Inland Seas Angler
# GREAT LAKES BASIN REPORT©
## Special Report – Lake Michigan Update
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# Lake Michigan Update

*Index of Reports*



# Lake Michigan Salmon Stocking Strategy (LMC)

## Background

Introduced Pacific salmon (coho and Chinook salmon) in the 1960s provided top-down predatory control for the invasive alewife, and established an extensive recreational fishery. At that time, predator-prey dynamics were most influenced by top-down mechanisms. As managers increased Chinook salmon stocking through the early 1980s, angler catch and harvest likewise increased. Eventually, the amount of stocked Chinook salmon exceeded the available prey and the Chinook salmon population became stressed. Intensive culture of Chinook salmon that carried the Bacterial Kidney Disease (BKD) pathogen resulted in a disease outbreak in the stressed lake population. Although stocking reductions occurred during the BKD outbreak, the first concerted effort to bring the predator-prey relationship into balance, resulting in a 25% lakewide reduction in Chinook salmon stocking, occurred in 1999.

As Lake Michigan's productivity continued to decrease through the 2000s, fishery managers continued to see signs of low prey biomass and over-abundance of predators. In ongoing efforts to achieve predator-prey balance, Chinook salmon stocking was reduced lakewide by 25% in 2006 and 50% in 2013. A subsequent stocking reduction of 900,000 Chinook salmon equivalents (see explanation of equivalents later in this document) was recommended in 2016 to be implemented during 2017 and 2018. This most recent reduction represents a change in management strategy from only reducing Chinook salmon to multi-species reductions (including Chinook salmon, Coho salmon, lake trout, brown trout and rainbow trout) beginning in 2017. While the actual cause for decreased lakewide productivity has yet to be established, it is apparent that top-down management of the prey resource is no longer a simplistic mechanism. The shift in productivity has contributed to reduced and sporadic prey fish production, which has resulted in variable growth and survival of predatory salmon and trout.

In order to evaluate the increasingly complex set of information on the Lake Michigan fishery, the Salmonid Working Group of the Lake Michigan Technical Committee created an approach called the "Red Flags". The Red Flags were used from 2004 through 2014 to evaluate the Lake Michigan fishery. Stocking adjustment recommendations were triggered by deviations from historic trends for 15-20 individual time-series of biological and fishery indicators.

The Lake Michigan Technical Committee's Red Flags Analysis was utilized to identify imbalance in the relation between predators and prey fish and was critical for determining when a change in management strategy was justified. Previous changes to stocking levels also were guided by the CONNECT model and a salmon stocking model developed by Drs. Michael Jones and Jim Bence, both with the Quantitative Fisheries Center at Michigan State University. Following a 2005 meeting, the Lake Michigan Committee (LMC) decided that a re-development and expansion of the salmon stocking model would be beneficial in guiding future stocking recommendations. The redeveloped salmon decision model included catch-at-age model components for estimation of alewife biomass and standing stock of Chinook salmon predators. The model was run for several scenarios (e.g., status quo or 25% reduction in Chinook stocking) and model outputs were used in evaluation of risks (e.g., alewife population collapse) associated with different management actions.

Four strategic stocking options were presented to the public in April 2012. Two options, one of which employed a feedback mechanism, included reductions in strictly Chinook salmon. Two other options included reductions in Chinook salmon and other species. It was decided that an option of "status quo", included in the previous two stocking reductions (1999 and 2006), was not warranted at this time due to historically low alewife abundances, new information regarding natural recruitment of Chinook salmon including immigration of salmon from Lake Huron, and constituent and fishery managers' discomfort with risk associated with that option.

A 50% reduction in Chinook salmon stocking, in addition to altering future stocking based on a Chinook salmon weight feedback mechanism (3-year evaluation), was generally preferred by fishery managers and constituents. This option provided for more rapid reaction to predatorprey imbalance compared to the other options under consideration (3-year vs. 5-year evaluation) and resulted in reduced risk of low alewife biomass, decreased Chinook salmon weights, decreased Chinook salmon harvest, and decreased Chinook salmon catch-per-uniteffort (CPUE).

In addition to adopting the 50% reduction option, several other key decisions were made during this period to guide salmonid management in the future:

1) 2012 stocking plans were established as the stocking baseline
2) Species equivalents could be used in some situations to account for different numbers of salmonids in agency hatcheries
3) The LMC reaffirmed its support for lake trout rehabilitation
4) The LMC agreed to limit overages of actual stocking numbers to 5% of target production numbers
5) The LMC agreed to use a feedback mechanism to identify a predator-prey imbalance and change the salmon stocking strategy when needed
6) Until a better indicator was developed, the LMC adopted weight of age 3+ female Chinook salmon at the Strawberry Creek Weir (WI) as a feedback mechanism trigger.

For a full description of this information, please read the document titled "Lake Michigan Salmonine Stocking Strategy, Lake Michigan Committee, July 2014." **http://www.glfc.org/pubs/lake_committees/michigan/Lake%20Michigan%20Committee%20Salmon%20Stocking%20Strategy%202014.pdf**

A critical review of the Red Flags Analysis was started in 2012 and completed in 2014. This review led to a new approach called the predator-prey ratio (PPR) analysis. This analysis is based on a simple concept of maintaining a predator (Chinook salmon) and prey (alewife) balance, but incorporates detailed datasets and analytical approaches to account for the complexity in the Lake Michigan fishery. The PPR analysis was created with the intention of replacing the Red Flags Analysis.

Herein, we describe how the PPR analysis will be used to inform salmonine stocking levels in future years. First, we describe the PPR approach, associated auxiliary indicators and additional principles (e.g., Fish Community Objectives) that the LMC views as important when making stocking adjustment recommendations. Then we present a salmonine stocking strategy that incorporates the PPR as a feedback mechanism trigger to inform the LMC about appropriate stocking adjustments to achieve and maintain balance in predator and prey fish communities. Maintaining balance between predators and prey is key to sustaining quality fisheries because too many predators might contribute to substantial reductions in prey populations (e.g., alewife in Lake Huron) and too few predators may lead to inefficient use of resources and overabundant prey populations (e.g., alewife in Lake Michigan during the 1960s). The guidance provided in this strategy document supersedes the guidance provided by the LMC in its 2014 document titled Lake Michigan Committee Salmon Stocking Strategy.

## Chinook Salmon and Alewife Predator-Prey Ratio

The PPR is used to annually evaluate the relationship between salmonine predators and prey fish in Lake Michigan. Specifically, it is a ratio of total lakewide biomass of Chinook salmon (≥ age 1) to total lake-wide biomass of alewives (≥ age 1; **Fig 1).** Statistical-catch-at-age (SCAA) models are used to estimate abundance of Chinook salmon and alewife by age class using data from multiple agency surveys. Abundance estimates are then multiplied by species- and age specific average body weights and summed across ages to generate total lakewide biomass estimates for each species.

For example: $(abundance \times ave.\ weight\ of\ age\ 1\ Chinook) + (abundance \times ave.\ weight\ of\ age\ 2\ Chinook) + (etc.\ for\ each\ age\ class) = total\ Chinook\ biomass$

The ratio of Chinook salmon to alewife biomass is used as an indicator of lakewide balance of predators and pelagic prey because Chinook salmon and alewife are principal components of the sport fishery and pelagic prey fish community, respectively, which provide adequate data for producing biomass estimates for both species. The PPR is relatively simple to interpret: a high ratio suggests too many predators with few prey fish, while a low ratio suggests too few predators with abundant prey. Although conceptually simple, the ratio is a very comprehensive and complex analysis that incorporates datasets from multiple agencies throughout Lake Michigan and integrates many of the predator and prey fish population parameters formerly used in the Red Flags Analysis.

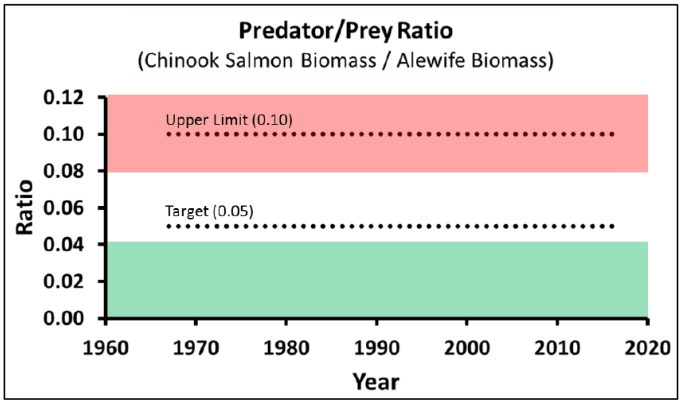


**Fig 1. Predator-prey ratio (PPR) with target and upper limit reference points and color coded management action zones**.

