YPTG uses catch-at-age simulations to assess ecological risk and inform allowable harvest recommendations for Lake Erie's yellow perch management units. This risk-simulation approach has been used since 2003, and uses a calculated stock-recruitment relationship for Lake Erie yellow perch along with estimates of population abundance and estimates of environment factors affecting the stock-recruitment relationship to assess risks associated with different levels of exploitation on yellow perch stock (YPTG 2003). Predictions of spawner biomass, survival rates, and the probability of having undesirably low levels of yellow perch abundances comparable to those estimated in 1993 and 1994 are used to evaluate the risks of different target fishing mortality rates and corresponding harvests.

Once the LEC has considered the WTG and YPTG recommendations, the committee members reach consensus on lakewide allowable harvests for walleye and yellow perch in Lake Erie, and the harvest is apportioned to individual states and provinces based on the amount of lake surface area (for yellow perch) and available habitat (for walleye) in their jurisdictional waters. For example, in 2008, Michigan, Ohio, and Ontario received 9.1, 50.31, and 40.58% of the allowable harvest of yellow perch from management unit MU1, which is the furthest west management unit of the lake. Until the early 1990s, the Ontario commercial gill-net fleet harvested the majority of the yellow perch caught in Lake Erie (YPTG 1993). Due to differences between jurisdictions regarding the appropriate sharing of the lake-wide TAC, the yellow perch TAC-sharing formulas have changed over the years with a phased approach leading to the final percentages adopted in 2007 (YPTG 2007).

The various U.S. states and province of Ontario make their own decisions as to how their yellow perch and walleye allocations will be divided among recreational and commercial fishers. Presently, the U.S. states allocate most of their harvest to recreational fisheries, while Ontario allocates all of its walleye and yellow perch quota to the commercial fishery due to limited recreational harvest. In Ohio, commercial fishing for walleye is illegal, thus all walleye harvest is allocated to the recreational fishery. For yellow perch, Ohio's allocation to the commercial fishery depends on the projected status of the population. When the abundance of age-2 and older yellow perch in the three westernmost management units (Management Units 1-3) is estimated at greater than 100 million fish, the yellow perch population is considered in Maintenance mode and the commercial fishery is allocated 35% of Ohio's total yellow perch quota. When the abundance of age-2 and older fish is estimated at between 25 and 100 million fish, the population is considered in Conservation mode and the commercial fishery is allocated 30% of Ohio's total yellow perch quota. When the yellow perch population is estimated at less than 25 million age-2 and older fish, the population is considered in Rehabilitation mode and the commercial fishery is allocated 10% of Ohio's total yellow perch quota. This quota allocation strategy of Ohio's was developed based upon several principles, including the desire to maintain healthy stocks of yellow perch in all management units, the effectuation of science-based management of Lake Erie resources, the achievement of quota compliance in all management units, the reduction of commercial fishery bycatch, and the implementation of Policy 2 of the Ohio Department of Natural Resources Division of Wildlife which states that recreational anglers will be afforded the first opportunity to take the harvestable portion of Lake Erie's fish populations. The advantages of using these allocation percentages are that they result in guaranteed allocation to the commercial fishing industry and they permit the Ohio Department of Natural Resources some flexibility in distributing commercial quota among its management units, which helps ensure that quotas are not exceeded (Jeff Tyson, Ohio Department of Natural Resource, personal communication).

Saugeen Ojibway Decision Analysis and Adaptive Management

Co-management of the commercial fisheries in Saugeen-Ojibway waters of Lake Huron off the Bruce Peninsula began in 2000 after a tri-partite Fishing Agreement was reached between the Saugeen-Ojibway, Fisheries and Oceans Canada, and the Province of Ontario. Presently, all lake whitefish in the area around the Bruce Peninsula are allocated to the Saugeen-Ojibway, with the tribes being responsible for monitoring harvest through commercial catch sampling. Commercial fishing TACs for Saugeen-Ojibway waters are decided upon by the Saugeen

Ojibway Nation Territories Joint Council based on recommendation from Nawash Fisheries Assessment Biologists.

The Saugeen-Ojibway advocate the use of a Decision Analysis and Adaptive Management (DAAM) approach to make decisions about allowable harvest in their management waters of Lake Huron. Decision analysis is a specific form of decision making that explicitly takes into account key uncertainties as quantitative variables to evaluate the effects of various management options (Morgan and Henrion 1990; Peters and Marmorek 2001). Decision analysis recognizes the existence of multiple competing hypotheses about the ‘state of nature’ (i.e., the condition of the world). These variable states of nature lead to the recognition of different possible outcomes for each management option being considered (Peterman and Anderson 1999). While decision analysis allows for complex problems to be reduced to smaller more manageable components, which can be re-assembled after analysis (Peterman and Peters 1998), it also provides the ability to rank management options on the basis of stakeholder satisfaction, expected value, and ultimately to determine the management option that has the best overall performance, over a range of hypothesized responses to management actions (Peters and Marmorek 2001).

Adaptive management views all management actions as an opportunity to learn about the system in order to improve future management decisions. In this sense, every key uncertainty in management becomes a learning opportunity (Grumbine 1994; Murray and Marmorek 2003). Five key uncertainties have been identified regarding lake whitefish populations in Lake Huron as they relate to management decision-making about data analyses, interpretation, and harvest level determination (Crawford et al. 2001). Uncertainties pertaining to the distribution of lake whitefish populations in Lake Huron, the formation and ongoing maintenance of a lakewide commercial fishery database, the development of retroactive conversion factors for different measures of gillnet effort, the validation of age estimates for harvested lake whitefish populations, and the development of age-structured models, based on validated age estimates, for use in generating testable predictions of population response to alternate harvest strategies were specified (Crawford et al. 2001). Since 2000, the Saugeen-Nawash Nation has used a discrete form of the Schaeffer biomass production model for assessing the status of lake whitefish stocks and for projecting how stocks will respond to different levels of harvest. The Schaeffer biomass production model includes quantities such as population carrying capacity, intrinsic rate of population growth, biomass at time *t*, and catch at time *t* to estimate biomass of the fishery in the future. Risk of population collapse can be evaluated by varying scenarios in terms of catch and state of the fishery (Harford et al. 2006).

Beginning in 2007, the Saugeen Nawash began modeling the biomass production model from a Bayesian state-space perspective, which allowed the incorporation of parameter, process, and observation uncertainty during the model fitting process. Consequences of alternative TACs for Saugeen Nawash commercial fisheries are projected forward under different population and management scenarios for up to 10 years. Performance of different harvest strategies are evaluated in terms of how close the strategy is to attaining a target population size and surplus production level while minimizing the risk of population collapse. Total allowable catches that minimize risk of population collapse and come close to attaining a target population size get presented to the Saugeen Ojibway Nation Territories Joint Council for consideration.

Wisconsin and Ontario Individual Transferrable Quotas

Both the Wisconsin Department of Natural Resources and the Ontario Ministry of Natural Resources manage commercial fisheries through Individual Transferrable Quotas (ITQs). Individual transferrable quotas are market-based allocation systems that assign individuals or enterprises the privilege or right to harvest specified shares of the TAC for a species (McKay et al. 1995). Individual transferrable quotas are a recent innovation in the field of fisheries management, having been first proposed during the 1970s, but have become increasingly common as a commercial fishery management tool particularly for marine systems (Branch 2008). Arnason (2005) estimated that 10% of worldwide marine harvest is managed through an ITQ system. Ontario implemented a province-wide ITQ system for its commercial fisheries in 1984. In Wisconsin, the first individual quotas were to lake trout commercial fishers in Lake Superior during the 1970s (Anderson and Leal 1995). The Wisconsin Department of Natural Resources also uses ITQs to manage part of the Lake Michigan bloater and lake whitefish commercial fisheries. Ninety percent of the bloater TAC is assigned to ITQs, while the remaining ten percent is left to a common-property fishery (Anderson and Leal 1995).

A major feature of ITQs is that quota shares can be bought, sold, leased, or inherited among fishers. Thus, quota shares are considered a quasi-form of private property. However, it is important to note that this ownership extends only to the quota share, and not to the resource itself. In Ontario, quota shares have been purchased from provincial fishers by the Province of Ontario and allocated to First Nation governments to accommodate Aboriginal fisheries (Ebener et al. 2008b). In Wisconsin, there are some limits on quota transfers. Leases or sales of quotas in some cases must be approved by the Wisconsin Department of Natural Resources and Lake Michigan or Lake Superior Commercial Fishing Board (Anderson and Leal 1995).

Purported advantages to managing commercial fisheries through ITQs include the reduction of overexploitation, promotion of conservation, improvements in market conditions, and promotion of commercial fisher safety. Individual transferrable quotas are believed to promote conservation because individual fishers have a vested interest in ensuring long-term sustainability of the resource (Branch 2008). As stock productivity and TACs increase, so does the allowable harvest of individual fishers. Some criticisms of ITQs include that they can concentrate power within a few individuals (i.e., quota landlords) who can then unduly influence market condition, reduce opportunity for new fishers, and encourage “high-grading” where fish of lesser-value are simply discarded (Copes 1986; McCay et al. 1995). Ebener et al. (2008b) describes how the value of individual lake whitefish changes based on body weight; they note that a “jumbo” lake whitefish may command as much as 20 cents to 1 dollar more per pound than a “medium” lake whitefish at the time of processing. Under such a pricing scenario, there may be greater incentive for commercial fishers to discard smaller lake whitefish in favor of catching larger and more valuable fish. Individual transferrable quotas can also be inefficient for multi-species fisheries, especially in cases where quota species (e.g., walleye) are caught as bycatch in gear targeting non-quota species (e.g. white bass). Low quotas for the bycatch species may reduce targeted effort and landed value for the non-quota species. It can also increase incentive for commercial fishers to discard bycatch in order to keep catching more non-quota species.

Coming to an agreement on how catch will initially be allocated is one of the largest difficulties in implementing an ITQ system (McCay et al. 1995). From a general standpoint, a number of factors can be considered when determining quota share, including catch history and capital investment. There is also growing interest in developing initial allocation formulas that reflect factors other than historic catch record, such as the fisher’s compliance with fishery regulations, use of "clean" fishing techniques and historic participation even if current catches are relatively small (Buck 1995). When Wisconsin switched to an ITQ system for its commercial fisheries, individual fisher shares were calculated based on a percentage of yields in recent years (Anderson and Leal 1995). Past performance also was a basis in setting individual fisher shares when Ontario switched to an ITQ system (Cowan and Paine 1997).

With ITQ systems, the task of setting TACs remains a governmental responsibility. In Wisconsin, TACs are set by the Natural Resources Board, which is a seven-member, governor-appointed panel that sets policy for the Wisconsin Department of Natural Resources. The methods used to determine TACs are species dependent. For Green Bay, Wisconsin, yellow perch for example, TACs are set using SCAA modeling to project population abundance. The yellow perch SCAA models use creel survey, commercial catch, and trawl survey data to estimate the number of yearling and older yellow perch in Green Bay. Total allowable catches can then be adjusted based on anticipated changes in fish recruiting to the fishery. For most species, however, there is insufficient information available to conduct assessment similar to that of Green Bay yellow perch and instead TACs are based on indices of stock status, such as annual differences in commercial fishing or survey catch per unit effort (Mohr and Ebener 2007).

The frequency that TACs are changed also is species dependent and to a certain extent is linked to how much information is available for evaluating a stock status. For Green Bay yellow perch, annual TACs over the last decade have ranged from 9 to 215 mt. Similarly, in Canadian waters of Lake Ontario where lake whitefish is a commercially important species and where additional sampling is conducted to evaluate status of the stocks, TACs have ranged from 93 to 308 mt since 1998. For a species such as rainbow smelt in Lake Michigan where there is far less assessment data available compared to Green Bay yellow perch or Lake Ontario whitefish, TACs for Wisconsin commercial fishers have been set at 453 mt since 1991, with no more than 11 mt coming from Green Bay (Lake Michigan Fisheries Team 2008). Similarly, bloater TACs for Wisconsin commercial fishers have been set at 1,630 mt since 1988.

Overview of Trends in Commercial Fisheries

Information on commercial fish production in the Great Lakes was “officially” collected as early as 1867 in Canada, and 1879 in the United States (Baldwin et al. 2002), though some written records of yields date from the early 1800s. Based on the descriptive writings of early authors (e.g., Milner 1874; Klippart 1877; True 1887; Keyes 1894), it appears that yields of many species had already begun to decline prior to initial collection of harvest information. In this section, commercial yields are reported back to 1914, the first year that yields were tabulated from all management jurisdictions. Licensed commercial fisheries in Michigan were not required to submit daily catch reports until 1929, and mandatory catch reporting by commercial fishers was not instituted in Ontario until the 1940s. Additionally, the reported yields in some cases do not include harvest by First Nation communities. Therefore, both historical and modern yields should be viewed as minimum estimates of actual commercial harvest.

Up until the early 1980s, commercial fishery yields in the Great Lakes were relatively stable (Figure 7). While there certainly were declines in yields of historically important commercial species during this time period, commercial fishers were able to offset these declines by implementing changes in gear, location, techniques, and by targeting other species. For example, declines in Lake Erie commercial yields of blue pike and cisco were offset by increased yields of rainbow smelt and yellow perch. Since the early 1980s, however, overall Great Lakes commercial fishery yields have declined consistently (Figure 7). Since 1983, commercial fishery yields across the Great Lakes have declined on average 3.5% per year. Overall, there has been a 60% decline in commercial yields between 1983 and 2006. Declines in commercial yields have occurred on each of the Great Lakes except for Lake Huron where commercial yields have increased slightly as a result of the recovery of the lake whitefish commercial fishery. In 2006, the overall commercial fishery yield for the Great Lakes was approximately 21,200 mt, which was the third lowest yield on record since 1914. The lowest commercial fishery yield between 1914 and 2006 was in 2003. The combined commercial fishery yield for all lakes in 2003 was 19,700 mt, which was a decrease of nearly 70% of that recorded in 1914 (Figure 7).

Lake Erie

Although the second smallest of the Great Lakes in area and smallest in volume, Lake Erie historically supported and continues to support the largest commercial fishery on the Great Lakes. In many years, Lake Erie commercial yields exceeded those of the other four lakes combined. Lake Erie commercial fishery yields peaked at more than 34,000 mt in 1914 and 1956, but have generally been less than 13,000 mt since 2000 (Figure 7). The fraction of Lake Erie commercial fishery yields harvested by U.S. and Canadian commercial fishers has changed over time. Prior to the 1950s, U.S. commercial yields were generally greater then Canadian commercial yields (Figure 8). In recent years, however, Canadian commercial yields have been four to five times greater than those of the United States (Figure 8).

The commercial fishery in Lake Erie has shifted over the years, changing from harvest of native coregonids (ciscoes and lake whitefish), to native percids (blue pike, walleyes, and sauger) and finally to its current focus on walleyes, rainbow smelt, yellow perch, and white perch. Several ecological stresses, including eutrophication (Beeton et al. 1999), habitat alteration (Hayes 1999), species introductions (Leach et al. 1999), and overfishing have contributed to these shifts in commercial exploitation. Many of the historically important native species, including lake trout, ciscoes, and blue pike, have failed to recover following population collapses, although recent increases in the commercial catch of lake whitefish is encouraging.

Prior to commercial exploitation of lake sturgeon in Lake Erie, the species was regarded as a nuisance that often damaged or destroyed fishing gear. Commercial fishers captured lake sturgeon with large mesh gill nets simply to remove them from fishing areas; oftentimes, captured lake sturgeon were simply disposed of along the shoreline and were burned. The first record of commercial catch of lake sturgeon in Lake Erie was in 1885, with an estimated yield of approximately 2,400 mt. By the 1920s, Lake Erie fishery management agencies began closing lake sturgeon commercial fisheries because of dwindling populations. The last year of reported commercial harvest of lake sturgeon in Lake Erie was 1983. Abundance of lake sturgeon in Lake Erie is believed to have substantively recovered and the species is now regularly caught in the Ontario Lake Erie Partnership Index Fishing Survey and as bycatch in commercial gill and trap nets. When caught as bycatch, lake sturgeon must be released alive or surrendered to authorities if dead.

Ciscoes most likely dominated commercial yields in Lake Erie from the early 1880s until the early 1920s, but yields fluctuated erratically even during the late 1800s (Scott 1951; Hartman 1972). Annual lakewide yields of ciscoes in Lake Erie averaged in excess of 8,000 mt from 1914 to 1924. The cisco fishery collapsed during the late 1920s, with yields dropping below 225 mt by 1929 (Figure 9). Regier et al. (1969) attributed this collapse to increased fishing intensity in Canadian waters, coupled with continued intense fishing with bull nets in U.S. waters. Van Oosten (1930) reported high exploitation of heavily concentrated schools of cisco in 1923 and 1924 off of Long Point, Ontario. An exceptionally strong 1944 year class resulted in a resurgence of the fishery from 1945 to 1947, but commercial yields have been insignificant since

1960 (Figure 9). Invasions of exotic rainbow smelt and alewife, coupled with elevated nutrient and silt loading, likely contributed to the final collapse of Lake Erie ciscoes (Smith 1968).

From 1914 to 1950, lake whitefish commercial yields from Lake Erie averaged approximately 1,200 mt (Figure 9). Strong year classes of lake whitefish in 1936 and 1944 resulted in commercial harvests in excess of 2,500 mt during the early and late 1940s, but from the 1950s to mid 1980s yields were generally insignificant (Lawler 1965). The decline in Lake Erie lake whitefish populations was attributed to overfishing, habitat degradation (e.g., siltation and physical destruction of spawning habitats), declining hypolimnion oxygen levels, increased water temperatures, rainbow smelt and sea lamprey predation, and competition with rainbow smelt (Trautman 1957; Lawler 1965; Leach and Nepszy 1965; Hartman 1972). By the late 1980s, lake whitefish abundance had increased sufficiently to support a small commercial fishery. In 2000, commercial yield of lake whitefish reached 600 mt, which was the largest commercial yield of lake whitefish in more than 50 years. One factor that likely contributed to the recovery of lake whitefish in Lake Erie is the resurgence of natural spawning in the Detroit River and western Lake Erie basin (Roseman 1997, 2000; Roseman et al. 2007).

