Summary of the Predator/Prey Ratio Analysis for Chinook Salmon and Alewife in Lake Michigan

Draft updated September 10, 2024 with standard results that include data through 2023

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. 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 was developed 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, changes in predator stocking rates, disease outbreaks, and invasive species. Notably, lake trout populations collapsed during the 1950s due to a combination of predation by invasive sea lamprey and overfishing. 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 lake trout along with 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 stocking level adjustments have been implemented to help sustain a balanced and diverse fishery.

Chinook salmon and alewife are important components of Lake Michigan's current ecosystem and fishery but maintaining a predator-prey balance is challenging. In Lake Michigan, Chinook salmon are a dominant predator whose diet consists mostly of alewives, an important 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. 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, which serve as the base of the food web. Naturally produced Chinook salmon are common and, in combination with stocked Chinook salmon and other trout and salmon species, these predators exert high predation pressure on alewife and other prey.

The currently used "Predator/Prey Ratio Analysis" and its precursor, a "Red Flags 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 (Clark et al. 2012), and subsequently led to the development and implementation of the Predator/Prey Ratio (PPR) Analysis approach (Clark et al. 2014; Jones et al. 2014; Lake MI SWG et al. 2014). 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 2023.

Predator/Prey Ratio:

The Predator/Prey Ratio Analysis consists of a Predator/Prey Ratio (PPR) for Chinook salmon/alewife and six secondary 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; Figure 1). A high PPR value indicates too many predators with insufficient prey and a low value suggests too few predators with surplus prey. 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 (SCAA; Tsehaye et al. 2014a; Tsehaye et al. 2014b) 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 (Figure 1). 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 (Figure 1). 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.

