Inland Seas Angler

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Highlights of the Annual Lake Committee Meetings

Great Lakes Fishery Commission proceedings, Milwaukee, WI

This first of a series of annual special reports is a summary of Lake Michigan. This lake committee report is from the annual Lake Committee meetings hosted by the Great Lakes Fishery Commission in March/April 2016. We encourage reproduction with the appropriate credit to the GLSFC and the agencies involved. Our thanks to Ed Makauskas & Vic Santuci, IL DNR; Brian Breidert, IN DNR; Dale Hanson, Charles Bronte, Jessica Barber and Mark Holey, USFWS; the many other DNR biologists who make this all happen, and also thanks to the staffs of the GLFC and USGS for their contributions to these science documents. Thanks also to the Great Lakes Fishery Commission, its staff, Bob Lamb & Marc Gaden, for their efforts in again convening and hosting the Upper Lake Committee meetings in Milwaukee.

Lake Michigan

Index of Reports

Abbreviation	Expansion
CPH	Catch per hectare
CWT	Coded Wire Tag
KT	1,000 metric tons
MDNR	MI Dept. of Natural Resources
USFWS	U.S. Fish and Wildlife Service
WTG	Walleye Task Group
YAO	Age 1 and older
YOY	Young of the year (age 0)

Great Lakes Mass Marking Program 2016 Update and Result Highlights

2015 Tagging and marking activities

- 2.97 million Chinook salmon and 6.39 million lake trout were coded-wire tagged in 2015
- Smaller lots (< 0.2 million) of Atlantic salmon and brook trout were also coded-wire tagged in 2015
- Average final % tagged and clipped rates were 97.5% for Chinook salmon and 97.1% for lake trout
- Average throughput was 8,997 and 7,931 fish per hour for Chinook salmon and lake trout, respectively.

2015 Data and tag recovery activities

- In 2015, USFWS bio-technicians stationed on Lakes Michigan and Huron, sampled 48 ports and examined 21,200 salmonines, including 8,997 Chinook salmon and 6,517 lake trout.
- Over 60,000 coded-wire tags have been recovered since the inception of the project.

2015 Estimated contributions of wild lake trout to fisheries in Lakes Michigan and Huron

- In 2015, 53.2% of lake trout recovered in Lake Huron had no fin clip and were presumed wild **(Fig. 1).**
- 17.2% of lake trout recovered in Lake Michigan had no fin clip, with higher no-clip rates in southern Lake Michigan **(Fig. 1**).

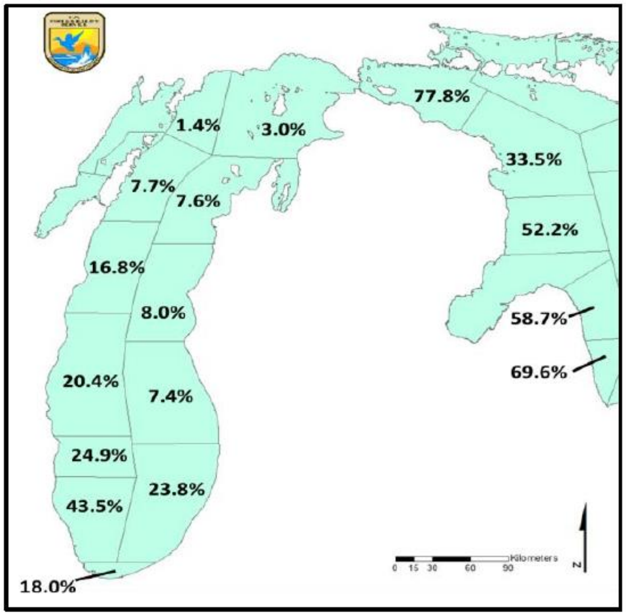


Fig. 1: Percent of lake trout recovered without a fin clip and presumed wild in each statistical district of Lakes Michigan and Huron.

2014 Estimated contributions of wild Chinook salmon to fisheries in Lakes Michigan and Huron

- In 2015, 69.4% of Chinook salmon (all ages) in Lake Michigan and 45.8% in Lake Huron were without a fin clip and CWT and presumed to be wild **(Fig. 2).**
- Estimated production of wild Chinook salmon from the 2014 year class was greater than the weak 2013 year class, but lower than from year classes 2006 – 2012 (**Fig. 3**).

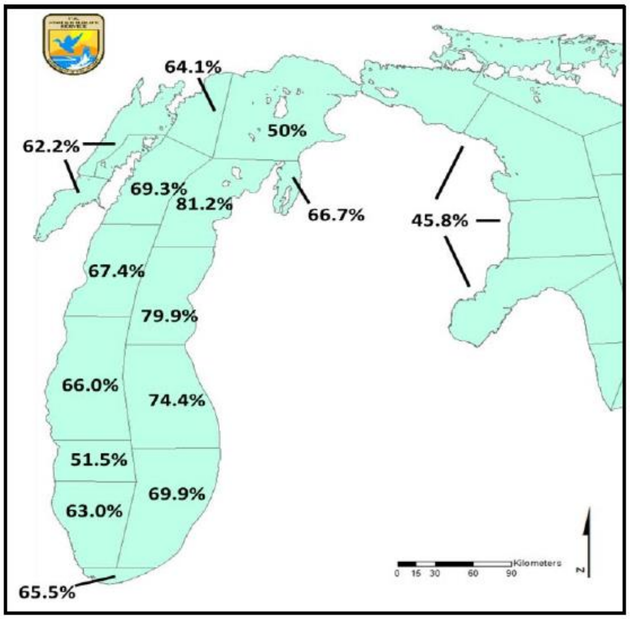


Fig. 2: Percent of Chinook salmon recovered without a fin clip and presumed wild in Lakes Michigan and Huron

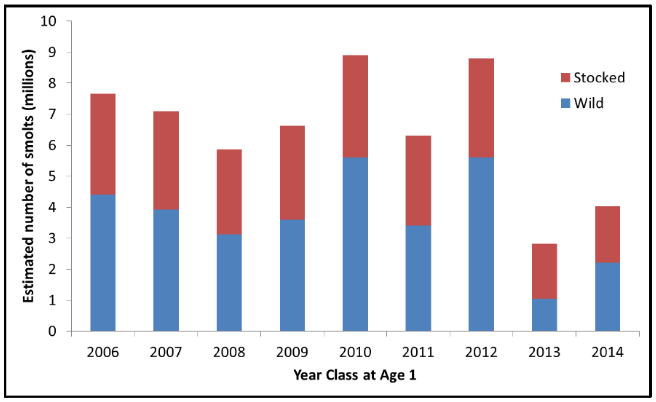


Fig. 3: Estimated number of wild and stocked Chinook salmon in the 2006 – 2014 year classes in Lake Michigan.

Estimated contribution of stocked Chinook salmon to the fishery by stocking district

- Chinook salmon stocked along the western shore of Lake Michigan have greater survival post-stocking than those stocked on the eastern shore and in Green Bay (Fig. 4). Even at eastern ports, fish stocked on the west shore tended to be caught the most (e.g., Frankfort, MI in **Fig. 7**).
- The analysis was based on the percentage of fish from each stocking location recovered in each district, corrected for number of fish stocked. Each Chinook salmon year class (2011 – 2013, total of 7,703 fish) was analyzed separately. Fig. 4 shows patterns across all three year classes.
- Underlying mechanisms are unknown, but could include differences in habitat (e.g., water temperature, food availability) that make western shore locations more favorable for young Chinook salmon; differences in rearing or release practices; or greater competition with wild Chinook salmon on the eastern shore.

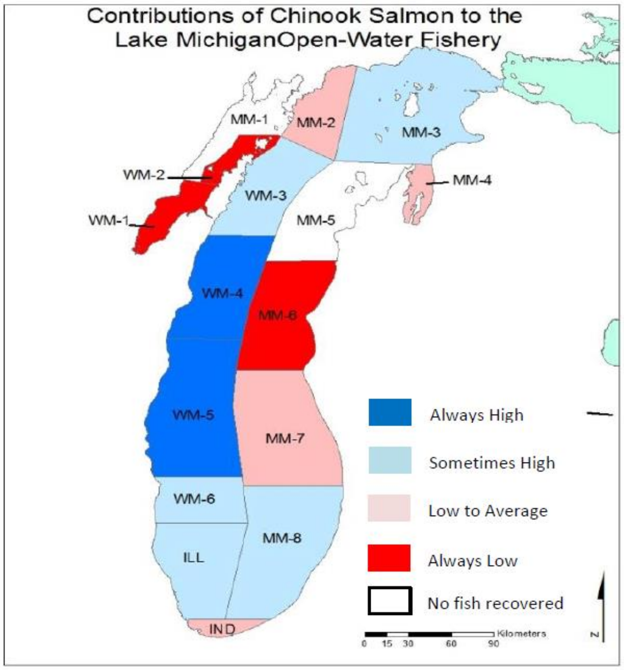

Contributions of Chinook Salmon to the Lake MichiganOpen-Water Fishery

Fig. 4: Map showing districts in which all year classes had high survival (dark blue), districts with high survival of some year classes (light blue), districts with consistently low to average survival (pink), and a districts where all year classes had low survival (red).

Chinook salmon movement patterns - between basins

- During April – August 2015, 96% of Chinook stocked in Lake Huron were recovered in Lake Michigan. 0% of Chinook stocked in Lake Michigan were recovered in Lake Huron over the same time period. Most mature Huron-stocked fish returned to Lake Huron in autumn to spawn.
- Chinook salmon move from Huron to Michigan with little reciprocal movement. Thus, we consider most Chinook stocked in Lake Huron as part of the Lake Michigan population for the purposes of the predator-prey ratio model, which is used to help maintain balance between predator and prey biomass in Lake Michigan.

Chinook salmon movement patterns – within Lake Michigan

- In the open-water fishery, over 90% of Chinook salmon were harvested in a different statistical district then where they were stocked during April – July. During Sept.-Oct., most (50-95% depending on age) were harvested in their stocking district. **(Fig. 5).** August was a transitional month.

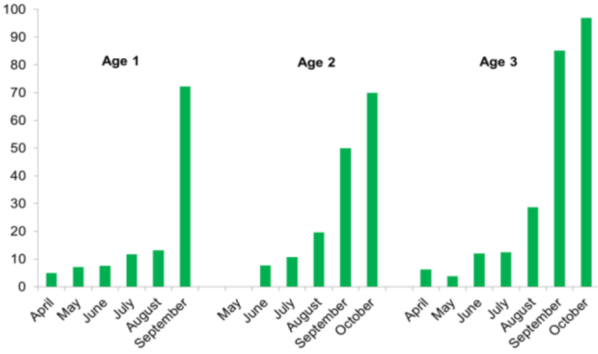
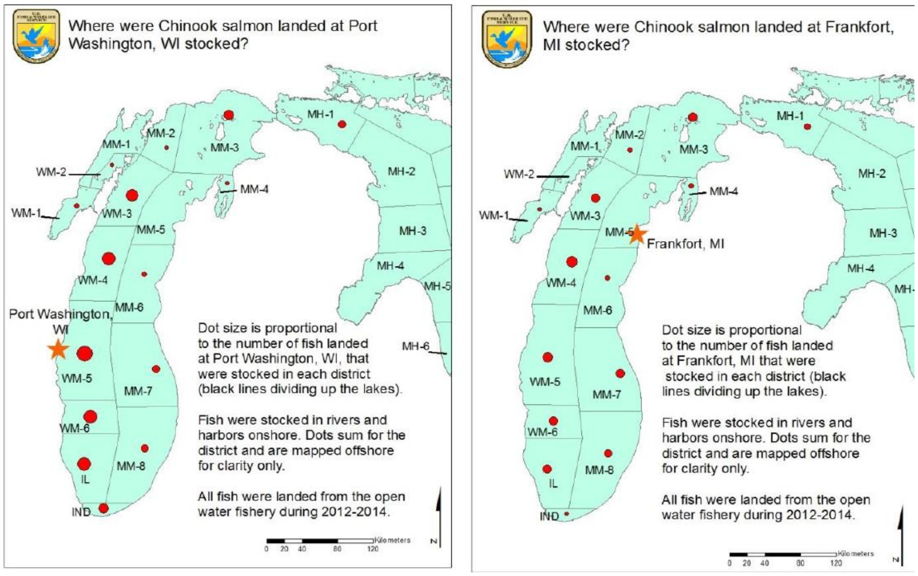


Fig. 5: Percent of Chinook from the 2011 year class recovered in the statistical district where they were stocked, by fish age and by recovery month.

- Mean distance between the centers of stocking and recovery districts during the open-water fishery was 117-151 km (73-94 mi), dependent on age. The distribution of distances travelled was a long right tail for all ages, with recoveries up to 520 km (323 mi) away from stocking location.
- Maps showing the stocking locations of coded-wire tagged Chinook landed at specific ports (31 in Lake Michigan, 11 in Huron, e.g., **Fig. 6**) are available upon request (matthew_kornis@fws.gov).


Where were Chinook salmon landed at Port Washington, WI stocked?

Dot size is proportional to the number of fish landed at Port Washington, WI, that were stocked in each district (black lines dividing up the lakes).

Fish were stocked in rivers and harbors onshore. Dots sum for the district and are mapped offshore for clarity only.

All fish were landed from the open water fishery during 2012-2014.

Where were Chinook salmon landed at Frankfort, MI stocked?

Dot size is proportional to the number of fish landed at Frankfort, MI that were stocked in each district (black lines dividing up the lakes).

Fish were stocked in rivers and harbors onshore. Dots sum for the district and are mapped offshore for clarity only.

All fish were landed from the open water fishery during 2012-2014.

Fig. 6: Origin of stocked Chinook salmon captured from 2012 – 2014 during the open water fishery at Port Washington, WI (left) and Frankfort, MI (right). The size of each circle corresponds with the number of fish per 100,000 stocked.

Post-stocking survival and movement of lake trout stocked at offshore refuges

- Analysis of coded-wire tagged lake trout recovered by spring assessment surveys (e.g., LWAP) showed that lake trout catch-per-unit-effort (CPUE, a proxy for survival) was affected by stocking location, genetic strain and length-at-stocking.
- CPUE was corrected for number of fish stocked.
- Lake trout CPUE was lowest from fish stocked in the Northern Refuge, likely due to mortality from sea lamprey and commercial fishing, and highest from fish stocked at Julian's Reef.
- In stocking locations with low lake trout mortality, Lake Michigan remnant genetic strains (Lewis Lake and Green Lake) had higher CPUE than Seneca Lake strain)
- Over 50% of lake trout stocked offshore in southern Lake Michigan were recovered in nearshore waters where they are accessible to the recreational fishery **(Fig. 7**).
- Spatial spread of lake trout from northern Lake Michigan was more limited.
- High CPUE of lake trout stocked in southern Lake Michigan may have contributed to increased recoveries of wild lake trout recently reported from that area by building spawning stock biomass.

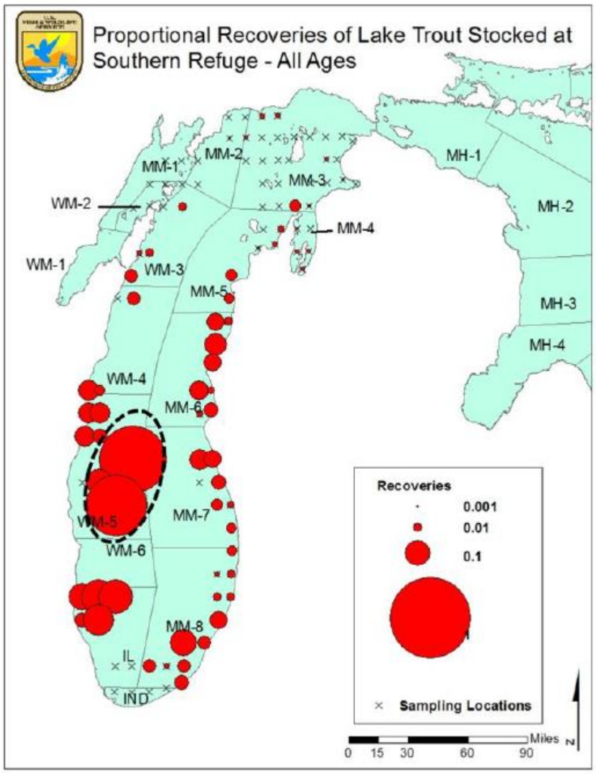


Fig. 7: Catch-per-unit-effort of lake trout stocked offshore at the Southern Refuge (dashed black oval). Dot size is proportional to CPUE. X's indicate sampling locations.

Stable isotopes of Lake Michigan salmon and trout

- Stable isotopes of carbon (δ13C, indicates offshore vs. nearshore foraging) and nitrogen (δ15N, indicates food web position) were analyzed to assess potential for competition.
- Lake trout had the most unique trophic niche, with <25% overlap with Chinook salmon, coho salmon and steelhead **(Fig. 8**) and greater reliance on offshore prey (e.g., bloater, sculpin; **Table 1**).
- *Oncorhynchus* spp. (Chinook salmon, coho salmon, and steelhead) were very similar isotopically.
- Niche overlap **(Fig. 8**) and diet mixing models **(Table 1**) suggest competition for declining pelagic prey fish (i.e., alewives and rainbow smelt) will be highest among Chinook salmon, coho salmon, steelhead, and brown trout.

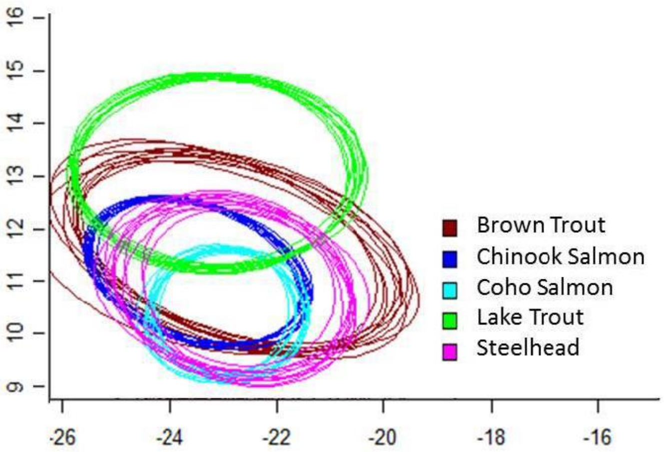


Fig. 8: Potential for competition among salmonines, based on overlap of trophic niche (ellipses).

Predator	Alewife & Rainbow Smelt	Bloater	Sculpin spp.	Round Goby	Stickleback spp.
Lake Trout	54.0	15.0	14.9	9.6	6.5
Chinook Salmon	84.9	0.8	0.5	5.6	8.2
Coho Salmon	80.1	1.2	0.7	11.7	6.3
Rainbow Trout	77.9	0.7	0.5	14.6	6.3
Brown Trout	71.6	2.8	1.9	13.3	10.4

Table 1: Percentage of fish prey in the diets of Lake Michigan salmon and trout, as estimated by stable C and N isotope Bayesian mixing models.

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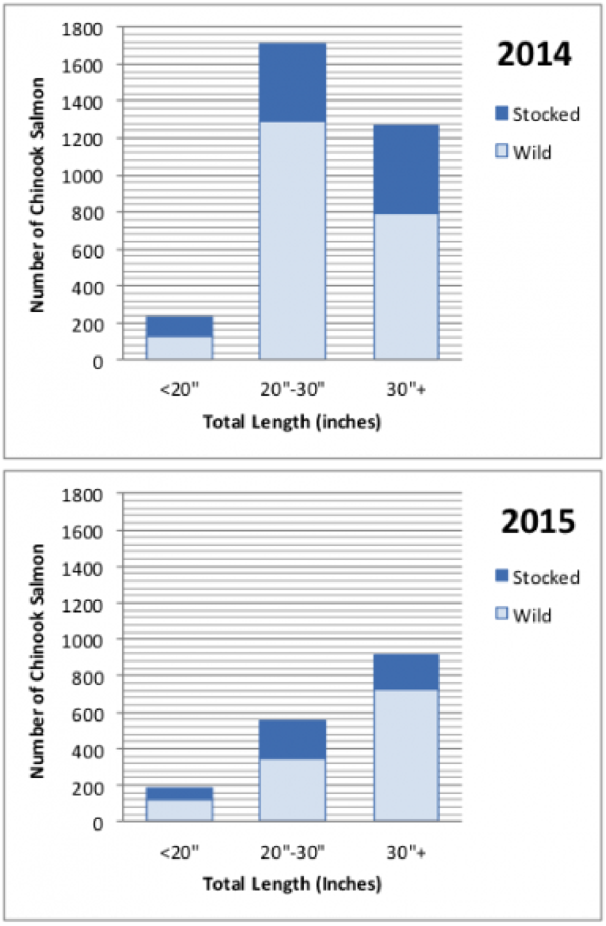
Lake Michigan Anglers Can Expect Fewer Large Chinook Salmon in 2016

Volunteers with the Salmon Ambassadors program found that medium-sized Chinook salmon were relatively scarce last year.

Great Lakes salmon anglers often assume that large Chinook salmon are “four-year-old” fish that are nearing maturity, and that the largest fish they catch are four-year-olds. In fact, most Great Lakes Chinook salmon mature and die before reaching Age 4. Fast-growing fish are particularly likely to mature earlier, so the Age 4 Chinook salmon that anglers do catch usually are not their largest fish, either.

Fig 1 - The number of mid-sized (20-30) Chinook salmon caught from Lake Michigan by Salmon Ambassadors fell from 1,707 in 2014 to 552 in 2015. This could mean large salmon will be tough to find in 2016.