A target of 0.05 and an upper limit of 0.10 have been established as reference points to guide interpretation of PPR results. These values were chosen based on literature reviews, risk assessment models from previous stakeholder meetings, and comparisons with Lakes Huron and Ontario. For example, ratio values near the 0.05 target suggest an acceptable predatorprey situation, whereas, ratio values approaching or above the upper limit of 0.10 suggest an unbalanced and potentially problematic ratio with overabundant predators relative to available prey biomass.

The LMC has set management action zones to help determine when discussions on modifications to lakewide stocking should be considered. The red area in Figure 1 (ratio at or above 0.08) suggests stocking reductions might be needed, the white area (ratio between 0.04 and 0.08) suggests no change in stocking is necessary and the green area (ratio at or below 0.04) suggests stocking increases might be needed.

The biological and fishery data needed to generate the PPR comes from a variety of sources and includes information from multiple agencies and species. These datasets are critical components of the analysis and represent extensive federal, state and tribal resource expenditures. Continued agency support for these projects should remain a high priority. Following is a list of lakewide datasets that are updated yearly and used in the analysis.

Lake-wide datasets used for Chinook salmon SCAA:
• Number of Chinook salmon stocked
• Percent wild for age-1 Chinook salmon (mass marking)
• Number of Chinook salmon harvested (charter & creel)
• Targeted salmonine boat fishing effort (charter & creel)
• Age & maturity of Chinook salmon harvested (creel & mass marking)
• Average weight of Chinook salmon harvested (creel & mass marking)
• Standard weight of 35-inch Chinook salmon
• Chinook salmon age composition from fall weir and harbor sampling

Lake-wide datasets used for alewife SCAA:
• Alewife abundance (trawl & hydro-acoustic)
• Age and weight distributions of alewife (trawl or hydro-acoustics)
• Numbers of salmon and trout stocked
• Estimates of salmon and trout abundance and consumption

## Auxiliary Indicators

Six auxiliary indicators also were developed to complement the PPR and provide additional information on predator and prey fish balance. Auxiliary indicators are calculated with lakewide datasets from several management agencies and include:
1) standard weight of 35-inch Chinook salmon from angler caught fish during July 1 to Aug 15,
2) average weight of age-3 female Chinook salmon from fall weir and harbor surveys,
3) catch-per-hour for Chinook salmon from charter boats,
4) percent composition of angler harvested weight by species,
5) lakewide biomass of alewives, and
6) age structure of the alewife population.

## Additional Principles

In addition to the PPR and auxiliary indicators, the LMC will evaluate the levels of salmon and trout in Lake Michigan and the available prey to determine if objectives, as outlined in “Fish- Community Objectives for Lake Michigan. 1995,” are being met. Specifically these objectives call for the following:

● *Establish a diverse salmonine community capable of sustaining an annual harvest of 2.7 to 6.8 million kg (6 to 15 million lb), of which 20-25% is lake trout and establish self-sustaining lake trout populations.*

● *Maintain a diversity of planktivore (prey) species at population levels matched to primary production and to predator demands. Expectations are for a lakewide planktivore biomass of 0.5 to 0.8 billion kg (1.2 to 1.7 billion lb).*

In addition to making recommendations about the balance of predators and prey that are consistent with the Fish Community Objectives for Lake Michigan, the LMC will also seek consistency with other LMC-approved guidance documents, including *A Fisheries Management Implementation Strategy for the Rehabilitation of Lake Trout in Lake Michigan*. **http://www.glfc.org/pubs/lake_committees/michigan/impstr_rehablktrout.pdf**

## Salmonine Stocking Strategy with PPR

In 2016, the LMC responded to record low alewife abundance estimates and a PPR value in excess of the 0.10 upper limit and recommended a predator stocking reduction of 900,000 Chinook salmon equivalents to be implemented over 2 years (2017 and 2018). This most recent stocking reduction represents a change in strategy from only reducing stocking of Chinook salmon (as in 1999, 2006 and 2013) to including all stocked salmon and trout species (i.e., Chinook salmon, coho salmon, lake trout, rainbow trout and brown trout) in agency stocking reduction proposals. The LMC has agreed to continue the use of this multispecies approach for stocking adjustments based on Chinook salmon equivalences and to use the PPR as a primary feedback mechanism to inform stocking decisions until a new strategy is adopted by the committee.

## Species equivalence

Fishery biologists commonly agree that not all species are equivalent in terms of diet requirements, overlap with specific prey fish, annual consumption or consumption over lifespan. "Chinook salmon equivalents" were developed in the 1980s for Lake Michigan salmonines as a way to compare prey fish consumption rates among species. The LMC has adopted these equivalence values **(Table 1)** for use in this stocking strategy. In addition, the LMC adopted a previously proposed equivalence rate for lake trout of 1.0 fall fingerling = 0.4 yearling lake trout. While these equivalence values are currently the best option for comparisons among stocked species, future research may provide updated values better suited to current lake conditions. The LMC will evaluate and consider using updated equivalence values should they become available in the future.

Table 1. Number of each species equivalent to one stocked Chinook salmon.

| Species | Number of fish equivalent to one (1) Chinook salmon |
|---|---|
| Chinook salmon | 1.00 |
| Coho salmon | 3.20 |
| Lake trout (yearling) | 2.30 |
| Lake trout (fall fingerling) | 5.75 |
| Rainbow trout | 2.40 |
| Brown trout | 2.20 |

Per LMC agreement, agencies will use species equivalences in Table 1 to determine the numbers of salmon and trout to be stocked in their jurisdictions when stocking adjustments are deemed necessary. Agencies may also account for hatchery shortages of one species by stocking more of a different species by using these species equivalences such that the number of Chinook salmon equivalences stays the same (e.g., replace a 24,000 rainbow trout shortfall with 32,000 coho salmon).

## Lake trout rehabilitation and changes to stocking

The LMC reaffirmed its commitment to lake trout rehabilitation for Lake Michigan but also agreed to reduce lake trout stocking from 2.75 to 2.54 million yearling equivalents by 2018, consistent with stocking location priorities outlined in its document, *A Fisheries Management Implementation Strategy for the Rehabilitation of Lake Trout in Lake Michigan*. Reductions in lake trout stocking from the previous stocking target of 2.75 million yearlings resulted in the elimination of lake trout fall fingerlings in 2016 and reductions in yearlings in 2017 and 2018, in recognition of the strong imbalance between trout and salmon predators and their pelagic prey. The LMC acknowledges: 1) the USFWS should be notified of any LMC requests to modify the stocking plans outlined in the Implementation Strategy (including revised tables); 2) when changes to lake trout stocking numbers are requested, fish already in the hatchery system should be used for stocking; 3) there is a lag between development of fish for stocking and potential requests for stocked fish; and, 4) changes to numbers of lake trout requested per the Implementation Strategy will likely become permanent if USFWS reduces its production capacity to coincide with LMC requests for reduced lake trout stocking (i.e., it will be very difficult for USFWS to reinstate a stocking event that has been discontinued by the LMC).

The LMC has asked the Lake Michigan Technical Committee to prepare a list of criteria for assessing when lake trout stocking may be reduced or terminated in response to increased natural reproduction in portions of Lake Michigan. Once adopted, these criteria may be used to guide future decisions on lake trout stocking.

## Planned and actual numbers

The LMC has agreed in good faith to keep actual stocking numbers of salmon and trout as near to target production numbers as possible. Deviations from targeted production numbers will be determined on an agency and calendar year basis by comparing production target totals for all species combined (measured in Chinook salmon equivalents) with equivalence measures of the actual number of stocked fish. Maintaining accurate stocking numbers will require communication between LMC members and their respective state hatchery managers. In addition, USFWS should be notified regarding changes to target lake trout production numbers, as the number of lake trout stocked should also be as near to the stated stocking target as possible.

## Feedback mechanism and frequency of stocking adjustments

The LMC adopted the PPR approach in 2014 with the intent to develop protocols on how this analysis would inform stocking recommendations in the future. After much discussion, the LMC decided to evaluate the PPR on an annual basis, along with the six auxiliary indicators and related Fish-Community Objectives targets, to guide future stocking recommendations. Except under extenuating circumstances, the LMC does not anticipate additional lakewide stocking changes for a minimum of 3 years following implementation of an adjustment. However, agencies can adjust individual species stocking numbers within their jurisdiction, as needed, assuming no net gain in stocked predator equivalences and assuming consistency with the LMC's lake trout implementation strategy.