Yields of blue pike, a subspecies of walleye noted for its distinct coloring, fluctuated markedly between 1900 and 1960, with peak yields resulting from the recruitment of one or two strong year classes per decade (Figure 9). During this time period, approximately 75% of the total harvest of blue pike was by U.S. commercial fishers. Strong year classes in 1939, 1940, 1944, and 1949, sustained the fishery through the mid 1950s, but recruitment failure after 1954 resulted in the collapse of the fishery from 1958 to 1960 (Parsons 1967). A few specimens of blue pike were captured throughout the 1960s and 1970s, but the subspecies is now believed to have been extirpated from Lake Erie.

Like the blue pike and cisco fisheries, the walleye commercial fishery in Lake Erie was drastically reduced circa 1960. From 1914 to 1934, lakewide commercial yields of walleyes were relatively stable, averaging around 800 mt annually. Beginning in 1935, commercial yields of Lake Erie walleye began to steadily increase. By the late 1940s, annual commercial yields exceeded 2,000 mt, and by 1956 and 1957 yields exceeded 6,000 mt (Figure 9). Yields declined rapidly as a series of weak year classes recruited to the fishery from 1954 to 1961 (Parsons 1970). By 1961, commercial yields of walleye were less than 500 mt (Figure 9). The decline in yields has been attributed to overfishing (Regier et al. 1969), environmental degradation leading to oxygen depletion in the central and western basins (Regier et al. 1969; Parsons 1970), declines in mayflies and other benthic invertebrates (Beeton 1966; Parsons 1970), and competition and predation with an expanding rainbow smelt population (Regier et al. 1969).

The walleye fishery was closed in 1970 because of mercury contamination, and Ohio instituted a 5-year ban on commercial harvest. Reductions in exploitation, coupled with improved water quality conditions, allowed walleye populations to recover through the 1970s and 1980s. During this period of recovery, recreational angling interest in walleye increased rapidly. During the 1970s, U.S. states shifted allocations for walleye from commercial to recreational fisheries, and by 1977, Ohio recreational anglers were catching more than twice their allocated quota. State agencies for the four U.S. states that border Lake Erie (Ohio, Michigan, Pennsylvania, and New York) instituted regulations to restrict commercial harvest of walleyes, including outright harvest bans and restrictions on gill-net operations (Hatch et al. 1990). As of 2006, Pennsylvania was the only U.S. state where walleye commercial fishing still occurred, although recent harvest from Pennsylvania's commercial fishery has generally been less than one metric ton. In contrast, Ontario, which has a small fraction of the number of recreational anglers compared to the U.S. states, has continued to allocate the majority of its share of the walleye recommended allowable harvest to commercial fishers (Roseman et al. 2008). Despite the majority of commercial harvest being restricted to Canadian waters of Lake Erie, lakewide commercial yields of walleye between 2005 and 2007 approached the peak yields of the mid 1950s. This was aided by strong walleye year classes in 1990, 1991, 1993, 1994, 1996, 1999, and 2003 (WTG 2008). Since 2003, walleye recruitment in Lake Erie has been relatively weak, which resulted in the LEC setting in 2009 the lowest lake-wide walleye recommended allowable harvest since 2004.

Since 1914, yellow perch has been a consistent producer for Lake Erie commercial fishers. Before 1950, yellow perch were a relatively minor component to the commercial fishery compared to blue pike and ciscoes (Figure 9). Shifts in fishing effort to yellow perch after collapses of the blue pike and walleye fisheries resulted in substantial increases in yellow perch commercial yields. By the late 1950s and lasting through the 1960s, commercial yields of yellow perch were in excess of 11,000 mt. A strong 1965 year class resulted in a peak yellow perch yield of 15,000 mt in 1969, with around 90% of these yields occurring in Canadian waters. During the 1990s, annual commercial yields of yellow perch only averaged 2,100 mt (Figure 9) due to poor yellow perch recruitment during the early 1990s (YPTG 2008). By 2006, lakewide yields had rebounded somewhat and were in excess of 4,000 mt due primarily to a strong 2003 year class (YPTG 2008).

Rainbow smelt were first documented in Lake Erie in 1935 (Van Oosten 1937); by 1948 some fishers had begun targeting rainbow smelt by deploying small mesh nets. During the mid to late 1950s, Ontario commercial fishers experimented with trawls as a fishing gear to increase harvest of rainbow smelt. Through the 1960s, annual commercial yields of rainbow smelt exceeded 5,000 mt (Figure 9). By 1965, Ontario had instituted a trawling license system with a daily quota of 20 mt, and the fishery was worth $2.7 million (USD) by 1967. An industry-initiated quota system was used as early as 1960 to stabilize prices for rainbow smelt. Presently, harvest of rainbow smelt is regulated under an ITQ system by the Ontario Ministry of Natural Resources. Commercial fishers in the United States have been less interested in harvesting rainbow smelt and the U.S. share of lakewide yield has typically been less than 4% of the lakewide total. The peak lakewide yield of rainbow smelt of nearly 20,000 mt occurred in 1982. Since 2000, annual commercial yields have averaged approximately 3,300 mt. In 2006, only 800 mt of rainbow smelt were harvested commercially from Lake Erie, the lowest commercial harvest in more than 50 years.

The Lake Erie commercial fishery for white perch, a species that first invaded the Great Lakes in 1950 (Mills et al. 1993), began during the mid 1970s. At first, commercial yields of white perch were low; for the first 8 years, yields did not exceed 100 mt (Figure 9). In 1991 and 1992, commercial yields peaked at over 3,000 mt, but subsequently declined to less than 200 mt by 1999. By 2005 and 2006, commercial yields once again exceeded 1,000 mt (Figure 9). White perch is a non-quota species for Ontario’s commercial fishing industry. Dockside price, the availability of white perch, and a fisher’s access to sufficient walleye and yellow perch quota to cover any bycatch of these quota species in the gear targeting white perch, are the only factors that limit harvest of white perch.

White bass is another species that is a non-quota commercially targeted fish that is important to the Lake Erie commercial fishery in both Ontario and U.S. waters. The largest white bass harvest in Ontario waters of Lake Erie was 2,790 mt in 2002 when the Coordinated Percid Management Strategy severely limited walleye and yellow perch harvests and commercial harvesters targeted white bass to maintain revenues.

Lake Huron

Gill-net operations were initially established in Lake Huron at or near Alpena, Michigan, and in Georgian Bay, Ontario, around 1835 (Koelz 1926). Early fisheries targeted lake whitefish in shallow waters and gradually shifted to fishing lake trout in deeper waters as inshore stocks of lake whitefish were depleted. Lakewide commercial yields have been more stable in Lake Huron than on lakes Erie and Michigan, although overall commercial fishery yield did decline in Lake Huron beginning around 1940. The mean annual yield of approximately 3,700 mt from 1941 to 1980 was less than half the mean annual yield from 1914 to 1940 (Figure 8). There was a slight increase in Lake Huron commercial yields during the late 1980s and early 1990s, which was due primarily to recovery of lake whitefish stocks. From 1914 to the late 1940s, U.S. commercial yields were typically several metric tons greater than that of Canadian commercial yields. However, since the 1950s, U.S. and Canadian commercial yields have been roughly equivalent (Figure 8). There has been an increase in the relative contribution of tribal-licensed commercial fishery yields to the U.S. side since tribal fishing rights were reaffirmed in northern Lake Huron (Figure 10). During the early 1980s, tribal yields accounted for generally less than 20% of the overall U.S. yields from Lake Huron. Between 2000 and 2006, tribal yields accounted for more than 50% of the overall U.S. yields (Figure 10). Tribal commercial fishers primarily target three species in Lake Huron: lake whitefish, lake trout, and Chinook salmon. During the early 1990s, bloater also was an important commercial species for tribal fishers. Lake whitefish and lake trout are presently harvested by large-boat trap-net operations and small-boat gill-net fisheries. Chinook salmon fisheries are primarily intercept gill-net fisheries, which target adult fish returning to Lake Huron tributaries in which they were stocked or spawned.

The lake whitefish commercial fishery in Lake Huron has gone through periods of both boom and bust. In 1880, lake whitefish commercial fishery yield was approximately 1,800 mt, but by 1899 yield had dropped to less than 600 mt (Koelz 1929). By 1914, lake whitefish yields increased to 1,200 mt. Between 1910 and 1930, lake whitefish yields were relatively stable with average lakewide yields ranging from 900 to 1,600 mt (Figure 11). The introduction of deep trap nets, the production of exceptionally large 1929 and 1943 year classes, and sea lamprey predation, all were factors that contributed to a destabilization of the lake whitefish fishery (Van Ooseten et al. 1946). The combination of the large 1929 year class and increased efficiency of deeper trap nets resulted in peak yields approaching 2,600 mt in 1931 and 1932. Increased fishing effort attracted by the strong 1929 year class of lake whitefish is believed to have resulted in overfishing that caused a partial stock collapse during the late 1930s. By 1945, lake whitefish yields had declined to 250 mt, or 10% of the yield that occurred only 12 years earlier (Figure 11). Recruitment of another exceptionally strong year class in 1943 resulted in separate peaks in U.S. and Canadian commercial yields due to delayed recruitment of this cohort in Georgian Bay (Cucin and Reiger 1966). U.S. yields peaked at over 1,400 mt in 1947, while Canadian yields peaked at almost 3,000 mt in 1953 (Baldwin et al. 2002). Lake whitefish yields declined again during the late 1950s after sea lamprey became numerous in the lake. In 1959, lake whitefish yields in Lake Huron were only 200 mt. After sea lamprey control efforts were initiated, the lake whitefish commercial fishery rebounded remarkably. By 1998, Lake Huron lake whitefish yields were in excess of 3,750 mt. Since the 1990s. commercial harvest of lake whitefish has met or exceeded the harvest goals set by fishery agencies (DeJardine et al. 1995).

When lake whitefish commercial yields were low in Lake Huron during the late 1800s, commercial fishing effort shifted its focus to lake trout. By 1890, lake trout surpassed lake whitefish as the primary fishery in Lake Huron in both U.S. and Canadian waters. From 1914 to 1940, lake trout commercial fishery yields generally ranged from 2,000 to 3,000 mt. By the late 1940s, however, both the U.S. and Canadian lake trout fisheries had collapsed (Figure 11). The lake trout collapse is believed to have been caused by a combination of sea lamprey predation and overexploition from commercial fishing, although the relative contribution of these factors is still debated (Hile 1949; Coble et al. 1990; Eshenroder 1992). A tribal commercial fishery for lake trout does still exist in Lake Huron, although yields are only around 10% of the average historical harvest from Lake Huron (Figure 11).

Cisco fisheries in Lake Huron developed during the early 1900s. Harvest of ciscoes was concentrated in U.S. waters, with approximately 80% of historical yields coming from Saginaw Bay. Cisco yields peaked in 1939 at nearly 3,300 mt, but declined rapidly from 1940 to 1945, and completely collapsed during the late 1950s. Since 1963, annual commercial yields of ciscoes in Lake Huron have been less than 30 mt. Although commercial fishing contributed to collapse of many cisco populations, habitat destruction and pollution in Saginaw Bay, and lakewide invasions of alewife and rainbow smelt are believed to have been the major contributing factors to the decline (Berst and Spangler 1972). Signs of a cisco recovery in North Channel, Georgian

Bay, and to a lesser extent in Lake Huron's main basin, and related concerns about cisco bycatch, prompted the Ontario Ministry of Natural Resources to re-designate cisco as a quota species for Lake Huron commercial fishermen. Initial quotas were based on observed incidental catch rates. Cisco bycatch in chub gill nets may become an issue if deepwater chubs recover sufficiently to once again become commercially valuable and targeted by commercial fishers.

Commercial yields of deepwater chubs (e.g., deepwater cisco, longjaw cisco, blackfin cisco, kiyi, bloater) from 1914 to the mid 1950s in Lake Huron were small in comparison to yields of cisco, lake trout, and lake whitefish. Mean annual yields from 1914 to 1956 was approximately 375 mt (Figure 11). After collapse of the cisco, lake trout, and lake whitefish fisheries during the late 1950s, commercial fishery operations began heavily targeting deepwater chubs (Berst and Spangler 1972). Commercial yields peaked in 1961 at approximately 2,500 mt, but subsequently declined to less than 90 mt by 1970 (Figure 11). Chub fisheries recovered quickly during the 1980s, beginning with a large 1977 year class, and by the mid 1990s commercial yields were slightly above the average from 1914 to 1956. By 2000, however, commercial yields had declined once again to less than 100 mt (Figure 11). In 2006, lakewide commercial yields of deepwater chubs was less than 1 mt. The only deepwater chubs that are known to still be present in Lake Huron are bloaters and small populations of shortjaw ciscoes. Deepwater cisco, blackfin ciso, shortnose cisco, and kiyi are believed to have been extirpated from the lake (Ebener et al. 2008a).

Walleye and yellow perch have provided small, yet relatively consistent commercial fisheries in Lake Huron for many years. The yellow perch fishery was initiated later than fisheries for lake whitefish, lake trout, and cisco, although yields exceeded 1,700 mt by 1900 (Baldwin et al. 2002). The commercial fishery for yellow perch is concentrated in the North Channel, Ontario's waters of the southern main basin, and Saginaw Bay in U.S. waters. Through the 1900s, lakewide yields of yellow perch were stable, ranging from a low of 122 mt in 1996 to a high of 819 mt in 1916, with an average yield of approximately 370 mt. Since 2000, mean annual commercial yields of yellow perch have only been around 120 mt (Figure 11). One factor that may be limiting yields of yellow perch in Lake Huron is predation by double-crested cormorants (Fielder et al. 2008).

According to Schneider and Leach (1979), the Saginaw Bay commercial walleye fishery historically has been the second-largest walleye fishery on the Great Lakes. Between 1914 and

1944, the annual lakewide commercial yield of walleye averaged 730 mt. Since 1947, annual commercial yields of walleye have averaged approximately 160 mt, a decline of 77% from historical yields (Figure 11). In 2005, the commercial yield of walleyes in Lake Huron was approximately 59 mt, which was the 4th lowest yield during the last 93 years.

Lake Michigan

Commercial fishing operations were established in Lake Michigan during the 1820s, and were dominated by near shore fisheries using haul seines during the early years (Milner 1874). Gill nets were first utilized by non-tribal commercial fishers in 1846, and pound nets were introduced during the 1850s. Early fisheries targeted near shore populations of lake whitefish, and yields had already begun to decline before the first yields were officially recorded in 1879 (Milner 1874; Smith and Snell 1891). Early declines were attributed to commercial overfishing and sawdust pollution from sawmills, which covered important feeding and spawning areas in the lake and its tributaries (Milner 1874; Smith and Snell 1891). From 1914 to the early 1960s, lakewide commercial yields in Lake Michigan were stable, averaging around 10,000 mt annually (Figure 8). From the mid 1960s to late 1970s, lakewide commercial yields more than doubled in size due largely to the initiation of a commercial fishery for alewife. By 1990, lakewide commercial yields in Lake Michigan had returned to levels observed before the alewife fishery developed. Since 1990, lakewide commercial yields have declined an average of 7% per year (Figure 8). Since 2000, annual lakewide commercial yields have averaged only 3,200 mt. The current commercial fishery in Lake Michigan consists primarily of lake whitefish, lake trout, chubs, and rainbow smelt.

Tribal commercial fishery yields have remained relatively stable in Lake Michigan since 1980. In 1980, tribal-licensed yields were approximately 680 mt. In 2006, tribal-licensed yields were approximately 1,200 mt. During this same time, there has been a substantial decline in state-licensed yields (Figure 10). From 1980 to 2006, state-licensed commercial yields declined from more than 10,000 mt to around 2,000 mt. This has resulted in an increase in the relative contribution of tribal-licensed yields to the overall commercial fishery. During the early 1980s, state-licensed yields were more then 20 times greater than tribal yields. By 2006, state-licensed yields were only twice as large as tribal yields (Figure 10).

Lake whitefish, lake trout, cisco, and lake sturgeon were the most important commercial species landed during the late 1800s. Before the turn of the 20th century, however, the lake sturgeon commercial fishery had completely collapsed. From 1914 to 1960, cisco yields were highly variable (Figure 12), with most of the harvest occurring in Green Bay. During this time period, yields were as low as 630 mt and as high as 5,100 mt. Cisco yields declined to a mean annual yield of 730 mt from 1941 to 1944, but an exceptionally large year class in 1943 resulted in elevated cisco yields from 1945 to 1956 (Figure 12). By 1960, Lake Michigan cisco harvest was approximately 100 mt, and declined to less than 1 mt by the mid 1970s. The collapse of the cisco commercial fishery has been attributed to overfishing and to possible competition or predation on cisco larvae by the expanding alewife population in Lake Michigan (Smith 1968, 1970).

Like the cisco commercial fishery, yields from the lake whitefish commercial fishery were highly variable from 1914 to 1960 (Figure 12). Lakewide yields of lake whitefish declined from almost 2,500 mt in 1930 to around 500 mt during the late 1930s and early 1940s. A large year class in 1943 resulted in a temporary increase in yields during the late 1940s and early 1950s, but by 1957 only 11 mt of lake whitefish were harvested commercially from Lake Michigan. After initiation of sea lamprey control, lake whitefish stocks in Lake Michigan began to rebound. During the 1990s, lake whitefish yields regularly exceeded post-1890 record levels. During the late 1990s, commercial harvest declined by almost half, but even this reduced level of yield was similar to the peaks that were observed in 1930 and the late 1940s (Figure 12).

Lake trout commercial harvest was remarkably stable from 1914 to 1945. The mean annual harvest during this time period was 2,800 mt, and ranged from 2,100 to 3,500 mt. After 1945, a substantial decline in lake trout harvest occurred. Between 1945 and 1950, lake trout commercial harvest had declined by more than 99% (Figure 12). By 1951 and 1952, lakewide commercial lake trout harvest was less than 5 mt. The lake trout collapse has been attributed to a combination of sea lamprey predation and commercial overfishing (Eschmeyer 1957), although sea lamprey predation alone could have caused the lake trout collapse. Because of sea lamprey control efforts and lake trout stocking programs, lake trout recovered enough to accommodate a small lake trout commercial fishery that has been operational since 1963. As of 2006, commercial yields from this fishery have not exceeded 450 mt (Figure 12).