Even so, the length of a salmon can provide a rough idea of the fish’s age. Growth rates vary from year to year, but in recent years the majority of Lake Michigan Chinook salmon over 30 inches long have been Age 3 fish. Chinook salmon from 20 to 30 inches long are most likely Age 2 fish, and those under 20 inches long are typically Age 1 fish. Remember that these are rough approximations, though. There is considerable overlap in length among age groups.

For anglers, the size of the fish is more important than its age anyhow. Anglers might enjoy catching big fish, but normally medium-sized fish are much more abundant in catches. This is a good thing because many small fish die before they get the chance to grow to larger sizes. Very small fish tend to be less common in angler catches — not because they are less abundant, but because anglers use baits and fishing methods that are not geared toward catching the smallest fish.

In 2014, volunteers with the Salmon Ambassadors program found what we would expect in most fisheries. Medium-sized (20- to 30-inch) Chinook salmon were more abundant than larger (and most likely older) salmon. In 2015 they found something very different. Large (30-inch and above) Chinook salmon were more prevalent in 2015 catches than smaller fish (see graph).

It may be tempting to blame this lack of small fish on the 50% stocking reduction that was implemented in 2013. Indeed, the stocking cut was designed to reduce the number of salmon in Lake Michigan and ease predation on declining bait fish (alewife). However, the biggest drop was not of stocked fish, but of wild fish.

In fact, Salmon Ambassadors data show that 53 percent of wild fish caught in 2014 were 20 to 30 inches long and this dropped to 33 percent in 2015. This reduction in medium-sized (mostly Age 2) Chinook salmon could translate to a drop in catches of large Chinook salmon for the 2016 fishing season. That is bad news for the fishery in the short term, but not necessarily in the long term. Fewer predators in the lake may give open water baitfish a chance to rebuild their populations.

The Salmon Ambassadors program is an angler science project led by Michigan Sea Grant and Michigan State U, and funded in part by Detroit Area Steelheaders. Anglers who volunteer for the program share information on wild and stocked catches with one another—and with biologists.

Volunteers track the length of each Chinook salmon caught over the course of the fishing season and look for a clipped adipose fin that indicates a stocked fish. At the end of the season, volunteers complete a short survey and return their data sheets. Results from 2015 were released in March 2016.

Michigan Sea Grant helps to foster economic growth and protect Michigan’s coastal, Great Lakes resources through education, research and outreach. A collaborative effort of the University of Michigan and Michigan State University and its MSU Extension, Michigan Sea Grant is part of the NOAA-National Sea Grant network of 33 university-based programs.

2015 Salmon Ambassadors results released

In 2014, Salmon Ambassadors found that wild fish accounted for 65-75% of the Chinook catch in Michigan waters of Lake Michigan. Results were somewhat similar in 2015, with wild Chinooks making up 72-81% of the catch in four Michigan regions of Lake Michigan:

► 72% wild in Manistee
► 81% wild in the Ludington area (including Pentwater)
► 74% wild in the Grand Haven area (Whitehall to Saugatuck)
► 72% wild in southwest Michigan (South Haven to St. Joseph)

Door Peninsula, Wisconsin, stood out in both 2014 and 2015 as the region with the highest-rated Chinook salmon fishing in July and August. The contribution of wild fish to Door County volunteer catches rose from 62% wild in 2014 to 69% in 2015. Northern Lake Huron and Southern Wisconsin had much lower contribution of wild fish (37% and 41%, respectively)

Volunteers with the program found that medium-sized Chinook salmon were relatively scarce last year. Kings in the 20-30" range last year were mostly Age 2, which means that Age 3 fish could be hard to find this year. ✧

DNR Surveys Find Lake Michigan Anglers Persevere, Diversify Catch

MILWAUKEE, Wis.– Lake Michigan anglers increased their efforts and reeled in greater numbers of native species including lake trout and walleye in 2015, even as the overall sport fish harvest declined due to lower catches of salmon and stocked trout.

Results from the Wisconsin DNR' 2015 survey of anglers on Lake Michigan bear out projections of lower overall catches dating to 2013 when surveys indicated a decline in forage fish including the alewives favored by chinook and coho salmon. In addition to stocking reductions of 30 percent instituted at that time, unusually cold weather and water temperatures this past spring likely also reduced harvest numbers for 2015, said Brad Eggold, DNR southern Lake Michigan fisheries supervisor.

"During 2015, chinook again accounted for the single largest component of the overall catch with an estimated harvest of 113,973, down from 130,698 in 2014," Eggold said. "Coho estimated catch also fell to 41,010 from 52,297 the prior year. On the flip side, lake trout catch was the highest since 2002."

The 2015 Lake Michigan creel surveys indicated that anglers caught 35,715 lake trout, up from 25,425 in 2014. Harvest estimates for walleye (99,302 in 2015, up from 96,193 in 2014) and northern pike (2,641, up from 814) also increased.

Catching fish during the 2015 season required greater effort as the harvest rate for salmonids declined to 0.099 fish per hour. Anglers collectively increased their time spent fishing by 3.4 percent to 2.7 million hours.

If judged by the total number of fish brought in, anglers who launched their own boats from ramps or marinas or invested in a charter trip were the most successful. The sport harvest from ramps and marinas totaled 346,536 fish, while charter captains helped clients bring in 91,255 fish. At a meeting of Lake Michigan charter captains and interested citizens recently held in Cleveland, Wis. Eggold said anglers will continue to find rewards from time spent on the water but may need to be flexible when considering where to fish and which species to target.

"The Lake Michigan fishery continues to change with variability in the forage base due to quagga mussels as well as low numbers of available forage in the lake," Eggold said. "Going forward, we will continue to work with stakeholders and partners in other states to monitor predator to prey ratios and balance stocking efforts with alewife numbers. We also will continue to look for opportunities to strengthen the diversity of the fishery."

DNR's annual creel survey dates to 1969 and last year captured the results from more than 12,500 angler interviews at ramps, shorelines, piers and streams in the Wisconsin waters of Lake Michigan stretching from Kenosha County to Green Bay. Each year, creel clerks interview anglers at established locations, measure fish and keep track of hours fished, numbers of boats and more. Results also include harvest estimates for guided charters from monthly reports that were initiated in 1976.

To learn more, visit DNR.wi.gov and search "Fishing Lake Michigan." Complete creel survey information can be found by searching "Lake Michigan management reports." Lake Michigan management reports." ✧

Summary of 2015 Lake Trout and Salmonid Stocking in Lake Michigan

Lakewide salmonid trends:

Chinook

Stocking reductions for Chinook salmon were initiated in 1999, 2006, and again in 2013 to reduce the predation pressure on the alewife prey base. In 2015, 1.79 million Chinook were stocked in the lake. Michigan reduced Chinook stocking in 2015 by roughly 2/3 of their 2006 – 2012 mean while other states cut stocking to a lesser degree (5 – 24%).

Brown trout

1.54 million brown trout were stocked lakewide in 2015 which was 11% higher than the previous 5 year mean; more browns were stocked in Michigan and Wisconsin waters relative to recent years.

Rainbow trout

Stocking has remained consistent over the years and 1.69 million rainbows were stocked lakewide in 2015.

Lake trout

At this time lake trout stocking is guided by an interim maximum stocking target of 2.74 (+ 10%) million equivalents until Federal hatchery production is capable of achieving higher stocking rates and the Lake Committee reaches consensus, informed by decision support tools and information, to increase stocking to the Strategy's prescribed target of 3.53 million equivalents. In 2015, stocking of 3.17 million yearling equivalents exceeded the interim target range by 5%. In 2016, fall fingerling stockings will be suspended to reduce stocking rates back to the interim target range.

Coho salmon

Lakewide 2.76 million Coho were stocked in 2015, a slight increase compared to recent years. More than twice the amount of Coho were stocked in Indiana streams compared to 2014.

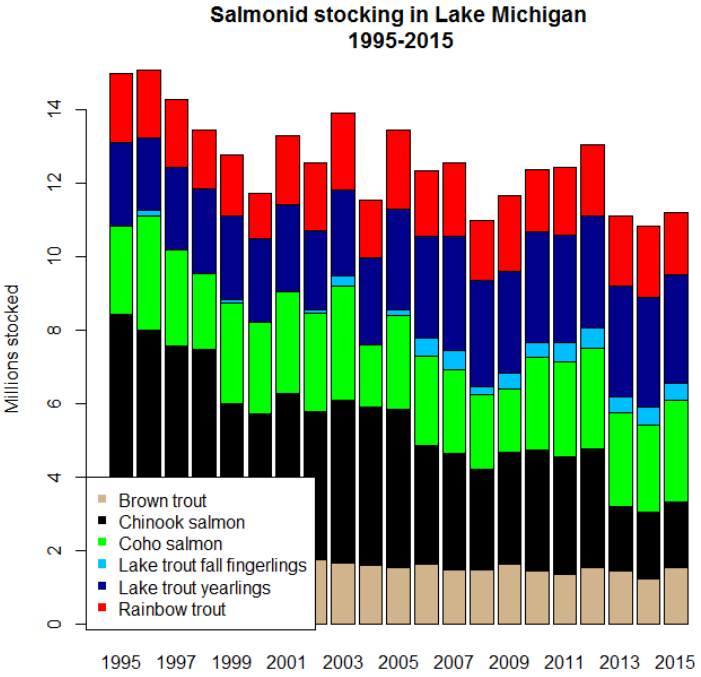
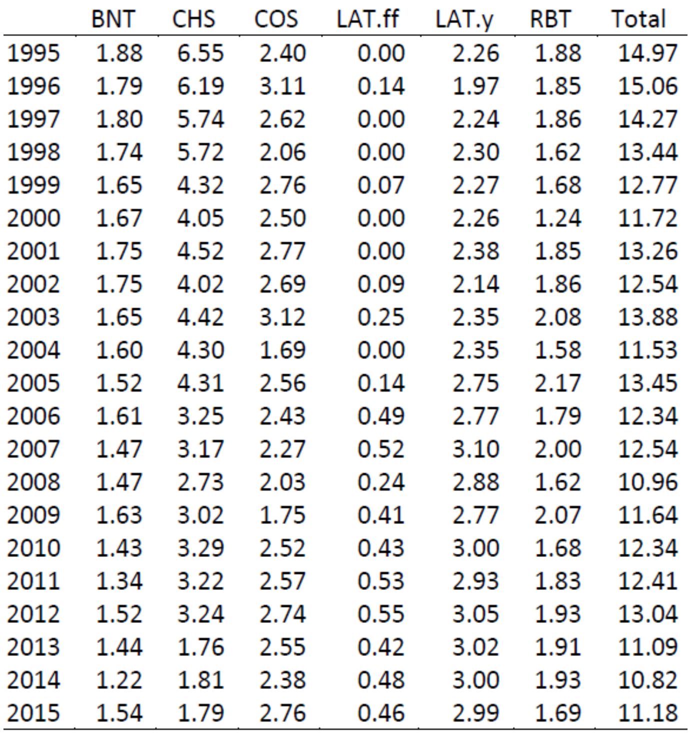


Fig 1- Trends in stocking for trout and salmon in Lake Michigan.



	BNT	CHS	COS	LAT.ff	LAT.y	RBT	Total
1995	1.88	6.55	2.40	0.00	2.26	1.88	14.97
1996	1.79	6.19	3.11	0.14	1.97	1.85	15.06
1997	1.80	5.74	2.62	0.00	2.24	1.86	14.27
1998	1.74	5.72	2.06	0.00	2.30	1.62	13.44
1999	1.65	4.32	2.76	0.07	2.27	1.68	12.77
2000	1.67	4.05	2.50	0.00	2.26	1.24	11.72
2001	1.75	4.52	2.77	0.00	2.38	1.85	13.26
2002	1.75	4.02	2.69	0.09	2.14	1.86	12.54
2003	1.65	4.42	3.12	0.25	2.35	2.08	13.88
2004	1.60	4.30	1.69	0.00	2.35	1.58	11.53
2005	1.52	4.31	2.56	0.14	2.75	2.17	13.45
2006	1.61	3.25	2.43	0.49	2.77	1.79	12.34
2007	1.47	3.17	2.27	0.52	3.10	2.00	12.54
2008	1.47	2.73	2.03	0.24	2.88	1.62	10.96
2009	1.63	3.02	1.75	0.41	2.77	2.07	11.64
2010	1.43	3.29	2.52	0.43	3.00	1.68	12.34
2011	1.34	3.22	2.57	0.53	2.93	1.83	12.41
2012	1.52	3.24	2.74	0.55	3.05	1.93	13.04
2013	1.44	1.76	2.55	0.42	3.02	1.91	11.09
2014	1.22	1.81	2.38	0.48	3.00	1.93	10.82
2015	1.54	1.79	2.76	0.46	2.99	1.69	11.18

Fig 1- Data (in millions) in stocking for trout and salmon in Lake Michigan.

Lake trout tagging and stocking locations

Per the *Implementation Strategy*, roughly 2/3 of the lake trout are stocked offshore in 1st Priority areas for rehabilitation efforts. These areas include reefs within the Northern Refuge (West Beaver, East Beaver, and Charlevoix Reef Complex groupings) and the Southern Refuge. The remaining 1/3 are stocked in 2nd Priority nearshore areas to support both recreational fisheries and rehabilitation efforts (Map 1).

Since 2010 all stocked lake trout have been marked with an adipose clip and a coded wire tag was implanted in the fish’s snout. For yearling lake trout a unique CWT code was used for each lake trout strain, and stocking location. All 1st Priority sites have distinct CWTs as do all 2nd priority sites within each statistical district. Fall fingerlings are marked with a CWT code designating whether fish were planted on either the eastern or western shore of Lake Michigan. This tagging scheme was designed to facilitate analysis of the better performing strains and stocking locations from subsequent recoveries in assessment surveys, and commercial and recreational fisheries.

In 2015, 1.47 million lake trout were stocked in the Northern 1st Priority sites and 0.74 million yearlings in the Southern Refuge 1st Priority sites. Nearshore areas (2nd Priority) received an additional 0.73 million yearlings and 0.46 million fall fingerlings. Lake trout stocking data showing locations, strains, and CWT numbers are provided in Table 2.

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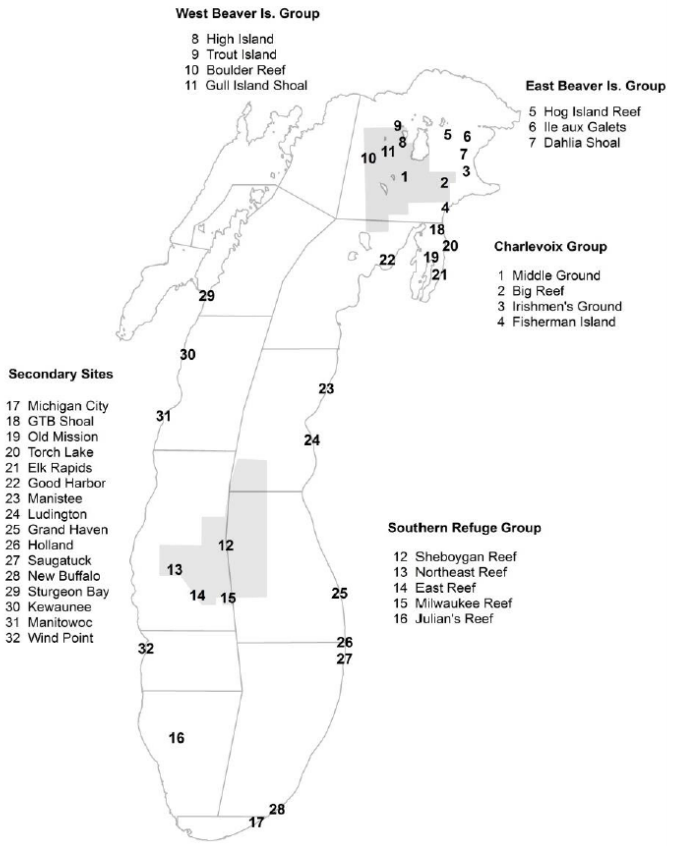


Fig 2 - First and 2nd priority areas as described in *A Fisheries Management Implementation Strategy for the Rehabilitation of Lake Trout in Lake Michigan*. Northern and Southern Refuges are indicated with shading and the gray lines subdivide the lake into statistical districts.

Status of Pelagic Prey Fishes in Lake Michigan, 2015

ABSTRACT

Acoustic surveys were conducted in late summer/early fall during the years 1992-1996 and 2001-2015 to estimate pelagic prey fish biomass in Lake Michigan. Midwater trawling during the surveys as well as target strength provided a measure of species and size composition of the fish community for use in scaling acoustic data and providing species-specific abundance estimates. The 2015 survey consisted of 27 acoustic transects (580 km total) and 31 midwater trawl tows. Four additional transects were sampled in Green Bay but were not included in lakewide estimates. Mean prey fish biomass was 4.2 kg/ha [20.3 kilotonnes (kt = 1,000 metric tons)], equivalent to 44.8 million pounds, which was 36% lower than in 2014 (31.7 kt) and 17% of the long-term (20 years) mean. The numeric density of the 2015 alewife year class was 25% of the time series average and nearly 9 times the 2014 density. This year-class contributed 8% of total alewife biomass (3.4 kg/ha). In 2015, alewife comprised 82.5% of total prey fish biomass, while rainbow smelt and bloater were <1% and 16.9% of total biomass, respectively. Rainbow smelt biomass in 2015 (0.02 kg/ha) was 74% lower than in 2014, <1% of the long-term mean, and lower than in any previous year. Bloater biomass in 2015 was 0.7 kg/ha and 8% of the long-term mean. Mean density of small bloater in 2015 (489 fish/ha) was slightly lower than peak values observed in 2008-2009 but was more than three times the time series mean (142 fish/ha).

Introduction

Alewives are the primary prey in Lake Michigan and of especial importance to introduced salmonines in the Great Lakes, however they are also predators of larval fish and are tied to thiamine deficiencies that contribute to recruitment bottlenecks in native fishes including lake trout. As such, alewives constitute an important component of the food-web. In particular, bottom trawls provide particularly biased estimates for age-0 alewives based on catchability estimates from stock assessment. Much of the alewife biomass will not be recruited to bottom trawls until age-3, but significant predation by salmonines may occur on alewives ≤ age-2.

Because of the ability of acoustic equipment to count organisms far above bottom, this type of sampling is ideal for highly pelagic fish like age-0 alewives, rainbow smelt, and bloater and is a valuable complement to bottom trawl sampling. Further, these two long-term surveys have enabled the development of a stock assessment model for alewife.

The 2015 acoustic survey of Lake Michigan was conducted by USGS, USFWS, and MDNR. The main basin sampling consisted of 28 transects **(Fig 1)** for a total transect distance of 580 km, which was similar to the sampling distance in Lake Huron in 2015.

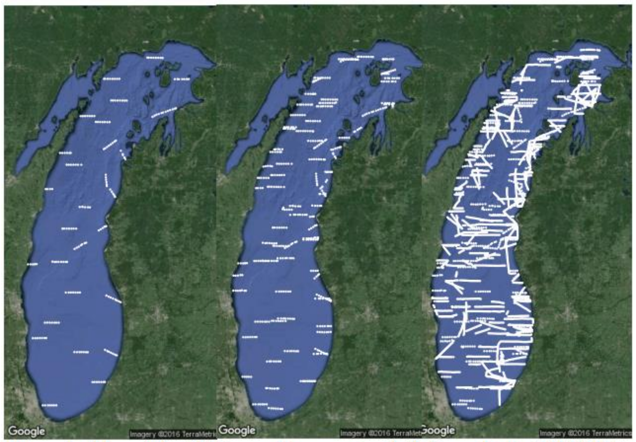


Fig 1. Map of the 2015 acoustic survey track (left panel), the 2013-2015 surveys (center panel), and the 2004-2015 acoustic survey tracks (right panel).

Alewife

The numeric density of the 2015 alewife year-class in 2015 was more than 8 times higher than the density of the 2014 year-class in 2014. At 277 fish/ha, the 2015 estimate was 25% of the long-term mean. While well below average, the numeric density of age-0 alewife in 2015 was the highest since 2012. The biomass density of age-1 or older alewife was 3.2 kg/ha **(Fig 2),** which was 32% of the long-term mean of 10 kg/ha and 32% lower than biomass density in 2014. The biomass of alewife ≥ age- 1 was predominantly the 2012 (48%), 2011 (19%), 2013 (17%), and 2010 year-classes (15%), respectively. The acoustic biomass density estimate for age-1 or older alewife (3.2 kg/ha) was nearly 23 times the bottom trawl estimate (0.14 kg/ha) in 2015 and over the time series (years in which both surveys took place), the acoustic estimates have been 5.5 times the bottom trawl estimates. Although we observed lower than average density of alewife in Lake Michigan, the density is still much higher than the density of alewife in Lake Huron, as no alewife were caught during the Lake Huron acoustic survey and only 30 caught in the Lake Huron bottom trawl survey.

