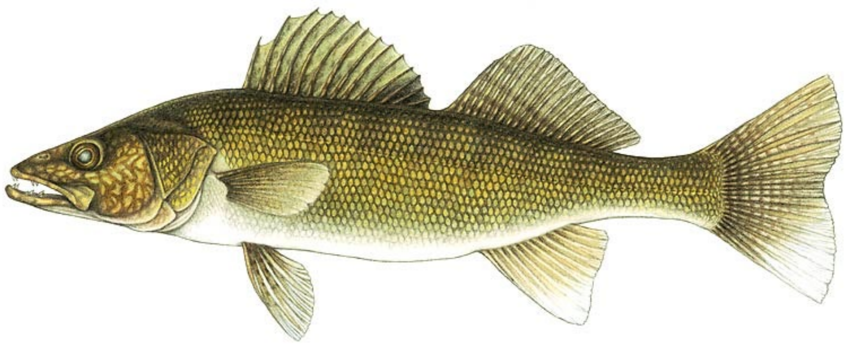
Report for 2020 by the

LAKE ERIE WALLEYE TASK GROUP

March 2021



Prepared by members:

Todd Wills	*Michigan Department of Natural Resources (MDNR)*
Pascal Wilkins	*New York Department of Environmental Conservation (NYDEC)*
Matt Faust (co-chair)	*Ohio Department of Natural Resources (ODNR)*
Mark DuFour	*Ohio Department of Natural Resources (ODNR)*
Ann Marie Gorman	*Ohio Department of Natural Resources (ODNR)*
Megan Belore	*Ontario Ministry of Natural Resources and Forestry (OMNRF)*
Andy Cook	*Ontario Ministry of Natural Resources and Forestry (OMNRF)*
Stephen Marklevitz (co-chair)	*Ontario Ministry of Natural Resources and Forestry (OMNRF)*
Tom MacDougall	*Ontario Ministry of Natural Resources and Forestry (OMNRF)*
Yingming Zhao	*Ontario Ministry of Natural Resources and Forestry (OMNRF)*
Mike Hosack	*Pennsylvania Fish and Boat Commission (PFBC)*

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***Note**: Data and management summaries contained in this report are provisional. Every effort has been made to ensure their correctness. Contact individual agencies for complete state and provincial data.*

Charges to the Walleye Task Group, 2020-2021

The charges from the Lake Erie Committee's (LEC) Standing Technical Committee (STC) to the Walleye Task Group (WTG) for the period of April 2020 to March 2021 were to:

1. Maintain and update the centralized time series of datasets:
    a. Required for bi-national population models and assessment and
    b. Produce the annual Recommended Allowable Harvest (RAH)
2. a. Maintain working knowledge of the most current academic and agency research related to Lake Erie walleye population assessment and modeling including estimating and forecasting:
    - Abundance
    - Age/Size/Spatial stock structure (migration rates)
    - Recruitment, and
    - Mortality (M)

   b. Provide critical evaluation and guidance for incorporating new research into Lake Erie walleye management to produce the most scientifically sound and reliable population models.
   c. Support analysis and review of Walleye Management Plan and assessment models for potential 2024 renewal.

Review of Walleye Fisheries in 2020

COVID19 impacts to the fishery and assessments
In 2020, Lake Erie's Walleye fisheries and agency assessments were impacted by the COVID19 pandemic. Below are brief jurisdictional summaries of COVID19 impacts to fisheries and assessment including agency-specific solutions for missing data.

Ontario: The Ontario commercial and recreational fisheries remained open during the pandemic. However, between March and May market demand for Walleye slowed and subsequently reduced commercial fishery harvest during the first half of the year (January – June) by approximately 29% from 2019 levels. This was followed by a 67% increase from 2019 levels in the second half of the year (July-December). Overall, the 2020 Ontario commercial harvest in pounds of fish was up 13% from 2019. The sport fishery remained open but there were several restrictions that limited access to the fishery including the closure of many boat ramps (April to May) and social distancing restrictions for boat and shore anglers.

The Ontario Partnership gill net survey and Ontario's contribution to the west basin interagency trawl survey were unimpacted by COVID19 restrictions. In Ontario's commercial catch sampling program, no sampling occurred from mid-March to June, which resulted in a lack of data to estimate harvest-by-age. To address this missing data, Ontario extended the first sampling time unit (strata) by one month. This period would have normally included fish sampled from March to June 30, with the second sampling period extending from July 1 to November. In 2020 the first sampling period included samples collected in March and July, with a sampling gap from April to June. The second period started Aug 1 and ended in November. When this solution was tested using 2017- 2019 data the weighted-average of age-specific composition differences was +8% in 2019 with a three-year average of +10%.

Ohio: The Ohio sport fishery remained opened with no boat ramp closures in 2020 but the charter boat fishery was functionally shut down from March to mid-May due to state imposed social distancing restrictions. The Ohio fall gillnet survey and contribution to the interagency trawl survey were unimpacted. Ohio's creel survey did not occur during April to June, and not all areas were sampled. This resulted in unsampled spatial and temporal sampling units (i.e., strata) that are used to calculated effort and harvest estimates. To compensate for this missing data, proportional expansion matrixes were developed to extrapolate effort and harvest data from sampled strata to the un-sampled strata in the west and central basins. For effort, proportional expansion factors were derived from the average effort observed in 2018 and 2019. For harvest, proportional expansion factors were derived from 2019 data only. This combination of data extrapolation was selected because it produced the lowest deviation from the observed estimates when tested using 2017-2019 data.

Social distancing measures also meant that Ohio was unable to collect biological data during the 2020 creel survey. These data are used to calculate harvest-at-age estimates. The solution for these missing data was to use biological data collected through cleaning stations for the early part of the year and through the fall gillnet index survey for the later part of the year. After compensating for the 15 inch minimum size limit, the age composition from these other age data sources were similar to the age composition in previous years creel surveys. When the combined Ohio solutions for missing data were evaluated using 2017-2019 data, total annual harvest estimate differed by +17% for 2019 and with a three-year average difference of +23%.

Michigan: The Michigan sport fishery remained open during the pandemic but had various restrictions including boat ramp closures that impacted access to the fishery. With assistance from the US Geological Survey, the Michigan fall gillnet survey was completed as scheduled. Michigan's creel survey did not occur between April and May and no biological data were collected. To compensate for missing effort data, linear regression was used to estimate April and May effort from the observed June to October 2020 effort. This regression approach used 1997-2019 creel data. The average monthly harvest observed from June to October was extended to April and May. A regression approach using 1997- 2019 data was also explored but produced the same results. For the missing biological data, Michigan used linear regression analysis to establish the age-specific composition relationships between the Michigan fall gillnet index survey and the sport fishery creel using 1997-2019 data, then used 2020 fall gillnet survey ages to estimate age-specific composition in the sport fishery. When the combined Michigan solutions were evaluated using 2017-2019 data the weighted-average of age specific composition differences was +32% in 2019 with a three-year average of +36%.

Pennsylvania: The sport fishery remained open with minimal social distances restrictions.

New York: The sport fishery remained open with minimal restriction, but the charter boat fishery was closed for May. There were no COVID19 impacts to New York's fall gillnet survey and creel surveys.

2020 fishery performance and characteristics

Fishery effort and Walleye harvest data were combined for all fisheries, jurisdictions and Management Units (MUs) (Figure 1) to produce lake-wide summaries. The 2020 total estimated lake-wide harvest was 6.381 million Walleye (Table 1), of which 5.845 million were harvested in the total allowable catch (TAC) area. This TAC-area harvest represents 57% of the 2020 TAC (10.237 million Walleye) and includes Walleye harvested in commercial and sport fisheries in MU 1, 2, and 3. An additional 0.537 million Walleye (8% of the lake-wide total) were harvested outside of the TAC area in MU 4&5 (Table 1). The estimated sport fish harvest of 2.542 million Walleye in 2020 represented a 25% decrease from the 2019 harvest of 3.390 million Walleye; harvest in 2020 was 11% above the long-term (1975-2019; Table 2).

The 2020 Ontario commercial harvest was 3.839 million Walleye lake-wide, with 3.609 million caught in the TAC area (Table 2). The 2020 Ontario angler estimates of harvest and effort were derived from the 2014 lake-wide aerial creel survey because angler creel surveys are not conducted annually in Ontario waters. It assumes 71,000 Walleye were harvested in Ontario within the TAC area during 2020, which is included in total Walleye harvest, but not used in catch-at-age analysis. Total harvest of Walleye in Ontario TAC waters was 3.680 million Walleye, representing 83% of the 2020 Ontario TAC allocation of

4.408 million Walleye. In 2020, the lake-wide Ontario commercial harvest was 9% higher than in 2019, and 82% above the long-term average (1976-2019; Table 2, Figure 2).

Sport fishing effort increased 4% in 2020 to total 4.257 million angler hours from 2019 (Table 3, Figure 3). Sport effort increased 46% in MU 2, and 115% in MU3 while there was a 30% decline in MU1 and 8% decline in MU4&5 (Table 3, Figure 4). The 2020 lake-wide average sport harvest per unit effort (HUE) of 0.58 Walleye/angler hour declined relative to 2019 and was 29% above the long-term (1975-2019) average of 0.45 Walleye/angler hour (Table 4, Figure 5). In 2020, the sport HUE declined across the lake (MU1 = -29%, MU2 = -34%, MU3 = -22%, MU = -46%) although it remained above long-term averages in all MUs (Table 4). Readers should be aware that 2020 estimates of sport harvest and effort are more uncertain than previous years due to impacts of COVID19 (see above).

The total commercial gill net HUE in 2020 (224.2 Walleye/kilometer of gillnet) decreased 9% relative to 2019 and remained above the long-term (1976-2019) lake-wide average (125.9 Walleye/kilometer of net; Table 4, Figure 5). Commercial gill net harvest rates decreased slightly in all areas (MU1 = -16%, MU2 = -7%, MU3 = -1%, MU4 = -17%) (Table 4). All MUs' HUE remained well above the long-term averages (Table 4).

Lake-wide harvest in the commercial fisheries was composed mostly of age 5 Walleye from the 2015 (54%) year class (Table 5; Table 6). Age 2 (2018 year class; 20%) and age 3 (2017 year class; 11%) fish were the next most harvested age groups. The mean age of fish caught in the 2020 commercial fishery increased slighted (0.8%) from 2019 and is 3% above the long-term average. (Table 7, Figure 6). Biological data required to estimate harvest-by-age was not collected for the Ohio and Michigan sport fisheries assessments due to COVID19. Ohio and Michigan estimates in Table 5 and Table 6 are presented only to document data populating the SCAA model. Due to the increased uncertainty of these estimates, we will not elaborate on age composition or average age of the sport harvest from Ohio and Michigan (Table 7). Available age composition data from Pennsylvania and New York showed the 2020 east basin (MU 4&5) sport fishery was dominated by age 5 (2015 year class; 39.7%), age 4 (2016 year class; 24.7%) and age 3 (2017 year class; 19%) Walleye. Mean age in the 2020 east basin (MU4&5) sport fishery increased 10% from 2019. The total mean age of sport and all gear harvest (Table 7, Figure 6) will not be presented for 2020 due to the biological sampling issues stemming from COVID19.

Statistical Catch-at-Age Analysis (SCAA): Abundance

The WTG uses a SCAA model to estimate the abundance of Walleye in Lake Erie from 1978 to 2020. The stock assessment model estimates population abundance of age 2 and older Walleye using fishery-dependent and fishery-independent data sources. The model includes fishery-dependent data from the Ontario commercial fishery (MU 1-3) and sport fisheries in Ohio (MU 1-3) and Michigan (MU1). The WTG model also includes data collected from three fishery-independent gill net assessment surveys (i.e., Ontario Partnership, Michigan, and Ohio).

2021 SCAA model configuration update

In 2016, Ohio switched from multifilament to monofilament gillnets[1] for their fall survey after completing several years (2007- 2008, 2010-2013) of comparisons between the two gear types (see Vandergoot et al. 2011 and Kraus et al. 2017*)*. This gear change posed two key challenges for the previous SCAA model configuration, which had been developed as part of the Lake Erie Percid Management Advisory Group (LEPMAG) process. First, the gear comparison study demonstrated different size selectivities between the multifilament and monofilament nets, and the gear change functionally represented the conclusion of Ohio's multifilament survey and start of a new monofilament survey. Second, the Ohio gear change was not accompanied with a similar gear change in the Michigan fall gillnet survey which decoupled the two surveys that were pooled in the model since 2011. The original purpose for combining these two surveys was low sample size and spatial coverage of the Michigan survey.

Michigan State University's Quantitative Fisheries Center (QFC) proposed a solution to address the Ohio gear change with modifications to the previous SCAA model. This solution indexed the older Ohio multifilament survey (1978 – 2015) to their new monofilament survey (2016- present) using the 6 years of gear comparisons and established Michigan's multifilament survey as an independent index.

This approach provided several benefits over using a simple gear conversion relationship (i.e., using a regression approach to predict age-specific multifilament catches from existing monofilament catches) and inputting converted survey data into the SCAA model. These benefits were:

1) Allowing the SCAA model to estimate new Ohio monofilament survey catchability (q) and population selectivities;
2) Minimizing the assumptions of relationships between the Ohio's monofilament and multifilament gear;
3) Reducing reliance and influence of the older Ohio multifilament gillnet survey over time as years of new Ohio monofilament gillnet survey data are acquired.