The LMC will use the following protocol to determine if salmonine stocking levels need to be adjusted.

1) Determine the current year PPR value. If the last two annual ratio values are within the red zone (at or above 0.08; see Figure 1), the LMC will hold discussions to determine if stocking reductions are appropriate. If the last two annual ratio values are within the green zone (at or below 0.04) and prey fish abundance is deemed adequate (e.g., alewife biomass > 100 kt), the LMC will hold discussions to determine if stocking increases are appropriate. If the last two values are within the white zone (between 0.04 and 0.08), the LMC will hold discussions to confirm that no change in stocking is necessary. Discussions will take place during the summer and a final recommendation to management agencies will be made prior to fall egg take. For example, during the summer, the LMC will evaluate the current and previous year's PPR values. If both values are in the red zone or both values are in the green zone, the Committee will discuss stocking changes.

2) The six auxiliary indicators will be calculated and made available for review annually. When the PPR triggers a stocking adjustment discussion, the LMC will evaluate the six auxiliary indicators to help determine an appropriate course of action (e.g., alewife biomass > 100 kt and increasing, fall weight of age-3 female Chinook salmon above 15 pounds and increasing, and charter boat angler catch rates declining would support a stocking increase).

3) Evaluate estimates of salmon and trout harvest potential and planktivore biomass in relation to achievement of Lake Michigan Fish-Community Objectives.

## *Baseline stocking numbers*

The LMC used 2012 state agency stocking plan numbers, rather than actual stocking numbers for Lake Michigan, as a baseline for the 2013 stocking reduction. For the most recent stocking reduction, the LMC agreed to use the average of the number of salmon and trout stocked from 2013-2015 as a more realistic baseline. These stocking data were provided by each jurisdiction and were based on calendar year (January 1-December 31). Numbers stocked were converted to Chinook salmon equivalents using values from Table 1. Species other than lake trout do not have fingerling-to-yearling conversion values, so the same equivalency value was used for fingerlings and yearlings in these species. In addition, the LMC agreed that stocking of undersized surplus fish from hatchery overproduction will be excluded from the annual stocking totals because these small fish are expected to have an extremely low survival rate. On average, about 10.8 million salmon and trout comprised of fall fingerlings, spring fingerlings and yearlings were stocked during 2013-2015 (**Table 2).** This number of stocked fish equaled 5.3 million Chinook salmon equivalents, which represented the new lakewide baseline for the 2016 reduction. Individual agency baselines ranged between 0.47 and 2.51 million equivalents (**Table 2).**

| | Stocking Plan 2012 | | 2016 Baseline | | 2018 Stocking Targets | |
|---|---|---|---|---|---|---|
| Agency | Number | Equivalents | Stocked number | Equivalents stocked | Target Number | Equivalents |
| Michigan | 6,928,500 | 3,711,635 | 5,665,070 | 2,514,635 | 5,053,719 | 2,220,810 |
| Wisconsin | 3,966,000 | 2,257,770 | 3,211,775 | 1,780,625 | 2,336,000 | 1,423,844 |
| Illinois | 870,000 | 483,045 | 882,858 | 473,914 | 790,000 | 391,757 |
| Indiana | 1,171,000 | 584,079 | 1,095,371 | 538,899 | 860,000 | 369,659 |
| **Grand total** | **12,935,500** | **7,036,529** | **10,855,074** | **5,308,073** | **9,039,719** | **4,406,070** |

**Table 2. Lakewide salmon and trout stocking numbers and Chinook salmon equivalents for Michigan, Wisconsin, Illinois and Indiana waters of Lake Michigan. Values represent the 2016 baseline (actual number of fish stocked for 2013-2015) and the proposed targets for 2018. Stocking plan numbers from 2012 are included for comparison.**

Once the 2016 stocking baseline was established by the LMC, state fishery agencies then submitted stocking plans to meet the goal of a lakewide predator reduction level of 900,000 Chinook salmon equivalents. Including USFWS lake trout stocking, LMC agencies recommended a lakewide 2018 stocking target of about 9.0 million salmon and trout totaling just over 4.4 million Chinook salmon equivalents (Table 2). Individual agency stocking targets ranged between 0.37 and 2.22 million equivalents.

The adopted 2018 lakewide and agency stocking targets in Chinook salmon equivalents (Table 2) will remain in effect until a new stocking adjustment is recommended by the LMC. At that time, the LMC will determine a new baseline by calculating the average of the annual numbers of salmon and trout stocked by each jurisdiction for the 3-year period before the adjustment decision year, and then use the new baseline when making stocking adjustments. If unexpected production issues occur for any species during the 3-year averaging period (e.g., due to egg availability, production losses, disease outbreaks, pump failures, hauling mishaps or other production facility problems), and with consensus approval by the LMC, an individual jurisdiction may substitute their planned baseline stocking numbers for actual stocking numbers for affected species when calculating the new baseline stocking level. This will prevent uncontrollable production events during the averaging period from negatively affecting agency baseline stocking numbers.

Annually each spring, the LMC will provide individual agency salmon and trout stocking targets and actual numbers stocked during the previous stocking year. Providing stocking information annually as both numbers of fish and corresponding Chinook salmon equivalents should simplify tracking of lakewide salmon and trout predator introductions in Lake Michigan.

### Stocking adjustment procedure

When making future stocking adjustments, the LMC will recommend a lakewide predator stocking level increase or decrease that is measured in Chinook salmon equivalents. Adjustments may include more than one stocked species and will be informed by the best available scientific data on predator and prey fish populations. The overarching goal for stocking adjustments is to move toward balance between salmon and trout predators and their pelagic prey while maintaining a sustainable sport fishery for Lake Michigan anglers.

The outline below is intended as a procedural guide for future stocking adjustments. In stocking adjustment years, it is anticipated that this process will occur between March (Lakes Meetings) and early October (prior to egg take).

1. Annually evaluate need for stocking adjustment using PPR, auxiliary indicators and related Fish-Community Objectives targets.
2. When a stocking adjustment is recommended, calculate new lakewide baseline stocking level as the average number of salmon and trout stocked during the previous 3 stocking years following protocols outlined above in section on baseline stocking numbers.
3. Determine lakewide change in predator stocking (reduction or increase) based on equivalences and forward the new consensus-derived stocking level recommendation for agency review.
4. Agencies begin constituent engagement and inform state and federal production facilities of potential stocking changes.
5. Each agency develops stocking adjustment options consistent with the LMC consensus recommendations. Agency stocking options may include adjustments to one or more species based on hatchery production capabilities and agency management goals and objectives.
6. LMC reviews, discusses and seeks consensus on agency stocking adjustments.
7. Agencies work with local constituents to finalize stocking plans.
8. With agency approval, consider announcement of proposed lakewide stocking adjustment recommendation in a LMC press release.
9. Stocking changes should be implemented the year following the adjustment recommendation year. Stocking adjustments may require 2 years following LMC decision to be fully implemented for species stocked as yearlings.

Adopted by the Lake Michigan Committee – November 7, 2018

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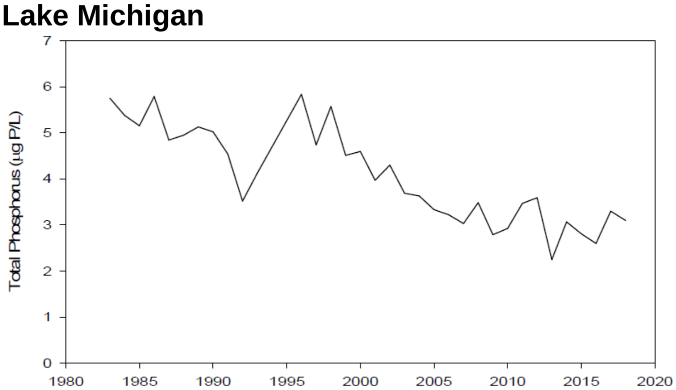
## Recent Trends for Lake Michigan Lower Trophic Levels

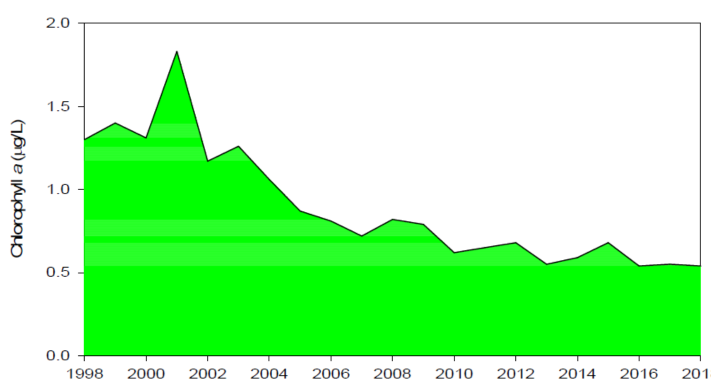
Offshore spring total phosphorus has declined substantially since the 1980s. Values have fallen from over 5.5 to under 4.0 reducing the overall productivity of Lake Michigan.

