

Chapter 4

Management of Commercial Fisheries for Lake Whitefish in the Laurentian Great Lakes of North America

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Introduction

Lake whitefish *Coregonus clupeaformis* were an important food source to aboriginal people of North America well before the arrival of European settlers (Kinietz 1965; Cleland 1982). Archaeological records indicate that they began to exploit lake whitefish populations of the Great Lakes somewhere during 3,000–1,000 B.C. (Cleland 1982; Spangler and Peters 1995). By 800 A.D. lake whitefish were a primary staple of aboriginal people in the upper Great Lakes and many of their villages were located adjacent to lake whitefish spawning grounds (Kinietz 1965; Cleland 1982). By the time European explorers entered the upper Great Lakes region in the early 1600s, aboriginal people had developed highly organized gill-net fisheries that targeted lake whitefish and other species in nearshore waters (Kinietz 1965; Cleland 1982; Goodier 1989). By the late 1700s aboriginal people were selling and trading lake whitefish to European settlers in the three upper Great Lakes (Cleland 1982; Spangler and Peters 1995).

European explorers and Catholic Jesu-

its exploring the upper Great Lakes region praised the abundance and fine flavor of lake whitefish. A Jesuit priest wrote that “where the Outaouaks and Huron live, there are caught at all times of the year great numbers of whitefish” and another explorer wrote that lake whitefish was the best of all the Great Lakes fish “weighing from four to sixteen pounds, and is of a superior quality in these waters” (Kinietz 1965; Goodier 1989). Other early explorers labeled lake whitefish as the “best fish in the world” saying that “one could eat it for days and never grow tired of it” (Kinietz 1965). When European settlers to North America discovered the delicate flavor and white flesh of lake whitefish they began extensive fisheries for the species.

Lake whitefish were the primary target of the first commercial fisheries in the Great Lakes because they spawned in large concentrations in shallow water near shore where they could be harvested with gill nets and seines by early settlers (Spangler and Peters 1995; Brown et al. 1999). Commercial fisheries for lake whitefish began in the late 1700s and more large-scale fisheries began in the 1820s all along the shorelines, principally by The American Fur Company and later by Hudson’s Bay Company and A. Booth Pack-

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ing Co. (Milner 1874; Nute 1926; Goodier 1989; Spangler and Peters 1995; Bogue 2000). Cities such as Detroit, Chicago, New York, and Cleveland were the primary markets for lake whitefish, which sold for \$6 a barrel in 1830 (Coberly and Horrall 1982; Goodier 1989; Brown et al. 1999). The fishery for lake whitefish intensified in the late 1800s and early 1900s as technology improved gear, fishing power, and processing of the catch (Nute 1926; Van Oosten et al. 1946; Lawrie and Rahrer 1972; Spangler and Peters 1995; Brown et al. 1999; Bogue 2000; Mohr and Ebener 2005a).

Lake whitefish populations and the fishery declined during roughly an 80-year period from the 1880s to 1960. Peak yields from lakes Superior, Huron, and Michigan occurred just as records were beginning to be kept in the 1880s. The largest recorded yield was about 11 million kg in 1879 and very large yields of roughly 10 million kg occurred prior to 1890 (Figure 1). Yield aver-

aged 3.2 million kg from the 1880s to 1955 and the greatest historical yield during this time came from Lake Huron, followed by lakes Michigan, Superior, Erie, and Ontario (Fleischer 1992; Spangler and Peters 1995). By 1900 populations of lake whitefish had been reduced in near shore waters by expanding fisheries (Lawrie and Rahrer 1972; Wells and McLain 1973; Spangler and Peters 1995) and degradation of tributary and near-shore habitat (Beeton 1965; Lawrie and Rahrer 1972; Hartman 1973; Wells and McLain 1973; Christie 1973; Spangler and Peters 1995; Reckahn 1995). Some substantial yields were obtained during 1910–1955, but they were short-lived and usually caused by production of large-year classes (Lawler 1965; Reckahn 1995) or excessive fishing (Van Oosten et al. 1946). Fisheries for lake trout *Salvelinus namaycush* and cisco *Coregonus artedii* developed in the early to mid-1900s as lake whitefish populations and their fishery yields declined (Spangler and Peters

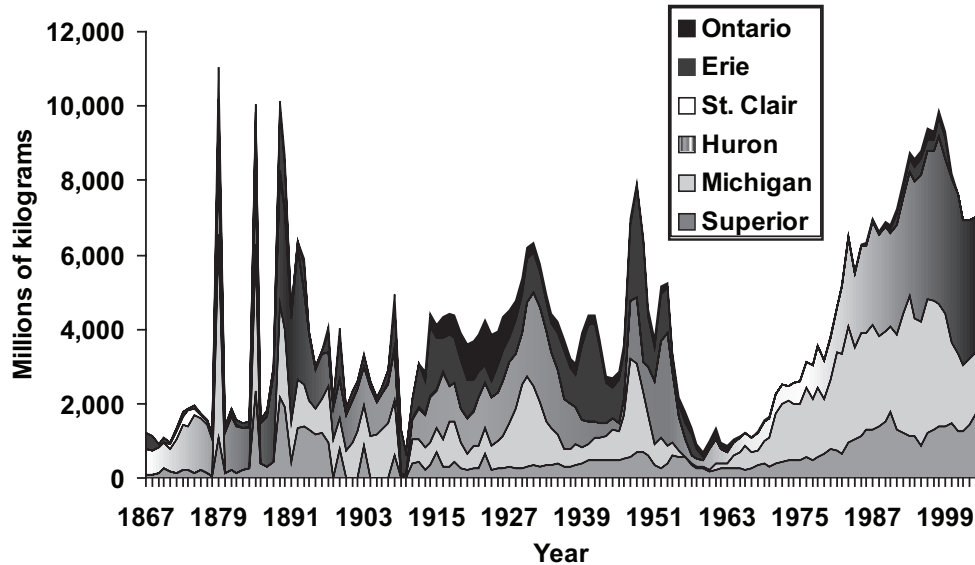


Figure 1. Commercial fishery yields of lake whitefish from the Great Lakes during 1867–2004 (Baldwin et al. 2000). The yield records are incomplete or missing from 1867 through 1913. Commercial fishery yield information during 1867–2000 obtained from the Great Lakes Fishery Commission website at www.glfc.org.

1995; Brown et al. 1999). The introduction of marine fish to the Great Lakes added the final insult to already stressed populations, and lake whitefish collapsed in all the Great Lakes during 1955–1970 (Fleischer 1992). The total fishery yield from the Great Lakes was only 701,000 kg in 1959 (Figure 1), and many commercial fishers believed lake whitefish were extinct by this time.

Thus over roughly 180 years lake whitefish went from being an abundant indigenous species to near extinction. Other indigenous fish species also suffered the same fate as lake whitefish during the same time period in the Great Lakes (Lawrie and Rahrer 1972; Berst and Spangler 1973; Christie 1973; Hartman 1973; Wells and McLain 1973; Legault et al. 1978; Bogue 2000). In response to the degradation of fisheries and fish habitat in the Great Lakes, state, provincial, and federal management agencies took aggressive steps to rehabilitate the Great Lakes aquatic ecosystem by restricting commercial fisheries, stocking the lakes with introduced Pacific salmon *Oncorhynchus* spp., controlling sea lampreys *Petromyzon marinus*, reducing inputs of man-made chemicals to the lakes, and restoring degraded habitats (Legault et al. 1978; Smith and Tibbles 1980; Keller and Smith 1990). These management actions in combination with favorable environmental conditions for growth and reproduction allowed lake whitefish populations to recover and today they support the largest commercial fishery on the Great Lakes (Ebener 1997; Mohr and Nalepa 2005).

Considerable research has been conducted on lake whitefish populations in the Great Lakes and at projecting appropriate harvest levels from the populations over the last 30 years (Patriarche 1976; Jacobsen and Taylor 1985; Rybicki and Schneeberger 1990; Ebener et al. 2005), yet few people have specifically described the commercial fishery for lake whitefish and its management (Ebener 1997; Mohr and Ebener 2005a) and no

one has taken an objective look at the basin-wide fishery. Significant ecological change brought about by recent invasive species has dramatically altered lake whitefish population dynamics, the fishery for them, and management (Mohr and Nalepa 2005). Our objective is to describe the status of the commercial fishery for lake whitefish in the Great lakes in relation to the fish's population dynamics, ecological change, market demands, and the global economy, and document evolution of management policies for regulating the fishery.

Past and Current Status of the Fishery and Their Ecosystem

Biological population status

Lake whitefish are a coldwater species indigenous to all of the Great Lakes and North America roughly north of latitude 45°. They are a member of the subfamily Coregoninae and the subgenera *Coregonus* (true whitefish), which are characterized by their subterminal mouth, low number of gill rakers, and benthic feeding behavior on macroinvertebrates (Lindsey 1981; Bernatchez et al. 1991). *Coregonus* evolved in northern Europe and Asia and radiated to North America during the Pleistocene (Bailey and Smith 1981; Bernatchez et al. 1991; Smith and Todd 1992) and colonized the Great Lakes after the Wisconsin glaciation (Lindsey et al. 1970; Bailey and Smith 1981; Stott et al. 2004). Lake whitefish are phenotypically highly variable and ecologically diverse throughout their distribution because of the different environments they inhabit and food resources they consume, but in the Great Lakes they are less differentiated than in other areas of North America (Lindsey 1981; Ihssen et al. 1981; Todd 1996; Bernatchez 2005). Bernatchez (2005) concluded that divergent natural selection has driven lake whitefish diversity and that changes to the trophic environments

of lake whitefish could result in a rapid evolutionary response over a few generations in their populations. Thus fisheries for lake whitefish vary from one area to another through time in response to how the species adapts to changes in its local environment.

Habitat

Lake whitefish occupy only a small portion of the total area in each Great Lake in waters of 1–145 m, but they are most commonly found in water between 15 and 55 m that is associated with the shoreline of the lakes or islands (Selgeby and Hoff 1996). In the central basin of Lake Erie lake whitefish are confined to a thin layer of water that makes up less than 9% of the area and 7% of the volume where there are sufficient oxygen levels (Cook et al. 2005). Lake whitefish spawn from late October into December with peak spawning during 1–20 November. Spawning sites are typically near shore in less than 5 m of water over hard stony substrates (Freeberg et al. 1990) along the exposed windward shorelines or reefs. They spawn over small to moderate-sized cobble substrates, but they have been observed to spawn on sand (Coberly and Horrall 1980; Goodyear et al. 1981). Few, if any, spawning grounds are located more than 2 km from a shoreline. In-lake spawning areas are in good condition for the most part because human populations have remained relatively low throughout the areas where most of the spawning habitats are located. Long-term cycles in water level and temperature caused by the hydrological cycle and other climatic factors interact to control long-term fluctuations in lake whitefish production (Reckahn 1986).

Habitat degradation in tributaries and their estuaries was an important cause of the decline in lake whitefish populations from the early 1800s through the 1960s (Smith 1917; Smith 1972; Lawrie and Rahrer 1972; Hartman 1973; Wells and McLain 1973; Chris-

tie 1973). Woody debris including sawdust from lumbering caused the loss of some estuary and river spawning populations of lake whitefish in every Great Lake. Hydroelectric barriers, navigation locks, and dewatering of rapids dramatically reduced abundance of spawning concentrations of lake whitefish in large tributaries (Smith 1917; Kaups 1984; Duffy and Batterson 1987; Edsall and Gannon 1993; Manny et al. 1988). As of 2005 lake whitefish spawned in only a few Great Lakes tributaries (Carney 2006).

Huge influxes of phosphorus and nitrogen to all the Great Lakes, except Superior and the main basin of Lake Huron, during the middle portion of the 20th century increased primary production and altered plankton and zooplankton composition and density (Colby et al. 1972). These limnological changes in turn influenced spatial distribution and growth of lake whitefish particularly in Lake Erie (Hartman 1973; Kenyon 1978). The Great Lakes Quality Agreement in 1978 brought about reductions in phosphorus concentrations and primary production in the four lower Great Lakes, but these changes have not been uniform among the lakes (Mills et al. 2005; Madenjian et al. 2002; Dobiesz et al. 2005).

Invasive species

The introduction of marine and freshwater fishes to the Great Lakes reduced abundance of lake whitefish starting in the early part of the 20th century. Sea lampreys, alewives *Alosa pseudoharengus*, and white perch *Morone americana* invaded the Great Lakes from the Atlantic Ocean through the Erie and Welland canals around Niagara Falls, while rainbow smelt *Osmerus mordax* entered through angler releases, but they all may have had effects on lake whitefish populations (Smith 1972; Lawrie and Rahrer 1972; Christie 1973; Wells and McLain 1973; Berst and Spangler 1973). Sea lamprey had their

greatest effects on adult lake whitefish during the 1950s and 1960s, but federal government actions to reduce sea lampreys were successful at increasing survival and abundance of lake whitefish (Spangler 1970; Christie 1973; Jensen 1976; Spangler et al. 1980; Spangler and Collins 1980; Reckahn 1995). Sea lamprey populations are only one-tenth as abundant as prior to control, but they continue to attack and kill lake whitefish, particularly in Lake Huron (Ebener 2006a).

Predation on larvae is the most likely effect of alewives, rainbow smelt, and white perch on lake whitefish abundance. Rainbow smelt have not been directly implicated in the decline of lake whitefish in the Great Lakes as they have in inland lakes, but they were considered detrimental to the populations (Loftus and Hulsman 1986; Evans and Loftus 1987; Reckahn 1995). Alewives have been blamed for the decline of a number of indigenous species in the Great Lakes but primarily after sea lampreys had already reduced abundance of adult fish (Smith 1972). The influence of alewives on lake whitefish abundance may be much less than previously suggested in Lake Michigan because Bunnell et al. (2006) have suggested that recovery of lake whitefish may have been a spurious correlation with the alewife reduction.