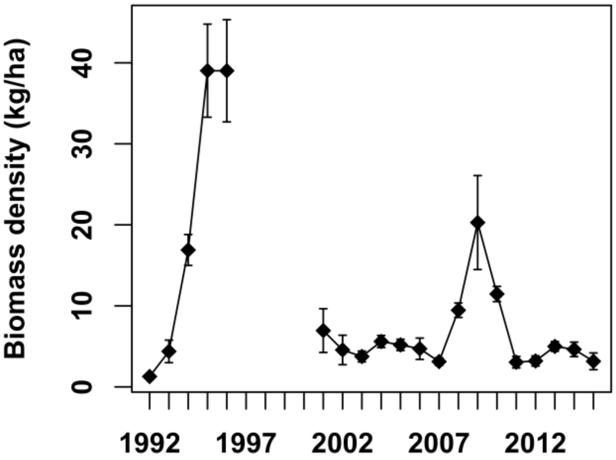


Fig 2- Biomass density of age-1 or older alewife in Lake Michigan during 1992-1996 and 2001-2016

Rainbow smelt

At 35 fish/ha, numeric density of small rainbow smelt (<90 mm) in 2015 **(Fig 3)** was the third lowest in the time series (the lowest was 2002). This density was 17% of the time series mean of 205 fish/ha. Similarly, at 0.008 kg/ha, biomass density of large rainbow smelt (≥90 mm) was the lowest in the 20 year survey time series and was <1% of the time series mean, indicating that smelt biomass remains low relative to the early years of the acoustic survey (1992-1996). Even though acoustic biomass density estimates of large smelt have always exceeded bottom trawl estimates, both surveys show there has been an order of magnitude decrease from 1992-1996 to 2001-2014. In addition to highlighting the large decline in rainbow smelt biomass in Lake Michigan, data from recent years provide strong evidence that biomass density in Lake Michigan is lower than in Lake Huron, where the 2014 acoustic estimate of large rainbow smelt biomass density was 34 times that in Lake Michigan.

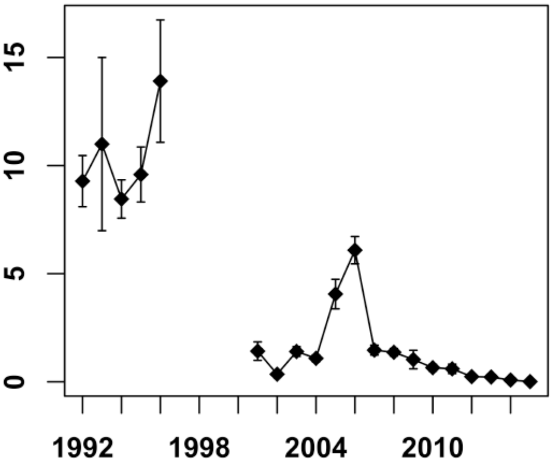


Fig 3- Biomass density of large rainbow smelt in Lake Michigan during 1992-1996 and 2001-2015.

Bloater

Densities of both small and large bloater have been≥ variable in 2001-2015. Mean numeric density of small bloater in 2015 (468 fish/ha) was 3.4 times the time series mean of 142 fish/ha (**Fig 4**). Biomass density of large bloater in 2015 was 0.7 kg/ha, which was only 34% of the 2014 value, 7% of the time series mean, and 2% of the mean in 1992-1996. Bloater biomass has been only 16% of total prey fish biomass density in 2001-2015, on average. This is in contrast to the 1992-1996 period, when bloater made up 48% of total prey fish biomass density. For much of the acoustic time series (1992- 2006), estimates of biomass density of large bloater were lower than estimates from the bottom trawl survey. From 2007-2014, acoustic estimates have been nearly five times bottom trawl estimates, on average but in 2015, the estimates were similar suggested that the continued decrease in bottom trawl biomass density of bloater might be the result of a shift in bloater bathymetric distribution to depths that are now deeper than the bottom trawl sampling. Support for this conclusion includes the fact that bloaters have shown plasticity in bottom depths occupied, with an increase from the 1930s to 2004-2007 as well as observations from commercial fishermen that the depth at which they capture bloaters has increased.

DISCUSSION

The results of the 2015 Lake Michigan acoustic survey indicate continued variability in alewife recruitment, persistently low biomass of rainbow smelt and bloater, and continued low abundance of native species. Peak alewife biomass occurred in 1995 and 1996 (≈40 kg/ha), and the two highest values during 2001-2015 were only half as high as in 1995-1996. Total prey fish biomass in 2014 was the lowest observed in the acoustic survey. Total pelagic fish biomass in Lake Michigan (4.2 kg/ha) was lower than in Lake Huron in 2014 (9.5 kg/ha) but similar to Lake Superior in 2011 (6.8 kg/ha).

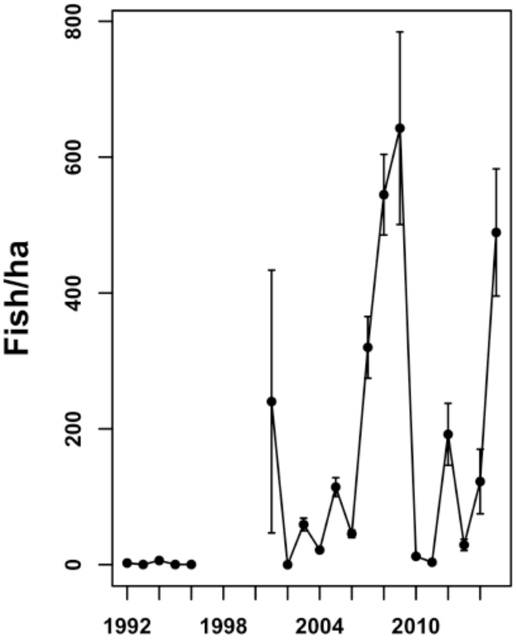


Fig 4- Biomass density of large bloater, 1992-2015 in Lake Michigan

While our highest alewife and rainbow smelt catches and catch-per-unit-effort with midwater tows generally occur near the thermocline in Lake Michigan, it is possible that some are located in the top 4 m and can't be captured with trawls because the ship displaces this water and the fish.

We are less concerned with bias in alewife and rainbow smelt densities attributable to ineffective acoustic sampling of the bottom because of their pelagic distribution at night, when our sampling occurs. In Lake Michigan, day-night bottom trawling was conducted at numerous locations and depths in 1987, with day and night tows occurring on the same day. These data indicate that night bottom trawl estimates of alewife density in August/September 1987 were only 6% of day estimates. Similarly, night bottom trawl estimates of rainbow smelt density were ≈ 6% of day estimates. However, bloaters tend to be more demersal; in Lake Superior, night acoustic/midwater trawl sampling may detect only 60% of bloater present. The day-night bottom trawl data from Lake Michigan in 1987 suggested that the availability of bloater to acoustic sampling at night was somewhat higher (mean = 76%, D. M. Warner, unpublished data). Slimy sculpins and deepwater sculpins are poorly sampled acoustically and we must rely on bottom trawl estimates for these species. We also assumed that our midwater trawling provided accurate estimates of species and size composition. Based on the relationship between trawling effort and uncertainty in species proportions observed, this assumption was likely reasonable.

We made additional assumptions about acoustic data not described above. For example, we assumed that all targets below 40 m with mean TS > -45 dB were bloater. It is possible that this resulted in a slight underestimation of rainbow smelt density. We also assumed that conditions were suitable for use of *in situ* TS to estimate fish density, which could also lead to biased results if conditions are not suitable for measuring TS and biased TS estimates are used. However, we used the Nv index to identify areas where bias was likely. We assumed that noise levels did not contribute significantly to echo integration data and did not preclude detection of key organisms. This assumption was supported by our estimates of noise. Detection limits were such that the smallest fish were detectable well below the depths they typically occupy. Finally, we have assumed that the estimates of abundance and biomass are relative and do not represent absolute measures. This assumption is supported by recent estimates of catchability derived from a multispecies age structured stock assessment model.

Prey fish biomass in Lake Michigan remains at levels much lower than in the 1990s, and the estimate of total lakewide biomass (20.4 kt) from acoustic sampling was the lowest in the time series. This is in contrast to 2008-2010, when biomass was relatively high (but still lower than in the 1990s). The recent decline, resulting primarily from decreased alewife biomass, demonstrates the dynamic nature of the pelagic fish community in Lake Michigan. The large difference between prey fish biomass in the 1990s and the 2000s resulted primarily from a decrease in large bloater abundance, but alewife and rainbow smelt declined as well. Bloater densities showed an increasing trend 2001-2009, driven primarily by increases in small bloater. A similar pattern was observed in Lake Huron, but only in Lake Huron has there been any evidence of increased abundance resulting from recruitment to larger sizes, as bottom trawl estimates of large bloater density have increased in recent years in Lake Huron but not in Lake Michigan. Alewife were the dominant component of pelagic prey fish biomass in 2015. Limited recruitment of small bloater, numerical dominance of alewife, along with the continued absence of other native species, suggests that little progress is being made toward meeting the Fish Community Objective of maintaining a diverse planktivore community, particularly relative to historical diversity.

Bloater and emerald shiner were historically important species, but bloater currently exist at low biomass levels and emerald shiner have not been captured in Lake Michigan by GLSC surveys since 1962. Similarly, kiyi are absent from offshore regions of Lake Michigan, which is in stark contrast to Lake Superior, where Yule et al. found kiyi to be the most numerous species in 2011. As a result, large areas of Lake Michigan which were formerly occupied by kiyi are now devoid of fish, and movement of energy and nutrients through diel vertical migration has essentially disappeared. In Lake Huron, collapse of the alewife population in 2003-2004 was followed by resurgence in emerald shiner abundance in 2005-2006 and by increased abundance of cisco. Given evidence from acoustic surveys from lakes Michigan and Huron, it appears that emerald shiners are suppressed by all but the lowest levels of alewife abundance.

While it is clear that abundance patterns for alewife have been driven in large part by continued high predation pressure, it is not clear what led to the drastic decline in bloater abundance from the 1980s to present. Recent stock-recruit modeling for bloater in Lakes Michigan and Huron indicated that bloater sex ratio and alewife abundance were related to recruitment. It is also possible that predation on small bloater by salmonines could be an important limit to recruitment at times as these small fish are found in the same location as alewife and at times can be important to some predators. Both Lake Michigan surveys suggest that recruitment in Lake Michigan is much more limited than in Lake Huron, where high densities of small bloater in 2007-2008 preceded increases in the abundance of larger bloater. However, the increase in biomass of large bloater in 2014 may be a sign that recruitment has improved over the past few years. ✧

Status and Trends of Prey Fish Populations in Lake Michigan, 2015

Abstract

The U.S. Geological Survey Great Lakes Science Center has conducted lake-wide surveys of the fish community in Lake Michigan each fall since 1973 using standard 12-m bottom trawls towed along contour at depths of 9 to 110 m at each of seven index transects. The resulting data on abundance, size and age structure, and condition of individual fishes are used to estimate various population parameters that are in turn used by state and tribal agencies in managing Lake Michigan fish stocks. All seven established index transects of the survey were completed in 2015. The survey provides abundance and biomass estimates between the 5-m and 114-m depth contours of the lake for prey fish populations, as well as burbot, yellow perch, and the introduced dreissenid mussels. Lake-wide biomass of alewives in 2015 was estimated at 0.5 kilotonnes (kt, 1 kt = 1000 metric tonnes), which was a record low. Age distribution of alewives remained truncated with no alewife exceeding an age of 6. Record low biomass was also recorded for slimy sculpin (0.05 kt), deepwater sculpin (0.4 kt) and ninespine stickleback (0.001 kt). Bloater biomass increased ninefold from 0.3 kt in 2014

to 2.8 kt in 2015. Round goby biomass decreased from 2.0 kt in 2014 to 0.3 kt in 2015. Rainbow smelt biomass was estimated at 0.06 kt in 2015. Burbot lake-wide biomass (0.5 kt in 2015) has remained below 3 kt since 2001. Age-0 yellow perch abundance was estimated to be 0.3 fish per ha, which is indicative of a weak year-class. Lake-wide biomass estimate of dreissenid mussels in 2015 was 2.4 kt. Overall, the total lake-wide prey fish biomass estimate (sum of alewife, bloater, rainbow smelt, deepwater sculpin, slimy sculpin, round goby, and ninespine stickleback) in 2015 was 4.0 kt, a record low. In 2015, bloater and deepwater sculpin, two native fishes, constituted over 78% of this total.

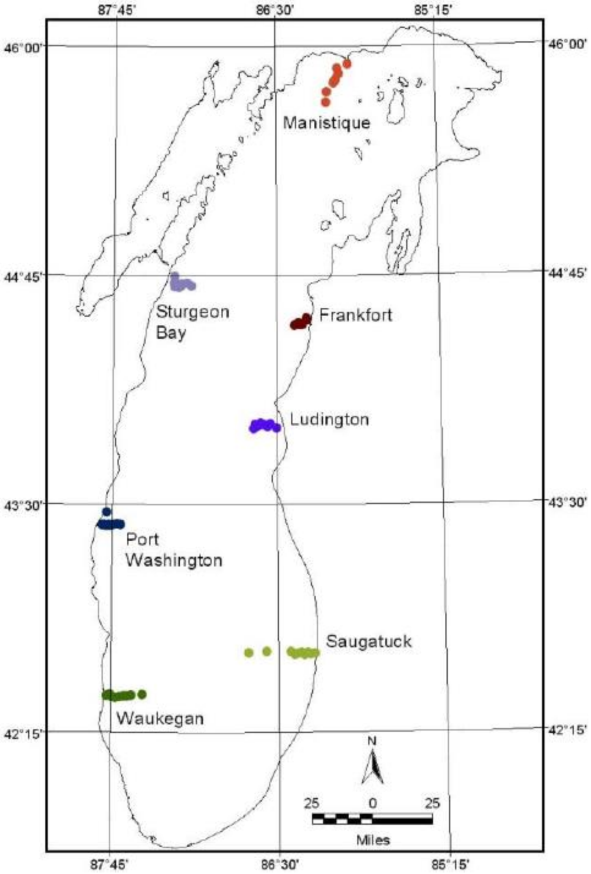


Fig 1- Sampling locations for GLSC bottom trawl

The U.S. Geological Survey Great Lakes Science Center has conducted daytime bottom trawl surveys in Lake Michigan during the fall annually since 1973. From these surveys, the relative abundance of the prey fish populations are measured, and estimates of lake-wide biomass available to the bottom trawls (for the region of the main basin between the 5-m and 114-m depth contours) can be generated. Such estimates are critical to fisheries managers making decisions on stocking and harvest rates of salmonines and allowable harvests of fish by commercial fishing operations.

Ages were estimated for alewives, using otoliths) and bloaters, using scales, from our bottom trawl catches. Our surveys are situated off Manistique, Frankfort, Ludington, and Saugatuck, Michigan; Waukegan, Illinois; and Port Washington and Sturgeon Bay, Wisconsin **(Fig 1).** All seven transects were completed in 2015.

Alewife

Since its establishment in the 1950s, the alewife has become a key member of the fish community. As a larval predator, adult alewife can depress recruitment of native fishes, including burbot, deepwater sculpin, emerald shiner, lake trout, and yellow perch. Additionally, alewife has remained the most important constituent of salmonine diet in Lake Michigan for the last 45 years. Most of the alewives consumed by salmonines in Lake Michigan are eaten by Chinook salmon. A commercial harvest was established in Wisconsin waters of Lake Michigan in the 1960s to make use of the then extremely abundant alewife that had become a nuisance and health hazard along the lakeshore. Lake Michigan currently has no commercial fishery for alewives.

According to the bottom trawl survey results, adult alewife biomass and numeric density equaled 0.14 kg per ha in *2015*, a record low (**Fig 2**).

This continued depression of adult alewife abundance likely reflects an intensified amount of predation exerted on the alewife population by salmonines since the late 1990s due to six factors: (1) a relatively high percentage of wild Chinook salmon in Lake Michigan (averaging 50% age-1 individuals between 2006-2010), (2) increased migration of Chinook salmon from Lake Huron in search of alewive, (3) increased importance of alewives in the diet of Chinook salmon in Lake Michigan between the mid-1990s and the 2000s, (4) a decrease in the energy density of adult alewives during the late 1990s, a reduction in the effects of bacterial kidney disease on Chinook salmon survival after 2003, and (6) a recent increase in lake trout abundance due to increased rates of stocking and natural reproduction. The long-term temporal trends in adult alewife biomass, as well as in alewife recruitment to age 3, in Lake Michigan are attributable to consumption of alewives by salmonines.

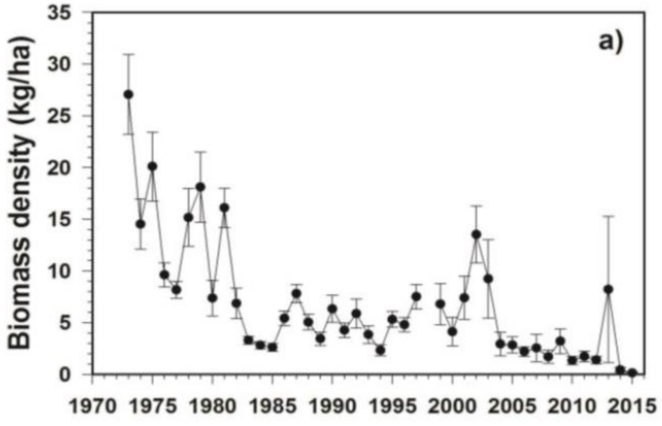


Fig 2-Density of adult alewives as biomass, 1973-2015

In 2015, 53% of the adult alewives were age-3 (2012 year-class) fish, while age-2 (2013 year-class), age-5 (2010 year-class), and age-4 (2011 year-class) fish represented 21%, 14%, and 11%, respectively, of the adult alewives (**Fig 3**). Only 1% of the adult alewives were age-6 fish, and no alewives older than age 6 were caught. Thus, the recent trend of age truncation in the alewife population continued through 2015. Prior to 2008, age-8 alewives were routinely captured.

Our results for temporal trends in adult alewife density were in general agreement with results from the lake-wide acoustic survey, which indicated that biomass of adult alewife during 2004-2015 was relatively low compared with biomass during 1994-1996. For adult alewife biomass density, the acoustic estimate exceeded the bottom trawl estimate by a factor of 2.4, on average. However, in 2015, the acoustic estimate (3.16 kg per ha) was more than 20 times greater than the bottom trawl estimate (0.14 kg per ha), although both estimates indicated low biomass of adult alewives. Bottom trawl survey results indicated a 68% decrease in adult alewife biomass density between 2014 and 2015, while acoustic survey results indicated a 32% decrease in adult alewife biomass density between 2014 and 2015.

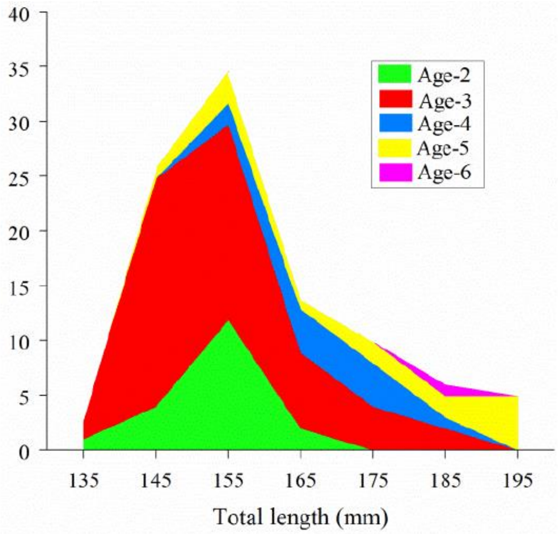


Fig 3-Age-length distribution of alewives ≥ 100 mm total length caught in bottom trawls, 2015. No alewives < 100 mm total length were captured in the bottom trawl survey during 2015.

Bloater

Bloaters are eaten by salmonines in Lake Michigan, but are far less prevalent in salmonine diets than alewives. For Chinook salmon, the importance of bloater (by wet weight) in the diets has declined between 1994-1995 and 2009-2010. The bloater population in Lake Michigan also supports a valuable commercial fishery, although its yield has generally been declining since the late 1990s. Adult bloater biomass density in our survey has been < 10 kg per ha since 1999 **(Fig 4)**. In 2015, bloater biomass equaled 0.78 kg per ha. Numeric density of age-0 bloaters (< 120 mm TL) was 1 fish per ha in 2015, suggesting continued poor bloater recruitment, aside from 2005, 2008, and 2009 when age-0 bloater abundance exceeded 25 fish per ha. The exact mechanisms underlying the relatively poor bloater recruitment since 1992 (**Fig 4**), and the low biomass of adult bloater since 2007 **(Fig 4),** remain unknown.

An important consideration when interpreting the bottom trawl survey results is that bloater catchability may have decreased in recent years, in response to the proliferation of quagga mussels and the associated increased water clarity and decreased *Diporeia* spp. densities. An hypothesis is that the bloater population remains largely within our sampling area, but bloaters (both age-0 and adult) are less vulnerable to our bottom trawls either owing to behavioral changes (more pelagic during the day) or increased ability to avoid the net while on the bottom (due to clearer water).

A comparison of the two surveys revealed that the bloater biomass estimate from the bottom trawl survey was 79% higher, on average, than that from the acoustic survey during 1992-2006. Since 2007, however, the biomass estimate for the acoustic survey was 57% higher, on average, than that for the bottom trawl survey. Nonetheless, the adult bloater biomass density estimate for the bottom trawl survey (0.78 kg per ha) exceeded that for the acoustic survey (0.60 kg per ha) in 2015. Results from both surveys indicated that age-0 bloater abundance increased between the 1992-1996 and 2005-2015 periods. However, whereas both surveys yielded similar estimates of age-0 bloater abundance during 1992-1996, acoustic survey estimates of age-0 bloater abundance averaged more than 20 times higher than those from the bottom trawl survey during 2005-2015. One plausible explanation for these inconsistent relative differences in results between the two surveys over time is that bloater catchability with the bottom trawl survey decreased sometime during the 2000s.