### Offshore Spring Total Phosphorus, 1983-2018, Lake Michigan



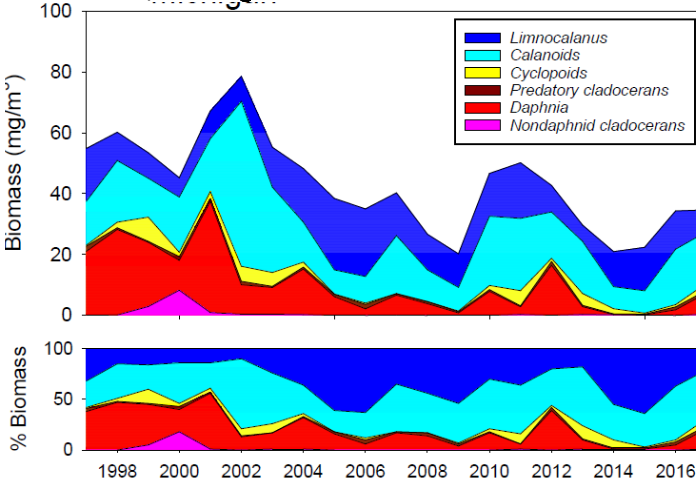

Offshore May Chlorophyll levels have dropped since 1998, showing that this declining level of chlorophyll have led to reduced spring algae blooms a key component for fish production.

### Offshore May Chlorophyll, 1997-2018 Lake Michigan

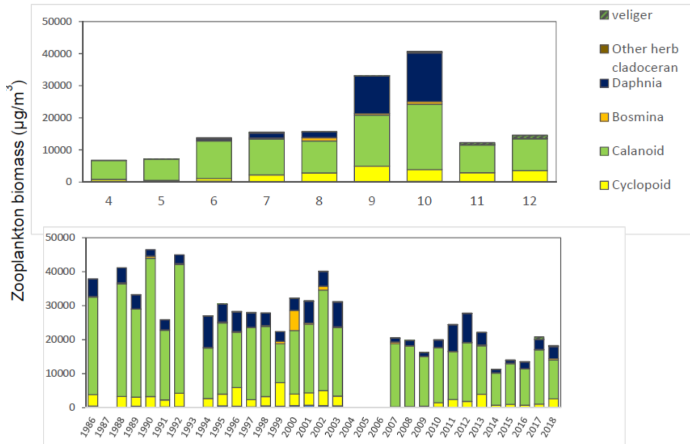



A key crustacean, Daphnia, has declined in offshore samples and larger bodied zooplankton have taken their place, namely Limnocalanus and calanoid copepods.

**Offshore Crustacean Zooplankton (August), 1997-2017, Michigan**

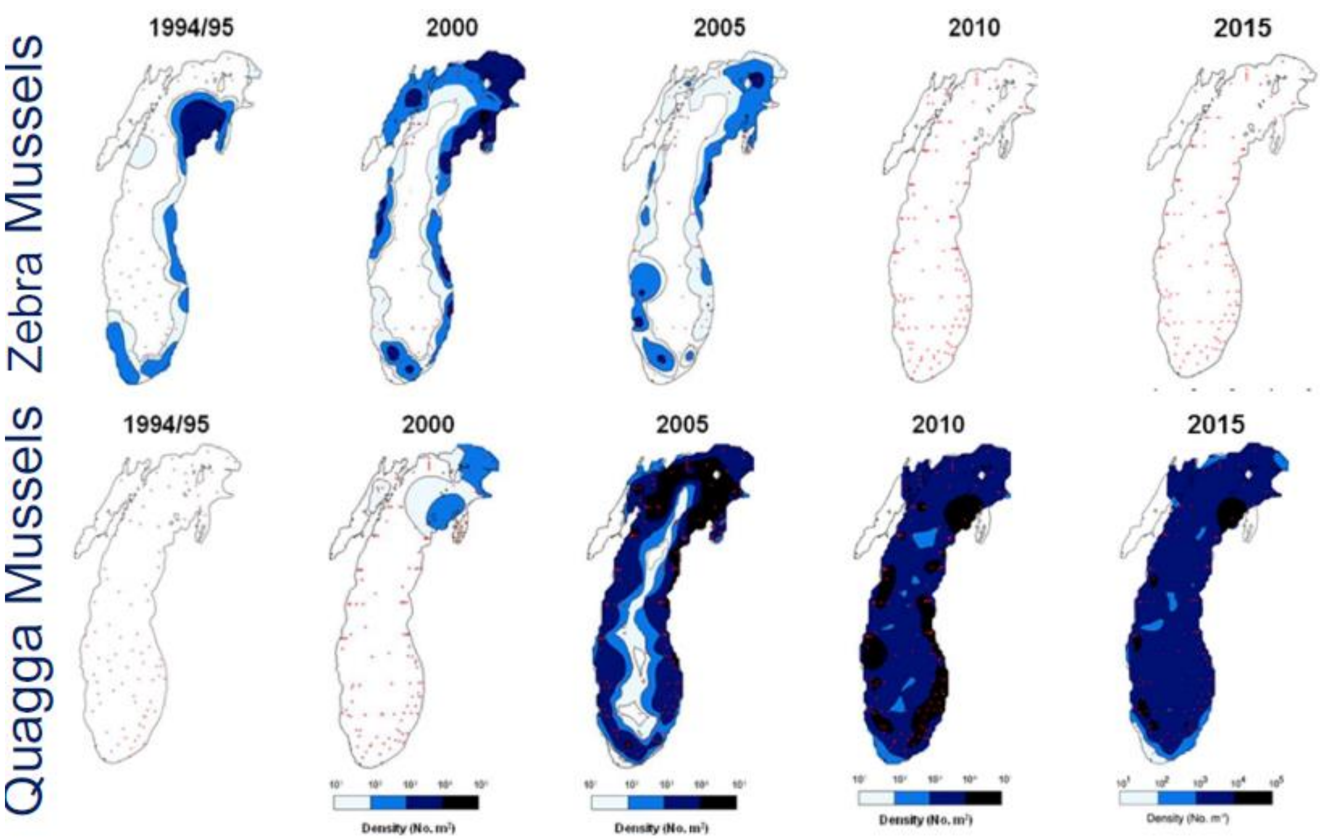



**Offshore zooplankton (Muskegon 110-m)**

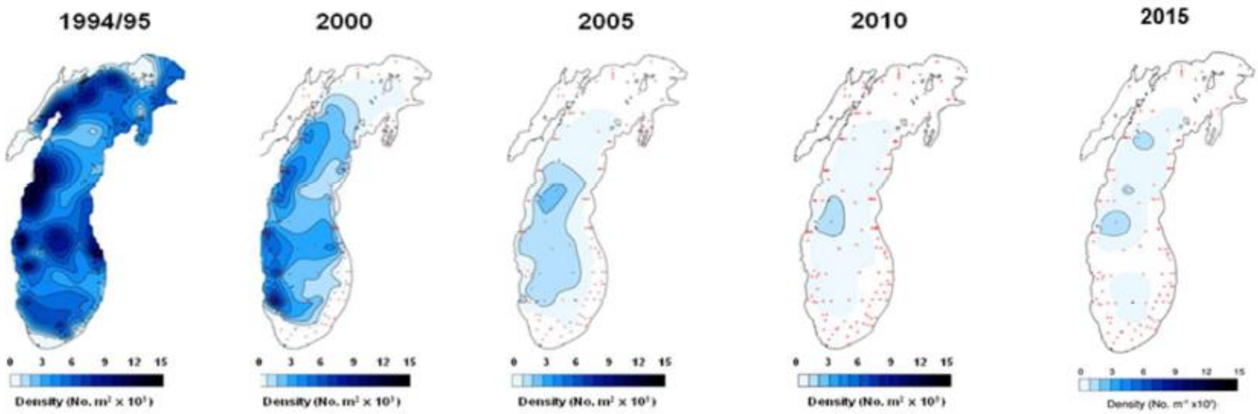



Offshore zooplankton at Muskegon has remained at about the same levels the past decade but remains lower than observed in the 1980s and 1990s.