Despite general acceptance of QFC's proposed solution amongst WTG members there were three issues that required evaluation to determine a final model configuration. These issues were:

1) When should the previously combined Michigan and Ohio (MI-OH) multifilament gillnet surveys be split in the model:
    - Option 1: Split in 2016, when the Ohio gear change occurred, or
    - Option 2: Split in 1978, when the surveys began.

[1] In 2016, the ODNR switched to a monofilament gill net configuration. The ODNR's multifilament gill nets were 1,300 ft (396 m) in length, 6 ft (1.8m) deep, with thirteen 100-ft (30.5 m) panels consisting of mesh sizes from 2 to 5 inches (51-127 mm stretched) and twine diameter of 0.37mm. The monofilament gill nets are 1,200 ft long (366 m) by 6 ft deep (1.8 m) with twelve 100-ft (30.5 m) panels with mesh sizes from 1.5 to 7 inches (38–178) mm and twine diameter that varies with mesh size from 0.20 to 0.33 mm. Comparisons between these multifilament and monofilament index gill net configurations are described in Vandergoot et al. (2011) and Kraus et al. (2017).

2) Including Ohio's gear comparison data in the SCAA model increases its overall complexity and there was some concern it could result in unexpected model performance. Should the gear comparison be included in the model or should the gear change be treated as a hard transition from the Ohio multifilament to monofilament surveys?

3) Do SCAA model changes require a new management strategy evaluation (MSE)?

To evaluate issues 1 and 2, the WTG compared four models (Models 1-4, Table A1). A fifth model was included in this evaluation to examine the SCAA sensitivity to the Michigan multifilament survey. Performance for each model configuration was evaluated based on precision, retrospective pattern bias, and parsimony.

Precision: Precision was evaluated using the coefficient of variation (CV) of model outputs including: total abundance, fishing mortality rates, Ontario commercial fishery harvest, Ohio sport fishery harvest, Ontario Partnership survey CUE, F_{msy} and SSB_0 (Table A2 and Figure A1). Higher precision (i.e., lower CV) indicates less uncertainty in model outputs which would be particularly important when the population is at low abundance. At low abundances, P* reductions effecting recommended allowable harvest (RAHs) are less likely (unless abundance truly requires the reduction) in models with higher precision. The precision analysis demonstrated greater precision in the models with the MI-OH surveys split in 1978 (models 3 and 4) than models with MI-OH split in 2016 (models 1 and 2). Greater precision was also observed in models that includes the gear comparison data (models 1, 3, and 5) than models without (models 2 and 4)

Retrospective pattern bias: The retrospective pattern bias was evaluated using the Mohn's rho statistic for model outputs including total abundance, fishing mortality rates, Ontario commercial fishery harvest and catchability, Ohio sport fishery harvest and catchability, and Ontario Partnership survey CUE (Table A3, Figure A2). Negative patterns signified underestimation and potential for under exploitation, while positive patterns signified overestimation and potential for over exploitation. The retrospective pattern bias analysis demonstrated less retrospective trend bias in models with MI-OH split in 1978 (models 3 and 4) had than models with MI-OH split in 2016 (models 1 and 2). Less retrospective trend bias was also observed in models using catch comparison (models 1, 3, and 5) than models without (models 2 and 4).

Parsimony: Parsimony was evaluated by examining the numbers of parameters in the model and objective function components[2] (Table A4). These metrics were evaluated based on the principle that the simplest model with the minimum number of parameters needed to explain a given phenomenon should be used. Traditionally parsimony would be evaluated using Akaike Information Criterion (AIC) or Bayesian Information Criterion (BIC), however both these metrics required models to have the same underlying datasets, which our evaluation did not have. The model including the gear comparison but excluding the MI survey data (Model 5) was the most parsimonious of the models evaluated. Models with MI-OH surveys split in 2016 (models 1 and 2) were more parsimonious than models with MI-OH split in 1978 (models 3 and 4). Models without the catch comparison (models 2 and 4) were slightly more parsimonious than models without (models 1, 3).

Based on the evaluation of the 5 different model configurations, the WTG recommended the following modification to the previous SCAA:

[2] Objective function (O-F) components – the number of separate data sources included in the objective function. These data sources are compared to estimated values, and the difference is minimized within the objective function. The minimization procedure (maximum likelihood) is carried out by repeatedly adjusting the parameter estimates until the aggregate likelihood is maximized.

1) use the Ohio gear comparison survey to aid transition from the previous multifilament to the new monofilament fall gillnet survey, and
2) Split the MI-OH multifilament surveys in 1978, (i.e., Model 3).
3) The slight increase in model complexity (i.e., parameters +5 to +10% and objective function components +13%) are justified, given the improved precision and retrospective pattern bias performance.

To address issue 3 (MSE requirement), the WTG worked from the premise: *"if the underlying stock-recruitment relationship holds and the fisheries efficiencies remain stable then the F_{msy} and SSB_0 values will not change and neither would the harvest policy reference points and there would be no need for a new MSE"*. In consultation with the QFC, the WTG developed a comparative evaluation of the new model configuration (Model 3) to the previously MSE evaluated model configuration. This evaluation looked for obvious qualitative differences in the recruitment and fishery catchabilities time-series outputs including: age-2+ abundance, age-2 abundance, $SSB_{0,}$ Ontario commercial catchability, Ohio sport catchability and Ontario Partnership survey catchability. Defining "significant qualitative differences" is not simple, but for the purpose of this evaluation QFC and WTG defined it as major differences that "jump out" in model output data. For all evaluated model outputs, both models produced similar time-series trends and annual estimates (Figure A3). Therefore, the WTG concluded a MSE of the new model configuration was not necessary.

After presenting these recommendations to the LEC and the LEPMAG during 2020-2021, the revised SCAA model was used to estimate walleye abundance and provide a recommended allowable harvest for the 2021 TAC year. This model includes:
1) estimated selectivity for all ages within the model without the assumptions of known selectivity at age;
2) integrated age-0 trawl survey data into the model;
3) a multinomial distribution for the age composition data; and
4) time-varying catchability using a random walk for fishery and survey data
    a. including the age-0 trawl survey
    b. **[NEW]** excluding the new Ohio monofilament gillnet survey, which is estimated as a fixed parameter during 2016-present.
5) **[NEW]** Use of Ohio's gear comparison data to index the Ohio multifilament gillnet survey (1978 – 2015) to the new Ohio monofilament survey (2016- present).
6) Instantaneous natural mortality ($M = 0.32$) is assumed constant among years (1978-2020) and ages (ages 2 through 7 and older).
7) The abundances-at-age are derived from the estimated parameters using an exponential survival equation.
8) **[NEW]** Separation of the Ohio and Michigan survey data in 1978

It is important to note that the modification to the previous SCAA model follows 4 years of the WTG using an interim solution. The temporary solution used age-specific regressions to convert Ohio's monofilament gill net catches to a multifilament equivalent, which were then pooled with Michigan data. These age-specific regressions were generated using catch data from the Ohio gear comparison study. Between 2017-2019, the WTG used linear regression to convert monofilament to equivalent multifilament catches and shifted to robust regression in 2020 using lmRob function in the robust R package (Wang et al. 2017) because this method better handled influential (i.e., outlier) observations. Therefore, as we move to a more holistic approach, some shifts in model output are expected in 2021 relative to the outputs from previous years models.

Summary of 2021 SCAA model result

Based on the 2021 integrated SCAA model, the 2020 west-central population (MU1-3) was estimated at 70.6 million age 2 and older Walleye (Table 8, Figure 7). An estimated 32.8 million age 2 (2018 year class) fish comprised 46% of the age 2 and older Walleye population. Age 5 (2015 year class) Walleye represented the second largest (32%) and age 3 (2017 year class) the third largest (9%) components of the population. Based on the integrated model, the number of age 2 recruits entering the population in 2021 (2019 year class) and 2022 (2020 year class) are projected to be 48.7 and 24.6 million Walleye, respectively (Table 9). The 2021 projected abundance of age 2 and older Walleye in the west-central population is projected to be 95.5 million fish (Table 8; Figure 7).

Harvest Policy and Recommended Allowable Harvest (RAH) for 2021

In March 2021, the WTG applied the following Harvest Control Rules as identified in the Walleye Management Plan (WMP; 2015-2024):

- *Target Fishing Mortality* of **60%** of the fishing mortality Maximum Sustainable Yield (60%F_{MSY});
- Threshold *Limit Reference Point* of **20%** of the Unfished Spawning Stock Biomass (20%SSB_0);
- Probabilistic Control Rule, P-star, P*= **0.05** ;
- A limitation on the annual change in TAC of ± **20%**.

Using results from the 2021 integrated SCAA model, the estimated abundance of 95.514 million age-2 and older Walleye in 2021, and the harvest policy described above, the calculated mean RAH for 2021 was 15.218 million Walleye, with a range from 11.891 (minimum) to 18.544 (maximum) million Walleye (Table 9). The WTG RAH range estimate is an AD Model Builder (ADMB, Fournier et al. 2012) generated value based on estimating ± one standard deviation of the mean RAH. AD Model Builder uses a statistical technique called the delta method to determine this standard deviation for the calculated RAH, incorporating the standard errors from abundance estimates at age and combined gear selectivity at age. The target fishing rate, (60%F_{MSY} = 0.358) in the harvest policy was applied because the probability of the projected spawner biomass in 2022 (74.621 million kg) falling below the limit reference point ($SSB_{20\%}$ = 11.847 million kg) after fishing at 60%F_{MSY} in 2021 was less than 5% ($p < 0.05$). Thus, the probabilistic control rule (P*) to reduce the target fishing rate and conserve spawner biomass was not invoked during the 2021 determination of RAH.

In addition to the RAH, the Harvest Control Rule adopted by LEPMAG limits the annual change in TAC to ± 20% of the previous year's TAC. According to this rule, the maximum change in TAC would be (+) or (-) 20% of the 2020 TAC (10.237 million fish), and the range in 2021 TAC for LEC consideration would be from 8.190 million fish to 12.284 million fish.

COVID19 consideration of model performance

The WTG performed sensitivity analysis on potential effects to the 2021 RAH resulting from the increased uncertainty in harvest-by-ages estimates from the Ohio and Michigan sport fisheries. The minimal and maximum divergence (%) based on missing data solutions analysis using 2017 -2019 data was applied to 2021 harvest-by-age estimates from the impacted agency surveys and output RAHs examined. Mean RAH divergence for both scenarios (Min and Max) were approximately 2% and the 2021 TAC range for LEC consideration remained 8.190 million fish to 12.284 million fish.

Other Walleye Task Group Activities

The following represents WTG progress and developments on Charge 2a and 2b. During 2020-2021, this work focused on *(1) Movements, Migrations and Spatial Ecology, (2) Stock Structure,* (3) *Recruitment*.

Movements, Migration and Spatial Ecology

Since 2011, WTG members have participated collaboratively in several Great Lakes Acoustic Telemetry Observation System (GLATOS; https://glatos.glos.us/) studies across Lake Erie. Insights from this ongoing work help to inform an evolving understanding of such things as stock contributions to mixed fisheries (see Stock Structure, below) and to the interpretation of survey data. Together with colleagues from the University of Windsor, Michigan State University, and USGS, manuscripts dealing with seasonal occupancy of Walleye by basin and related to spawning site fidelity are anticipated in the coming year.

In 2020, data from all Task Group associated Walleye telemetry projects on the lake were made available to a GLFC Science Transfer project team tasked with creating a combined dataset for the purposes of asking and visualizing collective management questions related to general and proportional distribution across the lake. This work will generate best management practices for combining already large individual datasets into a single resource as well as tools for managers to directly query and summarize Walleye spatial information.

Stock structure

In recent years there has been an effort to improve our understanding of Walleye stock structure at the lake-wide scale to inform future iterations of the walleye management plan. One of the major information gaps associated with Walleye stock structure is how western and eastern basin stocks interact to influence fisheries and survey results in the eastern basin.

Previous attempts to use genetic approaches to determine relative stock contributions to mixed fisheries in Lake Erie have been confounded by an inability to discriminate between individual spawning aggregations due to weak spawning stock genetic structure. By focusing on more coarse stock structure using next-generation sequencing technologies (i.e. RAD sequencing; Rapture Panels) it has recently become possible to accurately discriminate stock structure at a basin-level scale. Individual fish can be accurately assigned to basin of origin with 89-99% accuracy. This coarser level of discrimination was sufficient to address questions about local and migratory (western and central basin) stock contributions to eastern basin fisheries.

Walleye Task Group members, together with colleagues from the University of Wisconsin-Stevens Point, Ohio State University and the Aquatic Research and Development Section of OMNRF used these techniques to assign proportional contributions by basin (eastern or central/western), to the commercial and sport fisheries of the eastern basin between 2016 and 2018 (Euclide et al, 2020). Previous tagging studies demonstrated that western origin fish contribute significantly to eastern fisheries. This work largely confirmed that finding, while also quantifying annual, seasonal, and spatial variability in these contributions. In fact, eastern basin walleye stocks can have a larger influence on eastern basin fisheries than previously thought and likely contribute substantially to harvest during particular times and in particular locals.