Deepwater chub commercial harvests included blackfin cisco, deepwater cisco, shortjaw cisco, shortnose cisco, longjaw cisco, kiyi, and bloater (Todd and Smith 1992). Deepwater chub yields varied considerably prior to the 1940s. Beginning in 1940, yields of deepwater chubs increased substantially (Figure 12). By 1952, deepwater chub commercial yields exceed 5,000 mt, with a mean annual yield of 4,800 mt from 1950 to 1962. This increase in harvest coincided with a shift from large-mesh (4½”) to small-mesh (2½”) gill nets (Smith 1964) and an increase in fishing effort due to the decline in lake trout (Brown et al. 1987). As a result, both large- (blackfin cisco, deepwater cisco) and medium-sized (shortjaw cisco, longjaw cisco, shortnose cisco, and kiyi) chub species were severely depleted. Deepwater chub yields peaked in 1960 at 5,700 mt (Figure 12), but declined temporarily after 1963 following the botulism deaths of several people from consuming smoked chubs (Baldwin et al. 2002). By the mid 1960s, only the bloater, the smallest of the deepwater chub species, contributed significantly to commercial yields (Brown et al. 1987). Lakewide yields of deepwater chubs declined to less than 500 mt by the mid 1970s (Figure 12) despite regulatory restrictions that were enacted to protect the species complex. The states of Michigan, Wisconsin, Illinois, and Indiana agreed to close the deepwater chub fishery in 1976 (Brown et al. 1985). A strong 1977 year class resulted in the reopening of the fishery in 1979, and yields rebounded to almost 1,400 mt by 1985 (Figure 12). It should be noted, however, that the production of the large 1977 bloater year class was likely only coincident to the closure of the fishery in the previous year because large year classes of several indigenous fish species occurred at this time in Lake Michigan and throughout the other Great Lakes. Since 1999, annual yield of deepwater chubs in Lake Michigan has averaged approximately 800 mt.

Although yields from the yellow perch commercial fishery in Lake Michigan historically were substantially smaller than yields for other commercially exploited species, by the late 1930s, yellow perch along with lake trout and deepwater chubs dominated commercial yields in both numbers and value (Gallagher and Van Oosten 1943). During the early 1960s, commercial yields of yellow perch peaked at 2,600 mt, but then subsequently declined to less than 1,000 mt. From 1965 to 1985, the mean annual commercial harvest of yellow perch was approximately 450 mt (Figure 12). During the late 1980s and early 1990s, yellow perch commercial yields again exceeded 1,000 mt, but by the mid 1990s yields were less than 500 mt. As a result of perceived mid 1990s declines in yellow perch abundance in southern Lake Michigan, commercial fisheries in Indiana, Illinois, and southern Wisconsin were restricted to smaller quotas (Francis et al. 1996) and were eventually closed (Wilberg et al. 2005). As of 2006, these commercial fisheries remained closed, although commercial fisheries in Green Bay remained open. Since 2000, annual commercial yield of yellow perch has averaged around 20 mt. Declines in Lake Michigan yellow perch abundance have been attributed to a combination of low recruitment and overharvest (Wilberg et al. 2005).

The alewife, which was first reported in Lake Michigan in 1949, was first harvested commercially by trawling during the late 1950s (Smith 1968). Although not harvested for human consumption, alewives from the Great Lakes were marketed for use in fish meal, fertilizer, and pet food (Smith 1968; Brown 1972). Alewife commercial yields exploded through the late 1950s and early 1960s, reaching 19,000 mt in 1967 (Figure 12). The trawl fishery, which had been located primarily in Wisconsin waters since the 1970s, maintained yields of more than 4,500 mt until 1990. Due to concerns that commercial harvest of alewife could affect the forage base for Lake Michigan salmonids, the Wisconsin Department of Natural Resources eliminated the directed harvest of alewife by commercial fishers in the early 1990s. Commercial fishers are allowed to keep and market alewife caught as bycatch from the commercial fishery for rainbow smelt. Between 1992 and 2006, the average annual yield of alewife caught as bycatch has been approximately 23 mt.

Lake Ontario

Compared to the other Great Lakes, commercial yields from Lake Ontario have been small (Figure 8). Historically, most commercial yields were from Canadian waters, primarily from shallow areas in the eastern end of the lake and the Bay of Quinte. The current U.S. commercial fishery primarily targets yellow perch and bullheads. In 2006, commercial yield of the U.S. commercial fishery was 2 mt. In comparison, commercial yield of the Canadian commercial fishery was 280 mt. Species that currently are exploited by the Canadian commercial fishing industry include bullheads, common carp, freshwater drum, northern pike, walleye, white perch, lake whitefish, and yellow perch.

During the late 1800s, cisco dominated commercial fishery yields from Lake Ontario, although walleye and blue pike were likely the most valuable species for the fishery (Smith 1892). At least three species (lake sturgeon, Atlantic salmon, and blackfin cisco) were substantially reduced or extirpated before 1900 (Smith 1892). Lake sturgeon and Atlantic salmon populations were impacted by a combination of overfishing and habitat alteration due to damming of tributaries used for spawning (Smith 1995). Blackfin cisco populations collapsed in response to overfishing, similar to the collapses experienced by this species in lakes Huron, Michigan, and Superior.

The primary cold-water species in Lake Ontario, including ciscoes, deepwater chubs, lake whitefish, lake trout, and burbot, all collapsed between 1930 and 1960, and none currently produce yields at or near historical levels (Figure 13). Lake trout yields peaked in 1925 at approximately 500 mt, and declined steadily to less than 20 mt by 1948 (Figure 13). By the early 1960s, lake trout were extirpated from Lake Ontario, but have been subsequently reintroduced as part of rehabilitation efforts. Lake trout continue to be harvested as bycatch from the lake whitefish commercial fishery.

From 1914 to 1944, combined yields of ciscoes and deepwater chubs were erratic, occasionally reaching as high as 1,000 mt and as low 200 mt (Figure 13). Severe reductions in the abundance of kiyi occurred during the early 1930s, which left bloaters as the primary component of the deepwater chub fishery after 1935. Cisco and deepwater chub populations in Lake Ontario collapsed during the mid 1950s, probably due to a combination of overexploitation and competition with expanding rainbow smelt populations (Christie 1972). From 1998 to 2007, combined yields of ciscoes and deepwater chubs averaged approximately 0.9 mt in Ontario waters of Lake Ontario.

Lake whitefish commercial fisheries, operating primarily out of eastern Lake Ontario, produced exceptionally high yields during the early 1920s (Figure 13). Lakewide commercial yields of lake whitefish exceeded 1,200 mt in 1923 and 1924. By 1930, yields had declined considerably, but were fairly stable at around 200 mt until the late 1950s and early 1960s. Yields of lake whitefish declined to negligible levels between 1961 and 1970 (Figure 13). The commercial fishery then recovered from the late 1980s to early 2000s, reaching a peak yield of nearly 300 mt in 1996, but subsequently declined again (Figure 13). In 2005, the lakewide commercial yields of lake whitefish in Lake Ontario was less than 25 mt.

The Lake Ontario commercial fishery compensated for the dwindling yields of ciscoes, lake trout, and lake whitefish by increasing fishing effort on species such as yellow perch, white perch, American eel, common carp, bullheads, rainbow smelt and sunfish. Although both yellow perch and American eel had historically been harvested by commercial fishers in Lake Ontario, commercial yields of these two species began to increase around 1960, which was when yields of ciscoes, deepwater chubs, lake trout, and lake whitefish collapsed. Lakewide yields of yellow perch increased from 27 mt in 1959 to 455 mt in 1970 and 640 mt in 1983 (Figure 13). This increase in commercial yields of yellow perch, however, was only temporary. In 2006, lakewide commercial yields of yellow perch was approximately 100 mt (Figure 13), which is a level similar to what was harvested before the collapse of the cisco, lake trout, and lake whitefish fisheries.

Historically, American eel was a relatively minor component of the lakewide commercial fishery in Lake Ontario. Beginning in the 1960s, however, the importance of the American eel to the Lake Ontario commercial fishery increased (Figure 13). Beginning in the early 1980s, yields of American eel became very erratic. From 1978 to 1982, yields of Amercian eel declined by more than 70%, but then recovered somewhat by 1984. From 1985 to 1988, some Ontario commercial licenses for American eel were bought out by the provincial government in order to help stabilize catches (MacGregor et al. 2008). By the early 1990s, however, yields of American eel began to decline once again (Figure 13). As a result, quotas for American eel in Canadian waters of Lake Ontario were reduced by 50% in 2001 and again in 2002 (MacGregor et al. 2008). Decline of the American eel in Lake Ontario and the St. Lawrence River has been purported to be due to overfishing, habitat changes, and blocked migration to tributaries resulting from the construction of hydroelectric dams. In 2004, the commercial fishery for American eel in Canadian waters of Lake Ontario was closed (MacGregor et al. 2008), which caused conflict as Ontario commercial fishers believed they were unfairly bearing the brunt of the blame for the American eel collapse. Despite their objections, the commercial fishery has remained closed. Steps are being taken to restore American eel, including the stocking of wild young eels in the St. Lawrence River, and research into trap and transport of large yellow phase eels for release downstream of the St. Lawrence River hydroelectric generating stations (A. Mathers, pers.com.). Additionally, American eel quotas on Ontario commercial fishing licenses have been set to zero and commercial fishers were provided with a one-time transition payment based on the last 5 years of the fishery. No American eel commercial fishery has yet to be closed in any other jurisdiction in the entire range of the species. American eel has been designated as a Species of Special Concern under the Canadian Species at Risk Act and Endangered under the Ontario

Endangered Species Act, although in the United States the U.S. Fish and Wildlife Service determined that listing the species as threatened or endangered was not warranted (Federal Register 2007).

White perch are believed to have invaded Lake Ontario via the Mohawk River in 1950 (Mills et al. 1993). Commercial yields of white perch in Lake Ontario were first reported in 1958; by 1965, lakewide commercial yield of white perch was approximately 270 mt. The peak commercial yield of white perch was approximately 350 mt in 1976. Since 1997, however, commercial yields of white perch in Lake Ontario have been less than 10 mt (Figure 13).

Lake Superior

Commercial activity in Lake Superior was initiated in the 1700s when two fur trading companies established commercial fishing stations (Nute 1944). The first pound net operations were established at Whitefish Point in 1850 (Koelz 1926), and commercial pound net operations were established in Canadian waters less than 10 years later. Early fisheries targeted lake whitefish and lake trout. Total commercial yields were approximately 1,800 mt during the early 1870s, rose to almost 11,600 mt in 1941, and have declined to less than 1,500 mt since 2000 (Figure 8). Current yields from Lake Superior are composed of historically important native species including cisco, lake trout, lake whitefish, and bloater, although some species that were once considered to be commercially important, such as lake sturgeon, blackfin cisco, shortjaw cisco, kiyi, and sauger have been extirpated or occur at very low abundance. U.S. commercial yields have consistently been greater than those of Canada, with the largest discrepancy in yields occurring between the 1930s and 1960s (Figure 8). Since 1980, the differences in U.S. and Canadian commercial yields have been minor in comparison to these earlier years. Relative contributions of state and tribal licensed commercial fisheries on U.S. water of Lake Superior have fluctuated substantially since the 1980s. In most years, yields of state-licensed commercial fishers have exceeded those of tribal-licensed commercial fishers, with the exception of 1990 and 1991 when tribal-licensed commercial fishery yields were approximately 10% greater than those of state licensees.

During the 1900s, commercial harvest of ciscoes was greater than that of all other species combined. Cisco fisheries developed during the 1890s and exceeded the combined catch of lake trout and lake whitefish by 1908 in U.S. waters (Baldwin et al. 2002). Development of the cisco fishery was slower in Canadian waters, and cisco catches did not exceed other species until the mid 1910s (Baldwin et al. 2002). Lakewide commercial yields of ciscoes averaged 5,500 mt from 1936 to 1962, and declined from a peak harvest of 8,700 mt in 1941 to less than 600 mt since 2000 (Stockwell et al. 2009; Figure 14). Selgeby (1982) identified sequential overexploitation of discrete stocks as the cause of fishery declines in the Wisconsin waters of Lake Superior, although poor recruitment and competition with exotic rainbow smelt have also been implicated (Stockwell et al. 2009). A cisco roe fishery has become well established in Ontario waters of Lake Superior, particularly in the Thunder and Black Bay areas. Black Bay cisco harvests have declined to approximate 50 mt in recent years; however, harvests have been maintained at an average of 150 mt since the mid 1990s.

Commercial yields of lake whitefish in U.S. waters of Lake Superior declined from 2,300 mt in 1885 to 172 mt in 1922 (Koelz 1929), almost resulting in commercial extinction in U.S. waters. Catches of lake whitefish in Canadian waters also declined during this time period (Baldwin et al. 2002). There was a slight recovery of lake whitefish yields from 1925 to 1950 (Figure 14), but populations declined again in response to sea lamprey predation (Lawrie and Rahrer 1972). After sea lamprey control was initiated during the 1960s, lake whitefish commercial yields began to rebound, with lakewide commercial yields of lake whitefish reaching approximately 1,350 mt in 1990, which was the highest yields observed in more than 75 years (Figure 14). Lake whitefish commercial yields have fallen to between 600 and 900 mt since this peak occurred, but catches have remained fairly stable during this period (Figure 14).

From the early 1910s to early 1950s, commercial yields of lake trout were fairly stable at around 2,000 mt. It is believed that lean lake trout composed the bulk of commercial yields of lake trout, with siscowet and humper lake trout representing around 20% of commercially harvested fish. Commercial harvest of lake trout declined quickly and substantially during the late 1950s and early 1960s; this decline has been attributed to a combination of fishery overharvest and sea lamprey predation (Jensen 1978, 1994; Coble et al. 1990). Like lake whitefish, commercial harvest of lake trout rebounded during the 1960s after initiation of sea lamprey control, but current yields are less than 5% of what they were during earlier time periods. The majority of current yields of lake trout continues to consist of lean lake trout, but there is growing interest in expanding the commercial fishery for siscowet lake trout for the production of Omega-3 fish oils for human consumption.

The deepwater chub species complex in Lake Superior was composed of seven species (deepwater cisco, blackfin cisco, shortjaw cisco, kiyi, shortnose cisco, longjaw cisco, and bloater) that were harvested and reported as a mixed-stock fishery (Todd and Smith 1992). This stock complex was fished with small-mesh gill nets in the deeper waters of Lake Superior (MacCallum and Selgeby 1987). The deepwater chub fishery was affected by market demand and the sequential collapse of deepwater chub fisheries on lakes Michigan, Huron, and Erie (Lawrie and Rahrer 1972). By the late 1880s, stocks of blackfin cisco were depleted in Lake Michigan, resulting in a shift in fishing effort to Lake Superior. Blackfin ciscoes were intensively fished in Lake Superior for a decade, and were reported to be commercially extinct by 1907 (Koelz 1929). The collapse of the Lake Erie cisco fishery during the 1920s caused increases in fishing effort and yields of ciscoes and shortjaw ciscoes from Lake Superior (Lawrie and Rahrer 1973). Harvests of shortjaw ciscoes sustained the deepwater chub fishery through the 1930s, but there was a gradual shift in species composition from shortjaw ciscoes to bloaters (Koelz 1929; Dryer and Beil 1968). Reduced predation following the collapse of lake trout stocks increased deepwater chub abundance during the 1950s and early 1960s (Hansen 1990). Deepwater chub fisheries did not develop beyond a bycatch fishery in Canadian waters until experimental fisheries were initiated in 1971. Redirected fishing effort toward deepwater chubs and increased efficiency of nylon gill nets resulted in intense exploitation of deepwater chub stocks. Deepwater chub yields averaged 700 mt from the late 1950s until 1980, but subsequently declined to 35 mt by 1990 (Figure 14). Since 2003, deepwater chub yields have been less than 20 mt.

Rainbow smelt invaded Lake Superior during the early 1930s, and reached commercially harvestable levels by the early 1950s (Lawrie and Rahrer 1972). Commercial harvests increased during the 1950s and 1960s, with peak yields exceeding 1,800 mt in 1976 (Figure 14). After 1976, there were major declines in abundance and yields (Hansen 1990; Selgeby et al. 1994) and by 1992 yields had declined to less than 30 mt (Figure 14). Since 2003, lakewide commercial fishery yields of rainbow smelt in Lake Superior have been less than 10 mt. The commercial fishery for rainbow smelt has been primarily concentrated in the western portion of Lake Superior, from Thunder Bay, Ontario to Ashland, Wisconsin.

Historical Perspective and Prognoses for the Future

Change has been a salient feature in nearly every aspect of the Great Lakes commercial fishing industry over its long history, from the equipment used, to how catch is allocated, and to what, when, and where species are targeted. Given the ever growing number of impending threats to the Great Lakes ecosystem, including global climate change and additional introductions of exotic species, change will likely continue to be a defining characteristic of the Great Lakes commercial fishing industry.

Most populations of commercially important fish species have either partially or completely collapsed at some point during the last 200 years. Although many people have been quick to blame commercial fishery overharvest as the sole reason for many of these collapses, the cumulative effects of habitat alteration/destruction and water quality degradation have often been unrecognized or underestimated causes as well (Egerton 1985). Several species of fish, including Atlantic salmon (Lake Ontario), lake trout (lakes Michigan, Erie, and Ontario), blue pike (lakes Erie and Ontario), and several species of deepwater chubs (all lakes), have been extirpated from individual lakes or the entire system. Efforts to restore some of these species have had limited success, which suggests that suppressive factors continue to exist. For example, the failure of ciscoes to recover in any of the lakes except Lake Superior (Stockwell et al. 2009) is likely related to continued suppression by exotic alewife and rainbow smelt (Smith 1970; Crowder 1980). Although there have been some notable recoveries, such as the recovery of lake whitefish and bloaters in lakes Michigan and Huron, the question of whether these recoveries will endure remains an issue given ongoing changes to the Great Lakes ecosystem. The lake whitefish recovery in particular may be tenuous given the declines of *Diporeia*, which is a large benthic amphipod and historically the primary diet item of lake whitefish, throughout many areas of the Great Lakes (Nalepa et al. 1998, 2009a, 2009b). This decline of *Diporeia* has resulted in lake whitefish shifting consumption to less nutritious items, such as chironomids, fingernail claims, and dreissenid mussels (Pothoven et al. 2001; Pothoven and Nalepa 2006). This, in turn, has raised concerns that lake whitefish condition and growth could be detrimentally affected and result in elevated rates of natural mortality because of increased susceptibility to infectious disease (Wagner et al. in press).

