STATE OF MICHIGAN
DEPARTMENT OF NATURAL RESOURCES

FR35 May 2022

Status and Trends of the Fish Community of Saginaw Bay, Lake Huron 2012–2017

David G. Fielder, Andrew S. Briggs, and Michael V. Thomas

www.michigan.gov/dnr/

FISHERIES DIVISION
FISHERIES REPORT 35

Suggested Citation Format

Fielder, D. G., A. S. Briggs, and M. V. Thomas. 2022. Status and trends of the fish community of Saginaw Bay, Lake Huron 2012–2017. Michigan Department of Natural Resources, Fisheries Report 35, Lansing.

For information or assistance on this publication, contact:

MICHIGAN DEPARTMENT OF NATURAL RESOURCES,
Fisheries Division
PO BOX 30446
LANSING, MI 48909
517-373-1280

TTY/TDD: 711 (Michigan Relay Center)

Michigan Department of Natural Resources
Fisheries Report 35, 2022

Status and Trends of the Fish Community of Saginaw Bay, Lake Huron 2012–2017

David G. Fielder

Michigan Department of Natural Resources, Alpena Fisheries Research Station, 160 East Fletcher, Alpena, Michigan 49707–2344

Andrew S. Briggs and Michael V. Thomas[1]

Michigan Department of Natural Resources, Lake St. Clair Fisheries Research Station, 33135 South River Road, Mt. Clemens, Michigan 48045

Abstract

The Saginaw Bay fish community assessment that began in 1971, continued with annual trawling and gillnetting surveys each September 2012–2017. Abundance and other population indices for Walleye *Sander vitreus* continued to reflect a recovered population that has not contracted substantially since the liberalization of the recreational fishery in late 2015. Walleye reproductive success remained strong but resulting recruitment has become more variable which is consistent with density dependent changes in stock-recruitment relationships. Yellow Perch *Perca flavescens* remained at low abundance but exhibited good reproductive success and appear limited by a high total annual mortality rate between age 0 and age 1. Walleye diet continues to reflect considerable predation on Yellow Perch, which is among the factors thought to be contributing to the suppression of that species. Yellow Perch that did survive past age 1 grew fast and exhibited early onset of maturity, especially in females. Overall prey fish indices remained low; Mimic Shiners *Notropis volucellus* have increased and are now a prominent component of the trawl catch, while the invasive Round Goby *Neogobius melanostomus* remained abundant in Saginaw Bay but are probably underrepresented by trawling. Alewives *Alosa pseudoharengus* remained absent from Saginaw Bay and native Cisco *Coregonus artedi* have not recovered. Another native species, the state threatened Lake Sturgeon *Acipenser fulvescens*, continued to remain absent from the survey catch.

[1] Retired

INTRODUCTION

Lake Huron's Saginaw Bay sustains substantial recreational, commercial, and bait-harvest fisheries that annually yield as many as 22 million fish (Fielder et al. 2014). The fisheries reflect the bay's coolwater habitat with recreational fishing emphasis on Walleye and Yellow Perch and commercial fishing emphasis on Yellow Perch and Lake Whitefish (See Appendix A for a list of common and scientific names of fishes and other aquatic organisms mentioned in this report). Year-round recreational fishing effort averaged more than 800,000 angler hours between 2012 and 2017. There are 21 state-issued commercial fishing licenses in Saginaw Bay with about 9 or 10 actively fishing in most recent years (Michigan Department of Natural Resources (MDNR), Fisheries Division unpublished data).

Like the rest of Lake Huron, Saginaw Bay has experienced ongoing colonization by invasive species in recent decades including Dreissenid mussels in the early 1990s and Round Goby by the mid-1990s (Ricciardi and MacIsaac 2000). Subsequently, the fish community of Lake Huron underwent an enormous paradigm shift in 2003–2004 with the collapse of invasive Alewife stocks (Riley et al. 2008) and the decline of the recreationally-important Chinook Salmon fishery (Johnson and Gondor 2013). The entire demersal and pelagic fish community underwent a restructuring with shifts of production from pelagic fishes to more benthic and littoral production (Hecky et al. 2004; Riley and Roseman 2013).

The new fish community of Lake Huron resulted in substantial gains in reproductive success for some native species including Lake Trout and Walleye and was principally attributed to release from the deleterious effects of Alewives (Fielder et al. 2007; Riley et al. 2007; He et al. 2013). In response, Walleye fingerling stocking in Saginaw Bay was suspended in 2006 and recovery goals and objectives that were previously established for the Saginaw Bay stock of Walleyes (Fielder and Baker 2004) were formally met in 2009 (Fielder and Thomas 2014). Fielder and Baker (2019) chronicled the history of fisheries management in Saginaw Bay leading to the recovery of the Walleye stock. Yellow Perch also exhibited increases in reproductive success but experienced high mortality of pre-recruits resulting in continued declines in abundance and fishery yields.

Stock assessment modeling of the Saginaw Bay Walleye stock indicated that the population of age 2+ peaked in 2007 at four million fish (Fielder and Bence 2014). Using a stochastic management simulation model (Fielder et al. 2016) to gauge management options, fishery managers sought to adapt harvest policies from the statewide default suite of regulations to tailored regulations specific to the Saginaw Bay Walleye population to more fully use the recovered population within limits of sustainability. This resulted in liberalization of the daily possession limit in the recreational fishery from five to eight Walleyes and a reduction in the minimum length limit from 381 mm total length to 330 mm. The liberalization of the recreational Walleye harvest policy was also intended to help address the high pre-recruit mortality of Yellow Perch by reducing predation. More conservative Yellow Perch harvest policies, such as a reduction in the recreational possession limit from 50 fish/day to 25 fish/day, and the retirement of one inner bay small mesh trap-net license in the commercial fishery, were also implemented to increase the abundance of adult Yellow Perch. This suite of management changes was implemented in October of 2015 and continued through the remainder of the reporting period for this report (2017).

The objectives of this analysis are to 1) document trends in abundance, recruitment, size and age structure, condition, and growth rates for many of the Saginaw Bay fish stocks; 2) evaluate the presence of invading species; 3) quantify diet patterns for select species; and 4) archive data and analysis for future use, and thereby provide a basis for evaluating progress towards existing management goals and the development of new ones.

The trawling portion of the annual netting survey has been in place since 1971 and Weber (1985) summarized results through 1984. Haas and Schaeffer (1992) updated the trawling results through

1989. The gillnetting portion of the survey was added in 1989 and Fielder et al. (2000) summarized both trawling and gillnetting results through 1997. Fielder and Thomas (2006) further summarized results through 2004 and Fielder and Thomas (2014) for results through 2011.

STUDY AREA

Saginaw Bay lies entirely in Michigan's waters of Lake Huron and spans a surface area of 2,960 km². The inner bay is shallow, averaging 4.6 m in depth, while the outer bay depth averages 14.6 m. The inner and outer bays are defined by a line between Point Au Gres and Sand Point (Figure 1). Land use in the watershed is a mixture of industry and agriculture, but there are also large tracts of forested area (Johnson et al. 1997). There are several tributary systems to Saginaw Bay, the largest being the Saginaw River collection of tributaries. Water in Saginaw Bay loosely circulates in a counterclockwise direction (Beeton et al. 1967; Danek and Saylor 1977) and the flushing rate is approximately once every 186 days (Beeton et al. 1967; Keller et al. 1987). The inner portion of Saginaw Bay is generally regarded as eutrophic with productivity declining towards the outer bay region. Saginaw Bay's limnology was further described by Beeton et al. (1967), Johengen et al. (2000) and the bay's water chemistry by Smith et al. (1977).

METHODS

Trawling

Bottom trawls have proven an effective gear for sampling prey species and all ages of Yellow Perch in Saginaw Bay since the first trawl survey was completed in 1971. Since the 1980s, trawling locations in the inner bay have been based on a 2 minute latitude x 2.8 minute longitude grid system. Fish samples were collected during daylight hours between September 6th and 25th of each year by the Michigan Department of Natural Resources (MDNR) Research Vessel (R/V) Channel Cat from four fixed index grids in the inner bay: Au Gres (north quadrant), Pinconning (west quadrant), North Island (east quadrant), and Coreyon Reef (south quadrant) (Figure 1). The Au Gres index grid was located near the city of Au Gres, and conditions there more closely resemble those of the less eutrophic outer bay. The Pinconning index grid was located at a bottom depression known locally as the "Black Hole." This grid, closest to the mouth of the Saginaw River, has organic sediments dominated by pollution tolerant benthic macroinvertebrates (Nalepa et al. 2003; Schneider et al. 1969). The North Island index grid was located off Wildfowl Bay, a shallow sub-bay that serves as a nursery area for many fish species. The Coreyon Reef index grid is located on a sandy flat that was once an important spawning reef. Prior to 2016, three replicate trawl tows were conducted at each of the fixed stations and three more replicates at an additional randomly selected grid in each quadrant for a total of 24 tows each year. Beginning in 2016, six separate grids per quadrant were trawled with one of those at each of the index grids. The other five grids were randomly selected within each quadrant. This resulted in same 24 trawl tows each year but better spatial representation and avoidance of unintended cluster designs which in turn led to improvements to analytical methods.

The two-seam otter trawl used for all tows had a 10.66 m headrope with 4.6 m wings and 18.9 m overall length and was constructed of 76, 38, and 32 mm graded stretched-measure mesh from gape to cod end, with a 9 mm stretched-mesh liner in the cod end. The net was towed along the bottom for 10 minutes by a single warp and 45.7 m bridle at a speed of approximately 2 knots. Based on trawl mensuration, the average gape width and height dimensions with this gear configuration were 7 m x 1 m (MDNR unpublished data). Water temperature and Secchi disk transparency were recorded at each grid and total weight and number of each fish species collected in each trawl tow were recorded. Large catches (>10 kg) of forage fish were sometimes subsampled by selecting 25% to 40% of the total catch. Total length in millimeters was recorded for up to 150 individuals of each forage species at each index grid, including age-0 Yellow Perch. All age-1 and older Walleye and Yellow Perch captured in the trawl were weighed to the nearest 0.01 kg and measured; most age-1 and older Walleye were also sacrificed and examined for stomach contents on board the survey vessel immediately after capture. The stomach was removed immediately, after which prey fish in the stomach contents were identified to species, if possible, and counted. Prey fish that were unidentifiable were classified as unidentifiable fish remains and counted.

Scale or dorsal spine samples for age and growth analysis were taken from a maximum of 25 age-1 and older Yellow Perch and 10 age-1 and older Walleye per 25 mm size group. For each year total catch and catch per unit effort (CPUE, number of fish per 10-minute tow) of Yellow Perch was estimated by age and sex. Estimates were weighted to account for bias inherent in stratified random subsampling for age estimation following the procedure outlined by Schneider (2000). The mean catch by age was used to estimate survival for ages 1–6 with a standard catch curve analysis (Miranda and Bettoli 2007). Overall and age-specific (age 1–6) sex ratios were determined by dividing the male catch by the female catch for each year and denoted as 'M/F'.

A forage index value was calculated for each year by summing the mean CPUE (kilograms of fish per 10-minute tow) for the most common forage species, including Alewife, Emerald Shiner, Gizzard Shad, Mimic Shiner, Rainbow Smelt, Round Goby, Spottail Shiner, Trout-Perch, age-0 White Perch, and age-0 Yellow Perch. Some summaries of trawling data are supplemented with results from earlier years to provide context and aid interpretation. Some analyses were also delineated by the years after the collapse of Alewives (2003–2017) to allow for comparisons before and after this event.

Gillnetting

Gillnetting of Walleyes was based on the work of Isbell and Rawson (1989), who showed that gill-net catch could be effectively used as a measure of abundance and recruitment for Walleye and other species. Gill-net sampling was performed at eight fixed stations from the MDNR R/V Chinook from 1989 until 2016 and then by the R/V Tanner concurrent with the trawling in early September of each year. Gill nets were 335 m long by 2 m deep, constructed of multifilament twine with 30.5 m panels of 38, 51, 57, 64, 70, 76, 83, 89, 102, 114, and 127 mm stretch nylon mesh; the 38 mm mesh was added in 1993. Two overnight, bottom net sets were made in depths greater than 3 m at each sample site and effort was divided between the inner and outer bay (Figure 1). All fish caught were measured for total length in mm. Walleyes, Northern Pike, Yellow Perch, and Smallmouth Bass were also weighed in grams with sex and maturity scored upon internal examination of gonads according to the criteria of Goede and Barton (1990). Dorsal spines or fin rays were collected for age interpretation from these same species. Yellow Perch were subsampled for these metrics by including specimens caught from every other net lift. Walleye diet was noted by examining the stomach contents and reported as frequency of occurrence, which is the percentage of fish with non-empty stomachs that contained at least one of a selected food item (Windell and Bowen 1978).

Gill-net CPUE was calculated as the number of each species per 335 m net lift. Condition was examined by calculating relative weight for Walleye (Murphy et al. 1990) and Yellow Perch (Willis et al. 1991) and expressed by stock density length indices (Gabelhouse 1984). Proportional stock density (PSD) and relative stock density (RSD), an index of the size structure of the population, were also determined according to the size designations of Anderson and Gutreuter (1983) for Walleye and Anderson and Neumann (1996) for Yellow Perch. Growth rate was indexed as mean length-at-age at capture and compared to the Michigan average for the fall season as reported by Schneider (2000).

To examine trends and noteworthy changes, analyses of key common metrics from this gill-net survey from 2012–2017 were used to make comparisons with data from 1989–2011 surveys.

Statistical Analysis

Analysis of variance (ANOVA) was used to test for differences in trawl and gill-net catch rates among years and time periods. Analysis of variance was also used to test for differences in Yellow Perch mean length-at-age among years for trawl data and for Walleye and Yellow Perch mean length-at-age from gill-net data. Trawl and gill-net catch rates (CPUE) often have a lognormal distribution, so distributions of CPUE values were graphically examined (Stewart-Oaten 1995). Trawl and gill-net data were examined for normality using Lilliefors Test and for homogeneity of variance using Bartlett's or Levene's Test. When substantial deviations from normality were observed, nonparametric Kruskal-Wallis (KW) procedures with post hoc multiple comparisons were used to test for statistical differences in mean CPUE among and between years or time periods for both gear types. Statistical differences between individual means of some metrics of interest were determined by a t-test when departures from normality were not observed or by a Mann-Whitney U (MW-U) test otherwise. Some means are reported with two standard errors of the mean (SEs) which approximate 95% confidence intervals to assist in visually examining the summarized data for significant differences. For some metrics of interest, true 95% confidence intervals are reported.

Calculations of means and SEs for trawling catch rate data were conducted using equations for simple random sampling. The assumptions of such a sample design are met well for the trawl design but not for the paired sets in the gill-net portion of the survey, which constitutes a single stage cluster design. While the means from a cluster design are still unbiased and mathematically equivalent with those from simple random sampling, the SEs are not. Standard errors of the mean for gillnetting CPUE are calculated using the standard single stage cluster design (Thompson 2002). Aside from the difference in sampling design between the two gears, both survey elements strive for broad spatial coverage across the expanse of the bay via fixed site selection for the gill-net survey and the use of quadrants for the trawl survey. This approach likely magnifies catch differences, especially between the inner and outer bay environments. Consequently, the magnitude of variability of the data is likely exaggerated by the design, and resulting expression of variability such as SEs and confidence intervals can be regarded in this analysis as conservative. Biological data from the gill-net catch is not believed to be influenced by clustering as there is little or no spatial component for such metrics within the Saginaw Bay fish populations and means and SEs are based on the simple random sampling formulations of pooled data.

Total annual mortality rates for Walleye and Yellow Perch were calculated using two methods with numbers by ages for fish collected with gill nets. The point-in-time catch curve method assumes equal annual recruitment. However, because this is unlikely and because time series of numbers at age data were available, we also estimated total annual mortality using the "cohort" method (Ricker 1975; Miranda and Bettoli 2007). The cohort method assumes equal vulnerability of ages to the gear over time. In each case, the actual computation was based on the Robson-Chapman method of catch curve estimation of mortality (Hilborn and Walters 1992; Miranda and Bettoli 2007). The point-in-time approach to total annual mortality estimation represents the time period reflecting the ages of the fish in the collection (multiple year classes). The cohort method reflects the time period spanned by a single year class over its longevity. While similar, the two methods take a different approach to total annual mortality estimation. Given the importance of this metric, it is estimated and reported both ways allowing for a more in-depth evaluation of these rates.

Simple linear regression analysis was used to develop length/weight relationships for some species based on natural log transformed data and linear regression. A Von Bertalanffy length-at-age model was fit for Walleye and Yellow Perch using individual data rather than means, with model parameters calculated according to Isely and Grabowski (2007). Maturation of male and female Walleyes was defined as age at 50% maturity from gill-net data and was derived by solving for age at a maturity score of 50% between immature and mature by applying and assuming a linear relationship in maturity and age between the two age groups that bracketed the 50% maturity threshold. All statistical tests for this study were performed according to Sokal and Rohlf (1981) and conducted at a significance level of $P \leq 0.05$ based on two-tailed hypothesis testing unless otherwise stated. SPSS computer software or R statistical software were used for statistical analyses (R Core Team 2013; SPSS 2010).

RESULTS

Trawling

The trawling survey completed a total of 144 trawl tows in inner Saginaw Bay from 2012–2017. During this time period mean water temperatures at trawling sites varied between 12.5º C and 22.7º C, exceeding the long-term mean of 17.9º C in five of the last six years of the survey and continuing the trend of warmer mean water temperatures during the fall trawl survey since the early 1990s (Figure 2). Mean fall Secchi depth recorded at trawling sites varied between 1.40 m and 2.24 m from 2012–2017, continuing an increasing trend observed since 2000 (Figure 3).

