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Fish Population Dynamics of Saginaw Bay, Lake Huron 1998–2004

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Abstract.–Saginaw Bay's fish community is annually surveyed by the Michigan Department of Natural Resources. Fish are collected in the bay by fall sampling with gill nets and trawls. Walleyes spawning in the Tittabawassee River are captured with electrofishing gear and tagged. This report summarizes survey findings for 1998–2004 and is supplemented with some reports from sport and commercial fisheries. The production of age-0 percids (walleyes and yellow perch) has increased substantially. Analysis of walleye origins, aided by oxytetracycline marking of stocked fish, indicated that about 80% of recent year classes were naturally reproduced. This was attributed principally to the decline and near absence of adult alewives which are believed to prey upon, and compete with, newly hatched percid fry. Ideal spring climate conditions are also thought to have aided reproduction in 2003. Survival of these abundant age-0 percid year classes has been only moderate for walleyes and very poor for yellow perch. Predation and overwinter mortality were identified as the principle losses. Since 2003 age-0 walleyes and yellow perch have been growing much slower than previous cohorts. Adult walleyes stemming from year classes prior to the recent increase in natural reproduction continued to grow very fast. Walleye total annual mortality rate and exploitation rate were generally low. The yellow perch population has declined to some of the lowest levels measured since monitoring began in 1971 because of poor survival of age-0 yellow perch and an overall trend of lower recruitment since zebra mussel colonization in the early 1990s. Other species of notable abundance in Saginaw Bay collections include channel catfish, white sucker, and white perch. The exotic round goby, which became abundant during this reporting period, is now ubiquitous in the bay. Despite profound changes in the bay's fish community since 2003, the overall prey fish base remains abundant and largely underutilized. Notably absent from survey catches were lake herring and lake sturgeon, once historically abundant in the bay. Saginaw Bay's fish community appears to be in a major transition stemming from the scarcity of adult alewives. The increased percid production speaks favorably to the ability of the bay's habitat to still produce large year classes but new factors appear to be limiting the survival of these cohorts. Walleye abundance is increasing as a result of the increased recruitment and is expected to make significant advances toward recovery objectives. Some management recommendations are offered including a more conservative approach to harvest by the yellow perch fisheries.

Introduction

Saginaw Bay's fish community and fisheries have experienced enormous change. The history of the bay can be organized into three time periods. The first time period is characterized by unbridled commercial exploitation beginning as early as the 1830s (Lanman 1839). The commercial fishery in Saginaw Bay expanded, and from 1912 to 1940 accounted for 28% of all the commercial yield of Lake Huron (Baldwin and Saalfeld 1962). The bay produced the second largest walleye (common and scientific names of fishes mentioned in this report are in Appendix 1) fishery in the Great Lakes (Schneider and Leach 1977). The commercial yield of many species was largely sustained until the mid-1940s but vacillated during periods of overfishing and recovery. Collapse of the commercial fisheries of the bay in the mid-1940s was most pronounced for walleyes.

The second time period in the bay's history, from the mid-1940s through the early 1970s, represents a highly degraded state. The decline in the fisheries was probably fueled more by degradation of habitat and water quality than by overexploitation (Schneider 1977; Schneider and Leach 1979). Concurrent with this degradation was a proliferation of invasive species including alewives. The decline of walleye, which played the ecological role of top piscine predator, also coincided with increases in suckers and carp (Hile and Buettner 1959). Yellow perch remained as the only commercially marketable population.

The most recent period is one of recovery, characterized by improving conditions. It began with the passage of the Clean Water Act of the early 1970s which has led to improved water quality. The Michigan Department of Natural Resources (MDNR) began a program of walleye stocking to reestablish a viable predator population and fishery (Keller et al. 1987). By the early 1980s, a substantial sport fishery had developed for walleye. The commercial fishery for walleye, closed in 1970, has not been reinstated. The sport fishery now regularly harvests in excess of 50,000 walleyes per year (MDNR, unpublished data). Despite these gains, full walleye recovery has still not been achieved. This was also a period plagued with further exotic invasions. The MDNR and others invested considerably in research and management initiatives during this period to understand the factors limiting the reproduction and recruitment of various species, and to document the dynamics and quality of the fish community and its fisheries.

Fielder (2002a) examined the recent sources of walleye recruitment and found them to include stocking, localized natural reproduction, and wild immigrants from the Lake Erie-St. Clair corridor. That study used oxytetracycline (OTC) marking of hatchery fish. Hatchery fish contributed an average of 80% to year class strength (based on locally produced fish, i.e., fish not immigrating into the bay); 20% were from natural reproduction. Fielder (2002a) concluded that the vast majority of locally produced wild recruits came from reproduction in rivers. Reef-based production, which is believed to have been a historically important source of juvenile walleyes to the bay's population, was found to be largely lacking in the 1990s.

On the whole, Saginaw Bay was characterized through the 1980s and 1990s to be overly dominated by forage fishes, with too few predators to achieve an ecological balance (Keller et al. 1987; Haas and Schaeffer 1992; Fielder et al. 2000). The consequences were an overgrazed zooplankton community, biomass concentrated in undesirable fishes, suboptimal fisheries, dependence on stocking, and vulnerability to further exotic invasion (Fielder and Baker 2004). Yellow perch, by contrast with walleye, experienced some years of very high production, but it was accompanied by slow growth and stunting that compromised the quality of the fishery (Haas and Schaeffer 1992; Fielder et al. 2000).

Despite the sometimes slow progress to recovery during the last 30 years, considerable information has been gathered and a great deal has been learned through various research and management initiatives. This collective knowledge was the basis for a management plan for completing the recovery of walleyes in Saginaw Bay. Fielder and Baker (2004) established three recovery goals for walleyes in the bay: establish predator/prey balance, build the walleye population to carrying capacity, and restore self sustaining levels of natural reproduction. That plan, although specific to walleye recovery, sought to effect larger-scale ecological change in the bay's ecosystem through the restoration of a top predator (the walleye), thereby benefiting the whole fish community. Walleye stocking was continued during this time (Appendix 2) to increase predation rates and promote recovery (Fielder 2004). Specific quantitative objectives and decision point criteria for evaluating progress towards these goals were also formulated. The walleye recovery plan called upon on-going MDNR research projects to provide adaptive management feedback information. Those projects included the annual (fall) fish community netting assessment, the annual (spring) walleye tagging operation, the on-going OTC marking evaluation, and the sport catch survey.

This report presents findings from annual netting survey and walleye tagging operation for 1998 through 2004, and provides an update on the status of the walleye population and the rest of the fish community. Specifically, the objectives of these studies and this report are to document trends in abundance, recruitment, size and age structure, and condition and growth rates for many of the species collected. We also evaluate the presence of invading species and the food habitats for select species. For walleyes, the additional parameters of exploitation, tag-based mortality rate estimation, and movement are reported. For the purpose of perspective, some information from the OTC marking and sport catch studies are also included. Additionally, an objective of this report is to archive data and analyses for future use, and to provide a base for evaluating progress towards existing management goals and development of new ones.

The trawling portion of the annual netting survey has been in place since 1970 and Weber (1985) summarized results through 1984. Haas and Schaeffer (1992) updated the trawling results through 1989 and Fielder et al. (2000) summarized the results through 1997. The gill netting portion of the fish community survey began in 1989 and results through 1997 were summarized by Fielder et al. (2000). The walleye tagging portion of the study originated in 1981. Results through 1989 were reported by Mrozinski et al. (1991) and from 1989 to 1997 by Fielder et al. (2000).

Study Area

Saginaw Bay lies entirely within Michigan waters of Lake Huron and spans a surface area of 2,960 km^2. 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 industrial and agricultural. There are several tributary systems to the bay, the largest being the Saginaw River. Bay water circulates in a counterclockwise direction during prevailing westerly winds (Danek and Saylor 1977) and the flushing rate is approximately 186 days (Keller et al. 1987). The inner portion of the 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) and the bay's water chemistry by Smith et al. (1977).

Methods

Trawling

Trawling locations in the inner bay have been based on a 2 minute latitude x 2.8 minute longitude grid system since the 1980s. Fish samples were collected in the fall of each year by the MDNR research vessel RV *Channel Cat* from three fixed index grids in the inner bay: Au Gres (north quadrant), Pinconning (west quadrant), and North Island (east quadrant, Figure 1). The Au Gres station was located near the city of Au Gres, and conditions there more closely resemble those of the less eutrophic outer bay. The Pinconning station was located at a bottom depression known locally as the "Black Hole." This station, closest to the mouth of the Saginaw River, has organic sediments rich in pollution-tolerant benthic macroinvertebrates (Schneider et al. 1969). The North Island station was located off Wildfowl Bay, a shallow sub-bay that serves as a nursery area for many fish species. In addition, fish were collected with trawls in at least one randomly selected grid from each of the four quadrants of the bay. Total trawl effort, while not fully uniform by year, spanned a geographically representative area (Table 1).

Only those trawl tows conducted during September are discussed in this report. The gear was a 10.66-m headrope, two-seam otter trawl with 4.6-m wings and 18.9 m overall length. The trawl was constructed of 76-mm, 38-mm, 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 by a single warp and 45.7-m bridle along the bottom for 10 minutes at a speed of approximately 2 knots. Based on trawl mensuration, the average gape width and height dimensions were 7 m x 1 m. Water temperature and Secchi disk transparency were recorded at each trawling site. Some summaries of trawling data are supplemented with results from earlier years (Fielder et al. 2000; Haas and Schaeffer 1992; Weber 1985) to facilitate interpretation. Total weight and number for each fish species collected in each tow were recorded. Large catches (>10 kg) of forage fish (Appendix 1) were sometimes subsampled by selecting 25% to 40% of the total catch. Length-frequency distributions were recorded for at least 150 individuals of each forage species, including age-0 yellow perch, at the index trawl stations.

Scale samples were taken from yellow perch for age and growth analysis. In addition, a maximum of 52 adult and 10 age-0 yellow perch were sampled for diet at each of the three fixed stations. Yellow perch were sampled randomly, stunned on ice, and immediately frozen with liquid nitrogen to stop digestion. These fish were kept frozen until processed in the laboratory. Finally, up to 300 yearling and older yellow perch were collected from random grids, placed on ice, and then frozen for later dry weight analysis in the laboratory.

For each year, estimates of age- and sex-specific yellow perch total catch and catch-per-unit-effort (CPUE) were calculated. The estimation method accounted for bias inherent in subsampling for age estimation. The mean catch by age (ages 1 to 6) was used to estimate survival for ages 1 to 6 with a standard catch curve analysis (Quinn and Deriso 1999). Age-specific sex ratios were determined by dividing the male catch by the female catch for each age, from age 1 to 6, during each year. The overall sex ratio for each year was determined by dividing the total male catch by the total female catch.

Yellow perch were thawed in the laboratory, measured, and weighed. Fish were eviscerated, sexed, and checked for redworm (*Eustrongylides tubifex* and *Philometra cylindracea*) infestation. Viscera were weighed after removal and weighing of stomach contents. Somatic weight (total weight of an eviscerated individual) was also recorded. Stomach contents were preserved in ethanol. To determine somatic tissue water content, yellow perch and their excised viscera were dried at 90^{o} C for two days in a drying oven and weighed to 0.0001 g. Percent water content was used as an indicator of fat content. Elliot (1976) found that as food ration size increased, protein and fat increased and percent water content decreased. Stomach contents of specimens were evaluated between 1998 and 2002 by counting and identifying all items to the lowest taxonomic level possible, given the stage of digestion. The diet was analyzed for frequency-of-occurrence: the percentage of fish with non-empty stomachs that contained at least one of a selected food item (Windell and Bowen 1978).

Scale samples were taken from walleye for age and growth analysis. Walleyes were also examined for stomach contents. The fish were sacrificed and the stomach was removed immediately. Stomach contents were enumerated and identified to the lowest taxonomic level permitted by digestion. Percent abundance (by number) for each prey item was calculated as the percent of each prey item type or species (including unidentified fish) encountered in the stomach contents in a given year. In 2001 and 2002, a few stomachs from freshwater drum and channel catfish were also examined to determine if these species were consuming the invading round goby.

Fielder et al. (2000) investigated the effects of the zebra mussel colonization of Saginaw Bay on trawl CPUE for various species, age-specific yellow perch CPUE, mean total length for the major forage species, and yellow perch condition. They suspected that zebra mussel changes in energy cycling in the bay could be manifested in changes in abundance, growth, and survival for some fish species. We continued their approach by comparing these factors between the pre-zebra mussel period (1986 to 1990) and the post-zebra mussel period (1993 to 2004). The colonization years of 1991 and 1992, considered transitional years, were excluded. In addition, we estimated yellow perch survival and sex ratios for pre- and post-zebra mussel periods. We derived survival estimates from pre- and post-zebra mussel periods with a standard catch curve analysis (Quinn and Deriso 1999) of the average age-specific catch rates, for ages 1 to 6, across each time period. The mean age-specific sex ratio for the two time periods was calculated by averaging the sex ratio for each age from 1 to 6 across the time period.

Gill Netting

Isbell and Rawson (1989) showed that gill net catch could be effectively used as a measure of abundance and recruitment for walleye and other species in Lake Erie, an environment similar to Saginaw Bay. Our gill net sampling was performed at nine fixed stations from the MDNR research vessel *Chinook*, concurrent with the fall trawling survey (Table 2). 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. Gill nets were fished on the bottom overnight in water deeper than 3 m. Two net sets were made at each sample site (Figure 1; Table 2). Gill netting effort was divided between inner and outer bay environments (Table 2). Catch-per-unit-effort was calculated and expressed as the number of each species per 335 m of net. The 38-mm mesh was added to the study in 1993; consequently, gill net CPUE was also expressed without that panel to facilitate comparison to data in Fielder et al. (2000). Yellow perch and channel catfish were subsampled from some catches by including detailed data recording on specimens caught from every other net set.

Walleyes, northern pike, yellow perch, and smallmouth bass were measured for total length (mm) and weight (g), and examined for sex and maturity. Scales or dorsal spines were collected for age interpretation. Spines were also collected from channel catfish for aging. Walleye were also examined for diet as above.

All other species in the survey catch were measured for total length. Condition was expressed as relative weight for walleye and yellow perch, according to the equations developed by Murphy et al. (1990) and Willis et al. (1991), respectively. Proportional-Stock-Density (PSD) and Relative-Stock-Density (RSD) 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 same season (fall) as reported by Schneider (2000).

Walleye Tagging

Walleye tagging was conducted annually at the Dow Dam site on the Tittabawassee River, a tributary of the Saginaw River system (Figure 1). Tagging was performed during the walleye spawning migration and typically spanned a 1-week period in late March or early April. Each year, 3,000 walleyes were tagged. Numbers tagged each year did not reflect the magnitude of the run. Walleyes were collected with a 230-volt DC electrofishing boat, measured, identified to sex, and scales were taken for age interpretation. Fish scales were selected for aging on the day that the proportion of males and females was most equal.

Tagging was limited to fish ≥381 mm to ensure vulnerability to the fishery (15-in minimum length limit). Serially numbered monel metal tags with a return postal address were attached to the maxillary bone and walleyes were released at the tagging site. Over 80,000 walleyes have been tagged since inception of the study in 1981.

The presence of tags was promoted within the angling community with requests for their return or report. Because walleye tagging had been occurring in Saginaw Bay for many years, there has been concern over possible nonreporting by anglers. A non-reporting correction factor of 2.33, based on $100 reward tags, was previously derived for the Saginaw Bay walleye fishery (MDNR, unpublished data). This correction factor was applied to the analysis of subsequent years in this report. Persons reporting tags were sent an informational letter.

Tag recovery data were analyzed using the tag-recovery program ESTIMATE (Model 1), for year-specific survival and recovery rates (Brownie et al. 1985). ESTIMATE is a stochastic model that uses maximum likelihood estimation to estimate tag recovery parameters. This method is believed superior to older ad-hoc methods. Because the model estimates parameters based on this maximum likelihood function, year-specific values generally improve with subsequent years of data. For this reason, year-specific values reported in this report may differ slightly from those reported in the past. The program estimates an annual recovery rate, which is the percentage of tags that were returned in the first year that came from the year's tagging effort. This is equivalent to year-specific exploitation rate. Also provided is an estimate of mean recovery rate for the entire time series. Both the annual and mean rates are multiplied by the nonreporting correction factor and reported as exploitation rate. Also estimated by the program is total annual survival rate 'S' (yielding total annual mortality estimates A) based on both first-year returns and a matrix of returns from multiple years. ESTIMATE cannot estimate year-specific survival for the last tagged year in the time series. Estimates for this time series derived added statistical power from return data for previous tagging years (since 1981). Results for these earlier time periods were presented by Keller et al. (1987), Mrozinski et al. (1991), and Fielder et al. (2000).

Each tag return location was assigned latitude and longitude based on capture location provided by the angler. This information was put into a geographic information system (GIS) and stratified by year, season, and sex. Inferences about movement patterns were made by visual inspection of the spatially mapped output.

OTC Marking of Hatchery Walleyes

Since 1997, walleyes reared for stocking in Saginaw Bay have been marked with oxytetracycline hydrochloride, a chemical that binds with bones and calcified tissues in fishes. These calcified tissues exhibit a fluorescent ring when examined under ultraviolet light. Walleye fry destined for Saginaw Bay were marked according to the methods of Fielder (2002b) and specimens were collected and analyzed for the mark using fluorescence microscopy (Fielder 2002b). Sagittal otoliths were examined for the presence of the mark. Composition of walleye year classes (wild or hatchery) was expressed as percentages for age-0 (generally late summer or fall fish) and age-1 fish. These age groups were used because they are believed to be undiluted by immigrant walleyes. Specimens analyzed were generally those from trawling and gill netting collections, sometimes supplemented with specimens from other independent collections the same year. The analysis included a variety of sources and locations from around the bay to overcome patchiness in the distribution of newly stocked fish. Better mixing of wild and hatchery fish is believed to occur by age 1, and we attach greater importance to proportion estimates at that age.

Statistical Analysis

Trawl and gill net CPUE data were examined for normality (Lilliefors test) and homogeneity of variance (Bartlett's test). We used both parametric ANOVA procedures and nonparametric Kruskal-Wallis (KW) procedures to test for statistical differences in mean CPUE among years for both gear types. Similarly, these tests were used to test for statistical differences within biological parameters over time within gear types. Statistical differences in mean lengths for forage species were evaluated with *t*-tests.

Scheffe multiple comparison procedures were used to further evaluate some significant differences detected by ANOVA. Analysis of variance procedures were also used to test for differences in yellow perch mean length-at-age among years from trawl data and for walleye and yellow perch mean length-at-age from gill net data. Some means are reported with two standard errors of the mean (which approximate 95% confidence intervals) to highlight significant differences. The tag return analysis program ESTIMATE provides a chi-square goodness of fit (CS) test statistic to test for significant differences in recovery rates among years and for the overall fit of the data to the model assumptions. A *Z*-test was also used in some instances to compare year-specific recovery rate and survival estimates to the mean for the time series as well as to compare between specific years. Simple linear regression analysis was used to develop length-weight relationships for some species from the gill net collections and to examine the correlation with some other data sets. Total annual mortality rate was calculated for yellow perch (for both trawl and gill net collections) and channel catfish (from gill net collections) based on the Robson-Chapman method (Van Den Avyle and Hayward 1999) or standard catch curve analysis (Quinn and Deriso 1999). Von Bertalanffy equation and parameters describing growth rate with age (with data from the gill net collections) were calculated for some species according to Van Den Avyle and Hayward (1999). All statistical tests for this study were performed according to Sokal and Rohlf (1981) and conducted at a significance level of $P_{\alpha} = 0.05$. SPSS computer software was used for statistical analyses (SPSS 1997).

Results

Trawling

From 1998 to 2004, a total of 217 trawl tows were made in inner Saginaw Bay during daylight hours between 10 September and 1 October (Table 1). Mean water temperatures at the trawling sites, recorded since 1987, ranged from 15.3 ºC to 21.6 ºC and exceeded 20 ºC only in 1998, 2002, 2003, and 2004 (Figure 2). In general, a pattern of warmer mean fall water temperatures is evident since the early 1990s. Mean fall Secchi disk transparencies recorded at the trawling sites ranged from 1.04 m to 1.55 m, with the lowest transparency in 2000 and the highest in 2003 (Figure 3). No trend in mean fall Secchi transparency was apparent.

Species composition and catch rates.–For the 7- year period from 1998 to 2004, a total of 639,048 fish were caught in fall survey trawls in the inner portion of Saginaw Bay. Species composition varied considerably among years (Table 3). Overall, the most abundant species were alewife, spottail shiner, trout-perch, white perch, and yellow perch. In combination, these five species accounted for at least 67% of the total catch each year. Rainbow smelt and round goby were also abundant in some years. Round gobies were first captured in survey trawls in Saginaw Bay in 1999, and by 2004 accounted for over 17% of the total catch by numbers.