Invasive dreissenid mussels have had the most profound recent effect on lake whitefish in the Great Lakes; particularly lakes Michigan, Huron, and Ontario. There has been little observable effect on lake whitefish in Lake Erie although dreissenid mussels are abundant there, and mussel abundance in Lake Superior is too low to be detrimental to lake whitefish. Zebra mussel *Dreissena polymorpha* and quagga mussel *D. bugensis* abundance increased quickly in water less than 75 m in the four lower Great Lakes in the early 1990s (Nalepa and Schloesser 1993; Mills et al. 2005) and these increases were followed almost immediately by significant declines in abundance of lake whitefish prey such

as indigenous benthic macroinvertebrates and especially the amphipod *Diporeia* spp. (Pothoven et al. 2001; Pothoven 2005; Mills et al. 2005; Nalepa et al. 2005). Researchers estimated a loss of 5,100 metric tons of *Diporeia* biomass in the 10–50 m depth zone of Lake Ontario between 1994 and 1997 (Lazano and Scharold 2005), and *Diporeia* abundance has declined to zero at many sites within lakes Michigan, Huron, and Ontario. After the loss of *Diporeia*, its composition in the diet of lake whitefish declined dramatically and lake whitefish diets diversified as they began eating mainly dreissenid mussels; gastropods, opossum shrimp *Mysis relicta*, ostracods, oligochaetes, and zooplankton were also in the diet (Hoyle et al. 1999; Pothoven et al. 2001; Pothoven 2005; Hoyle 2005). Body condition of lake whitefish declined substantially concurrent with the loss of *Diporeia* (Hoyle et al. 1999; Pothoven et al. 2001; Mohr and Ebener 2005b). Essentially, the caloric content of food eaten by lake whitefish has declined since the loss of *Diporeia* and lake whitefish now forage over broader geographic areas, in deeper water, and more on pelagic organisms than they did only 15 years earlier.

Distribution and movement of stocks

At least 56 stocks of lake whitefish are recognized for management purposes in the Great Lakes (Ebener 1997). Distances of one hundred kilometers or more separate some stocks (Imhof et al. 1980; Casselman et al. 1981; Scheerer and Taylor 1985; Ebener and Copes 1985), while distances of 5–20 km separate other stocks (Budd 1957; Clary 1962; Dryer 1964; Casselman et al. 1981; Koziol 1982; Walker et al. 1993; Stott et al. 2004). Most lake whitefish stocks inhabit areas within 50 km of the spawning site, but some stocks are very migratory; thus spatial distribution of discrete stocks overlap during the nonspawning season and the commercial fisheries harvest multiple stocks in some instances (Budd



Figure 2. The Great Lakes including locations referenced in this chapter and lake whitefish management units.

1957; Dryer 1964; Cucin and Regier 1965; Ebener and Copes 1985; Scheerer and Taylor 1985; Ebener 1990; Walker et al. 1993). For example, a stock of lake whitefish in lower Whitefish Bay, Lake Superior, spawns in Canadian waters but spends considerable time during the nonspawning season in U.S. waters (Chippewa Ottawa Resource Authority, unpublished data).

Movement of some stocks has changed through time in response to changes in the food web brought about by dreissenid mussels and declines in *Diporeia*. Geographic and bathymetric shifts in distribution of lake whitefish occurred in eastern Lake Ontario (Owens et al. 2005) and northern Green Bay (M-01) during the late 1990s. The lake whitefish spawning stock in Lake Michigan management unit M-01 was fairly sedentary and was seldom captured outside Green Bay during 1978–1980 (Ebener and Copes 1985), but during 2003–

2005 almost one-half of the spawning stock inhabited the main basin of Lake Michigan south of the Door Peninsula (Chippewa Ottawa Resource Authority, unpublished data). The largest concentration of *Diporeia* now remaining in Lake Michigan is found along the western portion of the main basin from the tip of the Door Peninsula to Milwaukee, Wisconsin (Figure 2)—where much of the spawning stock from M-01 is now found during the nonspawning season. *Diporeia* were common in Green Bay during the 1970s and 1980s, but are now absent from there (T. F. Nalepa, Great Lakes Environmental Research Laboratory, personal communication).

Sexual maturity

There is considerable variability in rates of sexual maturity among lake whitefish populations in the Great Lakes that is not size- or

age-dependent, but rather is inversely related to growth potential of individual stocks (Taylor et al. 1992; Beauchamp et al. 2004). Lake whitefish begin to mature between 30 and 45 cm total length (TL) and ages 2–8 years, and complete maturity is typically achieved between 37 and 55 cm TL and ages 4–12 years with males reaching maturity sooner than females (Taylor et al. 1992). On average, roughly 60%, range 39–84%, of female lake whitefish from northern lakes Michigan and Huron and eastern Lake Superior will spawn by the time they reach 43 cm TL (17 in, which is the minimum legal length limit of many commercial fisheries). The age of maturity in lake whitefish occurs near the inflection of the growth curve, and implies a relationship between age and length at maturity, the growth coefficient, and asymptotic length (Jensen 1985). Stocks of lake whitefish with large maximum growth potential reach maturity at relatively large sizes, while stocks with smaller maximum growth potential reach maturity at a much smaller size; consequently age at maturity is inversely related to prereproductive growth rates and the time to achieve asymptotic size is positively correlated with age at maturity (Taylor et al. 1992; Beauchamp et al. 2004).

Recruitment

Recruitment of lake whitefish to fishable sizes in the Great Lakes is primarily a function of adult stock size and water temperature mediated by other biotic and abiotic events (Lawler 1965; Christie and Regier 1971; Henderson et al. 1983; Taylor et al. 1987; Freeberg et al. 1990; Brown et al. 1993). For many, but not all stocks of lake whitefish, cold winters that produce considerable ice cover to protect eggs from large wind events will result in abundant year classes of lake whitefish, but only if spring water temperatures warm at a steady rate and zooplankton size and density are appropriate (Taylor et al. 1987; Freeberg et al. 1990).

Recovery of lake whitefish populations in the Great Lakes began with production of year classes in the 1960s and since then annual recruitment has been good and reasonably stable with exceptionally abundant year classes being produced sporadically. Production of the 1972 and 1977–1978 year classes began the modern-day recovery of lake whitefish populations in the Great Lakes (Ebener and Copes 1985; Scheerer and Taylor 1985; Casselman et al. 1996). The abundance of the 1982–2000 year classes, as estimated with statistical catch-at-age analysis (Bence and Ebener 2002), was fairly constant but not consistent among the three upper Great Lakes (Figure 3). In Lake Ontario production of the 1987–1995 year classes was considerably greater than previous year classes, but production declined to near zero for the 1998–2002 year classes before increasing again in 2003–2005 (Figure 3). This consistent and high production of year classes in the Great Lakes helped the commercial fishery achieve the large yields taken in the 1990s.

Growth dynamics

Recovery of lake whitefish populations, in combination with changes in the lower food web, has dramatically altered their growth dynamics. Density-dependent declines in growth and increasing age at maturity were occurring in lakes Superior, Huron, and Michigan prior to arrival of dreissenid mussels and the subsequent declines in *Diporeia* (Taylor et al. 1987; Mohr and Ebener 2005b; Hoyle 2005; Ebener 2006b; Kratzer et al. 2007; Wright and Ebener 2007). The loss of *Diporeia* in lakes Michigan, Huron, and Ontario further reduced growth and condition, and delayed age at maturity of lake whitefish. Substantial declines in mean weight-at-age and body condition of lake whitefish from lakes Ontario, Huron, and Michigan began in the early to mid 1990s shortly after proliferation of dreissenid mussels and

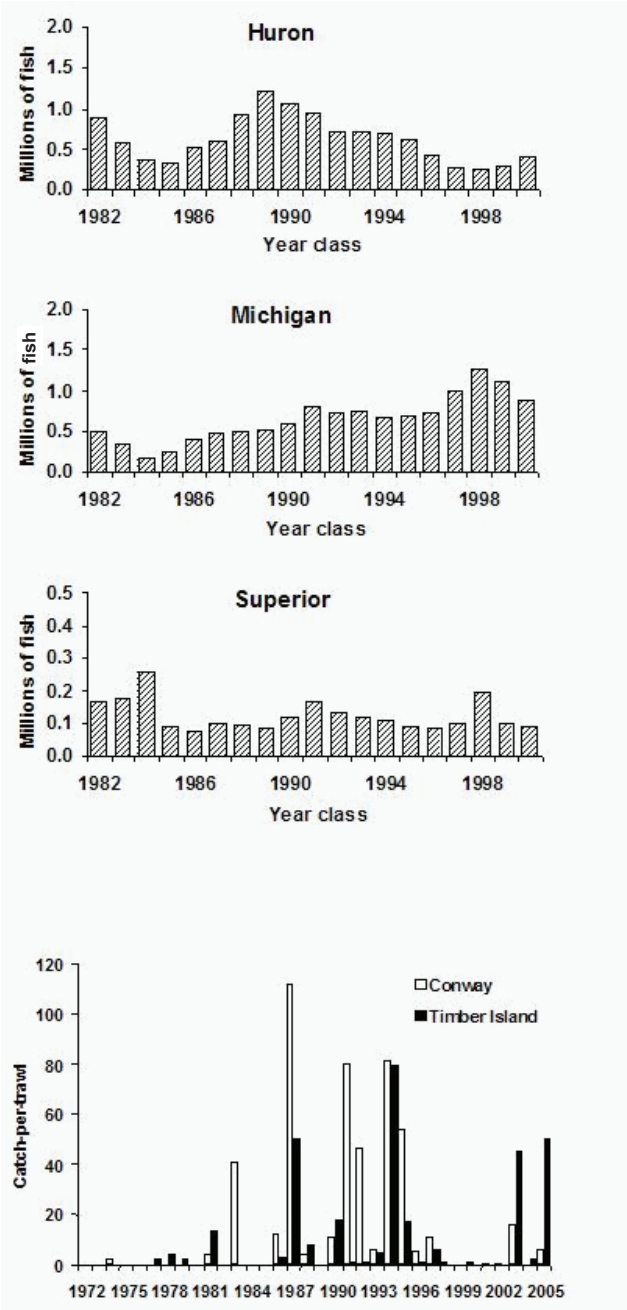


Figure 3. Average abundance (millions of fish) of the 1982–2000 year classes of lake whitefish in selected areas of lakes Huron (H-01, H-02, H-04), Michigan (M-01 to M-06 and M-08), and Superior (S-04, S-05, S-07, S-08) estimated by statistical catch-at-age analysis, and indices of age-0 lake whitefish at two spawning shoals in the Kingston Basin of Lake Ontario during 1972–2005. Average recruitment at age-4 in lakes Huron and Superior and age-3 in Lake Michigan was weighted by the square kilometers of surface area in the management units (see Figure 2 for management unit locations).

declines in abundance of *Diporeia* (Hoyle et al. 1999; Pothoven et al. 2001; Hoyle 2005; Mohr and Ebener 2005b; Schneeberger et al. 2005). Dreissenid mussels essentially exacerbated the normal density-dependent growth dynamics of lake whitefish and the loss of *Diporeia* is preventing full recovery of their growth rates to levels observed earlier in the 20th century (Kratzer et al. 2007; Wright and Ebener 2007). Indirectly, the loss of *Diporeia* may also affect larval lake whitefish survival and growth because both are positively correlated with lipid content of the eggs of females (Brown and Taylor 1992).

Exploitation

Lake whitefish in the Great Lakes typically respond to additional fishing pressure by growing faster, maturing at younger ages, increasing fecundity, and possibly surviving better at younger ages (Jensen 1981, 1985; Taylor et al. 1987; Liu and Jensen 1993). Heavily exploited stocks of lake whitefish typically have higher estimates of reproduction per individual than lightly or unexploited stocks. Lake whitefish populations have sustained themselves under substantial exploitation in the Great Lakes primarily because they begin reproducing at small sizes before they become fully vulnerable to fishing gear. Most male lake whitefish and probably one-half the females have spawned once before they become fully vulnerable (≈ 48 cm TL) to the fishing gear. Exploitation rates typically range from 10 to 30% for lake whitefish stocks but in some stocks it has exceeded 50% (Woldt et al. 2006; Ebener and Copes 1985; Scheerer and Taylor 1985; Rybicki and Schneeberger 1990; Schorfhaar and Schneeberger 1997).

The change in bathymetric distribution of stocks in lakes Michigan and Ontario, and probably elsewhere, due to changes in water clarity and food availability, has reduced exploitation and shifted the jurisdictions where

some stocks of lake whitefish are harvested. Exploitation of lake whitefish in M-01 ranged from 47 to 64% during 1979–1980 (Ebener and Copes 1985), but was less than 10% during 2004–2005 (Chippewa Ottawa Resource Authority, unpublished data). During 1978–1980, the State of Michigan licensed commercial fishery accounted for 90% of the exploitation on the M-01 stock, whereas during 2004–2005 the state of Wisconsin fishery accounted for over 50% of the exploitation. Movement of lake whitefish out of the Kingston Basin in eastern Lake Ontario and into deep water and into New York waters reduced exploitation on that stock because there is no commercial fishery for lake whitefish in New York.

Fish health

Little is known about the fish health of lake whitefish because their populations are self-sustaining and fishery agencies in the Great Lakes have focused their efforts on understanding and minimizing diseases of hatchery-reared trout and salmon. One of the authors (JAH) has documented a die-off of juvenile lake whitefish less than 350 mm TL in eastern Lake Ontario from an unknown cause in the summer of 1996 and 1997. In the summer of 2006 there was an epizootic of lake whitefish in management unit H-05 of Lake Huron due possibly to viral hemorrhagic septicemia (VHS) because the disease was detected in lake whitefish from the nearby management unit H-04 in the summer of 2005 (Ebener and Arts 2007; MiDNR 2007). The causative agent of bacterial kidney disease (BKD) *Renibacterium salmoninarum* has been found in lake whitefish from Lake Michigan and Huron, and fish from management unit H-02 in Lake Huron showed active clinical signs of BKD in the summer of 2004 (Ebener and Arts 2007). Fatty acid profiles of lake whitefish vary among stocks (Ebener and Arts 2007) due probably to spatial differences

es in food preferences (Pothoven et al. 2001; Pothoven 2005; Pothoven and Nalepa 2006) and different levels of ecosystem stress. We suspect that VHS, BKD, and essential fatty acids play a key, but yet undefined, role in the rate and magnitude of natural mortality in lake whitefish populations of the Great Lakes (Ebener and Arts 2007).