SPECIES COMPOSITION AND CATCH RATES

During 2012–2017 a total of 203,390 fish were caught in the fall trawl survey. Species composition varied considerably among years (Table 1, Appendix B); the most common species captured were Mimic Shiner, Trout-perch, Round Goby, Yellow Perch, and White Perch, which accounted for at least 77% of the total catch each year. Round Goby, an invasive species which first appeared in survey trawls in 1999, made up an average of 14% of the total catch from 2012–2017.

Several notable patterns or occurrences that have been observed in previous reports continued in the most recent survey period. Alewife CPUE collapsed after 2003 and has been at or near zero since 2005. Mean Alewife CPUE has varied among time periods (KW test, H=24.94, df=4, P<0.001) and the 2012–2017 period CPUE was significantly less than the 1980s (KW post hoc test, H=21.12, P=0.013) and 1990s (KW post hoc test, H=21.92, P=0.008) mean CPUE by over three orders of magnitude. Since 2003, Walleye CPUE in the trawl survey has been higher than any previous survey period, due to strong reproductive success as indicated by age-0 catch rates (Table 2). Yellow Perch age-0 CPUEs have generally been higher than from 1992–2002 (Table 3). Forage index values have varied among time periods (KW test, H=18.26, df=4, P=0.001) and the 2012–2017 forage index values were lower than during the 2000s (KW post hoc test, H=-23.33, P=0.006) but similar to the 70s (KW post hoc test, H=-2.44, P=1.000), 80s (KW post hoc test, H=-14.43, P=0.333), and 90s (KW post hoc test, H=-15.53, P=0.220; Table 1, Figure 4). Cisco, historically abundant, remained absent from the trawl survey catch.

CPUE, SURVIVAL, SEX RATIO, AND GROWTH OF YELLOW PERCH

Mean age-specific CPUEs for ages 1 and older Yellow Perch have been low since the Alewife collapse in 2003 but increased for ages 2–4 in 2017 (Table 4). Age-0 CPUE of Yellow Perch has been greatest since the Alewife collapse, but low survival has resulted in similar or lower age-1 Yellow Perch CPUE than other time periods. Catch curve analysis of trawl samples for Yellow Perch ages 1–6 produced an estimate of total annual mortality of 71% since the Alewife collapse in 2003, compared to 47% before. The male to female sex ratio for Yellow Perch across ages 1–6 has been near 1.0 since the Alewife collapse. Age-specific sex ratios during the post-Alewife time period were nearly even for age 1 (M/F: 1.03), then skewed towards females for ages 2 and 3, and then heavily skewed towards males for ages 4, 5, and 6 (Table 5).

Based on mean length-at-age at time of capture, female Yellow Perch grew faster than male Yellow Perch in Saginaw Bay (Table 6). On average, for the 2012–2017 period males reached a length of 200 mm by age 3 while females reached the same length by age 2. Saginaw Bay Yellow Perch growth was well above statewide average growth rates for ages 1–5. Saginaw Bay Yellow Perch mean length-at-age has generally maintained a trend of faster growth since the mid-1990s (Figure 5), particularly for ages 2, 3, and 4. However, during the 2012–2017 period growth has remained relatively consistent or even declined, particularly for ages 1, 2, and 3.

DIET OF WALLEYE

Prior to 2003, Alewives were consistently the most frequently occurring prey item in non-empty Walleye stomachs (Table 7). However, from 2003–2005 Yellow Perch were found in a higher proportion than any other taxa. Since 2005, only one Walleye stomach examined contained an identifiable Alewife. White perch were the most frequently occurring prey item in 2006. From 2007–2017, Gizzard Shad and Yellow Perch have been the primary prey items found in the stomachs of Walleye collected in the trawl survey. The diversity of prey items was highest in 2008 and 2014, with nine species identified from Walleye stomachs in both years. Round Gobies first appeared in Walleye diets in 2000 and continued to account for a small percentage of the diet in the most recent years.

Gillnetting

The gill-net portion of the fish community survey collected a total of 15,724 specimens spanning 30 different species between 2012 and 2017, for an average of about 2,600 fish per year. The most abundant species were: Yellow Perch, Walleye, Gizzard Shad, and White Sucker (Table 8). Notably absent from the gill-net collections were Cisco and Lake Sturgeon, both of which were historically abundant (Baldwin et al. 2009) and are now designated as state threatened species (Latta 2005). Catch rates for commonly encountered species were mostly similar within the current time period. For example, CPUE of Walleye ranged from a mean of 21.3 fish/net lift (2015) to a high of 49.5 fish/net lift (2017) but was not significantly different among those years (KW test, df=5, P=0.133). Walleye catch rates continued to increase compared to earlier reporting periods. While there was no significant difference for the Walleye gill-net catch rate between the current reporting period (2012–2017) and the last period (2005–2011; MW-U P=0.176), there was a significant difference between mean CPUE during the post recovery period of 2009–2017 (33.5 fish/net lift) and the earlier period of 1993–2008 (17.1 fish/net lift; MW-U P<0.001).

Yellow Perch CPUE did not vary significantly among the survey years (KW test, df=5, P=0.535), or between the current reporting period (2012–2017) and the last (2005–2011) (MW-U P=0.701). There was, no significant difference in Yellow Perch CPUE between the pre-Walleye recovery period of 1993–2008 (mean 43.0 fish/net lift) and the post Walleye recovery period (since 2009; mean 50.1 fish/net lift) (MW-U P=0.054). Similarly, there was no significant difference in CPUE of White Sucker (KW test df=5, P=0.234) or Channel Catfish (KW test df=5, P=0.689), there was, however for Gizzard Shad (KW test df=5, P<0.001). Gizzard shad ranged from a mean high of 85 fish/net lift in 2012 to a low of 2.5 fish/net lift in 2015 (Table 8). Mean gill-net catch rate of yearling Walleye, as one expression of year class strength, varied over the time series (Figure 6) and significantly during the reporting period (KW test df=5, P<0.001) from a mean high of 7.7 fish/net lift in 2017 to a mean low of 0.6 fish/net lift in 2015.

The Walleye age distribution broadened across the reporting period from a low of eight year classes represented in 2014 to a high of 16 in 2017 (Table 9). Walleye mean age varied significantly (ANOVA, df=1,489, P<0.001), exhibiting an increasing trend until 2017. Walleye diets continued to be dominated by Yellow Perch and Gizzard Shad, a trend that has been observed since 2003 (Table 10). Round Gobies were the third most common diet item in most years. Alewives were a common diet item in the study time series until 2004 when they dropped from the frequency of occurrence except for a small proportion in 2013. Conversely, Yellow Perch were an infrequent dietary item until 2003 and common after that. Gizzard Shad have figured prominently in Walleye diets during many years throughout the time series (Table 10) and were nearly always young of the year.

Walleye growth rate, as indicated by mean length-at-age (at capture), varied little over the reporting period (Table 11). The five year mean for the reporting period was 412 mm, which was significantly less (t-test, df=883, P<0.001) than the maximum management target of 425 mm (Fielder and Baker 2004). However, the 486 mm mean length of age-3 Walleyes during the 1989–2008 pre-recovery period was significantly larger than the 404 mm age-3 Walleye mean length-at-age observed during the post recovery period of 2009–2017 (ANOVA, df=1692, P<0.001). Walleye age-3 mean length an important indicator of recovery (Fielder and Baker 2004) has trended below the recovery threshold since 2004 (Figure 7). Walleye condition, as indicated by relative weight, varied significantly during the reporting period from a low of 74% in 2014 to a high of 86% in 2016 for all sizes combined (Table 12; KW test, df=5, P<0.001). Walleye population size structure as denoted by proportional stock density exceeded the recommended PSD range of 30–60% between 2013–2016, suggesting a paucity of stock to quality sized (250–380 mm) Walleyes relative to those greater than quality-sized fish (380mm; Table 13). Similarly, there was relatively low abundance of Preferred (510 mm) and Memorable (630 mm) sized Walleyes when compared to the MDNR recommended values for ‘quality’ Walleye fisheries in Michigan (Table 13; MDNR unpublished data). Age at 50% maturity was 2.89 for male Walleye and 3.50 for females (Table 14), which is greater than the 2005–2011 reporting period values of 2.50 and 2.96, respectively.

Total annual mortality rate (A) as indicated by point-in-time catch curves varied significantly during the reporting period from a low of 37% in 2017 to a high of 62% in 2012 (Table 15). The mean point-in-time derived total annual mortality rate was 50% for the reporting period. When examined by cohort for years approximately spanning the reporting period, total annual mortality rate was similar and averaged 47% (Table 16).

The age distribution of Yellow Perch continues to be skewed towards younger individuals. Yellow Perch ages included as many as eight year classes in most years but were principally comprised of ages 1–3 (Table 17). The mean age of Yellow Perch collected by gill net ranged from a low of 1.6 years in 2013 and 2017 to a high of 2.0 years in 2012. The average age for Yellow Perch across the reporting period was just 1.8 years, which differed significantly from the mean age of 1.6 years for the 2005–2011 reporting period (t-test, df=5,240, P<0.001). Yellow Perch mean length-at-age varied just 5 mm from the state average for September capture (Table 11). This is a substantial decrease in growth rate compared to the previous reporting period growth index which averaged 49 mm. The condition of Yellow Perch for the reporting period, as indicated by relative weight, ranged from a low of 89% in 2013 to a high of 99% in 2015 (Table 12). The overall mean for the time period was 95% which was significantly greater than the overall mean of 90% for the previous reporting period (t-test, df=5,175, P<0.001). The PSD of Yellow Perch was within recommended ranges for all years except 2012 (Table 13).

The total annual mortality of Yellow Perch from point-in-time catch curves averaged 61% for the reporting period and ranged from a low of 53% in 2014 to a high of 73% in 2012 (Table 15). This was similar to the mean value for the previous reporting period at 66%. The 56% total annual mortality estimate based on the cohort method was slightly lower for the reporting period (Table 16). Length/weight regression equations and length/age Von Bertalanffy equations for Walleye and Yellow Perch are presented in Appendix C.

DISCUSSION

Walleye

The Saginaw Bay Walleye population continued to attain recovery targets during the 2012–2017 reporting period. Since 2017 the Walleye population in Saginaw Bay has been at recovery targets for nearly a decade and stocking was suspended in 2006 so the present population is principally wild. Abundance of the Walleye population during the post-recovery period is evident in the gill-net CPUE trends (Table 9). Despite the liberalization of the recreational fishery harvest regulations, by the end of this reporting period the relative abundance of Walleye was at its greatest value since 1994. This is in contrast to trends in population size as estimated by statistical catch at age (SCAA) models (see Fielder and Bence 2014) that suggest the overall Saginaw Bay stock of Walleyes has contracted from a high of 3.7 million age 2 and older fish in 2007 to 2.1 million age 2 and older fish in 2016, a 42% reduction.

A telemetry study of Saginaw Bay Walleyes (Hayden et al. 2014) documented as much as 37% of adult fish make a migration to the open waters of Lake Huron from approximately June through October. It is likely that some of the variability observed in the gill-net survey CPUE is reflective of not just abundance trends but also migration patterns of returning Walleyes that time of year. Slightly earlier or later migration of returning Walleyes may increase or decrease gill-net CPUE. The increasing water temperatures in the Saginaw Bay (Figure 2) may be affecting return dates for Walleyes that emigrated from Saginaw Bay earlier in the year. This in turn may account for the differences between gill-net survey CPUE trends and those indicated by the SCAA model. While the SCAA model includes the gill-net CPUE as one data source, it also fits the estimates to a greater variety of data, including harvest levels from various fisheries.

If the Walleye population is contracting in Saginaw Bay, it may be a reflection of saturation of carrying capacity based on available prey and adult habitat. A similar phenomenon was observed in Lake Erie when its Walleye population first recovered, resulting in a resurgence in Walleye abundance and then a contraction to a more intermediate level (Drouin and Soper 2017). Trends in recovery of native species may mirror that observed for invasions of nonnatives that often expand exponentially and then decline to some steady state. A changing stock–recruitment relationship with year class production not being as great in recent years as during the initial recovery appears to be driving this for Saginaw Bay.

While recruitment may be lower, reproductive success of Walleye in Saginaw Bay, as evidenced by the trends in fall age-0 trawl CPUE, has been relatively stable in recent years (Table 2). Fielder and Thomas (2014) reported that they believed year class strength was no longer well predicted by abundance of age-0 Walleyes in the fall, a departure from that reported for earlier years by Ivan et al. (2011). The decoupling of year class strength and fall age-0 abundance appears to be continuing during this reporting period. For example, the 2016 trawling catch rate of age-0 Walleyes was the lowest for the reporting period but was the highest as yearlings in the 2017 gill-net catch. Juvenile Walleye abundance is not believed to be affected by trends in migration as understood for older Walleyes. Generally wild Walleye recruitment remains higher when compared to the pre-recovery period (before 2003) but may vary more now because the population is at a higher density and the capacity of the prey base and habitat. We believe that Walleye reproductive success will remain strong providing the current fish community assemblage remains the same and Alewives remain scarce.

It is not immediately known what the relative contributions of different tributaries are to Saginaw Bay's Walleye reproduction and subsequent recruitment. Fielder (2002) documented various sources of Walleye recruitment during the pre-recovery period, where reproduction was almost entirely tributary based with evidence of the Tittabawassee River being one of the largest producers. It is believed that before its collapse in the mid-twentieth century the historic Walleye population in the bay was also sustained by contributions from offshore rock reef spawning (Schneider and Leach 1977; Schneider and Leach 1978). Similar to how tributary-spawning Walleyes in Saginaw Bay home back to their natal spawning grounds for reproduction purposes (Hayden et al. 2017) the propensity for some Walleyes to spawn on offshore reefs is a heritable trait (Jennings et al. 1996) and there is evidence that such an endemic strain still persists in the bay (Billington et al. 1998; Kalejs 2017). Fielder and Baker (2004) called for investments in offshore rock reef habitat restoration in the inner portion of Saginaw Bay as one strategy to help diversify sources of Walleye reproduction and infuse more resiliency in the population. A grant to fund two experimental reefs was awarded from the United States Environmental Protection Agency to the Michigan Department of Environmental Quality in 2017, with plans for construction in 2019. This survey series will be one way to evaluate such habitat improvements in the years to come.

The considerable abundance of Walleyes in Saginaw Bay has provided for an expanded recreational fishery. Angler harvest rate of Walleyes during the April–October open water fishery has increased by 561% from 1994–2005 to 2007–2017 (MDNR unpublished data). The harvest rate by anglers targeting Walleyes has averaged an impressive 0.48 Walleyes/hour since 2006, which is higher than the targeted harvest rate of 0.45 fish/hour for Lake Erie Walleyes during the same period (Walleye Task Group 2018). The size structure of the population, however, has declined with no trophy size Walleyes encountered in the survey catch and infrequent collections of those in the preferred size range. One key definition of recovery was defined on growth rates declining to a target level, and Fielder and Baker (2004) used growth rates as a surrogate for indicating when Walleye abundance came to capacity of Saginaw Bay. Growth has predictably slowed for Walleye during the post recovery period; the growth rate of age-3 Walleyes has been at or below the target of 110% of the state average rate during the reporting period (Figure 7). Part of the paucity of larger Walleyes in the population may also be a function of overall relative size structure in that smaller fish are so abundant they are expected to make up a larger proportion of the harvest. Fishery managers have yet to decide if population size structure and the size of Walleyes harvested are criteria for management changes. It was recognized that if the liberalization of the recreational Walleye harvest regulations was successful in reducing the density of Walleyes, growth rates may increase.

While the Walleye population of Saginaw Bay has experienced considerable change since attaining recovery, the total annual mortality rate has remained relatively stable at about 50% (Tables 15 and 16). This value is intermediate to the 57% total annual mortality estimated by tag return analysis (Fielder 2014) in 2016 and the 34% total annual mortality estimated by the SCAA model for 2012–2016. The SCAA value may be lower because it was limited to age-4 and older Walleyes and better reflects the main basin migrant portion of the population. Regardless, these values are regarded as sustainable for a healthy Walleye population. The objective of the 2015 liberalization of the recreational harvest regulations was to increase fishing mortality by an additional 50%. It is not immediately evident from these estimates alone if mortality is increasing and will likely require recreational specific fishing mortality (F) estimates from SCAA to gauge. The increase in the number of year classes detected by the 2017 gill-net survey suggests greater longevity which might be consistent with lower mortality rates.

Yellow Perch

Yellow Perch abundance remains low in Saginaw Bay, continuing a trend since the early 1990s. The low abundance from 1990 to 2002 was characterized by poor reproductive success and was attributed to the effects of invasive Dreissenid mussels and perhaps by the effects of Alewives (Fielder and Thomas 2014). Like Walleye, reproductive success of Yellow Perch has increased greatly since Alewives disappeared from the fish community beginning in 2003, as evidenced by the age-0 trawl CPUE (Table 4). Despite the high abundance of age-0 Yellow Perch in the fall trawl series, they are relatively scarce the following year as age-1 fish. The mortality rate between age 0 and age 1 averaged 76% over the reporting period and was as great as 94% from 2012–2013. Yellow Perch fisheries have declined in response, with the recreational year-round harvest in 2017 at 221,082 fish, a 96% decline from their high in 1987; and the commercial yield averaging 16,616 kg since 2003, an 82% decline from the 1972–1984 average (MDNR unpublished data). While not absent, these fisheries are virtually collapsed when compared to their historical standards.