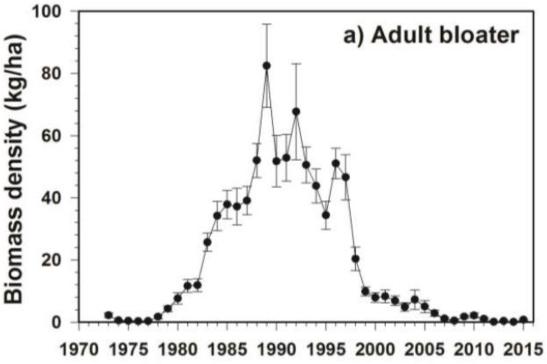


Fig 4-Biomass of adult bloater in Lake Michigan, 1973-2015

Rainbow smelt

Adult rainbow smelt have been an important part of the diet for intermediate-sized (400 to 600 mm) lake trout in the nearshore waters of Lake Michigan. For Chinook salmon, rainbow smelt comprised as much as 18% in the diets of small individuals in 1994-1996, but that dropped precipitously to 2% in 2009-2010 and rainbow smelt has been consistently rare in the diets of larger Chinook salmon since 1994. The rainbow smelt population supports commercial fisheries in Wisconsin and Michigan waters.

Adult rainbow smelt biomass density has remained at low levels since 2001, aside from a relatively high estimate in 2005 **(Fig 5).** Biomass density in 2015 equaled a record-low 0.0001 kg per ha. Age-0 rainbow smelt numeric density has been highly variable since 1999, but equaled only 23 fish per ha in 2015. Causes for the general decline in rainbow smelt biomass and production remain unclear. A recent analysis of our time series suggested that the productivity of the population has actually increased since 2000 (relative to 1982-1999), yet those recruits do not appear to be surviving to the adult population.

A comparison of the two surveys revealed that the rainbow smelt biomass estimate from the acoustic survey always exceeds that of the bottom trawl survey, on average by a factor of 5. This difference is not surprising given that rainbow smelt tend to be more pelagic than other prey species during the day. In 2015, the estimate for the acoustic survey was 84 times greater than that of the bottom trawl survey. Just as the case for the bottom trawl estimates, biomass density also reached a record low in 2015 for the acoustic estimates. The two surveys detected similar temporal trends, with adult rainbow smelt attaining biomass densities an order of magnitude higher during 1992-1996 than during 2001-2014 for both surveys.

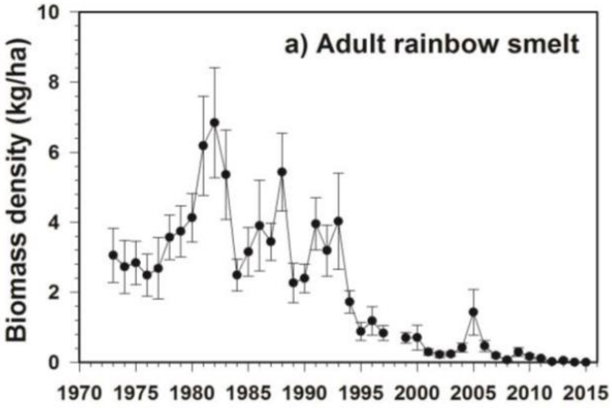


Fig 5-Density of adult smelt in Lake Michigan, 1973-2015

Sculpins

From a biomass perspective, the cottid populations in Lake Michigan have been dominated by deepwater sculpins, and to a lesser degree, slimy sculpins. Spoonhead sculpins, once fairly common, suffered declines to become rare to absent by the mid-1970s. Spoonhead sculpins were encountered in small numbers in our survey between 1990 and 1999, but have not been sampled since 1999.

Deepwater sculpin

Deepwater sculpin biomass density in 2015 was at a record-low 0.11 kg per ha **(Fig. 6a).** For every year since 2009, this biomass estimate has reached a record low. Previous analysis of the time series indicated deepwater sculpin density is negatively influenced by alewife (predation on sculpin larvae) and burbot (predation on juvenile and adult sculpin. Based on bottom trawl survey results, neither alewife nor burbot significantly increased in abundance during 2007-2015 to account for this decline in deepwater sculpins. Following no clear trend between 1990 and 2005, the biomass of deepwater sculpin sampled in the bottom trawl has declined precipitously since 2005.

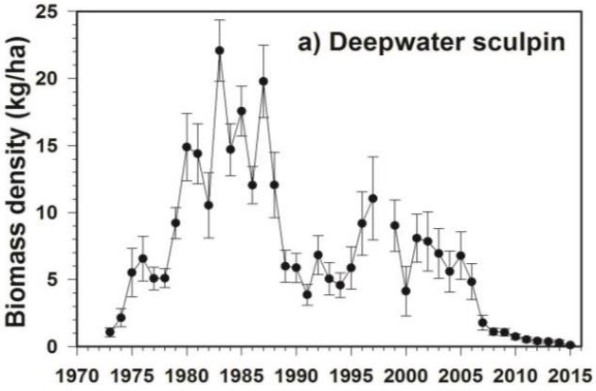


Fig 6a-Density of deepwater sculpin, 1973-2015

Slimy sculpin

Slimy sculpin is a favored prey of juvenile lake trout in nearshore regions of the lake, but is only a minor part of adult lake trout diets. When abundant, deepwater sculpin can be an important diet constituent for burbot in Lake Michigan, especially in deeper waters. Slimy sculpin biomass density has continued to decline over the past six years, reaching a record-low 0.01 kg per ha in 2015**. T**he slimy sculpin decline since 2009 coincided with a substantial increase in the rate of stocking juvenile lake trout into Lake Michigan and an increase in natural reproduction by lake trout.

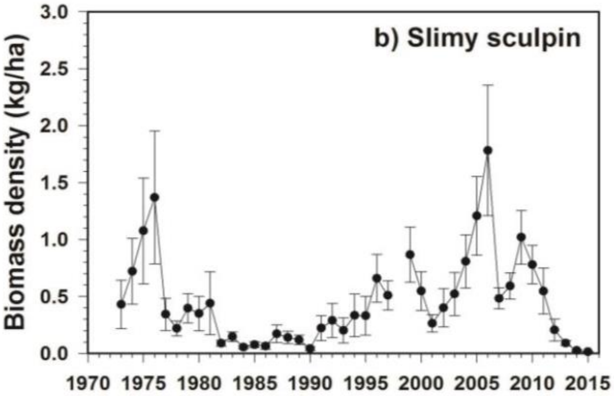


Fig 6b-Density of slimy sculpin, 1973-2015

Ninespine stickleback

Two stickleback species occur in Lake Michigan. Ninespine stickleback is native, whereas threespine stickleback is non-native and was first collected in the GLSC bottom trawl survey during 1984, but has been extremely rare in recent sampling years. Biomass density of ninespine stickleback in 2015 was only 0.2 g per ha, a record low. Since 2008, biomass has been maintained at or near record-low levels. One plausible explanation for the low ninespine stickleback abundance during 2008-2015 is that piscivores began to incorporate ninespine sticklebacks into their diets as the abundance of alewives has remained at a low level.

Round goby

The round goby is an invader from the Black and Caspian Seas. Round gobies have been observed in bays and harbors of Lake Michigan since 1993, and were captured in the southern main basin of the lake as early as 1997. By 2002, round gobies had become an integral component of yellow perch diets at nearshore sites (i.e., < 15 m depth) in southern Lake Michigan. Recent studies have revealed round gobies are an important constituent of the diets of Lake Michigan burbot, yellow perch, smallmouth bass, lake trout and even lake whitefish.

Round goby biomass density equaled 0.07 kg per ha in 2015 **(Fig 7).** Round goby abundance in Lake Michigan appears to be leveling off, or perhaps even declining, in response to control by piscivores.

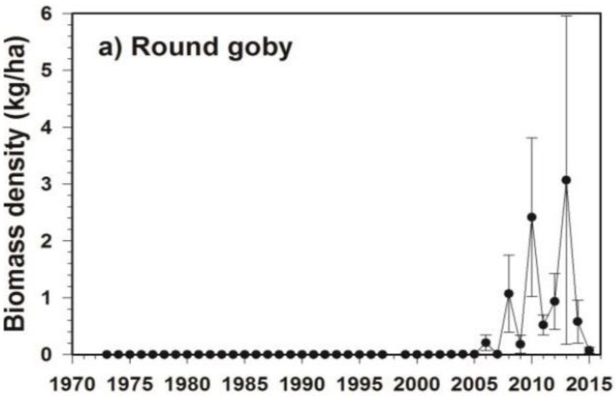


Fig 7-Density of round goby, 1973-2015

LAKE-WIDE BIOMASS

We estimated a total lake-wide biomass of prey fish available to the bottom trawl in 2015 of 4 kilotonnes (kt) (1 kt = 1000 metric tons) **(Fig 8a**). Total prey fish biomass was the sum of the population biomass estimates for alewife, bloater, rainbow smelt, deepwater sculpin, slimy sculpin, ninespine stickleback, and round goby. Total prey fish biomass in Lake Michigan has trended downward since 1989, primarily due to a dramatic decrease in bloater biomass **(Fig 8a).** Total biomass first dropped below 30 kt in 2007, and has since remained below that level with the exception of 2013 (when the biomass estimates for alewife and round goby were highly uncertain).

As **Fig 8b** depicts, the 2015 prey fish biomass was apportioned as: bloater 68.9% (2.78 kt), alewife 12.2% (0.49 kt), deepwater sculpin 9.6% (0.39 kt), round goby 6.4% (0.26 kt), rainbow smelt 1.6% (0.06 kt), slimy sculpin 1.3% (0.05 kt), and ninespine stickleback 0.02% (0.001 kt).

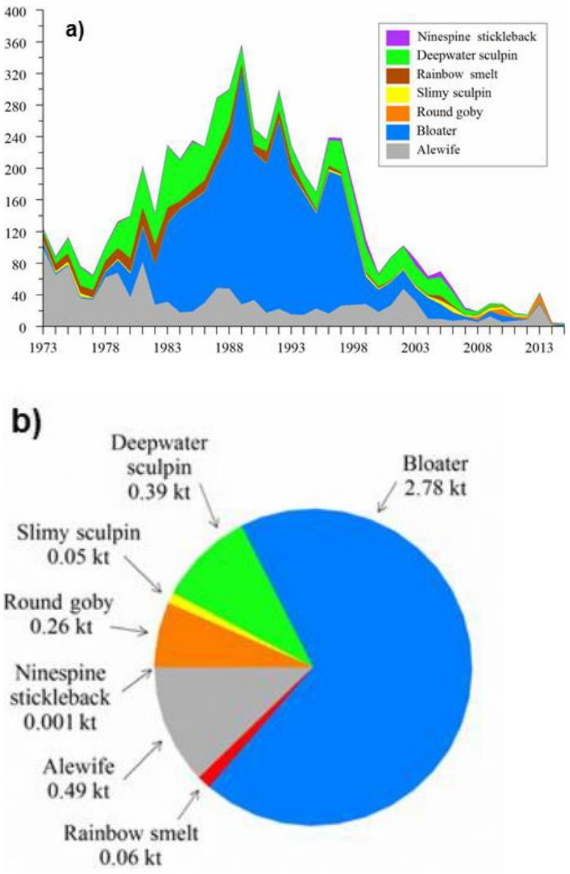


Fig 8-Lakewide (5-114 m depth region) biomass of prey fishes in Lake Michigan, 1973-2015 (a) and species composition in 2015 (b).

OTHER SPECIES OF INTEREST

Burbot

Burbot and lake trout represent the native top predators in Lake Michigan. The decline in burbot abundance in Lake Michigan during the 1950s has been attributed to sea lamprey predation. Sea lamprey control was a necessary condition for recovery of burbot in Lake Michigan, however a reduction in alewife abundance was an additional prerequisite for burbot recovery.

Age-0 yellow perch

The yellow perch population in Lake Michigan has supported valuable recreational and commercial fisheries. GLSC bottom trawl surveys provide an index of age-0 yellow perch numeric density, which serves as an indication of yellow perch recruitment success. The 2005 year-class of yellow perch was the largest ever recorded **(Fig 9**) and the 2009 and 2010 year-classes also were higher than average. In 2015, age-0 yellow perch abundance was only 0.3 fish per ha, which is indicative of a weak year-class.

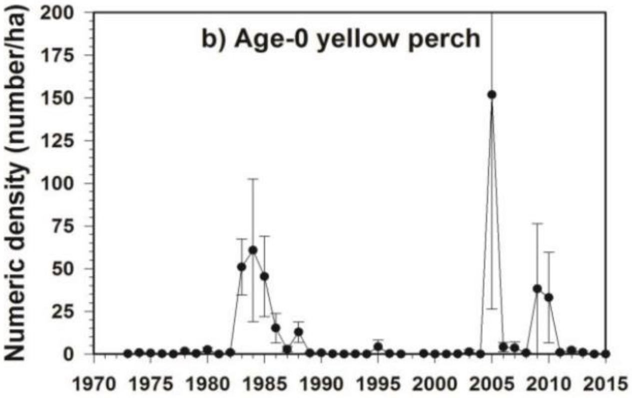


Fig 9 Numeric density of age-0 yellow perch, 1973-2015

Dreissenid mussels

The first zebra mussel noted in Lake Michigan was found in May 1988 in Indiana Harbor at Gary, Indiana. By 1990, adult mussels had been found at multiple sites in the Chicago area, and by 1992 were reported to range along the eastern and western shoreline in the southern two-thirds of the lake, as well as in Green Bay and Grand Traverse Bay. In 1999, catches of dreissenid mussels in our bottom trawls became significant and we began recording biomass for each tow. Lake Michigan dreissenid mussels include two species: the zebra mussel and the quagga mussel.

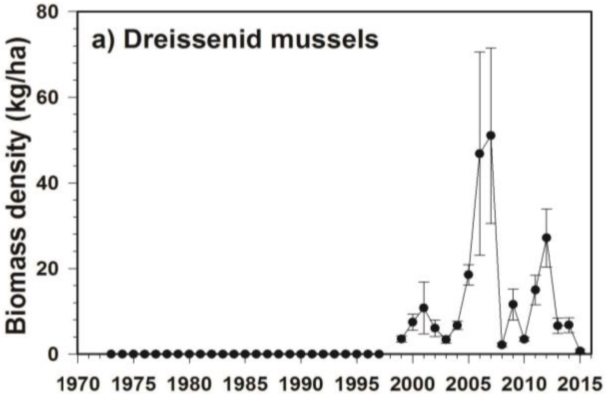


Fig 10 - Biomass density of dreissenid mussels in the bottom trawl between 1999 and 2015.

The quagga mussel is a more recent invader to Lake Michigan than the zebra mussel. According to the GLSC bottom trawl survey, biomass density of dreissenid mussels was highest in 2007 **(Fig 10),** which followed an exponential like increase between 2004 and 2006. The biomass density of dreissenid mussels in 2015 was 0.69 kg per ha, which was 90% lower than the 2014 biomass density of 6.79 kg per ha. Reasons for the drastic decline in dreissenid mussel biomass density between 2014 and 2015 were not clearly evident. Over this same period of dreissenid mussel increases, prey fish biomass was declining, which led to a dramatic increase in the percentage of dreissenids in the total bottom trawl catch. Some authors have attributed the recent decline in prey fish to food-web changes induced by the expansion of dreissenids. However, the bulk of the decline in total prey fish biomass may be better explained by factors other than food-web-induced effects by dreissenids, including poor fish recruitment, shifts in fish habitat, and increased predation on prey fish by Chinook salmon and lake trout.

A comparison of the biomass density of dreissenid mussels (0.69 kg per ha) with biomass density of all species of fish (1.37 kg per ha) caught in the bottom trawl in 2015 indicated that 33% of the daytime benthic biomass available to the bottom trawl was dreissenid mussels.

CONCLUSIONS

Total prey fish biomass estimated by the bottom trawl has revealed a record-low number every year since 2010, with the exception of 2013 when locally high catches of alewife and round goby caused a relatively high estimate (e.g., 43 kt) with high uncertainty. In 2015, total prey fish biomass was estimated to be only 4 kt. Prudently, we conclude that, based on the bottom trawl survey results, total prey fish biomass in Lake Michigan has remained at a low level since 2007.

This low level of prey fish biomass can be attributable to a suite of factors, two of which can be clearly identified: (1) a prolonged period of poor bloater recruitment since 1992 and (2) intensified predation on alewives by salmonines during the 2000s and 2010s. Adult alewife density has been maintained at a relatively low level over the last 11 years and the age distribution of the adult alewife population has become especially truncated in recent years. As recent as 2007, alewives as old as age 9 were sampled in this survey, whereas the oldest alewife sampled in 2013-2014 was age 5 and the oldest alewife sampled in 2015 was age 6.

In addition to the importance of top-down forces, prey fishes also may be negatively influenced by reduced prey resources (i.e., “bottom-up” effects). For example, several data sets are indicating a reduction in the base of the food-web- particularly for offshore total phosphorus and phytoplankton- as a consequence of long-term declines in phosphorus inputs and the proliferation of dreissenid mussels. Grazing of phytoplankton by dreissenid mussels appeared to be the primary driver of the 35% decline in primary production in offshore waters between the 1983-1987 and 2007-2011 periods. The evidence for declines in “fish food” in offshore waters of Lake Michigan is somewhat less clear. *Diporeia* has undoubtedly declined in abundance, but whether or not crustacean zooplankton and mysids have declined depends on which data set is examined. Crustacean zooplankton biomass density in nearshore waters appeared to decrease during 1998-2010, likely due to a reduction in primary production mainly stemming from grazing of phytoplankton by dreissenid mussels. The above-mentioned decline in *Diporeia* abundance appeared to have led to reductions in growth, condition, and/or energy density of lake whitefish, alewives, bloaters, and deepwater sculpins during the 1990s and 2000s. Of course, decreases in growth, condition, and energy density do not necessarily cause declines in fish abundance. The challenge remains to quantify bottom-up effects on prey fish abundances and biomasses in Lake Michigan. Given the complexities of the food web, disentangling the effects of the dreissenid mussel invasions and the reduction in nutrient loadings from other factors influencing the Lake Michigan food web will require a substantial amount of ecological detective work.

Whether or not the alewife population in Lake Michigan will undergo a complete collapse in coming years (similar to what occurred in Lake Huron) ultimately depends on the consumptive demand of the salmonines, and this estimate is based on many inputs (stocking rates, wild recruitment rates, immigration rates from Lake Huron). Lake Michigan managers reduced Chinook salmon stocking lakewide by 50% from 2012 baseline values beginning in 2013 to lower salmon consumption on alewives and try to maintain predator/prey balance. In addition, alewife sustainability will depend on the ability of the alewife spawning stock to produce another strong year-class, which will at least partially depend on appropriate environmental conditions being met. ✧

Harvest of Fishes from Lake Michigan during 2015

List of Figures associated with Lakewide Harvest

Figure 1 – Total Harvest of Fish by method from Lake Michigan, 1985 - 2015
Figure 2 – Total Harvest of Benthivore Fishes from Lake Michigan, 1985 - 2015
Figure 3 – Total Harvest of Salmonine Fishes from Lake Michigan, 1985 - 2015
Figure 4 – Total Harvest of Inshore Fishes from Lake Michigan, 1985 - 2015
Figure 5 – Total Harvest of selected Commercially Valuable Fish Species from Lake Michigan, 1985 - 2015