The Fishery After 1960

The recovery of lake whitefish populations and fisheries since 1960 has been phenomenal (Reckahn 1995; Ebener 1997; Mohr and Nalepa 2005) and they now support the largest commercial fishery on the Great Lakes. Commercial yield of lake whitefish increased by 248,000 kg/year from 1959 to 1998 before declining by 423,000 kg/year through 2004. The peak yield was 9.8 million kg in 1998 and the yield in 2004 was 7.3 million kg (Figure 1). Although the yield in 2004 was lower than the previous six years, it was still greater than 121 of the previous 138 years. Yield of lake whitefish observed over the last 46 years has been unparalleled in the Great Lakes basin and no doubt driven by both increased abundance and efficiency of the fishery. Present levels of commercial yield meet or exceed lake-specific objectives that have been developed by fishery management agencies to guide rehabilitation and protection of lake whitefish in lakes Superior, Huron, and Michigan (DesJardine et al. 1995; Eshenroder et al. 1995a; Horns et al. 2003).

Amazingly these yields occurred during a period of attrition in the fishery. In 1960, thousands of commercial fishing operations scattered along the shores of the Great Lakes harvested lake whitefish. Nearly 6,000 commercial fishers were employed in the U.S. and Canadian Great Lakes fisheries during the 1960s, but by the 1990s there were fewer than 3,000 (Brown et al. 1999). The decline in the number of fishers has continued, and only 620 licensees reported harvesting lake

whitefish during 2000–2005 (Table 1). The decline in number of licensed commercial fishers has been much greater in the U.S. than in Canada.

Yield and effort

While lake whitefish are harvested from all five Great Lakes, the fishery is concentrated in the upper lakes. During 1994–2004, Lake Huron accounted for 57% of the Great Lakes yield, followed by Michigan (28%), Superior (9%), Erie (4%), and Ontario (2%). Of the fishers that harvest lake whitefish, 79% do so in lakes Superior, Huron, and Michigan. Lake Superior has the greatest number of licenses, followed by lakes Michigan, Huron, Erie, and Ontario (Table 1). Three U.S. states, the Province of Ontario, and nine aboriginal (Native American) governments license commercial fisheries on Lake Superior, whereas only the Province of Ontario has a fishery on Lake Ontario. The Province of Ontario has the largest number of commercial fishers that harvest lake whitefish, followed by the Chippewa Ottawa Resource Authority (CORA), and the State of Wisconsin. The states of Minnesota, Illinois, Indiana, and New York have no commercial fisheries for lake whitefish.

More commercial fisheries use large-mesh gill nets of 114 mm stretch mesh and larger than any other gear to harvest lake whitefish. Large-mesh gill nets are used by 72% of the commercial licenses, while deep trap nets are used by 22%. Large-mesh gill nets are used on all the Great Lakes to harvest lake whitefish, but only Native American fishers and fishers licensed by the State of Wisconsin and the Province of Ontario can legally use them. The Province of Ontario has the largest gill net fishery, while CORA member tribes have the most licenses that use trap nets (Table 1). More fishers use trap nets on Lake Michigan than elsewhere. Two pound-net fisheries, one trawl fishery, and one hoop-net fishery make up the remainder of the lake whitefish fishery.

Table 1. Average number of commercial fishing licenses issued by each political jurisdiction on the Great Lakes and number of fishing operations using large-mesh gill nets, trap nets, and other types of fishing gears to harvest lake whitefish during 2000–2005. Other types of fishing gear include trawls, pound nets, and hoop nets.

Lake	Jurisdiction	Mgt units	Agency	Number licenses	Fishing gear			
					gill net	trap net	other	
Superior	Wisconsin	2	State of Wisconsin	10	4	5	0	
			Red Cliff tribal	25	24	1	0	
			Bad River tribal	1	1	0	0	
	Michigan	9	State of Michigan	8	2	6	0	
			Chippewa Ottawa tribal	47	45	8	0	
			Bad River tribal	5	5	0	0	
			Red Cliff tribal	4	4	0	0	
			Keweenaw Bay tribal	17	16	1	0	
	Minnesota	3	State of Minnesota	0	0	0	0	
			Grand Portage tribal	2	2	0	0	
	Ontario	34	Province of Ontario	35	35	0	0	
			Provincial communal	4	4	0	0	
			Batchewana tribal	12	12	0	0	
Superior total		48		170	154	21	0	
Huron	Michigan	8	State of Michigan	14	0	13	1	
			Chippewa Ottawa tribal	63	53	19	0	
	Ontario	16	Province of Ontario	58	58	2	0	
			Provincial communal	6	6	0	0	
			Saugeen Ojibway tribal	13	12	0	0	
	Huron total		24		154	129	34	1
	Michigan	Michigan	9	State of Michigan	11	0	10	1
Chippewa Ottawa tribal				73	62	30	0	
Wisconsin		5	State of Wisconsin	81	33	20	2	
Illinois		1	State of Illinois	0	0	0	0	
Indiana		1	State of Indiana	0	0	0	0	
Michigan total		16		165	95	60	3	
Erie	Ontario	3	Province of Ontario	103	53	1	0	
	Ohio	3	State of Ohio	2	0	2	0	
	Michigan	0	State of Michigan	0	0	0	0	
	Pennsylvania	1	State of Pennsylvania	1	0	1	0	
	New York	0	State of New York	0	0	0	0	
	Erie total		7		106	53	4	0
Ontario	Ontario	6	Province of Ontario	24	13	11	0	
	New York	0	State of New York	0	0	0	0	
	Ontario total		6		24	13	11	0

Trap net effort for lake whitefish has generally been declining over the last 25 years. Annual trap net effort ranged from 19,200–30,400 lifts and averaged 25,600 lifts/year during 1979–2004 (Figure 4). Trap net effort on Lake Michigan made up 45% of the basin-wide effort during 1979–2004 averaging 10,400 lifts/year, but declined 28% after 1991. Trap net effort also declined on lakes Erie and Huron, 63% from 1996 to 2003 and 45% from 1983 to 2004, respectively. Trap net effort on Lake Superior was relatively constant during 1979–2004, while trap net effort on Lake Ontario was insignificant in comparison to the other lakes.

Large-mesh gill net effort was more stable than trap net effort over the last 25 years. Annual large-mesh gill net effort ranged from 30,900–39,400 km and averaged 32,900 km/year during 1979–2004. Gill net effort has consistently been greatest on Lake Huron even though there are more gill net fishers on Lake Superior. Gill net effort on Lake Huron increased from 11,200 km in 1979 to an average of 17,900 km during 2000–2004. Gill net effort on Lake Superior has been much more variable ranging from 4,900–17,500 km/year during 1979–2004. Gill net effort in Lake Erie increased from 658 km in 1992 to 3,800 km in 2002 as abundance of lake whitefish increased. On Lake Ontario, large-mesh gill

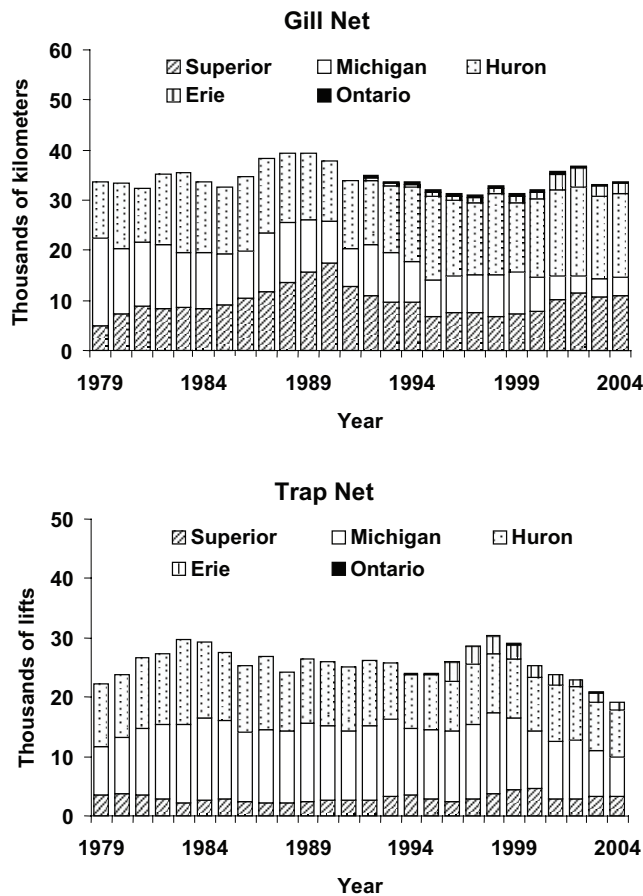


Figure 4. Large-mesh gill net and deep trap net commercial fishing effort for lake whitefish in each Great Lake during 1979–2004.

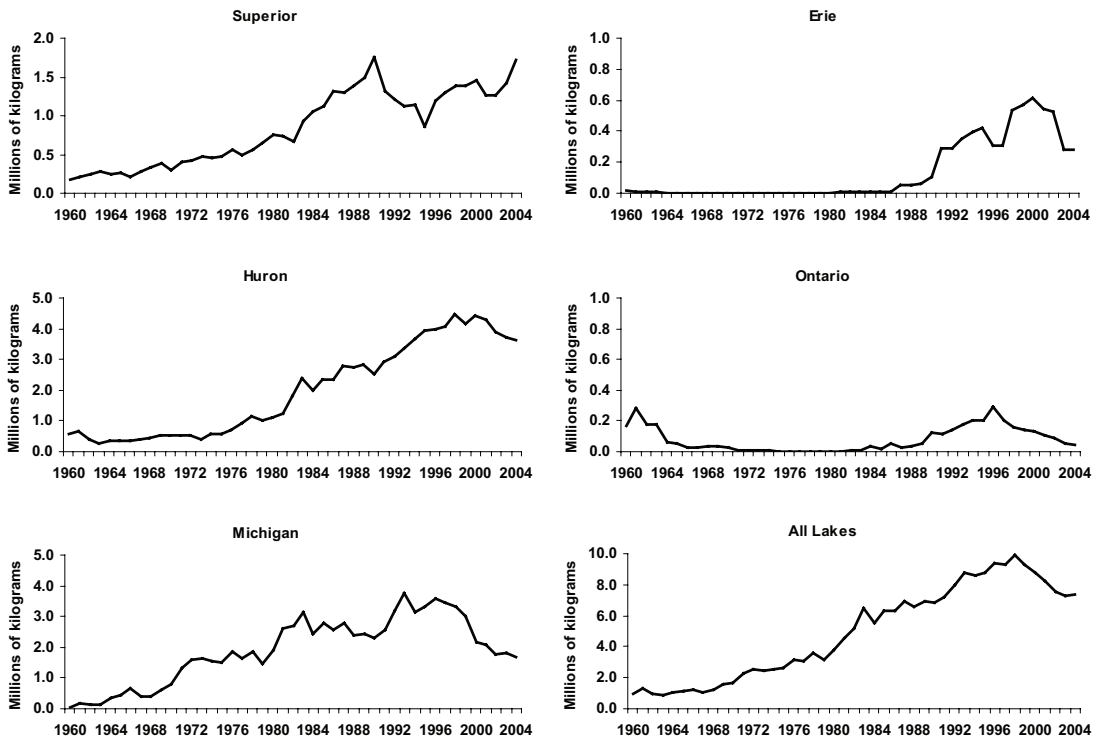


Figure 5. Commercial fishery yield (millions of kilograms) of lake whitefish from each Great Lake during 1960–2004.

net effort declined from 112 km in 1992 to 29 km in 2004 as lake whitefish populations declined in the Kingston Basin. On Lake Michigan, gill net effort declined 80% from 1979 to 2004 because of negotiated settlements between CORA member tribes and the State of Michigan and attrition of the gill-net fishery.

Patterns in yield were very similar among lakes, but the timing of when yields began to increase from historic lows was one to two decades earlier on the upper Great Lakes than on the lower lakes (Figure 5). Commercial fishery yield reached its lowest levels in 1957 in Lake Michigan (11,300 kg), 1959 in Lake Huron (203,600 kg), 1960 in Lake Superior (174,000 kg), 1970 in Lake Erie (0 kg), and 1981 in Lake Ontario (900 kg). In the three upper Great Lakes yield began increasing almost immediately thereafter. Commercial yield of lake whitefish increased at a much

slower, yet similar rate, in lakes Erie and Ontario. Yield peaked in 1993 in Lake Michigan (3.78 million kg), 1996 in Lake Ontario (0.29 million kg), 1998 in Lake Huron (4.49 million kg), and 2000 in Erie (0.61 million kg). Yield of lake whitefish from Lake Superior after 1960 peaked at 1.76 million kg in 1990, then declined through 1995 before increasing to 1.72 million kg in 2004.

Commercial yields are greater on Lake Huron because, unlike in other Great Lakes, lake whitefish are harvested throughout its waters. Lake whitefish are harvested in every management unit of Lake Huron except H-08 and the largest yields over the last 15 years have been from management units 4–4 and 4–5 (Mohr and Ebener 2005b). In Lake Michigan more than 90% of the commercial yield is taken from the northern one-third of the lake. The commercial fishery in Lake On-

tario operates almost solely in eastern Ontario waters around Prince Edward Island and the Kingston Basin management units 1–1 to 1–4 (Casselman et al. 1996; Hoyle 2005). The commercial fishery in Lake Erie occurs mainly in the western basin in Ontario waters. In Lake Superior commercial fishery harvests of lake whitefish are greatest in Whitefish Bay and the Apostle Islands, followed by the west and east sides of the Keweenaw Peninsula, and Thunder, Black, and Nipigon bays.

Bycatch

Bycatch in the lake whitefish fishery, particularly in large-mesh gill nets, has been substantial and considered one of the primary impediments to recovery of lake trout populations in the Great Lakes (Hansen 1999; Johnson et al. 2004a). An estimated 71,000 lake trout were taken incidentally in commercial gill-net fisheries for lake whitefish and deepwater ciscoes *Coregonus* spp. in Michigan waters of Lake Michigan in 1968 (Rybicki and Schneeberger 1990), while an estimated 30,000–66,000 lake trout were killed incidentally each year in the large-mesh gill net fishery for lake whitefish in Wisconsin waters of Lake Michigan during 1977–1983 (Holey 1985). Lake trout were not legal commercial fish species in either state-licensed fishery (see Evolution of Governance Structures section). Survival of lake trout released alive from a large-mesh gill net fishery varied seasonally from 21 to 31% in Wisconsin waters of Lake Superior during 1993 and 1994 where they could be legally harvested under individual transferable quotas (Gallinat et al. 1997). Survival of lake trout released from trap nets is considerably higher and was estimated to be 88% for the state-licensed trap-net fishery in northern Lake Huron in 1998 and 1999, and the lowest survival was during the summer (Johnson et al. 2004b).