Fielder and Thomas (2014) explored a variety of reasons for the poor survival of Yellow Perch, especially juveniles, but the prevalence of young individuals in the diet of predators elevates predation to the top of the list of likely factors. Yellow Perch have figured prominently in the diets of Saginaw Bay Walleye collected by MDNR trawls and gill nets since 2003 while they did not prior to then (Tables 7 and 10), and similar trends have been reported by other authors (Roseman et al. 2014). DeBruyne et al. (2017) described Double Crested Cormorant diet in Saginaw Bay and estimated that they consumed 17% as much Yellow Perch as the resident Walleye population. Many predators are likely using juvenile Yellow Perch as a forage fish in the bay, especially over winter and the following spring until the next year's forage fish production is complete. Predation on Yellow Perch is not limited to juveniles since total annual mortality was estimated across all ages encountered as high as 71% (from trawl estimated mortality rates) although that also includes any fishing mortality imposed on the older ages. The estimated total annual mortality rate of fish collected in gill nets was somewhat lower, but still higher than what is considered sustainable in the absence of regular recruitment.

Clearly the cause of low Yellow Perch abundance is poor survival and not an issue of reproductive success. The question vexing fishery managers is why Yellow Perch are so heavily preyed upon now, when historic commercial landing records show they previously existed at high abundance in the presence of high Walleye density (Baldwin et al. 2009). We continue to hypothesize that other species such as Cisco have previously served as a buffer for predation on Yellow Perch. Diet data since the late 1980s in this time series indicates that the diet was previously dominated by clupeids (Alewives and Gizzard Shad). Adult Cisco were historically very abundant in Saginaw Bay (Baldwin et al. 2009), at least at spawning time, and their progeny likely remained in the bay for some time until maturing, generating a predation buffer on Yellow Perch. Since Alewives have disappeared from most of Lake Huron, Cisco have not recovered and the absence of an abundant pelagic planktivore from the open water reaches of Lake Huron that used the bay as nursery grounds may represent a broken linkage to Saginaw Bay's fish community. This hypothesis is part of the basis for a new Cisco reintroduction stocking study being implemented in 2018 by the Lake Huron Committee of the Great Lakes Fishery Commission (GLFC) with the aim of reestablishing natural reproduction of Cisco. Fishery managers hope this effort, in combination with the liberalized harvest of Walleye, will collectively help promote better Yellow Perch survival. The MDNR also prescribed and implemented Cormorant management to reduce that form of predation but authority was revoked by the U.S. Fish and Wildlife Service in 2016 as the result of litigation.

Meanwhile, the Yellow Perch population of Saginaw Bay shows adaption to the high mortality rate. Yellow Perch populations will typically exhibit correlation between growth and mortality with high mortality resulting in faster growth for those individuals that do survive (Feiner et al. 2017). Such has been the case with Saginaw Bay since at least the mid-1990s. This in turn can result in early onset of sexual maturity, especially in females. Length at 50% mature in female Saginaw Bay Yellow Perch has dropped as low as 144 mm in recent years (Feiner et al. 2017). Yellow Perch have been documented to adjust their maturation schedule to mortality rates, likely as a plastic adaption in life history to ensure the ability to spawn at least once before dying (Feiner et al. 2015). Accelerated growth may have consequences for subsequent fishing mortality in that faster growing members of the population may recruit more quickly to fisheries and be susceptible to harvest sooner than their slower growing counterparts. This is evident in Saginaw Bay where sex ratios of age-3 and older Yellow Perch are skewed to favor males over females and females grow faster and larger than males (Tables 5 and 6).

Prey Fish Base

A declining trend in forage fish abundance was among the reasons for fishery managers' decision to liberalize recreational Walleye harvest regulations in 2015. The 2012–2017 mean index value from the trawl series (Table 3, Figure 4) was the lowest measured since the 1980s; the steepest decline in forage abundance has been since 2003, which is consistent with the period of improved Walleye reproductive success and attainment of recovery targets. It seems that Walleye predation has had consequences for prey fish species beyond that of just age-0 Yellow Perch. While Gizzard Shad periodically achieve year classes and figure prominently in Walleye diet in some years (Tables 7 and 10), this production doesn't appear to be enough to afford Yellow Perch the needed predation buffering. Gizzard Shad are at the northern limits of their range (Scott and Crossman 1979) and often fail to survive the winter so their contribution to Walleye diets may be limited to a relatively short window of time in the later summer and fall as young of year. Other species of abundance in the Saginaw Bay prey base are invasive species such as White Perch and Round Goby that are both regularly consumed by Walleyes. Conversely, the native Trout-Perch is abundant in the trawl data series but is infrequently observed in Walleye diets. The native Mimic Shiner has also become abundant since the decline of Alewives, but similar to Trout-Perch, are rarely found in Walleye diets as measured in September collections. Aside from their resurgence in the absence of Alewives, it is not immediately known why this species is flourishing in the bay when it was previously scarce.

Other Species

Smallmouth Bass are underrepresented in both the trawl and gill-net collections as they are not as vulnerable to those gears as adults prefer to inhabit rocky areas that are usually avoided as sample stations for the two gears due to gear fishability issues. Still, some Smallmouth Bass are encountered each year (Table 9). Northern Pike also do not figure prominently in either collection series yet many regard Saginaw Bay as typical Northern Pike habitat. It is possible they avoid trawling gear or are underrepresented in the collections by inhabiting waters shallower than those sampled by either trawls or gill nets. It has also been questioned if they may be vulnerable to bycatch mortality in the commercial trap-net fishery, but this has not been established.

Lake Whitefish are abundant in outer Saginaw Bay and are not commonly encountered by the two sampling series which focus on the inner bay area. Lake Whitefish are commercially fished and yield averaged 296,351 kg from 2012–2017 (MDNR unpublished data). For much of Lake Huron, Lake Whitefish recruitment has declined since the mid-1990s with as much as a 93% contraction in recruitment for Ontario waters of the southern main basin (Gobin et al. 2015). Saginaw Bay's greater productivity may be one stronghold for Lake Whitefish reproduction in that it may still contain food resources for newly hatched fry, while much of the main basin may be suffering from ecological shifts that no longer include substantial spring zooplankton blooms.

Two state threatened species have historically been abundant in the bay but today are extirpated (Cisco) or rare (Lake Sturgeon). Both collection series will be part of the evaluation strategy to gauge success or failure of stocked Cisco to survive and reproduce in the new GLFC experiment. The MDNR has begun a Lake Sturgeon stocking initiative in 2017 with an initial release of Lake Sturgeon fingerlings and has established an annual stocking target of 1,000 fish in the Saginaw River system. If successful, this survey series may help indicate any changes in abundance that result.

Ecological, Food Web Changes in Saginaw Bay and Climate Change

Lake Huron continues to be profoundly affected by restructuring of the food web triggered largely by the effects of the invasive Dreissenid mussels (Riley and Roseman 2013; He et al. 2015; Fetzer et al. 2017). The nearshore environments are not immune to this regime shift (Fetzer et al. 2017) but may play a moderating role in terms of offering bastions of greater productivity and food resources. Notable to Saginaw Bay has been the proliferation of algal forms that resist Dreissenid filtration such as Cladophora species (Francoeur et al. 2015; Francoeur 2017; Winslow et al. 2014). Still, on the whole, the food web changes in Lake Huron have played an important role in the recovery of Walleye and restoration of reproductive success in Yellow Perch (Fielder and Baker 2019).

One important objective of this long-term study has been to document the presence and effects of invasive species. Bighead Carp, Silver Carp, and Black Carp (sometimes collectively referred to as invasive carp species) have so far not invaded the Great Lakes but would find ideal environmental conditions in productive bays like Saginaw Bay. Consequently, efforts to contain invasive carp species to the Illinois River watershed are of great relevance for Saginaw Bay. Grass Carp have been documented, once in the bay and once in the Tittabawassee River (S. Herbst, Michigan DNR, personal communication) and remain a colonization threat to Saginaw Bay. Similarly, Eurasian Ruffe, already in the Great Lakes, have made it as close as Lake Huron's Thunder Bay (90 km away) but so far have not invaded Saginaw Bay. This warm water percid-like fish would also find ideal living conditions if it were ever to reach Saginaw Bay. All of these species have the potential to be substantial fish community disruptors and would jeopardize the recovery of Walleye, potential for Yellow Perch recovery, and the annual recreational fishery worth $33 million USD (Fielder et al. 2014).

Warm, productive nearshore embayments of the Great Lakes like Saginaw Bay may be among the habitats most affected by climate change (Mason et al. 2016; Collingsworth et al. 2017). Computer model simulations and projections indicate that Michigan summers could become more like Illinois or Indiana summers in a few decades and more like Tennessee and Arkansas by the end of the century (Mortsch and Quinn 1996; Kling et al. 2003; Hayhoe et al. 2010). Since 1987, mean surface water temperature at the time of the trawling work has increased significantly (Figure 2). Effects of climate change may include increased hypoxia events, botulism outbreaks, increased algal production, changing water levels, loss of the recreational ice fishery, and a restructuring of the fish community favoring warmer water species (Collingsworth et al. 2017). Possible effects might also include more favorable conditions for Alewife resurgence.

RECOMMENDATIONS

1. This survey series should be maintained as the critical fishery-independent assessment of the status of the Saginaw Bay fish community. In addition to providing benchmarks to assess key species like Walleye, Yellow Perch, and their prey, this survey provides continued surveillance for invasive species, a means to assess restoration of native species such as Cisco and Lake Sturgeon, and a time series for monitoring the effects of climate change and other anthropogenic stressors.
2. The gill-net portion of the study should be modified to eliminate the paired net sets, which would enable statistical analysis based on simple random sampling and provide greater spatial diversity in sample locations across Saginaw Bay.
3. This data series continues to indicate that the Saginaw Bay Walleye population remains high and the Yellow Perch population remains depressed. Fishery managers should continue to move forward with management objectives that promote predator and prey balance. This can be accomplished via increased fishing mortality of Walleye through liberalized recreational harvest regulations, and efforts to address Yellow Perch mortality rates, including Double Crested Cormorant *Phalacrocorax auratus* management, when and where possible.
4. Fishery managers should pursue Cisco restoration in Saginaw Bay and support the new reintroduction stocking effort to re-establish a species that can restore a link between the Lake Huron main basin and the bay and provide a predation buffer for Yellow Perch.

5. Lake Sturgeon remain absent or rare from the survey collections, therefore restoration should remain a priority and continue the recent reintroduction stocking effort along with pursuing fish passage at barriers when and where possible to promote spawning opportunities.
6. Local fishery managers should join efforts to contain invasive carp species and prevent their invasion of the Great Lakes.
7. Fishery managers should begin to prepare the fishing public, including commercial fishers, for the anticipated effects of climate change including more variability and uncertainty in future fish production and possible shift of species diversity within the fish community.

ACKNOWLEDGMENTS

The authors wish to acknowledge the contributions of the staff of the MDNR Southern Lake Huron Management Unit, most notably those of Jim Baker, Kathrin Schroder, Chris Schelb, Ryan Histed, and Vince Balcer. Their logistical efforts are essential to the annual success of the field work associated with this study. The authors also acknowledge the contributions of Dr. Jan-Michael Hessenauer of the MDNR Lake St. Clair Fisheries Research Station for contributions and oversight of the trawling component of this study for one year. Additional appreciation for the contributions of the crews of the R/V Tanner and R/V Channel Cat for their field work in these collections and the staff of both Alpena and Lake St. Clair fisheries research stations for laboratory work and other support. Appreciation to Dr. Troy Zorn and Todd Wills for critical reviews of earlier versions of this report. Also acknowledged is the clerical staff of the MDNR Fisheries Research section for assistance in the preparation and formatting of this manuscript. Administrative oversight was provided by Todd Wills and Gary Whelan. This study is funded in part by a grant from United States Fish and Wildlife Service, Federal Aid in Sport Fish Restoration Program.

REFERENCES

Anderson, R. O., and S. J. Gutreuter. 1983. Length, weight, and associated structural indices. Pages 283–300 in L.A. Neilson and D.L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Anderson, R. O., and R. M. Neumann. 1996. Length, weight, and associated structural indices. Pages 447–482 in B.R. Murphy and D.W. Willis, editors. Fisheries Techniques, Second edition. American Fisheries Society, Bethesda. Maryland.

Anderson, R. O., and A. S. Weithman. 1978. The concept of balance for coolwater fish populations. American Fisheries Society, Special Publication 11:371–381.

Baldwin, N. A., R. W. Saalfeld, M. R. Dochoda, H. J. Buettner, and R.L. Eshenroder. 2009. Commercial Fish Production in the Great Lakes 1867–2006 [online]. Available from http://www.glfc.org/great-lakes-databases.php.

Beeton, A. M., S. H. Smith, and F. F. Hooper. 1967. Physical limnology of Saginaw Bay, Lake Huron. Great Lakes Fishery Commission, Technical Report. 12, Ann Arbor, Michigan.

Billington, N., B. Sloss, and G. Moyer. 1998. Mitochondrial DNA analysis of Walleye (Stizostedion vitreum) populations from Michigan. Southern Illinois University, Cooperative Fisheries Research Laboratory, Technical Report to Michigan DNR, Carbondale.

Collingsworth, P. D., D. B. Bunnell, M. W. Murray, Y. C. Kao, Z. S. Feiner, R. M. Claramunt, B. M. Lofgren, T. O. Höök, and S. A. Ludsin. 2017. Climate change as a long-term stressor for the fisheries of the Laurentian Great Lakes of North America. Reviews in Fish Biology and Fisheries 27:363–391.

Danek, L. J., and J. H. Saylor. 1977. Measurements of summer currents in Saginaw Bay, Michigan. Journal of Great Lakes Research 3:65–71.

DeBruyne, R. L., D. G. Fielder, E. F. Roseman, and P. H. Butchko. 2017. Exploring potential effects of cormorant predation on the fish community in Saginaw Bay, Lake Huron. Journal of Great Lakes Research 43:387–393.

Drouin, R. and K. Soper. 2017. Lake Erie's western basin. Pages 39–58 in J. L. Markham and R. L. Knight, editors. The State of Lake Erie in 2009. Great Lakes Fishery Commission, Special Publication 2017-01, Ann Arbor, Michigan.

Feiner, Z. S., S. C. Chong, D. G. Fielder, J. A. Hoyle, C. Knight, T. E. Lauer, M. V. Thomas, J. T. Tyson, and T. O. Höök. 2017. Sex-based trade-offs among growth, mortality, and maturation in Great Lakes Yellow Perch stocks. Canadian Journal of Fisheries and Aquatic Sciences 74:2059–2072.

Feiner, Z. S., S. C. Chong, C. T. Knight, T. E. Lauer, M. V. Thomas, J. T. Tyson, and T. O. Höök. 2015. Rapidly shifting maturation schedules following reduced commercial harvest in a freshwater fish. Evolutionary Applications 8:724–737.

Fetzer, W. W., B. M. Roth, D. M. Infante, D. F. Clapp, R. M. Claramunt, D. G. Fielder, D. K. Forsyth, J. X. He, T. J. Newcomb, C. M. Riseng, K. E. Wehrly, and T. G. Zorn. 2017. Spatial and temporal dynamics of nearshore fish communities in Lake Michigan and Lake Huron. Journal of Great Lakes Research 43:319–334.

Fielder, D. G. 2002. Sources of Walleye recruitment in Saginaw Bay, Lake Huron. North American Journal of Fisheries Management 22:1032–1040.

Fielder, D. G. 2014. Mortality, exploitation, movement, and stock size of Saginaw Bay Walleyes, 1981–2011: 31 years of tag return analysis. Michigan Department of Natural Resources, Fisheries Report 04, Lansing.

Fielder, D. G., and J. P. Baker. 2004. Strategy and options for completing the recovery of Walleye in Saginaw Bay, Lake Huron. Michigan Department of Natural Resources, Fisheries Special Report 29. Ann Arbor.

Fielder, D. G., and J. P. Baker. 2019. Recovery of Saginaw Bay Walleye, Lake Huron. Pages 411–430 in W. Taylor, C. Kruger, and S-J. Youn, editors. From catastrophe to recovery: stories of fishery management success. American Fisheries Society, Bethesda, Maryland.

Fielder, D. G., and J. R. Bence. 2014. Integration of auxiliary information in statistical catch-at-age (SCA) analysis of the Saginaw Bay stock of Walleye in Lake Huron. North American Journal of Fisheries Management 34:970–987.

Fielder, D. G., J. E. Johnson, J. R. Weber, M. V. Thomas, and R. C. Haas. 2000. Fish population survey of Saginaw Bay, Lake Huron, 1989–97. Michigan Department of Natural Resources, Fisheries Research Report 2052, Ann Arbor.

Fielder, D. G., M. J. Jones, and J. R. Bence. 2016. Use of a structured approach to analysis of management options and value of information for a recreationally exploited fish population: a case study of Walleyes in Saginaw Bay. North American Journal of Fisheries Management 36:407–420.

Fielder, D. G., T. L. Kolb, T. M. Goniea, D. L. Wesander, and K. S. Schrouder. 2014. Fisheries of Saginaw Bay, Lake Huron 1986–2010. Michigan Department of Natural Resources, Fisheries Report 02. Lansing.

Fielder, D. G., J. S. Schaeffer, and M. V. Thomas. 2007. Environmental and ecological conditions surrounding the production of large year classes of Walleye (Sander vitreus) in Saginaw Bay, Lake Huron. Journal of Great Lakes Research 33:118–132.

Fielder, D. G., and M. V. Thomas. 2006. Fish population dynamics of Saginaw Bay, Lake Huron 1998–2004. Michigan Department of Natural Resources, Fisheries Research Report 2083, Ann Arbor.

Fielder, D. G., and M. V. Thomas. 2014. Status and trends of the fish community of Saginaw Bay, Lake Huron 2005–2011. Michigan Department of Natural Resources, Fisheries Report 03, Lansing.

Francoeur, S. N. 2017. Stimulation of Saginaw Bay charophyte photosynthesis by phosphorus. Journal of Great Lakes Research 43:192–197.

Francoeur, S. N., R. W. Pillsbury, and R. L. Lowe. 2015. Benthic algal response to invasive mussels in Saginaw Bay: a comparison of historical and recent data. Journal of Freshwater Ecology 30:463–477.