Catch-per-unit-effort, expressed as mean catch per 10-minute tow, also varied considerably among years (Table 4). A few noteworthy patterns or occurrences were apparent. Alewife CPUE in 2004 (10 alewife/tow) was the lowest recorded since 1974 (8 alewife/tow, Appendix 3). Similarly, gizzard shad CPUE in 2004 (2 gizzard shad/tow) was the lowest recorded since 1992 (0 gizzard shad/tow, Appendix 3). No johnny darters were collected in 2003 or 2004, after three consecutive years of declining CPUE since 1999. Round goby CPUE values steadily increased from 1999 to 2001, then oscillated. Length frequency distributions (Figure 4) indicate that the smallest size classes (age-0) of round gobies were depressed in abundance in 2003, resulting in a slight dip in CPUE. White bass CPUE values in 2003 and 2004 (Table 4) were the highest observed since 1986. Walleye CPUE values in 2003 and 2004 was the highest ever recorded for the time series due to record age-0 catch rates (Table 5). Similarly for yellow perch, the 2003 CPUE (2,469 per tow) was the highest observed since the survey began in 1971 (Table 6). Soft-rayed forage fish abundance in 2004 was the lowest since 1996 (Table 4), largely due to the low CPUE for alewives and spottail shiners.

Some general patterns were evident for mean CPUE by decade for certain species (Table 4), but they were not tested for statistical significance. Mean CPUE values apparently increased across the three decades for alewives, common carp, rainbow smelt, spottail shiners, walleyes, white suckers, and white perch. Emerald shiners and gizzard shad decreased across the three decades. Trout-perch, freshwater drum, and johnny darters were relatively abundant in the 1990s.

Pre- and post-zebra mussel periods in the trawl catch.–Comparison of mean CPUE values between pre- (1986–1990) and post- (1993–2004) zebra mussel periods indicated significantly lower CPUE values for some planktivores, such as emerald shiner and gizzard shad (Table 7). Several benthivores, including freshwater drum, trout-perch, white perch, and white sucker exhibited significantly higher CPUE values in the post-zebra mussel period. Both of the major piscivores, channel catfish and walleye, also had significantly higher CPUE values in the post-zebra mussel period. Conversely, yellow perch CPUE was significantly lower in the post-zebra mussel period. Age-specific CPUE values for yellow perch (Table 8) consistently declined by more than 85% for ages 1 through 9 when pre- and post-zebra mussel periods were compared. Only age-0 CPUE increased in the post-zebra mussel period and that was entirely due to the extraordinarily high 2003 age-0 CPUE (2,451). As yearlings, the CPUE for the 2003 cohort had declined to 22.9, representing a survival rate of just 0.9%.

Mean total length for the major forage species also differed between the pre- and post-zebra mussel periods (Table 9). Age-0 alewives, gizzard shad, rainbow smelt, white perch, and yellow perch all experienced significant declines in mean total length during the post-zebra mussel period. The age-0 yellow perch decline in length was a result of record low mean total lengths in 2003 and 2004. Spottail shiners and trout-perch of all ages were also significantly smaller during the post-zebra mussel period.

Colonization of Saginaw Bay by round gobies.–Survey trawls documented the colonization of Saginaw Bay by the round goby. In 1998, no round gobies were collected at any of the trawl sites around the inner bay (Figure 5). In 1999, low numbers of round gobies were captured in survey trawls in the southwest area of the bay near the Saginaw River, and also at the North Island index sites near Caseville. By 2000, round gobies had expanded across the Bay and were found at all sampled sites. From 2001 through 2004, round gobies continued to be captured in all trawl samples and mean numbers increased.

Survival, sex ratio, growth, condition, redworm, and diet of yellow perch.–Catch curve analysis of trawl samples for yellow perch ages 1–6 produced estimates for annual survival of 54% for the pre-zebra mussel period and 47% for the post-zebra mussel period (Figure 6). The shape of the catch curves differed between the two time periods. For the pre-zebra mussel period, the curve was nearly flat for ages 1–3, indicating high survival, with lower survival for ages 3–6. For the post-zebra mussel period, the curve exhibited a more consistent descending slope across all ages, suggesting survival had declined in the post-zebra mussel period for ages 1–3, and producing a better linear fit for the regression ($r^2 = 0.98$).

The yellow perch sex ratio was near 1.0 for age-1 yellow perch, but increased across ages 2 to 5 to a high of 3.47 M:F (Table 10). This suggests higher mortality rates for females than males, particularly for ages 5 and 6. For all ages combined, the overall sex ratio for the period from 1998 to

2004 was 1.19 M:F. This ratio was similar to that observed for the period from 1992–1997, but was significantly lower than the 2.50 M:F ratio recorded for 1971–1991.

Based on mean length-at-age, female yellow perch grew faster than male yellow perch in Saginaw Bay (Table 11). From 2002 to 2004, males attained a mean length of 203 mm by age 4, while females attained 203 mm by age 3. For both males and females, mean length-at-age has generally maintained a trend of improved growth since the mid-1990s. This trend is also apparent when the mean length at age for the sexes combined is compared with the statewide average mean length at age. For ages 1 to 4, Saginaw Bay yellow perch mean length generally exceeded the statewide average from 2002 through 2004.

In general, somatic tissue water content decreased with age for Saginaw Bay yellow perch, indicating older fish had higher somatic tissue energy reserves (Figure 8). Similarly, male yellow perch had higher somatic energy reserves for ages 1 to 4, than females. There was also a consistent pattern of higher somatic water content for both sexes of all ages during the period from 1998 to 2002 (Table 12), when compared with the pre-zebra mussel period (1986–1988) and the years immediately following zebra-mussel colonization (1993–1997).

Infection of yellow perch by redworm varied considerably across years (Figure 7). The peak infection rates were recorded in 2000 (83%) and 1988 (77%). From 2000 to 2004, the infection rate declined steadily to the lowest rate observed for the time period (19%). Within years, no differences were found in rates of infection between males and females.

Stomach contents were examined from 838 yellow perch collected by fall trawling from 1998 to 2002. We found few trends or patterns in the frequency of occurrence of diet items (Table 13). Round gobies first appeared in yellow perch stomachs in 2001 and roughly doubled in frequency of occurrence the following year. There were some other shifts in diet compared to earlier years. From 1986 to 1996, zooplankton was found in more than 50% of all the non-empty stomachs examined each year. However, zooplankton importance in the diet declined from 1998 through 2001 and reached a record low frequency of occurrence of only 5.1%. A similar but less drastic decline was apparent for chironomid larvae. For 7 of the 9 years sampled between 1986 and 1997, chironomid larvae frequency of occurrence exceeded 60%, but from 1998 to 2002 the frequency of occurrence was less than 50% for 4 out of 5 years. Generally, fish have been more frequently found in yellow perch stomachs since the mid-1990s.

Diet of other species.–The stomachs of walleyes caught in trawls were examined each year. Prior to 2003, alewives were the most frequently found prey item (Table 14). However, in 2003 and 2004 yellow perch became the most abundant prey item identified in the stomachs. In 2004, only one alewife was found among the 244 prey items in 112 non-empty walleye stomachs, accounting for less than 1% of the diet numerically. The diversity of prey items was highest in 2004, with seven species identified. 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.

Stomachs of other fish also contained round gobies. In 2001, 18 of 20 (90%) of non-empty freshwater drum stomachs contained at least one round goby. In 2002, 30 of 50 (60%) of non-empty freshwater drum stomachs contained round gobies. A small number (19) of channel catfish stomachs were also examined in 2001; 8 of 9 (89%) non-empty stomachs contained round gobies.

Gill Netting

Gill nets collected an average of 2,133 fish per year (Tables 15 and 16). A total of 39 species were represented. Walleyes were generally declining in abundance until they increased in 2003. Similar gains in production of yellow perch were not evident in the gill net collections as they had not recruited to the gear by 2003 or 2004. Other species of notable abundance in the gill net collections during the time series included: channel catfish, freshwater drum, white sucker, white perch, and gizzard shad. Northern pike, which can be an important sport species, occurred in low abundance. Notably absent from the fish community were Great Lakes muskellunge, lake sturgeon, and lake herring. The inclusion of the 38-mm mesh in 1993 (Table 16; Fielder et al. 2000) resulted in greater collections of yellow perch.

Walleye recruitment, as measured by yearling (age-1) gill net CPUE, was greatest for the 1998 year class (Table 17; Figure 9). Despite the enormous abundance of age-0 walleyes collected by trawling in 2003, the resulting yearling CPUE was no greater than that achieved by the 1998 year class. The 2002 walleye year class was also strong based on these data. The strong recruitment of walleyes in 2002–2004 led to a lower mean age for the population as a whole (Table 17). The annual mean ages differed significantly over the time series (KW, $P < 0.001$).

The growth rate of walleyes, as indicated by the mean length-at-age from the gill net collections, was very fast, greatly exceeding the Michigan average and the bay's historic (pre-collapse) average each year (Table 18). Walleye growth rate was consistent across the time series until 2004 when the large 2003 year class exhibited a significantly lower mean length at age-1 (KW, $P < 0.001$). Although age-3 walleyes also exhibited an apparent decline in growth rate in 2004, mean length at age did not differ significantly across the time series for that age (KW, $P = 0.082$).

Walleye diet, as indicated by percent abundance in stomachs examined from the gill net collections, abruptly switched in 2004 away from clupeids (alewives and gizzard shad) to percids (yellow perch and walleyes). This change was a sudden reversal of the predominance of clupeids in walleye diets since 1989 (Table 19). This dietary shift reflects changes in abundance and species composition evidenced in the trawl collections.

Condition of walleyes, as indicated by mean relative weight, changed little over the time series until 2004, when it dropped to its lowest level measured (Table 20). However, walleye condition in 2004 was significantly different from only 2001 (ANOVA, $P < 0.001$; Scheffe, $P < 0.001$). The size structure of the walleye population as indicated by PSD (Table 21) reflects the change in the age structure previously described. Proportional Stock Density, RSD-P, and RSD-M all declined to their lowest level in 2004, but were still well within the range recommended for a balanced walleye population (Anderson and Weithman 1978). The length-weight regression equation for 2004 and Von Bertalanffy growth equation for walleyes over the time series are presented in Appendix 4.

Like walleyes, the 1998 year class of yellow perch was strong compared to others in the time series (Table 22). The 1998 year class dominated the yellow perch age structure through 2001 (age-3) and remained evident through 2004. The mean age of yellow perch was lower since 2001 and varied significantly (KW, $P < 0.001$) over the time series. The large production of age-0 yellow perch detected by trawling in 2003 and 2004 was not evident in the gill net catch because they do not fully recruit to the gear until later ages.

Yellow perch growth rate as indicated by mean length-at-age data has improved over the time series, surpassing the Michigan average since 2001 (Table 18). The improvement in growth rate was evident across all age groups. The improvement was typified by age-3 yellow perch which were 55 mm longer in 2004 than in 1998. Length at age 3 increased significantly over the time series (KW, $P < 0.001$). The rate of improvement for mean length was greatest for most ages between 2000 and 2002.

Total annual mortality rate (A) of yellow perch as determined by the Robson-Chapman method was stable until 2001, increased until 2003, and then declined in 2004 (Table 23). Total annual mortality rate estimates from gill net collections are similar to those estimated from trawl collections (Table 23; Figure 6).

Condition of yellow perch as indicated by mean relative weight (Table 20) has not followed any discernable pattern, but has varied significantly over the study time series (KW, $P < 0.001$). Mean relative weight was highest in 2001 for most size categories of yellow perch and this coincides with the improvement in growth rate. Proportional stock density, including RSD-P and RSD-M, of yellow perch increased over the time series (Table 21). The 2004 length-weight regression equation and Von Bertalanffy growth equation for yellow perch over the time series are presented in Appendix 4.

As with walleyes and yellow perch, the 1998 year class of channel catfish figured prominently in the age structure and gill net CPUE over the time series (Table 24). On the whole, however, distinct patterns in channel catfish recruitment are not immediately discernable from these data. Mean age differed significantly over the time series (KW, $P < 0.001$), perhaps reflecting the influence of the 1998 year class.

Channel catfish grow slowly in Saginaw Bay compared to the Michigan average (Table 25). There has been no significant change in mean length-at-age data for age-3 channel catfish (ANOVA, $P = 0.085$). Since 1998, age-3 channel catfish grew 45 mm slower than the Michigan average.

Total annual mortality rate (A) for channel catfish as determined by the Robson-Chapman method ranged from 59% (2001) to 79% (2004) (Table 23). The 2004 length-weight regression equation and Von Bertalanffy growth equation for channel catfish over the time series are presented in Appendix 4.

Tagging (exploitation and related parameters)

A total of 20,775 walleyes were tagged at the Dow Dam site on the Tittabawassee River between 1998 and 2004, bringing the study total to 80,084 since 1981 (Table 26). The timing of the tagging operation targeted the peak of the spawning migration. Sex ratio has varied, but generally males were more abundant than females. Mean length was generally large (>500mm in most years), consistent with the lack of sexually immature fish in the migration (Table 27).

Female walleyes generally recruited to the spawning migration (indicating first maturity) at age 3 and appeared to be fully recruited by age 5 (Table 28). Females from the strong 1998 walleye year class achieved full maturity in 2003 and 2004, the two years of record age-0 production as indicated by the trawling. Mean age of walleyes in the spawning migration varied over the time series with no discernable pattern. Mean length-at-age data for the spawning migration is essentially equivalent to mean length-at-annulus data (Table 29). As with the specimens from the gill net collections, walleyes collected during tagging operation exhibited fast growth, exceeding the Michigan average.

A total of 3,688 tags were reported by anglers from 1990 to 2004 (Table 30). Table 30 presents the tag return matrix as of 2004, and was the data source from which year-specific estimates of recovery rate and survival were estimated by the computer program ESTIMATE. Exploitation rate (year-specific recovery rate multiplied by the correction factor for nonreporting) ranged from a low of 4.3% in 1995 to a high of 12.8% in 1992 and varied significantly among years (CS, $P < 0.001$; Table 31). The mean annual exploitation rate for the time period of 1992 through 2004 was 7.8% (95% CI ± 0.3). Total annual mortality (derived from year-specific estimates of survival) ranged from a low of 21.8% in 2002 to a high of 52.5% in 1999 (Table 31). The mean annual survival rate of walleyes from 1992 to 2004 was 64.6% (95% CI ±1.6%). The analysis of the tag return data fit the assumptions of year-specific recovery and survival rates in the ESTIMATE Model-1 (CS, $P = 0.270$).

From 1992 to 2004, the open water sport harvest of walleyes ranged from a low of 43,747 fish in 1999 to a high of 125,160 fish in 1993 (Table 31). The 1997 and 1998 year classes were an important element of the sport fishery during this time period, collectively exceeding 50% of the harvest in some years (Table 31). These year classes also figured prominently in the yellow perch fishery (Table 32). Yellow perch sport harvest has declined since 1990 (Table 32), as have commercial landings of yellow perch (Table 33). Commercial harvest has been increasing (in proportion) with respect to the recreational yield and surpassed the open water sport fishery for the first time in 2004 (Tables 32–33).

Geographic location of walleye tag returns is a function of both walleye movement and angler location. Between 1998 and 2004, walleyes moved as far north as Munuscong Bay in the St. Marys River and as far south as Lake Erie (Figure 10). The majority, however, remained in Saginaw Bay. There appeared to be no difference between male and female walleye distribution in Saginaw Bay except possibly more males were caught from the Saginaw and Tittabawassee rivers (Figure 11). Most angler tag returns come from the rivers in spring and the innermost portion of Saginaw Bay in winter (Figure 12). Although there are more tag returns from the post zebra mussel era (1993–present), their relative distribution doesn't appear appreciably different from tag returns before zebra mussel colonization (Figure 13). One exception may be a greater concentration of tag returns from the tip of the thumb after zebra mussel colonization.

Walleye OTC Marking

Stocked walleyes (as indicated by the presence of an OTC mark in examined specimens) accounted for the majority of each year class from 1997 to 2002 (Table 34). Prior to the substantial increase in naturally reproduced walleyes in 2003, hatchery walleyes accounted for an average of 80% of each year class, including the strong 1998 year class (82% stocked fish). In 2003 and 2004, stocked fish accounted for only 22% (average for both years combined) despite increases in stocking rate (Appendix 2).

Discussion

Walleye

The enormous increase in production of wild age-0 walleyes in 2003 and 2004 is a significant expansion from prior levels. Although increased stocking occurred simultaneously (Appendix 2), the record trawl catch rates (Table 5) were largely a product of natural reproduction as indicated by OTC marking results (Table 34). At age 0, measured by trawl CPUE, the 2003 year class was 16 times greater than the 2002 year class and 4.8 times greater than the 1998 year class. Of concern, however, is the resulting walleye recruitment measured as yearlings. Yearling walleye gill net CPUE has been one of the main measures of recruitment for this species. Year class strength of walleyes at the yearling stage stemming from the record 2003 year class was no greater than for the 2002 or 1998 cohorts (Figure 9; Table 17). Apparently, survival from age 0 to age 1 was much less for the record 2003 year class than prior year classes. It is probable that at very high densities, new factors become limiting to the survival of age-0 walleyes.

The poorer survival of the 2003 walleye year class between age-0 and age-1 may have been partly a result of predation. We observed walleye cannibalism for the first time in 2004 (Table 19). The 2003 walleye year class was also slightly smaller in length than previous years (Tables 5 and 18). A smaller average size may leave age-0 walleyes more vulnerable to overwinter thermal stress (if fat levels were also reduced; Newsome and Leduc 1975). Slower growth may also leave juvenile walleyes vulnerable to predation for a longer period (Houde 1987). This is an even greater concern for the strong 2004 walleye year class (Table 5). Their mean length at age 0 was well below the survey average and also below the Michigan average for that time of year (Tables 5 and 18).

Aside from the two record year classes produced at the end of this time series (2003 and 2004), walleye recruitment to age-1 has generally been increasing since the previous record high of 1998 (Figure 9; Table 17). In recent years, the 1998 walleye year class became the predominant cohort in the Saginaw Bay walleye population (Table 17), in the annual walleye spawning migration (Table 28), and in the sport fishery (Table 31). Previous weaker year classes—such as 1992, 1993, and 1996, some of which were nonstocked years (Fielder 2002a)—were no longer influencing the overall walleye age structure.

Why walleyes and yellow perch increased so substantially in production of young in 2003 and 2004 is an important question. It is impossible to determine from this data series if the increases are a result of greater fry production (improved incubation and hatch) or improved survival of fry upon emergence, or both. Outside of Saginaw Bay, 2003 was a substantial and often record year for production of age-0 percids in other parts of the Great Lakes, such as Green Bay for yellow perch (J. Hasz, Wisconsin DNR, personal communication), and parts of Lake Erie for walleyes (MDNR, unpublished data). It appears that a regional phenomenon occurred in 2003 that enhanced production of age-0 percids. Regional production trends have been observed before (including 1998) and are usually attributed to climate patterns that affected large areas in the spring and summer of those years (Schupp 2002).

Walleye year class strength may also have been influenced by factors unique to Saginaw Bay. For walleyes, females of the strong 1998 year class first fully recruited to the spawning migration in the Tittabawassee River in 2003 (Table 28). This may have increased egg production over past years. Another notable change was the decline of adult alewives that began in 2003. Surveys in the main basin of Lake Huron documented dramatic declines in the abundance of adult alewives in 2003 and 2004 (Schaeffer et al. 2005). Adult alewives spawn in Saginaw Bay and juveniles use it as a nursery area (Organ et al. 1979). This places adult alewives in the bay in close timing with the emergence of percid fry. Alewives have long been documented as a formidable predator and competitor on newly hatched walleye fry (Kohler and Ney 1980; Wells 1980; Brandt et al. 1987; Brooking et al. 1998) and have been reported as obstacles to walleye recovery in some Great Lakes locations (Hurley and Christie 1977; Bowlby et al. 1991). With adult alewives scarce in 2003 and 2004, walleye and yellow perch fry may have experienced greatly improved survival accounting for the increased production. Most likely it was a combination of factors that led to the record 2003 production of age-0 walleye. However, increased walleye age-0 production continued in 2004 and there was no regional climate phenomenon reported in that year. Of the various potential factors leading to the increased walleye age-0 production in 2003 and 2004, we believe the scarcity of adult alewives to be the most explanatory and significant, given that yellow perch were also affected. We consider the increased production of eggs (if any) as a result of the recruitment of the strong 1998 walleye year class to the spawning migration to be a secondary factor at most.