# Dreissenid Mussels in Lake Michigan- Density



# Diporia Density in Lake Michigan




# Invasive mussels challenge commercial whitefish fishing

Denise Purvis' family began fishing the waters of northern Lake Huron off Manitoulin Island in 1882. Over the years their operation came to expect the unpredictability of a livelihood dependent on the ability to capture wild fish. Purvis came back to the family business in the mid-1990s after college. Her return home coincided with the arrival of zebra and quagga mussels into the Great Lakes. The mussels have since become synonymous with the problem of invasive species in the Great Lakes. They've colonized the lakes and negatively impacted their ecology.

For Purvis and the dwindling number of Great Lakes commercial whitefish fishers, the fishery has fallen on hard times. Whitefish have been in decline across much of lakes Michigan and Huron, and many scientists and fishers suspect part of the reason is linked to the effects the mussels have had on the lake's food web. "The health of our fishery in northern Lake Huron is not healthy whatsoever," Purvis said.

## Lake whitefish decline

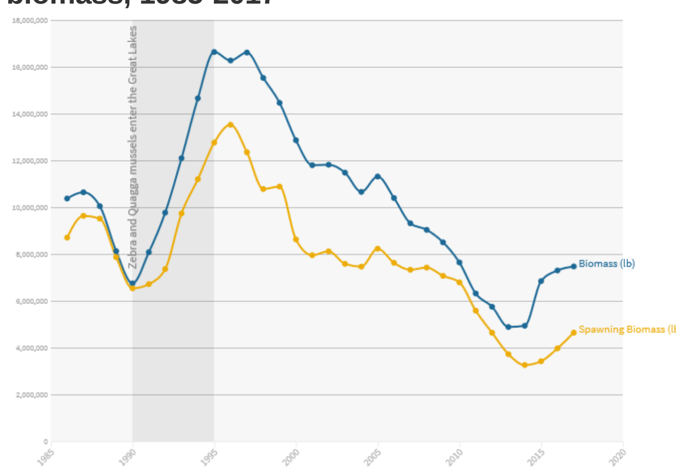
Dave Caroffino is a fisheries biologist in Charlevoix, working in the tribal coordination unit in the fisheries division of the Michigan DNR. Since 1985, the MDNR has been collecting data on whitefish in lakes Michigan, Huron and Superior as part of a legal settlement between the state of Michigan, the federal government and tribal governments.

"The vast majority of the monitoring data starting in 1985 comes from agency staff collecting biological samples from the fish caught by commercial fishers," Caroffino said. "That data wasn't used for a lot of stuff. It was kind of general patterns, general trends."

But now, this decades-long effort is showing clear declines in whitefish; a decline that coincided with the expansion of invasive mussels in the lakes.

MDNR estimates of total whitefish biomass in northern Lake Huron dropped 45% from their peak in 1997, when the mussels began to widely colonize the lakes, through 2017, when quagga mussels had succeeded in covering much of the lake bottom.

## Changes in northern Lake Huron whitefish biomass, 1985-2017



## Invasive mussels and whitefish

Whitefish are native to the Great Lakes. They are bottom feeders, foraging for invertebrates like diporeia, a relative of shrimp that grow to less than 1 centimeter in length. The diporeia live in the bottom sediment of the lakes, feeding on material in the sediments as well as plankton that settles to the lake bottom. Since the 1990s,diporeia numbers have plummeted in most of the Great Lakes. Because mussels are filter feeders, pulling plankton out of the water, some think the invasives caused the disappearance of diporeia and declines in whitefish.

Steve Pothoven is a fishery biologist at the NOAA's Lake Michigan Field Station in Muskegon. He has studied the relationship between diporeia and whitefish. "Lake Michigan had a spring phytoplankton bloom that would feed the diporeia," Pothoven said. Now, mussels feed on the plankton all winter.

In Lake Michigan "that spring bloom is gone now, and that is thought to be a consequence of the mussels," he said. Is this enough evidence to blame the loss of diporeia and drop in whitefish numbers on the mussels? "It seems like it should be really straight forward, if you look at a food web, but it's been really complicated," Pothoven said. In an ecosystem as complex as the Great Lakes, exceptions to the rule can always be found.

To understand what's happening on the lake bottom, hundreds of feet below the surface, scientists use a ponar grab sampler: a set of metal jaws lowered to the bottom to snap up sediment and the benthos. Researchers sample 150 sites in Lake Michigan and 100 in Lake Huron every five years.

Elgin oversees sampling in southern Lake Michigan. "We survey 46 sites in the southern third of Lake Michigan and we see them (diporeia) in only one site," she said. That site — B4 — historically had thousands of diporeia in a grab. "Now we get excited if we see 20," she said.

Quagga mussels are never in short supply for Elgin. They've even driven zebra mussels out of Lake Michigan and now carpet the lake bottom. She echoes Pothoven in noting the difficulty in laying the blame for diporeias' collapse solely at the foot of the mussels.

"You had diporeia decline in Lake Huron at the same time as Lake Michigan, when the mussel numbers were very low in Lake Huron," Elgin said. "Also, Lake Superior has low food levels, but they have healthy diporeia populations."

## Commercial fishers see problems

Jamie Massey has been fishing northern Lake Huron out of St. Ignace for 44 years. He sees a link between the mussels, diporeia and whitefish. In the past "we'd lift our trap nets and see diporeia all over the deck of the boat and hanging all over the trap nets," Massey said. Before the mussels, the water was cloudy and full of life, he said. "We watched them (the mussels) come in, filter everything out, and slowly but surely we could see the diporeia disappear and the health of the whitefish deteriorate day by day," he said.

With diporeia scarce, whitefish began to eat quagga mussels, though they're not as nutritious. Fishers began catching fewer, thinner, less commercially valuable whitefish.

## Slime rises in the lakes

As the mussels pulled plankton out of the water, it resulted in dramatic clearing of lakes Michigan and Huron. This allowed sunlight deeper into the lakes, opening new habitats for cladophora, an algae that grows in stringy masses on lake bottoms where fishers like to place their nets. When cladophora showed up in their nets instead of fish, fishers were surprised.

Denise Purvis recalled colleagues fishing in southern Lake Huron telling her about slime in their nets. This was before cladophora became an issue for Purvis in northern Lake Huron. "It was the first change in the whitefish fishery" from the mussels, she said.

With cladophora now present around Manitoulin Island, Purvis' crew has to carefully consider when to go fishing. "We had to change our fishing: like the way we fished, and what we fished and where we fished," she said. On windy days, when the lake is choppy, cladophora gets picked up and trapped in their nets. It can be so bad they've got to pull up the nets when they see a windy day coming, losing fishing days. The cladophora can wreck their fishing gear.

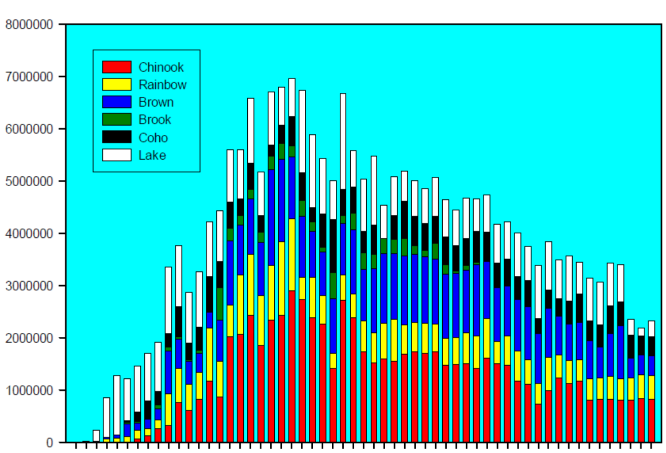
"We used to be able to fish through all that, and go out when it's rough," Purvis said. Purvis is lucky. The company also sells fish wholesale to buyers such as large grocers. But changes in Lake Huron, from the mussels and diporeia, to cladophora and an imbalance in predator fish numbers, have altered operations at Purvis Fisheries.

"What's changed for us to stay in business, now we have to buy a lot of fish that we never bought before," Purvis said. "Now I spend my whole time in the spring, right now, looking to people to buy fish. I have a harder time keeping employees and keeping those guys employed. "My company in the end can still make money," she said, but her employees who do the fishing can't.