In general, the largest contributions of western stocks to eastern fisheries occur between July and September. However, July contributions varied between 20% (2016) and 90% (2018).

Western basin stocks constituted most of the harvest during the peak walleye fishing season (July – September), whereas eastern basin individuals comprised much of the early season harvest (May – June). Furthermore, catches in more easterly sites contained more individuals of eastern basin origin than did more westerly sites. Notable differences were found between the commercial fishery in Ontario waters and the sport fishery in New York waters.

The results indicate that periodic reassessments of stock contributions to the harvest are likely necessary to characterize longer-term spatio-temporal variation in relative stock contributions and to inform management decisions and facilitate incorporation of the eastern basin into the lake-wide management framework.

Recruitment

Evidence of multiple Walleye stocks in Lake Erie exists, with decreasing stock productivity from west to east. However, migrations and mixing of stocks throughout the lake make evaluation of individual stock productivity difficult. For example, adult Walleye from western basin spawning grounds in the spring migrate to the cooler waters of the central and eastern basins in the summer, and then return to the west basin before spawning. While juvenile Walleye from both the western and eastern basin are believed to disperse from natal basins during the summer and fall, it is unknown if their migrations are similar to those of adults. To address uncertainty surrounding juvenile dispersal and productivity of Walleye stocks across Lake Erie, the WTG has reported basin-specific densities of yearling Walleye with standardized gill net indices since 2011 (WTG 2012).

In Figure 8, site-specific yearling Walleye catches are presented for the bottom set interagency (ON, NY) monofilament nets; the suspended (canned or kegged) Ohio monofilament nets (see footnote #1, page 3 for description); suspended Michigan multifilament nets; and suspended Ontario monofilament nets fished in 2020. Catches were standardized for net length (50 ft [15.2 m] panels) of mesh sizes ≤ 5.5” (140 mm) but correction factors were not applied to standardize fishing power between monofilament and multifilament nets. New York and Ontario monofilament nets share the same configurations with the exception that Ontario nets contain 2 panels instead of the one 50 ft (15.2 m) panel for mesh sizes ≥ 2” (51 mm). New York’s index gill nets were fished exclusively on bottom and were confined to shallower depths than nets fished in Ontario’s waters of eastern Lake Erie (Figure 8a).

In 2020, yearling (2019 Year class) Walleye catches occurred lake-wide where index nets were fished (Figures 8a and b). Yearlings were present in bottom and suspended nets and in nearshore and offshore areas. Yearling caught in the West basin trawl index yearling were the highest catch rates in the time series (62.4 fish/Ha). Based on Ontario’s Partnership gillnet survey yearlings were the 3rd strongest year class following the 2015 and 2003 year classes in the west/central part of the lake, but in east including the Pennsylvania Ridge were the strongest year class in the time series. However, in the New York gillnet survey yearling catches in the east were lower than in 2017 and 2018, reflecting possible stock-specific differences within the east basin. It is not uncommon to differences in patterns between the Ontario partnership and NY surveys which may be partially attributed to spatial different in yearling distributions.

The mean length of yearling walleye (2019 year class) from west basin interagency bottom trawls during August 2020 (205 mm) was lowest in the time series and well below average (270 mm) (Figure 9). Smaller size at age may reflect slower density-dependent growth, and as these fish enter the fisheries in 2021 as smaller than usual sizes, the WTG expects to see an increased release rate in the sport fisheries (because anglers may encounter many sub-legal Walleye) and that these smaller fish will exhibit delayed vulnerability to commercial gill net fisheries.

Currently, the young-of-the-year (YOY) index from the interagency west basin bottom trawl survey (Table 10) is integrated into the SCAA model to estimate age-2 Walleye abundance and forecast recruitment. While the interagency bottom trawl survey is a robust recruitment predictor, inclusion of additional YOY and yearling indices to form a composite recruitment index could supplement recruitment estimates. However, there are two factors limiting the integration of a composite recruitment index into the SCAA model:

1. Yearling indices are not available far enough in advance to forecast age-2 recruitment in the year following harvest, as required for assessing risk (i.e., P*) in the current Walleye Management Plan's probabilistic harvest control rule (Kayle et al. 2015). Options for overcoming this limitation would be exclusion of yearling indices from a composite recruitment index, running two integrated SCAA models (one with YOY and yearling data and the second model using only YOY data), or ignoring risk (i.e., removal of P*) from the Walleye Management Plan Harvest Policy. It is important to note that the two SCAA model options could result in conflicting abundance estimates.

2. Spatial, temporal, and gear type (bottom set vs. suspended gill nets) variability exist in Walleye YOY and yearling indices, along with inconsistencies in sampling intensity and effort. Previous examination of the available recruitment indices using a Principal Components Analysis (PCA) approach revealed challenges for integrating a composite recruitment index into the SCAA model (WTG 2016). Data transformations and missing years of data in some indices were primary concerns.

The WTG will continue to update the dataset of recruitment indices. However, composite Walleye recruitment indices will not be presented until concerns related to data transformations, missing years of data, and recent changes in index gear configuration are addressed. The WTG will also continue to explore and evaluate alternative recruitment estimation approaches to be considered for adoption in future Lake Erie Walleye Management Plans.

WTG Centralized Datasets

WTG members currently manage several databases that consist of fishery-dependent (harvest) and fishery-independent (population) assessment surveys conducted by the respective agencies. Annually, data are compiled by WTG members to form spatially-explicit versions of agency-specific harvest data (e.g., harvest-at-age and fishery effort by management unit) and population assessment (e.g., the interagency trawl program and gill net surveys) databases. These databases are used for trends and status evaluations, estimating population size and abundance using SCAA analysis, and the decision-making process regarding RAH. Ultimately, annual population abundance estimates are used to assist LEC members with setting TACs for the upcoming year and evaluate past harvest policy decisions. Use of WTG databases by non-members is only permitted following a specific protocol established in 1994, described in the 1994 WTG Report and reprinted in the 2003 WTG Report (WTG 2003).

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Table 1. Annual Lake Erie walleye total allowable catch (TAC, top) and measured harvest (Har; bottom, bold), in numbers of fish from 2010 to 2020. TAC allocations are based on water area: Ohio, 51.11%; Ontario, 43.06%; and Michigan, 5.83%. New York and Pennsylvania do not have assigned quotas, but are included in annual total harvest.

		TAC Area (MU-1, MU-2, MU-3)				Non-TAC Area (MUs 4&5)				All Areas
Year		Michigan	Ohio	Ontario [a]	Total	NY	Penn.	Ontario	Total	Total
2010	TAC	128,260	1,124,420	947,320	2,200,000				0	2,200,000
	Har	**55,248**	**958,366**	**983,397**	**1,997,011**	**34,552**	**54,056**	**23,324**	**111,932**	**2,108,943**
2011	TAC	170,178	1,491,901	1,256,921	2,919,000				0	2,919,000
	Har	**50,490**	**417,314**	**1,224,057**	**1,691,861**	**31,506**	**45,369**	**28,873**	**105,748**	**1,797,609**
2012	TAC	203,292	1,782,206	1,501,502	3,487,000				0	3,487,000
	Har	**86,658**	**921,390**	**1,355,522**	**2,363,570**	**36,975**	**44,796**	**28,260**	**110,031**	**2,473,601**
2013	TAC	195,655	1,715,252	1,445,094	3,356,000				0	3,356,000
	Har	**54,167**	**1,083,395**	**1,274,945**	**2,412,507**	**34,553**	**60,332**	**30,591**	**125,476**	**2,537,983**
2014	TAC	234,774	2,058,200	1,734,026	4,027,000				0	4,027,000
	Har	**42,142**	**1,303,133**	**1,324,201**	**2,669,476**	**61,982**	**84,843**	**52,675**	**199,500**	**2,868,977**
2015	TAC	239,846	2,102,665	1,771,488	4,114,000				0	4,114,000
	Har	**65,740**	**1,073,263**	**1,382,600**	**2,521,603**	**55,201**	**46,523**	**89,882**	**191,606**	**2,713,209**
2016	TAC	287,827	2,523,301	2,125,872	4,937,000				0	4,937,000
	Har	**65,816**	**855,820**	**1,959,573**	**2,881,209**	**50,963**	**32,937**	**112,743**	**196,643**	**3,077,852**
2017	TAC	345,369	3,027,756	2,550,874	5,924,000				0	5,924,000
	Har	**56,938**	**1,261,327**	**3,232,817**	**4,551,082**	**70,010**	**162,949**	**129,217**	**362,176**	**4,913,258**
2018	TAC	414,455	3,633,410	3,061,135	7,109,000				0	7,109,000
	Har	**176,089**	**1,972,295**	**3,478,713**	**5,627,097**	**123,503**	**270,189**	**263,204**	**656,896**	**6,283,993**
2019	TAC	497,357	4,360,194	3,673,449	8,531,000				0	8,531,000
	Har	**153,171**	**2,558,359**	**3,362,053**	**6,073,583**	**174,466**	**419,975**	**229,466**	**823,907**	**6,897,490**
2020	TAC	596,817	5,232,131	4,408,052	10,237,000				0	**10,237,000**
	Har	**191,490**	**1,973,038**	**3,680,335**	**5,844,863**	**84,615**	**208,760**	**243,175**	**536,550**	**6,381,413**

[a] Ontario sport harvest values were estimated from the 2014 lakewide aerial creel survey

These values are included in Ontario's total walleye harvest, but are not used in catch-at-age analysis.

Table 2. Annual harvest (thousands of fish) of Lake Erie walleye by gear, management unit, and agency. Means contain data from 1975 to 2019.

	Sport Fishery																Commercial Fishery					
	Unit 1				Unit 2			Unit 3			Units 4 & 5					Unit 1	Unit 2	Unit 3	Unit 4		Grand
Year	OH	MI	ON[a]	Total	OH	ON[a]	Total	OH	ON[a]	Total	ON[a]	PA	NY	Total	Total	ON	ON	ON	ON	Total	Total
2010	587	55	44	686	257	2	259	114	0	115	2	54	37	93	1,152	607	184	147	23	962	2,115
2011	224	50	44	318	104	2	106	89	0	90	2	45	32	79	593	736	262	181	29	1,208	1,801
2012	596	87	44	726	233	2	235	93	0	93	2	45	37	84	1,138	834	285	191	28	1,338	2,476
2013	757	54	44	855	190	2	192	136	0	136	2	60	35	97	1,280	737	297	195	31	1,260	2,540
2014	909	42	45	996	177	13	190	218	13	231	13	85	62	160	1,577	756	259	238	40	1,292	2,869
2015	746	66	45	857	187	13	200	140	13	153	13	47	55	115	1,325	633	354	325	77	1,388	2,713
2016	577	66	45	688	139	13	152	140	13	153	13	33	51	97	1,090	946	594	348	100	1,988	3,078
2017	592	57	45	694	316	13	330	353	13	367	13	163	70	246	1,636	1,735	918	508	116	3,277	4,913
2018	955	176	45	1,177	666	13	679	351	13	365	13	270	124	407	2,627	1,523	1,433	451	250	3,657	6,284
2019	1,297	153	45	1,495	947	13	960	314	13	327	13	420	174	607	3,390	1,666	1,237	387	217	3,507	6,897
2020	537	191	45	773	908	13	921	528	13	541	13	209	85	306	2,542	1,938	1,185	486	230	3,839	6,381
Mean	1,453	246	41	1,740	292	10	299	178	12	188	9	93	46	87	2,292	1,374	486	299	59	2,106	4,398

[a] Ontario sport harvest values were estimated from the 2014 lakewide aerial creel survey. These values are included in Ontario's total walleye harvest, but are not used in catch-at-age analysis.

Table 3. Annual fishing effort for Lake Erie walleye by gear, management unit, and agency. Means contain data from 1975 to 2019.

	Sport Fishery [a]																Commercial Fishery [b]				
	Unit 1				Unit 2			Unit 3			Units 4 & 5						Unit 1	Unit 2	Unit 3	Units 4&5	
Year	OH	MI	ON[c]	Total	OH	ON[c]	Total	OH	ON[c]	Total	ON[c]	PA	NY	Total		Total	ON	ON	ON	ON	Total
2010	1,403	226	--	1,629	652	--	652	219	--	219	--	188	140	328		2,828	1,918	1,371	1,401	247	4,937
2011	862	165	--	1,026	346	--	346	217	--	217	--	156	145	301		1,891	2,646	1,884	1,572	489	6,591
2012	1,283	242	--	1,525	560	--	560	182	--	182	--	160	169	329		2,597	4,674	2,480	2,298	352	9,804
2013	1,424	182	--	1,606	503	--	503	236	--	236	--	154	143	297		2,641	3,802	2,774	2,624	304	9,503
2014	1,552	131	101	1,683	459	85	459	441	71	441	70	171	187	358		2,940	7,351	4,426	2,911	254	14,943
2015	1,430	165	--	1,595	564	--	564	341	--	341	--	162	215	377		2,876	6,980	6,487	5,379	792	19,637
2016	1,514	236	--	1,750	439	--	439	397	--	397	--	141	217	358		2,944	6,980	7,969	4,523	1,448	20,920
2017	1,351	187	--	1,538	726	--	726	501	--	501	--	228	213	441		3,207	8,056	7,239	3,636	1,527	20,458
2018	1,239	261	--	1,500	813	--	813	354	--	354	--	248	229	477		3,144	5,215	7,421	2,636	1,896	17,168
2019	1,739	265	--	2,004	1,036	--	1,036	307	--	307	--	439	297	736		4,083	4,165	6,365	2,402	1,353	14,285
2020	1,111	301	--	1,413	1,511	--	1,511	659	--	659	--	395	279	674		4,257	5,759	6,576	3,049	1,738	17,122
Mean	2,844	647	102	3,549	755	62	770	412	111	442	106	220	233	283		4,994	8,667	5,674	4,393	761	18,618

[a] Ohio, Michigan, Pennsylvania and New York sport units of effort are thousands of angler hours.