While it might be hopeful to think that we have learned from our past mistakes and the days of crashed fish populations are behind us, unfortunately that is not the case. Recent closures of the American eel fishery in Lake Ontario suggest that threats continue to loom for many species. The closure of the American eel fishery also illustrates the difficulty in predicting future status of fish stocks in systems as large and dynamic as the Great Lakes. In the first edition of this book, Brown et al. (1999) characterized the prospects for future commercial exploitation of Lake Ontario American eel stocks and Lake Huron lake sturgeon stocks as excellent and fair. Less than 5 years after Brown et al. (1999) was published, the Lake Ontario commercial fishery for American eel was closed. Closures of the commercial fisheries for these and other stocks convey the sense that overexploitation by commercial fishers is the primary factor causing declines in abundance, which again is an oversimplification of the problems that these species have and will continue to face. American eel will continue to be affected by hydroelectric impoundments blocking recruitment to Lake Ontario tributaries and the Ottawa River. Hydroelectric turbines will continue to kill a large percentage of adult eels as they migrate down the St. Lawrence and Ottawa Rivers to the Atlantic Ocean on their way to the Sargasso Sea. As a result, despite the commercial fishery closures, continued declines in population abundance are a very real threat to the Lake Ontario American eel.

We anticipate that global climate change and threats of additional non-native species invasions and their possible effects on Great Lakes fisheries will increase over the next several years. Predictions of how the Great Lakes region will be affected by global climate change include increased air temperatures, increased precipitation, decreased water levels, and reduced ice-cover duration (Jones et al. 2006). How these factors will interact to influence Great Lakes fish populations remains uncertain, but we believe there will be increased calls to better understand how important fisheries might be affected by climate change. For example, lower water levels in Lake Erie are expected to increase exposure of reef areas to waves and wind-generated currents, which may have a strong effect on both yellow perch and walleye recruitment in the lake (Roseman et al. 2008). Casselman (2002) suggested that global climate change will favor the recruitment and production of warm-water species, such as panfish, and that these species could become more commercially important than cool and coldwater species. Increased commercial harvest of panfish species could contribute to their growth by preventing stunting, and these species could also contribute to local markets but could also contribute protein to local markets with a correspondingly smaller carbon footprint than for fresh fish protein that has been transported from some distance away.

Invasive species, such as alewife, rainbow smelt, and dreissenid mussels, have had large and lasting effects on Great Lakes fish populations, and it is likely that future invasions will be a source of concern. The most immediate invasive species threat to the Great Lakes may be Asian carp. Asian carp currently are found in the Illinois River, which connects the Mississippi River to Lake Michigan. In response to this threat, an electric barrier has been constructed to help prevent Asian carp from reaching the lake. Asian carp can grow extremely large and can consume large amounts of zooplankton. It is likely that the Great Lakes foodweb and ecosystem would be severely altered in the event that Asian carp do successfully invade the lakes. However, as per our earlier discussion about the adaptability of commercial fishers, it likely would not take long for commercial fishers to explore possible market opportunities for an Asian carp fishery, although it is uncertain if such a fishery would have any effects on Asian carp stocks in the event that they do successfully invade the Great Lakes.

Issues concerning allocations of harvest among recreational and state-, provincial-, and tribal-licensed commercial fishers will remain and likely expand due to concerns about how the Great Lakes ecosystem and native species may be affected by climate change and invasions of new exotic species. We also anticipate that in the future, allocation issues among political jurisdictions will arise due to the exploitation of admixed stocks of fish (e.g., lake whitefish) during certain times of the year across large areas of the lakes, with possible consequences that these mixed-stock fisheries may have on individual stock productivity. State- and provincial-licensed commercial fisheries will be allowed to continue as long as some form of co-existence can be maintained with recreational fishing and other recreational activities. Structured approaches to decision making will become increasingly valuable as management tools to resolve or reduce real or perceived conflicts between commercial and recreational stakeholders.

In some cases, certifications for sustainability and/or chain of custody will become increasingly important to maintain access to markets. The Ontario commercial fishing industry has embarked on the process of gaining sustainability certification for one of its most valuable fisheries, the Lake Erie yellow perch fishery. We anticipate that this global trend toward sustainability certification and rigorous traceability systems will expand to include commercial fisheries across the Great Lakes, with the largest, most valuable fisheries certified first followed by smaller and less-valuable fisheries. We anticipate that commercial fishers will continue to seek markets for underutilized or invasive species, including siscowet lake trout, suckers, common carp, rainbow smelt, white perch, white bass, freshwater drum and others. However, it is also likely that as such markets are explored ecosystem level effects from expanded fisheries will be an issue of concern for biologists and commercial fishers alike.

On a more positive note, the successful recovery of lake trout and cisco (Stockwell et al. 2009) in Lake Superior and lake whitefish in lakes Huron and Superior (Ebener et al. 2008b) indicate that rehabilitation of native species can occur in the face of various challenges including those that come from commercial fishery exploitation. Further, the efforts that were taken to restore these species can be used as possible guides for rehabilitating these and other species in other lakes or for rehabilitating other historically important species (e.g., Atlantic salmon). The continuing evolution of the Lake Huron fish community towards a resemblance of it historic structure, including naturally reproducing lake trout and increased abundances of walleye, emerald shiners (Schaeffer et al. 2008), and cisco (Stockwell et al. 2009), suggests the future may bode well for commercial fishers on this system. The evidence of river spawning populations of lake whitefish in tributaries to Green Bay and Lake Erie also are positive signs for the Great Lakes commercial fishing industry. We are hopeful, if not optimistic, that these recoveries will endure and will help lead to the recovery of other historically important Great Lakes fish species.

Acknowledgments

The authors thank Tom Gorenflo for co-authoring, along with RWB and MPE, the chapter on commercial fishing for the first edition of Great Lakes Fisheries Policy and Management, which facilitated the drafting of the chapter for the second edition. The authors also thank Dennis Cartier, Esteban Chiriboga, Travis Hartman, Kevin Kayle, Scott Nelson, Limei Zhang for their willingness to share data and/or information. We also wish to thank three anonymous reviewers for making suggestions that improved this chapter. This is publication 20YY-XX of the Quantitative Fisheries Center at Michigan State University.

Literature Cited

Allain, J., and J. -D. Fréchette. 1993. The Aboriginal fisheries and the Sparrow decision. Library of Parliament Background Paper BP-341E, Parliament of Canada, Ottawa, Ontario.

Anderson, T. L., and D. R. Leal. 1995. Fishing for property rights to fish. Pages 161-184 *in* R. E. Meiners and B. Yandle, editors. Taking the environment seriously, Rowman and Littlefield, Lanham, Maryland.

Arnason, R. 2005. Property rights in fisheries: Iceland's experience with ITQs. Reviews in Fish Biology and Fisheries 15:243-2264.

Anonymous. 1929. History of filleting. The Canadian Fisherman 16:34.

Applegate, V. C., and H. D. Van Meter. 1970. A brief history of commercial fishing in Lake Erie. U.S. Fish and Wildlife Service Fishery Leaflet 630.

Ashworth, W. 1987. The Late Great Lakes, an Environmental History. Wayne State University Press, Detroit, Michigan.

Atton, F. M. 1955. The relative effectiveness of nylon and cotton gill nets. Canadian Fish Culture 17:18-26.

Baldwin, N. A., R. W. Saalfeld, M. R. Dochoda, H. J. Buettner, and R.L. Eshenroder. 2002. Commercial Fish Production in the Great Lakes 1867-2000. Great Lakes Fishery Commission. Available: http://www.glfc.org/databases/commercial/commerc.php (January 2009).

Beeton, A. M. 1966. Indices of Great Lakes eutrophication. Great Lakes Research Division, University of Michigan Publication 15:1-8.

Beeton, A. M., C. E. Sellinger, and D. F. Reid. 1999. An introduction to the Laurentian Great Lakes ecosystem. Pages 3-53 *in* W. W. Taylor, and C. P. Ferreri, editors. Great Lakes fisheries policy and management: a binational perspective. Michigan State University Press, East Lansing, Michigan.

Belden, H. 1877. Historical atlas of Huron County. H. Beldon & Company, Toronto. Reprint by Richardson, Bond & Wright Ltd. Owen Sound, Ontario.

Berst, A. H., and G. R. Spangler. 1972. Lake Huron: effects of exploitation, introductions and eutrophication on the salmonid community. Journal of the Fisheries Research Board of Canada 29:877-887.

Binding, C. E., J. H. Jerome, R. P. Bukata, and W. G. Booty. 2007. Trends in water clarity of the lower Great Lakes from remotely sensed aquatic color. Journal of Great Lakes Research 33:828-841.

Branch, T. A. 2008. How do individual transferable quotas affect marine ecosystems. Fish and Fisheries 9:1-19.

Brege, D. A., and N. R. Kevern. 1978. Michigan commercial fishing regulations: a summary of Public Acts and Conservation Commission Orders, 1865 through 1975. Michigan Sea Grant Program Reference Report.

Brown, E. H., Jr. 1972. Population biology of alewives, *Alosa pseudoharengus*, in Lake Michigan, 1949-1970. Journal of the Fisheries Research Board of Canada 29:477-500.

Brown, E. H., Jr., R. W. Rybicki, and R. J. Poff. 1985. Population dynamics and interagency management of the bloater (*Coregonus hoyi*) in Lake Michigan, 1967-1982. Great Lakes Fishery Commission, Technical Report 44, Ann Arbor, Michigan.

Brown, E. H., Jr., R. L. Argyle, N. R. Payne, and M. E. Holey. 1987. Yield and dynamics of destabilized chub (*Coregonus* spp.) populations in Lake Michigan and Huron, 1950-1984. Canadian Journal of Fisheries and Aquatic Sciences 44(Suppl. 2):371-383.

Brown, R. W., M. Ebener, and T. Gorenflo. 1999. Great Lakes commercial fisheries: historical overview and prognosis for the future. Pages 307-354 *in* W. W. Taylor, and C. P. Ferreri, editors. Great Lakes fisheries policy and management: a binational perspective. Michigan State University Press, East Lansing, Michigan.

Buck, E.H. 1995. Individual transferable quotas in fishery management. Report for Congress. Committee for the National Institute for the Environment. Washington DC.

Busiahn, T. R. 1990. Fish community objectives for Lake Superior. Great Lakes Fishery Commission Special Publication 90-1, Ann Arbor, Michigan.

Calder, N. 2007. Marine diesel engines. McGraw-Hill, Blacklick, Ohio.

Casselman, J.M. 2002. Effects of temperature, global extremes, and climate change on year-class production of warmwater, coolwater, and coldwater fishes in the Great Lakes Basin. Pages 39-59 *in by* N.A. McGinn, editor. Fisheries in a Changing Climate, American Fisheries Society, Symposium 32, Bethesda, Maryland.

Charette, M., and A. Morgan. 2004. The economic impact of Lake Erie commercial fishing and fish processing industries. Report to the Ontario Commercial Fisheries' Association, Blenheim, Ontario.

Christie, W. J. 1972. Lake Ontario: effects of exploitation, introductions, and eutrophication on the salmonid community. Journal of the Fisheries Research Board of Canada 29:913-929.

Christie, W. J. 1978. A study on freshwater fishery regulation based on North American experience. FAO Fisheries Technical Paper 180.

Choctaw Nation v. United States. 1886. 119 U.S. 1, 27, 28.

Cobb, J.N. 1916. Pacific cod fisheries. Bureau of Fisheries Doc. No. 830, Washington D.C.

Coble, D. W., R. E. Bruesewitz, T. W. Fratt, and J. W. Scheirer. 1990. Lake trout, sea lampreys and overfishing in the upper Great Lakes: a review and reanalysis. Transactions of the American Fisheries Society 119:985-995.

Collins, J. J. 1979. Relative efficiency of multifilament and monofilament nylon gill net toward lake whitefish (*Coregonus clupeaformis*) in Lake Huron. Journal of the Fisheries Research Board of Canada 36:1180-1185.

Collins, J. J. 1987. Increased catchability of the deep monofilament nylon gillnet and its expression in a simulated fishery. Canadian Journal of Fisheries and Aquatic Sciences 44:129-135.

Cole, G. A. 1994. Textbook of limnology, 4th edition. Waveland Press, Inc., Prospect Heights, Illinois.

Copes, P. 1986. A critical review of the individual quota as a device in fisheries management. Land Economics 62:278-291.

Cowan E.R. and J. Paine, 1997. The introduction of Individual Transferable Quotas to the Lake Erie Fishery. Canadian Technical Report of Fisheries and Aquatic Sciences 2133. Fisheries and Oceans, Ottawa, Ontario.

Crawford, S. S., A. Muir, and K. McCann. 2001. Ecological basis for recommendation of 2001 Saugeen Ojibway commercial harvest TACs for lake whitefish (*Coregonus clupeaformis*) in Lake Huron, Report prepared for the Chippewas of Nawash First Nation, Wiarton, Ontario.

Crowder, L. B. 1980. Alewife, rainbow smelt and native fishes in Lake Michigan: competition or predation. Environmental Biology of Fishes 5:225-233.

Cucin, D., and H. A. Regier. 1966. Dynamics and exploitation of lake whitefish in southern Georgian Bay. Journal of the Fisheries Research Board of Canada 23:221-274.

DesJardine, R. L., T. K. Gorenflo, R. N. Payne, and J. D. Schrouder. 1995. Fish community objectives for Lake Huron. Great Lakes Fishery Commission Special Publication 95-1, Ann Arbor, Michigan.

Dochoda, M. R., and M. L. Jones. 2002. Managing Great Lakes fisheries under multiple and diverse authorities. Pages 221-242 *in* K. D. Lynch, M. L. Jones, and W. W. Taylor. Sustaining North American salmon: perspectives across regions and disciplines. American Fisheries Society, Bethesda, Maryland.

Dryer, W. R., and J. Beil. 1968. Growth changes of the bloater, *Coregonus hoyi*, of the Apostle Islands region of Lake Superior. Transactions of the American Fisheries Society 97:146-158.

Ebener, M.P., L. C. Mohr, S. Riley, E. F. Roseman, and D. G. Fielder. 2008a. Whitefishes and ciscoes. Pages 37-46 *in* J.R. Bence and L.C. Mohr, editors, The state of Lake Huron in 2004. Great Lakes Fishery Commission Special Publication 08-01, Ann Arbor, Michigan.

Ebener, M. P., R. E. Kinnunen, P. J. Schneeberger, L.C. Mohr, J. A. Hoyle, and P. Peeters. 2008b. Management of commercial fisheries for lake whitefish in the Laurentian Great Lakes of North America. Pages 99-144 *in* M. G. Schechter, N. J. Leonard, and W. W. Taylor, editors. International governance of fisheries ecosystems: learning from the past, finding solutions for the future. American Fisheries Society, Bethesda, Maryland.

Egerton, F. N. 1985. Overfishing or pollution? Case history of a controversy on the Great Lakes. Great Lakes Fishery Commission Technical Report 41, Ann Arbor, Michigan.

Eschmeyer, P. H. 1957. The near extinction of the lake trout in Lake Michigan. Transactions of the American Fisheries Society 85:102-119.

Eshenroder, R. L. 1992. Decline of lake trout in Lake Huron. Transactions of the American Fisheries Society 121:548-554.

Eshenroder, R. L., M. E. Holey, T. K. Gorenflo, and R. D. Clark, Jr. 1995. Fish community objectives for Lake Michigan. Great Lakes Fishery Commission Special Pulication 95-3, Ann Arbor, Michigan.

Fahnenstiel, G. L., G. A. Lang, T. F. Nalepa, and T. H. Johengen. 1995. Effects of zebra mussel (*Dreissena polymorpha*) colonization on water quality parameters in Saginaw Bay, Lake Huron. Journal of Great Lakes Research 21:435-448.

Federal Register. 2007. Endangered and Threatened Wildlife and Plants: 12-Month Finding on a Petition to List the American Eel as Threatened or Endangered. United States Fish and Wildlife Service, Department of the Interior. 50 CFR Part 17. Federal Register 72(22):4967-4997.

Fielder, D. G., A. Liskauskas, L. C. Mohr, and J. Boase. 2008. Nearshore fish community. Pages 47-58 *in* J.R. Bence and L.C. Mohr, editors, The state of Lake Huron in 2004. Great Lakes Fishery Commission Special Publication 08-01, Ann Arbor, Michigan.

Francis, J. T., S. R. Robillard, and J. E. Marsden. 1996. Yellow perch management in Lake Michigan: a multijurisdictional challenge. Fisheries 21(2):18-20.

Gallagher, H. R., and J. Van Oosten. 1943. Supplemental report of the United States members of the International Board of Inquiry for the Great Lakes fisheries. International Board of Inquiry for the Great Lakes Fisheries Report. Supplement 25-213.

GLFC (Great Lakes Fishery Commission). 1994. A joint strategic plan for management of Great Lakes fisheries. Great Lakes Fishery Commission, Ann Arbor, Michigan.

Great Lakes Fisheries. 1946. Great Lakes Fisheries. Convention between Canada and the United States of America signed at Washington, April 2, 1946. Edmond Cloutier, King's Printer, Ottawa, Ontario.

Grumbine, R. E. 1994. What is ecosystem management. Conservation Biology 8:27-38.

Hansen, M. J. 1990. Lake Superior: the state of the lake in 1989. Great Lakes Fishery Commission Special Publication 90-93, Ann Arbor, Michigan.

Hansen, M. J., J. W. Peck, R. G. Schorfhaar, J. H. Selgeby, D. R. Schreiner, S. T. Schram, B. L. Swanson, W. R. MacCallum, M. K. Burnham-Curtis, G. L. Curtis, J. W. Heinrich, and R. J. Young. 1995. Lake trout (*Salvelinus namaycush*) populations in Lake Superior and their restoration in 1959-1993. Journal of Great Lakes Research 21(Suppl. 1): 152-175.

Harford, W. J., S. S. Crawford, and C. W. Coppaway. 2006. 2006 Saugeen Ojibway Nations commercial harvest TACs for lake whitefish (*Coregonus clupeaformis*) in Lake Huron, Report prepared for the Chippewas of Nawash Unceded First Nation. Wiarton, Ontario.

Hartman, W. L. 1972. Lake Erie: effects of exploitation, environmental changes and new species on the fishery resources. Journal of the Fisheries Research Board of Canada 29:899-912.

Hatch, R. W., S. J. Nepszy, and M. R. Rawson. 1990. Management of percids in Lake Erie, North America. Pages 624-636 *in* W. L. T. van Densen, B. Steinmetz, and R. H. Hughes, editors. Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden.

Hayes, D. B. 1999. Issues affecting fish habitat in the Great Lakes basin. Pages 209-238 *in* W. W. Taylor, and C. P. Ferreri, editors. Great Lakes fisheries policy and management: a binational perspective. Michigan State University Press, East Lansing, Michigan.