Previously (Fielder 2002a; Fielder and Baker 2004) alewives were identified among the suite of factors affecting walleye production in Saginaw Bay, but spawning habitat was thought to be the most limiting factor. Based on recent events, it appears that adult alewives and their predation and competition effects are a greater determining factor in percid age-0 production than previously realized, and perhaps more limiting than spawning habitat. The questions then become: what factors are limiting walleye age-0 survival and ultimate recruitment to age 1 when age-0 production is high, and how sustainable is the increased production? If the adult alewife absence hypothesis is valid, then increased production will continue only as long as adult alewives remain scarce.

The removal of alewife predation as a limiting factor has special ramifications for offshore reef production of young walleyes. Fielder (2002a) concluded that walleye natural reproduction in Saginaw Bay was principally from river spawning and historically important reef-based spawning was no longer contributing. Spawning reef habitat degradation was believed to be chief among the factors leading to the loss of that reproduction source but alewife predation on newly hatched walleye fry emerging from reefs was also hypothesized to be another affecting factor. With this potential source of predation apparently removed during 2003 and 2004 due to the scarcity of adult alewives, what then, is the status of reef-based production?

Walleye growth rate continues to be very fast in Saginaw Bay as measured in both the population at large (Table 18) and in the spawning migration (Table 29). Fielder and Baker (2004) used mean length at age 3 as a bench mark for gauging walleye recovery. The primary recovery objective is to increase the walleye density such that age-3 growth rate declines to 110% of the Michigan average (sexes combined). Walleye mean length at age 3 has exceeded the Michigan average of 386 mm total length (measured in the fall) for each year since 1998 by an average of 126% (Table 18). The new strong 2003 and 2004 year classes appear to be growing slower. The 2004 year class was just 95% of the state average when measured at age 0. Similarly the 2003 year class was just 107% at age 0; however, growth of that cohort improved to 118% by age 1 (Table 18). It remains to be seen what length will be achieved when these slower growing cohorts reach age 3, beginning in 2006. Walleyes collected in gill nets often exhibit a larger mean length than walleyes from the same age group collected by trawls (Tables 5 and 18), especially for juveniles. This can be explained by the faster growing individuals becoming more vulnerable to the size-selective gill net. This gear bias is reduced or eliminated among older age groups.

Since 1989, walleye diet has always been dominated by clupeids, either gizzard shad or alewives depending on which were most prevalent in the bay in a given year (Tables 14 and 19). Walleye diet in 2004 was the first real departure from this pattern. Yellow perch have often contributed, but never figured prominently in walleye diet until 2003. Condition of walleyes, as indicated by relative weight, declined to the lowest level of the survey series for the smallest size category (stock-quality) and for the combined size group value (Table 20). These condition factors are not considered poor, but appear to be indicative of increased competition and slower growth since the increase in walleye age-0 density and the diet shift away from clupeids. Similarly, the Proportional Stock Density also reflects the influence of increased juvenile walleye density on the overall size structure of the walleye population by 2004 (Table 21).

Walleye stocking in Saginaw Bay has continued under the walleye recovery plan (Fielder and Baker 2004). The strategy has been to use stocking to increase predation rates on alewives so as to groom the Saginaw Bay environment to better favor percid production (Fielder 2004). A decision point for the possible discontinuation of walleye stocking was proposed by Fielder and Baker (2004). They proposed that stocking be discontinued once three out of five year classes are dominated by wild walleyes (as determined by OTC analysis). Table 34 indicates 2003 and 2004 cohorts were predominantly wild. One more predominantly wild year class by 2007 will trigger the decision.

Exploitation, based on tag returns, has been relatively low and stable since 1992, ranging from 4.3% to 12.8% per year (Table 31). Similarly, the open water sport fishery has been stable during this time period, and total annual mortality has been relatively low (Table 31). From this we can conclude that, between 1992 and 2004, sport fishery exploitation was not an important factor limiting walleye recovery. Sustainability of increased exploitation or mortality, however, cannot readily be determined from these data alone. It is also unclear what other mortality sources aside from the sport fishery are contributing. Other sources could include losses due to natural mortality and commercial by-catch. There is no commercial fishery in the bay for walleyes, but walleyes are often trapped in nets set for yellow perch and lake whitefish. It is possible for some walleyes to die from handling or from gilling in leads.

Movement of walleyes, as indicated by tag returns, indicates that the majority of walleyes spawning in the Tittabawassee River (where tagging occurs) remain principally in Saginaw Bay, although there is some movement up and down the Michigan coast line (Figure 10). Distribution of walleyes does not appear to be a function of sex (Figure 11) but may be influenced by season (Figure 12). In winter, walleyes appear to inhabit the innermost portion of Saginaw Bay, however, because tag returns are a function of both walleye movement and angler density, these spatial plots are influenced by angler location and are not unbiased indicators of walleye distribution. It is possible, and even likely, that walleyes also inhabit portions of the outer bay in winter as well. Tag return distribution does not appear different between pre-and post-zebra mussel eras (Figure 13).

Yellow Perch

The yellow perch population in Saginaw Bay was characterized by high abundance, slow growth, and poor condition in the 1980s (Salz 1989; Haas and Schaeffer 1992). Fielder et al. (2000) reported that yellow perch abundance declined drastically after 1989 and was characterized by lower abundance and improved growth and condition through the late 1990s. At the same time, redworm infection rates declined, and perch over 200 mm long became more common in trawl catches. Our most recent findings indicate that yellow perch abundance remained relatively low through 2004. Growth rates varied, but generally improved to exceed the statewide average. Redworm infection rate spiked in 2000, but then steadily declined in 2004. The decline could be a result of changes in yellow perch consumption of intermediate host organisms. Oligochaete worms are the primary intermediate host for *Eustrongylides* (Rosinski et al. 1997), which has a multiyear life cycle, and cyclopoid copepods are an intermediate host for *Philometra* (Molnar and Fernando 1975), which has a 1-year life cycle. Yellow perch diet analysis indicated yellow perch consumption of zooplankton declined after 1997. Additionally, lower yellow perch abundance as an intermediate host for both redworm species could also be a factor in the reduced occurrence of the parasites in Saginaw Bay.

Why has yellow perch abundance remained low since 1990? Generally, age-0 production has been lower, with some extremely poor cohorts, such as the 1992, 1993, 1994, 1999, and 2000. Additionally, the few recent cohorts that appeared strong as age 0 (such as 2001 and 2003) failed to carry through as strong cohorts at later ages. Apparently, Saginaw Bay yellow perch have experienced lower survival from age 0 to age 1 since zebra mussel colonization, especially after 1998. This coincides with a disturbing trend of declining mean length for age-0 yellow perch since 1999, with record low mean lengths in 2003 and 2004. Smaller yellow perch have been observed to experience lower overwinter survival due to increased predation and lower energy reserves (Post and Prankevicius 1987; Post and Evans 1989). In the case of the 2003 and 2004 cohorts, we believe survival was reduced by the unusually small size of the fish. Weather, density-dependent factors (such as strong year-classes), and food web shifts can all affect growth of age-0 yellow perch in a given year.

The estimate of mean annual survival for yellow perch since zebra mussel colonization of Saginaw Bay (0.47, Figure 6) was within the range of those reported from other areas of the Great Lakes. Yellow perch in the Les Cheneaux Islands (northern Lake Huron) experienced a survival rate ranging from a high of 0.55 in 1995 (Schneeberger and Scott 1997) to a low of 0.22 in 2002 (Fielder 2003). Schneeberger (2000) estimated mean annual survival for Little Bay De Noc yellow perch at 0.42 in 1996. Thomas and Haas (2005) reported annual survival for yellow perch in the western basin of Lake Erie at 0.57 based on catch-age model estimates. Our survival estimates, based on catch curve analyses, suggest that survival of yellow perch from ages 1 through 6 has been lower during the post-zebra mussel period, especially for ages 1 through 3. However, we are not convinced that this is a direct function of zebra mussel presence. Sex ratio data indicated female yellow perch experienced higher mortality rates than males for ages 2 through 5. Female Saginaw Bay yellow perch also exhibit faster growth than males (for a given age). Such a pattern of increased mortality on faster growing fish is well known in exploited fish populations (Ricker 1969; Parma and Deriso 1990; Machiels and Wijsman 1996; Sinclair et al. 2002). It is possible that fishing (both sport and commercial) could be a factor in the skewed male to female sex ratio and lower survival rate for Saginaw Bay yellow perch in recent years.

The open water sport fishery for yellow perch in Saginaw Bay has changed dramatically since 1997 when anglers harvested over 1.1 million yellow perch (Table 32). The harvest has been less than 600,000 fish since 2000. The age composition has shifted as well. From 1992 to 1996, age-5 and older fish accounted for 39% to 59% of the annual harvest. More recently, younger fish have become the focus of the harvest, with age-5 and older fish accounting for only 6% to 26% of the annual harvest. This may be partially explained by improved growth enabling anglers to harvest younger fish of acceptable size. Also, older fish were less abundant after 1997 due to weak cohorts in 1992–1994, and thus were less available to anglers.

The commercial yellow perch harvest has also declined in recent years (Table 33). Much of the decline is related to decreased effort, which was lower in 2003 and 2004 than any year since 1971.

Catch-per-unit-of-effort, expressed as kilograms per net lift, suggested that catch rates have been fairly stable since 1999. Unfortunately, the commercial trap-net CPUE is not standardized by 24-hour sets or even net-nights, so the temporal duration of a “net lift” is unquantified. When catches are light, commercial nets are sometimes left untended for longer periods of time. Conversely, when catches are good, it can be worth the time to tend the nets more regularly. Thus without some kind of standardization, commercial trap net CPUE may actually mask trends in fish abundance.

Comparison between the yields of the open water sport harvest (Table 32) and commercial harvest (Table 33) provided an indication of their relative contribution to exploitation of the Saginaw Bay yellow perch population. Prior to 1995, the commercial harvest represented between 12% and 25% of the total open-water annual yield. From 1995 through 2004, the proportion taken commercially increased to 28%–64%. Since 2000, commercial harvest has accounted for more than half of the total open water yellow perch yield from the bay. It is important to note that historically yellow perch have been a popular target of the recreational winter ice fishery and estimates of its yield are needed for a thorough analysis. Unfortunately, winter estimates of recreational harvest are lacking in some years. However, in general, winter sport harvest averages about 55% of the previous summer’s sport harvest (MDNR, unpublished data). When winter harvests were estimated and included in the total yield, the commercial yield accounted for 26% to 56% of the total annual yield from 2000 to 2004. Wilberg et al. (2005) found that catch-at-age modeling of the yellow perch fishery in southwestern Lake Michigan indicated that combined sport and commercial fishing mortality was a substantial contributing factor in a rapid decline of mature females during the mid-1990s. While catch-at-age estimates are available for the sport fishery on Saginaw Bay since the mid-1980s, the estimates are incomplete, especially for the ice fishery. Even more problematic is a lack of biological data from the commercial fishery harvest. Science-based management of the yellow perch fishery in Saginaw Bay would be facilitated by thorough monitoring of the harvest, effort, and biological characteristics for both the sport and commercial fisheries.

Channel Catfish

Abundance of channel catfish has been relatively stable over the survey reporting period (Tables 15 and 16). Channel catfish are a fairly abundant species in the Saginaw Bay fish community and may play an important ecological role as predators. Fielder and Baker (2004) called for increasing predation in an attempt to restore balance to the bay’s fish community which has been characterized by an underutilized prey base.

Not unlike walleyes and yellow perch, the 1998 year class of channel catfish was substantial and affected the age structure in subsequent years (Table 24). Channel catfish are relatively long lived in Saginaw Bay, sometimes reaching age 15. Their total annual mortality rate, however, is relatively high, averaging 68% since 1998 (Table 23). This is a substantial increase over the rates reported by Haak (1987) for 1985 (36%) and by Eshenroder and Haas (1974) for the early 1970s (49%).

Channel catfish are harvested by both recreational and commercial fisheries. Yield from the commercial fishery has been declining from a high of 280,329 kg in 1991 to 104,266 kg in 2004. The sport fishery has been steadily increasing since 1999 from a low of 3,620 fish to a high of 15,945 fish in 2004. When expressed as yield (by applying average weights from the gill net survey to numbers harvested), we see that the sport fishery has increased as a proportion of the total extractions (commercial and sport) from 3.4% (1999) to 12.2% in 2004. While the decline in commercial harvest may stem from market trends, collectively channel catfish harvest has been declining. Generally, an increasing total annual mortality rate in the presence of declining harvest suggests that either natural mortality is increasing or channel catfish recruitment has declined greatly, or possibly both. However, the survey gill net CPUE shows no declining trend to support the idea of lower recruitment (Table 16). It is also likely that total annual mortality rate estimates in Table 23 are influenced by variable recruitment. Cohort-based analysis of total annual mortality was not possible due to small sample sizes. Channel catfish may also be vulnerable to by-kill in commercial nets targeting other species.

Haak (1987) reported a decline in channel catfish growth in 1985 compared to earlier analyses. Channel catfish have exhibited slow growth throughout the gill net survey time series (Table 25) but there is no apparent trend since 1998. Direct comparisons with Haak (1987) are not possible because his results were expressed as mean length-at-annulus from back calculations while ours (Table 25) were expressed as mean length-at-capture age in the fall. Future analysis should compare growth at annulus data.

Other Native Species

Other important native species in Saginaw Bay include northern pike and smallmouth bass. Northern pike are encountered in the survey each year (Table 16) but are low in abundance compared to species like walleyes and yellow perch. The northern pike commercial fishery between 1919 and 1960 sustained an average yield of 8,981 kg (Baldwin and Saalfeld 1962). Applying mean weight data from our survey of 1.37 kg/fish, this sustained yield may have amounted to 6,555 northern pike. By contrast, 1,687 northern pike were harvested by the sport fishery in 2003 (MDNR, unpublished data). Northern pike production may be limited by suitable coastal wetland habitat for spawning or by access to remaining habitat. Like walleyes, it’s unclear to what extent pike abundance may be reduced because of by-kill in commercial trap nets, particularly by the gilling of juveniles in net leads.

Smallmouth bass are often underrepresented in surveys due to their lower vulnerability to trawling and gill netting. Insufficient numbers are collected to fully analyze age or size structure of the local population. Smallmouth bass, however, are not uncommon in the fishery; 2,137 of them were harvested in 2003 (MDNR, unpublished data). Due to the popularity of catch-and-release fishing among bass anglers, harvest estimates may under represent their place in the overall fish community and their importance to the sport fishery.

Notably lacking from our survey catches were lake herring, Great Lakes muskellunge, and lake sturgeon. Lake herring were historically abundant in Saginaw Bay, especially seasonally during their fall spawning congregation. The lake herring population sustained an average commercial fishery yield of 1,176,936 kg/year from 1903 to 1955 (Baldwin and Saalfeld 1962). No lake herring have been documented in the bay since 1975, and their main basin population is also in decline. Reasons for the decline of lake herring in the bay since the 1950s are not fully known but are thought to be a function of competition from alewives and rainbow smelt (Mason and Brandt 1996). These non-native planktivores have largely supplanted lake herring by fully occupying the pelagic planktivore niche (Eshenroder and Burnham-Curtis 1999). Lake herring persist in some northern reaches of Lake Huron, most likely because that area hosts lower numbers of alewives in most years. It is unclear if lake herring can mount a resurgence in Saginaw Bay now that adult alewives are scarce. Their recovery may be prevented by a lack of brood stock.

Great Lakes muskellunge are absent from the historic commercial fisheries records of Saginaw Bay (Baldwin and Saalfeld 1962). However they may have been recorded as northern pike in the early record keeping. Great Lakes muskellunge have not been documented in Saginaw Bay in modern times, but there is a large population in Lake St. Clair. In our opinion, the abundant and underutilized white sucker population in Saginaw Bay (Table 16) could support expanded populations of esocids, which in turn would further diversify the sport fishing opportunities available in the bay.

Lake sturgeon were historically abundant throughout Lake Huron and Saginaw Bay (Baldwin and Saalfeld 1962) and are still occasionally encountered by sport and commercial fishers (Hay-Chmielewski and Whelan 1997). A statewide rehabilitation strategy has been in place since 1997, but so far, given their absence from the collections in this time series, it appears that they still occur in very low abundance in Saginaw Bay. We expect lake sturgeon abundance will not increase in

Saginaw Bay until suitable fish passage or dam removal are implemented in the Saginaw River drainage, their historic spawning ground for the bay (Hay-Chmielewski and Whelan 1997).

Prey Fish Base

From 1998 to 2004, Saginaw Bay continued to support a diverse and abundant assortment of native and exotic fish species that served as potential prey for piscine and avian predators. Although young-of-year alewives declined greatly in 2004, native benthic species such as spottail shiners and trout-perch remained abundant. Gizzard shad and emerald shiners, while much less abundant in the trawl catches, are likely underrepresented by bottom trawls and probably make up a significant fraction of the available pelagic prey base. Spiny-rayed forage was also well represented by age-0 white perch and age-0 yellow perch in most years. The most recent addition to the Saginaw Bay prey base was the invasive round goby, first captured in survey trawls in 1999. The Saginaw Bay prey base has been underutilized since the 1970s (Keller et al. 1987; Haas and Schaeffer 1992) and walleye restoration has been a tool to improve the predator-prey balance of the fish community (Fielder 2004; Fielder and Baker 2004). Our survey results suggest that the prey fish component of the Saginaw Bay fish community remains abundant and diverse. However, if alewife adult abundance remains suppressed and adult walleye abundance increases as a result of increased natural recruitment, the predator-prey balance may be improved.

Round Goby

Survey trawl samples documented the spread of round gobies throughout Saginaw Bay over a period of only 2 years. Studies in other areas of the Great Lakes (Thomas 1993; French and Jude 2001; Corkum et al. 2004) have found that small round gobies (less than 70 mm) consume a wide variety of benthic invertebrates and thus could compete with other small benthic fishes for food resources. However, because adult round gobies feed on zebra mussels, they represent a new linkage in the Saginaw Bay food web between zebra mussels and the fish community. Our Saginaw Bay data indicate that walleyes, freshwater drum, channel catfish, and yellow perch have all incorporated round gobies into their diets. The benefits of this addition to the diets may be offset by potential competition with round gobies for benthic invertebrate food resources such as midge or mayfly larvae. Trawl catch rates also suggest that native johnny darters have declined to near extirpation in Saginaw Bay, after a period of increased abundance following zebra mussel colonization (Fielder et al. 2000).

Other Exotic Species

Alewife.–Since the 1970s, trawl catches have confirmed that Saginaw Bay served as a spawning and nursery area for Lake Huron alewives. While adult alewives have been rare in the fall survey, age-0 alewives have been common and sometimes extremely abundant. Age-0 alewives are efficient planktivores. Haas and Schaeffer (1992) reported that the zooplankton population in Saginaw Bay was characterized by low densities of very small planktonic crustaceans during the 1980s. They noted that the species composition and size ranges were indicative of heavy predation pressure from abundant foraging fishes such as alewife, rainbow smelt, and emerald shiners. Surveys in the main basin of Lake Huron documented dramatic declines in abundance of adult alewives in 2003 and 2004 (Schaeffer et al. 2005). Subsequently, our 2004 trawl survey recorded the lowest age-0 alewife CPUE since the early 1970s. Although age-0 alewives were abundant in 2003 in the bay, adults were scarce that year.

Alewife competition with native species has been suspected as a factor limiting the recruitment of several native fish species, including walleye and yellow perch (O'Gorman and Stewart 1999). Direct predation by adult alewives on eggs or fry, reduced growth and survival of fry due to competition for planktonic food resources, and high early life stage mortalities due to thiamine deficiencies (for salmonids) have been identified as alewife-associated mechanisms reducing recruitment for a variety of native fish species. We submit that the strong year classes of percids, as well as improved trawl catch rates for age-0 white bass in survey trawls in 2003 and 2004, provide compelling circumstantial evidence that alewives have suppressed the abundances of these native species in Saginaw Bay for many years through larval predation and competition.

Rainbow smelt.–As with alewives, Saginaw Bay rainbow smelt catches in survey bottom trawls contain mostly age-0 fish. In years of slow growth, many small age-0 rainbow smelt pass through the trawl mesh, causing cohort strength to be underestimated. If alewife abundance remains low, we suspect that rainbow smelt abundance could increase. Lake Huron surveys by other agencies (Schaeffer et al. 2005) indicate that adult rainbow smelt abundance experienced a modest rebound in 2003 and 2004 in the main basin of Lake Huron.