Gabelhouse, D. W., Jr. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273–285.

Gobin, J., N. P. Lester, A. Cottrill, M. G. Fox, and E. S. Dunlop. 2015. Trends in growth and recruitment of Lake Huron Lake Whitefish during a period of ecosystem change, 1985 to 2012. Journal of Great Lakes Research 41:405–414.

Goede, R. W., and B. A. Barton. 1990. Organismic indices and an autopsy-based assessment as indicators of health and condition of fish. Pages 93–108 in S. Marshall Adams, editor. Biological indicators of stress in fish. American Fisheries Society, Symposium 8, Bethesda, Maryland.

Haas, R. C., and J. S. Schaeffer. 1992. Predator-prey and competitive interactions among Walleye, Yellow Perch, and other forage fishes in Saginaw Bay, Lake Huron. Michigan Department of Natural Resources, Fisheries Research Report 1984, Ann Arbor.

Hayden, T. A., T. R. Binder, C. M. Holbrook, C. S. Vandergoot, D. G. Fielder, S. J. Cooke, J. M. Dettmers, C. C. Kruger. 2018. Spawning site fidelity and apparent annual survival of Walleye (Sander vitreus) differ between a Lake Huron and Lake Erie tributary. Ecology of Freshwater Fish 27:339–349.

Hayden, T. A., C. M. Holbrook, D. G. Fielder, C. S. Vandergoot, R. A. Bergstedt, J. M. Dettmers, C. C. Kruger, S. J. Cooke. 2014. Acoustic telemetry reveals large-scale migration patterns of Walleye in Lake Huron. PLoS ONE 9: E114833.

Hayhoe, K., J. VanDorn, T. Croley, II, N. Schlegal, and D. Wuebbles. 2010. Reginal climate change projections for Chicago and the US Great Lakes. Journal of Great Lakes Research 36:7–21.

He, J. X., J. R. Bence, C. P. Madenjian, S. A. Pothoven, N. D. Dobiesz, D. G. Fielder, J. E. Johnson, M. P. Ebener, A. R. Cottrill, L. C. Mohr, S. R. Kroproski. 2015. Coupling age-structured stock assessment and fish bioenergetics models: a system of time-varying models for quantifying piscivory patterns during the rapid trophic shift in the main basin of Lake Huron. Canadian Journal of Fisheries and Aquatic Sciences 72:7–23.

He, J. X., M. P. Ebener, S. C. Riley, A. Cotrill, and S. Koproski. 2013. Status of Lake Trout. Pages 36–42 in S. C. Riley, editor. The state of Lake Huron in 2010. Great Lakes Fishery Commission, Special Publication 13-01, Ann Arbor, Michigan.

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

Hilborn, R., and C. J. Walters. 1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Chapman and Hall, New York.

Hile, R. 1954. Fluctuations in growth and year class of the Walleye in Saginaw Bay. U.S. Fish and Wildlife Service, Fishery Bulletin 91, Washington, D.C.

Isbell, G. L., and M. R. Rawson. 1989. Relations of gill-net catches of Walleyes and angler catch rates in Ohio waters of western Lake Erie. North American Journal of Fisheries Management 9:41–46.

Isely, J. J., and T. B. Grabowski. 2007. Age and growth. Pages 187–228 in C. S. Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Ivan, L. N., T. O. Höök, M. V. Thomas, and D. G. Fielder. 2011. Long-term and interannual dynamics of Walleye and Yellow Perch in Saginaw Bay, Lake Huron. Transactions of the American Fisheries Society 140:1078–1092.

Jennings, M. J., J. E. Claussen, and D. P. Philipp. 1996. Evidence for heritable preferences for spawning habitat between two Walleye populations. Transactions of the American fisheries society 125:978–982.

Johengen, T. H., T. F. Nalepa, G. A. Lang, D. L. Fanslow, H. A. Vanderploeg, and M. A. Agy. 2000. Physical and chemical variables of Saginaw Bay, Lake Huron in 1994–1996. National Oceanic and Atmospheric Association, Technical Memorandum GLERL-115, Ann Arbor, Michigan.

Johnson, J. E., and D. Gonder. 2013. Status of introduced salmonines. Pages 50–59 in S. C. Riley, editor. The state of Lake Huron in 2010. Great Lakes Fishery Commission, Special Publication 13-01, Ann Arbor, Michigan.

Johnson, L. B., C. Richards, G. E. Host, and J. W. Arthur. 1997. Landscape influences on water chemistry in Midwestern stream ecosystems. Freshwater Biology 37:193–208.

Kalejs, N. I. 2017. An assessment of reef restoration potential in Saginaw Bay, Lake Huron. Master's Thesis. Purdue University. West Lafayette, Indiana.

Keller, M., J. C. Schneider, L. E. Mrozinski, R. C. Haas, and J. R. Weber. 1987. History, status, and management of fishes in Saginaw Bay, Lake Huron, 1981–1986. Michigan Department of Natural Resources, Fisheries Technical Report 87-2, Ann Arbor.

Kling, G. W., K. Hayhoe, L. B. Johnson, J. J. Magnuson, S. Polasky, S. K. Robinson, B. J. Shuter, M. M. Wander, D. J. Wuebbles, D. R. Zak, R. L. Lindroth, S. C. Moser, and M. L. Wilson. 2003. Confronting climate change in the Great Lakes region: impacts on our communities and ecosystems. Union of Concerned Scientists, Cambridge, Massachusetts, and Ecological Society of America, Washington, D.C.

Latta, W. C. 2005. Status of Michigan's endangered, threatened, special-concern, and other fishes, 1993–2001. Michigan Department of Natural Resources, Fisheries Research Report 2079, Ann Arbor.

Mason, L. A., C. M. Riseng, A. D. Gronewold, E. S. Rutherford, J. Wang, A. Clites, S. D. Smith, and P. B. McIntyre. 2016. Fine-scale spatial variation in ice cover and surface temperature trends across the surface of the Laurentian Great Lakes. Climatic Change 138:71–83.

Miranda, L. E., and P. W. Bettoli. 2007. Mortality. Pages 229–277 in C. S. Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Mortsch, L. D., and F. H. Quinn. 1996. Climate change scenarios for Great Lakes Basin ecosystem studies. Limnology and Oceanography 41:903–911.

Murphy, B. R., M. L. Brown, and T. A. Springer. 1990. Evaluation of the relative weight (Wr) index, with new applications to Walleye. North American Journal of Fisheries Management 10:85–97.

Nalepa, T. F., D. L. Fanslow, M. B. Lansing, and G. A. Lang. 2003. Trends in the benthic macroinvertebrate community of Saginaw Bay, Lake Huron, 1987 to 1996: responses to phosphorus abatement and the zebra mussel, Dreissena polymorpha. Journal of Great Lakes Research 29:14–33.

R Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Ricciardi, A., and MacIsaac, H. J. 2000. Recent mass invasion of the North American Great Lakes by Ponto–Caspian species. Trends in Ecology & Evolution 15:62–65.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada, Bulletin 191, Ottawa.

Riley, S. C., J. X. He, J. E. Johnson, T. P. O'Brien, and J. S. Schaeffer. 2007. Evidence of widespread natural reproduction by Lake Trout Salvelinus namaycush in the Michigan waters of Lake Huron. Journal of Great Lakes Research 33:917–921.

Riley, S. C., and E. F. Roseman. 2013. Status of the offshore demersal fish community. Pages 21–28 in S. C. Riley, editor. The state of Lake Huron in 2010. Great Lakes Fishery Commission, Special Publication 13-01, Ann Arbor, Michigan.

Riley, S. C., E. F. Roseman, S. J. Nichols, T. P. O'Brien, C. S. Kiley, and J. S. Schaeffer. 2008. Deepwater demersal fish community collapse in Lake Huron. Transactions of the American Fisheries Society 137:1879–1890.

Roseman, E. F., J. S. Schaeffer, E. Bright, and D. G. Fielder. 2014. Angler-caught piscivore diets reflect fish community changes in Lake Huron. Transactions of the American Fisheries Society 143:1419–1433.

Schneider, J. C. 2000. Manual of fisheries survey methods II: with periodic updates. Michigan Department of Natural Resources, Fisheries Special Report 25. Ann Arbor.

Schneider, J. C., F. F. Hooper, and A. M. Beeton. 1969. The distribution and abundance of benthic fauna in Saginaw Bay, Lake Huron. Pages 80–90 in Proceedings of the 12th Conference on Great Lakes Research held at the University of Michigan, Ann Arbor, Michigan, May 5–7, 1969. International Association of Great Lakes Research, Ann Arbor, Michigan.

Schneider, J. C., and J. H. Leach. 1977. Walleye (Stizostedion vitreum vitreum) fluctuations in the Great Lakes and possible causes, 1800–1975. Canadian Journal of Fisheries and Aquatic Sciences 34:1878–1889

Schneider, J. C., and J. H. Leach. 1979. Walleye stocks in the Great Lakes 1800–1975: fluctuations and possible causes. Great Lakes Fishery Commission, Technical Report 31, Ann Arbor, Michigan.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada, Bulletin 184, Ottawa.

Smith, V. E., K. W. Lee, J. C. Filkins, K. W. Hartell, K. R. Rygwelski, and J. M. Townsend. 1977. Survey of chemical factors in Saginaw Bay (Lake Huron). U. S. Environmental Protection Agency, Environmental Research Laboratory, Report 600/3-77-125, Duluth, Minnesota.

Sokal, R. R., and F. J. Rohlf. 1981. Biometry: the principles and practice of statistics in biological research, 2nd edition. W. H. Freeman and Company, San Francisco.

SPSS. 2010. SPSS for Windows. Release 19. IBM Inc. Armonk, New York.

Stewart-Oaten, A. 1995. Rules and judgments in statistics: three examples. Ecology 76:2001–2009.

Thompson, S. K. 2002. Sampling, 2nd edition. Wiley, New York.

Walleye Task Group. 2018. Report of the Lake Erie Walleye Task Group to the Standing Technical Committee. Great Lakes Fishery Commission, Lake Erie Committee, Ann Arbor, Michigan.

Weber, J. R. 1985. Calculation of growth and mortality of Yellow Perch, 1975 to 1984, in Saginaw Bay. Pages 172–195 in Michigan Department of Natural Resources, Fisheries Division, Dingell-Johnson Annual Report, 1985, Study 434, Ann Arbor.

Willis, D. W., C. S. Guy, and B. R. Murphy. 1991. Development and evaluation of a standard weight (Ws) equation for Yellow Perch. North American Journal of Fisheries Management 11:374–380.

Windell, J. T., and S. H. Bowen. 1978. Methods for study of fish diets based on analysis of stomach contents. Pages 219–226 in T. Bagnel, editor. Methods for the assessment of fish production in fresh waters, 3rd edition. Blackwell Scientific Publications, Oxford, England.

Winslow, K. P., S. N. Francoeur, and S. D. Peacor. 2014. The influence of light and nutrients on benthic filamentous algal growth: a case study of Saginaw Bay, Lake Huron. Journal of Great Lakes Research 40:64–74.

Publication Production Staff
Troy G. Zorn, Reviewer
Jan-Michael Hessenauer, Editor
Alan D. Sutton, Graphics
Ellen S. Grove, Desktop Publisher
Tina M. Tincher, Desktop Publisher

Approved by Gary E. Whelan
Date March 29, 2022

FIGURES

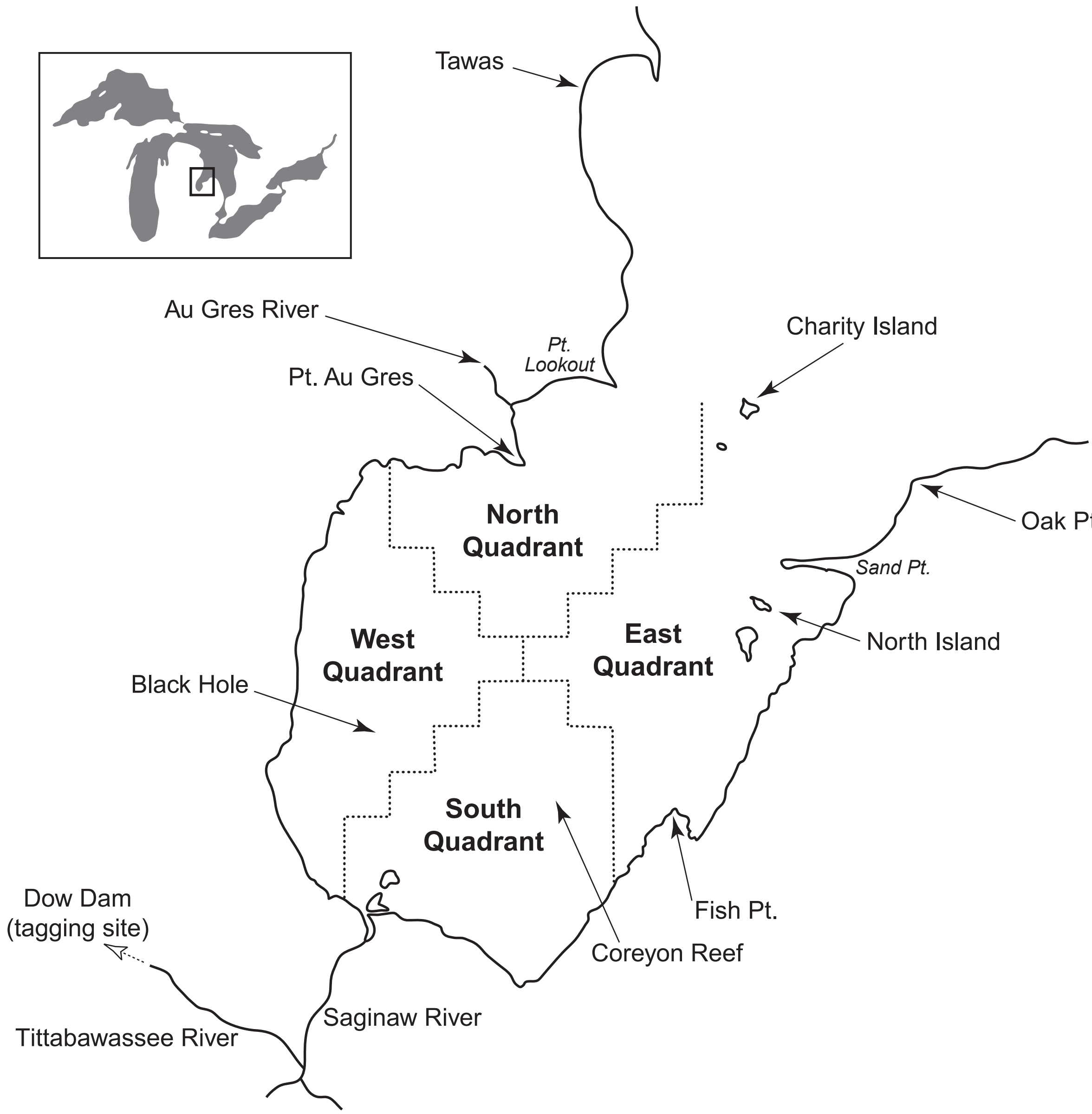

FIGURE 1. Saginaw Bay gill net sampling locations and trawling quadrants.

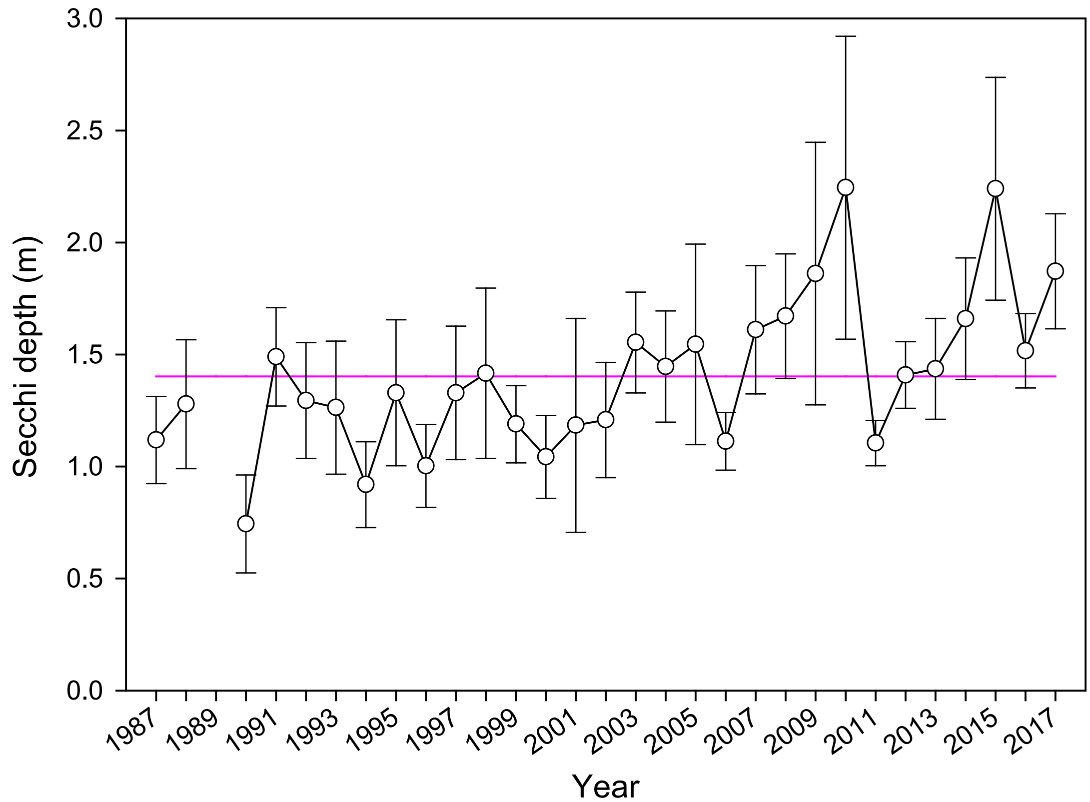

FIGURE 2. Mean (±2 SE) Secchi disk transparency recorded during fall trawling on Saginaw Bay, 1987–2017. No secchi depth data were recorded in 1989. Horizontal line represents mean Secchi depth from 1987 to 2017.