Management agencies have taken considerable action to minimize the incidental catch

of lake trout. The Province of Ontario purposefully limits commercial fishing for lake whitefish to the fall spawning period in the Kingston Basin and eastern Ontario waters of Lake Ontario because their bycatch is considerably greater during other seasons of the year. Lake trout are not stocked in northern Wisconsin waters of Lake Michigan around the Door Peninsula (Figure 2) to minimize their incidental catch in the large-mesh gill-net fishery. In addition, large-mesh gill nets are prohibited in areas south of the Door Peninsula. Refuges have been established in lakes Huron, Michigan, and Superior to provide lake trout protection from exploitation by commercial and recreational fisheries (Hansen et al. 1995; Holeý et al. 1995; Eshenroder et al. 1995b). Many state governments have prohibited the use of large-mesh gill nets to reduce the incidental catch of lake trout. Most negotiated settlements between Native American governments and state agencies over treaty rights (Brown et al. 1999) have revolved around minimizing the incidental catch of lake trout in the tribal gill-net fisheries (see Evolution of Governance Structures section).

Numerous studies have documented the incidental kill of other species important to recreational fisheries, including some considered endangered, in trap-net fisheries for lake whitefish (Smith 1988; Schorfhaar and Peck 1993; Johnson et al. 2004b). In Michigan waters of southern Lake Michigan 60–80% of yellow perch *Perca fluvescens*, Pacific salmon and rainbow trout *O. mykiss* caught in trap nets died from gilling (Smith 1988). In Lake Superior the common loon *Gavia immer* was regularly observed caught in trap nets and their mortality was 100% (Schorfhaar and Peck 1993). Mesh size in the top of the trap-net hearts was increased to 35.6 cm (14 in) stretch mesh to reduce mortality of the common loon. Other recommendations were made that would require shoaling twine (mesh of 50-mm or less) in the top of the pot over the tunnel to reduce gilling of fish.

Effects of dreissenid mussels

The invasion of dreissenid mussels and the decline of *Diporeia* spp. have substantially altered the lake whitefish fishery. The bathymetric distribution of lake whitefish in lakes Michigan, Huron, and Ontario increased (Hoyle 2005; Owens et al. 2005; Mohr and Ebener 2005b) as a consequence of the invasion of dreissenid mussels partly because the mussel's filtering activities increased light penetration in the water column (Barbiero et al. 2006) and partly because of the loss of *Diporeia* (Nalepa et al. 2005). Both trap-net and gill-net fisheries have increased their average depth of fishing in order to capture lake whitefish in deeper water (Mohr and Ebener 2005a, 2005b), but trap-net fisheries can't fish as deep as gill net fisheries because it is too difficult to keep the gear taut. Gill-net fisheries, on the other hand, have little problem pursuing lake whitefish in deeper water. Fishing in deep water further from shore requires a large vessel that increases the cost of fishing; consequently, the number of marginally profitable small boat gill-net fisheries has declined on the Great Lakes since arrival of dreissenid mussels. There is anecdotal information from commercial fishers in lakes Michigan and Huron that lake whitefish are once again beginning to inhabit waters of 25–35 m during much of the year, possibly to feed upon very abundant populations of dreissenid mussels (Pothoven and Nalepa 2006).

Poor condition and slow growth during the last decade has reduced the marketability of lake whitefish and the ability of the fishery to harvest them. During the early to mid-1990s commercial fishermen in lakes Ontario, Huron, and Michigan reported catching many emaciated lake whitefish, particularly in the trap-net fisheries. Fish buyers did not want these emaciated fish so trap-net fishers were forced to release many legal-sized fish that previously would have been harvested. Consequently, the minimum legal size limit

for trap net fisheries was effectively increased nearly 25 mm (one inch) on an ad hoc basis in many areas of the Great Lakes by the commercial fishermen themselves because 43–45 cm long lake whitefish are not easy to market even though they can be legally harvested. The loss of body girth in lake whitefish from lakes Ontario, Huron, and Michigan during the mid-1990s dramatically reduced catchability in the gill net fishery, consequently gill net fisheries must now catch more fish to achieve the same level of yield or to reach their individual harvest limits.

Catchability of lake whitefish by both trap nets and gill nets has declined because of substantial increases in biomass of the filamentous algae *Cladophora glomerata*. Beginning about 1994 commercial fishermen began reporting that their trap nets and gill nets were being clogged with a “green slime” that prevented the gear from fishing properly so nets had to be removed from the water and washed on shore or destroyed. Reports of green slime (*Cladophora*) clogging commercial gear have become more frequent and widespread annually since 1997, especially in the northern one-third of lakes Huron and Michigan. In these areas large wind events that occur in late May or early June leave commercial fishing gear smothered in *Cladophora*, consequently fishers must spend weeks to months cleaning their gear. *Cladophora* has been called the “wall of green” and has proliferated because of increased water transparency and phosphorus availability to the benthic environment following establishment of dreissenid mussels (Higgins et al. 2005). Many nearshore areas can no longer be fished during May through September because large suspended mats of *Cladophora* clog nets. The proliferation of *Cladophora* has reduced commercial yields in northern lakes Michigan and Huron by 20–30% during the late spring and summer since the late-1990s. The large-mesh gill-net fishery has been impacted to a much greater degree

than the trap-net fishery because trap nets can be removed and cleaned then set again when covered with *Cladophora*, whereas gill nets are typically destroyed or the twine is removed and replaced. In addition, trap nets can catch some fish when covered with the green slime, whereas gill nets can't.

Value of the fishery

Lake whitefish is one of the three prime commercial species of the Great Lakes along with yellow perch and the walleye *Sander vitreus*. The primary supply chain for fresh-caught lake whitefish is from commercial fishers to processors located along the shore of the Great Lakes then to larger-scale processors and markets in the U.S. Midwest region and eastern seaboard, and southern Ontario. The large-scale processors distribute value-added products and fresh lake whitefish to up-scale delicatessens and restaurants, large and small grocery markets, or sell the fish directly to consumers, throughout the U.S. and Canada. Fish are shipped via refrigerated trucks from the Great Lakes region to the large-scale processors every Tuesday or Friday, but when catches are large trucks will travel daily. Traditionally, whole or gutted lake whitefish were sold directly to New York City, Detroit, and Chicago for the Jewish community. Prices paid for lake whitefish always increase during the Jewish holidays of Rosh Hashana and Yom Kippur.

Processors purchase lake whitefish from commercial fishers based upon weight of individual fish. Lake whitefish that weigh less than three pounds are sold as "number ones," fish of three to four pounds are sold as "mediums," and fish greater than four pounds are sold as "jumbos." Since roughly the year 2000, lake whitefish weighing less than two pounds have been sold as "small number ones," and fish weighting between two to three pounds are sold as "large number ones." The lowest price per pound paid to

commercial fishers is for small number ones, thereafter, the price increases with weight class. Jumbo whitefish are always twenty cents to one dollar more per pound than mediums; mediums are usually ten to fifty cents more than large number ones, which are five to ten cents more than small number ones. Number ones make up the bulk of the yield (80%) from the Great Lakes. Medium and jumbo-sized lake whitefish make up a much larger proportion of the harvest in Lake Superior and Ontario waters in Lake Huron than in other lakes.

The value of the lake whitefish landed catch averaged U.S.\$16.6 million during 1994–2004. After 2001, the value of this fishery was higher in Canada than in the U.S. Prices paid to commercial fishers averaged U.S.\$0.77/lb during 1994–2004 and ranged from \$0.69/lb in 1995 to \$0.90/lb in 2000. Prices declined to \$0.82/lb in 2001 then further to \$0.80/lb in 2002 before increasing slightly in 2003 and 2004. The value of the harvest increased from \$16 million in 1994 to \$20 million in 2000 then declined as total catch and price per pound declined. The annual value of the harvest ranged from \$8.7 to \$10.2 million in the U.S. and \$6.0 to \$9.7 million in Canada during 1994–2000 (Table 2). After 2000 value in the U.S. ranged from \$6.0 to \$8.3 million compared to \$7.6 to \$9.0 million in Canada. Essentially, the value of the landed catch has declined in the Great Lakes since the mid-1990s largely because of reduced catches and declining price per pound in the U.S. Price per pound in Canada has increased from about U.S.\$0.65/lb in 1994 to \$0.83/lb in 2004 primarily due to increased prices for lake whitefish from Lake Huron.

Average price per pound was highest on Lake Michigan during 1994–2004, but the Lake Huron fishery was more valuable because of its greater yield. The average price paid for lake whitefish was U.S.\$0.83/lb from Lake Michigan, \$0.77/lb from Superior,

\$0.75/lb from Huron, \$0.70/lb from Erie, and \$0.56/lb from Ontario (Table 2). It is somewhat surprising that Lake Michigan fishers receive more money per pound for their fish since most restaurants and retail shops in the Great Lakes basin advertise their products as fresh “Lake Superior whitefish” to capitalize on consumers correct perception that Lake Superior is more pristine than the other Great Lakes. Processors pay more for Lake Michigan fish because they are reported to contain more fat, which imparts a better flavor in both fresh and smoked products. The cumulative dockside value of the landed catch from Lake Huron was U.S.\$102 million during 1994–2004 compared to \$55 million from Lake Michigan, \$17 million from Superior, \$7 million from Erie, and \$2 million from Ontario.

Prices of lake whitefish declined after the September 2001 attack on the World Trade Center in New York City, New York. Processing facilities in New York City were located near the World Trade Center and after the 9/11 attack fish could not be trucked to the processing facilities because roads were closed due to the disaster. After 9/11 many processors in the Great Lakes basin refused to accept small number ones, or offered unacceptably low prices for them. The reduced market demand for small number ones forced the commercial trap net fishery to further sort and release legal-sized lake whitefish just as they had to do because of declines in condition of lake whitefish. Faced with competition from all the “small fish” being harvested by trap-net fisheries in the U.S., gill-net fisheries in Canadian waters of Lake Huron switched to target the largest lake whitefish possible because the best prices were paid for mediums and jumbos. This selective harvest strategy for larger lake whitefish has been going on for at least ten years, but has been very evident since 9/11.

Prices paid to commercial fishers for lake whitefish have not kept pace with the cost of fishing and has begun to alter fishing

practices or cause displacement of fishers. U.S. commercial fishers received on average U.S.\$0.85/lb in 1980 for lake whitefish compared to \$0.79/lb in 2004. Canadian Great Lakes commercial fishers fared only slightly better as in 1980 they received on average U.S.\$0.89/lb compared to \$0.83/lb in 2004. Using the consumer price index to adjust 1980 dollars to 2004 dollars, U.S. and Canadian commercial fishers should have been receiving U.S.\$1.95 and \$2.04/lb, respectively, to keep pace with inflation. In response, many small and marginally profitable fisheries have discontinued fishing or fish only when lake whitefish are very abundant near shore in the spring and fall. Some trap-net fisheries have gone to lifting nets only one to two times per week instead of every day to reduce operating costs, or they fish more nets to increase yield. Finally, some gill-net operations only fish when the price of fish is highest during the winter and early spring.

Inconsistency in quality of lake whitefish sold to consumers has affected the price per pound paid to commercial fishers. The inconsistency can be attributed to differing harvest methods, differing practices of individual fishers, seasonality of production, and the difficulty in maintaining an extended shelf life. The trap-net fishery produces a much fresher and saleable product than the gill-net fishery; consequently gill net-caught lake whitefish are less valuable than trap net-caught fish. Large influxes of lake whitefish from trap-net fisheries flood processors during a few weeks in the spring and the fall, especially in the U.S. A seasonally large supply of lake whitefish during May through October for a limited market adds tremendous downward pressure on prices. The reduced prices place demands on commercial fishers to increase harvest levels as a means of meeting payroll and equipment payment obligations, thus contributing to further erosion of prices. In contrast to the open-water period, landings are low from December through March, when the market

Table 2. Landed value (millions of dollars) of the lake whitefish commercial harvest from the Great Lakes and average price per pound paid to commercial fishermen from the United States (U.S.) and Canada during 1994–2004. The Lake Ontario catch occurs only in Canada, whereas the Lake Michigan catch occurs only in the U.S.

Statistic	Year	Lake Superior		Lake Huron		Lake Erie		Lake Ontario		Lake Michigan
		U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	
Landed value (Millions \$U.S.)	1994	1.19	0.29	2.43	5.09	0.31	0.29	0.30		5.74
	1995	0.44	0.30	2.46	5.80	0.16	0.44	0.31		5.74
	1996	0.82	0.32	2.64	6.17	0.04	0.37	0.48		6.21
	1997	0.87	0.29	2.47	5.93	0.02	0.37	0.19		6.05
	1998	0.98	0.59	2.64	6.63	0.04	0.63	0.18		6.32
	1999	1.18	0.72	2.60	7.44	0.04	0.78	0.16		6.28
	2000	1.37	0.74	3.71	7.91	0.03	0.94	0.13		5.15
	2001	1.02	0.69	3.01	7.29	0.04	0.90	0.11		4.21
	2002	0.78	0.75	2.27	7.22	0.01	0.83	0.07		3.00
	2003	0.96	0.65	2.57	6.86	0.01	0.54	0.05		3.26
Price per pound (\$U.S.)	2004	1.24	0.72	2.31	6.41	0.01	0.52	0.04		3.21
	1994	0.87	0.63	0.73	0.63	0.76	0.63	0.67		0.79
	1995	0.64	0.67	0.66	0.67	0.71	0.62	0.68		0.75
	1996	0.71	0.70	0.70	0.70	0.86	0.59	0.74		0.78
	1997	0.70	0.66	0.68	0.66	0.76	0.57	0.43		0.80
	1998	0.69	0.67	0.75	0.67	0.78	0.56	0.52		0.87
	1999	0.79	0.81	0.80	0.81	0.79	0.65	0.52		0.94
	2000	0.96	0.81	1.02	0.81	0.76	0.72	0.45		1.07
	2001	0.84	0.77	0.87	0.77	0.79	0.78	0.48		0.91
	2002	0.69	0.84	0.74	0.84	0.71	0.79	0.39		0.77
	2003	0.73	0.84	0.80	0.84	0.77	0.90	0.39		0.82
	2004	0.75	0.84	0.81	0.84	1.00	0.85	0.36		0.80

is supplied with a large proportion of frozen product. Although freezing per se does not result in inferior products, frozen lake whitefish fillets held after several months do not compare in favor to fresh fish, nor does it command an equivalent price per pound. Frozen lake whitefish fillets sold after peak freshness has produced a deserved stigma that it is of lower quality than the fresh product. These inconsistencies in product availability and quality are contributing to stagnation in demand and prices for lake whitefish.