White perch.–Fielder et al. (2000) reported that of the white perch sampled in Saginaw Bay from 1989 through 1997, age 0 predominated in trawling and age 1 predominated in gill netting. Few white perch survived beyond age 1. The same was true for the more recent survey period (1998 through 2004). Apparently, mortality is extremely high for white perch. We suspect this is a result of severe winter conditions in the bay. White perch experience high mortality during long winters with especially cold temperatures (Hurley 1992). Johnson and Evans (1990) demonstrated that this winter mortality is also size dependent, with smaller age-0 white perch succumbing first. In Lake Erie, white perch and yellow perch diets overlapped and competitive interactions occurred (Parrish and Margraf 1990; Parrish and Margraf 1994). Chironomid larvae and zooplankton were important components of diet for white perch in Lake Erie and Lake Ontario (Hurley 1992). Although diet data for white perch from Saginaw Bay are lacking, we suspect that age-0 white perch and yellow perch in Saginaw Bay compete for zooplankton and benthic invertebrate food resources. Competitive effects of the extremely high white perch abundance in 1989 (Fielder et al. 2000), coupled with poor yellow perch condition, probably triggered the catastrophic decline of the yellow perch population in the bay during the winter of 1990.

Overview of Recent Saginaw Bay Ecological Change

Since the mid-1980s, Saginaw Bay has undergone a further series of exotic species invasions: white perch, spiny waterfleas, zebra mussels, quagga mussels, and round gobies. The recent population collapse of the exotic alewife might be viewed as a reverse invasion. Because of ongoing and overlapping impacts of each of these changes, the effect of any one is difficult to resolve. The following is our current interpretation of the sequence of changes and underlying mechanisms.

In the mid-1980s, Saginaw Bay was dominated by an overabundant yellow perch population that was characterized by strong recruitment, poor condition and growth, and high natural mortality, especially after age 3. These fish competed with abundant populations of spottail shiners, trout-perch, emerald shiners, alewives, and gizzard shad for limited benthic and planktonic food resources. White perch numbers exploded in the late 1980s and further stressed the yellow perch population through interspecific competition, resulting in substantial declines in yellow perch abundance between 1989 and 1991. Zebra mussels colonized the bay in the early 1990s, resulting in some improvement of benthic food resources, but reducing planktonic food resources. Yellow perch recruitment declined, possibly due to increased alewife predatory efficiency due to clearer waters, or perhaps due to reduced zooplankton availability for larval yellow perch. As a result, yellow perch adult abundance remained low and growth improved. Round gobies invaded the bay in 1999 and became widespread and abundant by 2001. This increased competition for benthic food resources and may have resulted in slower growth for age-0 yellow perch. However, the diet of age-1 and older yellow perch benefited from the addition of round gobies. The Lake Huron adult alewife population crashed in 2003, so predatory pressure on larval percids and other species (white bass) was released and strong age-0 production was seen in 2003 and 2004. However, mean lengths for those cohorts was low and overwinter survival appeared to have been poor.

Recovery plans have sought to restore balance to the fish community by restoration of walleyes, the bay's native key-stone predator (Fielder and Baker 2004). Objectives are not just to improve walleye fishing but to increase predation on prey resources, benefiting yellow perch growth and recruitment. Increased predation is also hoped to make the bay's fish community more resilient to the effects of and invasion by new exotic species. Alewife declines appear to have facilitated this desired shift and this survey series has documented the early effects of walleye resurgence. Additional years of data will be necessary before it can be determined if recovery objectives are achieved. The future will likely hinge on whether alewives remain scarce. Abundance of alewives in Saginaw Bay will likely depend on trends in the main basin of Lake Huron. It is unclear if a fully-recovered walleye population in Saginaw Bay could, through increased predation, keep alewives from becoming pervasive again in the bay, even upon recovery in the main basin. Consequently, there is a high degree of uncertainty over the future of the fish community in Saginaw Bay, although there is reason to be optimistic.

Recommendations

- Continue to monitor the walleye and yellow perch populations closely during this period of increased age-0 production and follow the decision criteria laid out in the Saginaw Bay walleye recovery plan (Fielder and Baker 2004). Renew and continue the trawling, gill netting, walleye tagging and harvest studies in Saginaw Bay.
- Take management actions to reduce, evaluate, and regulate the harvest of yellow perch. We believe the yellow perch fisheries are significantly depressed. Declining recruitment and failure of the perch population to realize any improvements as a result of the enormous age-0 production in 2003 suggest adult abundance will remain low.
    - Implement more conservative harvest measures as a means to preserve the yellow perch population until improved recruitment and survival can be realized.
        - Reduce the sport harvest limit to no more than 35 yellow perch as a conservation measure, as was done in southern Lake Michigan under similar circumstances.
        - Consider the closure of the yellow perch commercial fishery, by willing buyout, so as to reallocate perch harvest to the sport fishery.
    - Collect biological data on the commercial catch of yellow perch annually, as long as the commercial fishery continues, to better characterize that fishery and enable modeling.
    - Estimate total sustainable extractions via a statistical-catch-at-age model for yellow perch in Saginaw Bay and use such estimates to better define mortality sources.
- Establish and enhance other predator populations in the bay to more fully utilize the prey base.
    - Seek to protect and enhance northern pike spawning habitat (coastal wetlands).
    - Consider northern pike stocking to enhance that population so as to better utilize overabundant large prey items such as white suckers.
    - Consider beginning a Great Lakes muskellunge introduction program so as to establish a reproducing local population and to diversity the local fishery. Like northern pike, Great Lakes muskellunge could help to better utilize overabundant large prey items like white suckers.

- Pursue lake herring recovery in Saginaw Bay. Adopt the Lake Huron Lake Herring Recovery Plan developed by the Lake Huron Technical Committee.
- Conduct research to quantify by-catch and by-kill of walleye, northern pike, and channel catfish in commercial trap nets in Saginaw Bay, including gilling loses in the net leads.
- Conduct research to explore what factors are limiting survival of juvenile walleyes and yellow perch in years of high production.

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Figure 1.–Saginaw Bay gill net sites, trawling quadrants, and tagging site.

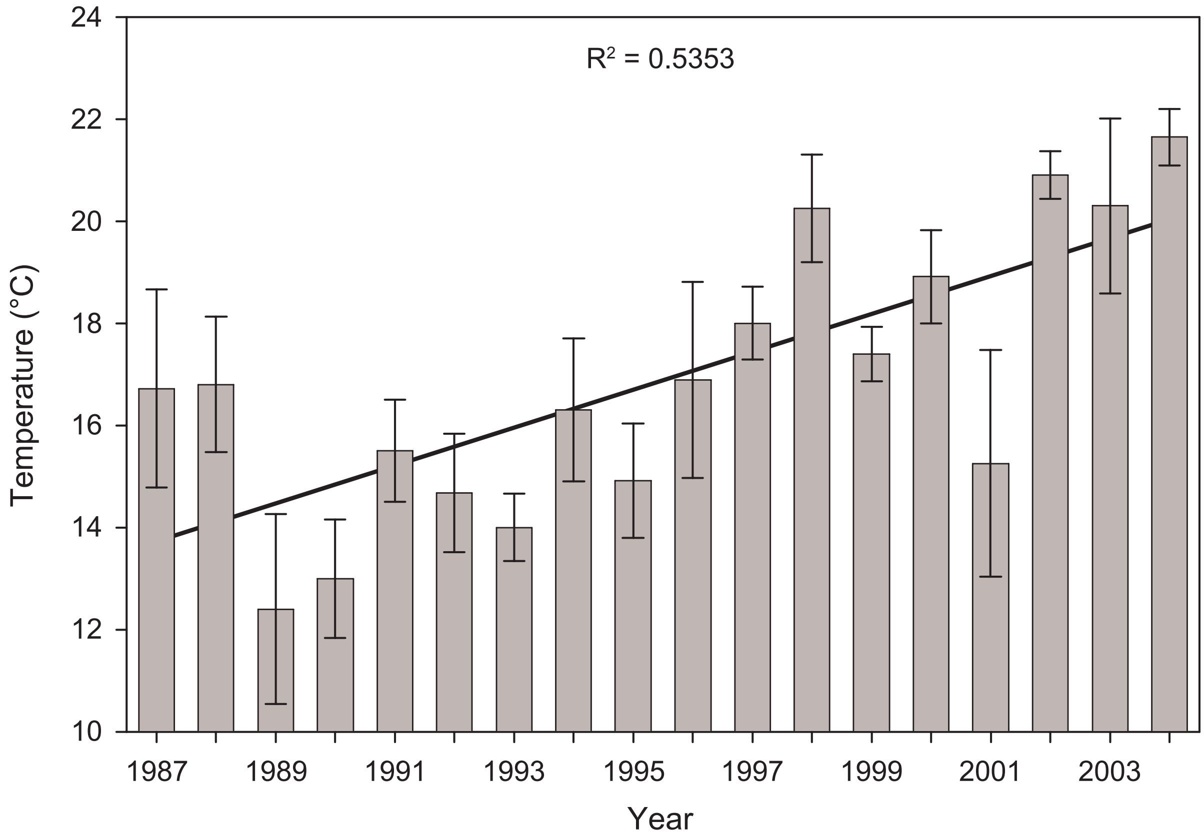

Figure 2.–Mean (±2 SE) water temperatures recorded during fall trawling on Saginaw Bay, 1987–2004.

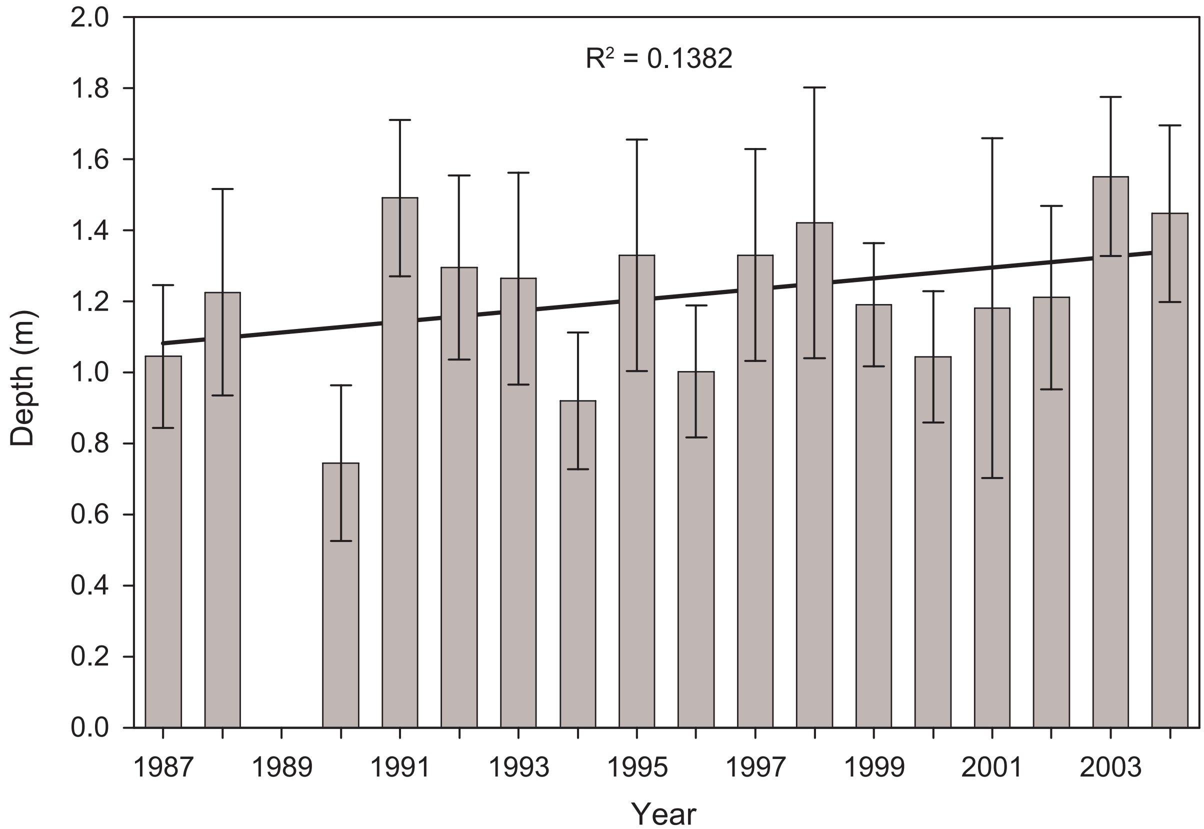

Figure 3.–Mean (±2 SE) Secchi disk transparency recorded during fall trawling on Saginaw Bay, 1987–2004.

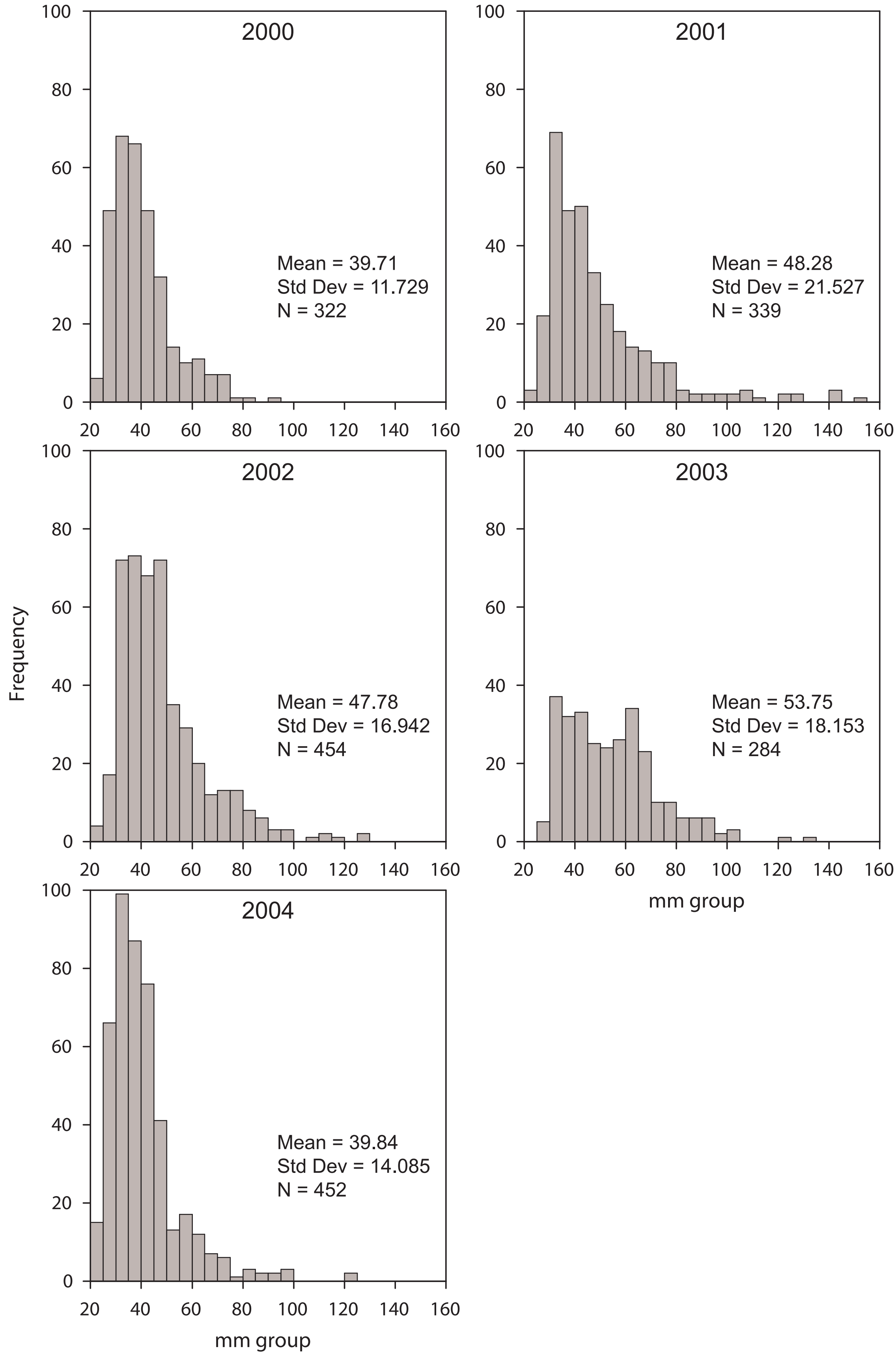

Figure 4.–Length frequency distribution of round gobies taken in trawls at index sites, 2000–04.

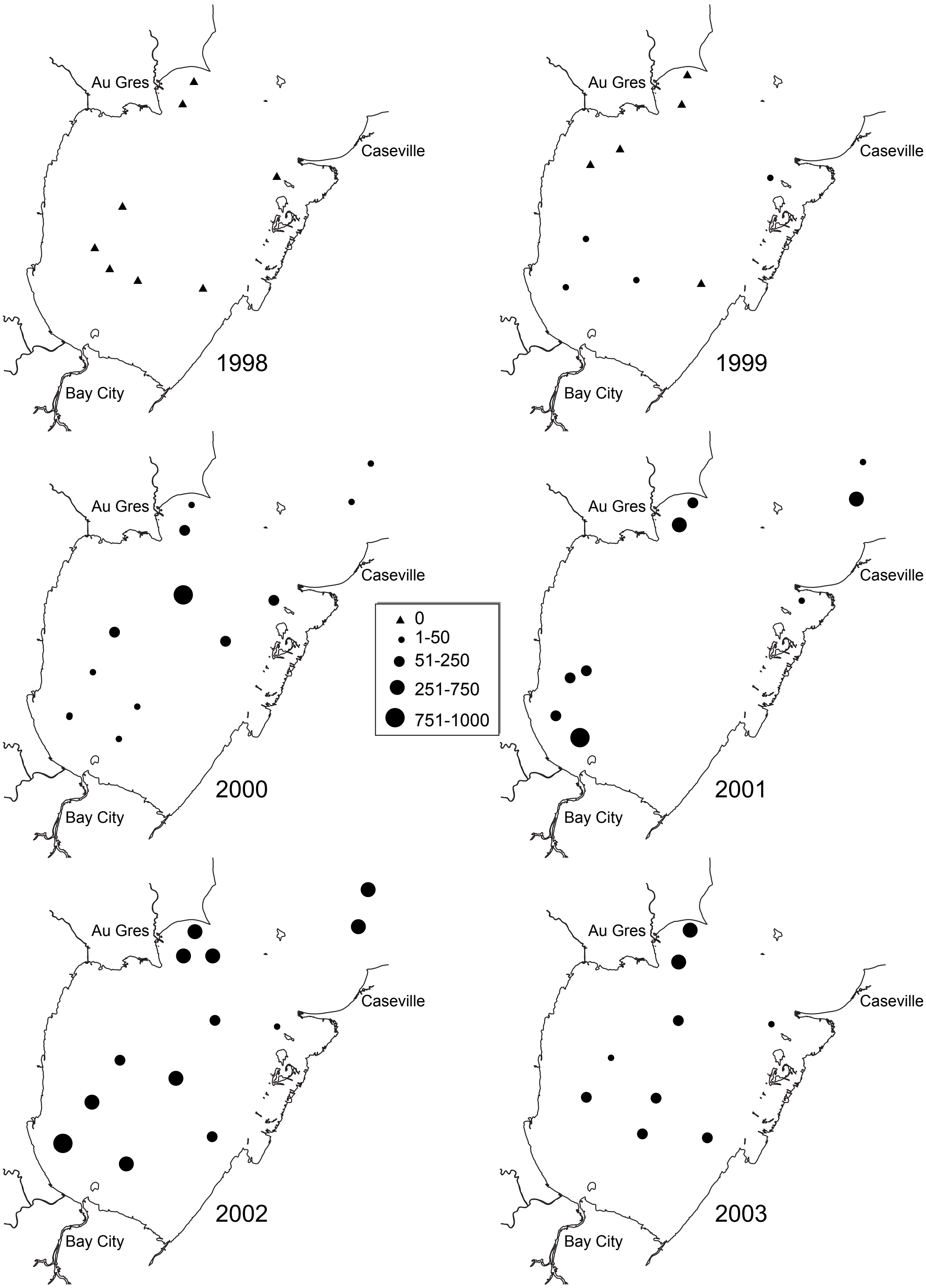

Figure 5.–Mean round goby CPUE for Saginaw Bay grids surveyed with bottom trawls, 1998–2003. Triangles represent grids with zero goby catches. Small circles represent grids with low round goby CPUE, while larger circles represent higher round goby CPUE.

