IV. Aquatic Ecosystem

Aquatic Ecosystem Change

Since French explorer Étienne Brûlé first saw Lake Huron in 1612, the lake ecosystem has undergone many changes. Among the most significant changes to the fish community have been the invasion of rainbow smelt (*Osmerus mordax*) in the 1920's, followed by alewife (*Alosa pseudoharengus*) and the sea lamprey (*Petromyzon marinus*) in the 1930s. Sea lamprey predation and overfishing led to the collapse of lake trout (*Salvelinus namaycush*) by the 1950's in most of Lake Huron (although two remnant stocks barely survived). With no predators to control alewife and smelt populations their numbers exploded and nuisance die-offs of alewives commonly littered beaches during the 1960s.

The turnaround came with sea lamprey control in the 1960s which allowed the survival of stocked Pacific salmon (*Oncorhynchus* spp.), lake trout and other predators. Restocking controlled both smelt and alewife populations, prevented nuisance alewife die-offs and resulted in exceptionally good fishing.

The original Lake Huron ecosystem had lake trout as the main predator together with burbot (*Lota lota*) in the deeper waters, and walleyes (*Sander vitreus*) being the main nearshore area predator. The historic preyfish base was dominated by cisco (or lake herring) (*Coregonus artedii*) and a number of other species of deepwater ciscos (*Coregonus* spp.) including the bloater (*Coregonus hoyi*), with sculpins (*Cottus* spp. and *Myoxocephalus quadricornis*), lake whitefish (*Coregonus clupeaformis*) and round whitefish (*Prosopium cylindraceum*) contributing to a lesser extent.

The historic Lake Huron off-shore ecosystem had fewer predator species (dominated by the then very abundant lake trout) and many more prey fish species than the present fish community. The current ecosystem has more predator species (although their total biomass is lower than that of lake trout before their near extinction) than before the lake trout collapse and introduced species remain prominent. Prey fish continue to be dominated by introduced species. Many of the original deepwater cisco species in Lake Huron are extirpated (Refer to the section divider for illustration of aquatic system).

In the 1990s the invasion of zebra and quagga mussels (*Dreissena polymorpha*, *Dreissena bugensis*) from the Caspian region changed the Lake Huron ecosystem significantly. Although the linkages are not well understood, these new invasives altered the foodweb with far-reaching consequences to the fish community. The round goby (*Neogoblus melanostomus*) another Caspian invasive, appeared shortly after the zebra mussel invasion and has become an important benthic preyfish in Lake Huron. The invasive alewife nearly disappeared after 2003. Stocking success for the introduced Chinook salmon, steelhead (rainbow) and brown trout declined as alewife numbers plummeted. Thus, Lake Huron has again seen dramatic changes to its ecosystem, this time starting with the introduction of dreissenid mussels in the early 1990s and peaking during 2003-2006, when the salmon and trout fisheries were significantly reduced in abundance, particularly in the lake's main basin. This decline in salmon and trout also occurred in Georgian Bay and the North Channel but were less dramatic. The following summary will outline some of the more significant recent changes.

Lower Trophic Levels

From 1998-2002, zooplankton abundance and biomass, as monitored by EPA, were relatively high. Larger zooplanters most important to prey fish, such as daphnid cladocerans, composed much of this plankton biomass. The relatively high abundance of larger zooplankton, daphnia in particular, implies low levels of planktivory. The United States Geographic Service (USGS) bottom trawling in fact documents a declining trend in prey fish biomass from 1995-2002. However, in 2003 offshore zooplankton biomass declined sharply, but bottom trawl estimates of planktivorous fish biomass also declined. Alewives virtually collapsed in 2003-04. These changes were most dramatic in the southern area of the main basin. Changes in zooplankton since 2002 are no longer as clearly linked to prey fish abundance. *Limnocalanus* spp., a large calanoid copepod that may be an important prey for ciscos and chubs, remained relatively abundant. *Limnocalanus* tends to stay near the bottom of the lake during daytime and may not be readily available to pelagic planktivores such as alewives.

National Oceanic and Atmospheric Administration (NOAA) and EPA monitoring has demonstrated that *Diporeia* (*Diporeia hoyi*), large benthic crustaceans, declined in abundance steadily from 1992-2005 and are now scarce in Lake Huron. Although not monitored consistently, the fairy shrimp, Mysis (*Mysis relicta*), another important benthic crustacean prey for the fish community, may also have declined in abundance. Both *Mysis* and *Diporeia* migrate vertically at night and, while suspended in the water column, become especially available to planktivorous fish.

The most likely causes for the observed changes in zooplankton abundance and composition are:

1. Sequestering of nutrients by invasive dreissenid mussels;
2. Replacement of zooplankton-edible forms of phytoplankton such as diatoms by bluegreen algae;
3. Predation by larger cladocerans, mainly the spiny water flea (*Bythotrephes cederstromi*);
4. Shift in planktivory by fish from macrocrustaceans (*Diporeia*) to zooplankton;
5. Extinction of the benthic-pelagic nutrient link once driven by vertically migrating macrocrustaceans and pelagic planktivorous fish;
6. Some combination of the above

Negative impacts by dreissenid mussels on native zooplankton likely include competition for primary productivity. This could lead to the sequestering of nutrients in the nearshore zone and on the bottom of the profundal zone, particularly on hard substrates most heavily colonized by dreissenids. Declining prey fish biomass measured by USGS in the offshore waters tends to fit this hypothesis. Fish prey biomass has remained rather stable in the North Channel, however. Low calcium concentrations in the North Channel recorded by Environment Canada appear to be limiting dreissenid abundance there. If true, the North Channel may serve as a kind of 'control' for the dreissenid-driven nearshore shunt hypothesis thought to be operational in the other basins of Lake Huron (Hecky *et al.* 2004).

Primary productivity is a measure of offshore production measured by EPA and EC. There have not been measurable declines in primary productivity of the offshore waters of the main basin of Lake Huron. The extent to which primary productivity has changed to forms (such as bluegreen or filamentous algae) not usable to zooplankton or the macrocrustaceans is unknown. Thus we cannot be sure if the decline in zooplankton and macrocrustacean abundance is related to reduction quality or quantity of food available to them.

The third potential cause for native zooplankton declines is through competition for food with large exotic cladocerans (specifically spiny water flea). However, this seems unlikely given that spiny water flea abundance has not increased significantly during the period of native zooplankton decline. EPA conducts sampling only twice a year, thus it is possible that some important changes in spiny water flea abundance could escape detection. The status of zooplankton may be different in Georgian Bay and the North Channel of Lake Huron compared to the main basin, especially in light of differences in calcium availability, fish abundance, and fish growth. However similar zooplankton studies are unfortunately not conducted on those basins.

The observed changes and timing of zooplankton abundance (Figure 4.1) are consistent with planktivory since adult fish prefer larger cladocerans (mainly *Daphnia* and bosminids) and calanoid copepods while larval fish prefer small nauplii (juvenile copepods), cyclopods and bosminids (cladocerans). Zooplankton, particularly the larger *Daphnia*, were relatively abundant from 1998-2002, which was also a period of declining prey fish biomass. The first sign of major declines of zooplankton in 2003 also coincided with a very large year class of alewives which may have exerted high predation pressure on zooplankton. However, this large year class survived poorly and alewives were almost absent by 2004. Despite the very low levels of abundance of the major forage fish species (rainbow smelt, lake herring, alewives and bloater) in the Main Basin after 2003, zooplankton showed no signs of recovery until 2007. USGS biomass estimates of planktivorous fish appear to be too low to account for the decline in zooplankton after 2003. If fish were driving the declines in zooplankton abundance it must be because they targeted zooplankton at a higher rate due to of the collapse of benthic macrocrustaceans (*Diporeia* and *Mysis*). A rise in zooplankton biomass was measured in 2007, but the increase was in confined to calanoid copepods, rather than in daphnids, which are more readily available to planktivorous fishes. The species composition in 2007, therefore, remained consistent with that expected of a heavily grazed zooplankton community.