Globalization

Great Lakes lake whitefish must now compete against a variety of fishery products in the retail and restaurant sectors. A global economy, the North American Free Trade Agreement, growth in domestic and international aquaculture, and expanding fishery industries in developing countries have created a greater selection of seafood for the consumer. An example of increased domestic competition for Great Lakes lake whitefish can be seen in the aquaculture industry, especially in Ontario waters of the Great Lakes. In 1999, approximately 3,600 metric tons of rainbow trout were produced in Ontario with a value of U.S.\$14.8 million. That is nearly equal to the current estimated value of the lake whitefish fishery in all of the Great Lakes.

The markets for lake whitefish are changing, forcing commercial fishers and Great Lakes processors to change their marketing strategies. For example, instead of only selling large quantities of product to large distribution centers, commercial fishers and Great Lakes processors now fillet a large amount of lake whitefish and sell the fillets locally, or ship processed fillets to large-scale processors instead of selling whole or gutted fish. Fillets sold locally in the Great Lakes basin are also now pin-boned: a process whereby auxiliary rib

bones are either pulled or cut out (v-cut) from the fillet to make them more palatable to consumers. Smoked whitefish sausage and “whitefish chip dip” are manufactured from the v-cut or from the flesh of smoked fish. Great Lakes processors also now sell breaded fillets produced from small number ones and vacuum pack fillets of fresh and smoked lake whitefish. The market value for lake whitefish roe (marketed as golden caviar) has been increasing over the last several decades and much of this product is shipped to northern European countries.

In recent years, the use of offshore processing by some inland producers has contributed to the low prices in local markets. Gutted lake whitefish are frozen and shipped to China where they are filleted, re-frozen, and shipped back to North America where they are sold at prices similar to fresh fillets. While the Chinese-frozen fillets must be labeled as an imported product, consumers will hardly notice the small print on the back of the package. Consumers purchasing these twice-frozen fillets are definitely getting a poor quality product in comparison to fresh fillets.

Of late, lake whitefish harvested from inland lakes in central and western Canada have appeared on the market in increasing quantities and lower prices, threatening the Great Lakes lake whitefish fishery. These inland-caught lake whitefish are perceived as being of low quality because they lack the color, texture and taste of lake whitefish from the Great Lakes, although these western Canadian fish are biologically the same species. The Freshwater Fish Marketing Corporation (FFMC), a Canadian Crown Corporation, distributes lake whitefish from Canadian inland lakes into the U.S. and Canada. In most years, Canadian inland lake fishers are paid less than U.S.\$0.40/lb for their lake whitefish (Anonymous 2005). The yield of lake whitefish from Canadian inland lakes purchased by FFMC was over 6.8 million kg in 2003, which near-

ly rivals that harvested from the Great Lakes. Lake whitefish is the FFMC single largest volume species, representing approximately one-third of all deliveries. The FFMC exports to the U.S. account for 67% of its sales, while 21% is sold in Canada. Both U.S. and Canadian Great Lakes fishers are competing with this product, since consumers and retail buyers do not differentiate inland lake whitefish from higher quality Great Lakes fish. The lower cost of these government-subsidized lake whitefish is pricing Great Lakes lake whitefish out of the market. First time buyers of lake whitefish are being introduced to an inferior product that ultimately has a negative effect on potential repeat customers.

Evolution of Governance Structures

Management of lake whitefish commercial fisheries in the Great Lakes is both simple and complex. The complexity occurs because at least 35 Native American governments, eight U.S. states, and the Province of Ontario manage lake whitefish on a stock-by-stock basis with little inter-jurisdictional cooperation. The simplicity occurs because most individual stocks of lake whitefish are contained within a single political jurisdiction so there is really little need for international governance of the populations. Regulations developed in the states of Michigan and Wisconsin and the Province of Ontario essentially determine the fate of lake whitefish commercial fisheries on the Great Lakes because these three political jurisdictions account for nearly all the yield of lake whitefish from the Great Lakes. The largest yields came from within the state of Michigan (54.7%) followed by the province of Ontario (33.1%) and the state of Wisconsin (11.8%) during 1971–2004. Of the 211 million kg of lake whitefish harvested from the Great Lakes during 1971–2004, only 0.96 million kg were taken from Great Lakes waters of the six other political jurisdictions.

Province of Ontario

Commercial fishing for lake whitefish in Ontario is thought to have begun in the early 1800s with the salting and shipping of lake whitefish from the Sault Ste. Marie area south to Detroit (Peters 1981). For the first part of the 19th century, American, Canadian, and Native American fishers all fished the same Canadian waters for lake whitefish, albeit, not always in harmony. Commercial fishing very quickly became an export business; with the majority of all Great Lakes Canadian fish being exported to the U.S. (Adams and Kolenosky 1974). The huge reported catches of lake whitefish in lakes Erie and Huron in the 1830s brought about Canadian federal interest in the fisheries because of concerns the populations would be overexploited since there were basically no regulations to govern the fishery. The creation of the Federal Fisheries Acts of 1857 and 1858, ahead of Canadian confederation, created one set of regulations for Canadian waters and was considered the beginning of a “modern fisheries administration” for Upper and Lower Canada.

Among other things, the Federal Fisheries Act stipulated that every net and fishery should be licensed and that fishing grounds needed to be leased from the Crown. This included American businesses fishing in Canada and Native Americans that did not recognize Canadian government intervention. Large American and European firms approved of the licensing process as it added security to their investments in the fishery businesses. The Federal Fisheries Act also regulated fishing seasons, imposed gear restrictions in certain areas, called for fishways on dams for potadromous salmonids and introduced the concept of fisheries overseers. One of the first amendments to the Federal Fisheries Act took place in 1868 when a closed season was imposed on the lake whitefish fisheries along with a restriction disallowing seine fishing for lake whitefish from May to August

(Canada Statutes, 31 Victoria c.60, May 22, 1868). Other standard regulations utilized in Ontario waters included minimum size limits, and season and area closures. The more contentious issues related to controlling gear type and quantity were managed in an ad hoc manner, with some restrictions applied to individual companies or by government agents in specific areas on individual lakes.

Access to Canadian waters was originally unrestricted and American companies dominated the commercial fishery largely due to the large markets in the eastern U.S. By the 1880s the lake whitefish commercial fishery yield had begun to increase exponentially, peaking in 1885 (Baldwin et al. 2000). The federal government's response was to appoint Ontario's first Royal Commission on the Fisheries of the Province in 1892 (CDMF AR SP No. 10c, 1893). This commission attempted to more closely document the harvests that were occurring, but more importantly to address the lack of rules and law enforcement associated with the commercial fisheries in Canadian waters of the Great Lakes.

The province of Ontario and the federal government fought over control of the Great Lakes fisheries throughout the 1880s and 1890s. Finally in 1898, the Privy Council heard a court case put forth by the province and decided that fisheries management would be split between the two parties. The province would take control of laws, licenses, taxation of the resource, and enforcement of the laws. The regulations on seasons, gear, taxation measures and the power of veto remained with the federal government (Peters 1981). Ontario quickly formed the new Ontario Department of Fisheries (ODF) in 1899 to oversee the fisheries of the province. This signaled the decline in the number of American businesses in the commercial fishing industry and the formation of Ontario businesses.

The ODF continued to license and manage the lake whitefish fishery although management was viewed as "politically" based. It

wasn't until the 1920s that Ontario hired its first fisheries scientists and began to explore the possibility of managing the resource from a scientific perspective. Unfortunately, this came about after the first collapse of the fisheries. The subsequent total collapse of lake whitefish and lake trout populations in the 1950s brought the need for more comprehensive management to the forefront.

Prior to, during, and after the collapse of lake whitefish populations, the principal management tool utilized by Ontario was the control of fishing effort. In some cases this meant limiting the number or size of pound nets or fyke nets, or the number of gill nets that could be employed per boat, or the restriction of mesh sizes to target specific segments of the population. The role of the government agents was eventually taken over by district managers and supervisors under the Ontario Department of Game and Fish, the Ontario Department of Lands and Forests, and then ultimately the Ontario Ministry of Natural Resources (OMNR), and it was these individuals who were responsible for determining which regulations would be used and where. In 1980 there were 37 different administrative districts that bordered the Great Lakes in Ontario, most of which had responsibilities for commercial fishing activity within the boundaries of their district.

In 1976 OMNR published a Strategic Plan for Ontario Fisheries (SPOF) (OMNR 1974) which outlined basic principles that the province should pursue in order to better manage the fishery resources it controlled. The development of four Great Lakes Assessment Units ensued, aimed at aiding managers in making more science-based commercial fishery management decisions. This document also recommended a rationalization of the commercial industry in Ontario. In 1980, the Deputy Minister of OMNR appointed a committee to address four issues: the modernization of the commercial industry in Ontario, the determination of methods for pre-

dicting resource availability, the development of policies for the regulation of commercial harvests, and the development of an improved system for the licensing of commercial fishermen (OMNR 1982).

The report on the modernization of the Ontario commercial fishery (OMNR 1982) created some of the most significant changes in the commercial fishery since its inception. In 1984, individual transferable quotas (ITQs) were implemented in all of the Great Lakes for all of the major commercially valuable fish species. Quotas for the most part consisted of large allocations to individual licenses for abundant species in well-defined management areas on each lake (Figure 2).

Even though this system replaced effort-based management, in many cases most of the same effort controls were incorporated into the new system. Emphasis was placed upon science-based assessment of the fish populations and the need for trust between regulators and fishers in both the evaluation of the populations and the provision of data from the commercial harvest (OMNR 1982). Additional license conditions were implemented in attempts to address issues such as sustainability of fish stocks, incidental catch rates, rehabilitation of indigenous fishes, and conflicts among fishermen and other user groups. The development of large recreational fisheries on the Great Lakes (Bence and Smith 1999) created a need for more closely managed commercial fisheries in order to ensure proper allocation among user groups and to minimize conflicts.

Great Lakes assessment units continued to collect and provide information that was then synthesized and provided to district managers who made final management decisions for their areas. In 1992, OMNR created four Great Lakes Management Units under a new Great Lakes Branch. The end result was that now both assessment and management were under the same leadership and management responsibility for each of the Great Lakes,

and were now assigned to one individual rather than several. This modern commercial fishery management structure still exists in Ontario today.

In an attempt to accommodate Native American (First Nations in Canada) fisheries for lake whitefish and other species the province of Ontario has “bought” ITQs from individual provincial fishermen and allocated them to the First Nation governments. There are 27 First Nations bordering Ontario waters of lake Huron and Superior, but not all them commercially fish for lake whitefish. In some instances OMNR has allocated ITQs for specific areas exclusively to the First Nations under what is termed communal fishing licenses. Essentially, these communal licenses are an agreement between a First Nation and OMNR over allocation of lake whitefish resources, with the First Nation agreeing that the province has primary management responsibility but licensing is the responsibility of the First Nation. There are currently four communal licenses issued on Lake Superior and six issued on Lake Huron. In other areas such as the Bruce Peninsula of Lake Huron (Figure 2) the province has purchased lake whitefish ITQs from provincial-licensed fishers so as to accommodate co-management with First Nation governments that do not want to forfeit management responsibility (see Saugeen Ojibway section).

State of Michigan

Brege and Kevern (1978) summarized the evolution of the governance structures affecting state-licensed fisheries for lake whitefish in the State of Michigan during 1865–1975. The summary was based on a review of the following sources: Michigan Public Acts, 1865 through 1973; Michigan Administrative Code, 1954, plus Annual Administrative Code Supplements during 1954–1975; Michigan Natural Resources Laws compiled by the Department of Natural Resources in

1972; Michigan Statutes Annotated, Vol. 9, Title 13; Michigan Compiled Laws, 1871, 1897, 1915, 1929, 1948, and 1970 editions. According to the authors, commercial fisheries in Michigan waters of the Great Lakes were largely unregulated in the early to mid 1800s, but became much more restricted over time. During this period, there was a co-evolution as changes in regulations sought to deal with and address innovations and changes in fishing gear and techniques. All regulations between 1865 and 1955 were brought about as legislative acts (Table 3). Starting in 1955, Act 218 empowered the Michigan Conservation Commission to “suspend, abridge, extend, modify, increase, or decrease the open seasons and size limits on fish as established by the commercial fishing law of 1929.” Subsequently, Act 336 switched commercial fishery regulatory authority to the Director of Michigan Department of Natural Resources (MiDNR) in 1968.

Significant changes in regulation of the commercial lake whitefish fishery in Michigan occurred in the 1960s. The MiDNR established a Great Lakes fishery management policy in 1966 that favored recreational fishing over commercial fishing (Legault et al. 1978; Keller and Smith 1990; Rybicki and Schneeberger 1990). Then, in 1969, Michigan established a limited entry program for commercial fisheries in the upper Great Lakes to: (1) preserve, protect, and enhance the fishery resource itself; (2) make the commercial fishery an asset that contributes to the public good rather than being a liability; and (3) restore and improve the economic viability of the commercial fishing business (W.R. Crowe, MiDNR memorandum, 1968), as well as to prevent over-capitalization of the fishery (Keller and Smith 1990). Also in 1969, a Zone Management Plan was established to help manage the fisheries for maximum public benefit. Toward that end, the Zone Management Plan banned gill nets from areas regarded as important for lake

trout rehabilitation, and terminated commercial fishing for yellow perch, walleye, and lake trout, reserving these major species for recreational fisheries. Reducing conflicts between recreational and commercial fisheries has been a priority for the State and another reason for the Zone Management Plan. A 1970 revision of the Zone Management Plan gave the MiDNR Director authority to fix species-specific catch quotas in each zone of the Great Lakes. For example, commercial fishing for lake whitefish in Michigan waters of Lake Erie was prohibited in 1973.