[b] Estimated Standard (Total) Effort in kilometers of gill net = (walleye targeted effort x walleye total harvest) / walleye targeted harvest.

[c] Ontario sport fishing effort was estimated from 2014 lakewide aerial creel survey, values are in rod hours

[d] Ontario sport fishing effort is not included in area and lakewide totals due to effort reporting in rod hours

Table 4. Annual catch per unit effort for Lake Erie walleye by gear, management unit, and agency. Means contain data from 1975 to 2019.

	Sport Fishery [a]															Commercial Fishery [b]				
	Unit 1				Unit 2			Unit 3			Units 4 & 5					Unit 1	Unit 2	Unit 3	Unit 4	
Year	OH	MI	ON[c]	Total	OH	ON[c]	Total	OH	ON[c]	Total	ON[c]	PA	NY	Total	Total	ON	ON	ON	ON	Total
2010	0.42	0.24	--	0.39	0.39	--	0.39	0.52	--	0.52	--	0.29	0.26	0.28	0.39	316.7	134.5	105.0	94.5	194.9
2011	0.26	0.31	--	0.27	0.30	--	0.30	0.41	--	0.41	--	0.29	0.22	0.26	0.29	278.3	138.9	115.0	59.0	183.3
2012	0.46	0.36	--	0.45	0.42	--	0.42	0.51	--	0.51	--	0.28	0.22	0.25	0.42	178.4	114.8	83.1	80.3	136.5
2013	0.53	0.30	--	0.51	0.38	--	0.38	0.58	--	0.58	--	0.39	0.24	0.32	0.47	194.0	107.0	74.2	100.7	132.5
2014	0.59	0.32	0.45	0.56	0.39	0.16	0.39	0.49	0.19	0.49	0.18	0.50	0.33	0.41	0.51	102.8	58.4	81.8	156.8	86.5
2015	0.52	0.40	--	0.51	0.33	--	0.33	0.41	--	0.41	--	0.29	0.26	0.27	0.43	90.6	54.5	60.3	97.3	70.7
2016	0.38	0.28	--	0.37	0.32	--	0.32	0.35	--	0.35	--	0.23	0.23	0.23	0.34	135.5	74.6	77.0	69.0	95.0
2017	0.44	0.30	--	0.42	0.44	--	0.44	0.70	--	0.70	--	0.71	0.33	0.53	0.48	215.3	126.9	139.6	76.2	160.2
2018	0.77	0.67	--	0.75	0.82	--	0.82	0.99	--	0.99	--	1.09	0.54	0.83	0.81	292.0	193.1	171.0	132.0	213.0
2019	0.75	0.58	--	0.72	0.91	--	0.91	1.02	--	1.02	--	0.96	0.59	0.81	0.81	399.9	194.4	161.3	160.1	245.5
2020	0.48	0.64	--	0.52	0.60	--	0.60	0.80	--	0.80	--	0.53	0.30	0.44	0.58	336.5	180.2	159.3	132.5	224.2
Mean	0.49	0.37	0.40	0.47	0.35	0.26	0.35	0.42	0.19	0.41	0.11	0.39	0.20	0.27	0.45	179.05	91.96	77.24	76.12	125.9

[a] Ohio, Michigan, Pennsylvania and New York sport CPE = Number/angler hour

[b] Commercial CPE = Number/kilometer of gill net

[c] Ontario sport fishing CPE was estimated from the 2014 lakewide aerial creel survey values are in number/rod hour

[d] Ontario sport fishing CPE is not included in area and lakewide totals due to effort reporting in rod hours

Table 5. Catch at age of walleye harvest by management unit, gear, and agency in Lake Erie during 2020. Units 4 and 5 are combined in Unit 4.

		Commercial	Sport					All Gear
Unit	Age	Ontario	Ohio	Michigan	New York	Pennsylvania	Total	Total
1	1	114,308		0			0	114,308
	2	500,149	11,275	17,408			28,683	528,832
	3	223,034	41,762	21,139			62,901	285,935
	4	55,073	42,001	26,112			68,113	123,186
	5	969,960	402,888	92,015			494,903	1,464,863
	6	58,039	28,058	22,382			50,440	108,479
	7+	17,601	10,870	12,434			23,304	40,905
	Total	1,938,164	536,854	191,490	--	--	728,344	2,666,508
2	1	57,703					0	57,703
	2	230,145	35,756				35,756	265,901
	3	126,496	74,380				74,380	200,876
	4	37,246	69,061				69,061	106,307
	5	680,981	664,300				664,300	1,345,281
	6	36,717	46,291				46,291	83,008
	7+	15,534	18,085				18,085	33,619
	Total	1,184,822	907,873	--	--	--	907,873	2,092,695
3	1	57,029					0	57,029
	2	33,540	39,465				39,465	73,005
	3	55,474	47,482				47,482	102,956
	4	22,647	37,990				37,990	60,637
	5	296,259	367,538				367,538	663,797
	6	15,748	25,644				25,644	41,392
	7+	4,895	10,192				10,192	15,087
	Total	485,592	528,312	--	--	--	528,312	1,013,904
4	1	64,791					0	64,791
	2	18,325			799	1,491	2,290	20,615
	3	12,905			6,398	49,208	55,606	68,511
	4	7,242			29,167	43,243	72,410	79,652
	5	117,012			25,546	90,960	116,506	233,518
	6	4,738			3,024	5,965	8,989	13,727
	7+	5,303			19,682	17,894	37,576	42,879
	Total	230,316	--	--	84,615	208,761	293,376	523,692
All	1	293,831	0	0	0	0	0	293,831
	2	782,159	86,496	17,408	799	1,491	106,194	888,353
	3	417,909	163,625	21,139	6,398	49,208	240,369	658,278
	4	122,208	149,053	26,112	29,167	43,243	247,575	369,783
	5	2,064,212	1,434,726	92,015	25,546	90,960	1,643,246	3,707,458
	6	115,242	99,992	22,382	3,024	5,965	131,363	246,605
	7+	43,333	39,146	12,434	19,682	17,894	89,157	132,490
	Total	3,838,894	1,973,038	191,490	84,615	208,761	2,457,904	6,296,798

Table 6. Age composition (in percent) of walleye harvest by management unit, gear, and agency in Lake Erie during 2020. Units 4 and 5 are combined in Unit 4.

		Commercial	Sport					All Gears
Unit	Age	Ontario	Ohio	Michigan	New York	Pennsylvania	Total	Total
1	1	5.9	0.0	0.0	--	--	0.0	4.3
	2	25.8	2.1	9.1	--	--	3.9	19.8
	3	11.5	7.8	11.0	--	--	8.6	10.7
	4	2.8	7.8	13.6	--	--	9.4	4.6
	5	50.0	75.0	48.1	--	--	67.9	54.9
	6	3.0	5.2	11.7	--	--	6.9	4.1
	7+	0.9	2.0	6.5	--	--	3.2	1.5
	Total	100.0	100.0	100.0	--	--	100.0	100.0
2	1	4.9	0.0	--	--	--	0.0	2.8
	2	19.4	3.9	--	--	--	3.9	12.7
	3	10.7	8.2	--	--	--	8.2	9.6
	4	3.1	7.6	--	--	--	7.6	5.1
	5	57.5	73.2	--	--	--	73.2	64.3
	6	3.1	5.1	--	--	--	5.1	4.0
	7+	1.3	2.0	--	--	--	2.0	1.6
	Total	100.0	100.0	--	--	--	100.0	100.0
3	1	11.7	0.0	--	--	--	0.0	5.6
	2	6.9	7.5	--	--	--	7.5	.
	3	11.4	9.0	--	--	--	9.0	10.2
	4	4.7	7.2	--	--	--	7.2	6.0
	5	61.0	69.6	--	--	--	69.6	65.5
	6	3.2	4.9	--	--	--	4.9	4.1
	7+	1.0	1.9	--	--	--	1.9	1.5
	Total	100.0	100.0	--	--	--	100.0	100.0
4	1	28.1	--	--	0.0	0.0	0.0	12.4
	2	8.0	--	--	0.9	0.7	0.8	3.9
	3	5.6	--	--	7.6	23.6	19.0	13.1
	4	3.1	--	--	34.5	20.7	24.7	15.2
	5	50.8	--	--	30.2	43.6	39.7	44.6
	6	2.1	--	--	3.6	2.9	3.1	2.6
	7+	2.3	--	--	23.3	8.6	12.8	8.2
	Total	100.0	--	--	100.0	100.0	100.0	100.0
All	1	7.7	0.0	0.0	0.0	0.0	0.0	4.7
	2	20.4	4.4	9.1	0.9	0.7	4.3	14.1
	3	10.9	8.3	11.0	7.6	23.6	9.8	10.5
	4	3.2	7.6	13.6	34.5	20.7	10.1	5.9
	5	53.8	72.7	48.1	30.2	43.6	66.9	58.9
	6	3.0	5.1	11.7	3.6	2.9	5.3	3.9
	7+	1.1	2.0	6.5	23.3	8.6	3.6	2.1
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 7. Annual mean age (years) of Lake Erie walleye by gear, management unit, and agency. Means include data from 1975 to 2019.
Average age will not be presented in 2020 because biological data was not collected in MI and OH sport fishery surveys

	Sport Fishery															Commercial Fishery					All Gears
	Unit 1				Unit 2			Unit 3			Units 4 & 5					Unit 1	Unit 2	Unit 3	Unit 4		
Year	OH	MI	ON	Total	OH	ON	Total	OH	ON	Total	ON	PA	NY	Total	Total	ON	ON	ON	ON	Total	Total
2010	5.72	5.38	--	5.69	6.37	--	6.37	7.30	--	7.30	--	7.16	7.16	7.16	6.12	4.11	4.82	6.14	7.79	4.64	5.44
2011	5.98	4.35	--	5.68	7.79	--	7.79	8.03	--	8.03	--	8.40	7.76	8.13	6.74	4.86	5.26	6.73	8.33	5.31	5.78
2012	4.97	4.46	--	4.91	5.78	--	5.78	8.13	--	8.13	--	8.92	7.65	8.35	5.60	4.86	5.33	7.15	7.25	5.34	5.47
2013	5.16	4.26	--	5.10	6.91	--	6.91	8.09	--	8.09	--	8.79	8.13	8.55	5.95	4.91	4.64	7.09	7.36	5.24	5.60
2014	5.79	6.05	--	5.80	7.13	--	7.13	8.30	--	8.30	--	8.29	8.00	8.17	6.57	5.26	5.80	8.29	8.35	6.02	6.31
2015	6.23	5.85	--	6.20	6.88	--	6.88	8.73	--	8.73	--	7.43	8.29	7.89	6.74	4.57	6.30	8.58	8.08	6.14	6.42
2016	5.17	4.98	--	5.15	5.46	--	5.46	6.91	--	6.91	--	7.48	8.06	7.83	5.68	3.25	4.07	4.97	8.69	4.07	4.61
2017	4.54	4.39	--	4.52	3.52	--	3.52	3.67	--	3.67	--	4.17	5.68	4.63	4.14	2.90	2.65	2.86	5.86	2.93	3.32
2018	3.91	3.73	--	3.88	3.56	--	3.56	3.95	--	3.95	--	4.09	4.92	4.35	3.88	3.25	3.18	3.18	4.19	3.28	3.53
2019	4.36	4.12	--	4.33	4.37	--	4.37	4.53	--	4.53	--	4.70	5.10	4.82	4.45	3.82	3.99	3.86	4.29	3.91	4.17
2020	NA	NA	--		NA	--		NA	--		--	4.95	6.05	5.27	NA	3.83	4.11	4.12	3.63	3.94	NA
Mean	4.21	3.89	3.66	4.16	4.49	6.58	4.50	5.48	6.72	5.50	8.07	6.57	7.32	6.88	4.44	3.60	3.85	4.89	6.67	3.83	4.08

Table 8. Estimated abundance at age, survival (S), fishing mortality (F) and exploitation (u) for Lake Erie walleye, 1985-2021 (from ADMB 2021 catch at age analysis recruitment integrated model, M=0.32).