Hayes, D. B., C. P. Ferreri, and W. W. Taylor. 1996. Active fish capture methods. Pages 193-220 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2^{nd} edition. American Fisheries Society, Bethesda, Maryland.

Henderson, B. A., and S. J. Nepszy. 1992. Comparison of catches in mono-and multifilament fill nets in Lake Erie. North American Journal of Fisheries Management 12:618-624.

Hewson, L. C. 1951. A comparison of nylon and gill nets used in the Lake Winnipeg winter fishery. Canadian Fish Culture 11:1-3.

Hile, R. 1949. Trends in the lake trout fishery of Lake Huron through 1946. Transactions of the American Fisheries Society 76:121-147.

Hile, R. 1962. Collection and analysis of commercial fishery statistics in the Great Lakes. Great Lakes Fishery Commission Technical Report 5, Ann Arbor, Michigan.

Horns, W.H., C.R. Bronte, T.R. Busiahn, M.P. Ebener, R.L. Eshenroder, T. Gorenflo, N. Kmiecik, W. Mattes, J.W. Peck, M. Petzold, D.R. Schreiner. 2003. Fish-community objectives for Lake Superior. Great Lakes Fishery Commission Special Publication 03-01, Ann Arbor, Michigan.

ITU (International Telecommunication Union). 2009. World telecommunication/ICT indicators database. Geneva, Switzerland.

Jannetta, J. M. 1991. The constitutional status of native hunting and fishing rights in Canada and the United States: a comparative analysis. Native American Studies Conference, Lake Superior State University, Sault Ste. Marie, Michigan.

Jensen, A. L. 1978. Assessment of the lake trout fishery in Lake Superior: 1929-1950. Transactions of the American Fisheries Society 107:543-549.

Jensen, A. L. 1994. Larkin's predation model of lake trout (*Salvelinus namaycush*) extinction with harvesting and sea lamprey (*Petromyzon marinus*) predation: a qualitative analysis. Canadian Journal of Fisheries and Aquatic Sciences 51:942-945.

Jester, D. B. 1973. Variations in catchability of fishes with color of gillnets. Transactions of the American Fisheries Society 102:109-115.

Jester, D. B. 1977. Effects of color, mesh size, fishing in seasonal concentrations, and baiting on catch rates of fisheries in gill nets. Transactions of the American Fisheries Society 106:43-56.

Johnson, J. E., J. L. Jonas, and J. W. Peck. 2004a. Management of commercial fisheries bycatch, with emphasis on lake trout fisheries of the upper Great Lakes. Michigan Department of Natural Resources Fisheries Research Report 2070, Ann Arbor, Michigan.

Johnson, J. E., M. P. Ebener, K. Gebhardt, and R. Bergstedt. 2004b. Comparison of catch and lake trout bycatch in commercial trap nets and gill nets targeting lake whitefish in northern Lake Huron. Michigan Department of Natural Resources Fisheries Research Report 2071, Ann Arbor, Michigan.

Jones, M. L., B. J. Shuter, Y. Zhao, and J. D. Stockwell. 2006. Forecasting effects of climate change on Great Lakes fisheries: models that link habitat supply to population dynamics can help. Canadian Journal of Fisheries and Aquatic Sciences 63:457-468.

Kennedy, W. A. 1970. A history of commercial fishing in inland Canada. Fisheries Research Board of Canada, Manuscript Report Series (Biological) 871.

Kerr, S. J., and G. C. LeTendre. 1991. The state of the Lake Ontario fish community in 1989. Great Lakes Fishery Commission Special Publication 93-3, Ann Arbor, Michigan.

Keyes, C. M. 1894. The fishing industry of Lake Erie, past and present. U.S. Fishery Commission Bulletin 13:349-353.

Kinietz, W. V. 1940. The Indians of the Western Great Lakes, 1615-1760. The University of Michigan Press, Ann Arbor, Michigan.

Klippart, J. H. 1877. History of Toledo and Sandusky fisheries. Ohio State Fish Commission Annual Report 1:31-42.

Knight, R. L. 1997. Successful interagency rehabilitation of Lake Erie walleye. Fisheries 22(7):16-17.

Koelz, W. 1926. Fishing industry of the Great Lakes. Pages 554-617 *in* Report of the U.S. Commissioner of Fisheries for 1925.

Koonce, J. F., A. B. Locci, and R. L. Knight. 1999. Contribution of fishery management in walleye and yellow perch populations of Lake Erie. Pages 397-416 *in* W. W. Taylor, and C. P. Ferreri, editors. Great Lakes fisheries policy and management: a binational perspective. Michigan State University Press, East Lansing, Michigan.

Lac Courte Oreilles Band v. Voight. 1983. 700 F.2d 341.

Lake Michigan Fisheries Team 2008. Lake Michigan Management Reports. Wisconsin Department of Natural Resources, Madison, Wisconsin.

Lawler, G. H. 1950. The use of nylon netting in the gill net fishery of Lake Erie whitefish. Canadian Fish Culture 7:22-24.

Lawler, G. H. 1965. Fluctuations in the success of year-classes of whitefish populations with special reference to Lake Erie. Journal of the Fisheries Research Board of Canada 22:1197-1227.

Lawrie, A. H., and J. F. Rahrer. 1972. Lake Superior: effects of exploitation and introductions on the salmonid community. Journal of the Fisheries Research Board of Canada 29:765-776.

Lawrie, A. H., and J. F. Rahrer. 1973. Lake Superior: a case history of the lake and its fisheries. Great Lakes Fisheries Commission Technical Report 19, Ann Arbor, Michigan.

Leach, J. H., and S. J. Nepszy. 1976. The fish community in Lake Erie. Journal of the Fisheries Research Board of Canada 33:622-638.

Leach, J. H., E. L. Mills, and M. R. Dochoda. 1999. Non-indigenous species in the Great Lakes: ecosystem impacts, binational policies, and management. Pages 185-208 *in* W. W. Taylor, and C. P. Ferreri, editors. Great Lakes fisheries policy and management: a binational perspective. Michigan State University Press, East Lansing, Michigan.

Locke, B., M. Belore, A. Cook, D. Einhouse, R. Kenyon, R. Knight, K. Newman, P. Ryan, and E. Wright. 2005. Lake Erie walleye management plan. Lake Erie Committee, Great Lakes Fishery Commission, Ann Arbor, Michigan.

MacCallum, W. R., and J. H. Selgeby. 1987. Lake Superior revisited: 1984. Canadian Journal of Fisheries and Aquatic Sciences 44(Suppl. 2):23-36.

MacGregor, R., A. Mathers, P. Thompson, J. M. Casselman, J. M. Dettmers, S. LaPan, T. C. Pratt, and B. Allen. 2008. Declines of American eel in North America: complexities associated with bi-national management. Pages 357-382 *in* M. G. Schechter, N. J. Leonard, and W. W. Taylor, editors. International governance of fisheries ecosystems: learning from the past, finding solutions for the future. American Fisheries Society, Bethesda, Maryland.

Mansfield, J. 1899. History of the Great Lakes. J. H. Beers & Co., Chicago, Reprinted by Freshwater Press Inc., Cleveland, Ohio.

McCay, B. J., C. F. Creed, A. C. Finlayson, R. Apostle, and K. Mikalsen. 1995. Individual transferable quotas (ITQs) in Canadian and US fisheries. Ocean and Coastal Management 28:85-115.

McCullough, A. B. 1989. The commercial fishery of the Canadian Great Lakes. Canadian Parks Service, Environment Canada.

Mills, E. L., J. H. Leach, J. T. Carlton, and C. L. Secor. 1993. Exotic species in the Great Lakes: a history of biotic crises and anthropogenic introductions. Journal of Great Lakes Research 19:1-57.

Milner. J. W. 1874. Report on the fisheries of the Great Lakes: the results of inquiries prosecuted in 1871 and 1872. Pages 1-78 *in* Report of the Commissioner for 1872 and 1873, U.S. Commission of Fish and Fisheries, Washington D.C.

Minnesota Historical Society. 1973. The land of the Ojibwe. Ojibwe Curriculum Committee, American Indian Studies Department, University of Minnesota, and the Education Services Division, Minnesota Historical Society.

Mohr, L. C., and M. P. Ebener. 2007. Evaluation of two harvest policies for managing lake whitefish (*Coregonus clupeaformis*) populations in a Laurentian Great Lake, Lake Huron. Page 471-483 *in* M. Jankun, P. Brzuzan, P. Hliwa, and M. Lucznski, editors. Biology and management of coregonid fishes – 2005. Advances in Limnology 60, Stuttgart, Germany.

Morgan, M. G., and M. Henrion. 1990. Uncertainty: a guide to dealing with uncertainty in quantitative risk and policy analysis. Cambridge University Press, Cambridge, United Kingdom.

Murray. C., and D. R. Marmorek. 2003. Adaptive management and ecological restoration. Pages 417-428 *in* P. Frieerici, editor. Ecological restoration of southwestern ponderosa pine forests, Ecological Restoration Institute, Flagstaff, Arizona.

Nalepa, T. F., D. J. Hartson, D. L. Fanslow, G. A. Lang, and S. J. Lozano. 1998. Declines in benthic macroinvertebrate populations in southern Lake Michigan, 1980-1993. Canadian Journal of Fisheries and Aquatic Sciences 55:2402-2413.

Nalepa, T. F., D. L. Fanslow, and G. A. Lang. 2009a. Transformation of the offshore benthic community in Lake Michigan: Recent shift from the native amphipod *Diporeia* spp. to the invasive mussel *Dreissena rostriformis bugensis*. Freshwater Biology 54:466-479.

Nalepa, T. F., S. A. Pothoven, and D. L. Fanslow. 2009b. Recent changes in benthic macroinvertebrate populations in Lake Huron and impact on diet of lake whitefish (*Coregonus clupeaformis*). Aquatic Ecosystem Health and Management 12:2-10.

Notzke, C. 1994. Aboriginal peoples and natural resources in Canada. Coptus University Press, Concord, Ontario.

Nute, G. L. 1944. Lake Superior. The American Lakes Series. Bobbs-Merrill, Indianapolis, Indiana.

Parsons, J. W. 1967. Contributions of year-classes of blue pike to the commercial fishery of Lake Erie, 1943-1959. Journal of the Fisheries Research Board of Canada 27:1475-1489.

Parsons, J. W. 1970. Walleye fishery of Lake Erie in 1943-1962 with emphasis on contributions of the 1942-1961 year classes. Journal of the Fisheries Research Board of Canada 27:1475-1489.

People v. Jondreau. 1971. 384 Mich. 539, 544, 185 N.W.2d 375.

People v. LeBlanc. 1976. 399 Mich 31; 248 NW2d 199.

Peterman, R. M., and J. L. Anderson. 1999. Decision analysis: a method for taking uncertainties into account in risk-based decision-making. Human and Ecological Risk Assessment 5: 231-244.

Peterman, R. M., and C. N. Peters. 1998. Decision analysis: taking uncertainties into account in forest resource management. Pages 105-127 *in* V. Sit and B. Taylor, editors. Statistical Methods for Adaptive Management Studies, Handbook No. 42. British Columbia Ministry of Forestry, Victoria, British Columbia.

Peters, C.N., and D.R. Marmorek. 2001. Application of decision analysis to evaluate recovery actions for threatened Snake River spring and summer Chinook salmon (Oncorhynchus tshawytscha). Canadian Journal of Fisheries and Aquatic Sciences 58:2431–2446.

Piper, D. C. 1967. The international law of the Great Lakes: a study of Canadian-United States Cooperation. Commonwealth Studies Center, Duke University Press, Durham, North Carolina.

Pothoven, S. A., and T. F. Nalepa. 2006. Feeding ecology of lake whitefish in Lake Huron. Journal of Great Lakes Research 32:489-501.

Pothoven, S. A., T. F. Nalepa, P. J. Schneeberger, and S. B. Brandt. 2001. Changes in diet and body condition of lake whitefish in southern Lake Michigan associated with changes in benthos. North American Journal of Fisheries Management 21:876-883

Province of Ontario. 1885. An act to regulate the fisheries of this province. Statutes of the Province of Ontario, John Notman, Queen's Printer, Toronto.

Pycha, R. L. 1962. The relative efficiency of nylon and cotton gill nets for taking lake trout in Lake Superior. Journal of the Fisheries Research Board of Canada 19:1085-1094.

Regier, H. A., V. C. Applegate, and R. A. Ryder. 1969. The ecology and management of the walleye in western Lake Erie. Great Lakes Fishery Commission Technical Report 15, Ann Arbor, Michigan.

Roseman, E.F. 1997. Factors influencing the year-class strength of walleye in western Lake Erie. M.S. Thesis. Michigan State University, East Lansing.

Roseman, E.F. 2000. Physical and biological processes influencing the year-class strength of walleye in western Lake Erie. Ph.D. Dissertation. Michigan State University, East Lansing.

Roseman, E. F., G. W. Kennedy, J. Boase, B. A. Manny, T. N. Todd, and W. Stott. 2007. Evidence of lake whitefish spawning in the Detroit River: implication for habitat and population recovery. Journal of Great Lakes Research 33:397-406.

Roseman, E. F., R. L. Knight, E. Wright, D. Einouse, K. Kayle, K. Newman, and R. L. Hoopes. 2008. Ecology and international governance of Lake Erie's percid fisheries. Pages 145-172 *in* M. G. Schechter, N. J. Leonard, and W. W. Taylor, editors. International governance of fisheries ecosystems: learning from the past, finding solutions for the future. American Fisheries Society, Bethesda, Maryland.

Ryan, P.A., R. Knight, R. MacGregor, G. Towns, R. Hoopes, and W. Culligan. 2003. Fish-community goals and objectives for Lake Erie. Great Lakes Fishery Commission Special Publication 03-02, Ann Arbor, Michigan.

Rybicki, R. W., and P. J. Schneeberger. 1990. Recent history and management of the state-licensed commercial fishery for lake whitefish in Michigan waters of Lake Michigan. Michigan Department of Natural Resources, Fisheries Division, Fisheries Research Report 1960, Ann Arbor, Michigan.

R. v. Jones. 1993. 3 Can. Native Law R. 182.

Schaeffer, J. S., D. M. Warner, and T. P. O'Brien. 2008. Resurgence of emerald shiners *Notropis atherinoides* in Lake Huron's main basin. Journal of Great Lakes Research 34:395-403.

Schneider, L. C., and J. H. Leach. 1979. Walleye stocks in the Great Lakes, 1800-1975: fluctuations and possible causes. Great Lakes Fishery Commission Technical Report No. 31, Ann Arbor, Michigan.

Scott, W. B. 1951. Fluctuations in abundance of the Lake Erie cisco (*Leucichthys artedi*) population. Royal Ontario Museum, Contribution 32.

Selgeby, J. H. 1982. Decline of lake herring (*Coregonus artedi*) in Lake Superior: an analysis of the Wisconsin herring fishery, 1936-1978. Canadian Journal of Fisheries and Aquatic Sciences 39:554-563.

Selgeby, J. H., C. R. Bronte, and J. W. Slade. 1994. Forage species. Pages 53-62 *in* M. J. Hansen, editor. The state of Lake Superior in 1992. Great Lakes Fishery Commission Special Publication 94-1, Ann Arbor, Michigan.

Sitar, S. P., J. R. Bence, and A. P. Woldt. 2007. Stock assessment models. Pages 8-16 *in* A. P. Woldt and S. P. Sitar, editors. Technical Fisheries Committee Administrative Report 2006: Status of Lake Trout and Lake Whitefish Populations in the 1836 Treaty-Ceded Waters of Lakes Superior, Huron and Michigan in 2005, with recommended yield and effort levels for 2006. http://www.michigan.gov/documents/dnr/2006-status-report_215230_7.pdf.

Smith, H. M. 1892. Report on the fisheries of Lake Ontario. Bulletin of the U.S. Fish Commission 10:177-215.

Smith, H. M., and M. M. Snell. 1891. Review of the fisheries of the Great Lakes in 1885. Pages 1-33 *in* Report of the Commissioner for 1887. U.S. Government Printing Office, Washington D.C.

Smith, S. H. 1964. Status of the deepwater cisco populations of Lake Michigan. Transactions of the American Fisheries Society 93:155-163.

Smith, S. H. 1968. Species succession and fishery exploitation in the Great Lakes. Journal of the Fisheries Research Board of Canada 25:667-693.

Smith, S. H. 1970. Species interactions of the alewife in the Great Lakes. Transactions of the American Fisheries Society 99:754-765.

Smith, S. H. 1995. Early changes in the fish community of Lake Ontario. Great Lakes Fishery Commission Technical Report No. 60, Ann Arbor, Michigan.

Sparrow v. The Queen. 1990. 1 S.C.R. 1075.

Stansby, M. E. 1963. Industrial fishery technology; a survey of methods for domestic harvesting, preservation, and processing of fish used for food and for industrial products. Reinhold Press, New York.

State v. Gunroe. 1972. 53 Wis.2d 390.

Stewart, T.J., R.E. Lange, S.D. Orsatti, C.P. Schneider, A. Mathers, M.E. Daniels. 1999. Fish-community objectives for Lake Ontario. Great Lakes Fishery Commission Special Publication 99-01, Ann Arbor, Michigan.

Stockwell, J. D., M. P. Ebener, J. A. Black, O. T. Gorman, T. R. Hrabik, R. E. Kinnunen, W. P. Mattes, J. K. Oyadomari, S. T. Schram, D. R. Schreiner, M. J. Seider, S. P. Sitar, and D. L. Yule. 2009. A synthesis of cisco recovery in Lake Superior: implications for native fish rehabilitation in the Laurentian Great Lakes. North American Journal of Fisheries Management 29:626-652.

TFRC (Technical Fisheries Review Committee). 1992. Status of the Fishery Resource – 1991. An assessment of lake trout and lake whitefish in treaty-ceded waters of the upper Great Lakes: State of Michigan. A Report by the Technical Fisheries Review Committee on the Assessment of lake trout and lake whitefish in waters of the upper Great Lakes ceded in the Treaty of 1836, September 29, 1992. United States Fish and Wildlife Service, Ann Arbor, Michigan.

Thompson, R. 1978. Fishing ports on Lake Erie. Historical Planning and Research Branch, Ontario Ministry of Culture and Recreation, Toronto.

Todd, T. N., and G. R. Smith. 1992. A review of differentiation in Great Lakes ciscoes. Polish Archives of Hydrobiology 39:261-267.