State of Wisconsin

Development of present-day management policy in Wisconsin for the most part occurred independently on Lake Superior and Lake Michigan, but first on Lake Superior. The commercial fishery for lake trout was closed in 1962 throughout U.S. waters of Lake Superior, including Wisconsin where there were 67 commercial licenses. In 1967 the Wisconsin legislature passed a resolution promoting limited entry to the fishery so the Wisconsin Department of Natural Resources (WiDNR) immediately capped the number of commercial licenses. The WiDNR also developed a policy for permitting new fishers into the fishery that took into account a persons’ investment into the fishery or amount of gear they owned, or how much time they spent participating in the fishery (Chiarappa and Szylvian 2003). By the time the lake trout fishery was opened again in Wisconsin waters of Lake Superior in 1970 only 21 commercial licenses were allowed to participate. In 1976 the 70,000-ha Gull Island Shoal Refuge was created to protect lake trout from expanding gill net and recreational fisheries (Swanson and Swedberg 1980). A series of negotiated settlements ensued between WiDNR and Native American governments over allocation of fish resources and regulation of the commercial fishery in Wisconsin wa-

Table 3. Chronology of public acts and orders that affected fishing for lake whitefish in Michigan waters of the upper Great Lakes during 1865–1975. See Brege and Kevern (1978) for details.

Year	Act / Order	Mesh / gear	Authority	Size limit	Season	Reporting	License	Area	By catch	Quotas
1865	350	X	X							
1875	188				X					
1885	91		X							
1897	151	X		X	X					
1899	88	X								
1901	100	X								
1903	13							X		
1903	78				X					
1903	108	X								
1905	275							X		
1905	324							X		
1907	5							X		
1907	102	X						X		
1907	153						X			
1907	212							X		
1909	213	X		X	X	X	X		X	
1913	97	X		X		X				
1919	159	X	X	X				X	X	
1927	158					X	X			
1929	84	X	X			X	X		X	
1931	159							X		
1933	255	X	X	X			X			
1934	25							X		
1935	221	X								
1937	348	X			X	X	X			
1939	312						X	X		
1953	195			X						
1955	218		X							
1957	277				X					
1960	3				X					
1965	9				X			X		
1968	16	X								
1969	17						X	X	X	
1970	17	X	X			X		X		X
1970	20						X			
1973	17				X					X
1974	17	X								X

ters of Lake Superior. These settlements (see section on Governance of Native American Fishers, Lake Superior Ojibway) established additional refuges and restricted areas where commercial fishing for lake whitefish was prohibited, it also limited fishing effort and implemented individual quotas for lake trout. In 1997 the number of commercial licenses permitted in Wisconsin waters of Lake Superior was reduced to ten through a retirement program in which eleven commercial fishers were compensated for permanently retiring their operations and fishing gear.

On Lake Michigan the policy was to limit entry into the fishery to control further capitalization and prevent overexploitation of lake whitefish populations and other species (Legault et al. 1978; Chiarappa and Szylvian 2003). Unlike in the State of Michigan and other U.S. Great Lakes states where large-mesh gill nets were banned for commercial use (Legault et al. 1978; Chiarappa and Szylvian 2003), WiDNR policy permitted use of large-mesh gill nets for catching lake whitefish. The State of Wisconsin recognized the value of the commercial fishery, though it did not seem that way to many fishers, and wanted it to be viable, continuous, and compatible with recreational fishing.

The structure of the current lake whitefish management policy in Wisconsin waters of Lake Michigan began in 1968 when the state issued a simple one page policy statement that gave preference to recreational fisheries because of their greater economic value to society (Legault et al. 1978). Wisconsin later retracted that policy and in 1975 took a new approach where biological principles were used to attain optimum sustainable use of the resource (Legault et al. 1978), however, the groundwork had already been laid for a philosophical shift in management that endorsed, among other strategies, limiting entry to the commercial fishery. Commercial fishing advisory boards were established which, unlike in other

states, were dominated by the commercial fishing industry. The advisory boards were established to assist in development of management policy and legislation that affected the fishery, and to deal with industry decisions such as licensing and allocation of quotas among fishers (Legault et al. 1978; Chiarappa and Szylvian 2003). Through the boards, the commercial fishing industry had enormous power in terms of controlling their own destiny.

Significant changes to the lake whitefish fishery on Lake Michigan occurred with passage of Senate Bill 409 (SB 409) in the Wisconsin legislature in 1979. SB 409 implemented the concepts of limited entry and zone management, created a fee structure for licensing and re-licensing commercial fishers and gave WiDNR regulatory authority over the commercial fishery under Chapter 25 of the administrative code (Legault et al. 1978; Chiarappa and Szylvian 2003). The commercial fishing industry had considerable input into the legislation and successfully inserted a provision that called for legislative review of all regulation changes. The review process meant that any changes recommended to Chapter 25 by the WiDNR first had to be reviewed in a series of meetings with the commercial fishing industry before being presented for discussion to the Natural Resources Board. Zone management was implemented to segregate commercial and recreational fisheries and essentially concentrated the lake whitefish fishery in areas of Green Bay and Door County (W-1 to W-3), although several fisheries were also allowed to operate in W-4 and W-5.

Limited entry did not become reality in Wisconsin waters of Lake Michigan until 1989. There was a significant influx of new commercial fishers to the Wisconsin fishery in Lake Michigan after the 1985 negotiated settlement between MiDNR and Native American governments in Michigan (U.S. v Michigan 1985; Doherty 1990). These new

fishers were displaced from Michigan waters because of the settlement and long-time Wisconsin fishers were concerned about viability of their lake whitefish fishery with so many new entrants to the fishery. Consequently, the commercial fishing industry and WiDNR reached an accord to cap the number of licenses and implement ITQs for lake whitefish. WiDNR developed a TAC for lake whitefish in their waters of Lake Michigan and allocated it among three zones. An individual fisher's share of the TAC in a zone was calculated as their percentage of past yields from that zone over a specified period of years. Fishers were also required to harvest a minimum weight of lake whitefish in a year in order to receive a license the following year. As part of the 1989 regulation change fishers were required to complete a daily catch report that summarized the total weight of lake whitefish onboard their fishing vessel after lifting nets but before landing their catch.

A new package of commercial fishing regulations, created to accommodate operation of the fishery, was put forth by the commercial fishing industry and WiDNR and was adopted by the Wisconsin legislature in 2006. One provision allows a commercial fisher to transfer their lake whitefish ITQ from one boat to another in their fishery for minimal cost. A second new regulation allows a fisher with either health or economic problems to designate their quota to a boat owned by a different fisher in order to meet the minimum level of annual allowable harvest. The new package of regulations also implements electronic reporting. Under the electronic reporting system commercial fishers would essentially have a wireless laptop computer onboard the fishing vessel with which they could enter their daily catch report and transmit the information to the local WiDNR office. The new electronic reporting system abolishes the mandatory catch reporting every two weeks, but it has not been implemented as of 2006.

The last significant regulatory change created a "fleet license" which allows commercial operations with more than one license and several boats to define how the landed catch in the coming year will be reported and allocated among the licenses and boats. Only one daily catch report needs to be completed under a fleet license instead of a catch report for each boat.

Governance of Native American Fisheries

Re-affirmation of treaty-reserved fishing rights by courts in the U.S. and Canada has produced the most recent significant structural change to the lake whitefish fishery in the Great Lakes. Federal court decisions in Wisconsin, Michigan, and Ontario during the late 1960s to the mid-1990s reaffirmed that the treaties signed between Native American/First Nation people and the U.S. and Canadian governments in the mid 1800s had reserved certain commercial and subsistence activities that could not be regulated by state/provincial governments except under specific circumstances (Doherty 1990; Brown et al. 1999; Dochoda 1999; Chiarappa and Szylvian 2003). These court decisions stimulated expansion of Native American fisheries that in turn increased competition for lake whitefish with state and provincial-licensed fishers (Legault et al. 1978; Doherty 1990; Chiarappa and Szylvian 2003).

As a consequence of the court decisions, Native American/First Nation governments and their commercial fisheries have been allocated a large share of the harvestable lake whitefish biomass in the Great Lakes. The original treaties did not specify how resources were to be shared, rather, these allocation decisions have been either negotiated between state, provincial, federal, and native governments, or imposed by federal courts. Regardless, Native American governments are now either the primary managers or they have co-management responsibility

in most traditional lake whitefish commercial fishing areas of lakes Superior, Huron, and Michigan (United States v. Michigan 2000). In Ontario the exertion of treaty-reserved and aboriginal rights has resulted in several Aboriginal Fishing Agreements being negotiated with individual First Nations. These fishing agreements take several forms but essentially outline the rules and conditions under which commercial fishing activity will be conducted, they outline reporting and enforcement roles and responsibilities, and some include provision for data exchange and joint decision-making processes. Native American/First Nation governments can impose further restrictions on their fishers that are above and beyond those set out in the Aboriginal Fishing Agreements or negotiated settlements.

Re-affirmation of treaty rights has structurally changed the lake whitefish fishery in three areas—Lake Superior, Michigan waters of Lake Michigan, and Lake Huron. In the 1836 treaty-ceded waters of eastern Lake Superior, northern Lake Huron, and nearly all Michigan waters of Lake Michigan CORA regulates the activities of five member tribes that commercially fish lake whitefish (Doherty 1990; Brown et al. 1999; Chiarappa and Szylvian 2003). The Saugeen Ojibway share co-management responsibility with OMNR in Ontario waters of Lake Huron surrounding the Bruce Peninsula (Mohr et al. 1997). Lastly, four Ojibway governments either share or have sole management responsibility of lake whitefish fisheries in areas of Lake Superior outside the 1836 ceded waters.

Chippewa Ottawa Resource Authority

In 1982 the Bay Mills Indian Community, Sault Ste. Marie Tribe of Chippewa Indians, and the Grand Traverse Band of Ottawa and Chippewa Indians formed the Chippewa/Ottawa Treaty Fishery Management Author-

ity (COTFMA). The creation of COTFMA was made possible in May 1979 when a U.S. District Court ruled in favor of these tribes treaty-reserved fishing rights but stipulated that their fishing activities could be regulated by the state of Michigan if those activities were shown to deplete fish resources (called the “Fox Decision”). Subsequently, the U.S. Department of the Interior established interim regulations to guide commercial fishing activities by members of the three tribes in November 1979. In 1981 the U.S. federal government allowed the federal regulations to lapse, thus exposing COTFMA activities to regulation by MiDNR. To prevent state regulation the three tribes formed COTFMA and authorized it to regulate commercial and subsistence fishing activities by their members in 1836 ceded waters (Doherty 1990; Brown et al. 1999; Chiarappa and Szylvian 2003).

During the process to reaffirm treaty-reserved fishing rights many confrontations arose between tribal fishermen and sport anglers (Doherty 1990; Chiarappa and Szylvian 2003). Tribal commercial fishers believed they had the right to fish anywhere in the 1836 ceded waters, while sport anglers believed that tribal fishing would deplete fish resources and depress property values in important recreational areas such as Grand Traverse Bay in Lake Michigan (Figure 2) (Chiarappa and Szylvian 2003). Physical confrontations occurred between tribal commercial fishers and sport anglers, and tribal commercial fishers routinely had their nets either tampered with or destroyed by recreational fishers. Newspaper headlines fanned the flames by claiming the tribes were given unlimited ability to deplete fish resources in Michigan as a result of the Fox Decision. In 1984 both COTFMA and state-licensed commercial fisheries for lake whitefish were halted in several management units through U.S. District Court Action that was supported by all parties well before the usual fall spawning season closure because the total allowable catch for those units

had been exceeded. There was no allocation of lake whitefish to state-licensed or tribal-licensed fisheries at this time; consequently an open-access fishery had been created in which a primarily tribal small-boat gill-net fishery competed against a state-licensed trap-net fishery for the available lake whitefish.

Essentially, the tribal commercial fishery was viewed as the single greatest threat to the sustainability of the fisheries; particularly lake trout. Much of MiDNR Great Lakes fishery policy had focused on eliminating gill-net fisheries and reducing commercial fishery bycatch of trout and salmon. In addition, the U.S. Fish and Wildlife Service (USFWS) had spent millions of dollars to rear and stock lake trout in hopes of rehabilitating self-sustaining populations. Both MiDNR and USFWS were convinced that tribal commercial fishing with gill nets in the 1836 ceded waters would prevent rehabilitation of lake trout (Legault et al. 1978; Doherty 1990; Chiarappa and Szylyan 2003). Tribal commercial catches of lake trout were sizable (160,000 kg) in some areas and insignificant (<100 kg) in others at this time (TFRC 1981).

Lake Committees of the Great Lakes Fishery Commission (GLFC) (www.glfc.org) had spent considerable time developing plans and strategies to promote rehabilitation of lake trout in lakes Superior, Huron, and Michigan during the early 1980s (Dochoda 1999; Hansen 1999). Lake committees were composed of a fishery manager from each of the states with political jurisdiction on a Great Lake (Dochoda 1999). Native American governments were not members of any of the five lake committees during the early 1980s, but biologists from COTFMA did participate in development of the lake trout rehabilitation plans on lakes Superior, Huron, and Michigan. Consequently the lake committees served to help coordinate management of lake trout, and indirectly management of lake whitefish in the three upper Great Lakes. These plans included refuges,

primary rehabilitation zones, maximum mortality targets, and other strategies that were designed to control fishing mortality because it was viewed as a significant impediment to rehabilitation of lake trout.