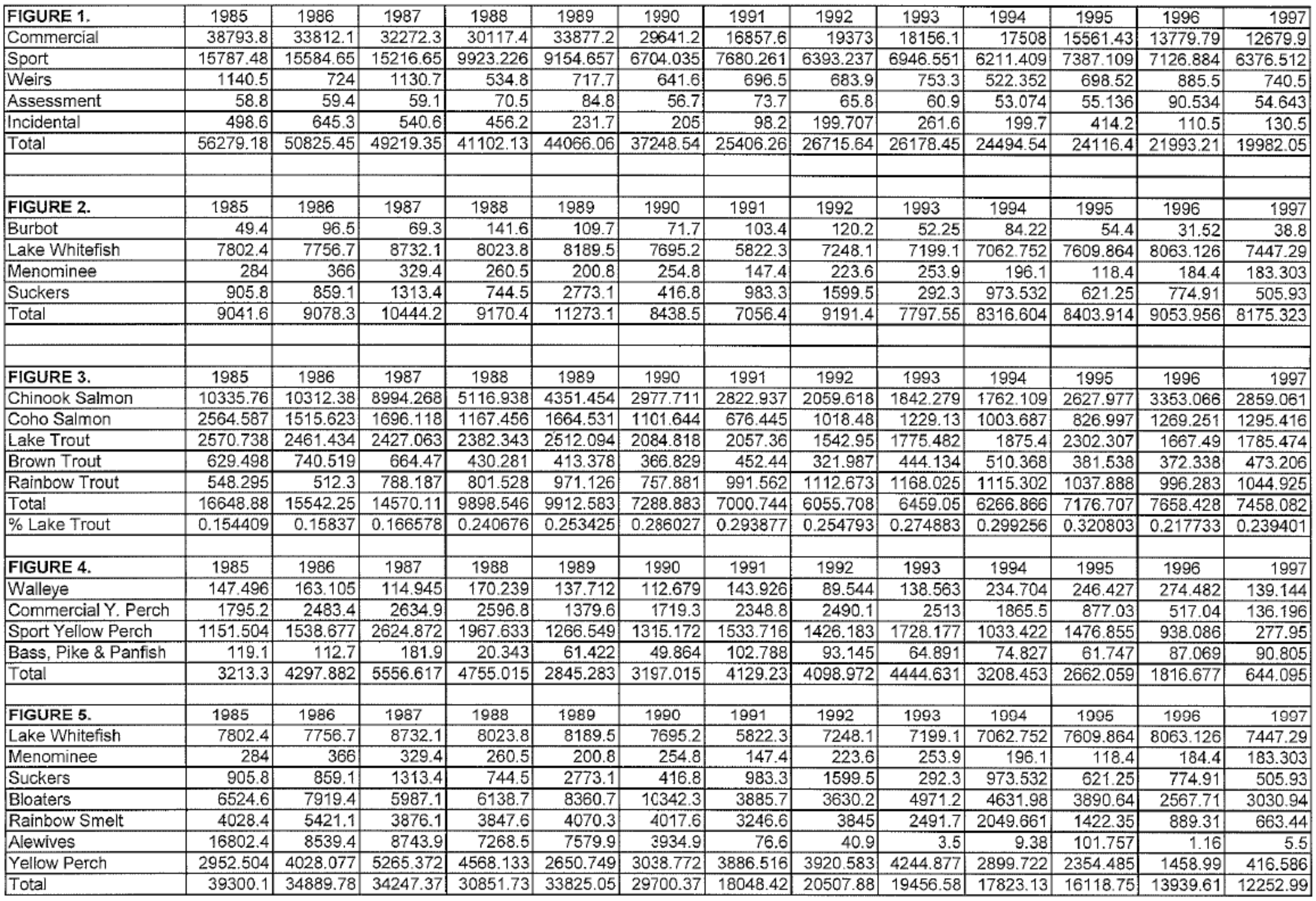


FIGURE 1.	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Commercial	38793.8	33812.1	32272.3	30117.4	33877.2	29641.2	16857.6	19373	18156.1	17508	15561.43	13779.79	12679.9
Sport	15787.48	15584.65	15216.65	9923.226	9154.657	6704.035	7680.261	6393.237	6946.551	6211.409	7387.109	7126.884	6376.512
Weirs	1140.5	724	1130.7	534.8	717.7	641.6	696.5	683.9	753.3	522.352	698.52	885.5	740.5
Assessment	58.8	59.4	59.1	70.5	84.8	56.7	73.7	65.8	60.9	53.074	55.136	90.534	54.643
Incidental	498.6	645.3	540.6	456.2	231.7	205	98.2	199.707	261.6	199.7	414.2	110.5	130.5
Total	56279.18	50825.45	49219.35	41102.13	44066.06	37248.54	25406.26	26715.64	26178.45	24494.54	24116.4	21993.21	19982.05
FIGURE 2.	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Burbot	49.4	96.5	69.3	141.6	109.7	71.7	103.4	120.2	52.25	84.22	54.4	31.52	38.8
Lake Whitefish	7802.4	7756.7	8732.1	8023.8	8189.5	7695.2	5822.3	7248.1	7199.1	7062.752	7609.864	8063.126	7447.29
Menominee	284	366	329.4	260.5	200.8	254.8	147.4	223.6	253.9	196.1	118.4	184.4	183.303
Suckers	905.8	859.1	1313.4	744.5	2773.1	416.8	983.3	1599.5	292.3	973.532	621.25	774.91	505.93
Total	9041.6	9078.3	10444.2	9170.4	11273.1	8438.5	7056.4	9191.4	7797.55	8316.604	8403.914	9053.956	8175.323
FIGURE 3.	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Chinook Salmon	10335.76	10312.38	8994.268	5116.938	4351.454	2977.711	2822.937	2059.618	1842.279	1762.109	2627.977	3353.066	2859.061
Coho Salmon	2564.587	1515.623	1696.118	1167.456	1664.531	1101.644	676.445	1018.48	1229.13	1003.687	826.997	1269.251	1295.416
Lake Trout	2570.738	2461.434	2427.063	2382.343	2512.094	2084.818	2057.36	1542.95	1775.482	1875.4	2302.307	1667.49	1785.474
Brown Trout	629.498	740.519	664.47	430.281	413.378	366.829	452.44	321.987	444.134	510.368	381.538	372.338	473.206
Rainbow Trout	548.295	512.3	788.187	801.528	971.126	757.881	991.562	1112.673	1168.025	1115.302	1037.888	996.283	1044.925
Total	16648.88	15542.25	14570.11	9898.546	9912.583	7288.883	7000.744	6055.708	6459.05	6266.866	7176.707	7658.428	7458.082
% Lake Trout	0.154409	0.15837	0.166578	0.240676	0.253425	0.286027	0.293877	0.254793	0.274883	0.299256	0.320803	0.217733	0.239401
FIGURE 4.	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Walleye	147.496	163.105	114.945	170.239	137.712	112.679	143.926	89.544	138.563	234.704	246.427	274.482	139.144
Commercial Y. Perch	1795.2	2483.4	2634.9	2596.8	1379.6	1719.3	2348.8	2490.1	2513	1865.5	877.03	517.04	136.196
Sport Yellow Perch	1151.504	1538.677	2624.872	1967.633	1266.549	1315.172	1533.716	1426.183	1728.177	1033.422	1476.855	938.086	277.95
Bass, Pike & Panfish	119.1	112.7	181.9	20.343	61.422	49.864	102.788	93.145	64.891	74.827	61.747	87.069	90.805
Total	3213.3	4297.882	5556.617	4755.015	2845.283	3197.015	4129.23	4098.972	4444.631	3208.453	2662.059	1816.677	644.095
FIGURE 5.	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Lake Whitefish	7802.4	7756.7	8732.1	8023.8	8189.5	7695.2	5822.3	7248.1	7199.1	7062.752	7609.864	8063.126	7447.29
Menominee	284	366	329.4	260.5	200.8	254.8	147.4	223.6	253.9	196.1	118.4	184.4	183.303
Suckers	905.8	859.1	1313.4	744.5	2773.1	416.8	983.3	1599.5	292.3	973.532	621.25	774.91	505.93
Bloaters	6524.6	7919.4	5987.1	6138.7	8360.7	10342.3	3885.7	3630.2	4971.2	4631.98	3890.64	2567.71	3030.94
Rainbow Smelt	4028.4	5421.1	3876.1	3847.6	4070.3	4017.6	3246.6	3845	2491.7	2049.661	1422.35	889.31	663.44
Alewives	16802.4	8539.4	8743.9	7268.5	7579.9	3934.9	76.6	40.9	3.5	9.38	101.757	1.16	5.5
Yellow Perch	2952.504	4028.077	5265.372	4568.133	2650.749	3038.772	3886.516	3920.583	4244.877	2899.722	2354.485	1458.99	416.586
Total	39300.1	34889.78	34247.37	30851.73	33825.05	29700.37	18048.42	20507.88	19456.58	17823.13	16118.75	13939.61	12252.99

FIGURE 1.	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Commercial	12641.45	11256.38	7333.937	6893.822	6583.917	6164.763	6111.18	6735.312	7180.809	5943.786	7955.726	6603.572	6572.605
Sport	7095.2	7746.965	8143.368	8515.9	10739.96	9204.677	10941.46	10061.5	10990.32	10832.7	7348.65	7560.966	7006.4
Weirs	515.268	840.701	1124	1100.048	1210.463	688.937	746.908	442.572	603.323	518.467	314.06	386.1	225.63
Assessment	29.4646	39.884	34.856	38.8249	34.981	33.612	35.6	34.701	41.358	32.963	30.017	30.704	38.535
Incidental	178.94	229.7	231.445	192.42	129	133.6	130	175.4	0	104.2	32.37	0	0
Total	20460.32	20113.63	16867.61	16741.01	18698.32	16225.59	17965.14	17449.49	18815.81	17432.12	15680.82	14581.34	13843.17

FIGURE 2.	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Burbot	47.893	33.601	15.046	18.674	13.645	20.875	11.728	14.682	31.283	11.533	11.887	12.811	12.541
Lake Whitefish	7205.642	6793.035	4816.243	4745.976	3882.623	3909.841	4022.944	4215.897	5037.782	4660.22	6575.914	5945.74	5686.741
Menominee	135.347	85.75	27.154	12.515	8.651	6.715	21.093	12.702	1.36	2.21	7.654	9.286	6.881
Suckers	514.9876	47.899	8.962	17.711	7.111	125.931	3.481	29.414	6.769	4.574	4.209	2.681	6.239
Total	7903.87	6960.285	4867.405	4794.876	3912.03	4063.362	4059.246	4272.695	5077.194	4678.537	6599.664	5970.518	5712.402

FIGURE 3.	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Chinook Salmon	3038.005	4008.256	4473.565	5252.121	7359.653	6886.199	9186.923	8273.101	9142.229	8367.931	5622.706	5192.508	4921.566
Coho Salmon	895.077	1582.163	2155.828	1509.109	1835.275	1012.308	952.387	423.76	595.326	985.842	466.296	784.87	570.662
Lake Trout	2666.321	1987.835	1518.253	1436.249	1010.683	633.752	523.389	533.263	447.684	581.214	990.346	771.485	800.803
Brown Trout	317.836	407.701	513.562	330.12	392.858	222.207	183.797	260.806	158.108	231.861	176.22	146.06	155.39
Rainbow Trout	1353.609	1161.788	928.576	1167.748	1173.176	711.085	456.905	679.921	561.825	656.847	420.75	596.31	515.75
Total	8270.848	9147.743	9589.784	9695.347	11771.65	9465.551	11303.4	10170.85	10905.17	10823.7	7676.318	7491.233	6964.171
% Lake Trout	0.322376	0.217303	0.15832	0.148138	0.085857	0.066954	0.046304	0.052431	0.041052	0.053698	0.129013	0.102985	0.114989

FIGURE 4.	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Walleye	121.649	125.465	158.091	152.546	181.167	162.272	164.94	101.064	111.14	257.115	286.646	311.946	188.319
Commercial Y. Perch	211.052	176.65	57.98	38.99	19.99	19.349	17.981	23.575	90.695	65.296	69.109	62.276	75.994
Sport Yellow Perch	270.54	492.937	375.741	415.375	399.814	503.87	492.97	563.92	708.86	478.981	424.29	408.51	376.47
Bass, Pike & Panfish	65.145	48.045	41.208	44.768	56.235	92.779	65.668	56.05	67.582	92.67	61.24	35.92	42.49
Total	668.386	843.097	633.02	651.679	657.206	778.27	741.559	744.609	978.277	894.062	841.285	818.652	683.273

FIGURE 5.	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Lake Whitefish	7205.642	6793.035	4816.243	4745.976	3882.623	3909.841	4022.944	4215.897	5037.782	4660.22	6575.914	5945.74	5686.741
Menominee	135.347	85.75	27.154	12.515	8.651	6.715	21.093	12.702	1.36	2.21	7.654	9.286	6.881
Suckers	514.9876	47.899	8.962	17.711	7.111	125.931	3.481	29.414	6.769	4.574	4.209	2.681	6.239
Bloaters	2817.428	1792.945	1335.534	1226.781	1701.834	1626.466	1385.654	1531.916	986.635	583.809	304.347	246.756	137.779
Rainbow Smelt	701.48	1336.399	387.918	251.244	452.632	184.766	408.929	676.416	836.38	428.76	179.28	44.745	325.034
Alewives	92.903	16.857	48.904	109.097	200.129	97.6	63.81	44.262	28.774	20.321	62.489	6.487	17.356
Yellow Perch	484.249	680.803	437.909	460.711	421.802	526.103	513.301	591.831	802.854	546.654	495.391	472.712	454.202
Total	11952.04	10753.69	7062.624	6824.035	6674.782	6477.422	6419.212	7102.438	7700.554	6246.548	7629.284	6728.407	6634.232

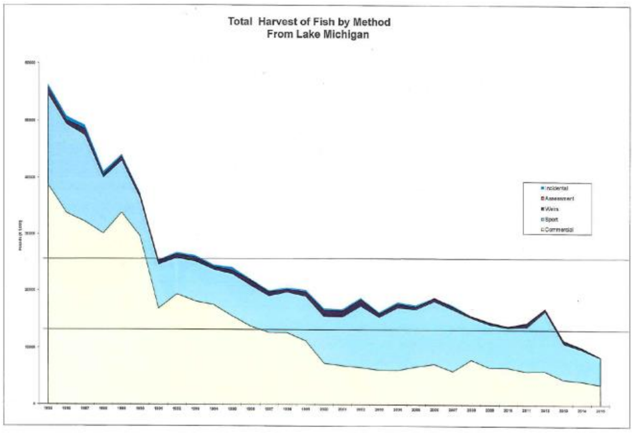
FIGURE 1.	2011	2012	2013	2014	2015
Commercial	5907.782	5970.909	4507.774	4202.217	3619.136
Sport	7788.191	10530.17	6391.274	5609.4	4791.533
Weirs	711.898	437.589	514.826	314.13	68.608
Assessment	38.5699	34.633	38.034	33.2601	44.5023
Incidental	0	0	0	0	0
Total	14446.44	16973.3	11451.91	10159.01	8523.779

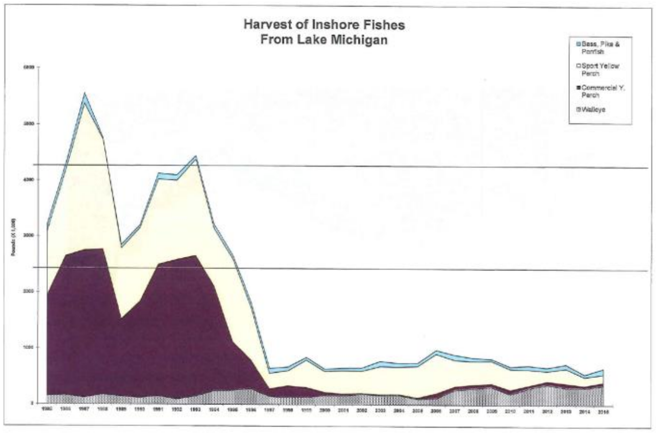
FIGURE 2.	2011	2012	2013	2014	2015
Burbot	19.054	13.131	10.59	9.075	10.193
Lake Whitefish	5282.207	5367.268	3890.744	3594.493	3266.397
Menominee	11.088	4.809	2.704	4.161	5.276
Suckers	3.321	3.738	8.6294	15.1144	18.165
Total	5315.67	5388.946	3912.667	3622.843	3300.031

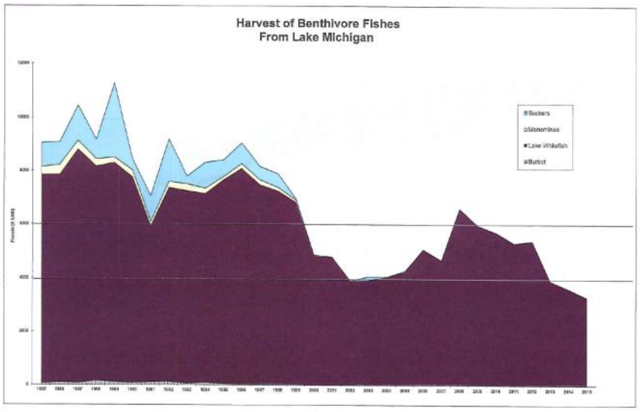
FIGURE 3.	2011	2012	2013	2014	2015
Chinook Salmon	4835.711	7818.958	3525.012	2954.228	2037.296
Coho Salmon	1405.332	925.7438	1220.322	530.56	441.1993
Lake Trout	972.607	1006.715	1231.361	1372.295	1284.935
Brown Trout	77.0645	143.001	147.055	194.745	146.296
Rainbow Trout	814.08	921.736	645.482	901.17	574.917
Total	8104.795	10816.15	6769.232	5952.998	4484.643
% Lake Trout	0.120004	0.093075	0.181906	0.230522	0.286519

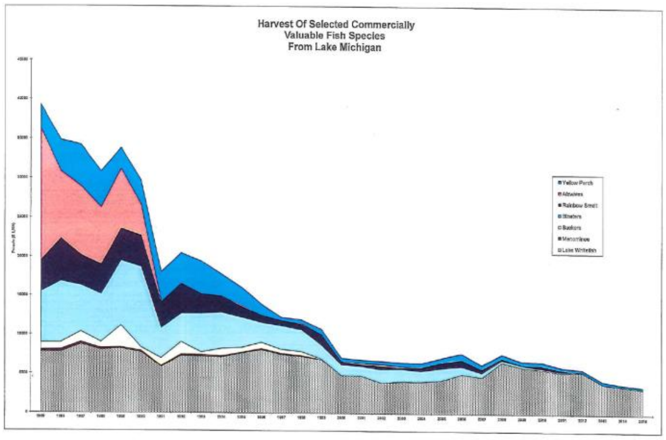
FIGURE 4.	2011	2012	2013	2014	2015
Walleye	291.279	359.151	302.12	293.0571	345.128
Commercial Y. Perch	50.789	59.672	77.484	46.884	54.853
Sport Yellow Perch	291.486	184.629	270.35	157.84	148.126
Bass, Pike & Panfish	69.33	64.348	75.742	45.6	104.15
Total	702.884	667.8	725.696	543.3811	652.257

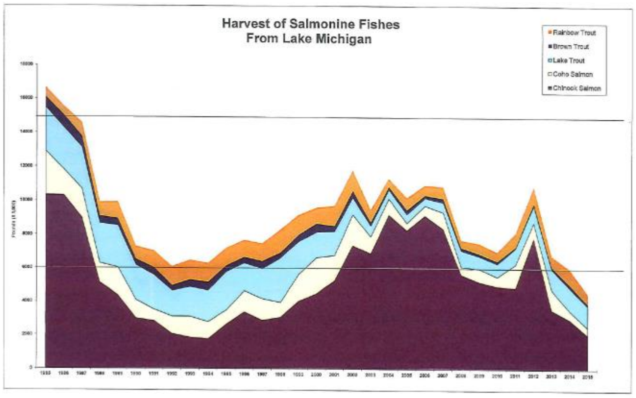
FIGURE 5.	2011	2012	2013	2014	2015
Lake Whitefish	5282.207	5367.268	3890.744	3594.493	3266.397
Menominee	11.088	4.809	2.704	4.161	5.276
Suckers	3.321	3.738	8.6294	15.1144	18.165
Bloaters	48.358	24.291	19.535	33.317	71.753
Rainbow Smelt	270.524	32.004	1.947	0.013	0.515
Alewives	0.996	42.565	5.948	0.37	7.572
Yellow Perch	343.019	245.149	348.728	205.376	203.504
Total	5959.513	5719.824	4278.235	3852.844	3573.182


Total Harvest of Fish by Method
From Lake Michigan
Incidental
Assessment
Weirs
Sport
Commercial

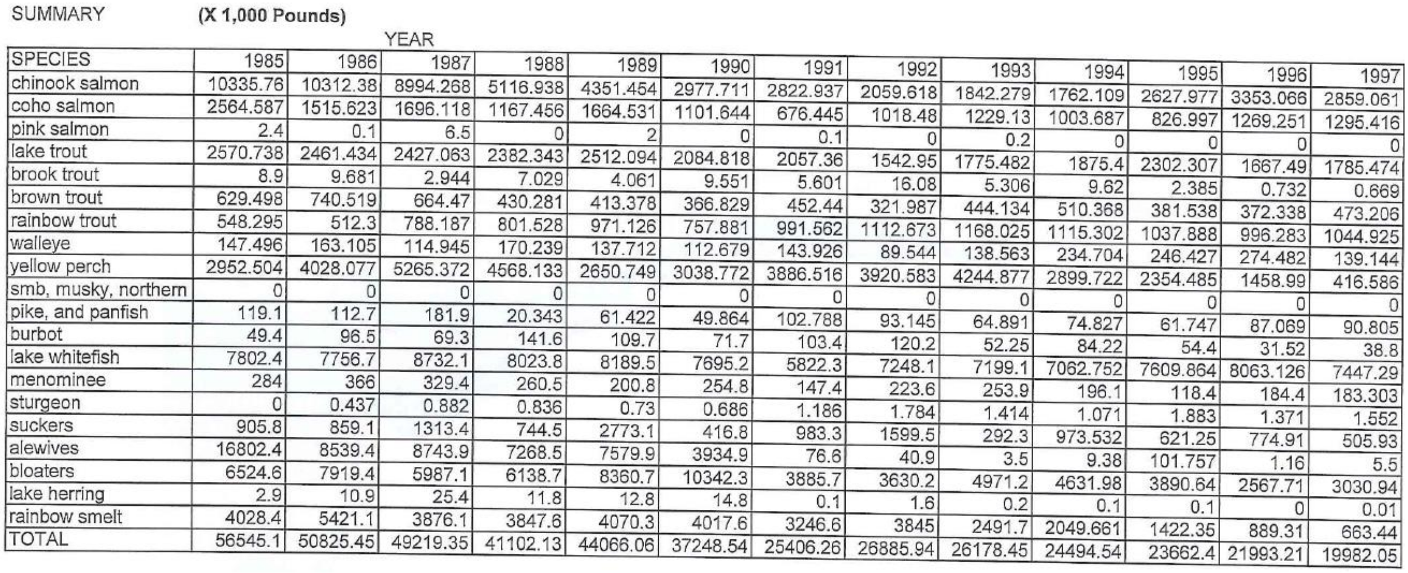

Harvest of Inshore Fishes
From Lake Michigan
Bass, Pike & Panfish
Sport Yellow Perch
Commercial Y. Perch
Walleye


Harvest of Benthivore Fishes
From Lake Michigan
Suckers
Menominee
Lake Whitefish
Burbot


Harvest Of Selected Commercially
Valuable Fish Species
From Lake Michigan
Yellow Perch
Alewives
Rainbow Smelt
Bloaters
Suckers
Menominee
Lake Whitefish


Harvest of Salmonine Fishes
From Lake Michigan
Rainbow Trout
Brown Trout
Lake Trout
Coho Salmon
Chinook Salmon

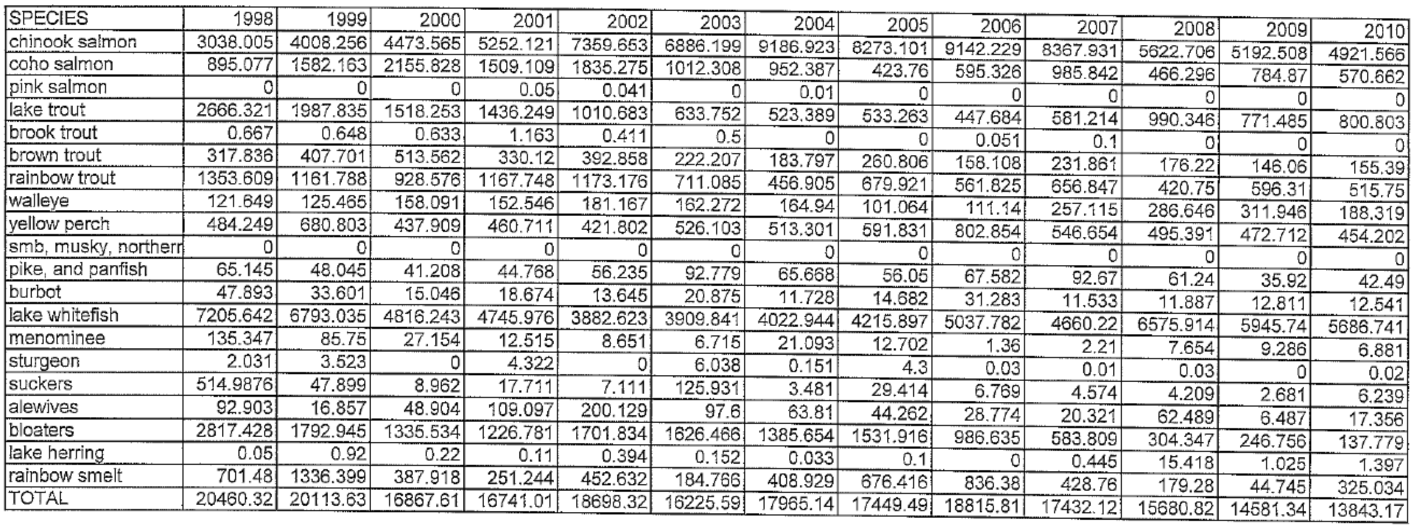
Summary of Lakewide Harvest for all agencies in pounds (including commercial, sport, Weir, assessment and incidental catch).