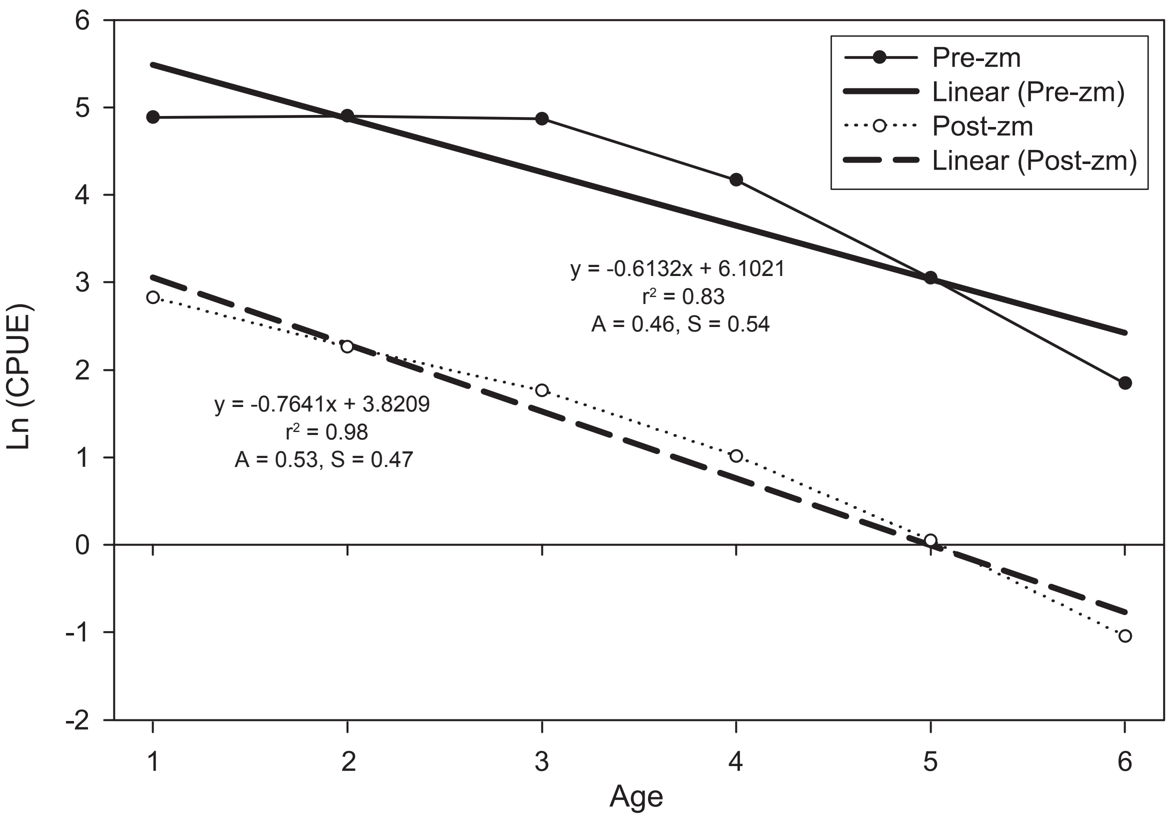

Figure 6.–Catch curves for yellow perch, ages 1 to 6, from Saginaw Bay fall trawling for pre-zebra mussel (1986–90) and post-zebra mussel (1993–2004) periods (zm = zebra mussel).

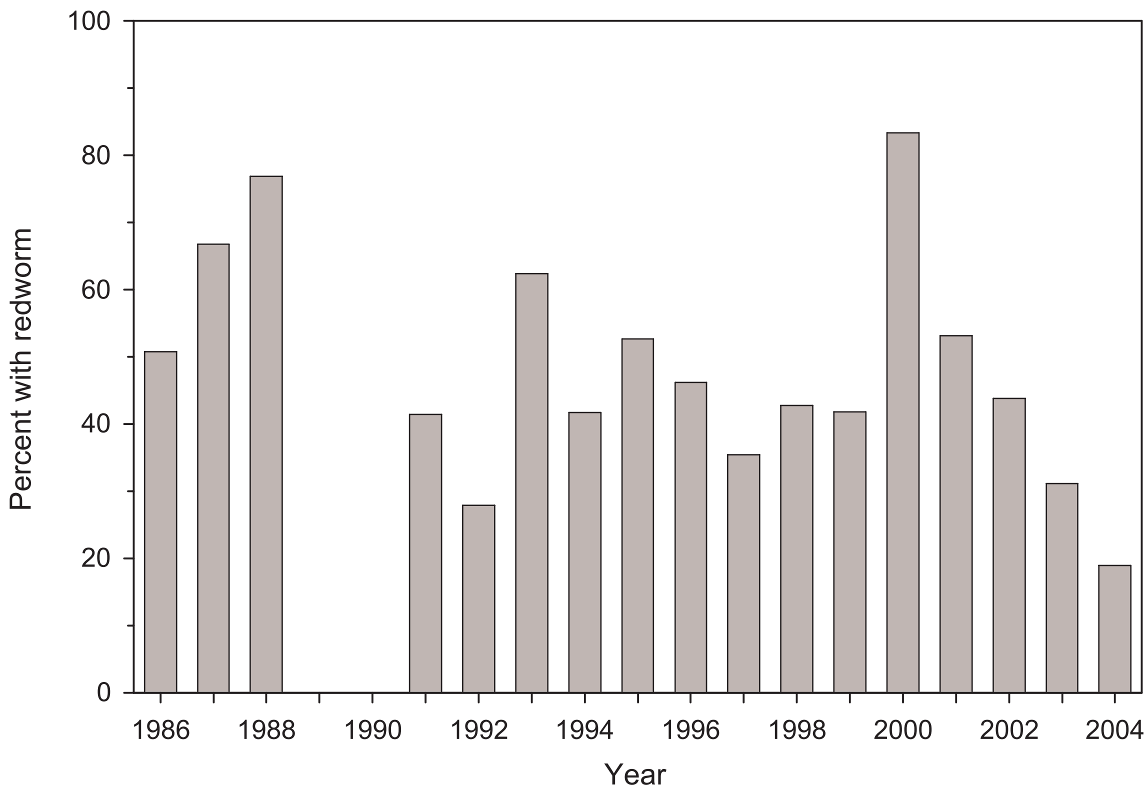

Figure 7.–Frequency of redworm in yellow perch from Saginaw Bay fall trawling, 1986–2004. No data is available for 1989 and 1990.

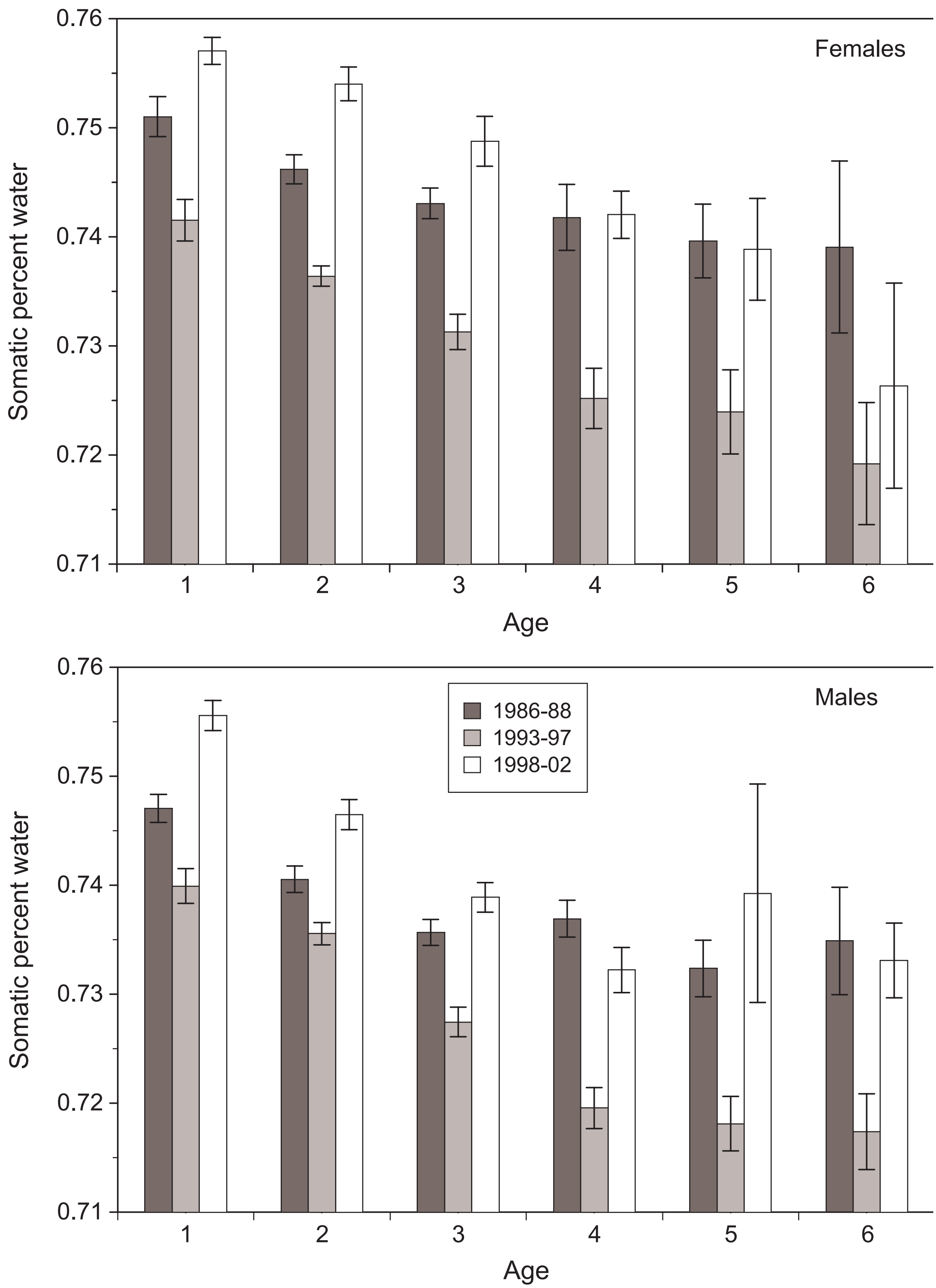

Figure 8.–Percent somatic water (by weight) in yellow perch collected in fall trawl tows in Saginaw Bay for three time periods.

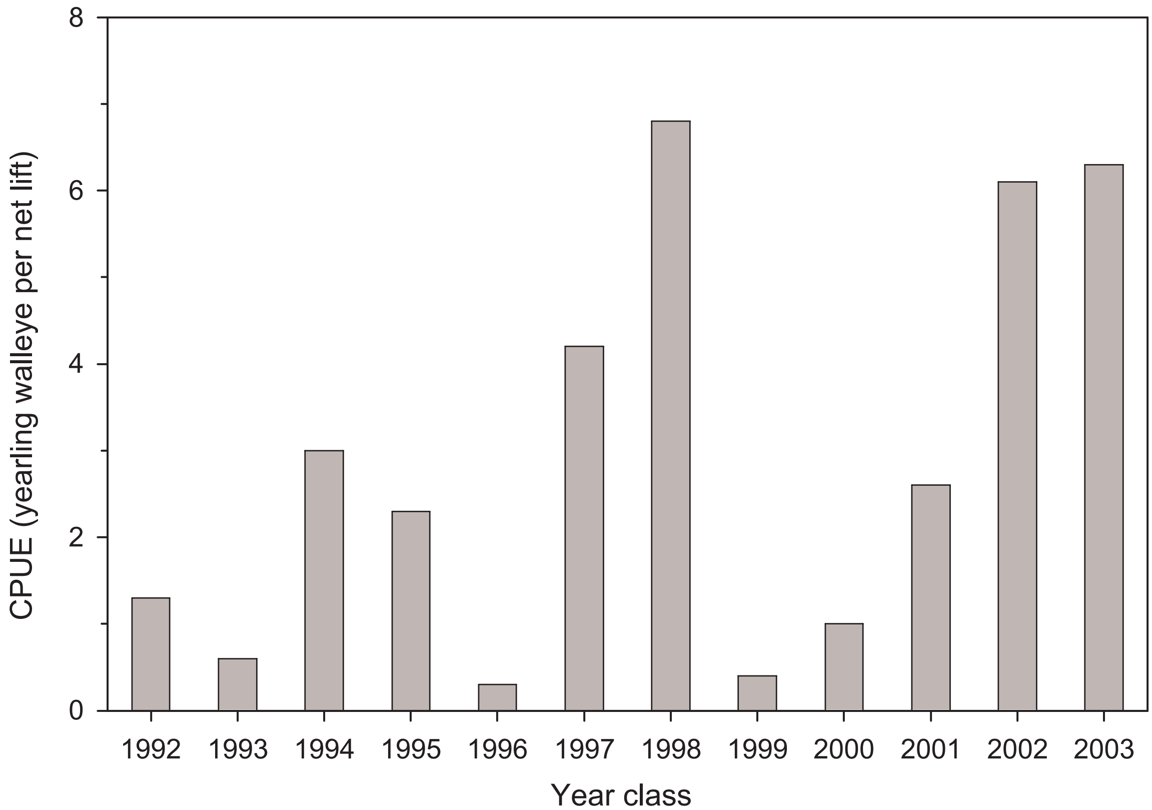

Figure 9.–Saginaw Bay walleye year class strength for 1992–2003 as measured by gill net CPUE of yearlings. Data for year classes 1992–96 from Fielder et al. (2000).

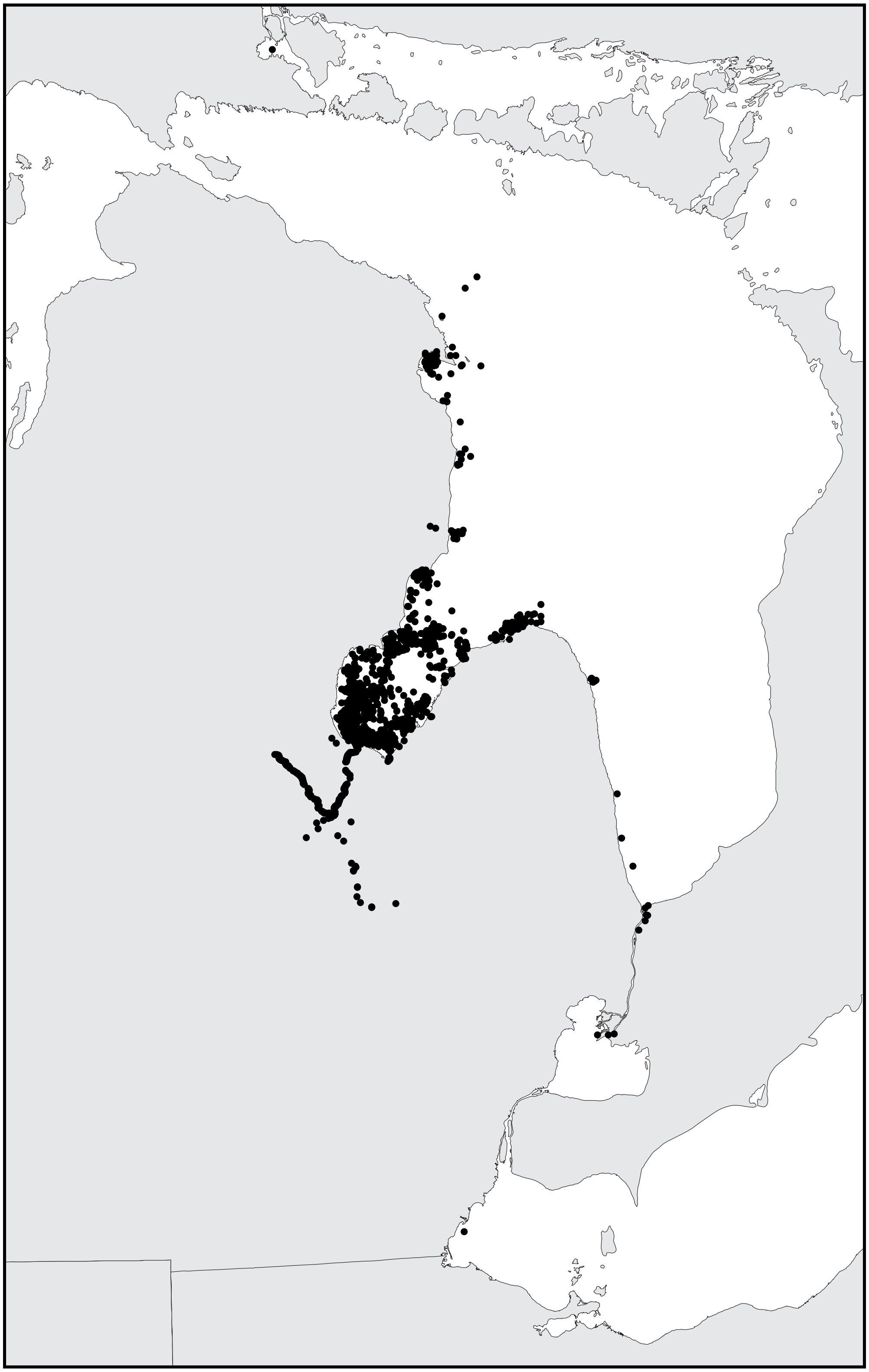

Figure 10.–Angler-reported tag returns in 1998–2004 for walleyes originally tagged at the Tittabawassee River, Dow Dam site. Each dot represents one walleye

Figure 11.–Angler-reported tag returns by sex, 1998–2004, for walleyes originally tagged at the Tittabawassee River site. Each dot represents one walleye.

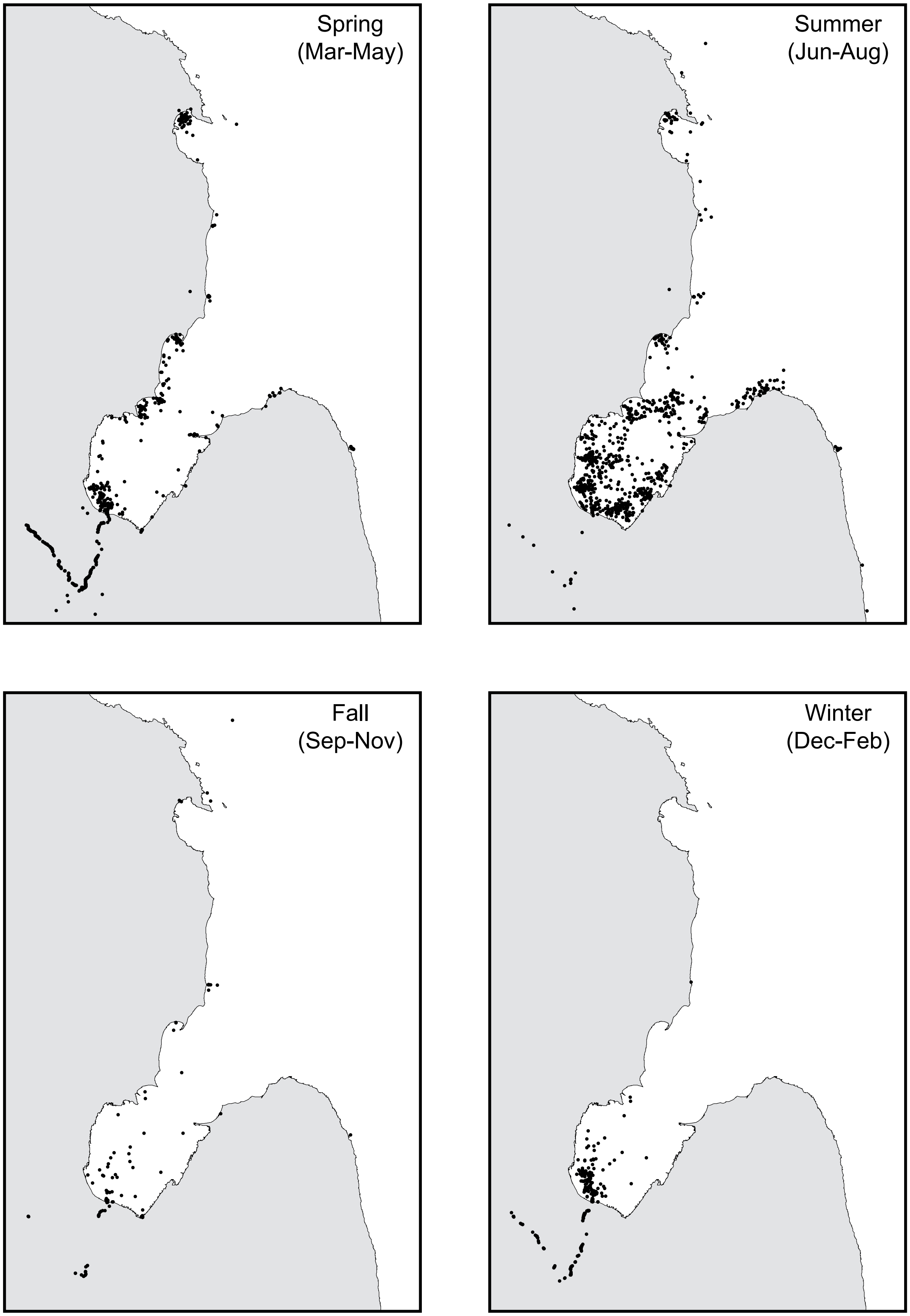

Figure 12.–Angler-reported tag returns in 1998–2004 for walleyes originally tagged at the Tittabawassee River, Dow Dam site. Each dot represents one walleye.