Toner, G. C. 1939. The Great Lakes fisheries: unheeded depletion. Canadian Forum 19(224):178-180.

Trautman, M. B. 1957. The fishes of Ohio. University of Ohio Press, Columbus, Ohio.

True, F. W. 1887. The fisheries of the Great Lakes, Pages 631-673 *in* G. B. Goode, editor. The fisheries and fishing industries of the United States, U.S. Commission on Fish and Fisheries, Washington D.C.

United States v. Michigan. 1979. 471 F.Supp. 192

United States v. Michigan. 1985. United States District Court, Western District of Michigan, Case No. M-26-73CA.

United States v. Michigan. 2000. United States District Court, Western District of Michigan, Southern Division, Case No. 2:73 CV 26.

University of Wisconsin Sea Grant Institute. 1988. The fisheries of the Great Lakes. University of Wisconsin Sea Grant Institute, Madison, Wisconsin.

Van Oosten, J. 1930. The disappearance of the Lake Erie cisco: a preliminary report. Transactions of the American Fisheries Society 60:20.

Van Oosten, J. 1937. Dispersal of smelt, *Osmerus mordax* (Mitchill), in the Great Lakes region. Transactions of the American Fisheries Society 66:160-171.

Van Oosten, J. 1938. Michigan's commercial fisheries of the Great Lakes. Michigan History Magazine 22(1):13.

Van Oosten, J., R. Hile, and F. W. Jobes. 1946. The whitefish fishery of Lake Huron and Michigan with special reference to the deep trapnet fishery. U.S. Fish and Wildlife Service Fishery Bulletin 50:297-394.

WTG (Walleye Task Group). 2008. Report of the Lake Erie Walleye Task Group to the Standing Technical Committee, Lake Erie Committee of the Great Lakes Fishery Commission, Ann Arbor, Michigan.

Wagner, T., M. L. Jones, M. P. Ebener, M. T. Arts, M. Faisal, T. O. Brenden, D. Honeyfield, and G. Wright. In press. Spatial and temporal dynamics of lake whitefish health measures: linking individual-based indicators to a management-relevant endpoint. Journal of Great Lakes Research

Wilberg, M. J., J. R. Bence, B. T. Eggold, D. Makauskas, and D. F. Clapp. 2005. Yellow perch dynamics in southwestern Lake Michigan during 1986-2002. North American Journal of Fisheries Management 25:1130-1152.

Woldt, A.P., Bence, J.R., and Ebener, M.P. 2007. Executive Summary. Pages 4-7 *in* A. P. Woldt and S. P. Sitar, editors. Technical Fisheries Committee Administrative Report 2006: Status of Lake Trout and Lake Whitefish Populations in the 1836 Treaty-Ceded Waters of Lakes Superior, Huron and Michigan in 2005, with recommended yield and effort levels for 2006. http://www.michigan.gov/documents/dnr/2006-status-report_215230_7.pdf

Woner, P. 1961. Ohio fisheries. Unpublished manuscript. Ohio Division of Wildlife.

Worcester v. Georgia. 1832. 31 US (6 Pet) 515, 582.

Wright, E., M. Belore, A. Cook, B. Culligan, D. Einhouse, T. Johnson, K. Kayle, R. Kenyon, R. Knight, and K. Newman. 2005. Decision analysis application for Lake Erie walleye management. Final report to the Lake Erie Committee, Great Lakes Fishery Commission, Ann Arbor, Michigan.

YPTG (Yellow Perch Task Group). 2003. Report of the Lake Erie yellow perch task group. Lake Erie Committee, Great Lakes Fishery Commission, Ann Arbor, Michigan.

YPTG (Yellow Perch Task Group). 2006. Report of the Lake Erie yellow perch task group. Lake Erie Committee, Great Lakes Fishery Commission, Ann Arbor, Michigan.

YPTG (Yellow Perch Task Group). 2007. Report of the Lake Erie yellow perch task group. Lake Erie Committee, Great Lakes Fishery Commission, Ann Arbor, Michigan.

YPTG (Yellow Perch Task Group). 2008. Report of the Lake Erie yellow perch task group. Lake Erie Committee, Great Lakes Fishery Commission, Ann Arbor, Michigan.

Figure Captions

Figure 1. Pound net (Panel A), gill net (Panel B), and trap net (Panel C) gear used to commercially harvest fish from the Great Lakes. Gill-net and trap-net images courtesy of Dave Brenner, Michigan Sea Grant. Pound-net image courtesy of NOAA National Marine Fisheries Service.

Figure 2. Fishing vessels commonly used by commercial fishers on the Great Lakes – trap-net tugs (Panels A and B) and gill-net tugs (Panels C and D). Photographs courtesy of Barry Pigeon.

Figure 3. Gill net retrieval (Panel A) and unloading of commercial fishery harvest (Panel B) through side sliding doors on a gill net tug. Photographs courtesy of the Ontario Ministry of Natural Resources.

Figure 4. Retrieval of a commercial trap net on the deck of a trap-net tug.

Figure 5. Dockside value (Panel A – reported values; Panel B – inflation adjusted values) of commercial fisheries yields in the United States (black line) and Canada (grey line) on the Great Lakes from 1939 to 2006. U.S. data from the Fishery Statistics of the United States and S. Nelson, U.S. Geological Survey Science Center, unpublished data. Canadian data from Statistics Canada and D. Cartier, Ontario Commercial Fisheries' Association, unpublished data. Inflation-adjusted values are in 2006 dollars. U.S. inflationary adjustments were made using an inflation calculator developed by the U.S. Department of Labor Bureau of Labor Statistics (http://data.bls.gov/cgi-bin/cpicalc.pl). Canadian inflationary adjustments were made using an inflation calculator developed by the Bank of Canada (www.bankofcanada.ca/en/rates/inflation_calc.html).

Figure 6. Treaty-ceded waters of lakes Michigan, Huron, and Superior where tribal fishing rights have been reaffirmed based on the 1836, 1842, and 1854 treaties between Native American tribes and the U.S. Federal Government. Ceded territory boundaries are representations and may not be the actual legally binding boundary.

Figure 7. Total commercial yields (mt) of the lakes Erie, Huron, Michigan, Ontario, and Superior commercial fisheries from 1914 to 2006 (Baldwin et al. 2002, S. Nelson, U.S. Geological Survey Great Lakes Science Center, unpublished data, and D. Cartier, Ontario Commercial Fisheries' Association, unpublished data).

Figure 8. The relative contribution of U.S. (black line) and Canadian (gray line) fisheries to overall yields of lakes Erie, Huron, Ontario, and Superior from 1914 to 2006 (Baldwin et al. 2002, S. Nelson, U.S. Geological Survey Great Lakes Science Center, unpublished data, and D. Cartier, Ontario Commercial Fisheries' Association, unpublished data).

Figure 9. Commercial yields (mt) of the Lake Erie commercial fishery for select species from 1914 to 2006 (Baldwin et al. 2002, S. Nelson, U.S. Geological Survey Great Lakes Science Center, unpublished data, and D. Cartier, Ontario Commercial Fisheries' Association, unpublished data).

Figure 10. Relative contribution of state (black line) and tribal (grey line) licensed commercial fisheries to overall U.S. commercial fishing yields for lakes Huron, Michigan, and Superior, from 1980 to 2006 (Baldwin et al. 2002, S. Nelson, U.S. Geological Survey Great Lakes Science Center, unpublished data).

Figure 11. Commercial yields (mt) of the Lake Huron commercial fishery for select species from 1914 to 2006 (Baldwin et al. 2002, S. Nelson, U.S. Geological Survey Great Lakes Science Center, unpublished data, and D. Cartier, Ontario Commercial Fisheries' Association, unpublished data).

Figure 12. Commercial yields (mt) of the Lake Michigan commercial fishery for select species from 1914 to 2006 (Baldwin et al. 2002, S. Nelson, U.S. Geological Survey Great Lakes Science Center, unpublished data). Note the different y-axis scale for alewife commercial yield.

Figure 13. Commercial yields (mt) of the Lake Ontario commercial fishery for select species from 1914 to 2006 (Baldwin et al. 2002, S. Nelson, U.S. Geological Survey Great Lakes Science Center, unpublished data, and D. Cartier, Ontario Commercial Fisheries' Association, unpublished data).

Figure 14. Commercial yields (mt) of the Lake Superior commercial fishery for select species from 1914 to 2006 (Baldwin et al. 2002, S. Nelson, U.S. Geological Survey Great Lakes Science Center, unpublished data, and D. Cartier, Ontario Commercial Fisheries' Association, unpublished data).

Figure 1

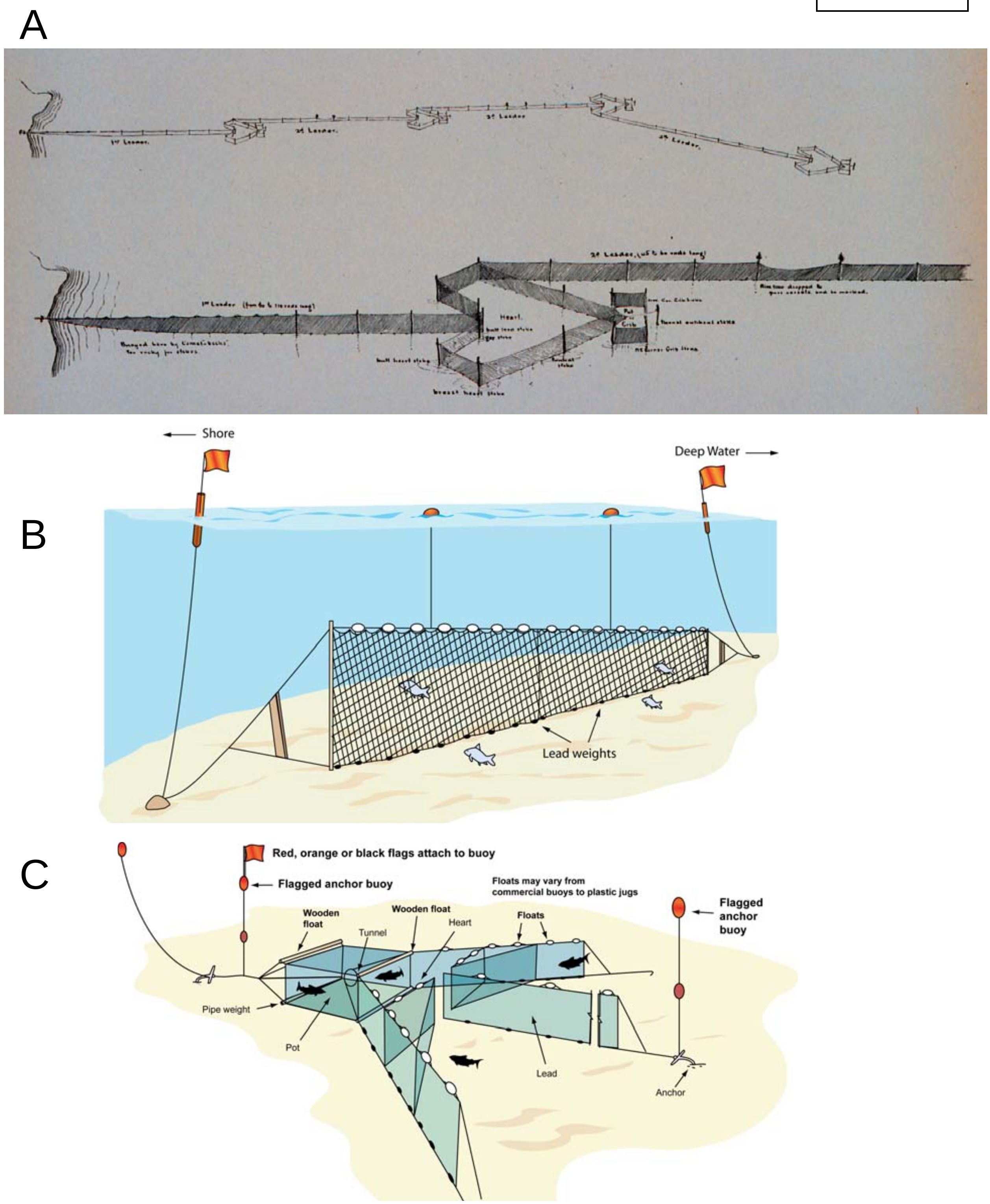

A
B
Shore
Deep Water
Lead weights
C
Red, orange or black flags attach to buoy
Flagged anchor buoy
Floats may vary from commercial buoys to plastic jugs
Flagged anchor buoy
Wooden float
Wooden float
Tunnel
Heart
Floats
Pipe weight
Pot
Lead
Anchor

Figure 2

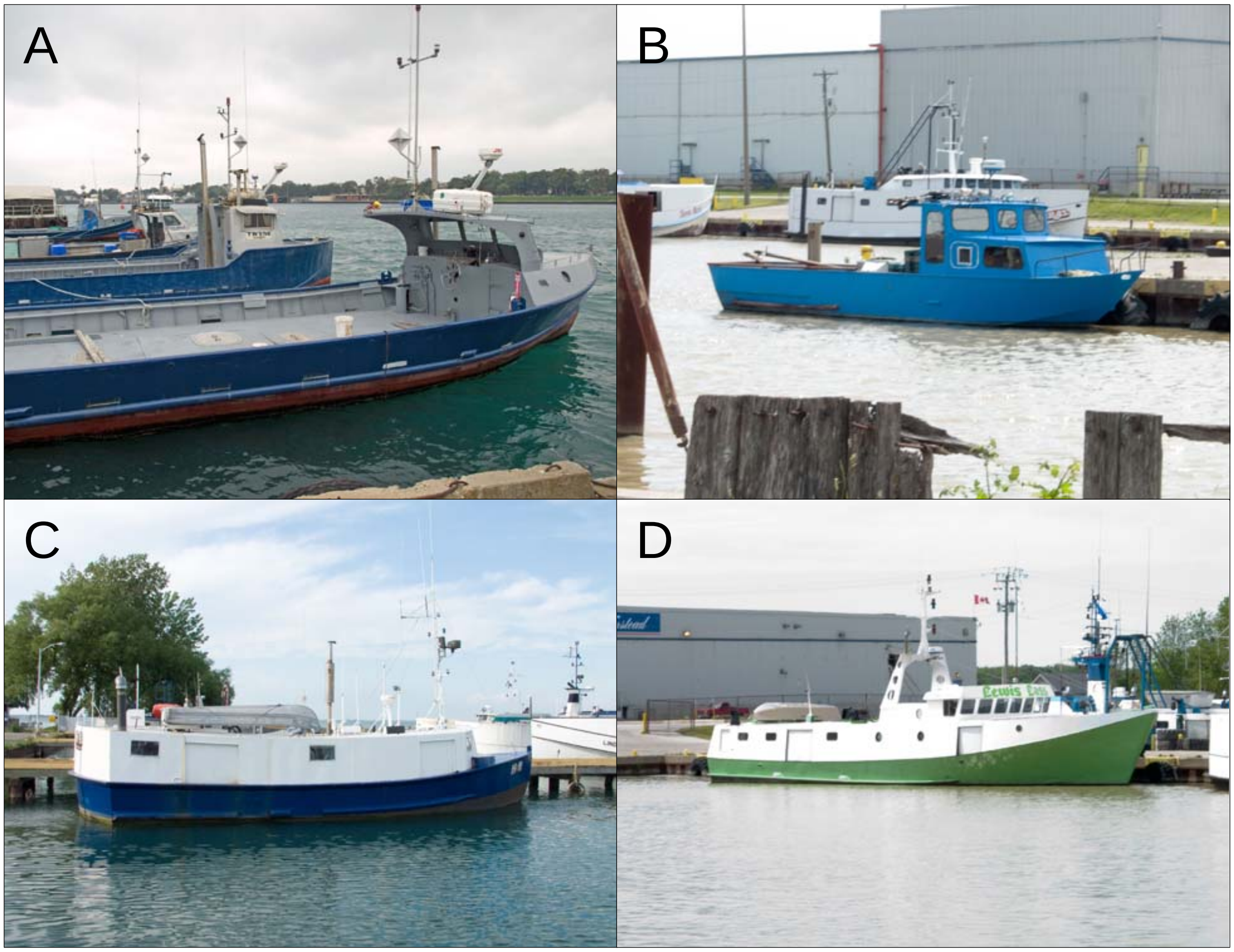
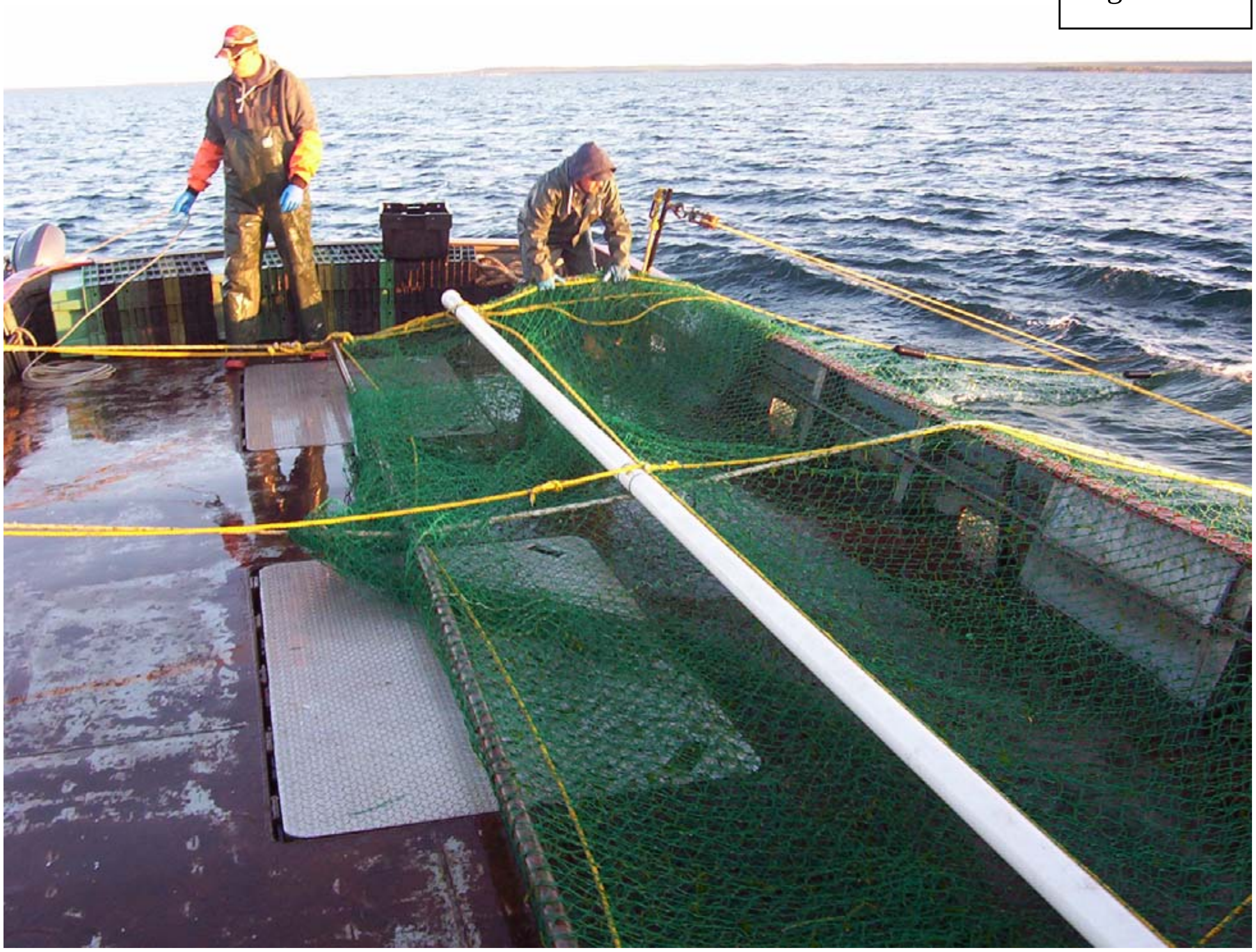