Potential competition between dreissenids and the macrocrustaceans *Mysis* and *Diporeia* would most likely be for food resources, particularly seston (including detritus). However, there is no indication that *Diporeia* are energetically deprived and the competitive mechanism, if any, remains obscure. But the fact that *Diporeia* have collapsed in Lake Huron is undisputed. All major benthic invertebrate groups (*Diporeia*, oligochaeta, sphaeriidae and chironomidae) declined in abundance from the early 1970s to 2000. Benthic invertebrates declined by approximately 50% in deep waters and 75% in nearshore areas over this period. The most severe declines were seen in the amphipod *Diporeia* where large areas of the lake were devoid of this species by 2000. In 2003, sampling showed *Diporeia* declined by an additional 57% in just three years. Samples collected in southern Georgian Bay from 2000 to 2003 have shown similar declines in *Diporeia* abundance. Some additional data collected on the benthic communities in Saginaw Bay from 1987-2000 have revealed that the decline in *Diporeia* began during 1992-1993, approximately the same time that zebra mussels invaded the area. A decline of *Diporeia* in other areas of the Great Lakes also coincided with the arrival of zebra mussels. By 2007, only a few pockets of *Diporeia* remained in the main basin of Lake Huron and they appear associated with upwelling areas characterized by cooler water temperatures.

Diporeia have much higher caloric value than other food items, with one *Diporeia* being the equivalent in energy content to hundreds of other individual zooplankters. Many pelagic forage fish species in Lake Huron (including rainbow smelt, alewives and bloater) have traditionally utilized *Diporeia* in their diet. Declines in zooplankton abundance which following the decline of *Diporeia* might indicate a shift to an increased plankton diet to compensate for decreases in benthic macrocrustacean availability. Alternatively, loss of *Diporeia* may have reduced the availability of nutrients

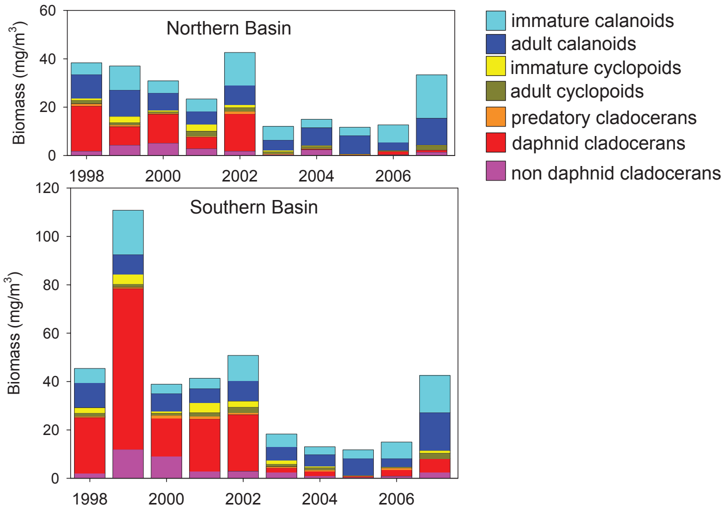

Figure 4.1. Summer zooplankton biomass, offshore waters of Lake Huron, 1998-2007. GLNPO data.

to the pelagic zone. Both *Diporeia* and *Mysis* feed on detritus settling to the bottom during daytime but undergo crepuscular migrations to and from the pelagic zone where they feed on plankton at night and, in turn, are preyed upon by planktivorous fish such as ciscos, chubs, and alewives. Since the formation of the Great Lakes during the last ice age, these glacial relics have served to transport nutrients from the benthic zone to fish of the water column. The collapse of these macrocrustaceans and their pelagic fish predators may not only have shifted predation by fish (those few remaining in the pelagic zone) to zooplankton, but also extinguished an important linkage connecting detritus settling to the benthic zone with productivity of the pelagic. Whatever the cause, the current zooplankton community of the main basin of Lake Huron is now very similar in biomass and composition to the much less productive waters of Lake Superior.

Dreissenid mussels, by removing planktonic algae, have also made waters of the Great Lakes much clearer. Increased water clarity has caused proliferation of benthic filamentous/colonial algae such as cladophora, spirogyra, and chara. The periodic dieoffs of these algae and wind events that wash the algae to shore have led to accumulations of decaying biological matter on beaches. These noxious deposits represent a loss of nutrients that otherwise would have been available to the foodweb and they also appear to be contributing to periodic outbreaks of Type E botulism.

From 2000 to 2007, zebra mussels were relatively stable or declining in abundance in areas sampled while quagga mussels showed an increase. Quagga mussels are closely related to zebra mussels but can tolerate much greater depths and are colonizing water depths that were not previously impacted by zebra mussels. Quagga mussels are now being sampled from water depths as great as 130 m.

The complexity of the foodweb and the variety of recent change agents identified to date strongly suggests that some combination of the above factors has been working to produce changes measured since 1997 in the fish community.

Prey Fish

Alewife

Along with rainbow smelt and bloaters, the alewife was, until 2004, among the three most common prey fish in Lake Huron. In 1998, there was a near collapse of adult alewives. Milder winters from 1997 to 1999 may have resulted in higher survival of young alewives which buffered the population from high predation levels and allowed for a period of recovery. From 2003 through 2007 there were very low adult numbers of alewives but an extremely large year class was produced in 2003 (Figure 4.2)

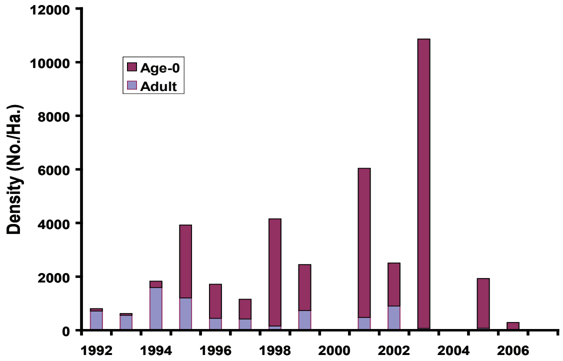

Figure 4.2. Alewife abundance in fall bottom trawls 1992-2007. No collections were made in 2000. Source: USGS data.

Ninety percent of the young of year in 2003 were less than 86 mm total length at the end of the summer, the size considered the minimum necessary to survive the winter. The 2003 year class was so abundant that competition for food sources appears to have lowered their growth and the fish were small entering the winter. Consequently, the 2003 year class did not survive, alewives have declined to record-low abundance, and the population is showing no signs of recovery.

Alewife numbers and biomass have reached near record low levels since the beginning of fishery surveys in the 1970's. This was likely due to some combination of climate, food web changes, and salmonid predation. Great Lakes winters have been the most and least severe in the past several years relative to the previous 20 years. Alewives tend to suffer lower mortality when mild winters prevail during their first year; this appears to affect their abundance for the rest of their lives. After 1995, alewife populations also experienced significant increases in predator consumption rates, principally due to increasing Chinook salmon reproduction. While alewives in 1984 reached the age of 8 years, despite increases in abundance they only survived until ages 3 to 4 by 2000-02.

Consecutive alewife recruitment failures have continued since 2003. Studies in 2004-07 reveal a 99% decline in alewife abundance from 2002. There was a slight increase in age-0 alewives observed in bottom trawls in 2005, but this was due to only a few high catches in northern regions of the lake. Adult abundance increased slightly in 2005, but their numbers remain very low compared to pre-2003 levels. As of 2007, no significant recruitment has occurred.