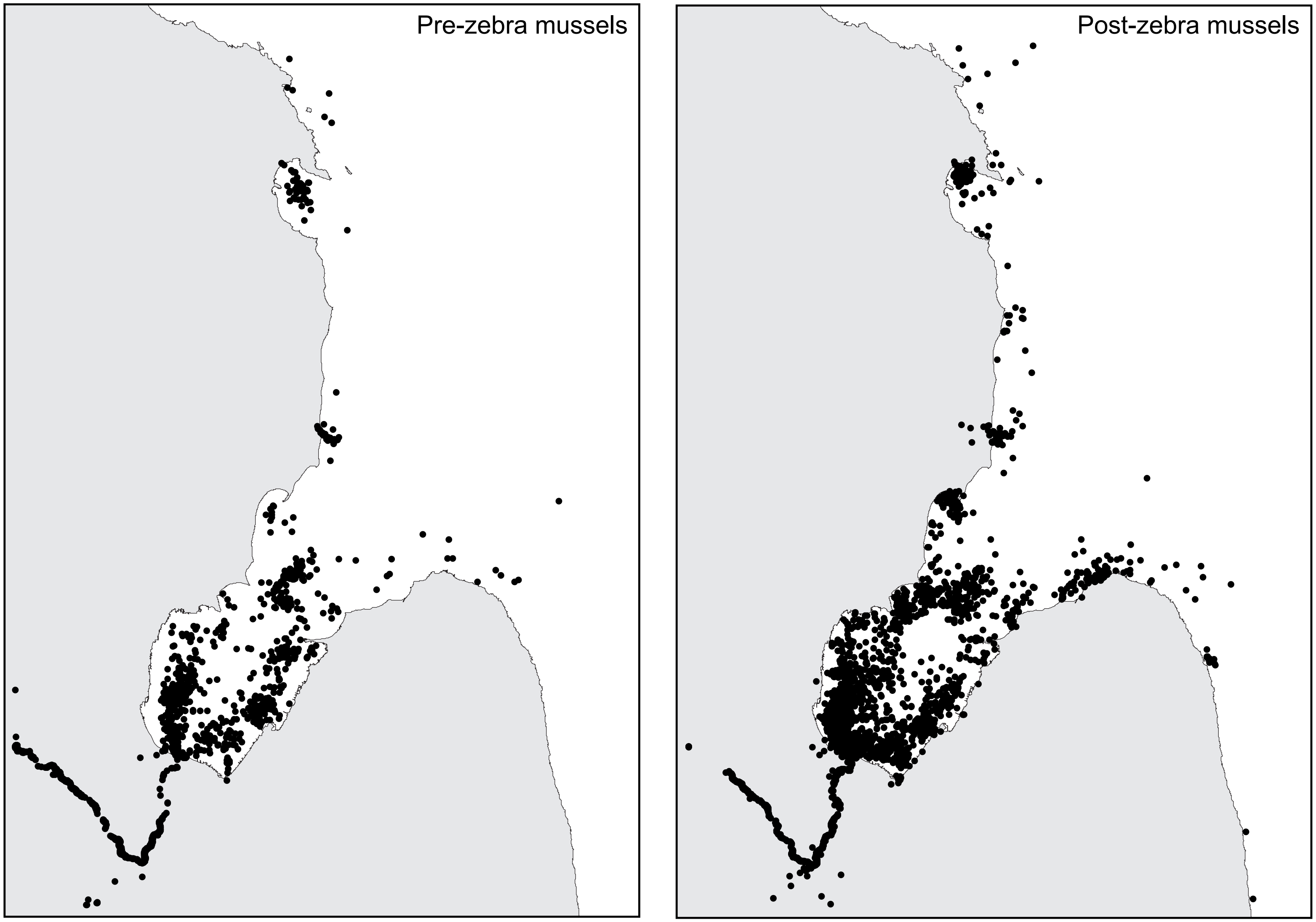

Figure 13.–Angler-reported tag returns, pre-zebra mussel (1981–90) and post-zebra mussel (1993–2004) colonization, for walleyes originally tagged at the Tittabawassee River site. Each dot represents one walleye.

Table 1.–Location of trawl stations and number of tows made in Saginaw Bay, 1998–2004.

Quadrant	Site description	1998	1999	2000	2001	2002	2003	2004
East	North Island and Wildfowl Bay	6	3	7	3	10	4	9
South	Coreyon Reef	6	6	6	3	7	9	10
West	Pinconning	9	9	9	9	10	7	9
North	Au Gres	6	10	9	10	10	10	9
Total		27	28	31	25	37	30	37

Table 2.–Number of fall gill-net sets (by location and area) for Saginaw Bay, Lake Huron, 1998–2004.

Station	Bay area	1998	1999	2000	2001	2002	2003	2004
Pt. Lookout/Au Gres River	Inner/Outer	2	2	2	2	2	2	2
Pt. Au Gres	Inner	2	2	2	2	2	2	2
Black Hole	Inner	2	2	2	2	2	2	2
Coreyon Reef	Inner	2	2	2	2	2	2	2
Fish Pt.	Inner	2	2	2	2	2	2	2
North Island	Inner	2	2	2	2	2	2	2
Oak Pt.	Outer	2	2	2	2	2	2	2
Charity Is.	Outer	2	2	2	2	2	2	2
Tawas	Outer	2	2	2	2	2	2	2
Total inner bay		11	11	11	11	11	11	11
Total outer bay		7	7	7	7	7	7	7
Survey total		18	18	18	18	18	18	18

Table 3.–Species composition (expressed as percentage of annual total catch by number) of Saginaw Bay fall trawl catches, 1998–2004.

	Survey year							
Species	1998	1999	2000	2001	2002	2003	2004	Avg
Alewife	40.8	3.0	9.8	29.9	13.0	11.5	0.4	15.5
Common carp	0.2	0.2	0.2	0.2	0.2	0.1	0.3	0.2
Channel catfish	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.1
Emerald shiner	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Freshwater drum	0.7	0.3	0.5	0.3	0.4	0.2	0.3	0.4
Gizzard shad	0.6	0.1	0.1	0.3	0.7	0.3	0.1	0.3
Johnny darter	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.1
Pumpkinseed	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Quillback	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.1
Rainbow smelt	1.3	1.2	11.7	9.5	5.6	7.1	10.0	6.6
Rock bass	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Round goby	0.0	0.1	3.7	8.3	13.1	2.5	17.1	6.4
Spottail shiner	14.1	70.4	27.5	18.8	36.1	21.5	10.0	28.3
Trout-perch	30.1	14.8	18.5	11.2	15.3	8.6	21.1	17.1
Walleye	0.2	0.3	0.0	0.1	0.1	0.7	1.3	0.4
White bass	0.0	0.0	0.0	0.0	0.0	0.2	1.9	0.3
White perch	7.7	5.1	26.5	16.3	11.5	7.9	13.4	12.7
White sucker	0.3	0.4	0.2	0.6	1.0	0.7	0.9	0.6
Yellow perch	3.8	3.3	1.1	4.2	2.5	38.8	23.0	10.9
All species	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total catch (no.)	95,698	46,762	100,158	77,275	91,222	152,619	75,314	91,292

Table 4.–Mean CPUE (number per 10-minute tow) of fish collected by fall trawling in Saginaw Bay, 1998–2004. Total number of tows is in parentheses.

Species	1998 (27)	1999 (27)	2000 (30)	2001 (27)	2002 (35)	2003 (27)	2004 (36)	Mean 1980s	Mean 1990s	Mean 2000–04
Alewife	1,590	82	337	1,242	348	831	10	228	307	554
Channel catfish	3	4	6	7	5	3	1	4	3	4
Common carp	7	6	6	9	6	4	7	3	5	6
Emerald shiner	1	1	1	1	1	1	2	47	8	1
Freshwater drum	26	9	16	10	11	9	7	7	17	11
Gizzard shad	23	3	3	9	19	20	2	36	20	11
Johnny darter	5	6	4	1	<1	0	0	2	12	1
Lake whitefish	0	<1	<1	0	1	<1	<1	<1	<1	<1
Pumpkinseed	0	2	0	0	<1	0	0	<1	<1	0
Quillback	0	4	1	4	2	3	1	2	1	2
Rainbow smelt	70	32	390	496	147	431	210	265	272	335
Rock bass	<1	5	<1	0	<1	<1	0	0	1	<1
Round goby	0	4	127	385	356	164	369	0	<1	280
Shorthead redhorse	0	<1	0	0	<1	0	<1	0	0	<1
Spottail shiner	665	1,935	1,011	863	967	1,340	210	489	539	896
Trout-perch	1,730	406	619	422	411	529	444	145	530	485
Walleye	10	7	2	2	4	42	28	1	4	16
White bass	2	<1	<1	0	<1	13	39	4	2	10
White perch	346	141	895	544	339	474	282	256	318	507
White sucker	12	10	7	24	26	38	19	7	12	23
Yellow perch	170	90	37	146	70	2,469	491	556	110	269
Soft-rayed forage index value [a]	3,391	2,464	2,641	2,869	2,394	3,269	1,253	1,210	1,548	2,485

[a] Soft-rayed forage index value is the sum of catch rates for alewife, emerald shiner, gizzard shad, rainbow smelt, round goby, spottail shiner, and trout-perch.

Table 5.–Number, catch rate (CPUE expressed as mean catch per 10-minute tow) and mean total length of age-0 walleyes in fall trawl samples on Saginaw Bay, 1986–2004. Mean length data not available prior to 1998 (–).

Year	Number of age-0 walleyes captured	Age-0 walleye catch rate	Mean length (mm)
1986	20	0.43	–
1987	34	0.46	–
1988	39	0.59	–
1989	19	1.27	–
1990	0	0.00	–
1991	28	1.89	–
1992	6	0.16	–
1993	1	0.02	–
1994	22	0.64	–
1995	14	0.36	–
1996	0	0.00	–
1997	83	2.18	–
1998	149	8.55	212
1999	20	0.74	198
2000	5	0.30	180
2001	27	0.98	–
2002	84	2.54	176
2003	1,114	40.80	171
2004	822	22.93	117

Table 6.–Number of young-of-the-year yellow perch caught per 10-minute tow (CPUE) and their mean total length, Saginaw Bay, fall 1970–2004[a].

Year	CPUE	Mean total length (mm)
1970	29.5	96.5
1971	20.2	91.4
1972	13.9	83.8
1973	30.6	91.4
1974	27.9	88.9
1975	247.9	88.9
1976	11.1	91.4
1977	52.9	91.4
1978	99.8	86.4
1979	166.7	78.7
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
1988	56.6	76.2
1989	252.8	71.1
1990	39.0	79.5
1991	110.8	70.2
1992	7.1	76.2
1993	0.5	90.7
1994	3.9	85.0
1995	98.9	72.8
1996	37.3	81.9
1997	83.3	73.8
1998	74.4	76.1
1999	19.5	92.4
2000	9.4	83.2
2001	133.9	77.1
2002	36.7	76.2
2003	2,450.7	69.7
2004	461.8	66.1

[a] Data prior to 1990 from Haas and Schaeffer (1992).

Table 7.–Mean CPUE for common species in Saginaw Bay fall trawl samples for pre-zebra mussel (1986–90), and post-zebra mussel (1993–2004) time periods.

	Pre-zebra mussel		Post-zebra mussel		K-W
Species	Mean catch rate	2 SE	Mean catch rate	2 SE	P value
Alewife	401.8	200.1	413.9	81.8	0.076
Common carp	5.2	1.2	6.0	0.7	0.003
Channel catfish	3.8	1.4	3.9	0.7	0.004
Freshwater drum	8.1	2.7	14.4	2.3	0.000
Emerald shiner	60.5	24.3	1.8	0.8	0.000
Gizzard shad	67.6	28.1	12.5	2.8	0.000
Johnny darter	2.8	1.0	8.9	2.1	0.007
Rainbow smelt	632.4	290.1	328.0	97.6	0.443
Spottail shiner	532.3	123.7	729.9	160.9	0.236
Trout-perch	288.7	84.1	586.7	114.0	0.001
Walleye	2.0	0.5	8.7	2.0	0.000
White perch	290.8	113.2	367.6	46.8	0.000
White sucker	7.0	1.5	16.9	3.4	0.000
Yellow perch	722.2	166.2	321.4	93.6	0.000

Table 8.–Mean CPUE (catch per 10-minute tow) by age for yellow perch in fall trawling at Saginaw Bay, 1986–2004. (zm = zebra mussel).

Survey year	Age											All ages	Yearling and older
	0	1	2	3	4	5	6	7	8	9	10		
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	2,450.8	4.6	11.1	1.1	0.5	0.8	0.3	0.1	0.0	0.0	0.0	2468.7	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
Mean:													
All years	246.1	48.8	43.5	39.4	19.7	6.8	2.1	0.5	0.1	0.0	0.0	407.1	161.0
1998–2004	455.1	20.7	9.5	6.1	2.5	0.7	0.3	0.1	0.0	0.0	0.0	495.0	39.9
Pre-zm (1986–90)	229.7	132.8	134.7	130.6	64.8	21.2	6.3	1.6	0.3	0.1	0.0	722.2	492.5
Post-zm (1993–2004)	284.8	16.9	9.6	5.8	2.8	1.1	0.4	0.1	0.0	0.0	0.0	321.4	36.6

Table 9.–Mean total length (mm±2 SE) of common forage species in fall trawl samples of Saginaw Bay for pre-zebra mussel (1986–90) and post-zebra mussel (1993–2004) time periods. All differences were significant as indicated by *t*-tests.

	Pre-zebra mussel		Post-zebra mussel		*t*-test
Species	Mean total length	2 SE	Mean total length	2 SE	sig.
Alewife (age 0)	77.5	0.5	69.7	0.4	0.000
Gizzard shad (age 0)	97.8	1.1	88.4	1.5	0.000
Rainbow smelt (age 0)	56.8	0.6	50.7	0.5	0.000
Spottail shiner (all ages)	80.4	0.6	71.6	0.4	0.000
Trout-perch (all ages)	80.9	0.6	68.7	0.4	0.000
White perch (age 0)	78.3	0.5	68.8	0.4	0.000
Yellow perch (age 0)	75.9	0.3	73.8	0.3	0.000

Table 10.–Mean male to female sex ratio (M:F) for yellow perch in Saginaw Bay based on fall trawl samples during three time periods. CI = confidence interval; N = number of years with data available in the time period.

	1971–91 [a]			1992–97			1998–2004		
Age	M:F ratio	95% CI	N	M:F ratio	95% CI	N	M:F ratio	95% CI	N
1	1.64	1.38–1.91	20	1.35	1.09–1.61	6	1.08	0.91–1.25	7
2	2.09	1.77–2.40	20	1.36	0.94–1.78	6	1.44	0.66–2.21	7
3	3.44	2.53–4.34	20	1.35	0.81–1.89	6	1.41	0.96–1.85	7
4	3.46	2.62–4.30	20	2.11	1.27–2.95	6	1.72	0.71–2.72	7
5	2.07	1.48–2.66	14	3.28	2.30–4.26	6	3.47	1.19–5.74	7
6	1.81	0.26–3.36	10	2.97	0.23–5.71	5	2.14	0.01–4.25	4
All ages	2.50	2.19–2.81	20	1.29	1.09–1.49	6	1.19	0.94–1.42	7

[a] Data prior to 1990 from Haas and Schaeffer (1992).

Table 11.–Mean length (mm) at age for yellow perch from Saginaw Bay fall trawling, 1988–2004[a]. SWA = fall statewide average (Schneider et al. 2000).

		Survey year																
Age	SWA	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
									Males									
1	–	119	120	124	124	124	131	145	135	132	131	123	136	140	139	128	134	128
2	–	137	141	146	146	149	155	159	169	166	166	146	154	157	172	166	165	175
3	–	150	157	165	167	164	178	176	179	189	195	172	155	169	180	190	187	201
4	–	164	170	175	184	181	194	191	192	200	202	202	183	172	190	203	211	225
5	–	177	185	186	201	187	202	200	203	211	219	211	196	210	227	213	215	240
6	–	201	194	195	212	209	213	200	211	219	219	219	–	218	264	228	243	235
									Females									
1	–	123	123	126	127	127	132	148	142	137	136	129	140	143	141	135	140	132
2	–	143	149	157	155	159	169	172	179	183	179	145	160	171	179	196	183	188
3	–	160	169	176	179	173	188	195	193	203	210	179	178	186	198	214	205	225
4	–	183	184	201	202	204	210	214	211	220	232	208	177	174	216	239	248	230
5	–	207	208	215	221	236	242	235	225	233	230	227	203	203	229	248	272	267
6	–	217	222	235	246	249	245	246	247	260	286	250	252	231	–	274	–	295
									Sexes combined									
1	127	123	128	127	131	127	133	148	138	135	133	125	138	144	139	132	137	130
2	160	147	150	167	154	155	158	165	173	172	173	149	171	169	172	194	175	183
3	183	158	153	167	165	163	186	184	184	197	202	178	204	183	186	196	198	212
4	208	157	162	177	184	184	206	200	197	205	217	206	222	210	207	213	219	227
5	234	167	181	167	208	183	235	213	210	216	222	225	212	253	233	217	222	244
6	257	189	205	172	230	218	237	214	226	235	239	237	–	230	264	255	243	245

[a] Data prior to 1990 from Haas and Schaeffer (1992); data for 1990 to 1997 from Fielder et al. (2000).

Table 12.–Proportion of water by weight in somatic tissue of yellow perch collected by fall trawling in Saginaw Bay during three time periods.

Age	1986–88		1993–97		1998–2002	
	Mean	2 SE	Mean	2 SE	Mean	2 SE
			Males			
1	0.7280	0.0034	0.7305	0.0030	0.7540	0.0019
2	0.7322	0.0018	0.7305	0.0017	0.7445	0.0020
3	0.7261	0.0017	0.7238	0.0027	0.7375	0.0019
4	0.7296	0.0026	0.7142	0.0039	0.7322	0.0033
5	0.7273	0.0034	0.7134	0.0051	0.7596	0.0178
6	0.7327	0.0060	0.7137	0.0066	0.7356	0.0042
			Females			
1	0.7324	0.0040	0.7316	0.0032	0.7551	0.0018
2	0.7383	0.0020	0.7303	0.0022	0.7515	0.0023
3	0.7343	0.0022	0.7252	0.0026	0.7458	0.0034
4	0.7363	0.0036	0.7180	0.0070	0.7398	0.0036
5	0.7339	0.0050	0.7163	0.0064	0.7365	0.0060
6	0.7344	0.0102	0.7152	0.0080	0.7247	0.0093

Table 13.–Frequency of occurrence for food items in yellow perch from Saginaw Bay fall trawl surveys, 1986–2002.