Within this context COTFMA-member tribal governments negotiated two 15-year agreements with the State of Michigan, U.S. Department of Interior, and various recreational and commercial fishing interests in 1985 and 2000 that allocated fish resources, primarily lake whitefish. Both settlements were later implemented by federal court-ordered Consent Decrees (United States v. Michigan 1985; United States v. Michigan 2000). The primary scope of the two Consent Decrees was to allocate fish resources, separate fishing areas for state-licensed and tribal-licensed fisheries, and to promote rehabilitation of lake trout. The 1985 Consent Decree divided the 1836 ceded waters into state-commercial, tribal-commercial, and recreational fishing zones. Lake trout refuges and primary lake trout rehabilitation zones recommended in the lake trout rehabilitation plans of lake committees for Superior, Huron, and Michigan were adopted into both Consent Decrees. The refuges were designed to provide sufficient protection to lake trout so that adult populations could build quickly and overcome the various bottlenecks to their reproduction in areas that contained large quantities of historically known lake trout spawning habitat (Holey et al. 1995; Eshenroder et al. 1995b). Primary rehabilitation zones surrounding the northern refuges in lakes Michigan and Huron were created in the 1985 Consent Decree where gill net fisheries could target lake whitefish, but only under restricted conditions. The 1985 Consent Decree established only a few specific protections for lake whitefish that included a seasonal spawning closure, minimum mesh size requirements, and a minimum length limit for the commercial sale of lake whitefish. Large-mesh gill-net fishing for lake whitefish was

essentially permitted in only a small amount of the total 1836 ceded waters by the 1985 Consent Decree to promote recovery of lake trout populations. Lake trout rehabilitation was deferred in areas open to gill-net fishing in each lake.

The 2000 Consent Decree differed from the 1985 Decree in that it mandated an allocation of fish resources between the tribes and State of Michigan, specifically described how lake whitefish populations would be managed, increased protection for lake trout, and expanded the tribal-only zones. Parties to the 2000 Consent Decree agreed that the 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. Instead, the tribes received 100% of the available lake whitefish in 13 of the 18 management units. In the other five management units lake whitefish stocks were shared with the state-licensed fishery, but COTFMA-member tribes were allocated 55–90% of the available lake whitefish TAC.

COTFMA was reorganized as part of the 2000 Consent Decree into CORA because two newly recognized tribal governments were signatory to the settlement. CORA was designed to oversee biological matters, fishery enhancement, law enforcement, judicial, and public information to ensure proper management of tribal commercial and subsistence fisheries and cooperative management with federal, state, and provincial agencies. The Great Lakes Resource Committee (GLRC) was established under the CORA charter to serve as the inter-tribal management body for the treaty fishery in the Great Lakes. The role of GLRC is to: 1) develop protocols for the management, preservation, and enhancement of all species and habitats; 2) promulgate regulations, including emergency orders; 3) coordinate law enforcement programs of member tribes; 4) participate in inter-tribal, interstate, and international bodies; and 5) re-

ceive reports from staff and from tribal, federal, and state biologists to develop methods of reducing harvests when necessary. The five tribes empowered CORA and GLRC with a four-step process to resolve disputes that may arise over decisions made or proposed changes that were not implemented (United States v. Michigan 2000, Appendix A).

A Technical Fishery Review Committee (TFRC) established by the 1985 Consent Decree was made up of biologists representing COTFMA, USFWS, and MiDNR. The TFRC was responsible for compiling an annual report outlining the status of fish stocks in the 1836 ceded waters including total allowable catch (TAC) levels for lake whitefish in each management unit (Ebener et al. 2005). Total allowable catches of lake whitefish were estimated annually during 1986–1991 (TFRC 1992), but these harvest levels were never enforced. The TFRC status reports and TAC estimates were provided to a five member Executive Council that was responsible for implementation of the 1985 Consent Decree and resolving disputes arising from the agreement.

The 2000 Consent Decree reorganized the TFRC into the Technical Fisheries Committee (TFC) that was to be the primary body for consultation and collaboration on biological issues. Among other charges, the TFC was to update fish population models to be used for harvest limits and act as a forum for development and review of harvest and effort limits. The TFC also reviews other biological issues, monitors harvests, coordinates research, monitoring, and assessment activities of the parties, and facilitates exchange of information. The Modeling Subcommittee (MSC) was created under the auspices of the TFC to implement statistical catch-at-age analysis of lake whitefish in both the shared and tribal zones.

In the shared management units the yield of lake whitefish was to be regulated by the parties in accordance with harvest limits that

were based on allowing a maximum of 65% total annual mortality on whitefish (Ebener et al. 2005). The harvest limits were to be determined on an annual basis, but with a lag of one year for each upcoming year: i.e. 2007 TACs are determined from data collected through 2005. The TACs were to be based on data collected from fisheries and appropriate statistical and mathematical modeling techniques, and strictly enforced in shared zones. Enforcement of the TAC was established by maintaining a running sum of the percent deviations between the previous years' harvest limit for each party and the actual harvest from a management unit for the same party. If in any year either the state or tribal harvest produced a positive 25% deviation from their respective harvest limit then management action was required. Management actions included reducing a party's harvest limit the following year by the amount of the over-harvest and increasing the allocation of the other party by the same amount. The party exceeding the harvest limit also had to take management action in the following year to keep its harvest within the allocation limit after the transfer of harvest to the other party (United States v. Michigan 2000).

The two Consent Decrees essentially created a governance structure whereby CORA, MiDNR, USFWS, and individual tribal governments could meet regularly to share data, estimate harvest limits, and cooperatively manage lake whitefish and other fish resources in the 1836 ceded waters. The 2000 Consent Decree established timelines for submitting annual harvest limits for lake whitefish to the parties for their evaluation and approval. As a consequence, timelines were also established by the TFC for exchange of fishery yield and effort and biological data among the biologists charged with estimating annual harvest limits. Very good relations have been established between biologists from each of the parties at the technical level and the

willingness of these individuals to exchange data and ideas has created an atmosphere of cooperation that bridges philosophical differences in management. A Law Enforcement Committee was also created by both Consent Decrees, but primarily the 2000 Consent Decree, whereby officers from CORA and MiDNR meet regularly to plan and coordinate annual enforcement effort, share information, and recommend regulations for governing the tribal and state fisheries. After the 1985 Consent Decree COT-FMA, now CORA, became a member of the GLFC lake Superior, Huron, and Michigan Lake Committees and Lake Technical Committees, which furthered collaboration and cooperation among tribal and state governments. Unfortunately, at the policy level of the Executive Committee resolution of outstanding issues among the parties remains elusive.

Lake Superior Ojibway

Besides the five CORA-member tribes, there are eight other Native American governments that license commercial fisheries for lake whitefish in Lake Superior. In Canada, the Fort William, Pays Plat, Pic River, and Batchewana governments license members to fish commercially but only Batchewana fishes without an OMNR communal fishing license or ITQ for lake whitefish. The Grand Portage, Red Cliff, Bad River, and Keweenaw Bay governments license commercial fisheries in the U.S. The Grand Portage, Red Cliff, and Bad River tribes have reached settlements with state governments that address allocation and resource management, while the Keweenaw Bay tribe has not. The Red Cliff, Bad River, and Keweenaw Bay tribes jointly manage an inter-tribal fishery in Michigan waters of Lake Superior independent of the state of Michigan. All these Native American tribes except Batchewana fish exclusively in Lake Superior.

The Great Lakes Indian Fish and Wildlife Commission (GLIFWC) was formed in 1984 as an inter-tribal, co-management agency exercising authority delegated by its eleven member tribes, to ensure off-reservation harvests while simultaneously protecting resources (www.glifwc.org). The Red Cliff, Bad River, and Keweenaw Bay tribes are members of GLIFWC's Lake Committee, which coordinates fishery management activities on Lake Superior. Unlike CORA that has direct management responsibility for the tribal fishery in the 1836 ceded waters, GLIFWC has no specific management responsibility; it only provides the forum for and assists member tribes with coordination activities among themselves. GLIFWC does provide scientific, enforcement, legal and policy, public information, and management expertise to its member tribes.

The most interesting aspect of the Native American commercial fisheries outside the 1836 ceded waters of Lake Superior is that there are few, if any, management strategies directly developed to protect lake whitefish. Instead, the focus of management is directed at lake trout so lake whitefish populations are basically managed as a by-product of lake trout rehabilitation. The Grand Portage Band reached a negotiated settlement with the state of Minnesota in 1988 that allowed unlimited subsistence use of all fish species within reservation boundaries of Lake Superior but restricted the commercial harvest of lake trout to a specific annual quota in the same waters. There is very little harvest of lake whitefish in the Grand Portage reservation waters and the tribe has no specific regulations that protect them. The Batchewana fishery primarily targets lake whitefish in eastern Ontario waters of Lake Superior. The Batchewana government has developed no regulations that specifically protect lake whitefish and they continue to be at odds with the government of Ontario over commercial fishery regulation and management responsibilities.

Regulations developed to govern the inter-tribal fishery in the 1842 ceded waters (see Brown et al. 1999) of central and western Michigan waters of Lake Superior are primarily focused on protecting lake trout and not lake whitefish. The Keweenaw Bay, Red Cliff, and Bad River governments initiated an inter-tribal fishing agreement to manage a commercial fishery in Michigan waters of Lake Superior ceded by the treaty of 1842 (management units S-01 to S-05 in Figure 2). This inter-tribal fishery began in 1984 after the federal court "Voight Decision" in 1983 reaffirmed treaty reserved fishing rights in these waters (Ebener et al. 1985). Since then there has been no negotiated settlement with the state of Michigan. Prior to 1984 the Keweenaw Bay Indian Community had been fishing Lake Superior waters within its reservation boundaries based on the 1965 "Jondreau Decision" that basically laid the groundwork for much of the present-day treaty fishing activities in U.S. waters of the Great Lakes (Doherty 1990).

Lake trout and their rehabilitation have been the primary concern in managing the Michigan inter-tribal fishery that harvested between 87,000 and 379,000 kg of lake whitefish annually since 1986 (Ebener et al. 1985; Ebener and Bronte 1986; Mattes et al. 2000). When the fishery began in earnest in 1985 each fisher was given a management unit-specific lake trout quota and the number of fishers from Bad River and Red Cliff was restricted. There were also limits on the amount gill net that could be fished and small refuges were established around important lake trout spawning reefs during the fall. The individual quotas were in place to limit large-mesh gill net effort because once a fisher reached their management unit-specific quota, they were required to cease fishing for lake whitefish. The only regulation directed at lake whitefish was the minimum legal-length limit of 43 cm TL and the spawning season closure of October 31 through November 27. Today there

are no ITQs for lake trout, rather each fisher is permitted to have no more than 3,700 m of large-mesh gill net in the water at any time and individual lake trout quotas have been abandoned in favor of management unit specific-limits on lake trout, but not lake whitefish.

Probably the most extreme example of how the lake trout rehabilitation process has structured modern-day fisheries for lake whitefish has taken place in the state of Wisconsin's Apostle Islands area of Lake Superior. The Wisconsin Supreme Court's "Gurnoe Decision" in 1972 found that reservation boundaries created by the treaty of 1854 extend into Lake Superior, thus guaranteeing the Red Cliff tribe's right to fish commercially in those waters adjacent to the reservation (Hansen et al. 1995; Spangler 1997). In 1981 the state of Wisconsin and Red Cliff tribe reached an agreement to limit the annual lake trout catch in the Apostle Islands (WI-2). The 1981 agreement established the Devils Island Refuge to minimize fishing mortality on lake trout (Busiahn 1982), and the agreement created numerous "restricted use areas." Commercial fishing for lake whitefish in these restricted use areas was prohibited altogether, or prohibited during certain seasons and at certain depths to both protect fish and reduce conflicts between recreational anglers and commercial fishermen. The Bad River tribe began commercial fishing in the Apostle Island areas in 1984 so a 10-year agreement was reached between Red Cliff, Bad River, and the State of Wisconsin in 1986 to allocate lake trout resources (Hansen et al. 1995). A third agreement among the three governments was reached in 1996 that maintained the refuges and restricted areas, but also addressed enforcement, and joint monitoring of commercial catches by biological and law enforcement staff from the three agencies.

The 1996 State-Tribal Lake Superior Agreement and several amendments to it produced considerable regulatory change to

the lake whitefish fishery in the Apostle Islands area. To ensure the lake trout quotas were not exceeded the agreement established an allowable effort regulation that was based upon the lake trout quota and the catch per unit effort (CPUE) of lake trout observed during onboard monitoring in three seasons of the fishing year. Prior to each fishing year, commercial fishers from each tribe are notified of their allocation of gill net effort (expressed as total feet of net that can be fished). Individual fishing effort allocations could be transferred among fishers if the tribe was provided written documentation of the transfer and the tribal biologist approved the transfer. Essentially the permissible amount of large-mesh gill net effort was inversely related to the amount of lake trout quota each fisher had remaining during a season.

Each of the State-Tribal Lake Superior agreements supported the establishment of a Biological Committee. The Biological Committee's primary responsibility is to estimate harvest limits for lake trout in WI-2, but they were also responsible for estimating CPUE of lake trout and evaluating the statistical bias and power of the on-board CPUE monitoring program. Biologists and wardens were required to estimate the average CPUE in each season that was used to adjust fishing effort in the following season. In the very recent 2006 State-Tribal Lake Superior Agreement the parties have requested the Biological Committee to develop a statistical catch-at-age model for lake whitefish stocks. The catch-at-age assessment may not be used to project harvest limits, but rather may be used to determine the health of lake whitefish populations and sustainability of current harvest levels.

Saugeen Ojibway

The 1990 "Sparrow Decision" by the Canadian Supreme Court (Sparrow v. The Queen 1990) was a landmark in the legal de-

velopment of Canadian aboriginal rights to use fish resources of the Great Lakes even though the decision had nothing to do with the Great Lakes or lake whitefish. The Sparrow Decision was a landmark because it presented the first occasion for the Supreme Court of Canada to explore the meaning of the aboriginal rights provision of Canada's new constitution that was created in 1982 (Jannetta 1991). Sparrow laid the groundwork for aboriginal and treaty rights and allocation of fish resources in Canadian waters of the Great Lakes in the same way that Jondreau, Gurnoe, and Fox did in U.S. waters.

An important component of Sparrow was how allocation and regulation occur. Fish are first allocated to the spawning population. If after the spawning target has been met and there is room for harvest, aboriginal food needs must be met. The nonaboriginal commercial fishery is allocated some harvest after spawning and aboriginal food needs have been met. Recreational fishing is the last group to be allocated a harvest. The mirror image occurs when regulation is to be applied to the fishery harvest; the first to be regulated is the recreational fishery and the last fishery to be regulated is the aboriginal fishery.