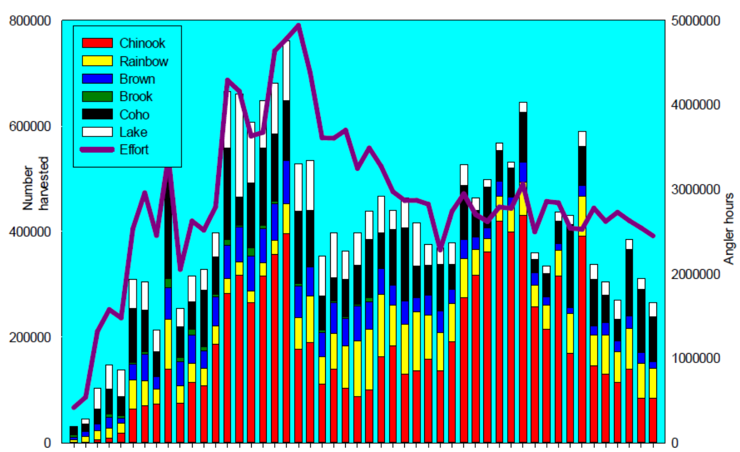
**Gill nets filled with quagga mussels and cladophora algae cover the bottom and side of a commercial fishing boat.**

# Wisconsin salmon and trout stocking and harvest information

## Wisconsin DNR
## Lake Michigan Salmon and Trout stocking from 1963 to 2019




## Wisconsin
## Lake Michigan Salmon and Trout harvest and effort,1969 to 2018



# Summary Predator/Prey Ratio Analysis for Chinook Salmon/Alewife

## Introduction:

Maintaining balance between predator and prey populations is critical for successful fisheries management. In Lake Michigan, several top predators contribute to important fisheries including native lake trout along with non-native Chinook salmon, Coho salmon, rainbow trout and brown trout. These predators are sustained through stocking and wild production, and stocking level adjustments to balance overall predator populations with available forage is a major component of ongoing fisheries management efforts. The Predator/Prey Ratio Analysis for Chinook salmon and alewife in Lake Michigan is a recently developed approach to help guide fisheries management decisions for stocking.

Lake Michigan historically has experienced wide fluctuations in populations of fish predators and prey, due largely to fishing exploitation, changes in habitat quality, and invasive species. Notably, native lake trout populations collapsed during the 1950s partly from overfishing and predation by invasive sea lamprey, and subsequently (without a top predator) invasive alewife populations greatly expanded. Sea lamprey control efforts were implemented in the late 1960s and, combined with abundant alewife forage, created opportunity to successfully stock top predators. Fisheries managers began stocking native lake trout along with non-native Chinook salmon, Coho salmon, rainbow trout and brown trout to utilize available forage and create diverse fishing opportunities. These stocking efforts continue today, and several past stockinlevel adjustments have been implemented to help sustain a balanced and diverse fishery.

Non-native Chinook salmon and alewife are important components of Lake Michigan's recent ecosystem and fishery, but not without challenges. In Lake Michigan, Chinook salmon are a dominant and generally mid-water predator whose diet consists mostly of alewives, a generally mid-water prey fish. Chinook salmon and alewives together support an important recreational fishery, and Chinooks are a preferred and targeted species for many recreational and charter anglers. During the late 1980s to early 1990s, this Chinook salmon population and fishery declined (despite high stocking levels) due to mortality from bacterial kidney disease and associated nutritional stress from relatively low alewife abundance. More recently, predator/prey and energy dynamics in Lake Michigan have changed due to bottom-up ecosystem effects (by invasive mussels) and top-down predation effects (by stocked and wild predators). Invasive filter feeding mussels are effective consumers of microscopic plants and animals, which is the same food that alewife and other forage fish eat. Naturally produced Chinook salmon are common, and in combination with stocked Chinooks (plus other trout and salmon species) these predators exert high predation pressure on alewife and other prey.

A "Red Flags Analysis" and the recently developed and implemented "Predator/Prey Ratio Analysis" were both designed to evaluate predator/prey balance and to provide guidance for stocking decisions. The Red Flags Analysis used from 2004-2011 looked at 15-20 individually plotted datasets and evaluated deviations from historic trends to trigger discussions about stocking level adjustments. A critical review of the Red Flags Analysis was completed during 2012 and subsequently a new approach called the Predator/Prey Ratio (PPR) Analysis was developed. These previously mentioned references provided detailed accounts of the Red Flags Analysis and development of the PPR Analysis (e.g., methods, pros, cons, etc.) but the intent of this document herein is to only summarize the PPR Analysis and provide results through 2017.

## Predator/Prey Ratio:

The Predator/Prey Ratio Analysis consists of a Predator/Prey Ratio (PPR) for Chinook salmon/alewife and five auxiliary indicators. The PPR is a ratio of total lake-wide biomass (i.e., weight) of Chinook salmon (≥age 1) divided by the total lake-wide biomass of alewives (≥ age 1**; Fig 1a).** A high PPR value indicates too many predators with insufficient prey and a low value suggests too few predators with surplus prey.

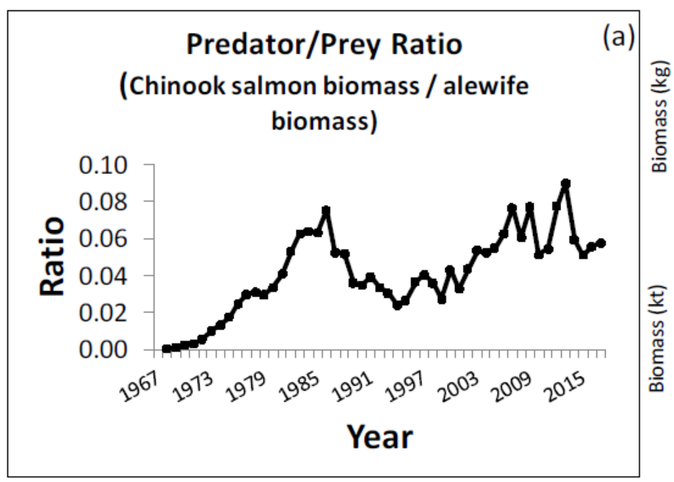
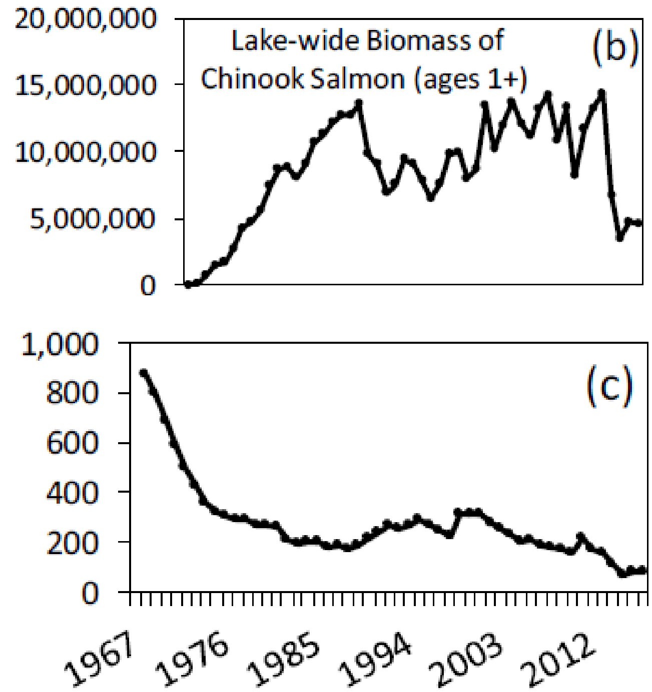



**Fig 1-Predator/Prey Ratio calculated for Chinook salmon and alewife in Lake Michigan (a) and separate components of this ratio plotted individually as Chinook salmon biomass (b) and alewife biomass (c). (Note: figures b and c have different scales for the y-axis.)**

The PPR is a fairly simple descriptor of balance between Chinook salmon and alewives, however the underlying methods are comprehensive and use statistical catch-at-age analysis that incorporate lake-wide datasets from several surveys and agencies (Table 1). Generally, SCAA models estimate fish abundance based on numbers of fish harvested, age of fish harvested, recruitment information (i.e., numbers of fish produced naturally and numbers stocked), and other factors. This modelling process can be explained simply as a mathematical approach to provide the most likely answer to the question of how many fish must have been present to produce the observed data. For the PPR, numbers of Chinook salmon lake-wide are estimated for each age class using a SCAA model, and these abundance estimates are then multiplied by age-specific average weights and summed to calculate total lake-wide biomass (**Fig 1b**). For example:

(abundance of age 1 Chinook × avg. weight of age 1 Chinook) + (abundance of age 2 Chinook × avg. weight of age 2 Chinook) +(etc. for each age class) = total lake-wide Chinook biomass.