Year	Age							Ages 2+		
	2	3	4	5	6	7+	Total	S	F	u
1985	6,233,620	52,897,100	4,209,240	4,272,270	955,187	1,430,270	69,997,687	0.651	0.109	0.089
1986	24,153,400	4,281,390	34,329,900	2,705,340	2,746,290	1,517,050	69,733,370	0.636	0.133	0.107
1987	23,382,800	16,253,700	2,668,040	21,127,900	1,673,140	2,625,220	67,730,800	0.640	0.126	0.102
1988	55,156,700	15,759,700	10,177,900	1,649,250	13,133,500	2,644,000	98,521,050	0.638	0.129	0.104
1989	11,437,000	36,612,800	9,585,510	6,096,960	998,583	9,571,120	74,301,973	0.633	0.137	0.110
1990	10,006,700	7,721,110	22,984,000	5,950,220	3,821,530	6,551,360	57,034,920	0.640	0.126	0.101
1991	5,109,050	6,808,450	4,898,970	14,473,700	3,778,140	6,565,660	41,633,970	0.650	0.110	0.089
1992	16,448,200	3,512,180	4,399,420	3,149,420	9,353,660	6,666,310	43,529,190	0.646	0.118	0.095
1993	22,005,100	11,140,900	2,199,760	2,737,620	1,974,510	10,047,800	50,105,690	0.621	0.157	0.125
1994	3,528,670	14,516,600	6,571,170	1,288,890	1,622,260	7,093,720	34,621,310	0.609	0.176	0.139
1995	18,314,300	2,350,950	8,724,230	3,933,280	781,086	5,286,850	39,390,696	0.616	0.164	0.130
1996	20,698,400	12,013,900	1,359,410	5,032,010	2,300,950	3,559,240	44,963,910	0.593	0.203	0.158
1997	2,344,600	13,247,700	6,583,550	742,069	2,795,760	3,277,460	28,991,139	0.581	0.223	0.172
1998	21,405,400	1,530,350	7,590,970	3,757,730	429,618	3,535,100	38,249,168	0.595	0.200	0.156
1999	10,411,700	13,608,600	824,882	4,078,440	2,057,010	2,177,860	33,158,492	0.609	0.177	0.139
2000	9,581,590	6,851,820	7,925,950	479,369	2,405,330	2,516,840	29,760,899	0.620	0.158	0.125
2001	29,737,000	6,371,160	4,084,670	4,716,980	289,456	2,996,100	48,195,366	0.674	0.075	0.062
2002	3,455,720	20,499,900	4,137,350	2,641,680	3,068,770	2,129,210	35,932,630	0.672	0.077	0.063
2003	23,540,000	2,415,580	13,720,600	2,761,080	1,772,660	3,493,650	47,703,570	0.682	0.062	0.052
2004	332,720	16,439,900	1,613,820	9,135,210	1,845,740	3,514,270	32,881,660	0.680	0.066	0.055
2005	99,402,900	236,823	11,170,700	1,093,210	6,209,500	3,637,760	121,750,893	0.700	0.037	0.031
2006	3,310,070	70,177,400	158,523	7,469,740	734,685	6,637,620	88,488,038	0.670	0.080	0.066
2007	6,725,480	2,342,330	46,932,400	105,696	5,002,990	4,924,680	66,033,576	0.671	0.079	0.065
2008	1,796,930	4,770,490	1,568,820	31,289,700	70,679	6,624,700	46,121,319	0.677	0.071	0.059
2009	17,129,800	1,274,580	3,217,720	1,055,580	21,141,200	4,512,730	48,331,610	0.691	0.050	0.042
2010	6,261,280	12,181,000	864,443	2,175,990	716,277	17,440,400	39,639,390	0.686	0.056	0.047
2011	6,331,740	4,468,190	8,330,010	589,135	1,486,280	12,338,400	33,543,755	0.687	0.055	0.046
2012	10,585,000	4,500,140	3,042,920	5,665,400	402,262	9,437,620	33,633,342	0.670	0.080	0.066
2013	7,821,750	7,438,190	2,950,520	1,988,730	3,723,510	6,447,700	30,370,400	0.664	0.089	0.073
2014	3,861,160	5,498,890	4,854,440	1,915,990	1,297,000	6,611,900	24,039,380	0.637	0.131	0.106
2015	5,779,250	2,682,030	3,457,030	3,032,600	1,203,620	4,932,070	21,086,600	0.637	0.131	0.105
2016	19,988,500	3,991,680	1,659,990	2,126,350	1,878,480	3,778,690	33,423,690	0.666	0.087	0.071
2017	75,788,900	13,853,100	2,499,400	1,033,680	1,333,440	3,538,230	98,046,750	0.684	0.060	0.050
2018	6,620,710	52,857,400	8,848,210	1,588,570	660,652	3,102,340	73,677,882	0.658	0.098	0.080
2019	9,393,460	4,654,010	34,584,800	5,765,470	1,040,120	2,454,320	57,892,180	0.653	0.106	0.086
2020	32,779,300	6,590,750	3,011,540	22,247,600	3,725,030	2,246,060	70,600,280	0.663	0.091	0.075
2021	48,700,400	22,824,700	4,179,250	1,899,000	14,117,700	3,792,450	95,513,500			

Table 9. Estimated harvest of Lake Erie walleye for 2021, and population projection for 2022 when fishing with 60% F_{msy}. The 2021 and 2022 projected spawning stock biomass values are from the ADMB-2021 recruitment-integrated model. The range in the RAH was calculated using ± one standard deviation from the mean RAH.

SSB_0=	59.236	million kilograms
20% SSB_0=	11.847	million kilograms
F_{msy} =	0.596	

	2021 Stock Size (millions of fish)	60% F_{msy}		Rate Functions			2021 RAH (millions of fish)			Projected 2022 Stock Size (millions)	
Age	**Mean**	**F**	**Sel(age)**	**(F)**	**(S)**	**(u)**	**Min.**	**Mean**	**Max.**	**Mean**	
2	48.700		0.270	0.096	0.659	0.079	2.848	3.843	4.838	24.573	
3	22.825		0.923	0.330	0.522	0.243	4.434	5.537	6.640	32.111	
4	4.179		0.972	0.348	0.513	0.254	0.839	1.060	1.280	11.917	
5	1.899		0.930	0.332	0.521	0.244	0.364	0.464	0.564	2.144	
6	14.118		0.893	0.319	0.528	0.236	2.632	3.329	4.027	0.989	
7+	3.792		1.000	0.358	0.508	0.260	0.774	0.985	1.196	9.376	
Total (2+)	95.514	0.358				0.159	11.891	15.218	18.544	81.110	
Total (3+)	46.813						9.043	11.375	13.707	56.537	
SSB	70.736	mil. kgs								74.621	mil. kgs

probability of 2022 spawning stock biomass being less than 20% SSB_0 = 0.000%

Table 10. Western basin age 0 walleye recruitment index observed in bottom trawls by the Ontario Ministry of Natural Resources (ONT) and Ohio Department of Natural Resources (OH) between 2000 and 2020.

Year Class	Year of Recruitment to Fisheries	OH+ONT Trawl Age-0 CPHa
2000	2002	4.113
2001	2003	28.499
2002	2004	0.139
2003	2005	183.015
2004	2006	5.402
2005	2007	12.665
2006	2008	2.051
2007	2009	25.408
2008	2010	7.238
2009	2011	7.107
2010	2012	26.260
2011	2013	6.502
2012	2014	6.417
2013	2015	10.584
2014	2016	29.050
2015	2017	84.105
2016	2018	9.224
2017	2019	22.852
2018	2020	255.581
2019	2021	225.310
2020	2022	97.480

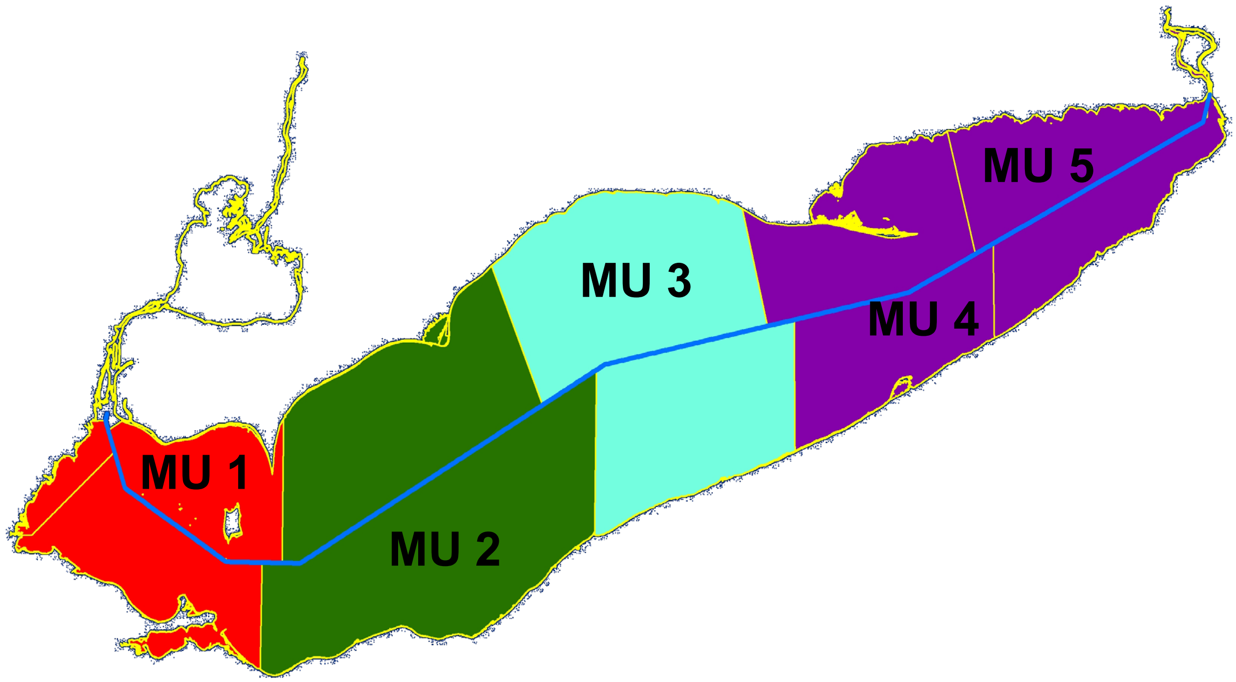


Figure 1. Map of Lake Erie with management units (MU) recognized by the Walleye Task Group for interagency management of Walleye.

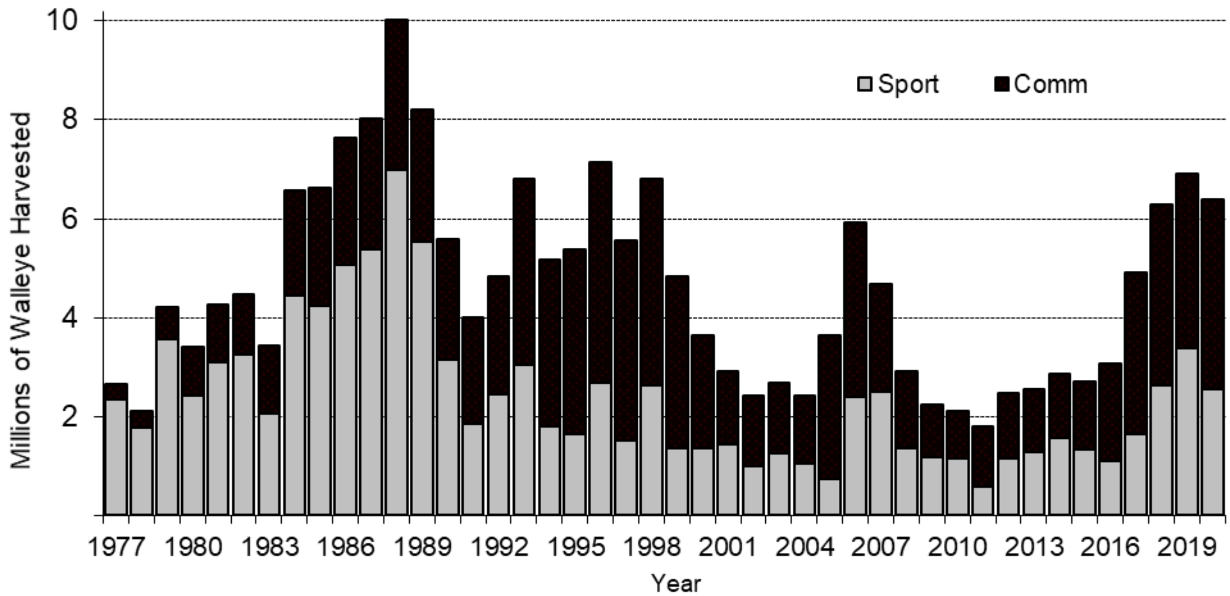


Figure 2. Lake-wide harvest of Lake Erie Walleye by sport and commercial fisheries, 1977-2020.