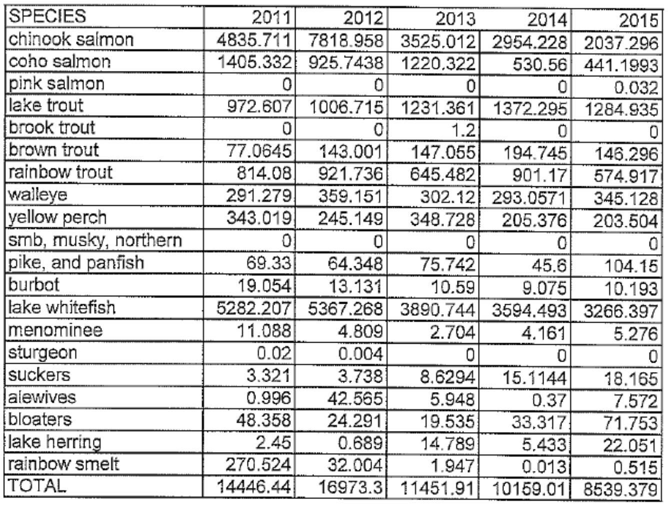
SUMMARY (X 1,000 Pounds)

YEAR

SPECIES	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
chinook salmon	10335.76	10312.38	8994.268	5116.938	4351.454	2977.711	2822.937	2059.618	1842.279	1762.109	2627.977	3353.066	2859.061
coho salmon	2564.587	1515.623	1696.118	1167.456	1664.531	1101.644	676.445	1018.48	1229.13	1003.687	826.997	1269.251	1295.416
pink salmon	2.4	0.1	6.5	0	2	0	0.1	0	0.2	0	0	0	0
lake trout	2570.738	2461.434	2427.063	2382.343	2512.094	2084.818	2057.36	1542.95	1775.482	1875.4	2302.307	1667.49	1785.474
brook trout	8.9	9.681	2.944	7.029	4.061	9.551	5.601	16.08	5.306	9.62	2.385	0.732	0.669
brown trout	629.498	740.519	664.47	430.281	413.378	366.829	452.44	321.987	444.134	510.368	381.538	372.338	473.206
rainbow trout	548.295	512.3	788.187	801.528	971.126	757.881	991.562	1112.673	1168.025	1115.302	1037.888	996.283	1044.925
walleye	147.496	163.105	114.945	170.239	137.712	112.679	143.926	89.544	138.563	234.704	246.427	274.482	139.144
yellow perch	2952.504	4028.077	5265.372	4568.133	2650.749	3038.772	3886.516	3920.583	4244.877	2899.722	2354.485	1458.99	416.586
smb, musky, northern	0	0	0	0	0	0	0	0	0	0	0	0	0
pike, and panfish	119.1	112.7	181.9	20.343	61.422	49.864	102.788	93.145	64.891	74.827	61.747	87.069	90.805
burbot	49.4	96.5	69.3	141.6	109.7	71.7	103.4	120.2	52.25	84.22	54.4	31.52	38.8
lake whitefish	7802.4	7756.7	8732.1	8023.8	8189.5	7695.2	5822.3	7248.1	7199.1	7062.752	7609.864	8063.126	7447.29
menominee	284	366	329.4	260.5	200.8	254.8	147.4	223.6	253.9	196.1	118.4	184.4	183.303
sturgeon	0	0.437	0.882	0.836	0.73	0.686	1.186	1.784	1.414	1.071	1.883	1.371	1.552
suckers	905.8	859.1	1313.4	744.5	2773.1	416.8	983.3	1599.5	292.3	973.532	621.25	774.91	505.93
alewives	16802.4	8539.4	8743.9	7268.5	7579.9	3934.9	76.6	40.9	3.5	9.38	101.757	1.16	5.5
bloaters	6524.6	7919.4	5987.1	6138.7	8360.7	10342.3	3885.7	3630.2	4971.2	4631.98	3890.64	2567.71	3030.94
lake herring	2.9	10.9	25.4	11.8	12.8	14.8	0.1	1.6	0.2	0.1	0.1	0	0.01
rainbow smelt	4028.4	5421.1	3876.1	3847.6	4070.3	4017.6	3246.6	3845	2491.7	2049.661	1422.35	889.31	663.44
TOTAL	56545.1	50825.45	49219.35	41102.13	44066.06	37248.54	25406.26	26885.94	26178.45	24494.54	23662.4	21993.21	19982.05

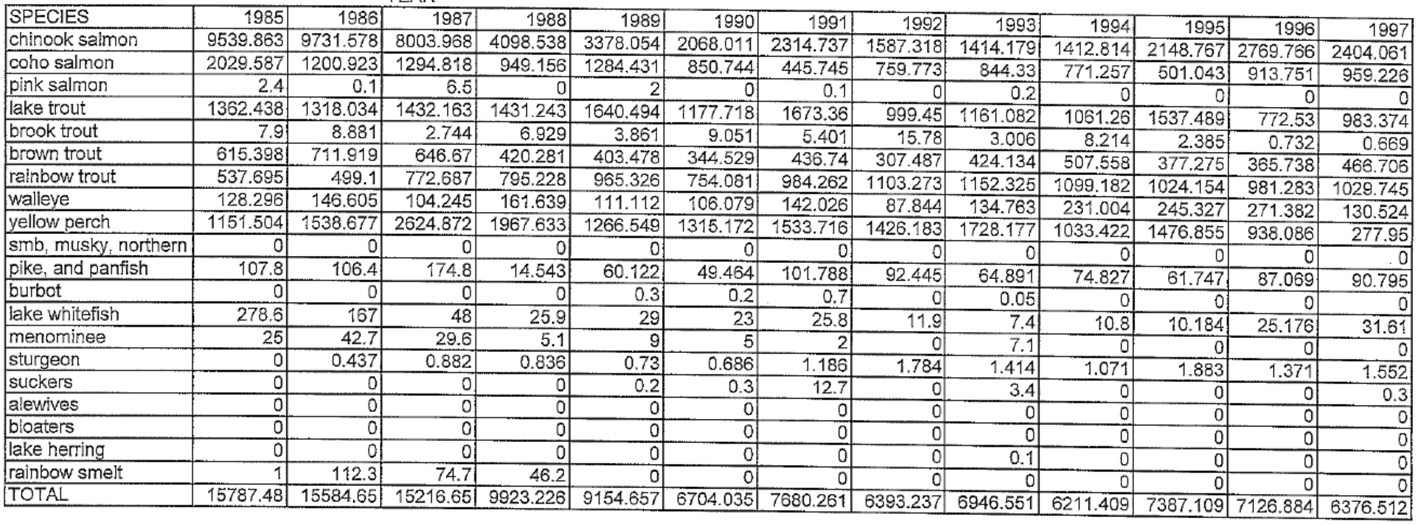


SPECIES	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
chinook salmon	3038.005	4008.256	4473.565	5252.121	7359.653	6886.199	9186.923	8273.101	9142.229	8367.931	5622.706	5192.508	4921.566
coho salmon	895.077	1582.163	2155.828	1509.109	1835.275	1012.308	952.387	423.76	595.326	985.842	466.296	784.87	570.662
pink salmon	0	0	0	0.05	0.041	0	0.01	0	0	0	0	0	0
lake trout	2666.321	1987.835	1518.253	1436.249	1010.683	633.752	523.389	533.263	447.684	581.214	990.346	771.485	800.803
brook trout	0.667	0.648	0.633	1.163	0.411	0.5	0	0	0.051	0.1	0	0	0
brown trout	317.836	407.701	513.562	330.12	392.858	222.207	183.797	260.806	158.108	231.861	176.22	146.06	155.39
rainbow trout	1353.609	1161.788	928.576	1167.748	1173.176	711.085	456.905	679.921	561.825	656.847	420.75	596.31	515.75
walleye	121.649	125.465	158.091	152.546	181.167	162.272	164.94	101.064	111.14	257.115	286.646	311.946	188.319
yellow perch	484.249	680.803	437.909	460.711	421.802	526.103	513.301	591.831	802.854	546.654	495.391	472.712	454.202
smb, musky, northerr	0	0	0	0	0	0	0	0	0	0	0	0	0
pike, and panfish	65.145	48.045	41.208	44.768	56.235	92.779	65.668	56.05	67.582	92.67	61.24	35.92	42.49
burbot	47.893	33.601	15.046	18.674	13.645	20.875	11.728	14.682	31.283	11.533	11.887	12.811	12.541
lake whitefish	7205.642	6793.035	4816.243	4745.976	3882.623	3909.841	4022.944	4215.897	5037.782	4660.22	6575.914	5945.74	5686.741
menominee	135.347	85.75	27.154	12.515	8.651	6.715	21.093	12.702	1.36	2.21	7.654	9.286	6.881
sturgeon	2.031	3.523	0	4.322	0	6.038	0.151	4.3	0.03	0.01	0.03	0	0.02
suckers	514.9876	47.899	8.962	17.711	7.111	125.931	3.481	29.414	6.769	4.574	4.209	2.681	6.239
alewives	92.903	16.857	48.904	109.097	200.129	97.6	63.81	44.262	28.774	20.321	62.489	6.487	17.356
bloaters	2817.428	1792.945	1335.534	1226.781	1701.834	1626.466	1385.654	1531.916	986.635	583.809	304.347	246.756	137.779
lake herring	0.05	0.92	0.22	0.11	0.394	0.152	0.033	0.1	0	0.445	15.418	1.025	1.397
rainbow smelt	701.48	1336.399	387.918	251.244	452.632	184.766	408.929	676.416	836.38	428.76	179.28	44.745	325.034
TOTAL	20460.32	20113.63	16867.61	16741.01	18698.32	16225.59	17965.14	17449.49	18815.81	17432.12	15680.82	14581.34	13843.17

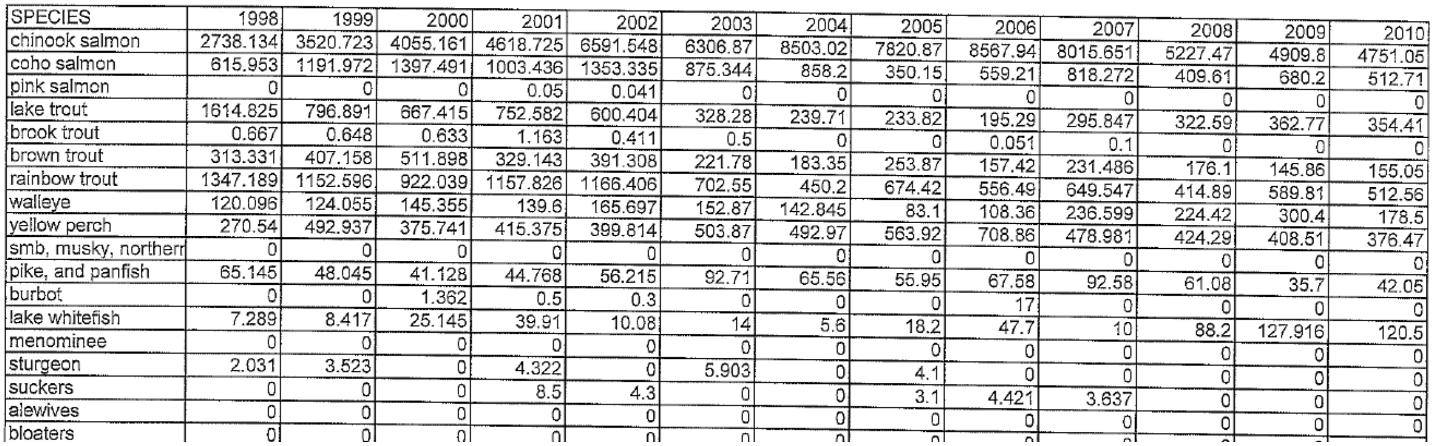


SPECIES	2011	2012	2013	2014	2015
chinook salmon	4835.711	7818.958	3525.012	2954.228	2037.296
coho salmon	1405.332	925.7438	1220.322	530.56	441.1993
pink salmon	0	0	0	0	0.032
lake trout	972.607	1006.715	1231.361	1372.295	1284.935
brook trout	0	0	1.2	0	0
brown trout	77.0645	143.001	147.055	194.745	146.296
rainbow trout	814.08	921.736	645.482	901.17	574.917
walleye	291.279	359.151	302.12	293.0571	345.128
yellow perch	343.019	245.149	348.728	205.376	203.504
smb, musky, northern	0	0	0	0	0
pike, and panfish	69.33	64.348	75.742	45.6	104.15
burbot	19.054	13.131	10.59	9.075	10.193
lake whitefish	5282.207	5367.268	3890.744	3594.493	3266.397
menominee	11.088	4.809	2.704	4.161	5.276
sturgeon	0.02	0.004	0	0	0
suckers	3.321	3.738	8.6294	15.1144	18.165
alewives	0.996	42.565	5.948	0.37	7.572
bloaters	48.358	24.291	19.535	33.317	71.753
lake herring	2.45	0.689	14.789	5.433	22.051
rainbow smelt	270.524	32.004	1.947	0.013	0.515
TOTAL	14446.44	16973.3	11451.91	10159.01	8539.379

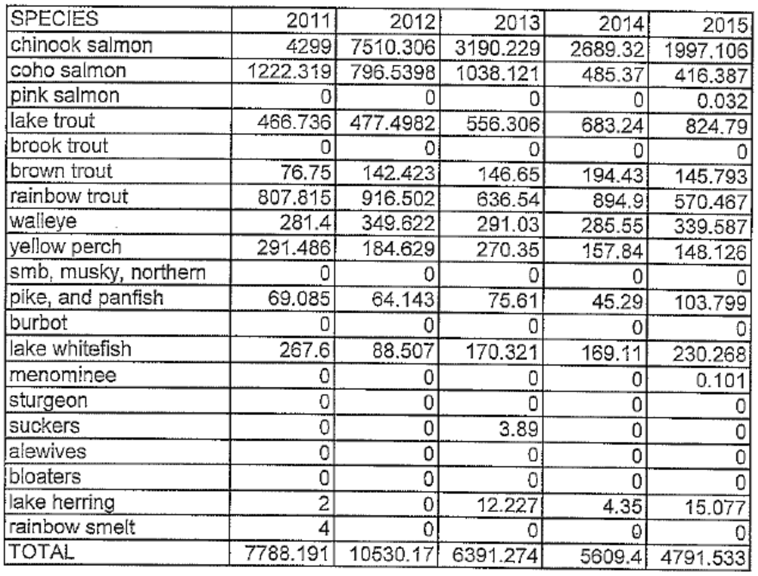
Sport Harvest for all State Agencies in 1000's of pounds



SPECIES	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
chinook salmon	9539.863	9731.578	8003.968	4098.538	3378.054	2068.011	2314.737	1587.318	1414.179	1412.814	2148.767	2769.766	2404.061
coho salmon	2029.587	1200.923	1294.818	949.156	1284.431	850.744	445.745	759.773	844.33	771.257	501.043	913.751	959.226
pink salmon	2.4	0.1	6.5	0	2	0	0.1	0	0.2	0	0	0	0
lake trout	1362.438	1318.034	1432.163	1431.243	1640.494	1177.718	1673.36	999.45	1161.082	1061.26	1537.489	772.53	983.374
brook trout	7.9	8.881	2.744	6.929	3.861	9.051	5.401	15.78	3.006	8.214	2.385	0.732	0.669
brown trout	615.398	711.919	646.67	420.281	403.478	344.529	436.74	307.487	424.134	507.558	377.275	365.738	466.706
rainbow trout	537.695	499.1	772.687	795.228	965.326	754.081	984.262	1103.273	1152.325	1099.182	1024.154	981.283	1029.745
walleye	128.296	146.605	104.245	161.639	111.112	106.079	142.026	87.844	134.763	231.004	245.327	271.382	130.524
yellow perch	1151.504	1538.677	2624.872	1967.633	1266.549	1315.172	1533.716	1426.183	1728.177	1033.422	1476.855	938.086	277.95
smb, musky, northern	0	0	0	0	0	0	0	0	0	0	0	0	0
pike, and panfish	107.8	106.4	174.8	14.543	60.122	49.464	101.788	92.445	64.891	74.827	61.747	87.069	90.795
burbot	0	0	0	0	0.3	0.2	0.7	0	0.05	0	0	0	0
lake whitefish	278.6	167	48	25.9	29	23	25.8	11.9	7.4	10.8	10.184	25.176	31.61
menominee	25	42.7	29.6	5.1	9	5	2	0	7.1	0	0	0	0
sturgeon	0	0.437	0.882	0.836	0.73	0.686	1.186	1.784	1.414	1.071	1.883	1.371	1.552
suckers	0	0	0	0	0.2	0.3	12.7	0	3.4	0	0	0	0.3
alewives	0	0	0	0	0	0	0	0	0	0	0	0	0
bloaters	0	0	0	0	0	0	0	0	0	0	0	0	0
lake herring	0	0	0	0	0	0	0	0	0.1	0	0	0	0
rainbow smelt	1	112.3	74.7	46.2	0	0	0	0	0	0	0	0	0
TOTAL	15787.48	15584.65	15216.65	9923.226	9154.657	6704.035	7680.261	6393.237	6946.551	6211.409	7387.109	7126.884	6376.512



SPECIES	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
chinook salmon	2738.134	3520.723	4055.161	4618.725	6591.548	6306.87	8503.02	7820.87	8567.94	8015.651	5227.47	4909.8	4751.05
coho salmon	615.953	1191.972	1397.491	1003.436	1353.335	875.344	858.2	350.15	559.21	818.272	409.61	680.2	512.71
pink salmon	0	0	0	0.05	0.041	0	0	0	0	0	0	0	0
lake trout	1614.825	796.891	667.415	752.582	600.404	328.28	239.71	233.82	195.29	295.847	322.59	362.77	354.41
brook trout	0.667	0.648	0.633	1.163	0.411	0.5	0	0	0.051	0.1	0	0	0
brown trout	313.331	407.158	511.898	329.143	391.308	221.78	183.35	253.87	157.42	231.486	176.1	145.86	155.05
rainbow trout	1347.189	1152.596	922.039	1157.826	1166.406	702.55	450.2	674.42	556.49	649.547	414.89	589.81	512.56
walleye	120.096	124.055	145.355	139.6	165.697	152.87	142.845	83.1	108.36	236.599	224.42	300.4	178.5
yellow perch	270.54	492.937	375.741	415.375	399.814	503.87	492.97	563.92	708.86	478.981	424.29	408.51	376.47
smb, musky, norther	0	0	0	0	0	0	0	0	0	0	0	0	0
pike, and panfish	65.145	48.045	41.128	44.768	56.215	92.71	65.56	55.95	67.58	92.58	61.08	35.7	42.05
burbot	0	0	1.362	0.5	0.3	0	0	0	17	0	0	0	0
lake whitefish	7.289	8.417	25.145	39.91	10.08	14	5.6	18.2	47.7	10	88.2	127.916	120.5
menominee	0	0	0	0	0	0	0	0	0	0	0	0	0
sturgeon	2.031	3.523	0	4.322	0	5.903	0	4.1	0	0	0	0	0
suckers	0	0	0	8.5	4.3	0	0	3.1	4.421	3.637	0	0	0
alewives	0	0	0	0	0	0	0	0	0	0	0	0	0
bloaters	0	0	0	0	0	0	0	0	0				



SPECIES	2011	2012	2013	2014	2015
chinook salmon	4299	7510.306	3190.229	2689.32	1997.106
coho salmon	1222.319	796.5398	1038.121	485.37	416.387
pink salmon	0	0	0	0	0.032
lake trout	466.736	477.4982	556.306	683.24	824.79
brook trout	0	0	0	0	0
brown trout	76.75	142.423	146.65	194.43	145.793
rainbow trout	807.815	916.502	636.54	894.9	570.467
walleye	281.4	349.622	291.03	285.55	339.587
yellow perch	291.486	184.629	270.35	157.84	148.126
smb, musky, northern	0	0	0	0	0
pike, and panfish	69.085	64.143	75.61	45.29	103.799
burbot	0	0	0	0	0
lake whitefish	267.6	88.507	170.321	169.11	230.268
menominee	0	0	0	0	0.101
sturgeon	0	0	0	0	0
suckers	0	0	3.89	0	0
alewives	0	0	0	0	0
bloaters	0	0	0	0	0
lake herring	2	0	12.227	4.35	15.077
rainbow smelt	4	0	0	0	0
TOTAL	7788.191	10530.17	6391.274	5609.4	4791.533

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Status of Yellow Perch in Lake Michigan 2015

Adult Relative Abundance

The data assembled were collected with either gill nets or bottom trawls (**Figs 1 to 7**). Generally, this information shows continuing low levels of adult yellow perch abundance in Lake Michigan. Some data series show relatively stable (but still low) levels over the past several years (**Figs 1, 4**), whereas others show a regular decline during this same time period **(Figs 3, 5).** Two data series documented slight increases from 2014 abundance **(Figs 2, 6**). Data from common gear types (graded-mesh gill net) fished in all jurisdictions are presented in **Fig 7;** these index data show that current abundance remains well below the historically observed abundance of the late 1980s and early 1990s.