Figure 3

Figure 4



2469

Figure 5

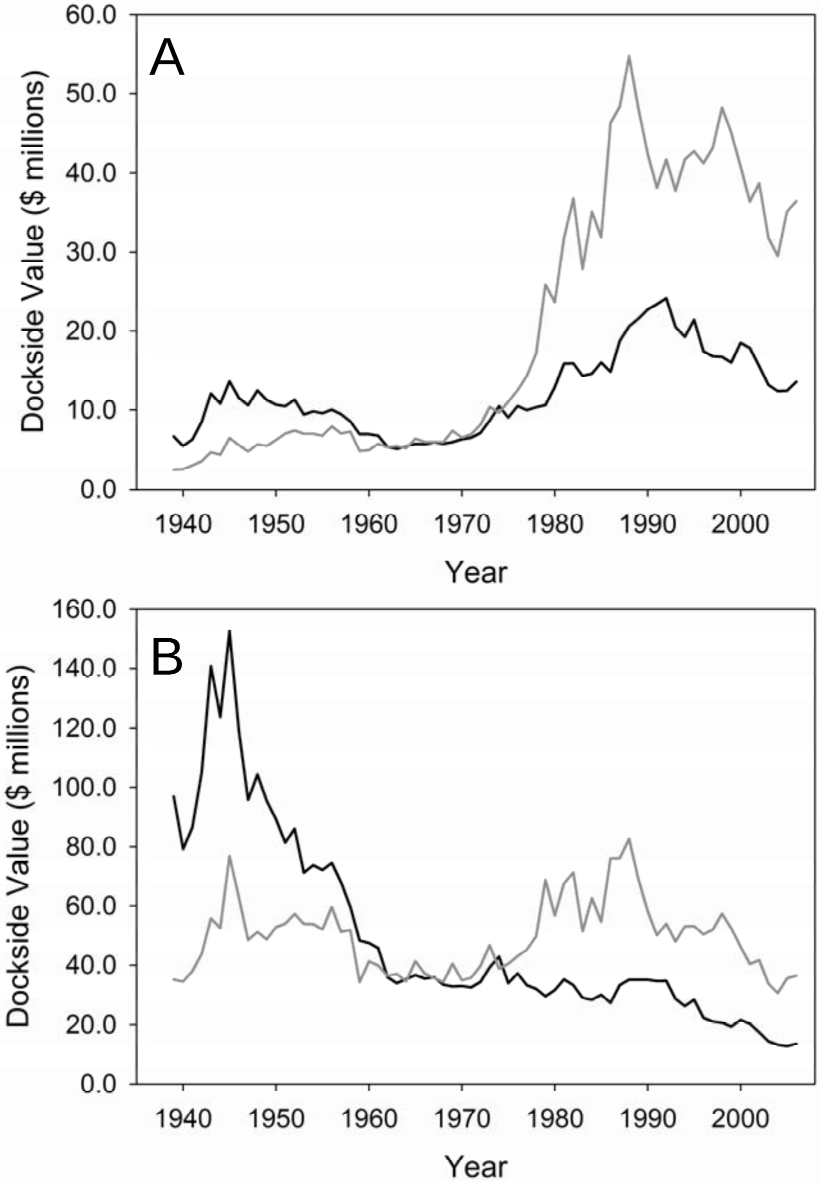
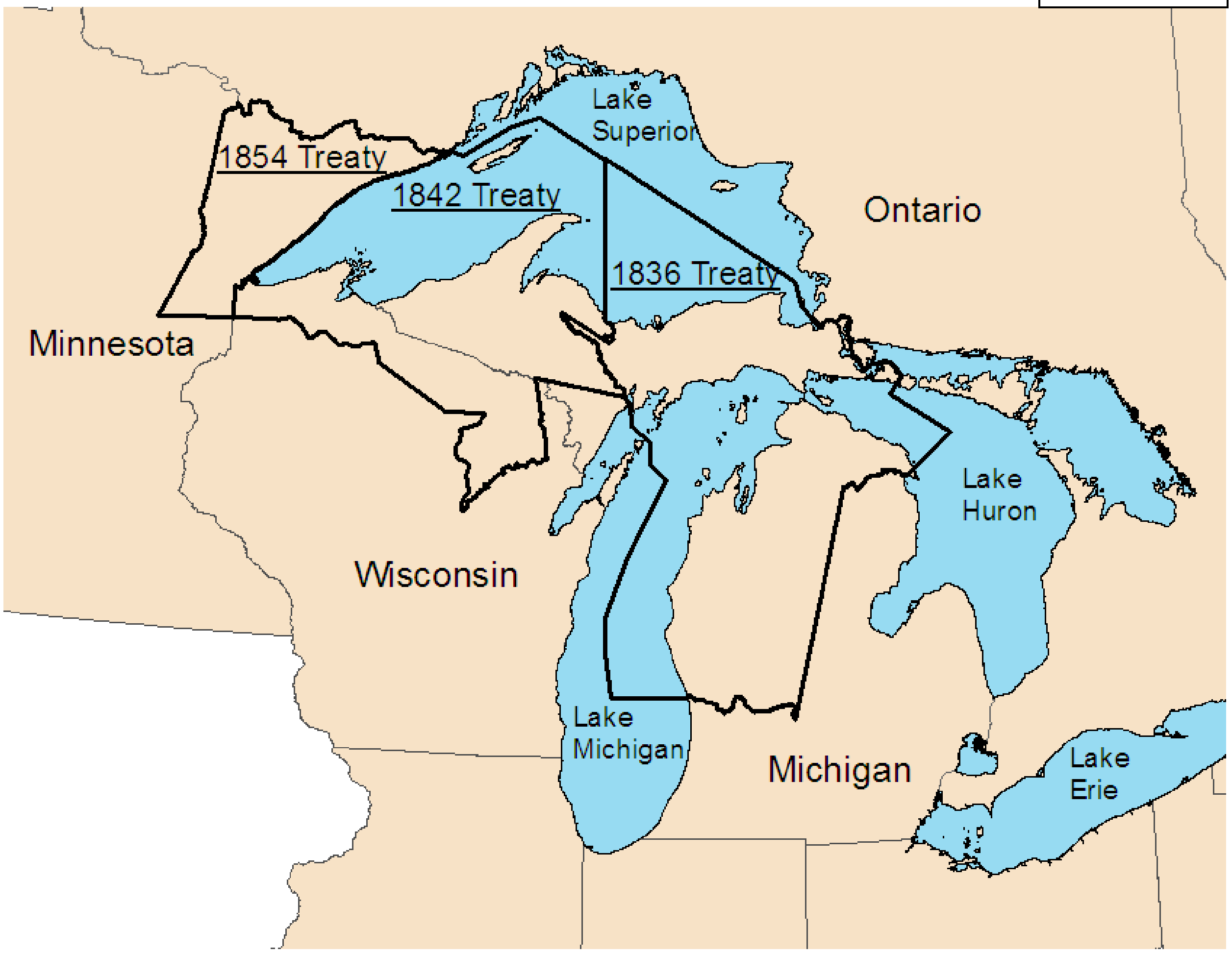


Figure 6



2470

2471

Figure 7

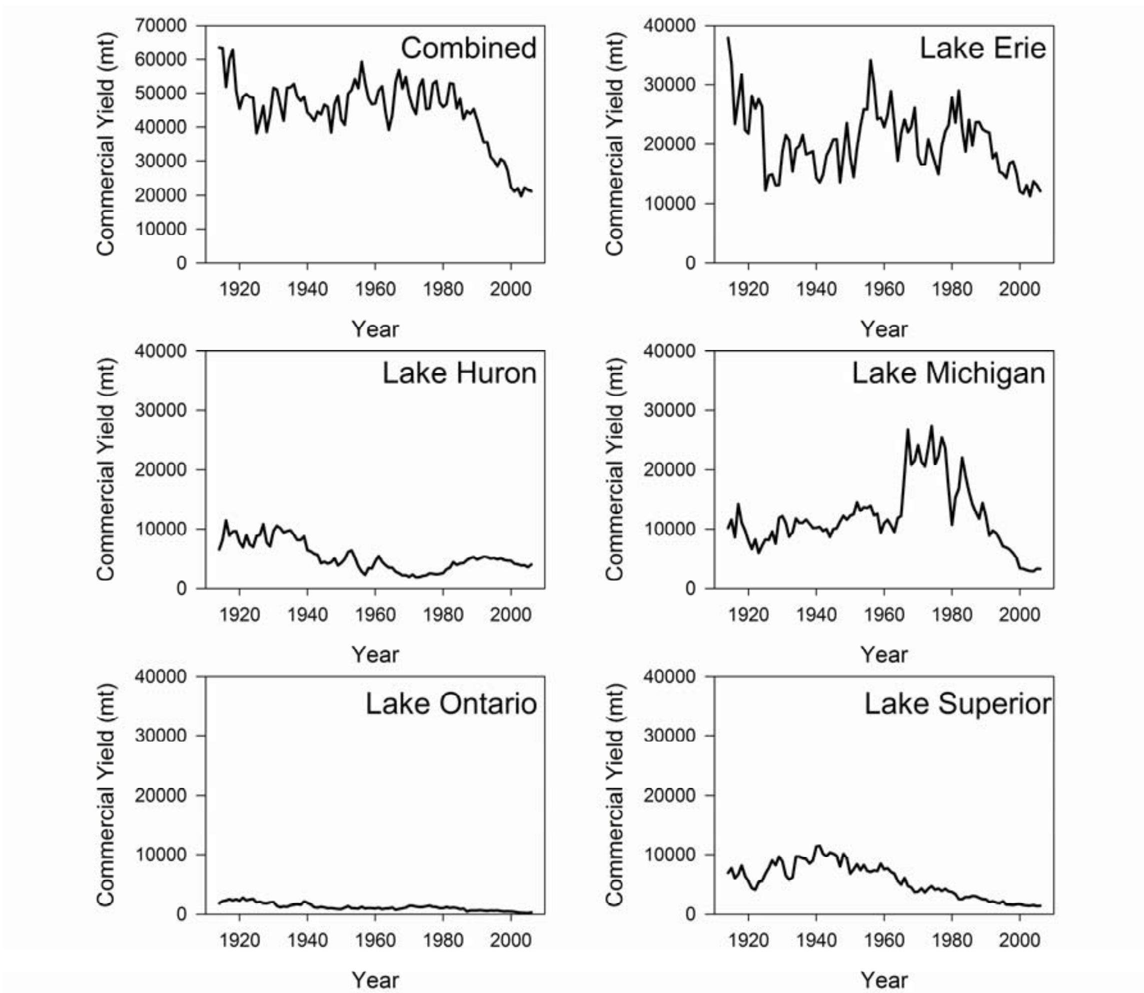
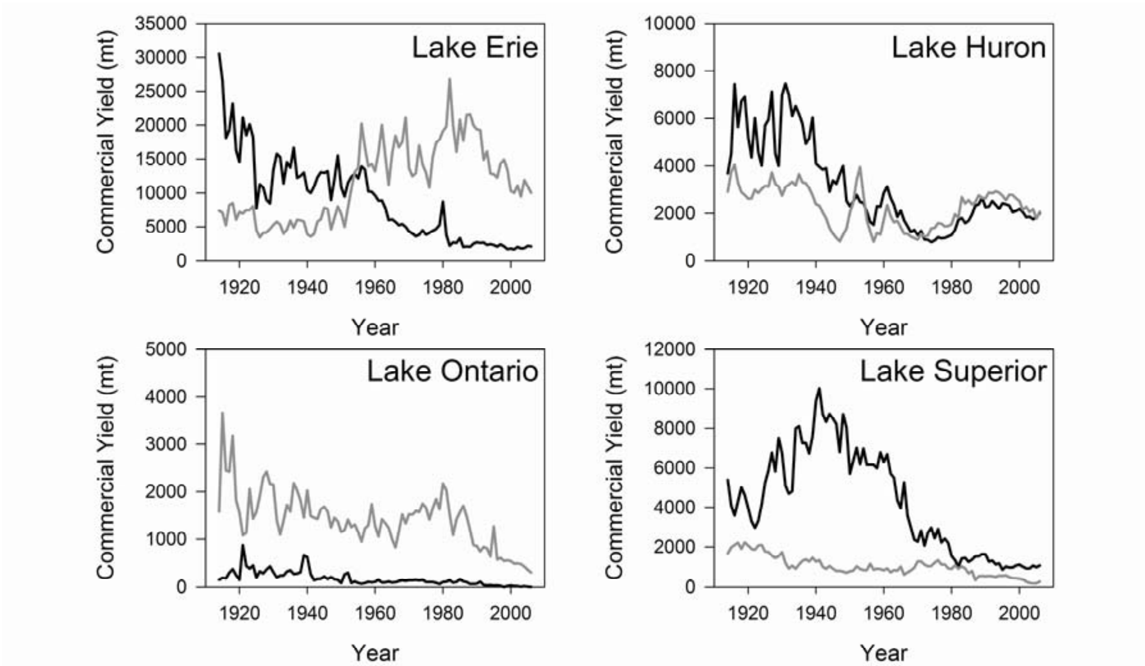