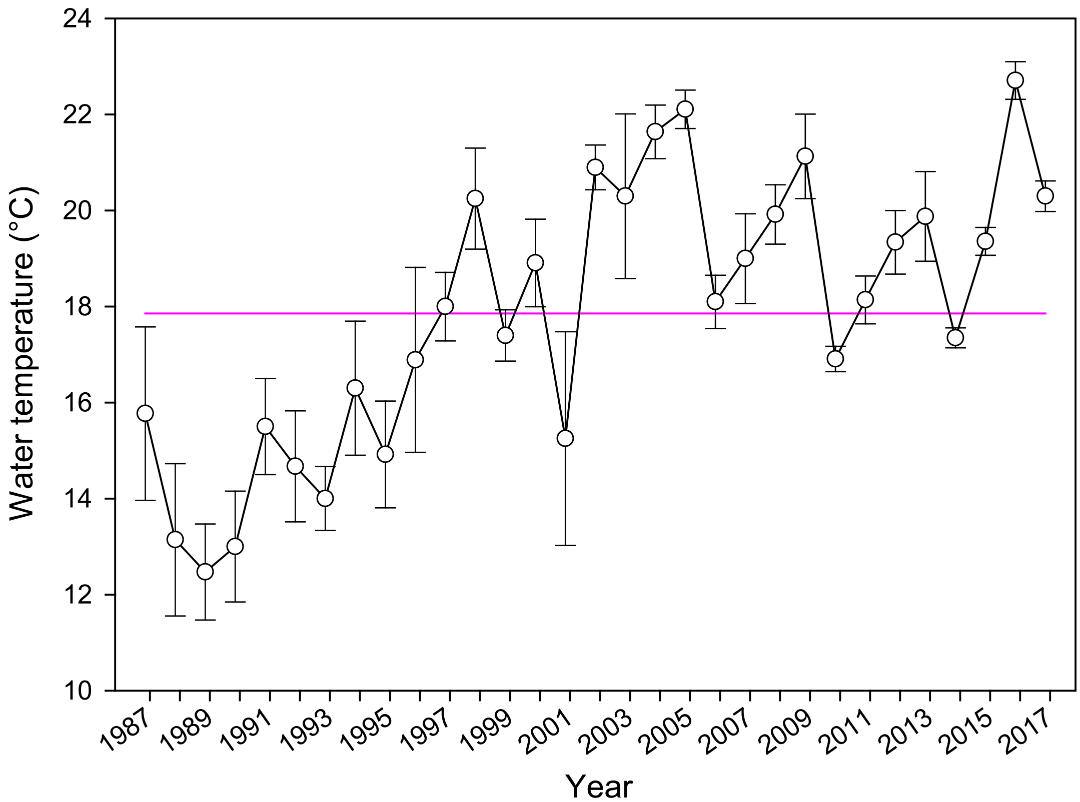

FIGURE 3. Mean (±2 SE) water temperatures (°C) recorded during fall trawling on Saginaw Bay, 1987–2017. Horizontal line represents mean water temperature from 1987 to 2017.

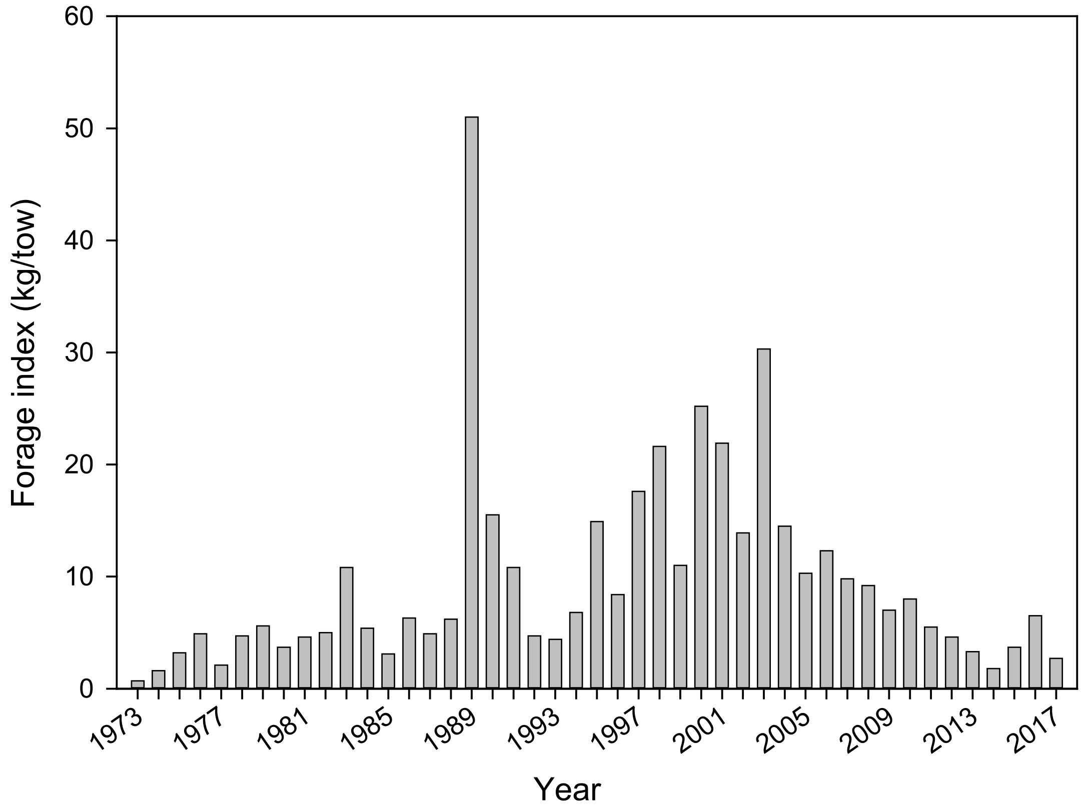

FIGURE 4. Trends in Saginaw Bay prey fish abundance. Prey fish composition for this index includes; Alewife, Emerald Shiner, Gizzard Shad, Rainbow Smelt, Spottail Shiner, Round Goby, Trout-perch, Age 0 White Bass, Age 0 White Perch, Age 0 Yellow Perch, and Mimic Shiner.

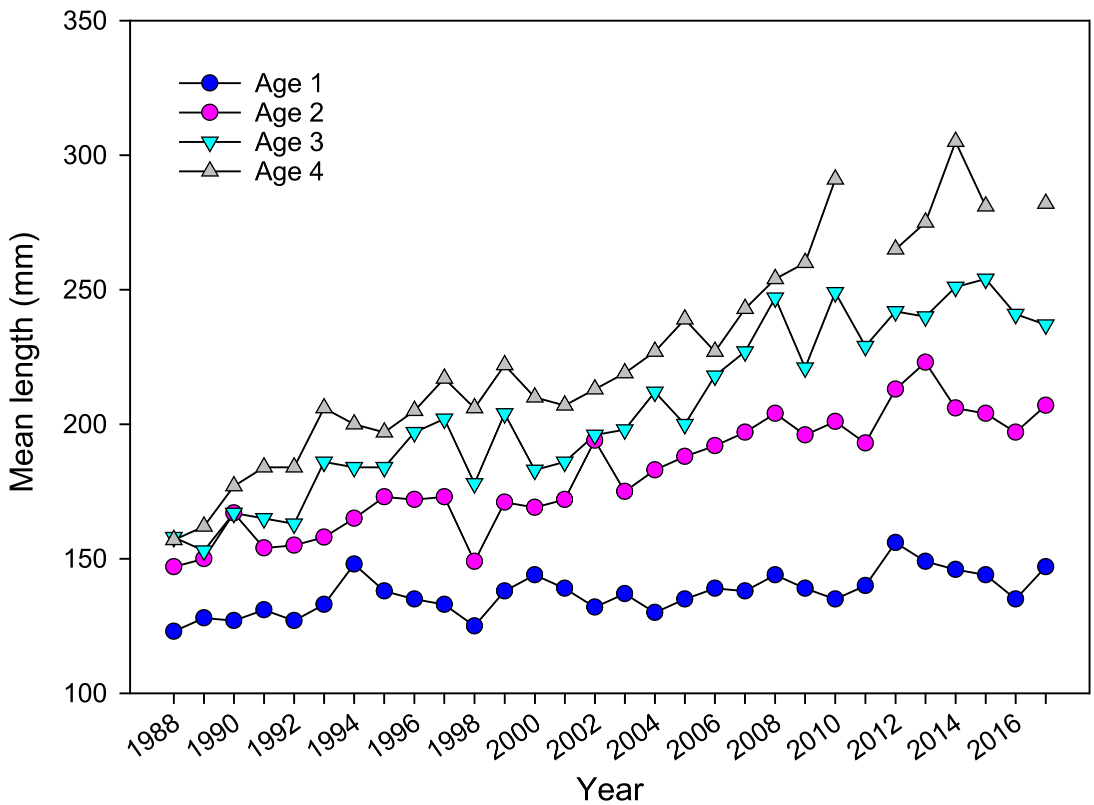

FIGURE 5. Mean length-at-age during September for Yellow Perch from Saginaw Bay trawls, 1988–2017. Statewide average lengths: age 1 = 127 mm, age 2 = 160 mm, age 3 = 183 mm, age 4 = 208 mm (Schneider 2000).

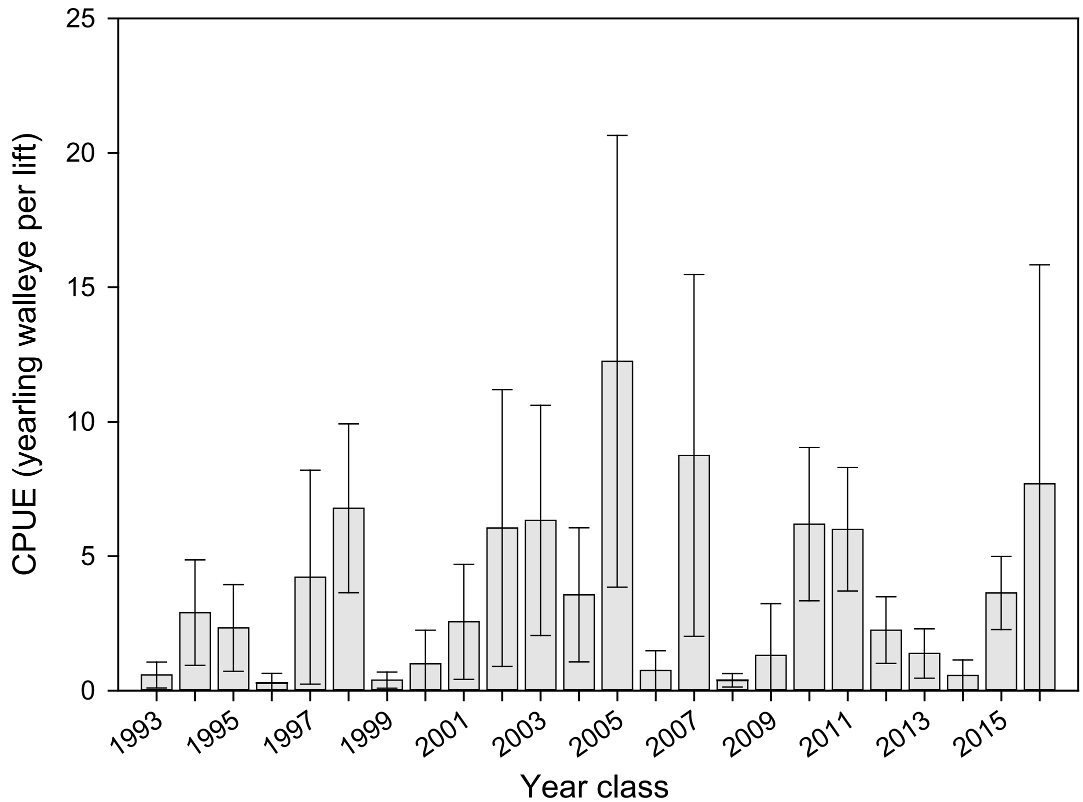

FIGURE 6. Walleye year-class strength as determined by gill-net catch-per-unit-of-effort (CPUE) of yearling Walleye in Saginaw Bay for year classes 1993–2016. Error bars represent two standard errors of the mean. Data for year classes 1993–1996 from Fielder et al. (2000), year classes 1997–2004 from Fielder and Thomas (2006), and year classes 2005–2011 from Fielder and Thomas (2014).

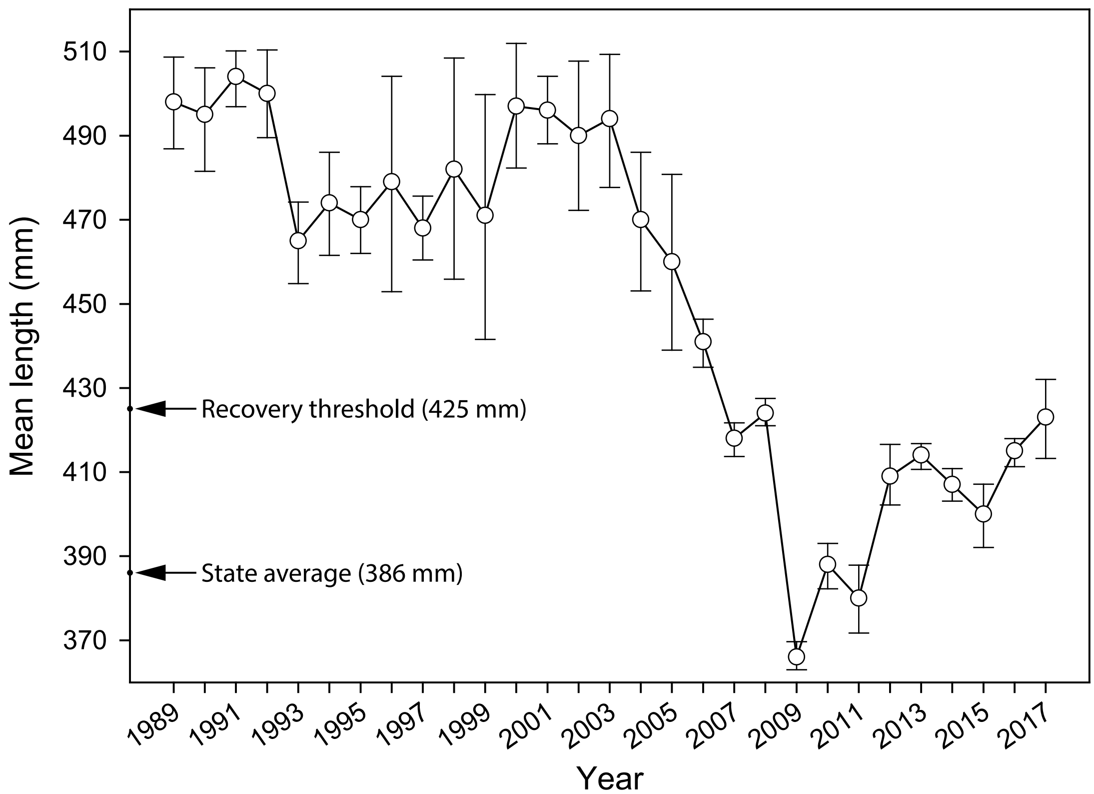

FIGURE 7. Trends in mean length of age 3 Walleyes (sexes combined) at September capture and their 95% confidence intervals. State average rate from Schneider (2000) and recovery threshold from Fielder and Baker (2004) indicated.

TABLES

TABLE 1. Mean catch per unit effort (CPUE) and forage index value (number of fish per 10-minute tow) for species collected from fall trawl samples in Saginaw Bay, 2012–2017, and decadal means. Forage index value is the sum of catch rates for Alewife, Emerald Shiner, Gizzard Shad, Mimic Shiner, Rainbow Smelt, Round Goby, Spottail Shiner, Trout-perch, age-0 White Bass, age-0 White Perch, and age-0 Yellow Perch. Twenty-four trawl tows were completed each year. AA = all ages, YOY = young of year (age 0). Measures of variability are omitted for clarity.