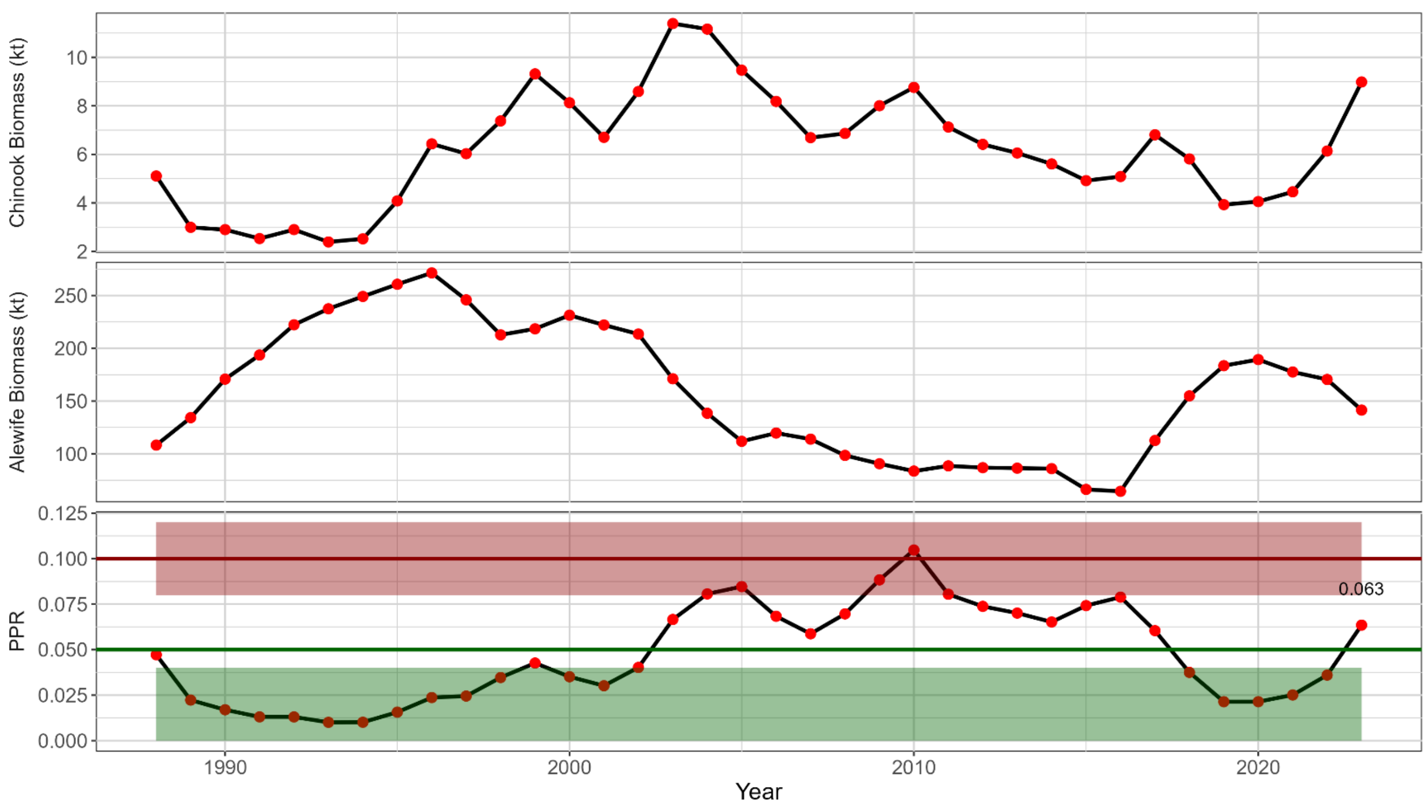

Figure 1. Predator/Prey Ratio (PPR) calculated for Chinook salmon and alewife in Lake Michigan (bottom) and separate components of this ratio plotted individually as Chinook salmon biomass (top) and alewife biomass (middle). Shaded areas and horizonal lines correspond to upper 0.1 (red) and lower 0.05 (green) management reference points. Note that panels have different vertical axis scales.

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

*Lake-wide datasets used for Chinook salmon SCAA:	*Lake-wide datasets used for alewife SCAA:
• Number of Chinook salmon stocked	• Alewife abundance (trawl & hydro-acoustic)
• Percent wild for age-1 Chinooks (mass marking)	• Alewife proportion by age (trawl)
• Number of Chinooks harvested (charter & creel)	• Numbers of salmon and trout stocked
• Age & maturity of Chinooks harvested (creel & mass marking)	
• Average weight of Chinooks harvested (creel & mass marking)	*(*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.)*

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 (Figure 1). Additional guidance and management action zones are provided by the Lake Michigan Committee (LMC 2018). 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. 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 approximately 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—used to derive the "prey" component of the PPR—incorporates consumption of alewives by several salmonid species, the current "predator" component of the PPR includes only Chinook salmon. Therefore, another important consideration under increasing PPR scenarios is that fewer alewives will be available as forage for non-Chinook predator species.

Recent Model Updates:

Numerous SCAA model updates were incorporated beginning in 2022 (data through 2021) with resultant changes on PPR results. Several of these updates were simply necessary to handle 2020 COVID-19 marking/sampling restrictions. However, more substantive changes in data input and/or model structure in the Chinook SCAA and alewife SCAA were aimed at improving accuracy of PPR estimates by better resolving data series which have lacked sufficient data or been held constant through time. For instance, reliance on both age-1 and age-2 Chinook salmon (formerly just age-1) for calculations of proportion wild and movement from Lake Huron improved historically low sample sizes owing to the higher selectivity of age-2 fish in the sport fishery. Likewise, decreased biomass of Chinook salmon since the early 2000s has resulted in proportionally greater consumption by lake trout and steelhead. Incorporating time-varied consumption and population dynamics of lake trout and steelhead (formerly fixed values since 2008) has improved recent estimates of alewife consumption and subsequent scaling of abundance and biomass. Updates to model inputs using data through 2023 indicated increased Chinook salmon biomass and declining alewife biomass relative to 2022. Corresponding to these changes, the PPR increased from 0.036 (2022) to 0.063 (2023; Figure 1).

Secondary Indicators:

Six additional datasets were established to compliment the PPR and provide supplemental feedback on predator/prey balance (Figure 2). These indicators are plotted as individual datasets through time (without targets or upper limits) to evaluate trends and recent conditions. These 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 (Figure 2a),
2. average weight of age-3 female Chinook salmon from fall weir and harbor surveys (Figure 2b),
3. catch-per-hour for Chinook salmon from charter boats (Figure 2c),
4. percent composition of angler harvested weight by species (Figure 2d),
5. lake-wide biomass of alewife (3e), and
6. age structure of the alewife population (Figure 2f).