Figure 8



2472

Figure 9

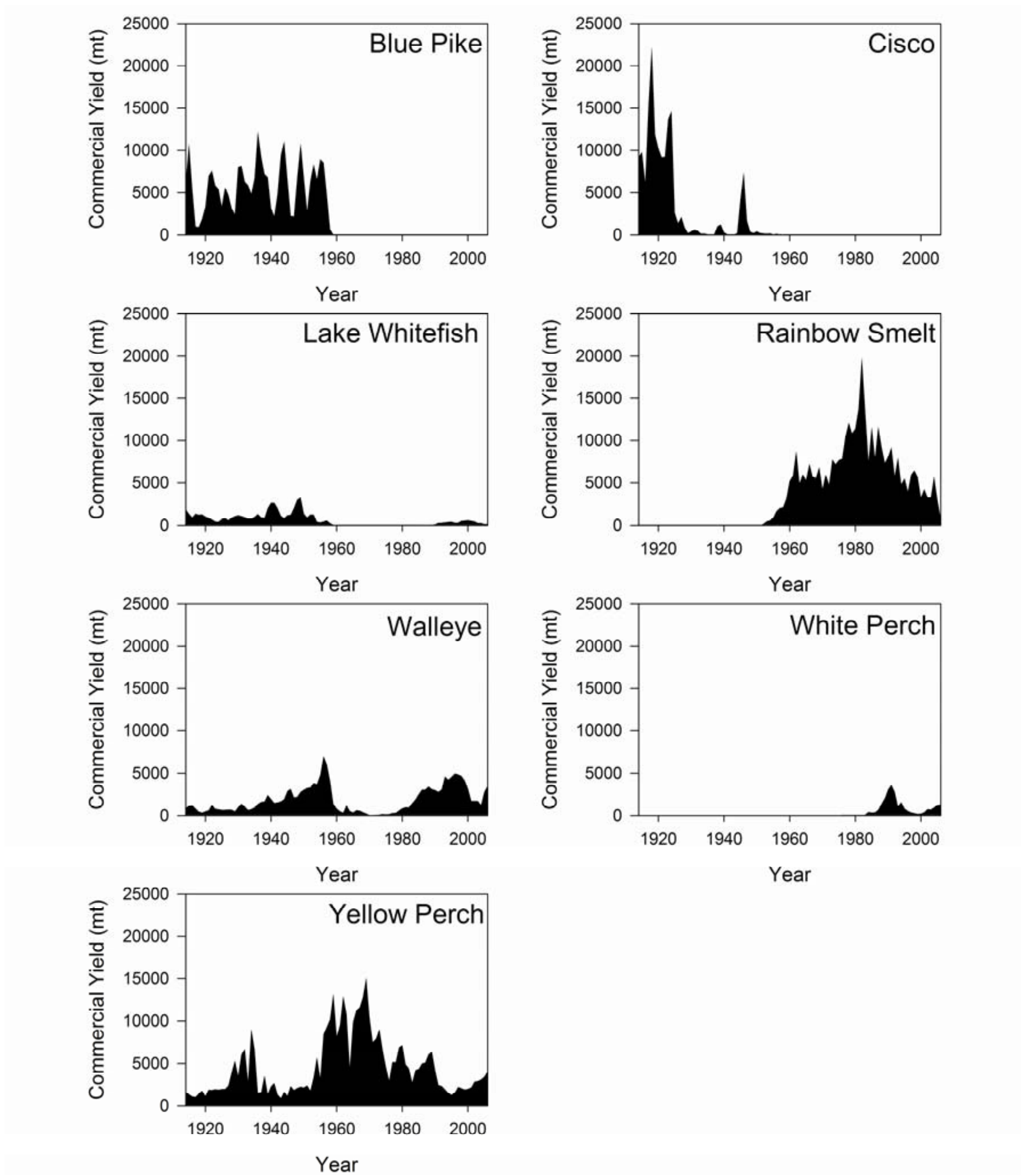
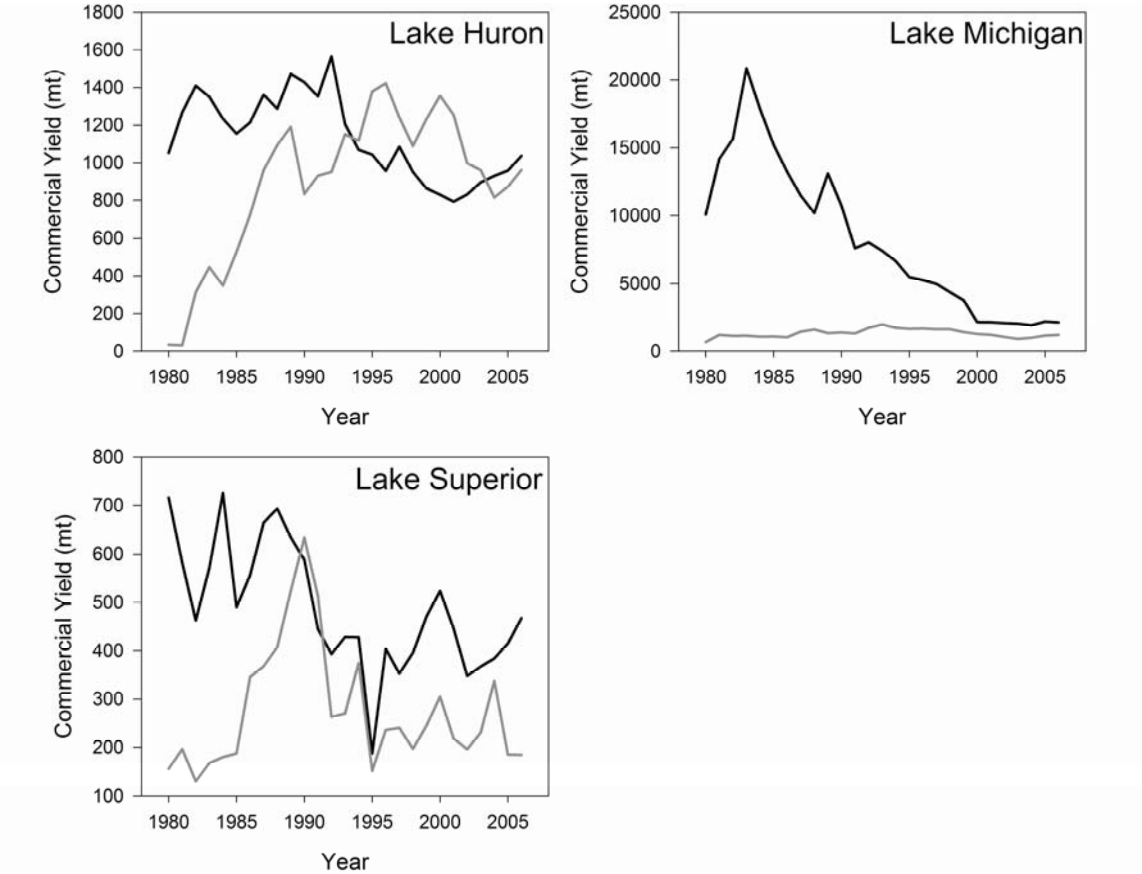
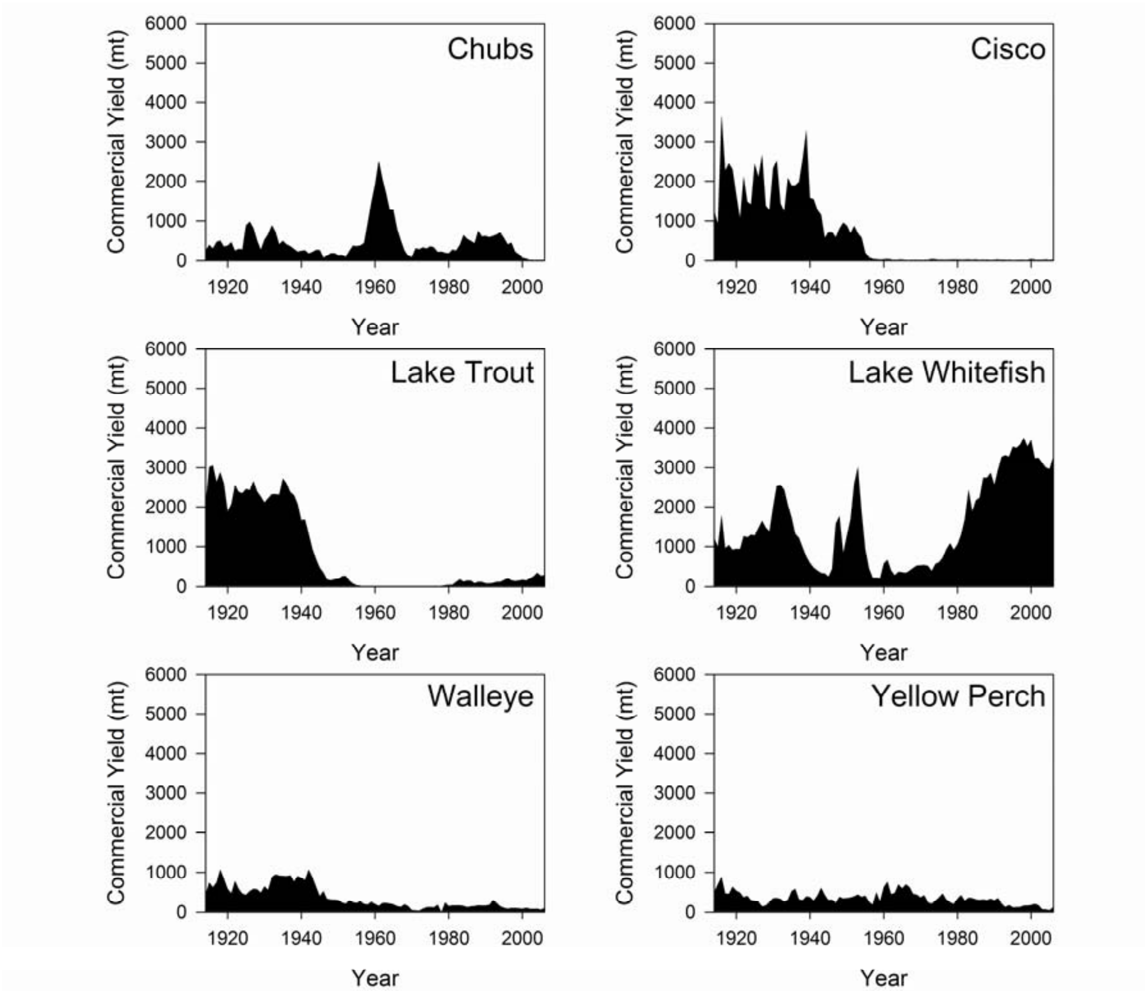

Blue Pike
Cisco
Lake Whitefish
Rainbow Smelt
Walleye
White Perch
Yellow Perch
Commercial Yield (mt)
0
5000
10000
15000
20000
25000
1920
1940
1960
1980
2000
Year

Figure 10



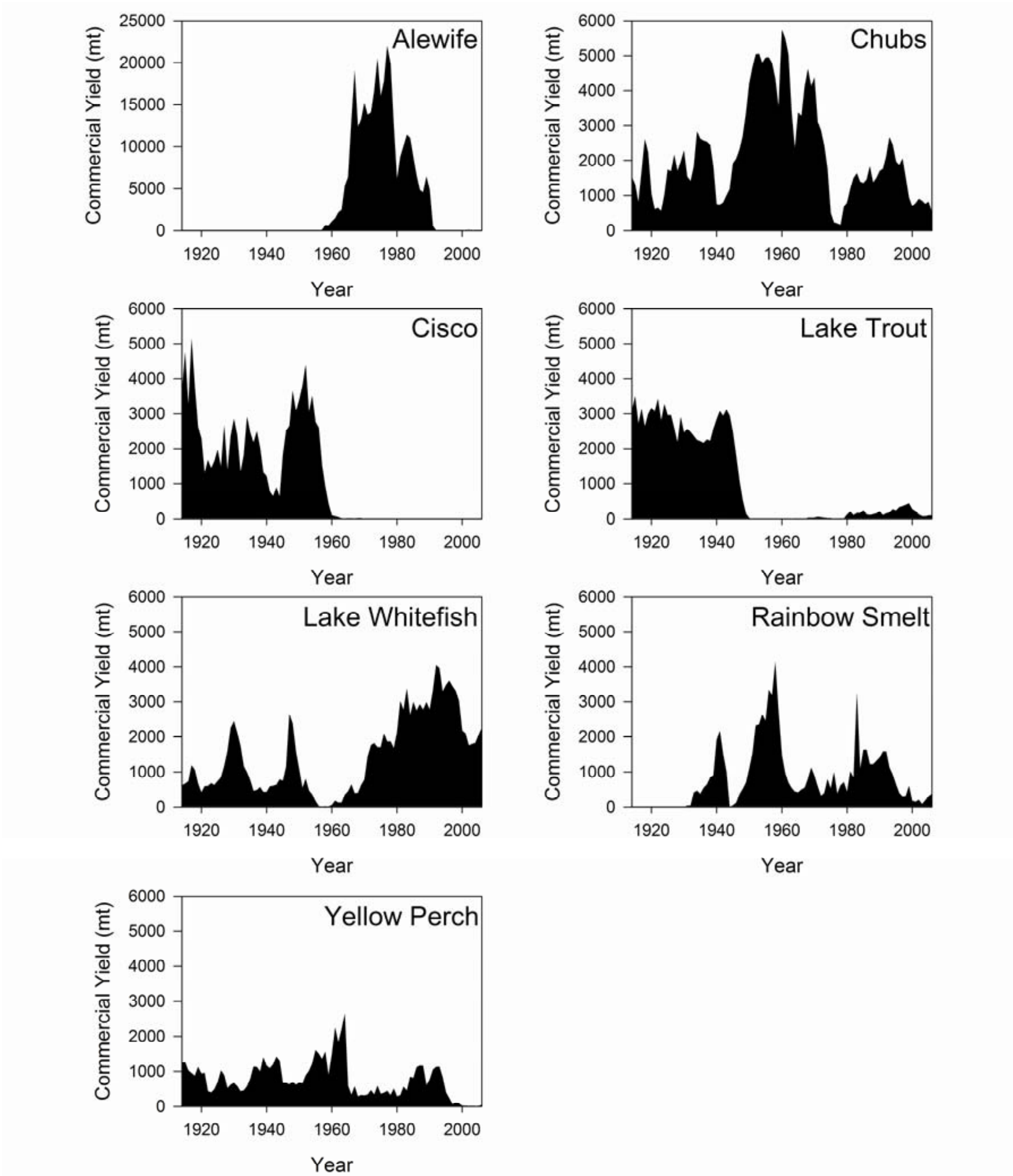
2474

Figure 11



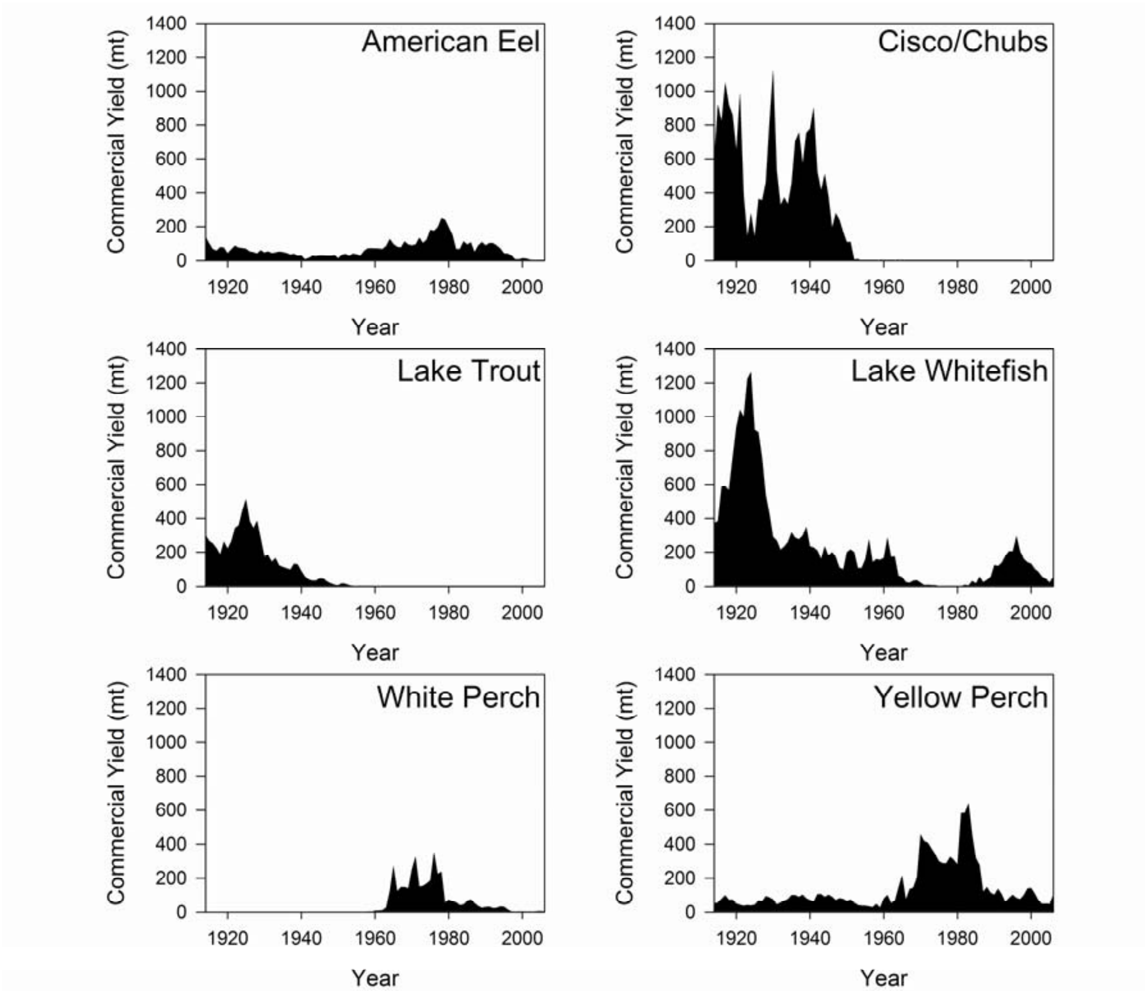
2475

Figure 12



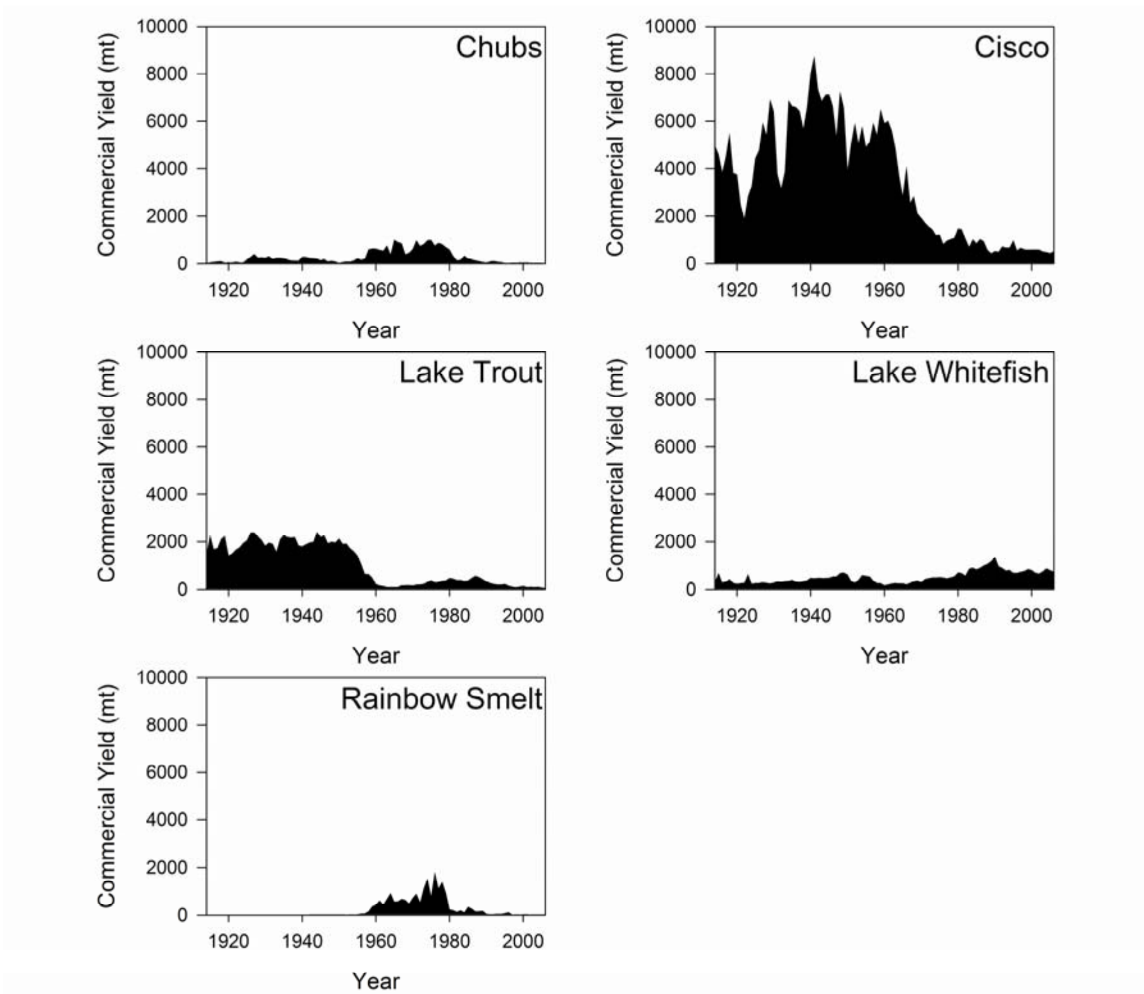
2476

Figure 13



2477

Figure 14


Chubs
Cisco
Lake Trout
Lake Whitefish
Rainbow Smelt
Commercial Yield (mt)
0
2000
4000
6000
8000
10000
Year
1920
1940
1960
1980
2000