	Year(s)							Decade mean			
Species	2012	2013	2014	2015	2016	2017	2012–17	1980s	1990s	2000s	2010s
Alewife	0.1	0.0	0.0	0.0	0.0	<0.1	0.0	227.7	305.3	274.1	0.0
Black Crappie	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Bluegill	0.5	0.0	0.0	0.0	<0.1	0.0	0.1	0.0	0.0	0.0	0.1
Brown Bullhead	0.0	0.0	0.0	0.0	0.0	<0.1	0.0	0.1	0.0	0.0	0.0
Burbot	0.0	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Common Carp	4.0	2.4	2.1	1.8	2.3	2.0	2.4	2.7	5.3	6.4	2.8
Channel Catfish	1.6	3.0	0.5	0.1	0.2	0.3	0.9	3.6	3.2	2.5	0.8
Emerald Shiner	4.8	7.1	39.0	4.2	3.0	16.0	12.4	46.7	8.6	7.0	10.7
Cisco	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Freshwater Drum	82.0	16.4	12.8	4.4	7.1	8.9	21.9	7.0	17.3	11.6	19.6
Gizzard Shad	38.2	40.0	16.5	26.9	15.3	42.3	29.8	35.9	19.8	12.2	25.1
Golden Redhorse	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Lake Whitefish	0.0	0.0	0.1	0.2	0.1	0.1	0.1	0.3	0.3	0.5	0.1
Largemouth Bass	0.0	<0.1	0.0	0.0	0.0	<0.1	0.0	0.0	0.1	0.1	0.0
Logperch	0.0	<0.1	0.8	0.1	0.7	1.4	0.5	0.0	0.1	0.2	0.4
Longnose Gar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0
Mimic Shiner	962.3	661.8	43.2	411.2	430.0	403.5	485.3	0.0	4.7	13.7	427.5
Northern Pike	0.0	0.0	<0.1	0.0	0.1	<0.1	0.0	0.0	0.0	0.0	0.0
Quillback	0.6	0.7	0.7	0.2	0.4	0.5	0.5	2.4	0.7	1.6	0.4
Rainbow Smelt	1.0	70.9	2.6	89.8	10.2	10.3	30.8	264.8	271.6	195.4	86.4
Rock Bass	0.0	<0.1	0.0	<0.1	0.1	0.0	0.0	0.0	0.6	0.1	0.0
Round Goby	81.5	85.7	165.2	436.7	123.2	108.7	166.9	0.0	0.4	269.8	166.7
Shorthead Redhorse	<0.1	0.0	0.1	0.1	0.0	0.2	0.1	0.0	0.0	0.0	0.1
Smallmouth Bass	0.0	0.0	0.0	<0.1	0.0	0.0	0.0	0.0	0.3	0.1	0.0
Spottail Shiner	99.8	130.3	11.2	12.7	21.9	26.8	50.4	489.3	479.8	560.7	77.2
Trout-perch	542.8	429.3	97.0	122.0	554.3	329.1	345.8	145.9	530.7	385.3	344.4
Walleye AA	19.6	30.9	32.8	30.0	11.3	31.5	26.0	1.1	3.4	22.8	28.4
Walleye YOY	11.8	27.3	23.3	29.9	6.2	26.6	20.9	0.4	1.6	18.4	23.2
White Bass	8.8	15.4	4.4	10.1	4.8	5.5	8.2	4.5	2.5	10.4	9.4
White Crappie	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
White Perch	223.8	51.2	54.3	142.8	350.4	35.8	143.0	255.9	310.7	482.0	193.7
White Sucker	4.1	3.6	4.7	4.9	3.6	3.6	4.1	6.8	11.7	16.5	4.9
Yellow Perch AA	143.0	164.9	73.4	197.0	149.7	187.9	152.6	555.8	110.0	417.5	169.8
Yellow Perch YOY	115.3	149.8	45.3	154.7	115.2	158.3	123.1	188.0	48.6	395.2	135.9
Forage index value	1,116.1	979.7	425.2	994.7	1,198.1	732.8	907.8	1,658.7	1,978.0	2,592.1	1,047.5

TABLE 2. Mean number captured, mean catch per unit effort (CPUE; number of fish per 10-minute tow), and mean total length of age-0 Walleyes (mm) collected from fall trawl samples in Saginaw Bay, 1986–2017. 2SE = two standard errors of the mean. Mean length data not available prior to 1998 or for 2001.

Year	Mean number captured	CPUE	2SE	Mean length	2SE
1986	20	0.4	–	–	–
1987	34	0.5	–	–	–
1988	39	0.6	–	–	–
1989	19	1.3	–	–	–
1990	0	0.0	–	–	–
1991	28	1.9	–	–	–
1992	6	0.2	–	–	–
1993	1	0.0	–	–	–
1994	22	0.6	–	–	–
1995	14	0.4	–	–	–
1996	0	0.0	–	–	–
1997	83	2.2	1.4	–	–
1998	149	8.6	7.0	212	2.4
1999	20	2.0	2.0	200	13.7
2000	5	0.3	0.3	180	8.6
2001	27	0.9	0.7	–	–
2002	84	2.2	1.1	176	7.6
2003	1,114	40.9	16.5	171	2.2
2004	822	19.9	4.5	117	1.4
2005	812	31.3	11.2	119	1.1
2006	24	1.3	0.8	162	7.5
2007	327	12.4	3.2	148	1.6
2008	183	6.0	1.5	144	2.6
2009	942	65.7	14.4	105	0.8
2010	576	30.8	14.1	119	1.7
2011	599	29.9	8.9	134	1.3
2012	243	11.8	2.9	142	2.8
2013	603	27.3	8.6	117	1.4
2014	539	23.3	6.0	120	1.9
2015	595	29.9	8.3	109	1.7
2016	149	6.2	2.2	147	3.0
2017	638	26.6	8.5	118	1.9

TABLE 3. Mean catch per unit effort (CPUE; number of fish per 10-minute tow) and mean total length (mm) of age 0-Yellow Perch collected from fall trawl samples in Saginaw Bay, 1980–2017. 2SE = two standard errors of the mean. Data prior to 1990 from Haas and Schaeffer (1992).

Year	CPUE	2SE	Mean total length (mm)	2SE
1980	39.0	–	86.4	–
1981	71.3	–	83.8	–
1982	686.7	–	76.2	–
1983	251.9	–	76.2	–
1984	171.0	–	78.7	–
1985	147.8	–	78.7	–
1986	71.4	–	73.7	–
1987	131.5	–	81.3	0.3
1988	56.6	–	76.2	0.7
1989	252.8	–	71.1	0.3
1990	39.0	–	79.5	0.4
1991	110.8	–	70.2	0.4
1992	7.1	–	76.2	1.2
1993	0.5	–	90.7	6.5
1994	3.9	–	85.0	5.5
1995	98.9	–	72.8	0.7
1996	37.3	–	81.9	0.8
1997	87.4	30.9	73.8	0.6
1998	112.5	49.4	76.1	0.7
1999	19.8	6.9	92.4	0.9
2000	7.1	3.5	83.2	2.1
2001	98.6	40.4	77.1	0.6
2002	26.4	12.2	76.2	0.8
2003	2,389.60	943.7	69.7	0.7
2004	389.9	100.5	64.9	0.7
2005	251.9	142.0	79.0	1.0
2006	87.1	57.9	72.8	1.1
2007	111.8	48.5	77.6	1.0
2008	207.8	123.5	78.7	1.0
2009	363.0	111.8	75.4	0.8
2010	205.8	93.5	86.2	0.8
2011	143.4	41.9	77.7	0.7
2012	115.3	35.2	87.4	1.0
2013	149.8	84.3	77.7	1.4
2014	45.3	24.5	81.0	0.5
2015	154.7	67.8	77.1	1.1
2016	115.2	59.9	81.2	1.0
2017	158.3	108.0	74.4	1.0

TABLE 4. Mean catch per unit effort (number of fish per 10-minute tow), by age, of Yellow Perch collected from fall trawl samples in Saginaw Bay, 1986–2017. Grand means are provided for the entire time series, the current reporting period (2012–2017) and the post-Alewife collapse period (2003–2017).

Survey year	Age 0	1	2	3	4	5	6	7	8	9	10	All ages	Age 1 and older
1986	117.6	132.8	125.9	128.4	21.2	3.0	0.7	0.5	0.0	0.0	0.0	530.0	412.4
1987	258.0	61.0	98.6	66.8	37.6	6.6	1.8	0.4	0.0	0.0	0.0	530.9	272.9
1988	458.9	263.8	248.6	309.4	171.6	56.8	13.5	1.7	0.9	0.0	0.0	1,525.3	1,066.4
1989	280.2	168.7	180.3	128.0	81.1	33.3	12.9	4.4	0.3	0.3	0.0	889.6	609.4
1990	34.0	37.8	20.2	20.5	12.6	6.1	2.8	0.9	0.3	0.1	0.1	135.3	101.3
1991	102.6	15.6	29.3	19.2	13.5	8.6	2.5	0.4	0.0	0.0	0.0	191.8	89.1
1992	7.7	44.5	8.5	6.6	4.0	2.5	0.7	0.3	0.0	0.0	0.0	74.9	67.2
1993	0.5	2.2	20.7	7.6	4.4	1.9	0.3	0.1	0.2	0.0	0.0	37.8	37.3
1994	3.5	1.4	2.8	10.1	2.5	1.0	0.2	0.1	0.0	0.0	0.0	21.7	18.2
1995	100.6	12.0	2.6	3.5	5.2	1.1	0.6	0.1	0.1	0.0	0.0	125.8	25.2
1996	37.9	30.9	5.9	3.7	2.7	3.2	0.8	0.0	0.0	0.0	0.0	85.0	47.1
1997	89.1	11.3	16.9	2.9	0.5	0.5	0.4	0.2	0.0	0.0	0.0	122.0	32.8
1998	74.4	54.1	11.7	6.6	1.7	0.4	0.3	0.1	0.0	0.0	0.0	149.2	74.8
1999	19.5	28.1	25.3	10.7	4.7	1.2	0.2	0.2	0.0	0.0	0.0	89.7	70.3
2000	9.4	4.0	11.6	8.3	4.3	1.0	0.5	0.2	0.0	0.0	0.0	39.2	29.8
2001	134.0	3.2	3.8	11.3	4.2	0.7	0.1	0.1	0.0	0.0	0.0	157.2	23.3
2002	36.7	28.1	1.1	1.6	2.0	0.5	0.2	0.1	0.0	0.0	0.0	70.3	33.6
2003	2,450.3	4.6	11.1	1.1	0.5	0.8	0.3	0.1	0.0	0.0	0.0	2,468.7	18.4
2004	461.8	22.9	2.0	2.8	0.5	0.4	0.3	0.0	0.0	0.1	0.0	490.7	28.9
2005	233.7	20.7	5.7	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	260.8	27.2
2006	84.9	6.5	3.0	1.6	0.2	0.1	0.1	0.0	0.0	0.0	0.0	96.4	11.4
2007	89.8	6.1	1.5	1.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	98.9	9.1
2008	214.4	20.1	1.0	0.5	0.1	0.2	0.0	0.0	0.0	0.0	0.0	236.2	21.8
2009	313.9	25.9	1.4	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	341.8	27.8
2010	203.0	30.8	1.7	0.7	0.1	0.1	0.0	0.0	0.0	0.0	0.0	236.2	33.2
2011	153.3	46.3	4.2	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	204.3	51.0
2012	118.0	17.5	6.7	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	143.0	25.0
2013	155.0	7.5	1.5	0.7	0.1	0.1	0.0	0.0	0.0	0.0	0.0	164.9	9.9
2014	50.8	20.1	2.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	73.3	22.5
2015	160.5	33.7	2.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	196.8	36.3
2016	116.4	28.0	5.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	149.7	33.3
2017	158.2	19.3	8.5	1.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	187.9	29.7
	Grand mean												
All years	210.3	37.8	27.2	23.7	11.8	4.1	1.2	0.3	0.1	0.0	0.0	316.4	106.1
2012–2017	126.5	21.0	4.3	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	152.6	26.1
2003–2017[a]	330.9	20.7	3.8	0.9	0.2	0.1	0.0	0.0	0.0	0.0	0.0	356.6	25.7

[a] Post-Alewife crash

TABLE 5. Mean male to female sex ratio (M/F), by age, of Yellow Perch in Saginaw Bay from fall trawl samples collected since the Alewife collapse in 2003. CI = confidence interval; N = number of years with data available in the time period.

Age	M/F ratio	95% CI	N
1	1.03	0.94–1.12	15
2	0.73	0.60–0.85	15
3	0.73	0.58–0.88	15
4	1.99	1.17–2.80	9
5	3.71	0.65–6.77	4
6	4.99	–	1
All ages	0.99	0.90–1.07	15

TABLE 6. Mean length-at-age (mm) of Yellow Perch collected from fall trawl samples in Saginaw Bay, 2012–2017. SWA = fall statewide average (Schneider 2000).

		Survey year						2012–17
Age	SWA	2012	2013	2014	2015	2016	2017	mean
				Males				
1	–	150	144	140	133	132	142	140
2	–	202	206	198	193	175	193	195
3	–	229	240	231	201	219	231	225
4	–	259	282	–	–	–	263	268
5	–	–	292	–	–	–	292	292
6	–	–	–	–	–	–	–	–
				Females				
1	–	160	159	150	144	137	149	150
2	–	221	233	211	212	203	216	216
3	–	251	260	265	267	262	242	258
4	–	277	271	305	–	–	295	287
5	–	–	–	–	–	–	–	–
6	–	–	–	–	–	–	–	–
				Sexes combined				
1	127	155	150	146	138	135	145	145
2	160	213	223	206	201	197	208	208
3	183	242	250	251	245	241	237	244
4	208	265	275	305	–	–	282	282
5	234	–	292	–	–	–	292	292
6	257	–	–	–	–	–	–	–

TABLE 7. Number of stomachs examined, incidence of empty stomachs, and frequency of occurrence (% of non-empty stomachs containing selected taxa) of food items found in age-1 and older Walleyes collected from fall trawl samples in Saginaw Bay, 1998–2017.

			Diet item											
Year	Stomachs examined	% Empty	Unidentified fish remains	Gizzard Shad	Alewife	Yellow Perch	Spottail Shiner	White Sucker	Round Goby	White Perch	Zebra Mussel	Trout-perch	Freshwater Drum	Other taxa
1998	51	27	57	0	41	14	0	0	0	3	0	0	0	0
1999	94	28	47	0	66	0	2	0	0	2	2	0	0	0
2000	43	26	59	0	44	0	6	0	3	3	0	0	0	0
2001	33	18	63	0	70	7	4	4	0	0	0	0	0	0
2002	33	27	56	4	28	4	8	0	8	4	0	0	0	0
2003	33	15	68	0	14	39	0	0	4	1	0	4	0	0
2004	176	36	63	0	1	53	5	0	7	6	0	1	0	2
2005	116	49	54	3	0	34	3	0	12	7	2	0	2	0
2006	271	37	64	16	1	13	2	0	7	24	0	1	0	0
2007	147	24	54	38	0	14	0	0	0	9	0	0	0	0
2008	182	22	59	33	0	22	1	0	7	17	1	1	0	4
2009	55	25	61	15	0	37	7	0	10	5	0	2	0	2
2010	77	22	22	33	0	42	7	0	7	3	0	2	0	2
2011	117	24	56	28	0	28	3	0	1	4	0	0	0	2
2012	169	41	45	49	0	13	5	0	4	1	1	2	0	1
2013	94	44	38	42	0	13	0	0	15	0	0	2	0	0
2014	207	26	53	42	0	3	1	0	3	3	1	1	0	11
2015	53	36	59	38	0	18	0	0	0	0	0	0	0	6
2016	122	37	48	44	0	12	1	0	5	6	0	1	0	3
2017	124	48	47	22	0	9	0	0	2	0	0	0	0	3

TABLE 8. Mean gill-net catch per unit effort (number per 335 m gill-net lift) and two standard errors of the mean (2SE) by species for Saginaw Bay, 2012–2017, at traditional netting locations (16 net sets or 5,364 m, total each year), including four net lifts from Charity Islands and Tawas Bay added in 1995. Data includes the 38 mm (1½ inch) mesh catch added in 1993.

	2012		2013		2014		2015		2016		2017	
Species	Mean	2SE	Mean	2SE	Mean	2SE	Mean	2SE	Mean	2SE	Mean	2SE
Alewife	0.00	0.00	0.06	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bowfin	0.00	0.00	0.06	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.12
Brown Bullhead	0.06	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.26	0.00	0.00
Brown Trout	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Burbot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.25
Common Carp	0.25	0.38	0.44	0.30	0.06	0.12	0.12	0.16	0.12	0.16	0.12	0.16
Channel Catfish	5.44	4.94	5.94	5.56	5.75	5.37	3.38	2.64	9.56	8.82	7.88	9.16
Chinook Salmon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.12	0.00	0.00
Cisco	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Freshwater Drum	8.44	3.94	15.00	5.15	9.75	7.59	5.88	5.99	18.69	14.12	6.06	3.74
Gizzard Shad	85.00	60.29	16.25	14.23	10.75	8.78	2.50	4.58	14.62	14.59	22.12	30.91
Goldfish	0.00	0.00	0.00	0.00	0.06	0.12	0.00	0.00	0.25	0.27	0.12	0.25
Lake Sturgeon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lake Trout	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lake Whitefish	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.50	0.00	0.00	0.00	0.00
Longnose Gar	2.62	4.03	6.19	10.60	0.25	0.50	0.00	0.00	1.38	2.48	0.06	0.12
Longnose Sucker	0.06	0.12	0.00	0.00	0.00	0.00	0.06	0.12	0.00	0.00	0.00	0.00
Muskellunge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Northern Pike	0.12	0.16	0.19	0.38	0.12	0.25	0.25	0.27	0.19	0.18	0.88	0.41
Northern Redhorse	0.06	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pumpkinseed	0.06	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quillback	1.19	0.68	1.50	1.18	1.81	2.45	1.38	1.54	0.69	0.60	0.81	0.89
Rainbow Smelt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.38	0.00	0.00
Rock Bass	0.81	1.07	0.06	0.12	0.12	0.25	0.00	0.00	0.25	0.50	0.12	0.25
Round Goby	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Round Whitefish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.12
Smallmouth Bass	1.00	1.12	0.19	0.26	0.06	0.12	0.12	0.25	0.25	0.33	0.25	0.27
Unidentified redhorse sp.	0.19	0.18	0.06	0.12	0.44	0.40	0.38	0.31	0.25	0.19	0.19	0.26
Walleye	43.75	19.72	33.56	20.85	29.50	17.57	21.31	13.96	45.88	22.41	49.50	32.41
White Bass	4.88	5.01	3.38	2.55	3.44	3.15	0.69	1.10	5.38	6.34	2.94	2.59
White Perch	6.62	4.46	5.50	3.23	7.31	6.16	4.25	3.74	9.12	10.78	28.19	18.59
White Sucker	13.06	9.54	10.62	9.29	10.25	8.83	29.06	23.29	10.62	6.21	10.75	9.86
Yellow Perch	36.88	25.07	22.56	15.83	23.94	19.74	107.69	120.98	52.25	38.32	63.40	59.02

TABLE 9. Catch per unit effort (CPUE; number of fish per 335 m gill-net lift) by year class of Walleye in fall gill-net survey catches, Saginaw Bay, 2012–2017. Total CPUE values are based on aged sample and therefore may differ slightly from the value reported in Table 8.