Given the poor survival of recent year classes, the future of alewives is uncertain. However, it's very likely that they originally invaded the upper lakes with few individuals and they have shown they can produce strong year classes during years with relatively low adult abundance. Therefore their resurgence is possible but given the extremely low numbers of adults and the low availability of zooplankton as prey, it is unlikely that adult alewives will recover, at least for some time, to their former abundance. The recovery of a strong and reproducing walleye population in Saginaw Bay and a large population of adult walleyes in Thunder Bay may further limit the potential for alewife recovery. Both bays were formerly very important spawning sites for alewives. It appears unlikely that spawning aggregations of alewives can rebuild in these bays in the face of such large walleye populations.

Rainbow Smelt

Similar to 2005 and 2006, the rainbow smelt population was dominated by age-0 fish in 2007. The age-0 fish were small and less than 10% of the population was larger than 100 mm. The low abundance of adult fish in 2007 suggests that the large numbers of small rainbow smelt observed in 2005 and 2006 did not translate into recruitment of larger rainbow smelt (Figure 4.3). In fact, the combined biomass for all age classes of rainbow smelt decreased by about 50% from 2005 to 2006-07 despite record-high density of age-0 fish observed in 2005. Few fish are now greater than 150 mm, whereas 200 mm adults were common in the 1970s and 1980s. The change is size structure suggests survival rates have declined. Adult smelt biomass, now in the range of 6 kg/ha, is not replacing former adult alewife biomass, which typically ranged 10-24 kg/ha. The lack of larger prey items, including smelt, could affect the growth rates and maximum sizes attained by predator fish.

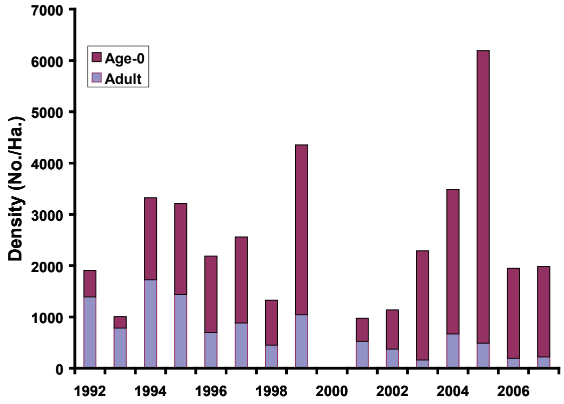

Figure 4.3. Rainbow smelt abundance in fall bottom trawls 1992-2007. No collections were made in 2000. Source: USGS data.

Bloater

The native bloater increased in abundance in 2004-07, with the 2007 year class being the strongest since 1992 (Figure 4.4). Historically, age-0 bloater abundance was much lower than smelt or alewives (less than 0.2 kg/ha). Bloater will therefore not significantly offset shifting predation demands resulting from the declining abundance of alewives. Adult bloaters are currently considered scarce compared to peaks in population cycles that occurred in the 1980s and mid 1990s. However, there is some evidence that individuals from the large year classes of 2005 and 2006 survived, and the adult population has increased.

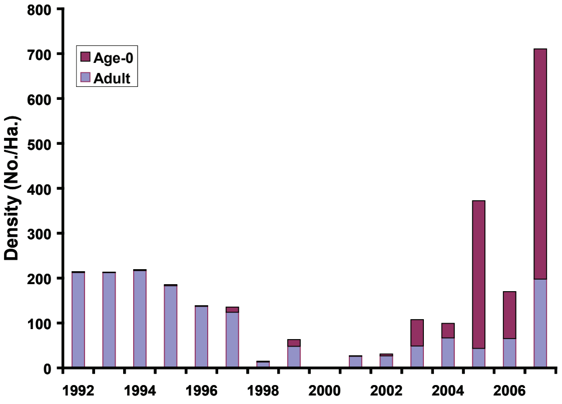

Figure 4.4. Bloater abundance in fall bottom trawls 1992-2007. No collections were made in 2000. Source: USGS data.

Cisco

Cisco (lake herring) have increased in Lake Huron. Ciscoes were captured for the first time in acoustic/midwater trawl surveys during 2007. Density and biomass estimates indicated that ciscoes were present at densities of slightly less than 9 individuals/ha in the main basin, and they represented about 30% of pelagic biomass. Those estimates may have been somewhat biased, but indicate that ciscoes are increasing although they are still not nearly as abundant as they are in Lake Superior.

Sculpins, Sticklebacks and Trout-Perch

Sculpins, sticklebacks (*Pungitius pungitius, Gasterosteus aculeatus*) and trout-perch (*Percopsis omiscomaycus*) are at lower abundance than during the previous decade. Numbers have remained consistently low since 2002 (Figure 4.5). Sculpin abundance in Lake Huron has fluctuated widely since 1992 but has been depressed since 1998. Deepwater sculpins comprise most of the total sculpin catch, while slimy sculpins are only a minor component of the deepwater fish community and were seen in low numbers in 2007. Deepwater sculpin abundance decreased from levels observed in 2006 and remains at near record-low levels. Density of ninespine sticklebacks decreased by about 50% of levels observed in 2006. Ninespine stickleback abundance has varied considerably since 1992 and low densities have been observed previously (1992-94 and 1998-99). However, the recent trend since 2001 is downward, and indicates that sticklebacks will not contribute to the fish community as an alternative prey species.

Troutperch density also continues a five-year overall decline. Their overall abundance remains low for the time series. As with sticklebacks, troutperch will not be an important alternative prey species.

Round gobies have not contributed significantly to the trawl catch and their numbers have declined in recent years. Their low representation in the trawl catch is surprising considering they contribute heavily to the diets of lake trout in the Main Basin and walleyes, catfish, drum, and smallmouth bass in Saginaw Bay and other nearshore areas.

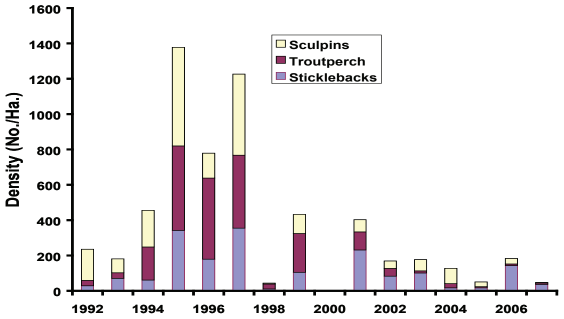

Figure 4.5. Abundance of sculpins, troutperch, and sticklebacks in fall bottom trawls 1992-2007. No collections were made in 2000. Source: USGS data.

Prey Fish Conclusions

Prey biomass in Lake Huron has remained low since 2004, almost totally a result of the drastic decline of alewives (Figure 4.6). Lake Huron is becoming more like Lake Superior in regards to its prey base. The availability of prey fish in Lake Huron remains in a depressed state since the collapse of alewife populations in 2003. Collections made in 2007 showed an overall increase in total prey biomass largely constituted by high numbers of small bloater and evidence of bloater recruitment to older age groups. Alewife density remains near the all-time low for the time series. Abundance of juvenile rainbow smelt was at an all-time high for this survey in 2005, but these small fish contributed little to lakewide biomass estimates in 2006 or 2007. Chinook salmon, although not native to the Great Lakes, have declined sharply due to depressed prey availability. Ecosystem stability and the future of the Chinook salmon sport fishery remain as concerns for fisheries managers and stakeholders

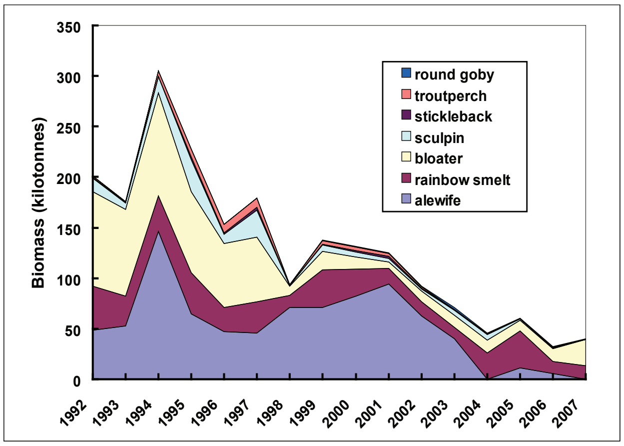

Figure 4.6. Estimated prey biomass in Lake Huron from fall bottom trawl surveys 1992-2007. Source: USGS data.