Following the Sparrow Decision an Ontario Court ruled in 1993 that members of the Saugeen Ojibway have a well-established right to fish commercially under the treaties of 1836, 1854, and 1862, and existing OMNR quotas infringe upon that right. The Ontario Court ruling gave a much higher priority to a lake whitefish fishery to the Chippewas of Nawash Unceded First Nation and Saugeen First Nation, collectively known as Saugeen Ojibway, that live along the eastern shores of Lake Huron on the Bruce Peninsula (Figure 2) than to the provincial-licensed fishery. Since the Sparrow Decision and the Ontario Court ruling the Saugeen Ojibway and the Province of Ontario attempted on numerous occasions to reach an agreement over allocation of lake whitefish populations around the Bruce Pen-

insula and co-management of those populations. In June 2000 an interim allocation and co-management agreement was achieved. The Agreement, among other things, sets out protocols for how data would be exchanged between the First Nations and OMNR, how TACs would be calculated, and how breaches of the Agreement would be dealt with. A second 5-year agreement was recently reached between the parties in 2005.

The 2005 Co-management Agreement allocated all the lake whitefish in the area around the Bruce Peninsula to the Saugeen Ojibway. Under the terms of the 2005 agreement the Saugeen Ojibway will be responsible for designating community fishers and monitoring the harvest through commercial catch sampling. All assessment data collected by the Saugeen Ojibway and OMNR will be shared through a joint bio-technical committee that makes recommendations on safe harvest levels. The First Nations agreed not to use large-mesh gill nets in certain bays along the Georgian Bay side of the Bruce Peninsula, although they maintain the right to do so. The agreement establishes a total allowable catch of lake whitefish by the Saugeen Ojibway in an open access large-mesh gill-net fishery with no ITQs. There are no seasonal closures of the fishery to accommodate spawning, and there are no minimum length limits or mesh size requirements imposed on the Saugeen fishery. Most of the Saugeen harvest is concentrated in the fall using small boats fished close to shore when lake whitefish are aggregated in shallow water to spawn. Ojibway people have fished in this manner for thousands of years (Kinietz 1965) so the Saugeen Ojibway view the co-management agreement as recognizing their traditional knowledge for managing the lake whitefish fishery.

The 2005 Co-management agreement also recommended using Decision Analysis and Adaptive Management (DAAM) as a strategy for managing the lake whitefish fishery. DAAM is a method of evaluating fishery

management options that explicitly incorporate uncertainty into decision making. In the case of the 2005 Co-management Agreement DAAM may be used to evaluate the effect on lake whitefish populations and the fishery of implementing varying levels of total allowable catch.

Provincial-First Nation Cooperation

Several formal partnerships have been established between the Province of Ontario and other First Nations to foster genuine interest in ensuring a sustainable resource of lake whitefish and other species. One example was in 1993 when the Union of Ontario Indians and the Province of Ontario signed the Anishinabek/Ontario Conservation and Fishing Agreement that ultimately created the Anishinabek/Ontario Fisheries Resource Center (AOFRC) in 1995. AORFC was to act as an independent center of excellence for fisheries assessment and management, recognized and trusted by First Nations, governments, and all users of fisheries resources (AOFRC 2003). The AORFC reports on stock status, evaluates stresses on fish populations and habitats, offers management recommendations, and facilitates information sharing and participation principally among Ontario First Nations and OMNR to promote sustainable fisheries and resolve conflict. The AOFRC integrates traditional knowledge of fishery resources by the First Nations with modern western science. A board of directors made up of commercial fishers, researchers, tourism and resource managers, and academic leaders oversees the AOFRC and seeks funds for its operation through partnership agreements with external agencies such as OMNR, the Northern Ontario Heritage Funding Corporation, and the federal government. In 2003 AOFRC staff embarked on a 3-year study to assess the status of lake whitefish in specific Ontario waters of lakes Huron and Superior that will also develop standard

methods for assessing lake whitefish populations (AOFRC 2003). In 2003 the Union of Ontario Indians and the province of Ontario signed a memorandum of understanding to establish an Anishinabek Ontario Resources Management Council to provide recommendations to the Minister of Natural Resources and Grand Council Chief on how to manage natural resources affecting First Nations in Ontario. The agreement has allowed discussions between OMNR and First Nations over fish and wildlife, enforcement policy, forestry, land, and waterpower management.

Recommendations for the Future

Harvest management

Kratzer et al. (2007) and Wright and Ebener (2007) both recommended that fishery managers needed to recognize that the carrying capacity for lake whitefish has been lowered in the Great Lakes because of the proliferation of dreissenid mussels, loss of *Diporeia* spp., and reductions in nutrient loading, particularly of phosphorus, to lakes Michigan, Huron, and Ontario (Madenjian et al. 2002; Mills et al. 2005; Dobiesz et al. 2005). Kratzer et al. (2007) further recommended fishery managers implement conservative harvest strategies in the future that protect the viability of lake whitefish stocks at the new lower productive capacity.

We believe that decades of regulatory change through 2006 have already produced conservative harvest management strategies for lake whitefish. We doubt that the fishery can sustain more conservative management policies given the poor economic condition of the fishery, low wholesale market prices, and reduced productivity of the lakes, and reduced catchability of lake whitefish due to the effects of dreissenid mussels. Instead, agencies should be more flexible and objective and work cooperatively with the industry to adopt regulations that give the fishery

flexibility to operate in a global economy and constantly changing environment, while minimizing bycatch. The new regulation changes implemented in Wisconsin in 2006 with the addition of a commercial “fleet” license are a good example of the flexibility that will be required to sustain a viable fishery for lake whitefish.

Recent application of statistical catch-at-age stock assessments to lake whitefish have provided a very useful tool for assessing their absolute abundance, mortality, and for projecting yield (Bence and Ebener 2002; Ebener et al. 2005; Belore et al. 2006). This “state of the art” methodology is being applied on nearly every Great Lake and it has even been recognized in negotiated settlements between state and Native American governments. While catch-at-age stock assessments have advanced our understanding of lake whitefish population dynamics, they are not without problems. In particular, the variations in reproduction over the last decade and substantial declines in growth have complicated the estimation of recruitment to the fishery, gear selectivity, and catchability in the catch-at-age assessments (Belore et al. 2006). If catch-at-age assessments are to be the standard for estimating harvest limits of lake whitefish, then future stock assessments should focus on how best to characterize catchability, changing gear selectivity, and levels of recruitment to the fishery. The Quantitative Fishery Center at Michigan State University (QFC <http://qfc.fw.msu.edu>) should provide the expertise necessary to make catch-at-age assessments a more viable tool for fishery managers. The Center is funded by the university as well as by the states of Michigan, Minnesota, and Ohio. This cooperative venture will be necessary for estimating harvest levels of lake whitefish and allocating those harvests since most Great Lakes fishery agencies do not possess the expertise or funds to commit to this type of analysis.

Marketing

The commercial lake whitefish fishery on the Great Lakes must continue to undergo a fundamental change to maintain the long-term viability of the industry. Poor market prices, the need for enhanced product quality controls, loss of traditional markets, international relations among governments, foreign competition, changes in regulatory requirements, ecological change, and fishery population dynamics have impacted the marketability and competitiveness of Great Lakes lake whitefish. To date, the response of the industry has been to invest in large freezer space to hold fish in the fall so as to smooth out the supply to the metropolitan areas during the winter when supplies of fresh fish are low. To stabilize Great Lakes lake whitefish product flow into the marketplace, and thereby prevent price drops due to glutted markets, it is imperative for commercial fishers to improve handling of fresh caught lake whitefish and use appropriate freezer storage practices to ensure the highest quality product.

For the Great Lakes commercial lake whitefish fishing industry to survive, it is critical that fishers and buyers, in conjunction with governments, develop a marketing strategy that capitalizes on the freshness and wholesomeness of the lake whitefish product, including product positioning and conduits to move this product to consumers. Michigan Sea Grant has initiated such a project in the State of Michigan in partnership with fishery stakeholders and funding from the National Sea Grant Office. Objectives of the Sea Grant initiative are to assess present markets and identify new ones, enhance consumer awareness of lake whitefish, improve quality control and product consistency, differentiate Great Lakes lake whitefish from inland lake whitefish, develop value added products, and enhance co-operative initiatives among disparate segments of the commercial fishing industry. Stakeholders involved in the Sea

Grant initiative include state- and tribal-licensed commercial fishers, state and tribal regulators, and Great Lakes basin processors. Thus far the project has succeeded in bringing all segments of Michigan's commercial fishery together for the first time to discuss their common welfare and generate a consensus action plan. A newly formed industry steering committee has developed a project action plan to create marketing opportunities. Among the project efforts have been development a quality assurance certification guideline, consumer product testing, creation of marketing tools, development of a professional web site, standard brand/quality assurance labeling, and future participation at culinary chef and restaurant association conferences.

The GLIFWC 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 on Lake Superior. GLIFWC is making extensive use of "product demonstrations" and promotions of products in target market communities to build a Lake Superior lake whitefish market brand and get consumers to commit to making regular purchases at tribal-member owned and operated fish processing locations and tribal owned grocery stores. GLIFWC is supporting tribal entrepreneurs in marketing fish through tribal bulk purchases for tribal and business enterprise consumption such as food services, restaurants, and casino dining. 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. GLIFWC will continue to partner with the Michigan Sea Grant Great Lakes lake whitefish-marketing project to help protect, promote, and preserve a major Native American community industry that is under assault by cheap foreign imports.

The need for international governance

There currently is no international governance of lake whitefish fisheries primarily because management agencies have larger fish to fry, so to speak. Lake whitefish is of little interest to recreational anglers who spend billions of dollars and millions of hours fishing the Great Lakes (Bence and Smith 1999). Since the 1960s many agencies, but not all, have spent more time minimizing the size of the commercial fishery than promoting it because recreational fishing is believed to provide larger economic benefits to society than commercial fishing (Brege and Kevern 1978; Legault et al. 1978; Bence and Smith 1999; Brown et al. 1999). State and provincial management agencies have focused a tremendous amount of their human and financial resources managing and promoting recreational fisheries for introduced Pacific salmon, rehabilitating populations of indigenous lake trout, for example, and providing an allocation of fishery resources to Native American governments. Licensing fees collected by the states, for example Michigan, are not nearly sufficient to fund the management of lake whitefish in this era of user pay philosophy; thus other funding sources, principally recreational fishing and hunting license fees subsidize most lake whitefish management by the states. There is a reluctance to increase reliance on these recreational funds for managing commercial fisheries and general tax dollars are seldom made available by state legislatures.

The biggest challenge to managing lake whitefish populations will continue to be introductions of aquatic plants and animals from outside the Great Lakes basin. Certainly commercial fishing reduced abundance of lake whitefish populations, but habitat destruction, and invasive species were the stresses that pushed their populations to the brink of extinction in the 1960s and early 1970s. Favorable environmental conditions,

control of sea lampreys, and reductions in abundance of invasive species were responsible for the recovery of lake whitefish populations (Ebener 1997; Bunnell et al. 2006). Commercial yields of lake whitefish since the late 1980s have been greater and more sustained than any other time in the last 100 years even though most fishing effort is directed at them and the effort occurs in smaller spatial areas than at any other time in recent history. Both the U.S. and Canadian governments must do a better job at stopping the flow of invasive species into the Great Lakes for the lake whitefish, and other fisheries, to be viable and sustainable.

The International Joint Commission was created by the U.S. and Canadian federal governments under the 1909 Boundary Waters Treaty to resolve disputes between the two countries on the Great Lakes and to pursue the common good of both countries as an independent and objective advisor to the two governments. Specifically, the International Joint Commission: 1) rules upon applications for projects affecting Great Lakes waters and may regulate the operation of these projects; 2) assists the two countries in the protection of the environment, including the implementation of the *Great Lakes Water Quality Agreement* and the improvement of air quality; and, 3) alerts the governments to emerging issues along the boundary that may give rise to bilateral disputes. We believe the International Joint Commission and the two federal governments have failed to protect Great Lakes waters from invasive species and we recommend that the current management strategy for stopping invasive species should be abandoned immediately in favor of a new policy and legislation that aggressively tries to stop any new introductions to the Great Lakes.

In an indirect way there has been international governance of lake whitefish populations. Stocking of trout and salmon and rehabilitation of lake trout coordinated by

management agencies within the lake committee structure of the GLFC have certainly fostered recovery and influenced management of lake whitefish populations (Ebener 1997). The forum provided by GLFC may be a place for international governance of lake whitefish populations. Fish community objectives for the Great Lakes developed under the GLFC's coordination umbrella certainly include lake whitefish. In addition, there has been considerably more research on lake whitefish funded and coordinated recently by the GLFC because the species has become a barometer for assessing food web disruptions caused by dreissenid mussels (Mohr and Nalepa 2005; Belore et al. 2006). Considering that lake whitefish fisheries have presented some of the largest obstacles for promoting lake trout rehabilitation, at least from the state and provincial points of view, it seems reasonable that coordinated management of lake whitefish populations and fisheries should occur at the lake committee level.

There are six areas in the Great Lakes where development of inter-jurisdictional and international governance of lake whitefish could occur within the GLFC structure. These areas are where the Great Lakes transition to one another and reproductively isolated stocks cross both international and state boundaries. These areas are: Whitefish Bay, Lake Superior; the northeastern and extreme southern main basin of Lake Huron; western Lake Erie including the Detroit River; eastern Lake Ontario in the Kingston Basin; and the Green Bay and the Door County area of Lake Michigan that share the North-Moonlight Bay and Big Bay de Noc stocks of lake whitefish (Ebener and Copes 1985). Initially, Rybicki and Schneeberger (1990) recommended that the states of Wisconsin and Michigan should coordinate management of lake whitefish in Green Bay because the fisheries in both states shared stocks. Subsequently, WiDNR proposed that the quotas they developed for Wisconsin waters of Lake Michigan should

be applied to the fishery in Michigan waters of Green Bay because they shared stocks. Significant disagreements developed between WiDNR, MiDNR, and CORA over coordinated management of these stocks that ultimately resulted in an external review of the stock structure information from the area. The review took place under the auspices of the Lake Michigan Committee of GLFC, but to date there has been no resolution. The debate over management of lake whitefish in Green Bay illustrates that international and inter-jurisdictional debates involving Great Lakes shared fish stocks will not be easily resolved.

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