	Survey year											
	2012		2013		2014		2015		2016		2017	
Year class	Age	CPUE	Age	CPUE	Age	CPUE	Age	CPUE	Age	CPUE	Age	CPUE
2017	–	–	–	–	–	–	–	–	–	–	0	0.1
2016	–	–	–	–	–	–	–	–	0	0.2	1	7.7
2015	–	–	–	–	–	–	0	0.1	1	3.6	2	18.4
2014	–	–	–	–	0	–	1	0.6	2	7.1	3	6.4
2013	–	–	0	0.1	1	1.4	2	4.6	3	12.6	4	5.1
2012	0	0.1	1	2.3	2	3.4	3	3.3	4	5.3	5	2.6
2011	1	6.0	2	8.9	3	11.3	4	6.6	5	7.3	6	4.4
2010	2	24.4	3	15.4	4	9.9	5	4.9	6	6.1	7	2.9
2009	3	6.4	4	3.2	5	1.9	6	0.3	7	1.9	8	0.9
2008	4	1.6	5	1.1	6	0.8	7	0.4	8	0.1	9	0.4
2007	5	2.8	6	1.3	7	0.3	8	0.4	9	0.8	10	0.3
2006	6	1.1	7	0.7	8	0.6	9	0.2	10	0.6	11	0.1
2005	7	1.1	8	0.5	–	–	–	–	11	0.1	12	0.1
2004	8	0.3	9	0.2	–	–	–	–	12	0.1	13	0.1
2003	9	0.1	–	–	–	–	–	–	–	–	14	0.1
2002	–	–	–	–	–	–	–	–	–	–	15	0.1
2001	–	–	–	–	–	–	–	–	–	–	–	–
2000	–	–	–	–	–	–	–	–	–	–	–	–
Mean age	2.5		3.0		3.5		3.8		3.9		3.3	
Total CPUE		43.8		33.5		28.5		21.3		45.8		49.4

TABLE 10. Number of stomachs examined, incidence of empty stomachs, and frequency of occurrence (% of non-empty stomachs containing selected taxa) of food items found in age-1 and older Walleyes collected from fall gill-net samples in Saginaw Bay, 1989–2017.

			Prey Item																				
Year	Stomachs examined	% Empty	Unidentified fish remains	Alewife	Burbot	Channel Catfish	Cisco	Crayfish spp.	Emerald Shiner	Freshwater Drum	Gizzard Shad	Mimic Shiner	Rainbow Smelt	Round Goby	Sand Shiner	Spottail Shiner	Trout-perch	Walleye	White Bass	White Perch	White Sucker	Yellow Perch	Dreissenids
1989	257	25.7	55.0	5.8	0.0	0.0	0.0	0.0	0.0	0.0	44.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
1990	508	37.4	42.5	0.9	0.0	0.0	0.0	0.0	0.0	0.0	57.9	0.0	0.3	0.0	0.0	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.0
1991	669	35.9	50.8	1.6	0.0	0.0	0.0	0.0	0.0	0.0	48.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.2	0.0
1992	171	55.6	61.8	7.9	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	5.3	0.0	0.0	2.6	0.0	0.0	0.0	0.0	1.3	1.3	0.0
1993	371	52.6	55.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0	39.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.0
1994	84	52.4	52.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.5	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0
1995	291	45.0	53.1	30.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	1.3	0.6	3.1	0.0
1996	267	34.1	23.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.1	0.0
1997	204	35.3	34.8	13.6	0.0	0.0	0.0	0.0	0.0	0.0	8.3	0.0	0.0	0.0	0.0	6.1	0.0	0.0	0.0	2.3	0.0	3.0	0.0
1998	234	47.4	50.4	40.7	0.0	0.0	0.0	0.0	0.8	0.0	3.3	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	1.6	0.0
1999	231	48.9	60.2	32.2	0.0	0.0	0.0	0.0	1.7	0.0	0.8	0.0	0.8	0.0	0.0	11.0	0.0	0.0	0.0	0.8	0.0	7.6	0.0
2000	119	47.9	72.6	33.9	0.0	0.0	0.0	0.0	0.0	0.0	8.1	0.0	0.0	1.6	0.0	3.2	0.0	0.0	0.0	11.3	0.0	4.8	0.0
2001	132	49.2	35.8	47.8	0.0	0.0	0.0	0.0	1.5	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5	0.0	3.0	0.0
2002	129	70.5	42.1	10.5	0.0	0.0	0.0	0.0	0.0	0.0	10.5	0.0	0.0	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	401	51.9	21.2	31.1	0.0	0.0	0.0	0.0	0.0	0.0	14.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	22.8	0.0
2004	216	65.7	37.8	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	2.7	0.0	1.4	0.0	9.5	0.0	0.0	1.4	56.8	1.4
2005	307	59.6	25.8	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.8	1.6	0.0	0.0	0.0	0.8	0.0	0.0	0.0	40.3	0.0
2006	603	59.2	73.6	0.0	0.0	0.0	0.0	0.0	1.2	0.4	17.1	0.0	0.0	4.5	0.0	0.0	0.0	1.2	0.0	2.8	0.0	17.1	0.8
2007	570	49.1	45.5	0.0	0.0	0.0	0.0	0.0	1.4	0.3	8.3	0.0	0.0	1.7	0.0	0.0	0.0	0.7	0.0	4.8	0.0	15.2	0.0
2008	553	46.1	66.1	0.0	0.0	0.0	0.0	0.3	0.7	1.3	22.5	0.0	0.0	5.4	0.7	0.0	0.0	0.0	0.0	7.7	0.3	9.1	0.0
2009	256	57.0	80.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.9	0.0	0.9	9.1	0.0	0.0	0.0	2.7	0.0	2.7	0.0	19.1	1.8
2010	470	66.6	12.5	0.0	0.0	0.0	0.0	0.0	5.1	0.0	16.0	0.0	0.6	2.9	0.0	0.0	1.0	0.0	0.0	0.6	0.3	12.1	0.0
2011	530	49.4	46.6	0.0	0.0	0.0	0.0	0.0	0.4	0.0	25.0	0.0	0.4	5.2	0.0	0.0	0.0	0.0	0.0	0.7	0.0	30.2	0.0
2012	700	62.0	43.9	0.0	0.0	0.0	0.0	0.0	0.8	0.4	33.1	0.4	0.0	3.4	0.0	0.0	0.0	0.0	0.0	1.5	0.0	11.3	0.0
2013	537	55.1	64.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	19.5	0.0	0.0	2.1	2.1	0.0	0.0	0.8	0.0	3.7	0.8	11.2	0.0
2014	472	83.9	40.8	0.0	0.0	0.0	0.0	0.0	3.9	0.0	42.1	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	1.3	0.0	5.3	0.0
2015	341	71.3	51.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	0.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	50.0	1.0
2016	734	63.1	66.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	24.0	0.0	0.7	3.4	0.0	0.0	0.0	0.0	0.4	3.4	0.4	10.0	0.0
2017	830	58.2	52.2	0.0	0.0	0.3	0.0	0.0	0.0	0.0	25.4	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.5	0.0

TABLE 11. Mean length-at-age (mm) and two standard errors of the mean (2SE) for Walleyes and Yellow Perch (both sexes combined) collected from fall gill-net samples in Saginaw Bay, 2012–2017. Statewide average lengths are from August–September (Schneider 2000). Saginaw Bay historic average length-at-age for 1926–1938 is also included for Walleyes (Hile 1954). No means are included for sample sizes less than 5 specimens. Growth index (mm) is calculated with methodology from Schneider (2000).

	Year												Average	
	2012		2013		2014		2015		2016		2017			Saginaw
Age	Mean	2SE	Mean	2SE	Mean	2SE	Mean	2SE	Mean	2SE	Mean	2SE	Statewide	Bay historic
							Walleye							
0	–	–	–	–	–	–	–	–	–	–	–	–	180	–
1	279.2	5.4	267.4	8.4	260.4	7.2	262.7	14.5	267.2	7.1	286.0	2.9	250	254
2	359.5	2.6	360.5	3.0	345.6	7.4	345.8	3.8	356.9	6.2	351.6	4.3	338	320
3	409.4	7.3	413.7	3.1	406.9	3.9	399.6	7.5	414.6	3.4	422.7	9.5	386	371
4	456.0	12.3	446.7	8.4	437.7	5.0	440.5	5.2	446.1	4.9	463.9	8.4	437	411
5	482.5	16.2	490.5	15.4	460.2	13.1	468.3	7.3	472.9	6.7	481.7	11.0	472	457
6	494.0	18.5	522.0	18.2	503.9	25.6	–	–	481.2	7.7	493.3	10.6	516	483
7	527.0	26.1	505.6	15.1	–	–	498.3	30.8	483.7	8.7	502.0	11.9	541	505
8	519.4	26.6	548.0	41.5	504.4	24.8	546.5	28.7	–	–	516.5	22.4	561	533
9	–	–	–	–	–	–	–	–	552.3	31.0	512.0	28.4	582	582
10	–	–	–	–	–	–	–	–	502.6	27.9	–	–		
Growth index	+3.2		+6.7		-5.8		-3.3		-5.9		-5.9			-15.2
							Yellow Perch							
0	–	–	–	–	–	–	–	–	–	–	–	–	84	–
1	155.3	2.4	157.0	2.2	155.9	2.9	151.1	1.6	152.8	1.7	154.7	1.6	127	–
2	203.8	4.2	217.8	6.9	193.6	7.3	210.8	3.1	202.7	3.5	209.0	2.9	160	–
3	233.5	6.1	265.7	7.9	248.5	10.1	261.0	5.5	231.3	8.4	240.7	8.6	183	–
4	254.9	17.5	281.8	17.7	296.3	16.6	295.2	6.0	269.3	15.1	282.0	12.1	208	–
5	261.0	57.4	–	–	–	–	309.5	13.2	–	–	–	–	234	–
6	–	–	–	–	–	–	–	–	–	–	–	–	257	–
7	–	–	–	–	–	–	–	–	–	–	–	–	277	–
8	–	–	–	–	–	–	–	–	–	–	–	–	292	–
9	–	–	–	–	–	–	–	–	–	–	–	–	302	–
Growth index	+8.8		+4.3		+4.6		+2.9		+3.6		+3.2			–

TABLE 12. Mean relative weight by length class (Gabelhouse 1984; Anderson and Weithman 1978; Anderson and Gutreuter 1983) and all sizes combined for Walleyes and Yellow Perch collected from fall gill nets in Saginaw Bay, 1999–2017. N = number of fish sampled.

	Length class				
Year	Stock-quality	Quality-preferred	Preferred-memorable	All sizes combined	N
			Walleye		
1999	88	90	86	88	231
2000	107	90	81	88	116
2001	103	96	92	94	114
2002	87	86	88	87	127
2003	90	90	86	90	382
2004	86	86	83	86	216
2005	83	82	81	83	307
2006	83	79	78	82	603
2007	84	82	79	83	570
2008	89	83	81	85	553
2009	82	79	76	81	254
2010	91	88	88	89	465
2011	72	72	72	72	528
2012	82	82	85	83	699
2013	84	81	80	82	535
2014	76	74	66	74	472
2015	82	83	80	83	341
2016	87	86	85	86	733
2017	86	83	83	85	788
			Yellow Perch		
1999	79	90	87	82	528
2000	90	86	90	89	358
2001	103	97	92	100	825
2002	95	101	92	96	458
2003	90	93	90	91	399
2004	101	97	88	99	380
2005	90	90	86	89	413
2006	93	91	87	92	285
2007	85	93	94	89	332
2008	97	92	92	96	428
2009	88	93	92	90	635
2010	88	90	90	90	367
2011	89	83	79	88	420
2012	95	91	89	93	399
2013	88	90	91	89	228
2014	100	83	88	97	219
2015	101	98	94	99	565
2016	92	90	92	91	405
2017	96	97	94	96	481

TABLE 13. Walleye and Yellow Perch proportional stock density (PSD)[a] and relative stock density (RSD-P and RSD-M)[b] in parentheses from fall gill-net data, 2012–2017 from Saginaw Bay, Lake Huron.

	Year					
Species	2012	2013	2014	2015	2016	2017
Walleye	42 (6,0)	72 (7,0)	79 (2,0)	74 (8,0)	81 (10,0)	55 (11,0)
Yellow Perch	55 (8,1)	40 (16,3)	40 (17,3)	41 (12,3)	38 (7,1)	47 (8,1)

[a] Stock and quality size for Walleye is 250 mm and 380 mm, respectively, Yellow Perch: 130 mm and 200 mm. Range of PSD values suggested as indicative of balance when the population supports a substantial fishery is 30–60 for Walleye and 30–50 for Yellow Perch (Gabelhouse 1984, Anderson and Weithman 1978).

[b] Preferred size for Walleye is 510 mm, memorable size is 630 mm. For Yellow Perch, it is 250 mm and 300 mm, respectively (Gabelhouse 1984, Anderson and Gutreuter 1983).

TABLE 14. Percent mature and age at 50% maturity for male and female Walleye in Saginaw Bay, 2012–2017 (all years combined).

	Males		Females	
Age	Number	% mature	Number	% mature
0	5	0.0	3	0.0
1	195	3.1	145	4.1
2	504	21.4	562	6.2
3	425	53.6	456	24.3
4	249	77.9	250	75.2
5	165	95.8	163	89.0
6	135	96.3	86	93.0
7	85	98.8	30	83.3
8	32	90.6	13	92.3
9	12	100.0	14	85.7
10	14	100.0	–	–
11	62	100.0	1	100.0
12	2	100.0	1	100.0
13	1	100.0	–	–
Age at 50% maturity	2.89		3.50	

TABLE 15. Total annual mortality rate and ±95% confidence interval (CI), determined by the Robson-Chapman method of point-in-time catch curve analysis, for Walleye and Yellow Perch collected from fall gill-net samples in Saginaw Bay, 1989–2017. Vacant cells (represented by a –) indicate insufficient data for calculation.

	Walleye		Yellow Perch	
Year	A	± 95% CI	A	± 95% CI
1989	0.53	0.025	–	–
1990	0.43	0.011	0.52	0.045
1991	0.41	0.010	0.67	0.029
1992	0.32	0.015	0.57	0.026
1993	0.40	0.014	0.50	0.020
1994	0.43	0.028	0.60	0.023
1995	0.41	0.015	0.55	0.024
1996	0.31	0.012	0.41	0.011
1997	0.33	0.015	0.50	0.016
1998	0.35	0.013	0.47	0.019
1999	0.45	0.015	0.46	0.010
2000	0.59	0.035	0.46	0.014
2001	0.41	0.028	0.58	0.015
2002	0.43	0.024	0.73	0.018
2003	0.47	0.016	0.60	0.015
2004	0.56	0.017	0.53	0.019
2005	0.70	0.018	0.79	0.018
2006	0.65	0.013	0.58	0.020
2007	0.59	0.014	0.51	0.014
2008	0.44	0.010	0.68	0.016
2009	0.55	0.022	0.67	0.012
2010	0.51	0.019	0.61	0.017
2011	0.34	0.009	0.75	0.018
2012	0.62	0.012	0.73	0.019
2013	0.59	0.015	0.63	0.022
2014	0.55	0.015	0.53	0.019
2015	0.44	0.015	0.62	0.015
2016	0.46	0.010	0.56	0.015
2017	0.37	0.006	0.61	0.014

TABLE 16. Total annual mortality rate (A) and ±95% confidence interval (CI), determined by the cohort method (applying the Robson-Chapman calculation method of catch curve analysis of year classes) for Walleye and Yellow Perch collected from fall gill-net samples in Saginaw Bay, 1989–2017 (1989–2012 year classes). Vacant cells (represented by a –) indicates insufficient data for calculation.

	Walleye				Yellow Perch			
Year class	A	± 95% CI	Years spanned	Ages spanned	A	± 95% CI	Years spanned	Ages spanned
1989	0.53	0.027	1990–1999	1–10	–	–	–	–
1990	0.46	0.037	1991–2001	1–11	0.47	0.033	1993–2001	3–11
1991	0.47	0.055	1993–2002	2–11	0.68	0.084	1996–2000	5–9
1992	0.25	0.073	1993–2002	1–10	0.37	0.051	1993–2000	1–8
1993	0.22	0.096	1994–2004	1–11	0.48	0.050	1996–2001	3–8
1994	0.39	0.062	1996–2005	2–11	0.61	0.046	1996–2001	2–7
1995	0.32	0.059	1996–2007	1–12	0.47	0.049	1997–2003	2–8
1996	0.13	0.134	1997–2004	1–8	0.46	0.058	1998–2004	2–8
1997	0.41	0.073	1998–2008	1–11	0.62	0.078	1999–2003	2–6
1998	0.45	0.063	1999–2007	1–9	0.53	0.044	1999–2005	1–7
1999	0.35	0.140	2002–2009	2–9	0.55	0.081	2001–2005	2–6
2000	0.34	0.219	2003–2010	3–10	0.60	0.084	2001–2007	1–7
2001	0.46	0.108	2003–2011	2–10	0.65	0.050	2003–2008	2–7
2002	0.38	0.059	2003–2011	1–9	0.72	0.135	2004–2007	2–5
2003	0.41	0.037	2005–2012	2–9	0.69	0.068	2005–2010	2–7
2004	0.41	0.031	2006–2017	2–13	0.56	0.065	2005–2010	1–6
2005	0.44	0.035	2007–2017	2–12	0.56	0.061	2006–2012	1–7
2006	0.50	0.065	2010–2017	4–11	0.56	0.086	2007–2010	1–4
2007	0.38	0.038	2008–2017	1–10	0.61	0.049	2008–2015	1–8
2008	0.47	0.085	2010–2016	3–9	0.75	0.042	2009–2015	1–7
2009	0.37	0.049	2010–2016	2–8	0.51	0.047	2010–2015	1–6
2010	0.41	0.032	2012–2017	2–7	0.63	0.037	2011–2017	1–7
2011	0.58	0.092	2013–2016	3–6	0.58	0.078	2012–2016	1–5
2012	0.50	0.127	2013–2016	2–5	0.52	0.054	2013–2017	1–5

TABLE 17. Catch per unit effort (CPUE; number of fish per 335 m gill-net lift) by year class for Yellow Perch collected from fall gill-net samples in Saginaw Bay, 2012–2017. Total CPUE values are based on aged sample and therefore may differ slightly from the value reported in Table 8.