Lake Huron managers are hopeful that recent declines in alewives will allow for the expansion of the native bloater and lake herring. This will provide a more stable, better adapted prey base and will hopefully provide larger-sized prey that can support larger-sized predator fish. Continued low alewife abundance would also reduce the detrimental impact of alewife predation on the fry of other species, particularly perch, walleyes, and ciscos. Alewives are also high in thiaminase, which has been shown to inhibit reproduction of predator species that eat them by causing thiamine deficiency in their progeny (early mortality syndrome).

Fish of Interest to the Recreational and Commercial Fisheries

Chinook Salmon

Chinook were first stocked into Michigan waters of Lake Huron in 1968 and in 1985 in Ontario waters. Stocking levels have varied, peaking in 1989 at over 5 million fingerlings but averaging 4.0 million from 1986 to 2004 (Figure 4.7). Chinook salmon became the dominant predator in Lake Huron through the 1980s and 1990s. During this period, they fed mainly on non-native forage fish (alewives and smelt are their preferred diet items). With the collapse of alewives in 2003-04, Chinook salmon rapidly declined to a fraction of their former numbers (Figure 4.8). Both growth rate and survival of Chinook salmon have proved to be proportional to alewife abundance. Lake trout remain abundant in the lake due to stocking, but they exert less predation pressure on the prey base than did Chinook salmon prior to their fall.

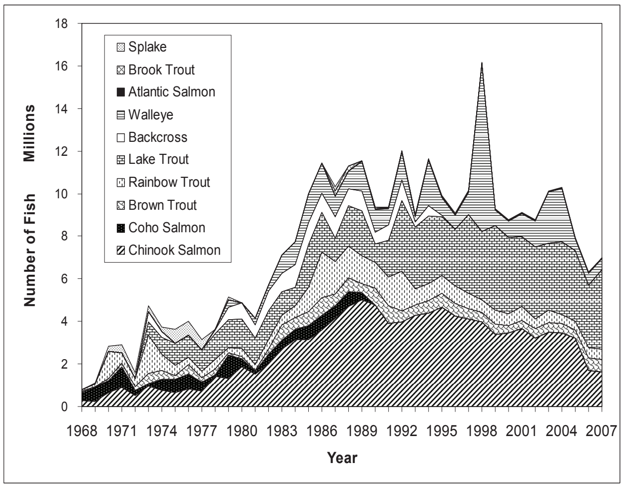

Figure 4.7. Number of predators stocked into the Lake Huron basin, 1968-2007.

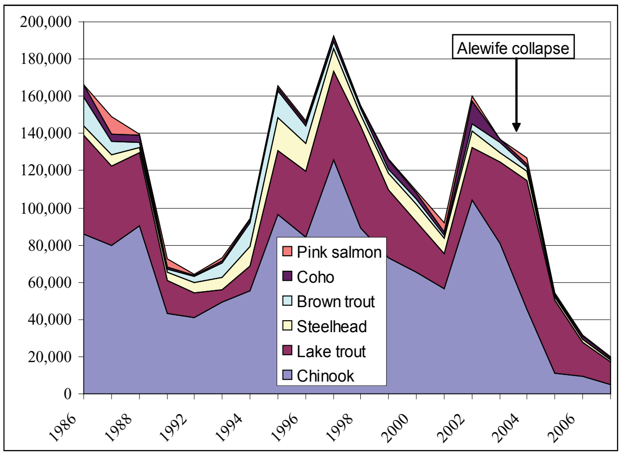

Figure 4.8. Number of trout and salmon caught at 10 Main Basin Index Ports, Michigan waters, Lake Huron, 1987-2007.

Balancing predator numbers with available prey has always been a difficult task in the Great Lakes. In the 1980s, Lake Michigan Chinook salmon consumption rates exceeded their prey availability and resulted in reduced growth rates and an outbreak of bacterial kidney disease (BKD) in the stressed fish. This resulted in a decline in predator abundance for a number of years.

By interagency agreement, Lake Huron stocking levels of predator species were capped at 1990 levels in 1991 (8.33 million salmonids) until such time as more information was available on the predator versus prey balance. In 1998, catch rates were very high and the condition (or plumpness) and growth of Chinook were very low due to the low abundance of alewives as prey. A computer tool named the “Lake Huron Consume Model” indicated prey consumption demand was exceeding prey availability. Bioenergetics modeling confirmed that Chinook salmon were the dominant predator in the lake. Stocking was consequently reduced by nearly 20% in 1999. A large year class of alewives produced in 1998 provided a good food source for Chinook salmon in 1998 and 1999, and growth rates recovered. However, alewives again declined in 2003 and were nearly absent by 2004. This resulted in record low average sizes of Chinook salmon that were in very poor condition with many exhibiting signs of chronic malnutrition. Most Chinook salmon stomachs observed in the main basin of Lake Huron were empty in 2005. When present, food items were dominated by rainbow smelt and sticklebacks. Alewives were nearly absent in the diet and most prey consumed were too small in size to be well suited to such a large predator. Despite concerns that declines in growth would result in disease outbreaks similar to the situation that occurred in Lake Michigan, to date BKD levels have remained relatively low and stable.

Ongoing low abundance of alewives in since 2003 has resulted in the lowest catch and harvest rates on record for Chinook salmon in the main basin.

Growth, condition and catch rates of Chinook salmon in Georgian Bay and the North Channel from 2000 to 2007 declined, but apparently not to the same levels observed in the main basin. This indicates that prey fish status differs among the basins of Lake Huron. Hydroacoustic surveys conducted by the United States Geological Survey (USGS) in 2004-07 revealed that Georgian Bay and the North Channel had the highest densities of prey fish biomass in Lake Huron. Smelt appear to be much more abundant in these two basins, which has likely been sustaining Chinook salmon and limiting declines in growth rates. Environment Canada monitoring shows that calcium concentrations are relatively low in the North Channel and may be limiting dreissenid abundance and, thus, foodweb disruption there.

In the late 1960s until the early 1990s, the number of Chinook salmon caught by anglers was proportional to the number of fish stocked. This started to change by the mid 1990s, and, even though stocking numbers were stable or declining, catch rates increased. Use of the “Consume” model in the late 1990s, made it apparent that the level of natural reproduction of Chinook salmon in Lake Huron was a critical unknown and could have a significant impact on predator demand. Initial estimates used in the model were 20% to 50% natural production depending on the basin, but these were only very rough estimates provided by management agencies.

Historically, little was known of the levels of natural reproduction of Chinook salmon in Lake Huron. In the 1980s, some wild fish were observed, mainly in Georgian Bay and the North Channel. Studies of young-of-the-year fish in the early 1990s indicated that less than 30% of the Chinook salmon were wild in Michigan waters.

Because of the uncertainty of the estimated levels of natural reproduction and the potential significant influence of reproduction on predator demand for food, a joint international study was designed and initiated in the early 2000s. From 2000 to 2003, all Chinook salmon stocked into Lake Huron were marked. Lake Michigan also contributed to the study since movement of Chinook salmon between Lakes Huron and Michigan has been documented. Assessment consisted of sampling fish from around the lake during June to August, prior to when the fish would be homing back to their natal streams.

This time period was chosen to assure estimates of wild fish were not biased by sampling elevated concentrations of hatchery fish homing to areas where they were originally stocked.

Results collected in 2003 to 2005 were surprising. In Michigan waters, 82% of the Chinook salmon were unmarked and presumed wild. The number was even higher in Ontario waters: unmarked Chinooks made up roughly 98% of Georgian Bay's harvest and 86% of the North Channel's. The results were consistent between the four years of the study. It is presumed that the majority of the natural reproduction in Lake Huron is from Ontario waters since most of the cold-water streams in the State of Michigan have been dammed and are inaccessible for spawning. As a result of this study and declining prey supplies, stocking of Chinooks in Michigan waters of Lake Huron was again reduced in 2006, by about 50%.