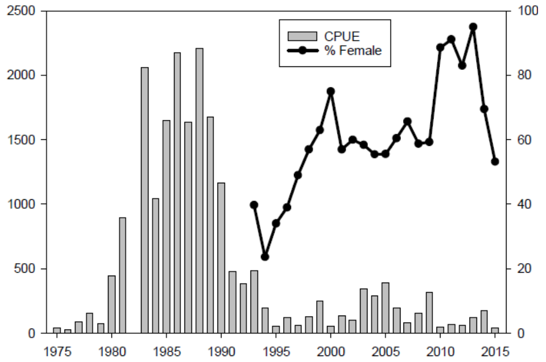

Fig 1- Adult yellow perch in Indiana waters 1975 –2015

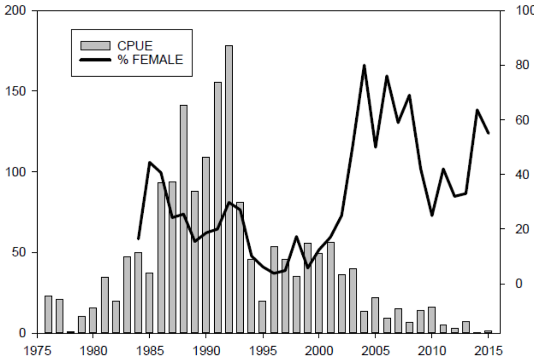

Fig 2- Adult yellow perch in Illinois waters, 1976– 2015

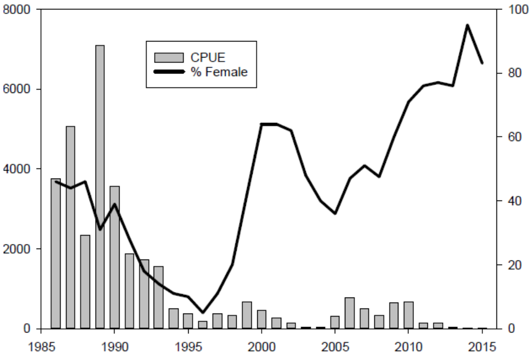

Fig 3- Adult yellow in Wisconsin waters, 1986 – 2015

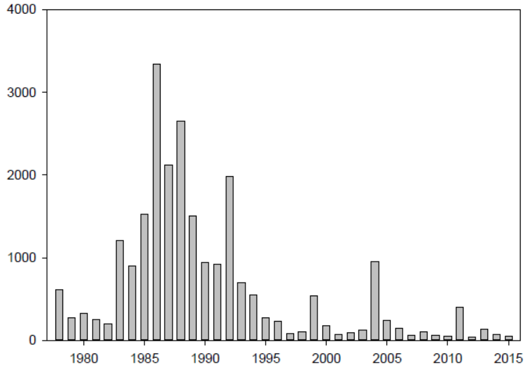

Fig 4- Adult yellow perch in Green Bay, WI, 1978 – 2015

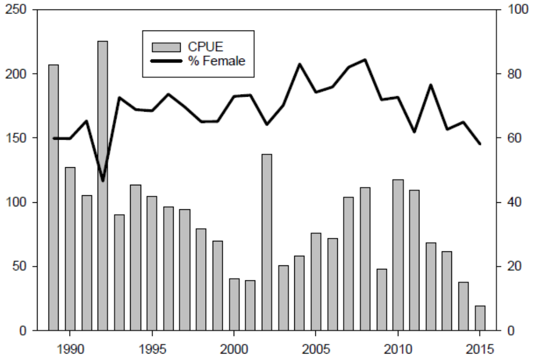

Fig 5- Adult yellow perch in Bays de Noc, MI, 1989 – 2015

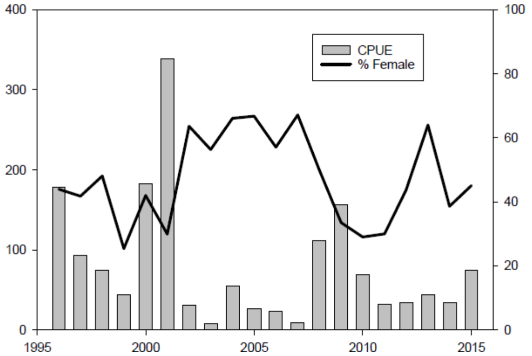

Fig 6- Adult yellow perch at Grand Haven, Saugatuck, South Haven, and St. Joseph, MI, 1996 – 2015

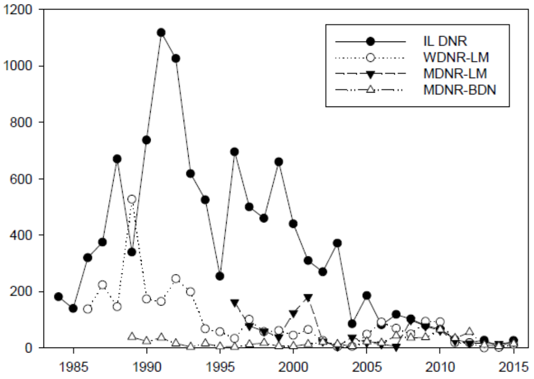

Fig 7- Yellow perch CPE from IL, WI, and MI; 1997-2014

Population Age Structure

The yellow perch adult population age structure was determined by evaluating otoliths, opercles, or spines. The 2012 year class was predominant in most areas of the lake, making up greater than 45% of the yellow perch population in Illinois waters and Green Bay**,** and greater than 60% in northern Lake Michigan / Bays de Noc**.** Significant contributions from 2010-2011 year classes were also observed. Additionally, significant contribution of the 2005 year class was still apparent (60%) in Wisconsin waters of western Lake Michigan**,** although samples sizes for 2015 collections were low.

Recruitment

Data collected using these traditional gears indicated increased (relative to 2014) production of young-of-year yellow perch occurred in all areas of Lake Michigan in 2015. In some cases, these increases were particularly dramatic. For example, Ball State University recorded the second highest summer trawl catch of yellow perch for their 32-y data series (**Fig 9),** and the Illinois DNR recorded their highest seine CPUE since sampling began in 1978 **(Fig 10).** However, recent observations of lack of production of YOY yellow perch have been just as consistent; indices of YOY yellow perch production have been at low levels in nearly all jurisdictions since 2011.

The YPTG agreed to implement a lakewide summer “micromesh” gill net assessment (beginning in summer 2007) to standardize assessment of young-of-year yellow perch production, especially in areas where standard trawl and seine surveys cannot be implemented. Preliminary evaluation of five years of data from this assessment were included in the 2012 report; this survey is continuing, and additional data analyses are ongoing.

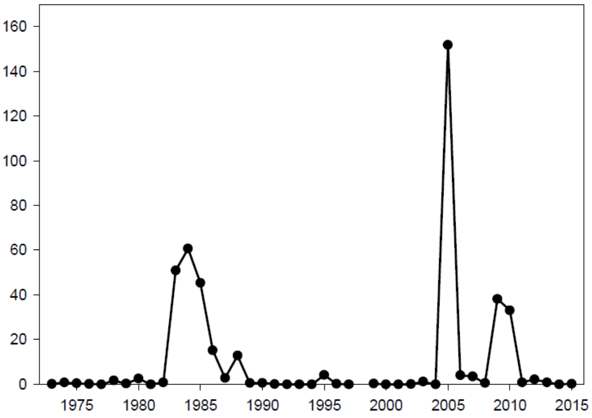

Fig 8- Density of age-0 yellow perch, lakewide, 1973 – 2015)

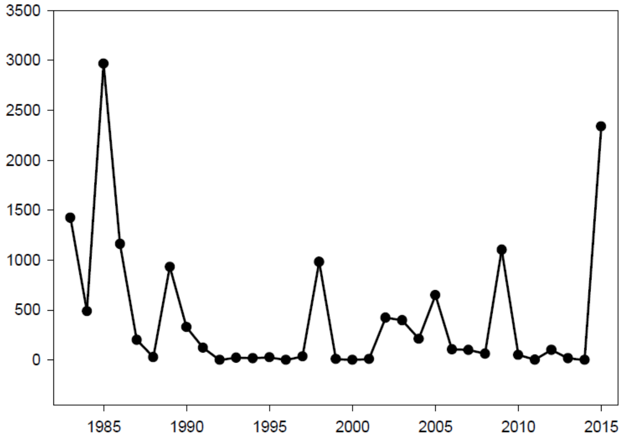

Fig 9- CPUE of YOY yellow perch from the Indiana waters, 1983 – 2015

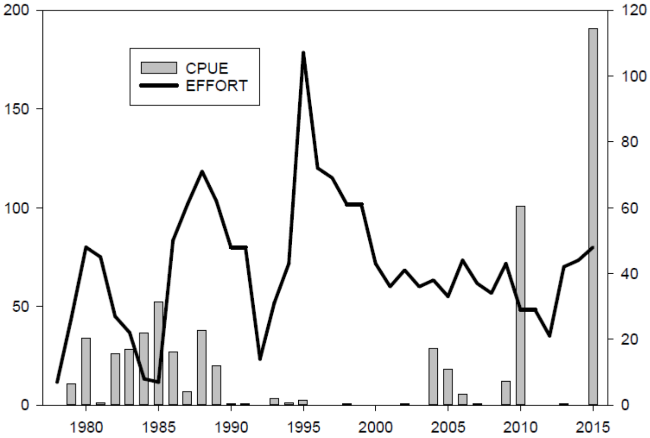

Fig 10- CPUE of YOY yellow perch from the Illinois waters, 1978 – 2015

2016 Yellow Perch Regulations and Harvest Trends

Sportfishing regulations:

Illinois
May 1 through June 15; closed to sportfishing for yellow perch
Daily bag limit 15 fish

Indiana
No closed season for yellow perch
Daily bag limit 15 fish

Michigan
No closed season for yellow perch
Daily bag limit; 35 fish (south of the 45th parallel) / 50 fish (north of 45th parallel
and Grand Traverse Bays)

Wisconsin (Lake Michigan)
May 1 through June 15; closed to sportfishing for yellow perch
Daily bag limit 5 fish

Wisconsin (Green Bay)
March 16 through May 19; closed to sportfishing for yellow perch
Daily bag limit 15 fish

Commercial regulations:

Illinois perch fishery remained closed
Indiana perch fishery remained closed
Michigan does not allow a commercial harvest (outside of 1836 Treaty waters)
Wisconsin perch fishery remained closed (outside of Green Bay, where quota for 2016 is 100,000 pounds)

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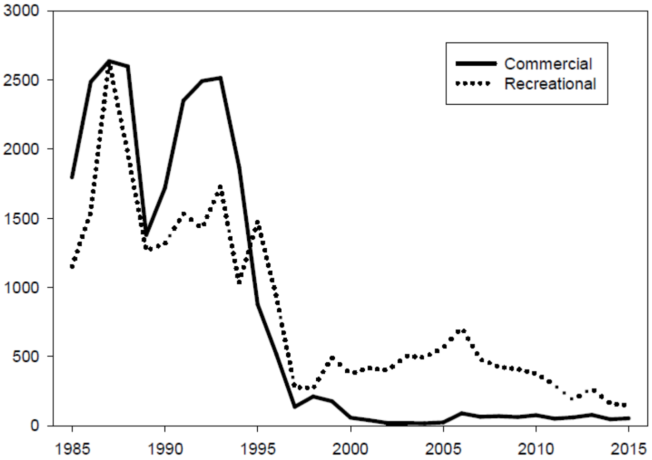

Fig 11- Lake Michigan lakewide harvest of yellow perch by commercial and recreational fisheries, 1985-2015

2015 Lake Michigan Lake Trout Working Group Report

This report provides a review on the progression of lake trout rehabilitation towards meeting the Salmonine Fish Community Objectives for Lake Michigan and the interim goal and evaluation objectives articulated in *A Fisheries Management Implementation Strategy for the Rehabilitation of Lake Trout in Lake Michigan*; we also include data describing lake trout stocking and mortality to portray the present state of progress towards lake trout rehabilitation.

Evaluation of Attainment of Fish-Community Objectives

Salmonine (Salmon and Trout) Objectives for Lake Michigan

Harvest

In 2015, total salmon and trout (SAT) harvest in Lake Michigan was 2.03 million kg, which is equal to only 75% of the 2.7 million kg specified in the FCO objectives **(Fig 1).** However, since 2013 the total harvest of lake trout has met the lower-end range, >0.54 million kg, specified for lake trout harvest objectives; this harvest objective for lake trout was previously met from 1985-2001, and again in 2013 – 2015. Since 2014 lake trout contributed to more than 20% of the SAT harvest, as they had throughout most of the 1990s**.**

Natural Reproduction

From the 2015 spring and fall gillnet assessment data, 45% of the lake trout captured in Illinois were wild origin (unclipped), 18 - 20% in WM4 and WM5, 7 – 13% in MM5 – MM8 **(Fig 2).** Wild lake trout recoveries in MM3, Grand Traverse Bay (MM4), and Indiana were near the 3% marking error rate. Similar proportions of wild lake trout were reported within the Great Lakes Mass Marking Program sampling of the recreational fishery where nearly 5,800 lake trout were examined in 2015. Substantial recoveries of wild lake trout were made in WM6 (24.9%), ILL (43.5%), MM8 (23.8%) and Indiana waters (18.0%); in Indiana and WM6 more intensive sampling was available in the recreational fishery than for assessment surveys

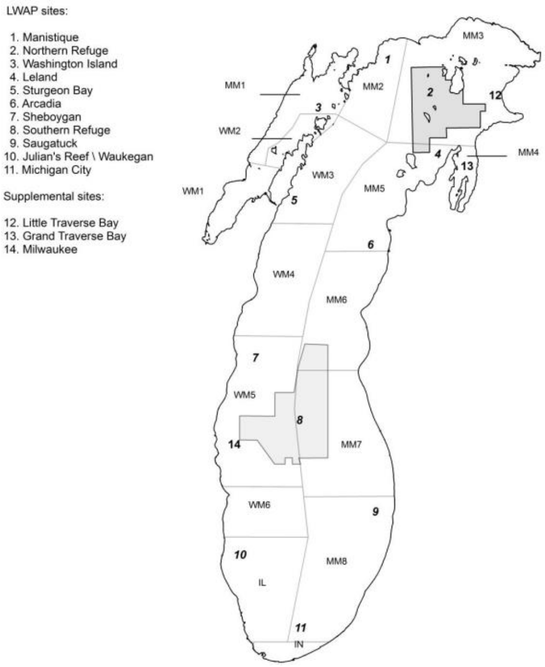

Fig 1- Data reporting stations for Gillnet surveys

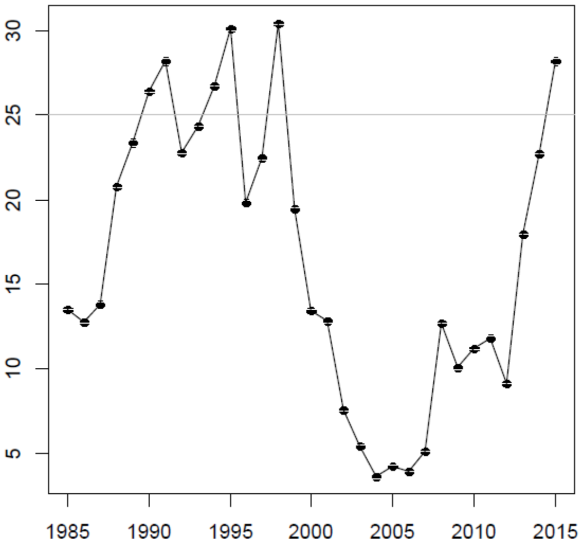

Fig 2- The percentage of SAT harvest comprised of lake trout; the horizontal gray line represents the upper range 25% specified in the FCO.

Evaluation Of Attainment Of Interim Stocking Targets, Mortality Targets, and Implementation Strategy Evaluation Objectives

Fish Stocking

Stocking hatchery reared lake trout to achieve lake trout rehabilitation is the primary feature of the “Fisheries Management Implementation Strategy for the Rehabilitation of Lake Trout in Lake Michigan” (Strategy) approved by the Lake Michigan Committee in January 2011. The maximum stocking target is 3.31 million yearlings and 550,000 fall fingerlings, or 3.53 million yearling equivalents where one fall fingerling = 0.4 yearling equivalents **(Fig 3).** The Committee adopted an interim stocking target when the strategy was approved not to exceed 2.74 million yearling equivalents until the Federal hatchery production is capable of achieving higher stocking rates and the Committee reaches consensus, informed by decision support tools and information, to increase stocking above 2.74 million equivalents. Nearly 2/3 of the fish stocked are targeted in first priority rehabilitation areas with rehabilitation as the primary objective. The remainder of the fish will be stocked in second priority rehabilitation areas with primary objectives being to support local fishing opportunities in addition to supporting rehabilitation.

Since 2008, lake trout have been stocked in accordance to the Strategy and this has substantially increased the numbers of fish stocked in high priority rehabilitation areas**.** In 2015, Lake Michigan was stocked with 2.99 million lake trout yearlings and 455,000 fall fingerlings which equates to 3.17 million yearling equivalents; 98.4% of these originated from Federal hatcheries. Lean strains represented 93% of all lake trout stocked while 206,000 Klondike Reef strain from Lake Superior were stocked at Northeast Reef within the Southern Refuge following a Strategy recommendation to introduce a deep-water morphotype to the underutilized deep-water habitats. Priority rehabilitation areas received 64.3% of the lake trout. Over 87% of the Federal lake trout were stocked in offshore waters using the M\V Spencer F. Baird.

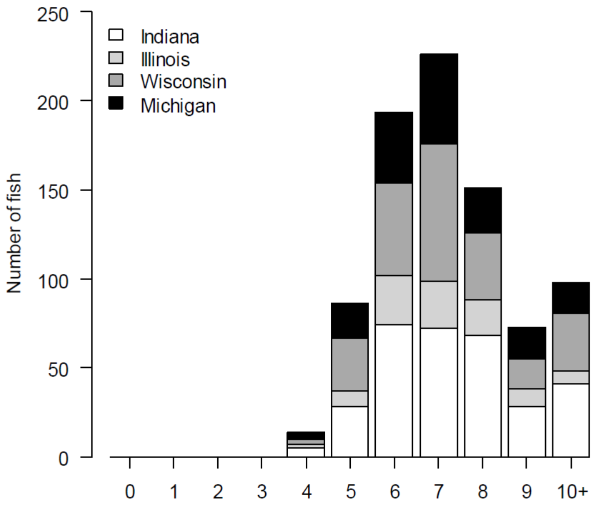

Fig 3- Histogram of the age-classes present among Mass Marking Program sampling of unclipped lake trout in the recreational fishery. A total of 842 of the 5,794 unclipped lake trout sampled in 2015 were aged from thin-sectioned otoliths.

Lake Trout Mortality

Tracking mortality experienced by Lake Michigan lake trout stocks is best accomplished by the stock assessment conducted for the sport and commercial fisheries within the 1836 Treaty waters. Mortality estimated by application of stock assessment models is partitioned into natural mortality, lamprey induced mortality, and fishing (both sport and commercial) mortality. The Strategy requires management agencies to “adjust local harvest regulations if appropriate when mortality rates exceed target levels”, and the target annual mortality rate has been set equal to 40%.

In northern Lake Michigan, total mortality rates for lake trout ages 6-11 have exceeded the maximum targeted annual mortality rate of 40% since 1997 (**Fig 4**). Commercial fishing represented the predominant component of mortality rates in the late 1990’s though 2002 and more recently from 2011 to present day. By 2000 the Manistique River dam failed as a lamprey barrier and subsequently lamprey numbers increased substantially. As a result, lamprey induced mortality was the primary source of mortality between 2003 and 2010.