	Survey year											
	2012		2013		2014		2015		2016		2017	
Year class	Age	CPUE	Age	CPUE	Age	CPUE	Age	CPUE	Age	CPUE	Age	CPUE
2017	–	–	–	–	–	–	–	–	–	–	–	–
2016	–	–	–	–	–	–	–	–	–	–	1	23.1
2015	–	–	–	–	–	–	–	–	1	22.0	2	21.0
2014	–	–	–	–	–	–	1	40.7	2	21.4	3	3.8
2013	–	–	–	–	1	11.9	2	35.6	3	5.9	4	0.5
2012	0	0.1	1	15.8	2	10.3	3	8.7	4	1.5	5	0.1
2011	1	13.0	2	6.0	3	4.1	4	5.1	5	0.1	6	0.0
2010	2	26.5	3	2.9	4	1.4	5	1.7	6	0.3	7	0.2
2009	3	9.1	4	0.6	5	0.4	6	0.3	7	–	8	–
2008	4	1.4	5	0.3	6	0.1	7	0.1	–	–	–	–
2007	5	0.4	–	–	–	–	8	0.1	–	–	–	–
2006	6	0.0	–	–	–	–	–	–	–	–	–	–
2005	7	0.1	–	–	–	–	–	–	–	–	–	–
2004	–	–	–	–	–	–	–	–	–	–	–	–
Number aged	405		230		225		647		409		487	
Mean age	2.0		1.6		1.9		1.8		1.8		1.6	
Total CPUE		50.6		25.6		28.1		92.4		51.1		48.7

APPENDICES

APPENDIX A. Common and scientific names of fishes and other aquatic organisms mentioned in this report.

Common name	Scientific name
Alewife	*Alosa pseudoharengus*
Bighead Carp	*Hypophthalmichthys nobilis*
Black Carp	*Mylopharyngodon piceus*
Black Crappie	*Pomoxis nigromaculatus*
Bluegill	*Lepomis macrochirus*
Bowfin	*Amia calva*
Brown Bullhead	*Ameiurus nebulosus*
Brown Trout	*Salmo trutta*
Burbot	*Lota lota*
Channel Catfish	*Ictalurus punctatus*
Chinook Salmon	*Oncorhynchus tshawytscha*
Cisco	*Coregonus artedi*
Common Carp	*Cyprinus carpio*
Emerald Shiner	*Notropis atherinoides*
Eurasian Ruffe	*Gymnocephalus cernua*
Freshwater Drum	*Aplodinotus grunniens*
Gizzard Shad	*Dorosoma cepedianum*
Golden Redhorse	*Moxostoma erythrurum*
Goldfish	*Carassius auratus*
Grass Carp	*Ctenopharyngodon idella*
Johnny Darter	*Etheostoma nigrum*
Lake Sturgeon	*Acipenser fulvescens*
Lake Trout	*Salvelinus namaycush*
Lake Whitefish	*Coregonus clupeaformis*
Largemouth Bass	*Micropterus salmoides*
Logperch	*Percina caprodes*
Longnose Gar	*Lepisosteus osseus*
Longnose Sucker	*Catostomus catostomus*
Mimic Shiner	*Notropis volucellus*
Muskellunge	*Esox masquinongy*
Northern Pike	*Esox lucius*
Northern Redhorse	*Moxostoma macrolepidotum*
Pumpkinseed	*Lepomis gibbosus*
Quillback	*Carpiodes cyprinus*
Rainbow Smelt	*Osmerus mordax*
Redhorse spp.	*Moxostoma* spp.
Rock Bass	*Ambloplites rupestris*
Round Goby	*Neogobius melanostomus*
Round Whitefish	*Prosopium cylindraceum*
Shorthead Redhorse	*Moxostoma macrolepidotum*
Silver Carp	*Hypophthalmichthys molitrix*
Smallmouth Bass	*Micropterus dolomieu*
Spottail Shiner	*Notropis hudsonius*
Trout-perch	*Percopsis omiscomaycus*
Walleye	*Sander vitreus* formerly *Stizostedion vitreum*
White Bass	*Morone chrysops*
White Crappie	*Pomoxis annularis*
White Perch	*Morone americana*
White Sucker	*Catostomus commersonii*
Yellow Perch	*Perca flavescens*

APPENDIX B. Mean catch-per-unit-effort (number of fish per 10-minute tow) for common species collected during fall bottom trawling in Saginaw Bay, 1971–2017, including data previously reported by Weber (1985), Haas and Schaeffer (1992), Fielder et al. (2000), and Fielder and Thomas (2014). NA = data not available for that year.

Survey year	Number of tows	Species																				
		Alewife	Channel Catfish	Common Carp	Emerald Shiner	Freshwater Drum	Gizzard Shad	Johnny Darter	Lake Whitefish	Mimic Shiner	Quillback	Rainbow Smelt	Rock Bass	Round Goby	Shorthead Redhorse	Spottail Shiner	Trout-perch	Walleye	White Bass	White Perch	White Sucker	Yellow Perch
1971	30	126.1	0.8	1.7	3.7	0.0	3.3	NA	NA	NA	NA	392.4	NA	0.0	NA	94.4	44.6	0.2	0.0	0.0	1.3	196.0
1972	15	109.3	1.3	3.5	2.5	0.0	1.0	NA	NA	NA	NA	375.4	NA	0.0	NA	419.4	99.9	0.0	0.0	0.0	1.3	151.0
1973	17	2.6	3.2	1.7	0.2	0.0	2.3	NA	NA	NA	NA	286.7	NA	0.0	NA	16.0	10.5	0.0	0.0	0.0	0.7	104.0
1974	30	7.7	14.2	9.0	0.9	0.3	21.5	NA	NA	NA	NA	139.2	NA	0.0	NA	191.7	119.9	0.0	0.0	0.0	0.6	256.0
1975	20	21.9	16.8	1.6	1.3	0.6	17.2	NA	NA	NA	NA	220.1	NA	0.0	NA	435.1	47.4	0.0	0.0	0.0	0.5	573.0
1976	20	40.7	0.8	0.6	0.2	0.0	370.0	NA	NA	NA	NA	779.9	NA	0.0	NA	93.9	9.2	0.0	0.1	0.0	0.4	272.0
1977	21	13.1	1.4	2.2	18.7	1.4	3.5	NA	NA	NA	NA	64.6	NA	0.0	NA	448.8	28.2	0.0	0.0	0.0	8.7	392.0
1978	18	71.6	0.8	0.5	0.3	0.4	146.5	NA	NA	NA	NA	498.6	NA	0.0	NA	562.6	24.6	0.0	0.0	0.0	4.5	286.0
1979	18	352.5	4.1	3.1	0.9	0.9	4.5	NA	NA	NA	NA	336.9	NA	0.0	NA	711.9	177.2	0.0	0.0	0.0	9.2	661.0
1980	20	83.7	11.2	1.0	0.2	1.4	48.1	NA	NA	NA	NA	801.6	NA	0.0	NA	441.8	45.4	0.1	0.0	0.0	1.3	703.0
1981	17	288.7	4.6	3.3	0.0	0.3	3.0	NA	NA	NA	NA	98.3	NA	0.0	NA	849.0	55.7	0.3	0.0	0.0	5.0	393.0
1982	13	127.1	0.7	0.1	3.1	3.6	1.9	NA	NA	NA	NA	265.5	NA	0.0	NA	211.5	30.3	0.5	2.5	0.0	14.5	1,319.0
1983	17	1,029.5	0.8	1.3	53.7	11.0	38.5	NA	NA	NA	NA	57.7	NA	0.0	NA	1,236.5	255.4	0.2	0.2	0.0	7.4	384.0
1984	12	58.3	3.2	1.3	2.8	7.7	7.2	NA	NA	NA	NA	249.7	NA	0.0	NA	787.1	148.0	0.3	9.8	0.1	14.3	444.0
1985	24	18.1	2.5	1.0	11.4	15.1	10.8	NA	NA	NA	NA	202.1	NA	0.0	NA	164.7	314.6	1.6	4.1	0.7	6.4	362.0
1986	46	303.5	2.9	5.7	242.0	16.8	10.5	2.6	0.4	0.0	0.0	366.0	0.0	0.0	0.0	284.9	156.7	1.4	13.4	10.8	5.5	420.0
1987	67	56.7	4.4	2.6	41.9	3.5	29.2	2.9	0.1	0.0	2.1	210.5	0.0	0.0	0.1	470.4	167.1	1.0	1.1	57.7	6.2	476.0
1988	38	85.7	3.9	5.4	54.9	0.9	41.3	3.2	0.5	0.0	6.9	176.0	0.0	0.0	0.0	106.8	53.6	2.6	10.4	168.3	4.4	258.0
1989	15	226.1	1.9	5.7	57.3	9.4	168.9	0.4	0.1	0.0	0.7	220.5	0.0	0.0	0.0	340.1	232.2	2.6	3.2	2,321.3	3.3	799.0
1990	16	16.4	4.8	5.3	44.9	23.5	45.8	1.3	0.2	0.0	0.3	47.8	0.0	0.0	0.0	197.6	135.2	1.5	3.6	681.8	11.2	151.0
1991	16	80.8	0.4	3.1	14.8	24.6	49.4	0.5	0.0	0.0	0.4	43.7	0.0	0.0	0.0	124.1	165.5	5.5	6.0	412.4	12.3	191.8
1992	36	302.5	0.3	2.9	9.3	2.8	0.3	11.5	0.0	0.0	0.1	280.2	0.0	0.0	0.0	182.0	199.9	1.1	0.1	91.5	7.6	74.9
1993	37	226.1	0.9	3.4	0.8	9.7	20.2	10.6	0.0	0.1	0.6	562.4	0.0	0.0	0.0	100.7	437.7	1.3	1.8	29.7	10.6	40.5
1994	32	48.3	6.0	8.8	0.0	27.8	8.5	10.8	0.0	0.0	0.6	57.9	0.0	0.0	0.2	203.1	512.5	2.0	6.1	183.0	9.8	24.2
1995	33	306.8	3.3	6.9	0.0	28.3	6.7	28.9	0.9	0.0	0.6	22.4	0.0	0.0	0.0	372.6	513.4	0.9	1.0	527.8	7.0	124.7

APPENDIX B. Continued.

Survey year	Number of tows	Alewife	Channel Catfish	Common Carp	Emerald Shiner	Freshwater Drum	Gizzard Shad	Johnny Darter	Lake Whitefish	Mimic Shiner	Quillback	Rainbow Smelt	Rock Bass	Round Goby	Shorthead Redhorse	Spottail Shiner	Trout-perch	Walleye	White Bass	White Perch	White Sucker	Yellow Perch
		Species																				
1996	30	98.7	6.3	4.4	0.9	16.3	22.9	20.7	0.1	0.0	0.6	15.2	0.1	0.0	0.0	209.5	474.1	1.3	0.4	277.2	7.7	85.0
1997	31	300.7	2.4	4.5	12.6	4.6	17.8	20.0	1.4	0.3	0.1	1,584.6	0.0	0.0	0.0	808.5	733.3	3.0	4.1	416.4	28.4	121.8
1998	27	1,590.5	3.0	7.5	1.4	26.2	22.7	5.2	0.0	0.1	0.0	70.0	0.3	0.0	0.0	665.0	1,729.8	9.7	2.0	345.8	12.4	173.6
1999	27	82.4	4.5	5.8	0.9	9.5	3.2	6.4	0.1	46.2	3.9	32.1	5.4	3.9	0.2	1,935.2	405.8	7.3	0.1	141.2	10.1	112.4
2000	30	337.3	6.1	5.6	0.7	16.4	3.0	3.9	0.3	30.1	1.1	390.1	0.1	127.1	0.0	1,101.4	619.2	2.4	0.0	894.7	7.1	36.7
2001	25	1,241.7	6.7	9.2	1.1	10.5	9.2	0.8	0.1	18.1	3.8	495.7	0.2	385.3	0.1	863.0	422.0	2.1	0.0	543.6	24.0	145.2
2002	35	347.7	4.6	5.9	0.9	11.1	18.8	0.0	0.9	67.2	1.9	146.6	0.1	356.4	0.0	967.1	411.3	3.6	0.5	339.7	25.9	66.5
2003	27	801.8	3.2	4.3	0.6	8.7	18.9	0.0	0.1	11.9	3.4	415.4	0.1	158.4	0.0	1,292.0	510.4	40.9	12.2	456.8	37.0	2,319.7
2004	36	10.0	1.4	6.7	1.8	6.9	1.8	0.0	0.6	1.4	0.9	210.0	0.0	369.1	0.1	210.0	444.0	28.1	39.5	282.0	18.6	485.0
2005	27	1.6	0.9	5.6	8.3	21.6	1.9	0.0	1.2	6.0	1.2	131.5	0.0	278.3	0.0	271.3	187.3	37.0	21.3	252.9	25.1	286.7
2006	27	1.2	0.9	10.7	9.2	14.2	11.7	0.0	0.0	0.0	1.1	5.7	0.0	30.6	0.1	313.8	304.1	14.0	2.0	491.0	8.5	96.4
2007	33	0.0	0.5	8.0	10.6	16.7	10.5	0.0	0.0	0.0	1.5	65.5	0.0	151.3	0.0	311.0	425.8	17.9	6.5	851.4	9.0	121.4
2008	37	0.0	0.4	4.9	34.3	9.5	30.6	0.0	0.1	1.8	1.5	26.3	0.1	523.4	0.1	165.6	268.8	11.8	7.3	646.0	4.1	226.7
2009	24	0.1	0.2	3.8	1.9	3.7	15.6	0.0	1.4	0.0	0.4	50.5	0.0	297.0	0.1	91.8	263.0	68.7	14.1	73.9	7.5	391.2
2010	24	0.0	0.4	3.7	0.5	5.6	6.6	0.0	0.7	132.6	0.7	5.7	0.0	209.1	0.0	86.6	297.0	36.1	12.3	452.5	5.3	240.1
2011	27	0.0	0.6	3.9	10.6	19.3	15.3	0.0	0.1	375.7	0.9	500.6	0.1	123.5	0.1	228.3	383.9	35.0	13.8	238.6	9.6	202.3
2012	24	0.1	1.6	4.0	4.8	82.0	38.2	0.0	0.0	962.3	0.6	1.0	0.0	81.5	0.0	99.8	542.8	19.6	8.8	223.8	4.1	143.0
2013	24	0.0	3.0	2.4	7.1	16.4	40.0	0.0	0.0	661.8	0.7	70.9	0.0	85.7	0.0	130.3	429.3	30.9	15.4	51.2	3.6	164.9
2014	24	0.0	0.5	2.1	39.0	12.8	16.5	0.0	0.1	43.2	0.7	2.6	0.0	165.2	0.1	11.2	97.0	32.8	4.4	54.3	4.7	73.4
2015	24	0.0	0.1	1.8	4.2	4.4	26.9	0.0	0.2	411.2	0.2	89.8	0.0	436.7	0.1	12.7	122.0	30.0	10.1	142.8	4.9	197.0
2016	24	0.0	0.2	2.3	3.0	7.1	15.3	0.0	0.1	430.0	0.4	10.2	0.1	123.2	0.0	21.9	554.3	11.3	4.8	350.4	3.6	149.7
2017	24	0.0	0.3	2.0	16.0	8.9	42.3	0.0	0.1	403.5	0.5	10.3	0.0	108.7	0.2	26.8	329.1	31.5	5.5	35.8	3.6	187.9

APPENDIX C. Length–weight regression equations and von Bertalanffy growth equations for Walleye and Yellow Perch. Natural log length–weight equations are based on data pooled for both sexes combined, from the fall gill-net collections in Saginaw Bay, 2012–2017. Weight (wt) is in grams, and length (len) is in mm. Von Bertalanffy equations are based on pooled length-at-age data from the 2012–2017 fall gill-net collections where ‘t’ is age in years.

Species	Sex	Length/Weight Equation	Len/Wt R^2	Von Bertalanffy Equation	K	L∞	t_o
Walleye	Males	ln(wt)=3.096 ln(len)-12.242	0.96	$L_t=506[1-e^{-0.3901(t+1.07)}]$	0.3901	506	-1.07
	Females	ln(wt)=3.082 ln(len)-12.176	0.95	$L_t=621[1-e^{-0.2548(t+1.35)}]$	0.2548	621	-1.35
	Combined	ln(wt)=3.085 ln(len)-12.188	0.95	$L_t=537[1-e^{-0.3546(t+1.06)}]$	0.3546	537	-1.06
Yellow Perch	Males	ln(wt)=3.075 ln(1en)-11.642	0.93	$L_t=399[1-e^{-0.2085(t+1.28)}]$	0.2085	399	-1.28
	Females	ln(wt)=3.165 ln(1en)-12.140	0.95	$L_t=392[1-e^{-0.2633(t+0.95)}]$	0.2633	392	-0.95
	Combined	ln(wt)=3.116 ln(1en)-11.875	0.94	$L_t=385[1-e^{-0.2576(t+0.99)}]$	0.2576	385	-0.99