	Survey year													
Taxa	1986	1987	1988	1991	1992	1994	1995	1996	1997	1998	1999	2000	2001	2002
Bosmina	5.5	1.6	3.4	2.7	17.6	5.8	0.8	1.7	1.2	0.8	0.0	0.0	2.1	0.0
Daphnia	1.3	0.3	0.6	0.0	2.0	0.0	0.0	0.0	0.0	0.0	1.7	2.1	0.0	0.0
Chydorid	67.1	25.5	27.2	19.1	61.8	41.8	8.0	19.0	13.9	16.2	1.1	0.0	0.0	0.0
Macrothricid	14.0	4.4	13.5	16.4	27.4	18.6	12.8	5.2	2.9	13.7	0.0	0.0	0.0	0.0
Leptodora	0.2	2.0	0.1	0.0	0.0	0.0	0.0	0.0	4.6	0.0	0.0	0.0	0.0	0.0
Copepod	37.6	51.3	45.5	57.3	46.1	39.5	41.6	53.4	30.6	28.2	0.6	0.0	3.6	12.7
Ostracod	27.4	25.6	34.4	39.1	63.7	45.3	48.8	50.9	45.7	26.1	10.8	4.3	0.0	0.0
Sida	23.3	16.5	3.2	1.8	38.2	24.4	3.2	8.6	6.4	6.6	0.0	0.0	0.0	0.0
Bythotrephes cederstroemi	0.0	0.0	0.0	0.0	21.6	13.9	20.8	0.0	1.2	0.0	0.0	0.0	0.0	0.0
All plankton	73.3	62.5	59.7	65.4	78.4	68.6	78.4	63.8	48.0	39.8	19.9	6.4	5.1	12.7
Ephemerida	3.5	0.2	0.7	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.6	0.7	0.0	0.0
Tricoptera	5.8	1.4	0.1	0.0	4.9	7.0	8.0	29.3	11.0	1.2	1.7	3.5	0.0	0.0
Chironomid pupae	28.3	30.2	33.9	3.6	25.5	3.5	12.8	26.7	11.6	8.7	6.8	7.8	0.7	11.3
Chironomid larvae	66.7	78.4	77.4	71.8	69.6	47.7	60.0	68.1	46.8	44.4	54.5	29.1	13.8	45.1
All insects	71.1	82.3	81.3	72.7	80.4	54.6	67.2	75.0	56.1	46.1	58.5	34.8	13.8	45.8
Pelecepod	7.4	3.6	3.8	9.1	3.9	0.0	5.6	11.2	14.4	11.6	5.7	0.7	6.5	19.0
Gastropod	3.3	0.7	0.5	0.0	0.0	0.0	0.8	0.9	2.3	0.0	1.7	2.8	0.7	0.7
Zebra mussel	0.0	0.0	0.0	0.9	16.7	20.9	1.6	12.9	4.6	4.6	0.0	2.1	0.7	0.7
Isopod	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.2	0.0	0.0	0.0	0.0	0.0
Hydracarina	8.5	2.5	9.4	0.9	2.9	1.2	0.8	0.0	1.2	0.0	0.0	0.0	0.0	0.0
Amphipod	4.4	1.9	1.3	0.0	28.4	15.1	0.0	4.3	36.4	2.9	19.3	17.0	0.7	0.7
All other invertebrates	19.2	8.6	14.0	10.9	41.2	33.7	8.8	21.6	49.7	17.8	23.9	19.1	8.0	20.4
Round goby	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	7.7
All fish	18.1	7.4	7.3	10.0	10.8	9.3	12.0	16.4	22.0	10.8	13.6	12.8	18.8	22.5
Percent of empty stomachs	32.7	35.4	39.2	37.9	47.8	42.1	31.0	46.8	26.1	34.4	17.6	45.4	63.0	30.3
Number of non-empty stomachs	636	945	1,009	110	102	86	125	116	173	158	145	77	51	99

Table 14.–Incidence of void stomachs and percent-abundance (by number) of food items found in stomachs of age-1 and older walleyes collected by fall trawling in Saginaw Bay, 1998–2004.

Year	Stomachs examined	% void	Unidentified fish remains	Gizzard shad	Alewife	Yellow perch	Spottail shiner	White sucker	Round goby	White perch	Zebra mussel	Trout-perch	White bass
1998	51	27	52	0	41	6	0	0	0	1	0	0	0
1999	94	28	27	0	70	0	1	0	0	1	1	0	0
2000	43	26	44	0	48	0	4	0	2	2	0	0	0
2001	33	18	25	0	69	3	1	1	0	0	0	0	0
2002	33	27	43	2	43	2	4	0	4	2	0	0	0
2003	33	15	51	0	17	30	0	0	1	1	0	0	0
2004	176	36	38	0	<1	51	3	0	3	3	0	<1	1

Table 15.–Mean (±2 SE) gill net CPUE (number of fish per 305 m of net) at traditional netting locations in Saginaw Bay, fall 1998–2004. Each year there were 14 net sets (4,270 m). Table omits four net lifts from Charity Islands and Tawas Bay added in 1995. Data omits the 38-mm (1½ inch) mesh catch added in 1993.

	1998		1999		2000		2001		2002		2003		2004	
Species	Mean	2 SE	Mean	2 SE	Mean	2 SE	Mean	2 SE	Mean	2 SE	Mean	2 SE	Mean	2 SE
Alewife	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Bigmouth buffalo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Black crappie	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Bowfin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brown bullhead	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brown trout	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.4	0.1	0.1	0.0	0.0
Burbot	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Common carp	0.1	0.1	1.6	1.0	0.1	0.2	0.1	0.2	0.9	0.8	0.3	0.3	0.1	0.2
Channel catfish	6.7	4.7	15.3	8.2	8.8	5.2	10.7	5.4	12.9	6.1	11.1	5.1	6.0	4.0
Chinook salmon	0.1	0.1	0.0	0.0	0.0	0.0	0.5	0.5	0.2	0.2	0.0	0.0	0.0	0.0
Freshwater drum	4.8	2.7	17.4	12.0	13.1	8.2	13.6	10.3	8.8	5.3	6.9	3.5	6.9	4.3
Gizzard shad	40.0	29.6	11.9	5.8	1.7	1.1	4.1	4.5	7.0	4.3	2.1	1.3	1.7	1.9
Goldfish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lake herring	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lake trout	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lake whitefish	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Longnose gar	0.2	0.3	0.1	0.1	0.2	0.3	0.1	0.1	0.0	0.0	0.3	0.3	0.4	0.5
Longnose sucker	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Muskellunge	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Northern pike	0.2	0.3	0.1	0.2	0.6	0.4	0.1	0.2	0.1	0.1	0.4	0.3	0.1	0.2
Northern redhorse	0.4	0.4	0.2	0.2	0.2	0.2	0.0	0.0	0.2	0.3	0.2	0.2	0.4	0.3
Pink salmon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pumpkinseed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quillback	0.1	0.1	3.0	2.0	1.9	1.6	1.7	1.6	1.4	1.3	1.5	0.9	2.1	1.6
Rainbow smelt	0.0	0.0	0.1	0.3	0.0	0.0	0.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Rainbow trout	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rock bass	0.1	0.2	0.5	0.7	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1
Round goby	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Round whitefish	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Smallmouth bass	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.0	0.0	0.1	0.2
Stone cat	0.2	0.2	0.0	0.0	0.1	0.2	0.5	0.9	0.1	0.2	0.1	0.1	0.0	0.0
Walleye	12.6	4.8	12.9	4.3	7.1	3.5	8.1	6.5	8.0	3.4	22.5	10.7	11.0	3.7
White bass	0.8	0.6	0.6	0.6	0.2	0.2	0.1	0.2	0.1	0.1	1.6	1.4	0.1	0.1
White crappie	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
White perch	3.4	3.4	21.2	6.8	23.2	9.0	12.8	11.1	10.2	13.4	21.4	17.1	20.6	31.4
White sucker	18.4	6.4	20.3	8.0	11.8	4.4	13.0	5.3	8.6	4.4	19.0	10.0	13.1	5.9
Yellow perch	12.4	4.7	24.9	8.2	14.6	5.8	48.0	20.3	12.5	3.0	18.4	7.5	30.7	13.7

Table 16.–Mean (±2 SE) gill net CPUE (number of fish per 335 m of net) by species at all sampled stations, in Saginaw Bay, 1998–2004. Each year there were 18 net sets (6,030 m). Table includes the four net lifts from Charity Islands and Tawas Bay added in 1995. Includes catch from the 38-mm (1½ inch) mesh panel.

	1998		1999		2000		2001		2002		2003		2004	
Species	Mean	2 SE	Mean	2 SE	Mean	2 SE	Mean	2 SE	Mean	2 SE	Mean	2 SE	Mean	2 SE
Alewife	0.5	0.8	0.1	0.1	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Bigmouth buffalo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Black crappie	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Bluegill	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Bowfin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brown bullhead	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brown trout	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.1	0.1	0.0	0.0
Burbot	0.0	0.0	0.1	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Common carp	1.4	0.8	0.1	0.2	0.2	0.2	0.2	0.2	0.7	0.6	0.5	0.5	0.1	0.2
Channel catfish	12.7	6.9	5.8	3.8	7.8	4.4	9.3	4.6	10.6	5.3	8.9	4.6	9.2	6.0
Chinook salmon	0.0	0.0	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.3	0.0	0.0	0.2	0.2
Freshwater drum	14.4	9.8	4.6	2.4	10.8	6.7	11.2	8.4	7.8	4.3	5.4	3.1	8.4	5.1
Gizzard shad	13.3	7.3	50.2	33.8	3.3	2.0	9.1	10.4	11.9	6.3	7.8	5.5	1.9	2.1
Goldfish	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lake herring	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lake trout	0.1	0.2	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.2
Lake whitefish	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Longnose gar	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.0	0.0	0.3	0.3	0.3	0.4
Longnose sucker	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.0
Muskellunge	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Northern pike	1.7	3.1	0.3	0.4	1.9	2.5	0.5	0.8	0.2	0.3	0.3	0.3	0.2	0.2
Northern redhorse	0.2	0.2	0.3	0.3	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.2
Pink salmon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pumpkinseed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quillback	2.3	1.7	0.1	0.1	1.5	1.3	1.3	1.3	1.1	1.0	1.2	0.8	1.6	1.3
Rainbow smelt	0.1	0.2	0.0	0.0	0.0	0.0	0.3	0.4	0.0	0.0	0.3	0.7	0.0	0.0
Rainbow trout	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rock bass	0.7	0.7	0.4	0.6	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.2	0.1	0.1
Round goby	0.1	0.2	0.0	0.0	0.4	0.3	0.3	0.4	0.2	0.2	0.1	0.1	0.0	0.0
Round whitefish	0.0	0.0	0.2	0.2	0.0	0.0	0.4	0.4	0.1	0.1	0.0	0.0	0.0	0.0
Shortnose gar	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Smallmouth bass	0.2	0.3	0.2	0.3	0.0	0.0	0.3	0.3	0.2	0.3	0.0	0.0	0.1	0.2
Stone cat	0.0	0.0	0.2	0.2	0.1	0.2	0.4	0.7	0.1	0.2	0.2	0.3	0.0	0.0
Walleye	12.8	4.0	13.0	4.1	6.6	2.9	7.3	5.3	7.2	3.1	22.0	11.6	12.2	5.0
White bass	0.5	0.5	1.8	1.0	0.2	0.2	0.2	0.2	0.1	0.1	4.3	2.8	0.1	0.1
White crappie	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0
White perch	25.0	9.1	2.9	2.8	20.8	8.9	11.6	10.2	8.3	10.8	19.2	15.5	16.8	25.2
White sucker	20.6	7.7	17.4	5.2	11.9	4.4	11.3	4.7	7.6	3.7	14.9	8.6	12.4	5.4
Yellow perch	66.6	17.4	31.3	9.7	34.4	15.7	59.7	25.6	32.7	11.3	34.6	14.4	38.7	15.4

Table 17.–Mean gill net CPUE by year class of walleye in fall surveys of Saginaw Bay, 1998–2004. A unit of effort is 335 m of gill net; 18 net sets were made each year.

	1998		1999		2000		2001		2002		2003		2004	
Year class	Age	CPUE	Age	CPUE	Age	CPUE	Age	CPUE	Age	CPUE	Age	CPUE	Age	CPUE
2004	–	–	–	–	–	–	–	–	–	–	–	–	0	0.2
2003	–	–	–	–	–	–	–	–	–	–	0	5.5	1	6.3
2002	–	–	–	–	–	–	–	–	0	0.3	1	6.1	2	2.9
2001	–	–	–	–	–	–	0	0.8	1	2.6	2	4.0	3	0.7
2000	–	–	–	–	0	–	1	1.0	2	1.0	3	1.1	4	0.7
1999	–	–	0	0.1	1	0.4	2	0.9	3	0.6	4	1.5	5	0.6
1998	0	0.7	1	6.8	2	3.1	3	2.4	4	1.4	5	1.8	6	0.3
1997	1	4.2	2	2.2	3	1.1	4	0.3	5	0.4	6	1.1	7	0.1
1996	2	0.2	3	0.2	4	0.1	5	0.2	6	0.3	7	0.7	8	0.1
1995	3	1.3	4	0.6	5	0.4	6	0.4	7	0.2	8	0.4	9	0.1
1994	4	2.4	5	0.8	6	0.2	7	0.2	8	0.2	9	0.1	10	0.1
1993	5	0.7	6	0.3	7	0.2	8	0.3	9	0.2	–	–	11	0.1
1992	6	0.6	7	0.8	8	0.8	9	0.4	10	0.1	–	–	–	–
1991	7	0.9	8	0.5	9	0.3	10	0.1	11	0.1	–	–	–	–
1990	8	0.8	9	0.3	10	0.1	11	0.1	–	–	–	–	–	–
1989	9	0.4	10	0.2	–	–	–	–	–	–	–	–	–	–
1988	10	0.4	11	0.1	–	–	–	–	–	–	–	–	–	–
1987	11	0.1	–	–	–	–	–	–	–	–	–	–	–	–
1986	12	0.1	–	–	–	–	–	–	–	–	–	–	–	–
Mean age	3.7		2.8		3.8		3.4		3.0		2.2		2.1	
Total CPUE [a]		12.7		12.8		6.6		7.3		7.2		22.3		12.0

[a] Data based on aged sample and therefore may differ slightly from values reported in Tables 15 and 16.

Table 18.–Mean length at age (mm±2 SE) for walleyes and yellow perch from Saginaw Bay based on fall gill net data for 1998–2004, compared with Michigan average lengths from August–September catches. The Saginaw Bay historic average for 1926–38 is also included for walleyes (Hile 1954). No means included for sample sizes of fewer than five specimens.

Age	1998		1999		2000		2001		2002		2003		2004		Michigan average [a]	Bay historic average [b]
	Mean	2 SE	Mean	2 SE	Mean	2 SE	Mean	2 SE	Mean	2 SE	Mean	2 SE	Mean	2 SE		
								Walleye								
0	227	9.7	–	–	–	–	200	5.0	203	14.1	193	5.4	171	23.5	180	–
1	341	4.2	361	2.9	333	7.8	350	5.1	344	5.7	349	3.6	296	5.0	250	254
2	–	–	438	8.1	436	6.5	426	6.9	434	8.8	434	9.3	418	5.0	338	320
3	482	25.4	–	–	497	14.1	496	7.9	490	15.9	494	15.1	470	15.0	386	371
4	508	22.0	505	20.1	–	–	524	20.4	504	25.9	515	12.1	520	14.2	437	411
5	496	42.1	544	13.3	512	34.2	–	–	567	26.6	548	10.9	545	34.8	472	457
6	565	16.4	570	28.1	–	–	553	25.2	588	57.3	554	13.5	553	27.4	516	483
7	551	13.9	560	25.9	–	–	–	–	–	–	559	18.4	–	–	541	505
8	570	18.5	563	35.4	581	27.6	552	17.3	–	–	599	33.3	–	–	561	533
9	612	45.9	588	15.9	576	66.3	578	25.3	–	–	–	–	–	–	582	582
10	624	45.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Growth index [a]	+52.8		+62.2		+57.2		+53.1		+78.0		+62.7		+56.3			-15.2
								Yellow perch								
0	–	–	–	–	–	–	91	14.0	–	–	–	–	–	–	84	–
1	153	3.7	149	2.4	149	11.1	147	1.7	152	1.2	154	2.1	166	42.3	127	–
2	154	2.0	159	1.8	157	1.7	174	4.2	188	5.5	181	3.2	207	4.6	160	–
3	172	3.7	184	5.0	175	3.3	189	4.4	227	5.0	217	4.8	227	4.0	183	–
4	198	9.3	199	4.3	194	4.4	215	4.9	247	6.1	237	9.1	263	9.4	208	–
5	217	4.8	212	4.3	211	6.2	245	6.5	277	13.0	244	10.4	294	23.0	234	–
6	235	10.4	226	4.8	230	7.6	267	21.7	296	31.0	248	31.3	305	14.5	257	–
7	251	12.9	252	9.9	250	6.4	288	19.1	–	–	–	–	–	–	277	–
8	–	–	269	13.1	264	9.3	–	–	–	–	–	–	–	–	292	–
9	–	–	284	13.2	–	–	–	–	–	–	–	–	–	–	302	–
Growth index [a]	-9.4		-11.7		-13.5		+10.7		+36.1		+18.8		+48.8			–

[a] Statewide Michigan average lengths and methods for calculating growth index (mm) from Schneider et al. (2000).
[b] From Hile (1954).

Table 19.–Incidence of void stomachs and percent-abundance of food items found in stomachs of walleyes taken in fall gill netting of Saginaw Bay, 1989–2004.

Year	Stomachs examined	% void	Unidentified fish remains	Gizzard shad	Yellow perch	Spottail shiner	Rainbow smelt	Alewife	Ninespine stickleback	White sucker	Round goby	White perch	Channel catfish	Walleye	Freshwater drum
1989	257	26	27	63	0	0	<1	8	1	0	0	<1	0	0	0
1990	508	37	22	76	0	0	<1	1	<1	0	0	<1	0	0	0
1991	669	36	34	63	<1	<1	0	2	0	<1	0	0	0	0	0
1992	171	56	62	2	2	2	14	17	0	2	0	0	0	0	0
1993	371	52	39	59	0	0	<1	2	0	0	0	0	0	0	0
1994	84	45	24	70	3	3	0	0	0	0	0	0	0	0	0
1995	291	45	31	28	1	<1	0	37	0	<1	0	1	0	0	0
1996	148	61	72	23	4	0	0	1	0	0	0	0	0	0	0
1997	204	35	59	12	3	7	0	17	0	0	0	2	0	0	0
1998	234	47	40	2	1	2	0	54	0	0	0	0	1	0	0
1999	231	49	36	<1	8	13	<1	41	0	0	0	<1	0	0	0
2000	119	48	57	9	2	1	0	22	0	0	1	1	8	0	0
2001	114	57	27	<1	2	<1	0	59	0	0	0	9	0	0	0
2002	129	63	49	23	0	0	0	20	0	0	8	0	0	0	0
2003	363	57	17	21	18	0	0	42	0	2	0	0	0	0	0
2004	216	66	24	0	57	1	0	0	0	<1	2	0	0	13	<1

Table 20.–Mean relative weight by length class for walleyes and yellow perch collected in gill nets from Saginaw Bay, fall 1989–2004. N = sample size.

Year	Stock-quality	Quality-preferred	Preferred-memorable	All sizes combined	N
			Walleye		
1989	100	95	95	96	259
1990	98	102	97	98	508
1991	95	96	95	96	689
1992	87	88	90	89	171
1993	91	91	88	90	382
1994	88	88	90	88	155
1995	92	93	92	95	302
1996	90	92	90	90	267
1997	95	90	92	91	204
1998	91	89	88	90	231
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
			Yellow perch		
1989	–	–	–	–	–
1990	98	97	92	97	101
1991	82	80	83	81	231
1992	82	86	86	84	202
1993	96	95	94	96	218
1994	99	96	92	96	203
1995	91	87	90	89	501
1996	96	93	90	95	1658
1997	94	95	93	94	962
1998	87	85	86	86	348
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

Table 21.–Walleye and yellow perch proportional stock density (PSD)[a] and relative stock density (RSD-P and RSD-M)[b] based on Saginaw Bay fall gill net data, 1998–2004.

Year	PSD	RSD-P	RSD-M
	Walleye		
1998	63	47	3
1999	55	25	3
2000	93	34	3
2001	85	48	4
2002	60	31	3
2003	65	30	1
2004	47	19	5
	Yellow perch		
1998	26	3	0
1999	23	4	1
2000	25	7	1
2001	46	9	2
2002	36	14	2
2003	41	7	1
2004	65	19	5

[a] Stock and quality sizes for walleye are 250 mm and 380 mm, respectively. These values for yellow perch are 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 (Anderson and Weithman 1978).

[b] Preferred size for walleye is 510 mm and memorable size is 630 mm. For yellow perch, these values are 250 mm and 300 mm, respectively (Anderson and Gutreuter 1983).

Table 22.–Mean gill net CPUE (number of fish per 335 m of net) by year class of yellow perch in the fall survey catches at Saginaw Bay, 1998–2004.