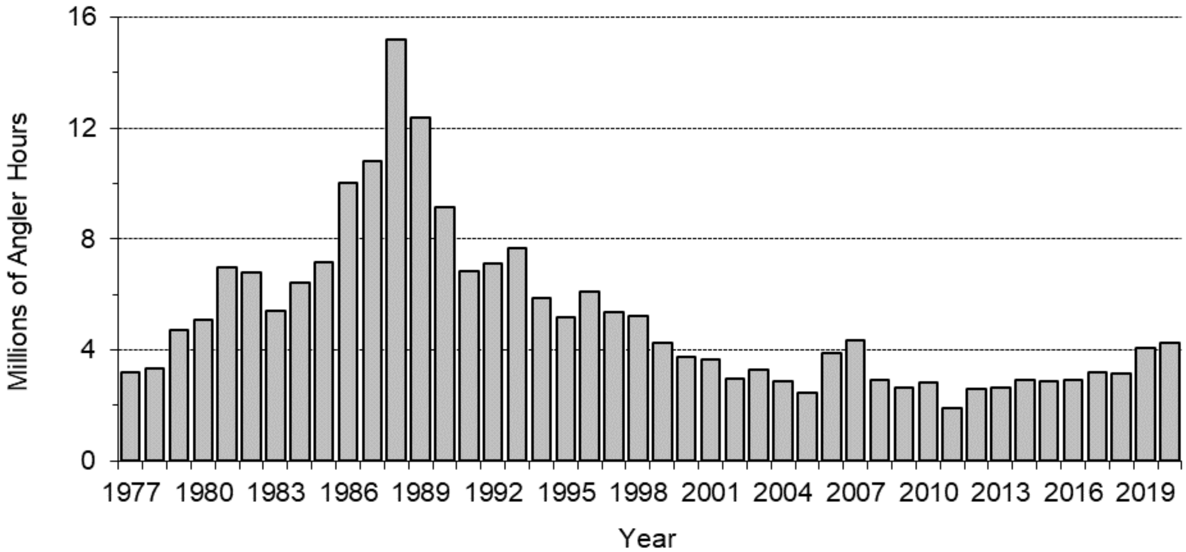


Figure 3. Lake-wide total effort (angler hours) by sport fisheries for Lake Erie Walleye, 1977-2020.

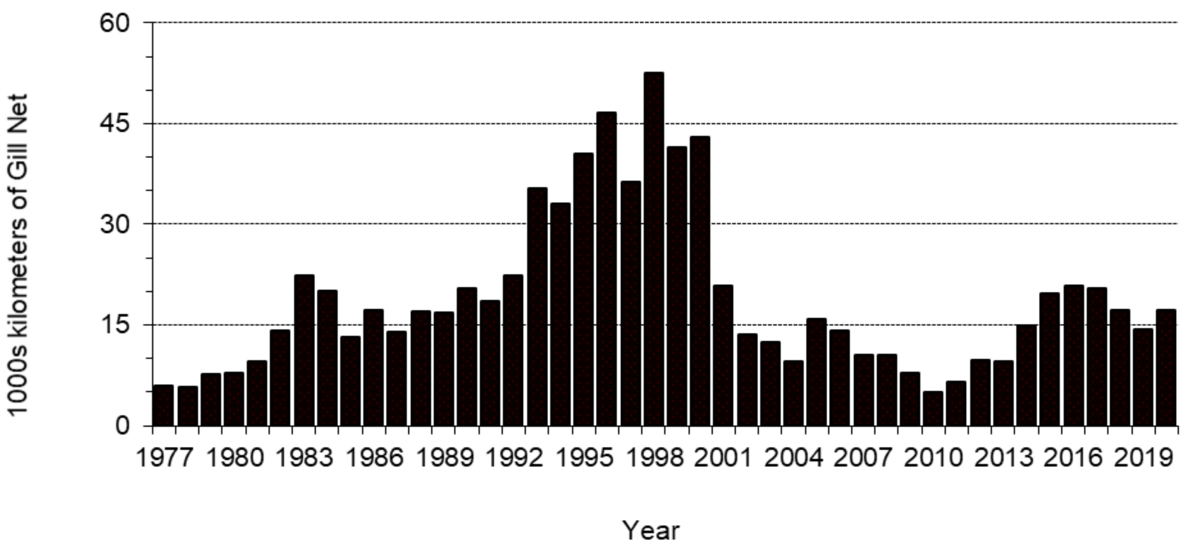


Figure 4. Lake-wide total effort (thousand kilometers of gill net) by commercial fisheries for Lake Erie Walleye, 1977-2020.

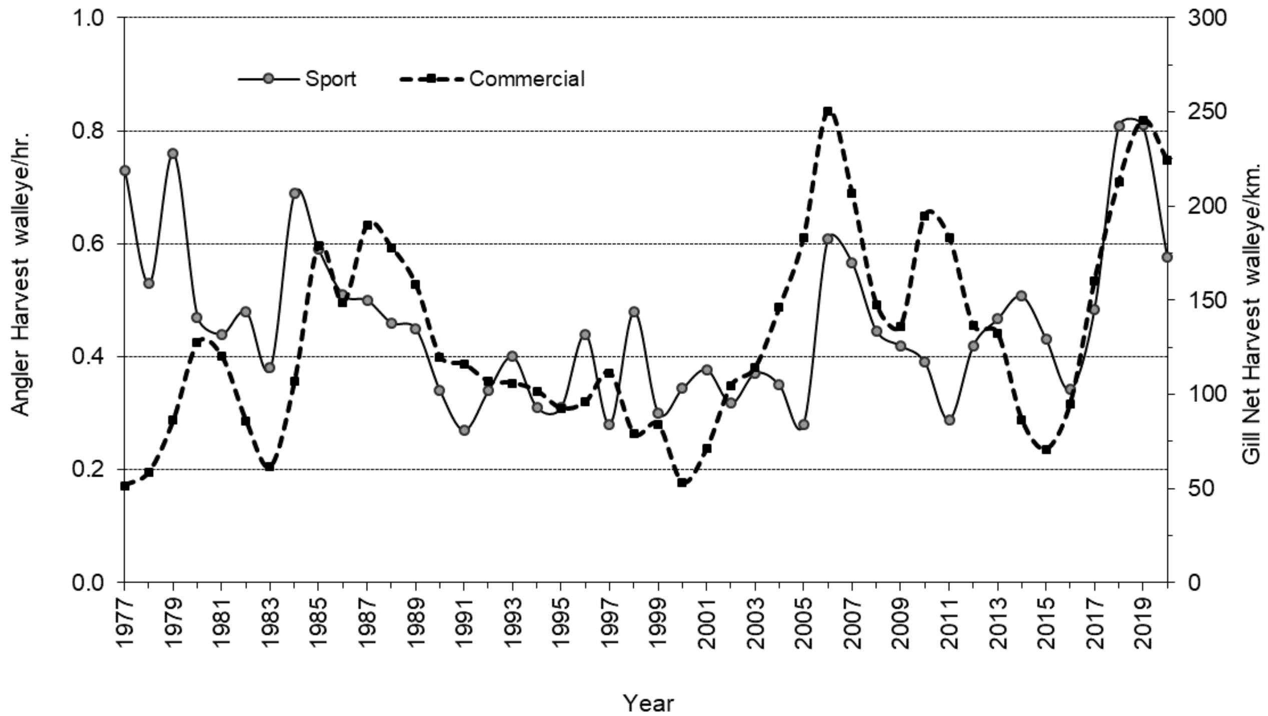


Figure 5. Lake-wide harvest per unit effort (HPE) for Lake Erie sport and commercial Walleye fisheries,1977-2020.

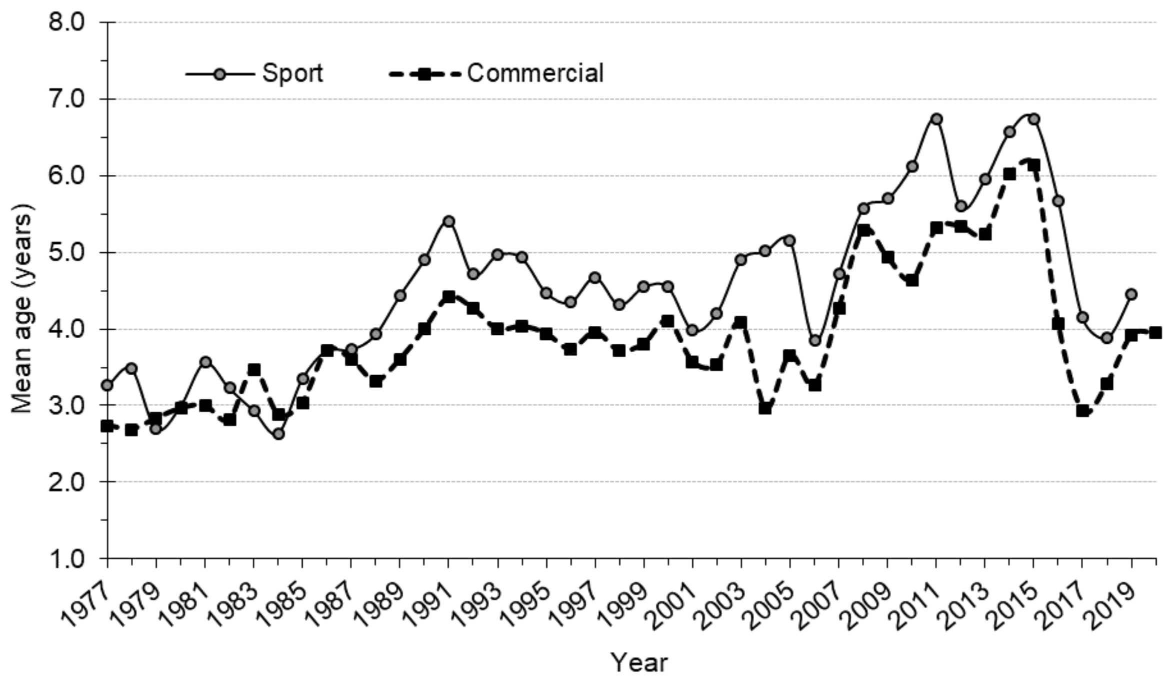


Figure 6. Lake-wide mean age of Lake Erie Walleye in sport and commercial harvests, 1977-2019. Average age will not be presented in 2020 because biological data was not collected in MI and OH sport fishery surveys due to COVID19 restrictions.

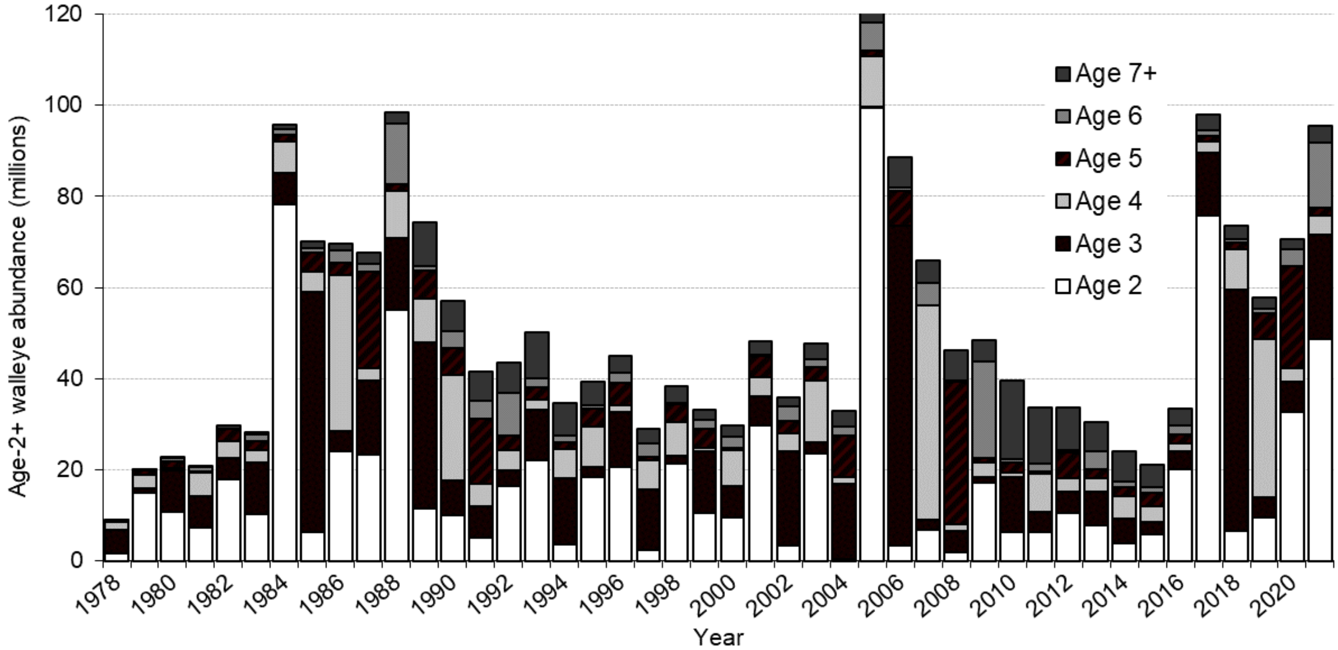


Figure 7. Abundance at age for age-2 and older Walleye in Lake Erie's west and central basins from 1978-2020 and the 2021 projection, estimated from the latest ADMB integrated model run. Data shown are from Table 8.