In the 1990s, the spawning runs of Chinook salmon in all areas of the lake consisted mainly of fish aged 3 to 5. Today the runs are dominated by age 2 and 3 fish. A shorter life span was once a disadvantage in that fish would be spawning at smaller sizes with fewer eggs, resulting in less likelihood of their contributing to future generations. Today it is evidently an advantage to spawn early while still able to contribute some energy to reproduction; large, older Chinooks are no longer favored due to the relatively low biomass and small size of prey fish since the foodweb change.

With no strong year classes of alewives in the foreseeable future, Chinook salmon are unlikely to regain their former position as the Main Basin's dominant predator.

Lake Trout

Lake trout were the original dominant predator in the Lake Huron ecosystem. Unsustainable harvest practices and sea lamprey predation led to their demise in the main basin of Lake Huron in the 1940s and their almost complete disappearance in Georgian Bay and the North Channel by the mid 1950s. Two small remnant populations survived in Iroquois Bay and Parry Sound.

Efforts to rehabilitate this species and return the lake to some semblance of its historic balance have resulted in the stocking of over 74 million pure strain lake trout during 1968-2007 (Figure 4. 6).

Half of the current stocking occurs in the main basin, with the other half split between Georgian Bay and the North Channel. Initially, stocking was done nearshore but recently more offshore stocking has occurred.

Lake trout in Parry Sound, a location of one of the two remnant stocks, have been deemed rehabilitated. This was accomplished through a combination of stocking and strict harvest controls. Lake trout natural reproduction has been observed in ten other locations in Lake Huron at various levels but to date no other locations have been fully rehabilitated.

Until recently the majority of observations of natural reproduction had been in embayment areas (Owen Sound, South Bay, Iroquois Bay, Parry Sound, Thunder Bay). Since 1984, a total of 270 wild young-of-the-year lake trout have been caught in MDNR bottom trawls in Thunder Bay, MI. The highest catch was in 1990 at 43 fish but numbers steadily declined through the 1990s and 2000s and no young-of -year fish were caught in 2002 or 2003. In 2004, 11 were caught, and another 15 in 2005. No young-of-year were taken in 2006, but 26 were taken in 2007. During 2007, all but 4 of the 26 young lake trout were caught in July. By late August none could be found. Either the young lake trout were not surviving or they were leaving the nursery grounds sooner then in earlier years. Twenty-two wild young-of–the-year lake trout were incidentally captured by USGS bottom trawling during prey assessment surveys in 2004 and an additional 11 in 2005. In 2004 the USGS fish were captured in the main basin over a wide area. By 2007 lower numbers were caught and only in the northern site near Detour. Evidently, lake trout reproduction rose somewhat after the collapse of alewives, but the numbers measured since 2004 have not yet been sufficient to be considered a major step toward recovery.
In the Main Basin, the percentage of lake trout lacking hatchery fin clips remains low and near background levels except at 6-Fathom Bank, about

45 miles offshore of Harrisville, where US Fish and Wildlife Service monitoring encountered 38 unclipped, presumably wild, lake trout per 1,000 ft of gillnet effort during assessment of the spawning population there during October 2007.

Lake trout reproduction has been generally higher in years of low alewife abundance. Peak years in the MDNR trawling in Thunder Bay were 1986-1990, when a total of 137 wild juveniles were taken. These fish were from years when alewife abundance was relatively low and lake trout spawning stock was high. The decline in alewives in 2004 and 2005, in addition to higher abundances of adult lake trout and lower sea lamprey predation associated with increased control, likely played a role in the more recent observation of lake trout natural reproduction. Alewives appear to limit natural reproduction of lake trout through both direct predation on fry and thiamine deficiency complex. Lake trout with a high proportion of alewives in their diet can accumulate thiaminase. This results in low thiamine levels in lake trout eggs and significant reductions in hatching success and fry survival.

Thiamine levels in lake trout eggs have been monitored in Lake Huron at several locations since 1996. In 2004-07, many areas of the lake showed declines in the number of lake trout reproductively impaired by low egg thiamine concentrations. This suggests that these lake trout are finding alternative food sources to alewives. Spring assessment netting has shown that more than half of the diet of lake trout in the main basin now consists of round gobies, indicating that a diet of gobies results in higher egg thiamine levels than one dominated by alewives

Adult stocks of lake trout have generally risen in the Main Basin since 1998. In 1998 the first successful control efforts were completed in the St. Marys River and in 2000 harvest restrictions were prescribed for Michigan's Native American commercial fishery that reduced fishing mortality substantially. Lake trout, in combination with walleyes (both native species) now share the role of leading predator fish in the Main Basin. Although the rehabilitation of lake trout has proven to be a long and difficult process, some success has been achieved in re-establishing spawning stocks and reproduction. The demise of alewives appears to provide an opportunity to build on the accomplishments achieved to date. The successful rehabilitation of lake trout in Lake Superior has provided the proof that rehabilitation of this native species in the Great Lakes is attainable.

Percids (Walleye and Yellow Perch)

Walleye historically were the dominant near-shore predator in Lake Huron. They are found in discrete populations in all three basins. Many localized populations are in various states of reduced abundance compared to historic levels. These declines are attributed to high fishing pressure, habitat alterations, water pollution, and effects of alewives. Since the majority of walleye populations spawn in rivers and require clean cobble spawning grounds they are very vulnerable to habitat degradation.

Saginaw Bay historically had the largest abundance of walleyes in Lake Huron but their numbers declined in the 1940s due to year class failures attributed to habitat loss, pollution, overfishing, and alewife predation on walleye fry. Key requirements for rehabilitation have been improvement of water quality, which has taken place under provisions of the Clean Water Act, restrictive fish harvest regulation, and stocking. Walleye year class strengths have been monitored in Saginaw Bay since the mid 1980s. A larger then usual year class was detected in 1998, a year of low adult alewife abundance. The 2003 year class was extraordinary large, almost five times the 1998 record, and corresponded in time with the collapse of adult alewives (Figure 4.9).

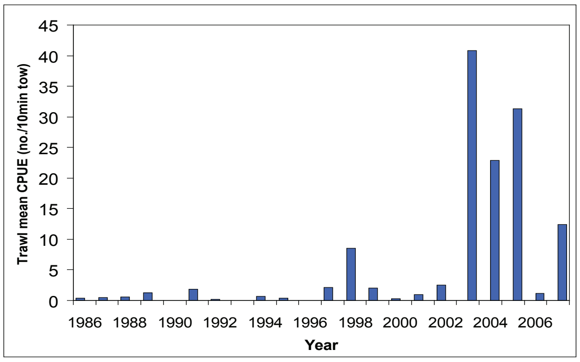

Figure 4.9. Trawl catch rates of age-0 walleyes, Saginaw Bay 1986-2007. Source: MDNR data.

Only 28% of the large 2003 year class could be attributed to stocked fish. Ideal climatic conditions and low alewife abundance are credited for this large year class. Similar large year classes were observed in Lakes Erie and Michigan in 2003. However, very strong year classes also were produced in Saginaw Bay in 2004, 2005, and 2007 that cannot be attributed to favorable climatic conditions; thus, the lack of alewives appears to be the chief factor in the ongoing reproduction success of walleyes in Saginaw Bay.

As the large year classes of 2003 and 2004 entered the recreational fishery, walleye harvest rose sharply and reached modern-record levels in 2007. Nearly 750,000 pounds of walleyes were harvested in Michigan waters by anglers during 2007. Walleyes now dominate the recreational fishery in Michigan waters.

Yellow perch (*Perca flavescens*) in Lake Huron have traditionally been an important species for both angling and commercial harvest and as prey, particularly for walleyes. As with walleyes, perch also experienced an unprecedented large year class in 2003 (Figure 4.10).