A similar process is used to estimate alewife biomass (**Fig 1c**). The alewife SCAA also incorporates consumption of alewives by several predator species including lake trout, rainbow trout, brown trout and Coho salmon, in addition to Chinook salmon.




| *Lake-wide datasets used for Chinook salmon SCAA: | *Lake-wide datasets used for alewife SCAA: |
|---|---|
| • Number of Chinooks stocked<br>• Percent wild for age-1 Chinooks (mass marking)<br>• Number of Chinooks harvested (charter & creel)<br>• Targeted salmonine boat fishing effort (charter & creel)<br>• Age & maturity of Chinooks harvested (creel & mass marking)<br>• Average weight of Chinooks harvested (creel & mass marking) | • Alewife abundance (trawl & hydro-acoustic)<br>• Alewife proportion by age (trawl)<br>• Numbers of salmon and trout stocked<br>*(*Contributing agencies for Chinook & alewife SCAA data include: Illinois Dept. of Natural Resources (DNR), Indiana DNR, Michigan DNR, U.S. Fish & Wildlife Service, U.S. Geological Survey, & Wisconsin DNR.)* |

**Table 1-Lake-wide datasets used for Chinook salmon and alewife statistical catch-at-age analyses for the PPR**

## Reference Points:

Specific values or reference points have been established to help interpret the PPR. An established target of 0.05 represents a balanced Chinook salmon/alewife ratio, while an established upper limit of 0.10 is a high and unbalanced ratio **(Fig 2).** Several criteria were used to develop these reference points, including examples from other lakes, literature reviews, and risk assessments. For example, the Chinook salmon population in Lake Ontario was relatively stable from 1989-2005 and during this period the average ratio (for Chinook salmon and alewife) was estimated to be 0.065.

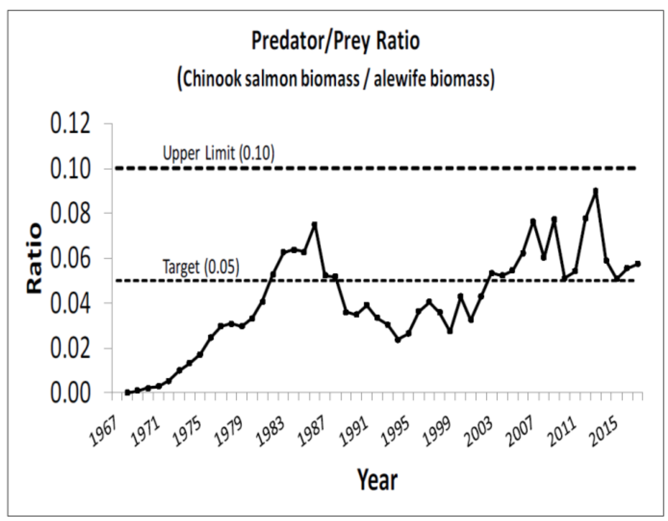
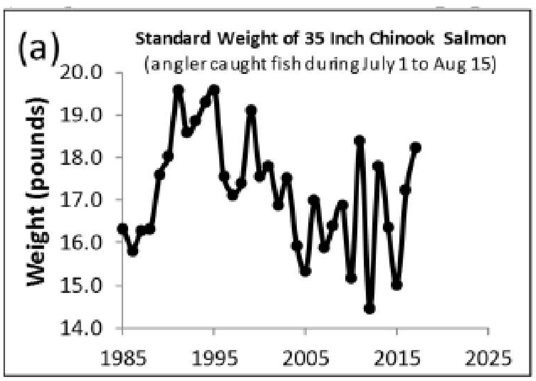


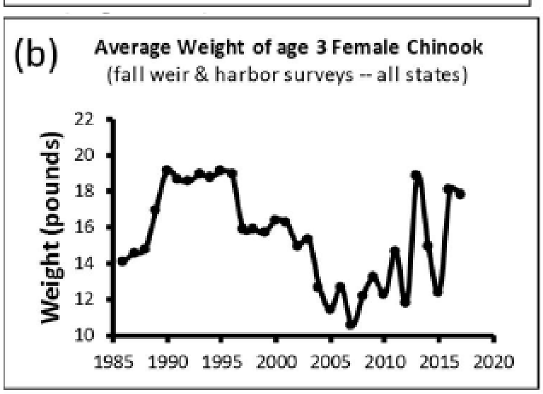

**Fig 2-Predator/Prey Ratio calculated for Chinook salmon and alewife in Lake Michigan (through 2017) with upper limit (0.10) and target (0.05) reference points**

In Lake Huron, the alewife population collapsed in 2003 following a five year period during which Lake Huron's estimated PPR averaged 0.11 (estimated at 0.12, 0.13, 0.11, 0.11, and 0.10 per year respectively for 1998-2002) and subsequently the Chinook salmon population collapsed in 2006. From published scientific literature, it is generally accepted there is a 10% efficiency in converting food to body tissue, so it would take 10 pounds of alewife to produce 1 pound of Chinook salmon (i.e., 1 pound Chinook ÷ 10 pounds alewife = 10% or 0.10). Risk levels (i.e., potential to collapse the alewife population) acceptable to fishery managers and stakeholders were also considered from previous public meetings. Although the alewife SCAA incorporates consumption of alewives by several salmonid species, the current predator model includes only Chinook salmon, so another important consideration especially as the PPR increases is that less alewife are available as forage for other predator species.

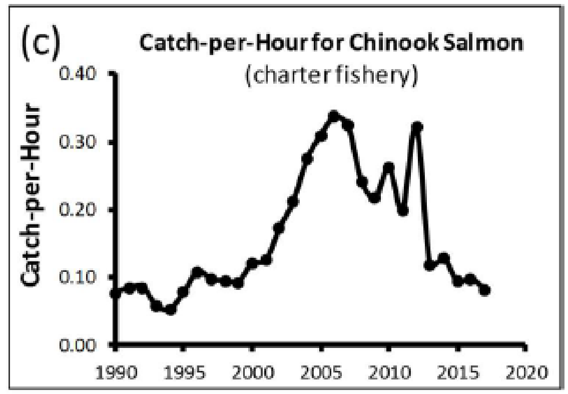
## Auxiliary Indicators:

Five additional datasets or "auxiliary indicators" were established to compliment the PPR and provide additional feedback on predator/prey balance (Figure 3). These auxiliary indicators are plotted as individual datasets through time (without targets or upper limits) to evaluate trends and recent conditions. Auxiliary indicators are calculated with lake-wide datasets from several agencies and include:




1) standard weight of 35 inch Chinook salmon from angler caught fish during July 1 to Aug 15 (**Fig 3a**),
2) average weight of age 3 female Chinook salmon from fall weir and harbor surveys **(Fig 3b)**,
3) catch-per-hour for Chinook salmon from charter boats **(Fig 3c)**,
4) percent composition of angler harvested weight by species (**Fig 3d**), and
5) age structure of the alewife population (**Fig 3e**).



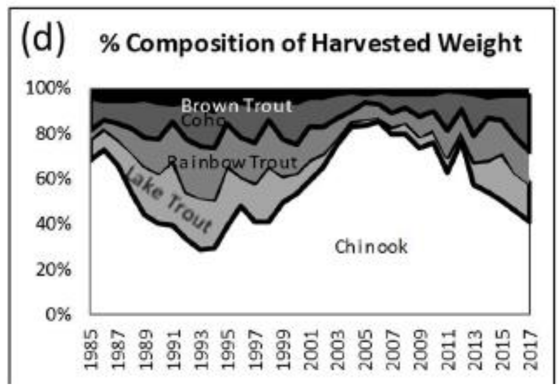
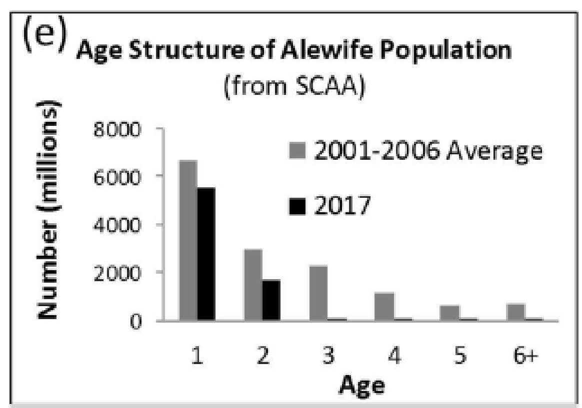




**Fig 3-Auxiliary indicators calculated with lake-wide datasets to compliment the Predator/Prey Ratio and provide additional information to guide fisheries management decisions.**

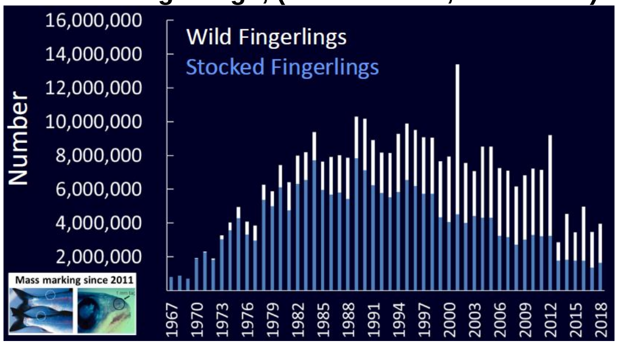



## Conclusions:

Overall, the PPR Analysis is a relatively new and focused approach to evaluate balance between a top predator (Chinook salmon) and its primary prey (alewife) that will provide guidance for future stocking decisions and should help achieve overall management goals of a balanced and diverse fishery within Lake Michigan's complex and dynamic ecosystem.