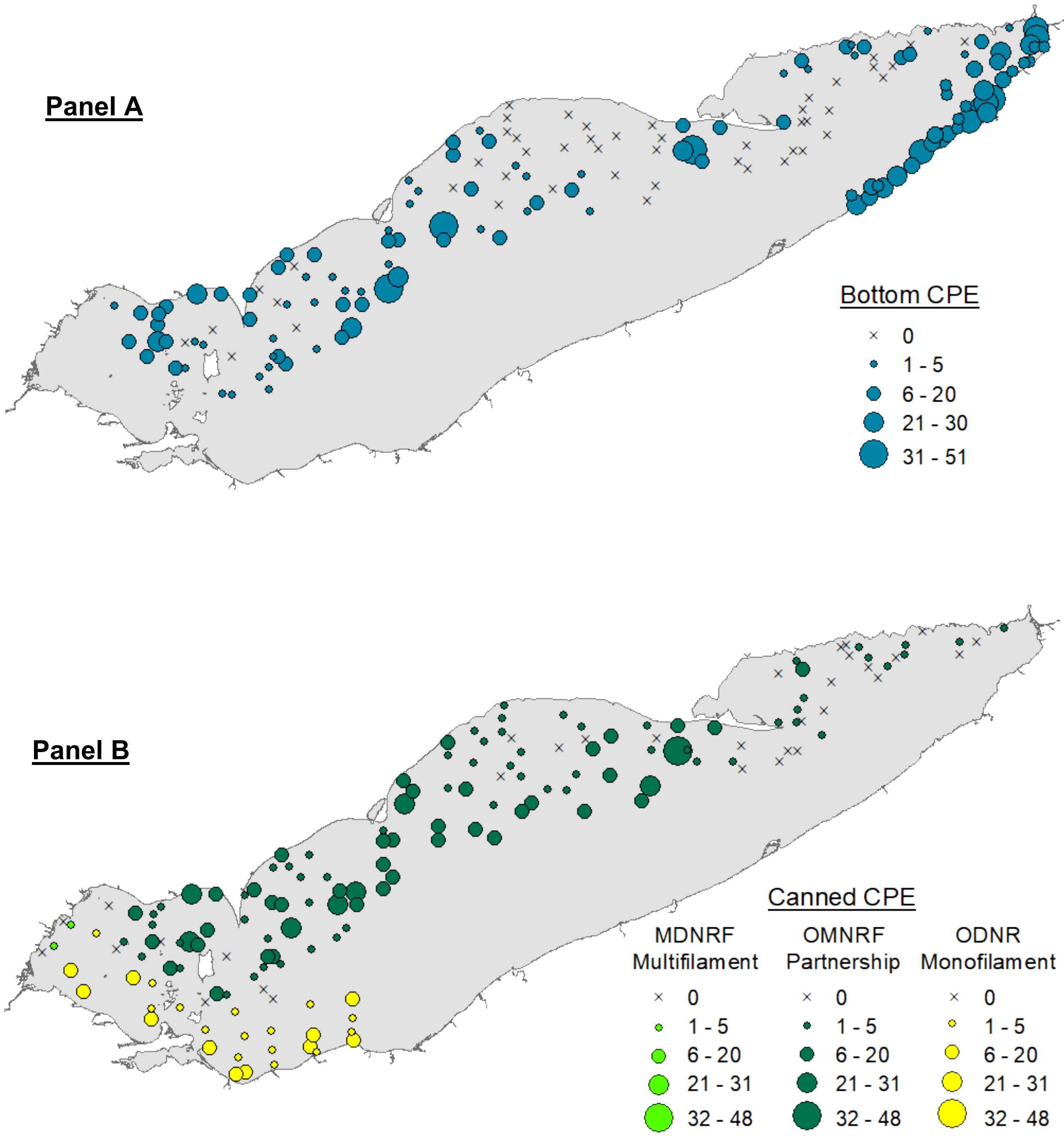


Figure 8. Relative abundance of yearling Walleye captured in bottom-set (Panel A) and suspended or kegged (canned) multifilament (Panel B) gillnets from Michigan, and monofilament gillnets from Ohio, New York, and Ontario waters in 2020. Catches have been adjusted to reflect panel length (standardized to 50 ft panels) and differences in the presence of large mesh (>5.5” excluded).

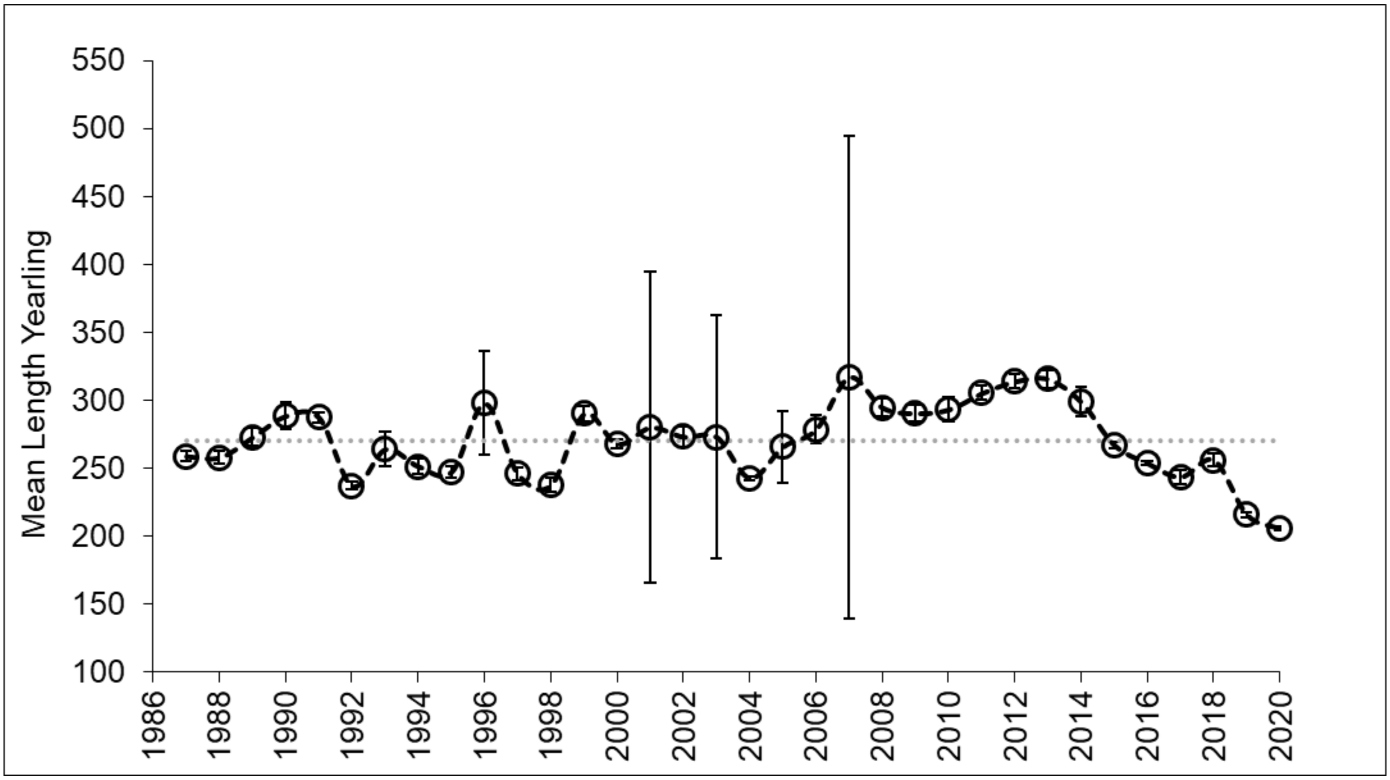


Figure 9. Annual mean total length of age 1 Walleye in Ohio and Ontario waters of western Lake Erie 1987-2020 with 95% confidence limits (black dashes above circles). Mean across years (1987-2020) presented as dashed line.

Appendix A: Lake Erie Walleye SCAA model configuration comparison detail model outputs

Table A1: Model configurations used to evaluate incorporation the Ohio multifilament to monofilament gillnet change into the Lake Erie Walleye SCAA. Michigan random walk catchability estimates informed by OH-MI priors. Fixed catchability re-estimated annually, using age-specific catch rations and SE estimates via mixed effects models. MI lamba was 7.6% when separated (based on number of sites) and OH dataset is same as MI-OH multifilament weighting.

Model #	MI & OH split	Gear comparison	Data Structure	Catchability Estimate
1	2016	Included	1. MI-OH multi (‘78-15) 2. MI multi (‘16-present) 3. OH mono (’16-present)	1. Random walk 2. Fixed 3. Fixed
2	2016	Excluded	1. MI-OH multi (‘78-15) 2. MI multi (‘16-present) 3. OH mono (’16-present)	1. Random walk 2. Fixed 3. Fixed
3	1978	Included	1. MI multi (’78-present) 2. OH multi (‘78-’15) 3. OH mono (’16-present)	1. Random walk 2. Random walk 3. Fixed
4	1978	Excluded	1. MI multi (’78-present) 2. OH multi (‘78-’15) 3. OH mono (’16-present)	1. Random walk 2. Random walk 3. Fixed
5	OH only	Included	1. OH multi (‘78-’15) 2. OH mono (‘16-present)	1. Random walk 2. Fixed

Table A2: SCAA model configuration precision (CV) results. Precision is presented as the coefficient of variation (CV) for model output metrics by model 1-3, (see table A1 for model details).

Metric	Model				
	1	**2**	**3**	**4**	**5**
Total Abundance	17.8	22.4	17.2	20.9	19.2
Total F	20.0	24.6	19.4	23.3	21.5
Ont. Com. Harvest	12.6	12.5	12.5	12.4	13.4
Oh. Sport Harvest	13.0	12.9	12.9	12.8	13.8
Partnership CPE	11.4	11.2	11.2	11.2	12.0
Fmsy	34.7	35.4	34.8	35.3	34.6
SSB_o	12.3	11.6	12.1	11.7	12.0
Average Score	**17.40**	**18.66**	**17.16**	**18.23**	**18.07**

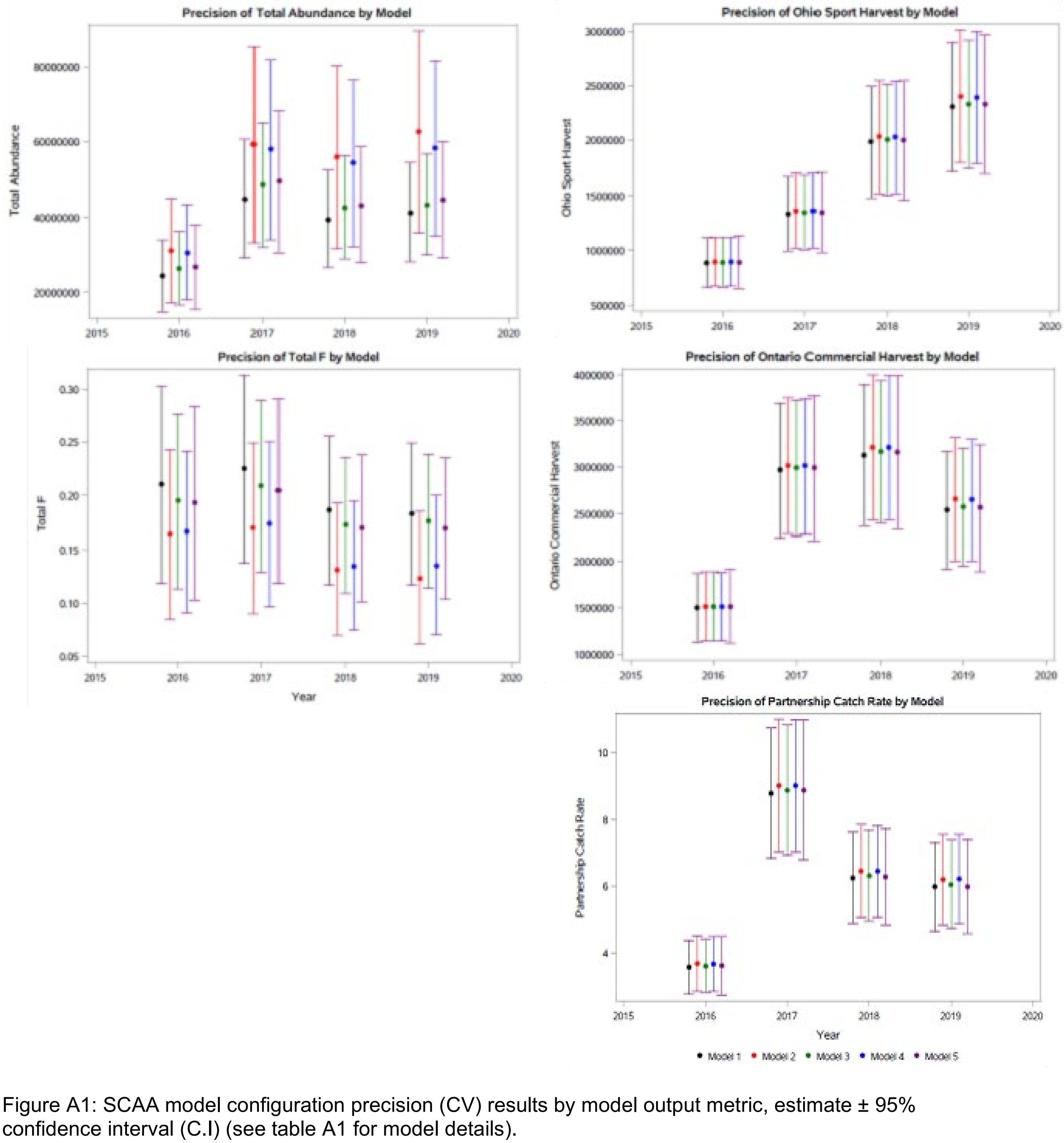
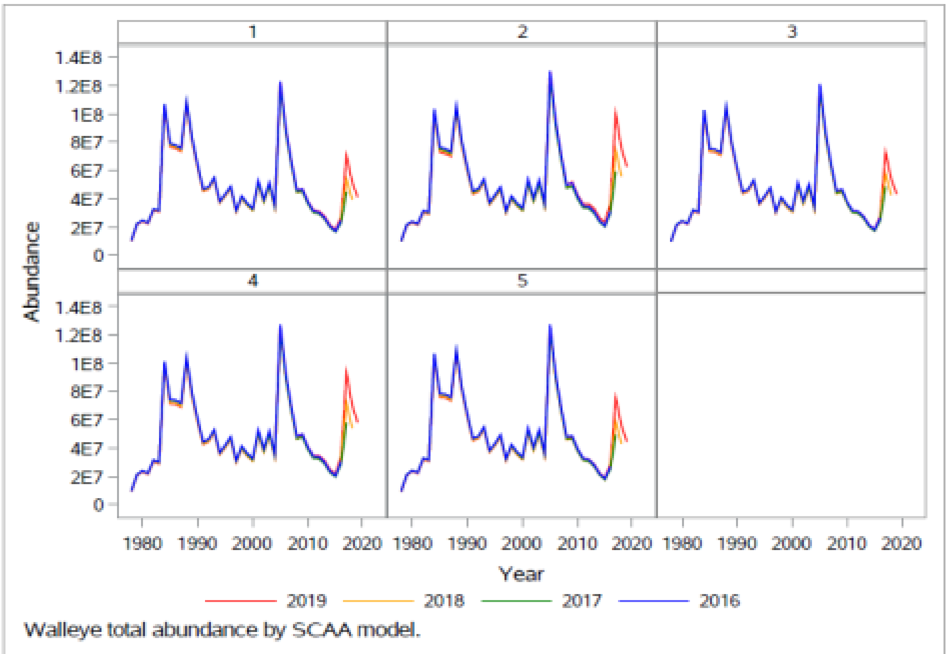


Figure A1: SCAA model configuration precision (CV) results by model output metric, estimate ± 95% confidence interval (C.I) (see table A1 for model details).