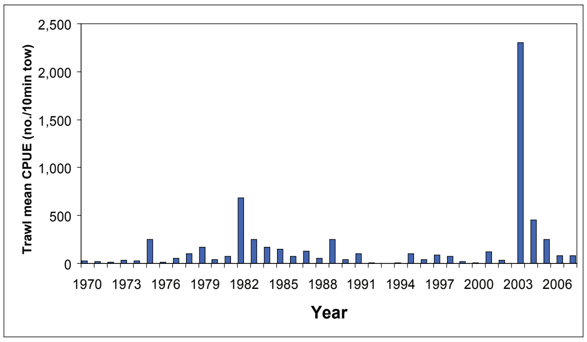

Figure 4.10. Trawl catch rates of age-0 yellow perch in Saginaw Bay 1970-2007. Source: MDNR data.

The 2004 and 2005, year class strengths were much lower than 2003 but still among the highest of record. Over-winter survival of recent year classes of yellow perch has been poor. Presumably the large year classes were competing with each other for limited food resulting in reduced fitness heading into winter. Predation pressure by predators, particularly walleyes, was also a factor in the poor survival of recent yellow perch year classes.

Reductions in alewife abundance seem to be benefiting reproduction of native walleyes and yellow perch. Good year classes of both species are likely to continue on a regular, if not annual, basis if alewives are maintained at low numbers. This will hopefully provide for a sustained recoveries of the yellow perch and walleye populations. Managers will need to be cognizant of other limiting factors to the percid populations, including prey supply and potential for rising exploitation.

Coregonids (Lake Whitefish, Bloater, Lake Herring, Shortjaw Cisco)

Lake whitefish are the most abundant and widely distributed member of the off-shore benthic community, occupying all areas of Lake Huron. They are the most sought after commercial fish species and have accounted for greater than 80% of the total commercial yield since 2000. Commercial yield of lake whitefish has declined from its peak in 1998 but harvest is still substantial and remains higher than at any other time in the last two centuries (Figure 4.11).

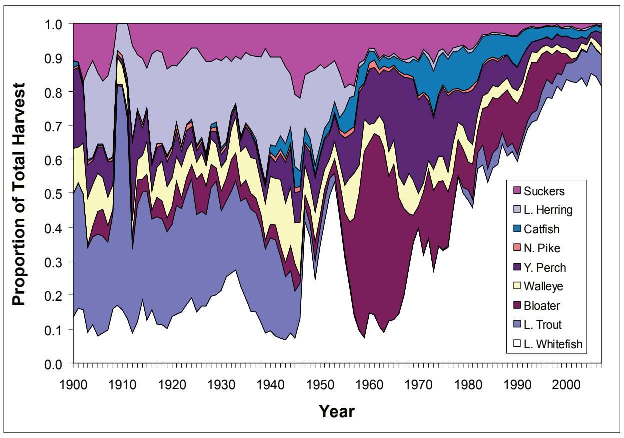

Figure 4.11. Commercial Harvest of Major Species in Lake Huron, 1900 to 2007.

Recent declines in the market price of lake whitefish have contributed to a drop in commercial fishing effort and yield. Declines in both mean weight at age and condition began in the late 1980s and early 1990s and continued through 2002. The mean weight at age appears to have stabilized or slightly increased since 2003. Declines in lake whitefish growth are likely related to the reduction of Diporeia as a diet item, which has resulted in reduced lipid content in whitefish. Dreissenid mussels and mysis are now the principal components of their diet.

In recent years lake whitefish have changed their distribution and are found in deeper water, possibly a result of an increase in water transparency related to the dreissenid invasion. Since 1997, large floating plumes of green algae (*Cladophora* spp.) have fouled commercial gear reducing catchability of lake whitefish. This increase in cladophora is probably related to increased water clarity as well. The change in distribution has led to increased numbers of lake trout being caught incidentally when the commercial fishery is targeting lake whitefish; this has been particularly evident since 2000. This incidental bycatch of lake trout has more serious consequences when in gillnets than in trapnets because the trapnet catch is usually live and at least 85% can be released without consequence. Most lake trout caught in gillnets are dead or moribund when brought aboard.

Bloater and the shortjaw cisco (*Coregonus zenithicus*) are the only two remaining deepwater ciscoes currently found in Lake Huron. The shortjaw cisco is considered endangered and is only located in limited areas in Georgian Bay. The commercial catch of bloaters declined dramatically in Lake Huron during 2000 to 2007 (Fig. 4.9). The reductions in catch occurred concurrently with observed declines in abundance and recruitment.

Lake herring are found in all three basins of Lake Huron but their distribution is restricted. They are common in the St. Marys River, North Channel, in waters of the north shore between the straits of Mackinac and Drummond Island, and in eastern Georgian Bay. Lake herring are not found in Michigan waters south of the Straits of Mackinac, but they are occasionally caught in the Ontario waters of the southern main basin. Unlike lake whitefish, growth rates of lake herring, based on mean weight-at-age, appear to be more stable. Abundance of lake herring appears to be slowly increasing in its core habitat of Georgian Bay and the North Channel and Ontario waters of the southern main basin. Managers are hopeful that increases in lake herring abundance will occur in the absence of alewives.

Saginaw Bay was traditionally a prime area for lake herring but very few are seen there today even when they appear to be increasing in other areas of the lake. Lake Huron managers are currently reviewing options for re-introducing this species to the Saginaw Bay and Thunder Bay areas through stocking and have been promoting their increase in abundance in other areas of the lake through harvest control.

Lake Sturgeon

The lake sturgeon is classified as "threatened" by the Department of Natural Resources under the authority of the endangered and threatened species provisions of Section 36503 of 1994 PA 451, MCL 324.36503. Canada is currently reviewing the status of Lake Sturgeon and this review could lead to an "at risk" designation for the species.

Lake sturgeon numbers declined precipitously during the early 20th century due to overfishing and construction of dams, which blocked access to and/or inundated spawning habitats crucial for the species' reproduction. While fishing controls are now in place that sharply limit or prohibit harvest, most spawning barriers remain. Removal of certain key dams and barriers to spawning habitat is essential for the recovery of this species.

The historically most important spawning habitats for lake sturgeon were in the mainstem sections of Lake Huron's larger tributaries such as the Thunder Bay, Au Sable, and Saginaw River sytems on the Michigan side and the Maitland, Saugeen, Nottawasaga, and Mississagi rivers on the Ontario side of Lake Huron. At least some spawning habitats for sturgeon in all of these above listed tributaries are now blocked or inundated by dams. Spawning habitat and a vibrant spawning population remain in the St. Clair River near the Bluewater Bridge and further downstream near Lake St. Clair. Consequently, measurable numbers of lake sturgeon remain in the southern management units of Lake Huron but the species is scarce or virtually absent in most other basins. Successful spawning persists in the lower Mississagi River, where a measurable population also persists. Recent studies suggest there may be a small reproducing population in the St. Marys River that spawns in the rapids at Sault Ste. Marie.

There is uncertainty regarding the risk posed by foodweb change for lake sturgeon. Native prey for sturgeon has been replaced by dreissenids and round gobies. Although sturgeon readily feed on gobies, the long-term outlook for sturgeon is guarded if Type-E botulism persists in Lake Huron. Gobies are thought to be vectors of the neurotoxin produced by *Clostridium botulinum*, the bacteria responsible for botulism. Lake sturgeon have been among the species of fish identified in botulism-kill areas of the Great Lakes.

Fishery Management Goals

Fish Community Objectives (FCO) for Lake Huron were developed in 1995, and in most cases, reflected yield targets for species or species groupings based on historic commercial fishery landings from 1912-1940. An emerging realization is that historic harvests, and even current harvest levels for some species, may not be sustainable in the long-term. Historic commercial fishery practices, such as switching to different targeted species, fishing different fish stocks, and changes in fishing effort and fishing power, may all have masked the steady decline of fish populations over this historic time period.