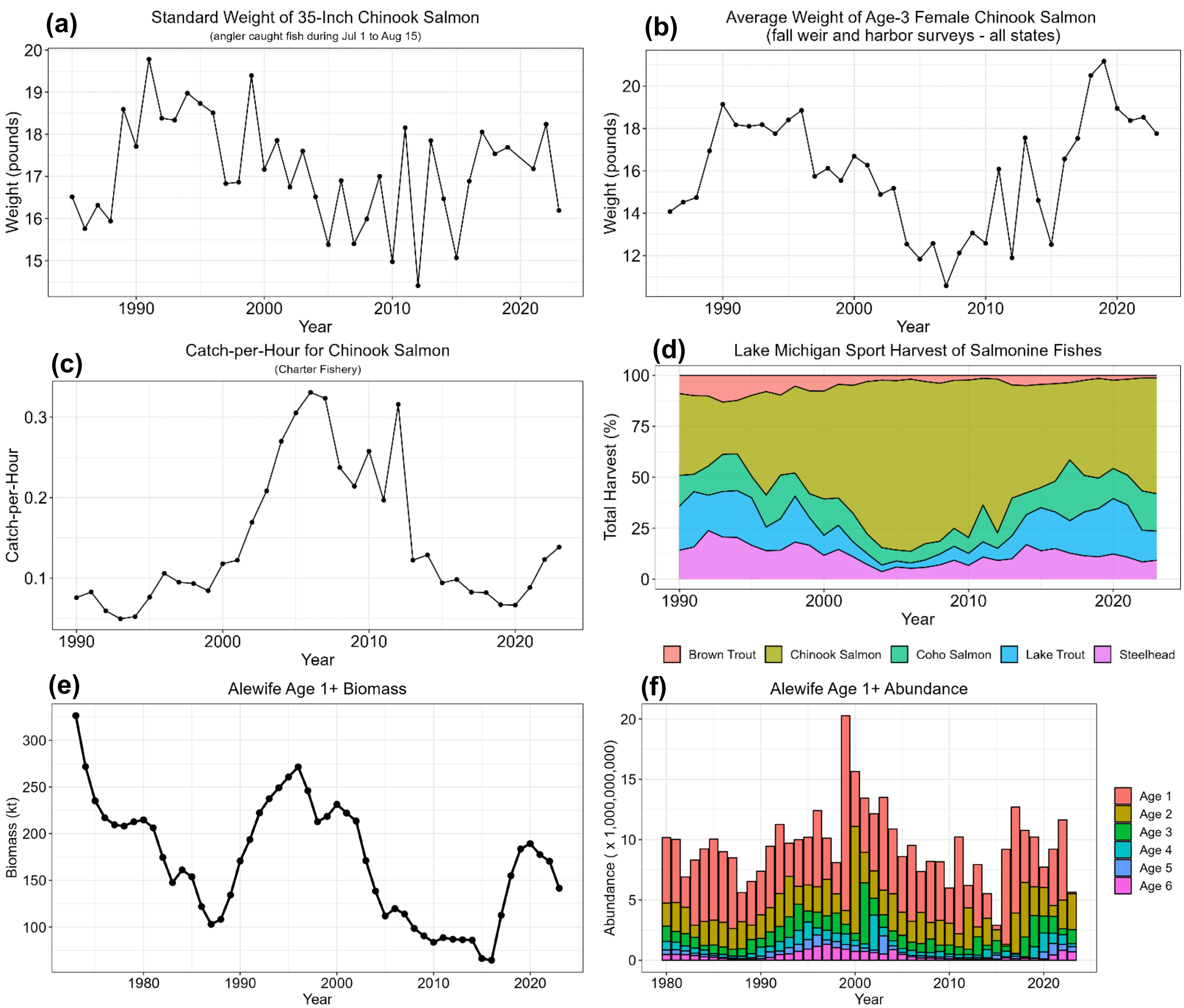

Figure 2. Additional indicators calculated with lake-wide datasets through 2023 to compliment the Predator/Prey Ratio and provide supplemental information to guide fisheries management decisions.

References:

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