Table A3: SCAA Model configuration retrospective pattern (Mohn’s ρ) results. Average score is based on absolute Mohn’s ρ for all output metrics (see table A1 for model details).

Metric	Model				
	1	**2**	**3**	**4**	**5**
Total Abundance	-0.235	-0.277	-0.201	-0.242	-0.217
Total F	0.183	0.254	0.124	0.191	0.150
Ont. Com. Harvest	-0.076	-0.070	-0.073	-0.0693	-0.074
Oh. Sport Harvest	0.021	0.006	0.015	0.005	0.016
Partnership CPE	-0.183	-0.168	-0.175	-0.166	-0.180
Ont. Com. Harvest q	-0.220	-0.294	-0.165	-0.233	-0.189
Oh. Sport Harvest q	0.170	0.234	0.123	0.182	0.143
Partnership cpe q	0.107	0.196	0.070	0.143	0.087
Average Score*	**0.15**	**0.19**	**0.12**	**0.15**	**0.13**



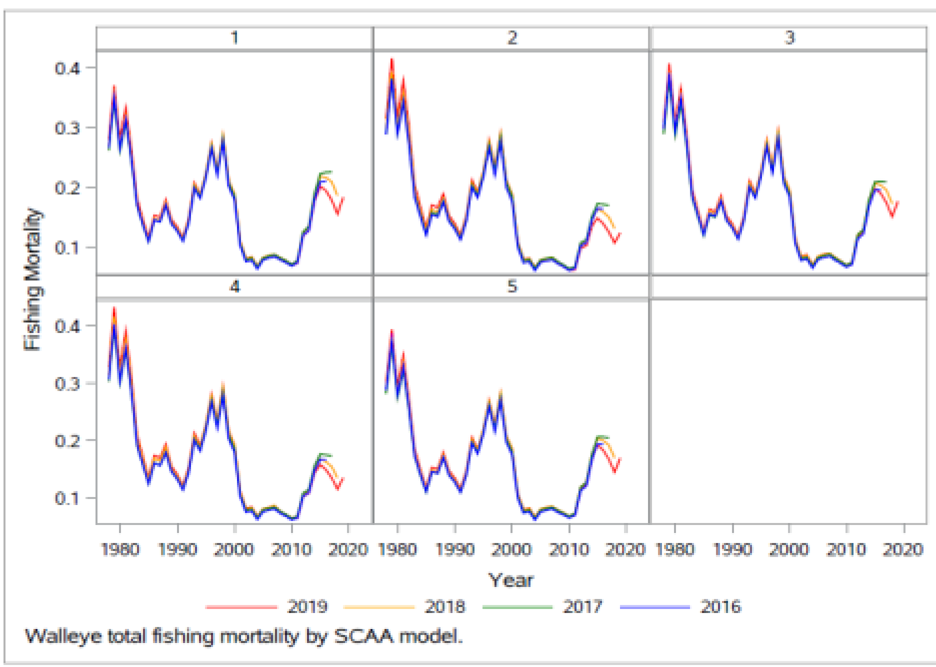


Figure A2: SCAA Model configuration retrospective pattern (Mohn's ρ) by model output metric for 2019-2016, (see table A1 for model details).

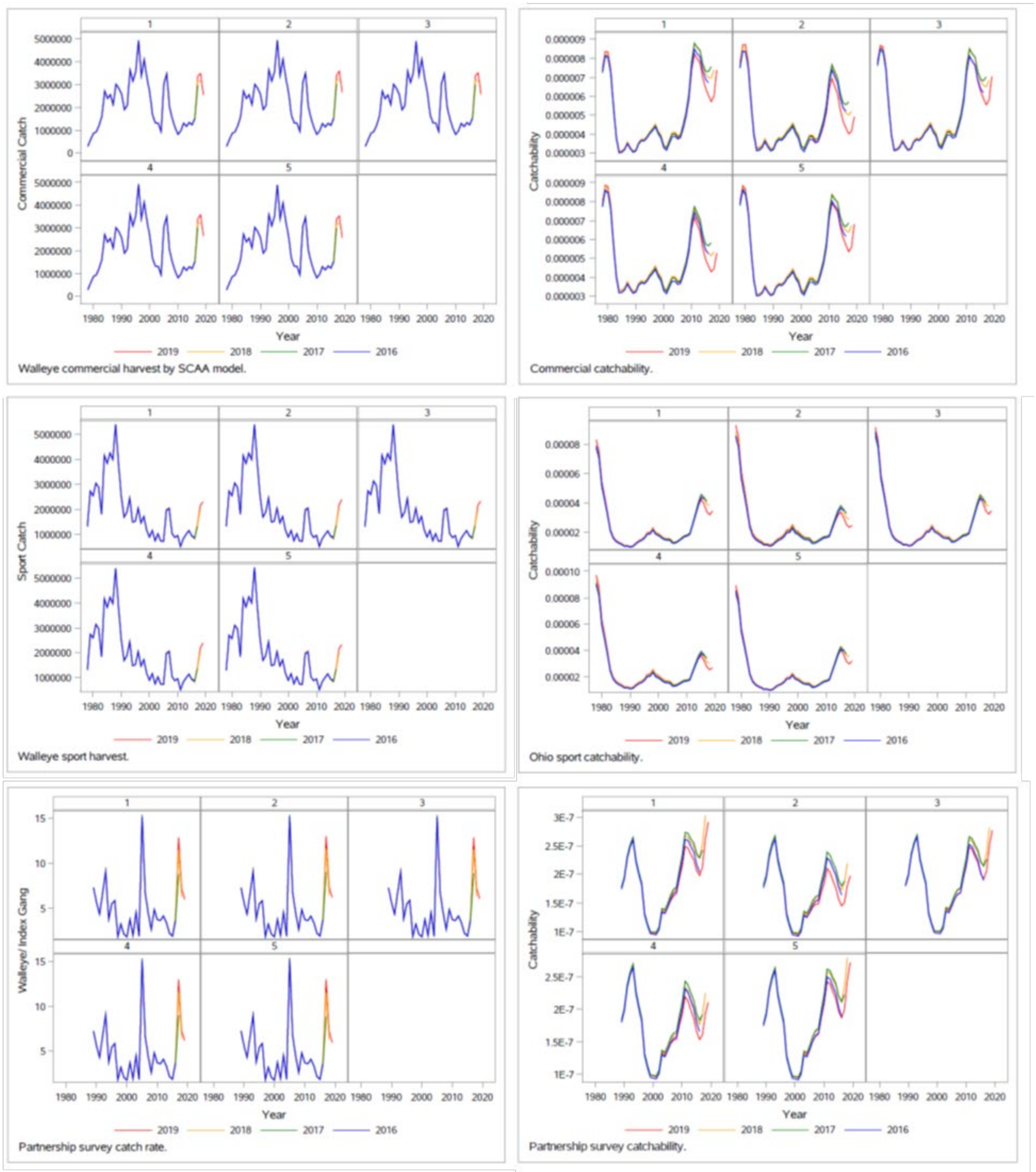


Figure A2: (continued): SCAA Model configuration retrospective pattern (Mohn's ρ) by model output metric for 2019-2016, (see table A1 for model details).

Figure A2: (continued): SCAA Model configuration retrospective pattern (Mohn's ρ) by model output metric for 2019-2016, (see table A1 for model details).

Table A4: SCAA model configuration parsimony results. (see table A1 for model details).

Metric	**Model**				
	1	**2**	**3**	**4**	**5**
Parameters	311	311	352	352	305
Objective function components **	22	21	23	22	20

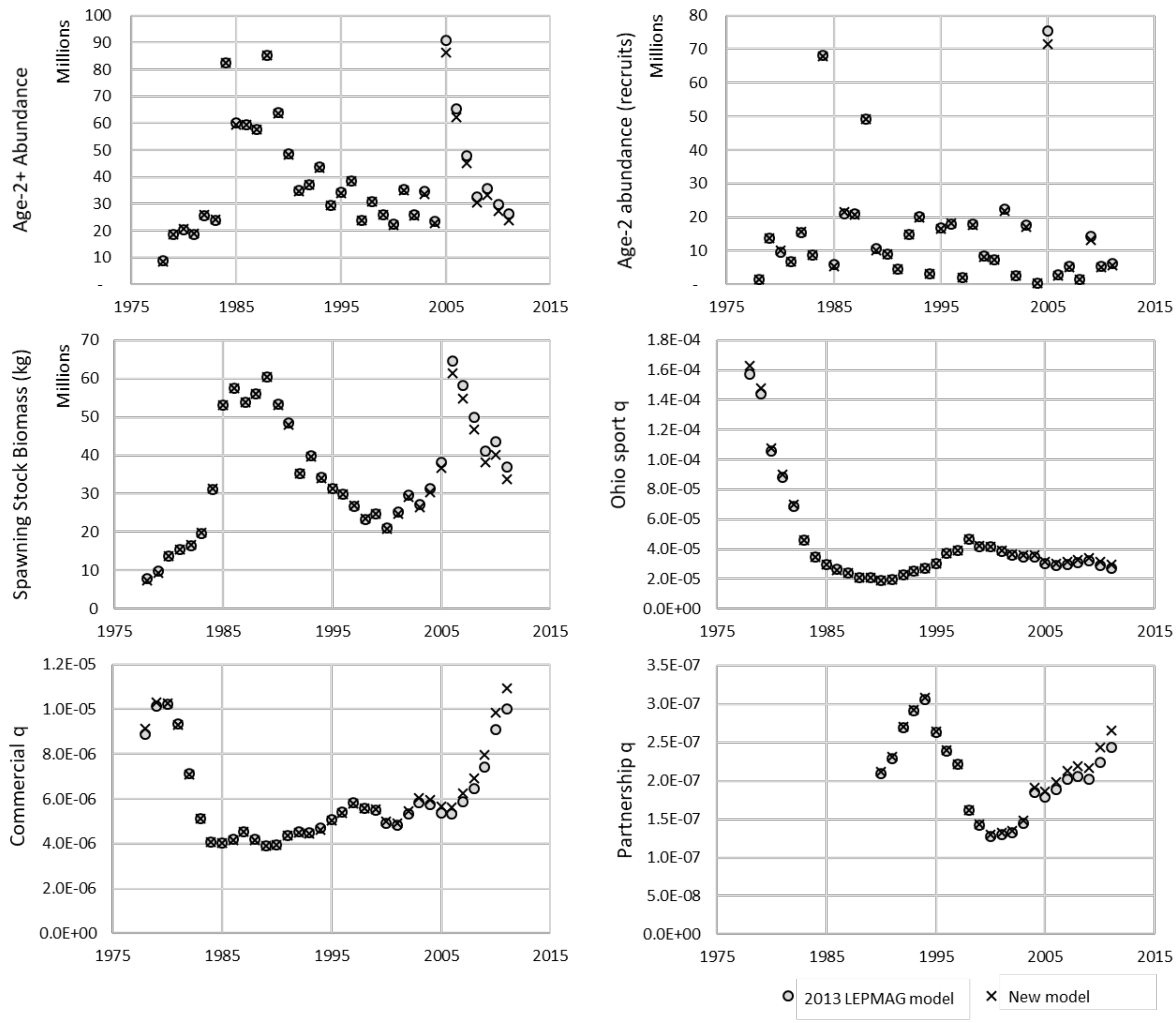


Figure A3: Comparative SCAA model outputs metric for the previous 2013 LEPMAG model and the new model configuration (model 3, see table A1).