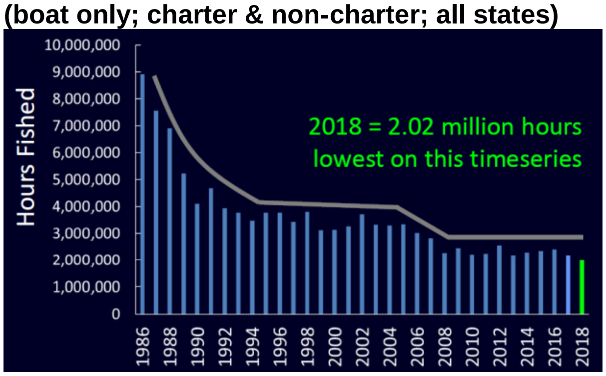
# Predator/Prey Ratio Analysis & Salmonid Working Group Updates

### Chinook Fingerlings, (stocked/wild; 1967-2018)

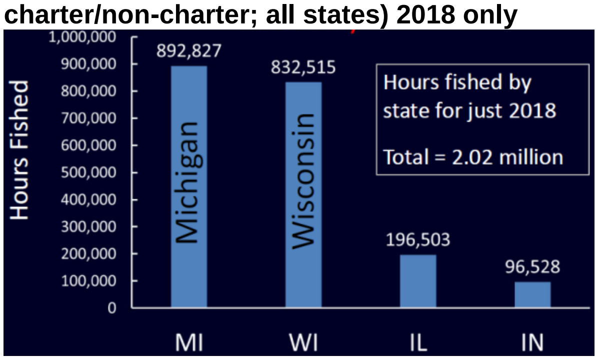



Recent estimates of % wild at age 1 have consistently been around 50% (e.g., high 2013 = 64.8%; low 2014 = 38.6%; 2018 = 60.4%)

### Targeted Angler Effort for Salmon/Trout Lake MI (boat only; charter & non-charter; all states)



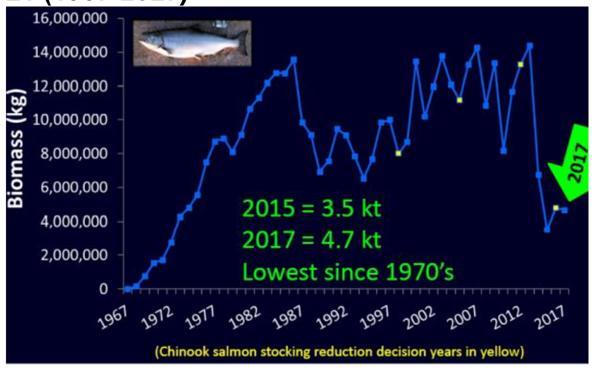

### Angler Effort for Salmon/Trout Lake MI (boat only; charter/non-charter; all states) 2018 only




### 2018 Estimated contributions of wild Chinook salmon to fisheries in Lakes Michigan and Huron

68% of Chinook salmon (all ages) recovered in Lake Michigan and 68% recovered in Lake Huron were without a fin clip and presumed to be wild, consistent with values from the past several years. Estimated production of wild Chinook salmon from the 2017 year class was greater than the weak 2013 and 2015 year classes and was just below the level observed from most year classes from the mid- to late-2000s.

### Total Lake-wide Biomass of Chinook Salmon Ages ≥1 (1967-2017)




### Total Lake-wide Biomass of Alewife Ages ≥1 (1968-2017)


### 2018 Tagging and marking activities

- 3.7 million Lake trout, 2.9 million steelhead, & 2.4 million Chinook salmon were fin clipped in 2018; most of the lake trout and steelhead, and 1.0 million of the Chinook salmon, were also coded-wire tagged.
- 0.6 million each of Atlantic salmon, brown trout, brook trout, and splake were also marked in 2018
- 98.5% of Chinook salmon, lake trout, and steelhead were successfully clipped or tagged in the hatcheries
- Throughputs averaged 8,764, 7,564, and 7,424 fish/hr for Chinook salmon, lake trout and steelhead respectively.

### 2018 Estimated contributions of wild lake trout to fisheries in Lakes Michigan and Huron

- 65% of lake trout recovered in Lake Huron had no fin clip and were presumed wild
- 30% of lake trout recovered in Lake Michigan had no fin clip and were presumed wild, and comprised a greater percentage of the catch in southern and central areas
- Catch per unit effort of wild lake trout increased over time in Lake Huron and southern Lake Michigan

# Great Lakes Angler Diet Flyer

## HELP YOUR GREAT LAKES FISHERY

GREAT LAKES ANGLER DIARY

### WHAT'S THE GREAT LAKES ANGLER DIARY?

A citizen science project that collects information from anglers to help paint a clearer picture of the health of Great Lakes fisheries.

### HOW DOES IT WORK?

- Access the web-based app from a computer or mobile device.
- Use the app to record information from fishing trips. The more you record, the more useful your data will be!
- Complete a short end-of-year survey.

### HOW DO I JOIN?

- Sign up by emailing *GLanglerdiary@gmail.com*.
- Receive a unique Volunteer Number via email.
- Register online at *www.GLanglerdiary.org*.

### FUNDING

Funded by donations from Detroit Area Steelheaders.

### WHAT INFORMATION CAN I RECORD?

Record as much or as little as you'd like during the fishing season. Here are some examples of ways you might use the app:

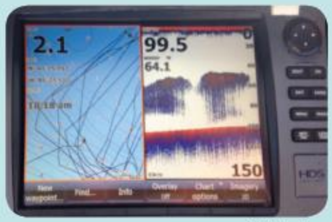
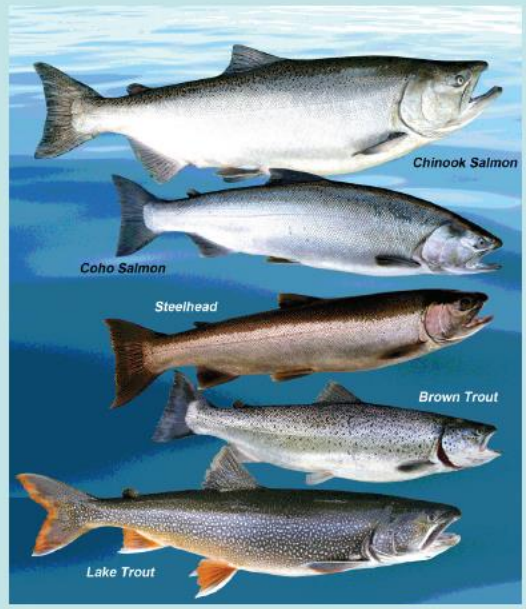



Photo: Joe Foy

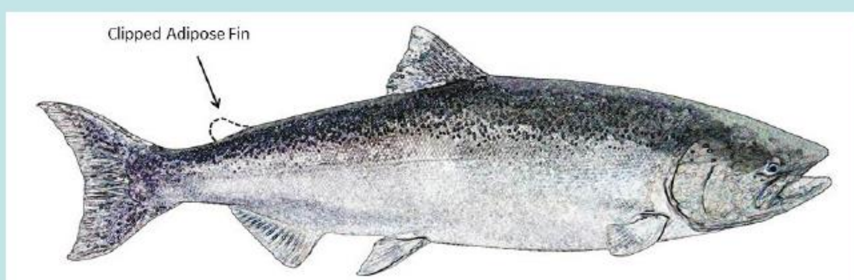
Upload bait ball images to show when and where baitfish are found.

Photo: Frank Krist

Collect fish stomachs for diet study in Lake Huron and Lake Michigan.




Record catch details for all trout and salmon species, plus cisco, walleye, musky, and sturgeon.




Check Chinook salmon for adipose fin clips to determine % Wild.

### CONTACT

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