In addition, the current ecosystem may not be as productive for some species as in the past because non-native prey species are not as efficient in linking primary and secondary production of the lake to higher food webs, including fish, as were historic species. For example, dreissenids have largely replaced *Diporeia* but are not nearly as rich in essential lipids and do not act as nutrient vectors between the benthic and pelagic communities. The diversity of ciscos that once inhabited the lake was probably more effective in transferring energy to larger lake trout than the round goby, which tends to be quite small. The introduction of non-native species such as zebra and quagga mussels and the spiny water flea may also divert much of the primary and secondary production of the lake to different pathways, making it unavailable to top predators.

The non-native Chinook salmon, which feed almost exclusively on alewives and smelt, are less likely to make the transition to feeding on newly invasive benthic species than indigenous lake trout. The lake trout has a much more varied diet, would historically have utilized some portion of the available benthic prey, and appears now to be doing so by consuming large numbers of round gobies. Gobies rarely appear in diets of Chinook salmon. Thus, the outlook for Chinook salmon, which until 2003 was the most important recreational species of Lake Huron in terms of economic activity generated by its fishery, appears bleak. It is doubtful that Chinook salmon will continue to contribute significantly to the harvest target set for salmonids in the FCOs.

The drafters of the FCOs had no way of anticipating the upheaval to Lake Huron's foodweb that came on the heels of their report. Revised FCOs will need to address such issues as: how will species of interest to Lake Huron's stakeholders respond to the new foodweb? What levels of harvest is sustainable for species such as walleyes, lake whitefish, yellow perch, and lake trout? Historical records are of questionable relevance because historical harvests were sustained by a foodweb that no longer exists. The number of changes the lake is currently undergoing makes strategic planning and fish population modelling particularly difficult. Are the changes currently occurring in Lake Huron permanent? Is productivity of the lake's pelagic zone going to continue to be low? If the introduction of additional exotic invaders is not stopped, this will continue to limit predictive capacity and sound strategic planning for the lake.

To better facilitate the cooperative management of fisheries resources a framework for inter-jurisdictional coordination of fisheries management based upon an ecosystem context was developed. This "ecosystem approach" to fisheries management recognizes that the resources of the Great Lakes must be managed as a whole, that healthy fish communities require stable, healthy, food webs, functional, interconnected, diverse habitats (including those in tributaries), and clean water. In order to support the FCOs, Environmental Objectives (EOs) were recently developed to describe the biological, chemical and physical needs of these desired fish communities. Implementation strategies and funding for remedial actions identified in the EOs are needed. Pollution of sediments with persistent contaminants, particularly in tributaries to Saginaw Bay, has resulted in widespread concern over the advisability of consuming fish products from Saginaw Bay and its tributaries. Correcting this issue and making stream habitats currently blocked by man-made barriers available to migrating fish, rank as key targets for future habitat work. Removal of barriers to spawning sites is probably the single most effective tool available to managers in restoring lake sturgeon and other potadromous species on Lake Huron.

Traditionally, the impacts of industrialization and human population density on Lake Huron have not been as great as some of the other Great Lakes. However, Michigan's rich supply of fresh water is likely to make the shores of the Great Lakes increasingly attractive to industry and power generating utilities. In addition, growing production of biofuels will increase the percentage of Lake Huron's watershed that is under intensive agricultural production, with the potential for attendant increases in nonpoint nutrient enrichment and sediment loading of tributaries. Lake Huron is also vulnerable to future potential anthropogenic impacts due to its close proximity to highly populous areas and its popularity as a destination for millions of cottagers, tourists and anglers; timely strategic planning to protect and enhance habitat is very important. The mounting development pressures on Lake Huron from improved highways, increases in year round residents, and diminishing resources in other locations, will likely increase harvest and development pressure and strain the achievement of resource sustainability. Continued vigilance is needed to insure that future development on Lake Huron is done in a sound ecologically sustainable manner while efforts to seek solutions to existing problems continue to occur.

A summary of issues identified in the Lake Huron Environmental Objectives is provided below:

Spawning and Nursery Habitats

Maintain, protect and restore the integrity and connectivity of wetland spawning, nursery and feeding areas throughout the Lake Huron basin. Coastal wetlands throughout Lake Huron provide critical spawning, nursery and feeding habitat for a variety of fish species. Northern pike (*Esox lucius*) and muskellunge (*Esox masquinongy*) spawn exclusively in wetland areas whereas other species such as yellow perch, walleye, and minnow species use these areas as nursery and feeding sites. Historical losses of Lake Huron wetlands through drainage, infilling and other physical alterations have been significant. Many remaining wetlands are degraded or no longer accessible due to shoreline armoring. Spawning and nursery wetland habitats identified as priority areas in the draft Environmental Objectives are: Saginaw Bay, St. Marys River, Les Cheneaux Islands, Eastern Georgian Bay and North shore of North Channel.

Protect and restore connectivity and functionality of tributary spawning and nursery areas throughout the Lake Huron Basin. The Lake Huron watershed is the largest of the Great Lakes with numerous rivers and streams draining into the basin. The principal spawning and nursery habitats for a variety of species, including lake sturgeon (*Acipenser fluvescens*), walleye, pacific salmonids, and suckers (*Catostomus* spp.) are found in these tributaries. Unfortunately, rivers and streams are some of the most altered and disrupted habitats in the Lake Huron basin. Many of the watersheds draining into Lake Huron have barriers to upstream access and have flow regimes that have been altered as a result of watershed land-use changes or hydro-electric generation needs. Spawning and nursery tributary habitats identified as priority areas in the draft Environmental Objectives are: Saginaw Bay watershed, St. Marys River, Garden River, Mississagi River, Spanish River, Moon River, Severn River, Nottawasaga River, Saugeen River, Au Sable River and Thunder Bay River.

Protect and restore reef spawning areas throughout the Lake Huron Basin. Lake Huron is a deep oligotrophic lake with a fish community that was historically dominated by deep dwelling species such as lake trout, whitefish and ciscoes. Most of these species utilize offshore or nearshore reefs for spawning purposes. Nearshore and offshore reefs are one of the most common habitat features throughout the Lake Huron basin. For the most part these habitats have not been physically altered to the same extent as other habitat types, however, the colonization of these habitats by invasive species such as zebra mussels and round goby (*Neogoblus melanostomus*) has accelerated in recent years and may in time degrade the quality of these habitats. Spawning and nursery reef habitats identified as priority areas in the draft Environmental Objectives are: Saginaw Bay, Manitoulin Island, Western shore of Bruce Peninsula (including Fishing Islands complex), Georgian Bay, Thunder Bay, Drummond Island, Mackinaw Island, Six Fathom Bank and Yankee Reef.

Shoreline Processes

Protect and rehabilitate nearshore habitats and reestablish the beneficial structuring forces of natural water exchanges, circulation, and flow that they provide. The alteration of nearshore areas due to human activities has been widespread throughout the Lake Huron basin but has been most pronounced in the populated areas in the southern part of the basin. Shoreline straightening, infilling, dredging, and other such activities alter nearshore currents, increase erosion and deposition of fine sediments and leads to the loss of habitat diversity. Since a majority of fish species inhabiting the basin use nearshore areas at some point in their life-cycle, altering these areas results in the loss of fish production and change in fish community structure. Priority areas identified in the draft Environmental Objectives for protection and rehabilitation are Saginaw Bay, Central and south-east shore of main basin, St. Marys River, Southern Georgian Bay, Thunder Bay, Les Cheneaux Islands and Eastern Georgian Bay/North Channel.