Since 2003 the Manistique River has been treated seven times which has effectively reduced abundance of lamprey in northern Lake Michigan and the mortality imposed on lake trout to a more manageable level. Lake trout mortality rates in the Southern Refuge priority area have not been estimated, but total annual mortality rates from the proximal waters of MM6\7 have been at or below 40% since 1999. Prior to 2003, recreational fishing was the main source of mortality in MM6\7, but with the reduction in overall recreational fishing effort since the 1990s, lamprey induced mortality is now substantially greater than fishing mortality in MM6\7.

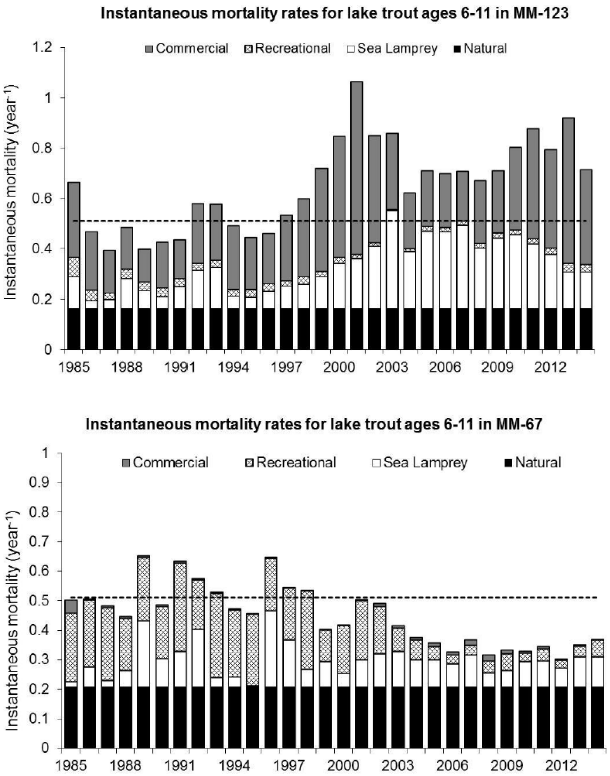

Fig 4- Instantaneous mortality rates for lake trout ages 6-11 in northern Lake Michigan and in MM6\7 waters proximal to the Southern Refuge. The black dashed line represents an instantaneous mortality rate of 0.51 that is equivalent to a 40% annual mortality rate.

Evaluation Objective 1

Increase the average catch-per-unit-effort (CPUE) to >25 lake trout 1000 feet of graded mesh gill net (2.5-6.0 inch) over-night set lifted during spring assessments by 2019.

In 2015, 159 gillnet lifts were completed lakewide to measure spring lake trout abundance. This included at least 6 lifts at each nearshore LWAP site except for Michigan City (n = 3 lifts). Increased effort was directed at the offshore reef complexes with 12 lifts on Northeast Reef in the Southern Refuge reef complex and 34 lifts at 6 reefs within the Northern Refuge reef complex. About 25% of the lifts stemmed from FIWS sampling that added additional effort to sites between Saugatuck and Manistique.

Spring survey CPUEs for the first priority areas including the Northern Refuge reef complex, Southern Refuge reef complex, and Julian's Reef, and second priority regions, all other areas, are shown in Figure 8. In the priority rehabilitation areas, lake trout CPUE remains below the 25 fish per 1000' benchmark. Spring survey CPUEs were at or near their highest values in the time series for the Northern Refuge reef complex (9.8 trout per 1000'), Little Traverse Bay including nearshore reefs of MM3 (12.7), and the northern waters of MM5 near Leland (15.1). All other areas of the lake, including the Southern Refuge (CPUE = 14.2) and Julian's Reef\Waukegan region (CPUE = 11.8), have fluctuating CPUEs that are below the 25 fish benchmark with no strong evidence for any trend upward or downward. Interestingly both first priority areas in southern Lake Michigan had previously been above the benchmark, Julian's Reef in 2005 and the Southern Refuge in 2012-13, yet CPUE in each area subsequently declined for unknown reasons.

Evaluation Objective 2

Increase the abundance of adults to a minimum catch-per-unit-effort of 50 fish per 1000 feet of graded mesh gill net by 2019.

In 2015, 54 spawner survey lifts from 9 regions were performed during October-November. Eastern Lake Michigan sites from Saugatuck north to Leland, except for Arcadia, were not surveyed in 2015. Fall CPUE in 2015 was near or above the 50 fish benchmark in all surveyed regions except for the Northern Refuge complex reefs where spawner abundance has been increasing but has remained below the benchmark of 50 lake trout per 1000'**.** Spawner abundance at Northeast Reef in the Southern Refuge was roughly 3-fold higher (154 per 1000') than that in other regions in the lake.

Evaluation Objective 3

Significant progress should be achieved towards attaining spawning populations that are at least 25% females and contain 10 or more age groups older than age-7 in first priority areas stocked prior to 2007. These milestones should be achieved by 2032 in areas stocked after 2008.

Since 1998, the percentage of females captured during the fall spawner surveys has generally exceeded the 25% benchmark and has reached as high as 45% (Fig 10). Age compositions were only reported from the Northern Refuge, nearshore MM3 / Little Traverse Bay, Grand Traverse Bay, and Sturgeon Bay sites. Sturgeon Bay met the criteria with 13 age-classes older than age 7, the oldest fish was aged at 23 years, and there were a substantial proportion in the 15+ group, whereas spawning populations in northern sites were predominantly younger fish between 4-8 years (Fig 11). For the Southern Refuge and Julian's Reef, the only age information available was from lake trout tagged with a coded wire tag (CWT). Of the CWT fish caught, 16 age-classes older than age 7 with a maximum age of 26 years were recorded for the Southern Refuge, and 11 age-classes older than age 7 with a maximum age of 30 were recorded for Julian's Reef.

Conclusions:

Since 2013, lake trout harvest from Lake Michigan has partly met the specified Fish-Community Objectives, as lake trout annual harvest has exceeded 0.54 million kg. The majority of the lake trout harvest has been from northern Lake Michigan, where lake trout annual mortality still exceeds the 40% target level. In the Southern Refuge and at Julian’s Reef, the Strategy evaluation objectives have largely been met, as lake trout populations in these areas are characterized by high spawner densities, a diverse age structure including older age-classes, and an increasing trend in the proportion of wild fish. However these populations are not considered self-sustaining yet as they are still stocked and comprised of > 50% hatchery fish. Among northern populations, higher stocking rates in the northern priority area have resulted in increasing lake trout density. Recently, sea lamprey induced mortality rates in this northern priority area have declined as a result of intensive lamprey eradication efforts on the Manistique River since 2003. Progress toward lake trout rehabilitation in this northern priority area can be accelerated by a reduction in fishing mortality such that the mortality target level is attained.

Fall spawner densities in the southern priority areas and western sites at Sturgeon Bay, Sheboygan, and Milwaukee have generally met or exceeded the 50 fish per 1000 feet benchmark since 2007, and recent natural reproduction is evident in each of the corresponding management units to varying degrees. Spawner densities at Arcadia (MM5) have also consistently exceeded the fall benchmark though evidence of natural reproduction is marginal with Great Lakes Mass Marking Program recoveries of wild fish just slightly above the 3% rate of marking error. Sites in northern Lake Michigan, including Grand Traverse Bay, the Northern Refuge, Little Traverse Bay, and nearshore MM3 reefs, have shown increasing spawner densities, but to date these populations are relatively young and substantial production of wild fish has yet to be observed.

The apparent onset of detectable and sustained natural reproduction by lake trout in Lake Michigan also coincided with reduced alewife abundance. A substantial increase in lake trout natural reproduction appeared to begin around 2004. Alewife abundance in Lake Michigan in 2004 was at a reduced level, and abundance has continued to decline to the present time. Reduced densities of alewives can facilitate natural reproduction by lake trout through decreased potential for alewife predation on lake trout larvae. Continued declines in alewife densities since 2004 were also weakly correlated with an increase in mean thiamine content within lake trout eggs, although by 2013 egg thiamine concentrations have dropped below 4 nmol\g at selected sites in eastern and southern Lake Michigan.

In summary, widespread recruitment of wild fish is now occurring in the southern priority rehabilitation area where evaluation objectives for spawner abundance, spawner age composition, percent spawning females, target mortality, and thiamine egg concentrations (in most years) have been achieved but not for spring abundance. Recruitment of wild fish, at a lesser scale, is now evident in mid-latitude management units, particularly on the western shore. We have shown that managing lake trout stocks to achieve the evaluation objectives provided in the Implementation Strategy remains an appropriate strategy to achieve progress toward lake trout rehabilitation in Lake Michigan. ✧

Sea Lamprey Control in Lake Michigan 2015

This report outlines the actions undertaken during 2015 by Fisheries and Oceans Canada (Department) and the U.S. Fish and Wildlife Service (Service) as partners of the Great Lakes Fishery Commission to control Sea Lamprey populations in Lake Michigan.

During 2015, the index of adult abundance in Lake Michigan was estimated to be 14,695 (95% CI; 13,985-16,492), which was less than the index target. The number of A1-A3 marks on Lake Trout from spring assessments in 2015 has not yet been analyzed.

Lake Michigan has 511 tributaries. One hundred twenty-eight tributaries have historical records of larval Sea Lamprey production, and of these, 91 tributaries have been treated with lampricides at least once during 2006-2015. Twenty-seven tributaries are treated every 3-5 years. Details on lampricide applications to Lake Michigan tributaries and lentic areas during 2015 are found in **Fig 1.**

●Lampricide applications were conducted in 20 streams and 3 lentic areas.

●This was the second year of an expanded large-scale treatment strategy that targeted consecutive year treatments to remove residual Sea Lampreys in large producing streams in lakes Michigan and Huron. The Jordan, Manistee, Boyne, Paw Paw, and Sturgeon rivers and lentic areas offshore of the Jordan and Boyne rivers were included as part of this effort.

●Significant rainfall during the Whitefish River treatment resulted in termination of the downstream portion of the treatment. The stream is scheduled for treatment again during 2016.

- A special appropriation from the State of Wisconsin to enhance Sea Lamprey control in Wisconsin waters led to a consecutive treatment of the Peshtigo River and was intended to remove any residual Sea Lampreys from the 2014 treatment.

- Marblehead Creek was deferred due to insufficient stream discharge.

- The mainstream of the Muskegon River was not treated in consecutive years based on results from post-treatment larval surveys that found few residual Sea Lampreys, while Bigelow Creek (Muskegon River tributary) was treated during both 2014 and 2015.

- The Paw Paw River (St. Joseph River tributary) replaced the mainstream of the Muskegon River on the treatment schedule.

- Hickory Creek (St. Joseph River tributary) was treated for the first time since 1965.

- Allegan 5 and Salt (Burns Ditch tributary) creeks were treated for the first time.

- Lacota Creek (Black River tributary) and the Rabbit River (Kalamazoo River tributary) were treated further upstream than the historical upper application points on each system.

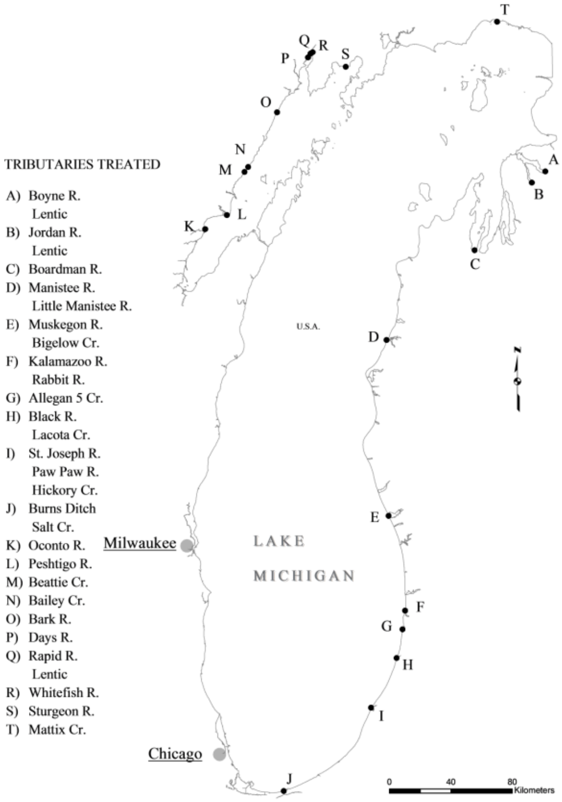

Fig 1- Location of tributaries treated with lampricides, 2015

Juvenile Trapping

- Trapping for out-migrating juvenile Sea Lampreys was conducted in the Galien River during October-December. Fyke nets were set in the mainstream and captured 30 out-migrating juveniles.

Barriers

The Commission has invested in 15 barriers on Lake Michigan. Of these, seven were purpose-built as Sea Lamprey control barriers and eight were constructed for other purposes, but have been modified to block Sea Lamprey migrations.

Barrier Inventory and Project Selection System (BIPSS)

- Field crews visited 97 structures on tributaries to Lake Michigan to assess Sea Lamprey blocking potential and to improve the information in the BIPSS database.

Operation and Maintenance

- Routine maintenance, spring start-up, and safety inspections were performed on seven barriers.

Ensure Blockage to Sea Lamprey Migration

- Boardman River – The Service worked with Traverse City Parks and Recreation Department to replace all stop logs in each section of the spillway during 2012. Surveys conducted upstream from the Union Street Dam during 2013-2015 found no spawning activity or larval recruitment. The Service will continue to monitor for escapement upstream from the dam.

- White River – During September 2012, the Service collaborated with the City of Hesperia, Department of Public Works to install new stop logs at the Hesperia Dam. No larval Sea Lampreys were collected above or below the dam during electrofishing surveys conducted during May 2015.

- Grand River – The City of Grand Rapids along with several citizens groups are proposing to remove the 6th Street Dam on the Grand River to provide for more varied use of the downtown rapids area. The current plan calls for removal of the existing structure and the creation of an artificial rapids complex that can be used by kayakers and anglers. A new inflatable crest structure is proposed approximately one mile upstream of the current location. The Service and Department reviewed concept design plans of the proposed structure and continue to coordinate on the project .

- Cedar River – Repairs to the Powers Dam were completed by Powers Township after the dam was breeched during spring 2014. Larval assessment surveys are planned for 2016 upstream from the dam.

●Trail Creek - The Sea Lamprey barrier was inundated by high water during July, which created a large hole near the access gate to the site barrier. The hole was filled with several tons of stone.

●The Service provided field support to Michigan State University researcher, Dr. Michael Wagner, to conduct EPA-funded Sea Lamprey alarm substance field trials on the Carp Lake River Outlet. Alarm cue tests were conducted to determine whether trap efficacy could be increased by incorporating a naturally derived repellent (Sea Lamprey “alarm cue”) alongside a synthesized partial sex pheromone (3kPZS) during the spawning migration. Initial results suggest that application of the repellent may be effective in moving migrants into the vicinity of trap entrances when traps are sited at barriers.

●Barrier removals/modification – Consultations to ensure blockage at barriers were conducted with partner agencies at 22 sites in 14 streams.

New Construction

●Manistique River – The U.S. Army Corps of Engineers (USACE) is the lead agency administering a project to construct a Sea Lamprey barrier to replace a deteriorated structure in the Manistique River. Project partners include the Commission, Service, MIDNR, City of Manistique, and Manistique Papers, Inc. The existing Manistique Papers, Inc. Dam was identified as the most feasible site for a new barrier. The project remained on hold while the Michigan Department of Environmental Quality completed review of the permit and wetland mitigation requirements.

●White River – The USACE is the lead agency on a project to construct a Sea Lamprey barrier on the White River. Project partners include the Commission, Service, and MIDNR. This project remained on hold due to fish passage concerns by the MIDNR.

●Little Manistee River – The USACE is the lead agency on this project to replace the current dam at the MIDNR egg taking facility on the Little Manistee River. The current barrier height is insufficient to prevent Sea Lampreys from migrating upstream. The USACE is pursuing this project under the Great Lakes Fishery Ecosystem Restoration program and is currently preparing design plans for the project, which is scheduled to be completed during 2016. Service staff met during October 2015 with the USACE and MIDNR to discuss design of a new barrier.

Larval Assessment

●Larval assessment surveys were conducted on 121 tributaries and 14 lentic areas. Surveys to estimate the abundance of larval Sea Lampreys were conducted in 20 tributaries.

●Surveys to detect the presence of new larval Sea Lamprey populations were conducted in 45 tributaries. A special appropriation from the State of Wisconsin to enhance Sea Lamprey control in Wisconsin waters led to additional surveys being conducted in 6 of these streams that had no history of infestation. No new Sea Lamprey infestations were discovered. The results of 22 gB surveys completed in the Fox River; Green Bay, Wisconsin, were also negative for Sea Lampreys.

●Post-treatment assessments were conducted in 22 tributaries and 4 lentic areas to determine the effectiveness of lampricide treatments during 2014 and 2015.

●Surveys to evaluate habitat and determine presence/absence of native or Sea Lampreys were conducted in the Root, Oak, and Menomonee (Milwaukee River tributary) rivers, upstream from the first Sea Lamprey barrier on each stream. These surveys were required to assess barrier removal requests. Larval habitat was limited and no lampreys were detected.

●A two-year evaluation of larval and juvenile Sea Lamprey production potential was completed on Grand River tributaries upstream from the 6th Street Dam. The purpose of the work was to evaluate the production potential of Sea Lampreys upstream from critical barriers by quantitatively assessing larval habitat and native lamprey abundances as a surrogate for Sea Lampreys. Results from the 2014-2015 study are pending.

●Larval assessment surveys were conducted in non-wadable lentic and lotic areas using 33.2 kg (active ingredient) of gB.

Juvenile Assessment

●The number of A1-A3 marks on Lake Trout from fall assessments in 2015 were submitted this February and have yet to be analyzed.

●Based on standardized fall assessment data, the marking rate during 2014 was 10.0 A1-A3 marks per 100 Lake Trout >532mm. The marking rate has been greater than the target of 5 per 100 Lake Trout for many of the previous 20 years, though it has been declining since 2006 (**Fig. 2**).

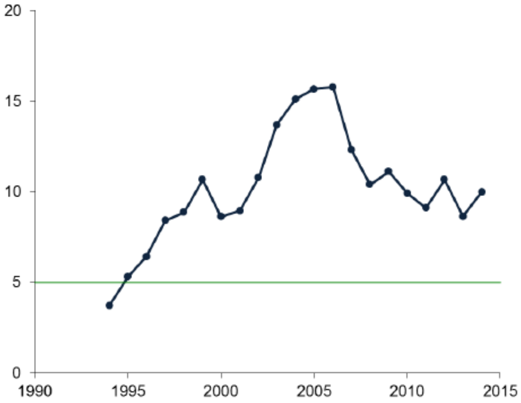

Fig 2- Average number of A1-A3 marks per 100 Lake Trout >532 mm from standardized fall assessments in Lake Michigan. The horizontal line represents the target of 5 A1-A3 marks per 100 Lake Trout.

Adult Assessment

●A total of 9,002 Sea Lampreys were trapped at 8 sites in 8 tributaries (**Table 1**).

●The index of adult Sea Lamprey abundance was 14,695 (95% CI; 13,985-16,492), which was less than the target of 24,874 **(Fig. 3**).

●Adult Sea Lamprey migrations were monitored in the Boardman and Betsie rivers through a cooperative agreement with the Grand Traverse Band of Ottawa and Chippewa Indians.

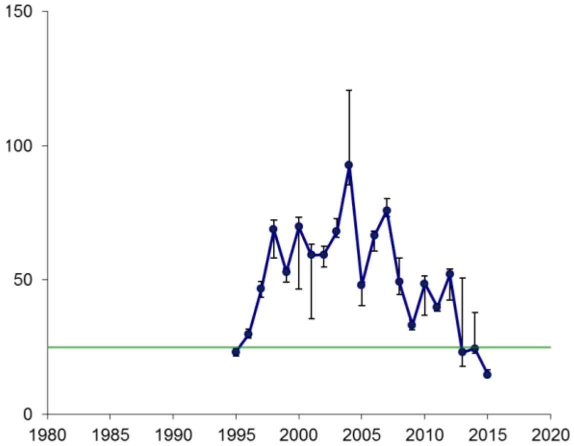

Fig 3- Index estimates with jackknifed ranges (vertical bars) of adult Sea Lampreys. The adult index in 2015 was 15,000 with jackknifed range (14,000-16,000). The point estimate met the target of 25,000 (green horizontal line). The index target was estimated as 5/8.9 times the mean of indices (1995-1999).

Tributary	Number Caught	Adult Estimate	Trap Efficiency	Number Sampled^{1}	Percent Males^{2}	Mean Length (mm) Males	Mean Length (mm) Females	Mean Weight (g) Males	Mean Weight (g) Females
Carp Lake Outlet (A)	575	910	63	43	56	470	462	223	228
Boardman R. ^{3} (B)	128	---	---	---	---	---	---	---	---
Betsie R. (C)	619	1,548	40	141	65	471	472	237	256
Big Manistee R. (D)	258	968	27	4	25	485	476	301	346
St. Joseph R. (E)	322	832	39	38	50	503	505	263	268
Trail Cr. ^{3} (F)	119	156	76	51	61	461	489	222	247
Peshtigo R. (G)	1,010	1,316	77	88	58	500	491	260	261
Manistique R. (H)	5,971	9,121	65	372	51	484	483	237	248
Total or Mean	**9,002**	---	---	**737**	**55**	**481**	**482**	**239**	**252**

Table 1- Information collected regarding adult Sea Lamprey captured in assessment traps or nets in tributaries of Lake Michigan during 2015

End Lake Michigan Report✧