Food Web Structure and Invasive Species

Protect and where possible enhance or restore fish community structure and function by promoting native species abundance and diversity and avoiding further invasive species introductions. Fish communities throughout the Lake Huron basin have undergone substantive change over the last century. Historically, the offshore fish communities were characteristic of a large, deep oligotrophic lake with lake trout and burbot being the dominant predators, and a variety of cisco species being the dominant prey species. In the nearshore waters, a relatively greater diversity of predators (walleye, northern pike, muskellunge, bass (*Micropterus* spp.)) were present as well as benthivores (sturgeon, suckers, channel catfish (*Ictalurus punctatus*)) and forage fish (herring, yellow perch, cyprinids). A variety of factors have been implicated in the loss or extinction of species in the basin and prominent among them is the proliferation of invasive species such as lamprey, alewives, rainbow smelt, and zebra mussels. Priority areas identified in the draft Environmental

Objectives for protection and enhancement and rehabilitation of fish community structure are the main basin, Saginaw Bay, St. Marys River, Les Cheneaux Islands and Severn Sound.

Water Quality

Protect and restore water quality throughout the Lake Huron basin and especially in the AOCs in order to avoid reductions in fish production and reduce or remove contaminant burdens from the fish community. Water quality throughout the Lake Huron basin has shown gradual improvement since the early 1970's. Some localized nutrient enrichment problems exist in Saginaw Bay and southeastern main basin and in northeastern Manitoulin Island. Acid rain and heavy metal contamination is still a localized issue in some parts of the North Channel and Georgian Bay. Consumption restrictions due to contaminant levels are in place throughout the basin for a variety of fish species. Priority areas identified in the draft Environmental Objectives for protection and restoration of water quality are Saginaw Bay, St. Marys River, Severn Sound, Southern Georgian Bay, central and northern Georgian Bay, North Channel, and southeast main basin.

Invasive Species

Lake Huron has been dramatically and forever changed by the invasion of non-native species, which have decimated native fish populations, and in some cases, permanently impacted fish communities. Invasive species are defined as species that do not originate in the Lake Huron ecosystem and have been introduced either intentionally or accidentally. Invasive species threaten the diversity and abundance of native species and the ecological stability of infested waters.

The introduction of invasive species into Lake Huron has altered or disrupted existing relationships and ecological processes. This disruption can cause significant changes to the Lake Huron ecosystem such as alterations of food webs, nutrient dynamics, reproduction, sustainability, and biodiversity. Invasive species have few natural enemies such as pathogens, parasites and predators. Without coevolved parasites and predators, they out-compete and even displace native populations. Not only do invasive species compete with native species for food and habitat, they may also increase cycling of persistent bioaccumulative chemicals in the food chain. For example, research has shown that zebra mussels and round gobies are contributing to the cycling and bioaccumulation of PCBs.

The recent invasion of zebra and quagga mussels, round gobies, the spiny water flea, white perch (*Morone americana*) and ruffe (*Gymnocephalus cemuus*) into Lake Huron heightens the uncertainty for expectations from the ecosystem.

The following is a description of a number of invasive species having a significant impact on the Lake Huron aquatic ecosystem.

Sea Lamprey - The sea lamprey has been a serious problem in the Great Lakes for more than 50 years. An adult lamprey can consume, and subsequently kill, up to 40 pounds of fish in just 12 to 20 months. The St. Marys River, which flows between Lake Superior and Lake Huron has become the most important spawning area for lampreys in the Great Lakes. By the1990s the St. Marys River was producing more sea lampreys than all other Great Lakes spawning tributaries combined.

Successful rehabilitation of Lake Huron lake trout populations has been hindered because of the high number of sea lamprey. Without question, the sea lamprey problem in northern Lake Huron, with increased lamprey production from the St. Marys River, is the most severe impediment to a healthy fish community in the lake.

Cost-effective sea lamprey control on the St. Marys, once thought to be impossible, may now be within reach because of a special program developed by biologists and research scientists working under the direction of the GLFC. During 1998 and1999, more than 840 hectares of the St. Marys River were treated with Bayluscide 3.2% Granular Sea Lamprey Larvicide. Additional treatments of sea lamprey "hot-spots" in the river have been conducted in more recent years. The larvicide treatments reduced the number of larval sea lampreys in the river by nearly 45%. Enhanced trapping and release of sterile male lampreys in the river reduced the reproduction potential by an estimated 92%. Although the GLFCs fish community objective for sea lamprey (75% reduction) was not met for the year 2000, the objective for 2010 (90% reduction) is attainable. However, funding for sea lamprey control remains at approximately 65% of that needed to fully fund the program.

Round Goby - The round goby are a small fish that feed chiefly on bivalves, amphipod, crustaceans, small fish, and fish eggs. Consumption studies of fish suggest round gobies might have a detrimental impact on native species through competition for food and predation on eggs and young fish. To help control the expansion of the goby into other waterways, river barrier systems are being implemented along with aggressive public education programs. Unfortunately, no effective measures have been found to decrease established populations of goby. Goby have continued to spread in Lake Huron and have been found in increasing numbers in the diets of lake trout, walleye, and burbot. There are concerns that this could increase contaminant levels in predators. In addition, although the mechanisms are not well understood gobies are implicated in recent outbreaks of botulism. Concerns also exist that gobies will out-compete native fishes, especially sculpins, and predate on the eggs and young of other fish, reducing both the diversity and density of prey and predators in the lake.

Eurasian Ruffe - The Eurasian ruffe was first identified in 1995 in Thunder Bay near Alpena, Michigan. Ruffe adapt well to various environments, mature quickly, and spawn over an extended period of time. Ruffe populations initially grew in number, yet they did not spread from the Thunder Bay region of Lake Huron. Fortunately, they have not been detected in Thunder Bay since 2003. Hopefully, this species will disappear from Lake Huron.

Spiny Water Flea - The spiny water flea was first discovered in Lake Huron in 1984 and is believed to have entered the waters of the Great Lakes through discharged ballast water. The spiny water flea has now colonized all offshore areas of the lake. Although its average length is rarely more than 1.5 cm, this predacious zooplankter can have a profound effect on a lake's plankton community.

Zebra and Quagga Mussels - Zebra mussels reproduce rapidly and are able to form dense layered colonies of over one million per square metre. Zebra mussels are a serious threat to the Lake Huron ecosystem because they have tremendous filtering capacity for sediments and phytoplankton. In many regions of the Great Lakes zebra mussels have had severe impacts on many native unionids and are of special concern to threatened and endangered species of bi-valves. Also, zebra mussels are a serious concern because they contribute to the cycling of contaminants by removing PCBs from the sediments and reintroducing them into the food web. Quagga mussels are similar to zebra mussels in many respects but they do prefer deeper water. They therefore have the potential to detrimentally impact aquatic species that use the deeper portions of the lake.

Other Aquatic Nuisance Species - Eurasian watermilfoil (*Myriophyllum spicatum*) is one of the most common species found in Saginaw Bay. Populations have thrived since the introduction of zebra mussels that contributed to higher water clarity. Eurasian watermilfoil is detrimental to Lake Huron because it reroutes nutrients from plankton, depriving energy to the fish community. Purple loosestrife is a perennial wetland plant that is impacting Lake Huron wetland ecosystems by out-competing native vegetation and changing the structure, function and productivity of the wetlands they invade. The plant can form dense monoculture stands sometimes hundreds of hectares in size. The fishhook water flea (*Cercopagis*), is one of the most recent invasive species to Lake Huron. Fishhook water fleas are a problem because, like the spiny water flea, they get tangled in the lines of both recreational and commercial fishery nets and have a large appetite for zooplankton. Further, ecological disruptions have not been completely determined, therefore, the fishhook water fleas are being closely monitored.

References

Hecky, R.E., Smith, R.E.H., Barton, D.R., Guildford, S.J., Taylor, W.D., Howell, T.D. and Charlton, M.N. 2004. The nearshore shunt: a consequence of ecosystem engineering by dreissenids in the Laurentian Great Lakes. Can J. Fish Aquatic Sci. 61:1285-1293.