	Year (no net lifts)													
	1998 (9)		1999 (9)		2000 (9)		2001 (9)		2002 (14)		2003 (10)		2004 (10)	
Year class	Age	CPUE	Age	CPUE	Age	CPUE	Age	CPUE	Age	CPUE	Age	CPUE	Age	CPUE
2004	–	–	–	–	–	–	–	–	–	–	–	–	0	0.4
2003	–	–	–	–	–	–	–	–	–	–	–	–	1	9.6
2002	–	–	–	–	–	–	–	–	0	–	1	6.1	2	7.0
2001	–	–	–	–	–	–	0	1.8	1	18.9	2	22.1	3	16.3
2000	–	–	–	–	0	–	1	10.0	2	3.2	3	5.8	4	2.1
1999	–	–	0	0.2	1	4.2	2	10.7	3	4.1	4	3.0	5	1.0
1998	0	0.1	1	22.0	2	13.7	3	21.9	4	5.1	5	2.3	6	0.7
1997	1	0.9	2	15.3	3	7.9	4	11.4	5	1.2	6	0.6	7	0.0
1996	2	9.2	3	5.0	4	4.1	5	3.3	6	0.6	7	0.1	8	0.1
1995	3	5.7	4	5.4	5	4.1	6	1.4	7	0.1	8	0.1	–	–
1994	4	3.2	5	6.2	6	2.7	7	0.7	–	–	–	–	–	–
1993	5	4.7	6	4.9	7	1.2	8	0.4	–	–	–	–	–	–
1992	6	1.9	7	2.1	8	0.8	9	0.1	–	–	–	–	–	–
1991	7	0.6	8	1.1	9	0.4	–	–	–	–	–	–	–	–
1990	8	0.4	9	0.6	10	0.1	11	0.1	–	–	–	–	–	–
1989	–	–	10	0.2	–	–	–	–	–	–	–	–	–	–
1988	–	–	11	0.1	–	–	–	–	–	–	–	–	–	–
Number aged	240		569		353		557		464		401		372	
Mean age	3.4		2.9		3.3		2.9		2.0		2.4		2.4	
Total CPUE [a]		26.7		63.2		39.2		61.9		33.1		40.1		37.2

[a] Data based on aged subsample and therefore may differ slightly from values reported in Tables 15 and 16.

Table 23.–Total annual mortality rate (A) for yellow perch and channel catfish in Saginaw Bay, 1998–2004, as determined by the Robson-Chapman method of catch curve analysis.

Year	Yellow perch (%)	Channel catfish (%)
1998	47	74
1999	46	65
2000	46	70
2001	58	59
2002	73	64
2003	60	64
2004	53	79
Mean	55	68

Table 24.–Gill net mean CPUE (number caught per 335 m) by year class of channel catfish in the fall surveys of Saginaw Bay, 1998–2004. Number of lifts subsampled for channel catfish age data in parentheses.

Year class	1998 (13)		1999 (11)		2000 (7)		2001 (5)		2002 (11)		2003 (6)		2004 (10)	
	Age [b]	CPUE [b]	Age	CPUE	Age	CPUE	Age	CPUE	Age	CPUE	Age	CPUE	Age	CPUE
2004	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2003	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2002	–	–	–	–	–	–	–	–	–	–	–	–	2	0.10
2001	–	–	–	–	–	–	–	–	–	–	–	–	3	0.50
2000	–	–	–	–	–	–	–	–	2	0.09	3	0.50	4	–
1999	–	–	–	–	–	–	2	0.60	3	0.45	4	6.67	5	1.60
1998	0	0.08	1	0.45	2	1.86	3	5.40	4	5.00	5	3.50	6	6.40
1997	1	0.15	2	–	3	0.71	4	1.00	5	0.09	6	0.50	7	0.70
1996	2	0.62	3	0.45	4	0.86	5	2.40	6	0.81	7	–	8	0.90
1995	3	2.00	4	4.82	5	3.00	6	2.00	7	1.09	8	0.33	9	1.50
1994	4	0.62	5	0.36	6	1.00	7	0.40	8	0.36	9	0.17	10	0.30
1993	5	0.15	6	0.54	7	0.27	8	0.20	9	0.27	10	–	–	–
1992	6	–	7	0.09	8	–	–	–	–	–	11	–	–	–
1991	7	0.23	8	0.27	9	0.27	–	–	–	–	12	0.17	–	–
1990	8	–	9	0.09	10	–	–	–	–	–	–	–	–	–
1989	9	0.15	10	–	11	–	–	–	–	–	–	–	–	–
1988	10	0.15	11	0.09	12	–	–	–	–	–	–	–	–	–
1987	11	–	12	–	13	0.14	–	–	–	–	–	–	–	–
1986	12	–	13	–	14	–	–	–	–	–	–	–	–	–
1985	13	–	14	–	15	0.14	–	–	–	–	–	–	–	–
1984	14	–	15	0.09	–	–	–	–	–	–	–	–	–	–
Number aged	56		80		60		60		90		71		120	
Mean age	4.2		4.4		4.8		4.2		4.9		4.6		6.4	
Total CPUE [a]		4.31		7.27		8.57		12.00		8.18		11.83		12.00

[a] Data based on aged sample and therefore may differ slightly from value reported in Tables 15 and 16.
[b] Includes a CPUE of 0.08 for each of ages 15 and 16.

Table 25.–Mean length at age (mm ±2 SE) for channel catfish based on fall gill net data for Saginaw Bay in 1998–2004, compared with statewide average lengths for August–September. No means included for sample sizes of less than 5 specimens.

	1998		1999		2000		2001		2002		2003		2004		Michigan
Age	Mean	2 SE	Mean	2 SE	Mean	2 SE	Mean	2 SE	Mean	2 SE	Mean	2 SE	Mean	2 SE	average [a]
0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1	–	–	174	8.3	–	–	–	–	–	–	–	–	–	–	165
2	279	24.2	–	–	231	9.6	–	–	–	–	–	–	–	–	284
3	310	29.6	310	29.2	258	49.1	293	11.9	330	49.4	–	–	300	14.1	345
4	340	12.9	343	6.0	325	14.9	333	35.2	330	9.8	359	11.1	–	–	401
5	–	–	–	–	358	15.7	372	37.1	–	–	384	17.9	401	28.8	450
6	–	–	432	37.0	373	17.2	403	22.6	412	35.3	–	–	425	8.4	490
7	–	–	–	–	–	–	–	–	449	22.4	–	–	456	34.9	523
8	–	–	–	–	–	–	–	–	–	–	–	–	460	25.6	559
9	–	–	–	–	–	–	–	–	–	–	–	–	491	28.5	589
10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	605
Growth index [a]	-33.7		-35.5		-85.0		-71.2		-59.5		-54.0		-70.5		

[a] Statewide Michigan average lengths and methods for calculating growth index (mm) from Schneider et al. (2000).

Table 26.–Number of walleyes tagged at sites in the Saginaw Bay system, 1986–2004.

Site	Year																			Total [d]
	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000 [c]	2001	2002	2003	2004	
	Tittabawassee River																			
Dow Dam	2,923	6,020	4,036	2,494	2,488	3,079	2,995	2,989	2,999	2,970	2,992	2,993	2,490	2,999	3,299	2,997	2,993	3,000	2,997	68,195
Sanford Dam	608	–	–	497	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1,636
	Other rivers																			
Kawkawlin River	–	56	–	74	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	368
Au Gres River	59	215	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	448
Saginaw River	–	–	115 [a]	–	418	–	–	–	–	–	–	–	–	–	–	–	–	–	–	533
Flint River [a]	–	–	–	–	–	–	–	–	–	–	–	–	2,994	2,997	2,993	–	–	–	–	5,991
	Saginaw Bay																			
Consumers Power	0	–	–	207	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	217
Pt. Au Gres	511	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	914
Black Hole [b]	529	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	529
Pinconning	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	56
Sand Point	–	1,108	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1,197
Total	4,630	7,399	4,151	3,272	2,906	3,079	2,995	2,989	2,999	2,970	2,992	2,993	5,484	5,996	6,292	2,997	2,993	3,000	2,997	80,084

[a] Returns analyzed and reported separately and not included in ESTIMATE model analysis.
[b] A 5.8-m deep depression about 11 km southwest of Pt. Au Gres in Grid 1507.
[c] Includes 300 reward-tagged fish.
[d] Total number since study inception in 1981.

Table 27.–Average total length (mm) by sex of walleyes collected by electrofishing below Dow Dam, Tittabawassee River, March–April 1981–2004.

Year	Female		Male		Total	
	Length	Number	Length	Number	Length	Number
1981	528	87	350	272	394	399
1982	516	179	452	513	467	697
1983	549	2,082	498	1,300	528	3,413
1984	584	1,052	472	2,421	505	3,540
1985	531	1,322	457	1,662	490	2,984
1986	536	1,370	465	2,023	493	3,574
1987	546	1,736	472	3,829	485	5,976
1988	582	549	477	3,338	490	4,033
1989	561	1,774	485	1,244	528	3,064
1990	582	972	493	1,481	528	2,467
1991	584	2,232	488	843	559	3,079
1992	610	1,491	483	1,497	556	2,995
1993	582	1,323	488	1,666	531	2,989
1994	599	1,452	531	1,534	564	2,999
1995	589	962	538	2,003	556	2,970
1996	627	1,376	556	1,614	589	2,992
1997	630	1,905	554	1,088	604	2,993
1998	589	1,170	544	1,311	564	2,489
1999	620	957	549	2,031	569	2,995
2000	630	531	540	2,756	555	3,299
2001	635	576	518	2,421	540	2,997
2002	594	809	536	2,178	551	2,993
2003	615	967	525	2,028	554	2,994
2004	602	1,095	529	1,902	556	2,997

Table 28.–Age composition (percent) of walleyes sampled from the Tittabawassee River at Dow Dam during spring electrofishing, 1992–2004.

	Age														Mean
Sample year	1	2	3	4	5	6	7	8	9	10	11	12	13	14+	age
1992															
Female	–	0.1	0.0	9.4	14.5	12.1	17.9	13.7	10.2	12.9	4.6	3.0	1.7	0.2	7.5
Male	–	0.6	19.5	30.8	17.4	17.6	11.4	1.0	1.0	0.3	0.4	–	–	–	4.8
1993															
Female	–	–	1.6	13.7	31.8	11.7	18.6	14.6	6.5	1.2	0.3	–	–	–	6.1
Male	–	–	33.3	25.6	14.2	12.6	9.0	2.9	1.1	1.3	–	–	–	–	4.6
1994															
Female	–	–	1.3	17.3	32.7	16.0	7.7	12.2	7.7	1.9	1.3	0.6	–	–	6.0
Male	–	–	4.9	18.9	12.8	10.4	13.4	17.1	12.8	4.9	1.2	–	–	–	6.5
1995															
Female	–	–	–	9.4	53.1	13.4	9.1	7.1	3.9	2.4	1.2	0.4	–	–	5.8
Male	–	–	1.3	9.0	20.5	21.0	12.7	14.0	12.5	7.6	0.7	0.4	0.2	–	6.7
1996															
Female	–	–	–	0.2	9.1	18.4	22.6	13.1	12.6	15.9	6.9	1.3	–	–	7.8
Male	–	–	0.6	0.8	6.3	16.1	18.9	21.9	18.4	13.0	3.1	0.9	–	–	7.8
1997															
Female	–	–	0.4	4.1	1.3	11.8	26.8	22.9	12.4	8.4	7.1	4.9	–	–	7.9
Male	–	–	–	1.5	0.3	15.2	23.6	27.3	16.1	9.2	4.0	2.0	–	0.6	7.9
1998															
Female	–	–	1.7	22.8	11.0	6.6	11.3	19.6	12.8	7.3	4.0	2.7	0.3	–	7.0
Male	–	–	6.8	9.3	3.4	4.8	16.4	22.7	17.7	10.3	6.2	1.5	0.9	–	7.6
1999															
Female	–	–	0.4	8.0	13.3	4.9	4.5	11.4	21.2	18.6	9.8	6.8	0.4	0.4	8.3
Male	–	0.6	1.7	13.2	8.5	5.2	7.4	23.5	19.8	12.4	4.5	1.2	0.8	–	7.6
2000															
Female	–	–	–	0.6	11.2	14.9	10.6	4.3	13.0	20.5	13.7	8.1	2.5	–	8.7
Male	–	4.4	11.7	2.2	9.0	11.4	5.8	8.2	21.8	14.1	8.3	2.5	0.6	–	7.4
2001															
Female	–	–	2.7	7.5	5.8	8.4	13.3	8.0	9.7	15.5	14.6	11.5	2.2	0.9	8.6
Male	–	–	25.4	9.5	3.0	9.1	10.5	11.0	14.2	9.5	5.4	1.9	0.5	–	6.6
2002															
Female	–	–	–	16.5	38.0	15.2	9.5	3.8	4.4	3.8	3.8	2.5	1.9	0.6	6.3
Male	–	–	0.8	31.4	28.9	7.1	7.9	7.5	2.9	7.1	4.2	0.8	1.3	–	6.0
2003															
Female	–	–	–	4.5	25.9	17.7	9.1	10.7	9.1	6.6	8.2	5.8	1.6	0.8	7.4
Male	–	1.2	5.5	13.1	26.2	17.7	12.8	11.9	4.9	4.0	2.0	0.6	–	–	6.1
2004															
Female	–	–	0.3	10.5	28.0	28.6	11.0	3.7	5.1	5.4	3.7	2.5	0.8	0.4	6.5
Male	–	–	9.7	6.3	16.2	25.2	13.3	11.7	4.5	6.5	3.8	1.8	0.7	0.4	6.6

Table 29.–Mean length at age (mm, with 2 SE in parentheses) by sex, for walleyes sampled in the tagging operation, Tittabawassee River at Dow Dam, spring 1998–2004. Michigan average lengths for April are included for comparison. No means included for sample sizes of less than 5 specimens.

	1998		1999		2000		2001		2002		2003		2004		Michigan
Age	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	average[a]
0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	180
2	–	–	–	–	390 (6)	–	–	–	–	–	–	–	–	–	264
3	430 (13)	–	430 (13)	–	446 (6)	–	447 (4)	480 (26)	–	–	451 (14)	–	447 (4)	–	353
4	481 (6)	525 (9)	481 (6)	525 (9)	477 (16)		478 (10)	538 (14)	481 (6)	544 (12)	490 (6)	533 (12)	496 (12)	529 (8)	401
5	515 (10)	559 (10)	515 (10)	559 (10)	510 (6)	553 (10)	507 (14)	542 (14)	502 (4)	545 (6)	514 (6)	568 (6)	518 (6)	573 (6)	447
6	530 (11)	585 (33)	530 (11)	585 (33)	529 (6)	580 (12)	530 (10)	606 (14)	535 (8)	547 (8)	533 (6)	588 (6)	542 (4)	599 (6)	488
7	543 (8)	643 (27)	543 (8)	643 (27)	540 (6)	600 (12)	550 (8)	610 (16)	542 (8)	608 (20)	542 (10)	607 (18)	557 (6)	619 (10)	523
8	562 (6)	643 (14)	562 (6)	643 (14)	552 (8)	633 (14)	565 (8)	641 (20)	555 (10)	643 (30)	554 (12)	656 (16)	569 (8)	644 (24)	549
9	582 (7)	663 (9)	582 (6)	663 (9)	569 (4)	632 (14)	582 (6)	646 (20)	582 (14)	663 (18)	582 (22)	678 (16)	585 (10)	681 (12)	569
10	597 (7)	678 (11)	597 (7)	678 (11)	589 (6)	672 (14)	582 (10)	688 (16)	578 (12)	646 (48)	575 (12)	703 (14)	607 (8)	684 (16)	586
11	604 (12)	699 (13)	604 (12)	699 (13)	599 (8)	677 (20)	600 (12)	702 (12)	596 (20)	698 (26)	600 (30)	710 (14)	–	715 (12)	–
12	608 (31)	708 (17)	608 (31)	708 (17)	614 (20)	702 (18)	613 (18)	705 (14)	–	–	–	725 (24)	–	735 (22)	–
13	–	–	–	–	–	–	–	741 (26)	–	–	–	–	–	–	–

[a] Sexes combined, from Schneider et al. (2000).

Table 30.–Tag return matrix for walleyes tagged at Dow Dam, Tittabawassee River during spring, 1990–2004.

Tag year	Recovery year 1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Total returns	Recovery rate
1990	59	52	51	33	9	6	4	5	1	1	3	0	0	0	1	225	2.37
1991	–	71	109	49	16	9	11	11	4	7	2	1	3	2	0	295	2.56
1992	–	–	165	83	30	21	14	11	12	11	6	2	1	0	0	358	5.56
1993	–	–	–	150	52	31	24	17	13	15	9	5	3	0	1	320	4.90
1994	–	–	–	–	76	52	44	36	18	16	12	2	1	1	1	259	2.50
1995	–	–	–	–	–	55	50	45	30	32	9	3	2	3	0	229	2.00
1996	–	–	–	–	–	–	73	74	54	47	20	10	9	3	0	290	2.68
1997	–	–	–	–	–	–	–	84	82	58	19	11	12	11	1	273	3.08
1998	–	–	–	–	–	–	–	–	95	69	24	19	13	10	7	237	3.64
1999	–	–	–	–	–	–	–	–	–	127	38	28	25	15	8	241	4.17
2000	–	–	–	–	–	–	–	–	–	–	86	45	49	45	13	238	2.77
2001	–	–	–	–	–	–	–	–	–	–	–	80	88	38	22	228	2.66
2002	–	–	–	–	–	–	–	–	–	–	–	–	156	58	36	250	4.74
2003	–	–	–	–	–	–	–	–	–	–	–	–	–	93	57	150	3.28
2004	–	–	–	–	–	–	–	–	–	–	–	–	–	–	92	92	3.07
Mean																	3.35
Total	59	123	325	315	183	174	220	283	309	383	228	206	362	279	239	3,688	

Table 31.–Walleye year class percent composition in the Saginaw Bay sport fishery, estimated April–October sport harvest with 2 SE of the harvest estimate, corrected annual exploitation rate, and total annual mortality rate, 1992–2004.

Year class	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1981	1.3	0.6	0.2	–	–	–	–	–	–	–	–	–	–
1982	3.1	2.1	–	0.7	0.2	–	–	–	–	–	–	–	–
1983	4.5	4.1	1.8	1.4	2.2	0.6	–	–	–	–	–	–	–
1984	4.9	4.8	4.4	4.2	2.7	2.4	0.2	–	–	–	–	–	–
1985	10.7	12.7	8.4	8.7	7.7	3.6	1.2	–	–	–	–	–	–
1986	18.3	10.6	11.6	9.7	10.2	6.7	2.5	–	0.9	–	–	–	–
1987	11.6	7.6	9.2	8.3	6.2	6.1	3.5	0.5	0.5	0.3	–	–	–
1988	16.5	14.1	13.8	11.1	7.0	6.7	3.7	0.5	1.1	0.8	0.7	–	–
1989	24.6	23.0	17.6	16.3	11.7	5.2	9.6	5.8	3.4	2.0	1.1	–	–
1990	4.5	15.5	14.8	12.7	9.2	9.7	11.3	9.7	3.9	2.9	2.0	0.4	0.3
1991	–	4.9	17.8	20.3	19.0	18.2	12.5	12.3	4.6	7.1	2.9	1.6	0.3
1992	–	–	0.4	6.4	6.7	11.5	8.0	8.9	8.7	6.6	4.0	1.4	0.6
1993	–	–	–	0.2	1.2	1.2	3.3	5.8	6.2	5.6	4.7	2.1	0.8
1994	–	–	–	–	15.7	25.2	28.1	24.9	13.5	7.8	6.7	5.4	2.5
1995	–	–	–	–	–	3.0	15.4	15.0	11.6	7.6	4.7	7.2	4.2
1996	–	–	–	–	–	–	0.6	4.7	3.2	3.0	5.1	7.9	6.4
1997	–	–	–	–	–	–	–	11.8	16.4	12.8	13.3	13.0	5.8
1998	–	–	–	–	–	–	–	–	26.0	40.8	37.8	21.9	10.0
1999	–	–	–	–	–	–	–	–	–	2.7	11.8	18.2	17.8
2000	–	–	–	–	–	–	–	–	–	–	5.3	10.3	10.8
2001	–	–	–	–	–	–	–	–	–	–	–	10.7	33.3
2002	–	–	–	–	–	–	–	–	–	–	–	–	6.9
Number aged	224	631	500	424	401	330	512	990	438	593	450	516	360
Harvest (no) [a]	64,447	125,160	68,170	47,887	47,566	78,128	80,801	43,747	58,018	44,178	45,244	66,734	60,188
2 SE of harvest no	(8,702)	(18,357)	(11,907)	(9,208)	(9,990)	(15,109)	(11,614)	(16,893)	(28,002)	(17,832)	(21,452)	(25,587)	(21,845)
Exploitation	12.8	11.7	5.9	4.3	5.7	6.5	8.9	9.9	6.1	6.2	12.0	7.0	7.2
Total mortality [b]	39.8	34.6	22.9	39.5	24.6	32.7	28.8	52.5	44.8	46.8	21.8	44.4	–

[a] Numbers of fish, from previous MDNR creel survey reports.
[b] Annual rate for last year cannot yet be calculated.

Table 32.–Yellow perch year class percent composition in Saginaw Bay sport fishery, mean weight, and estimated April–October sport harvest by number with 2 SE of the harvest estimate and by weight 1992–2004.

Year class	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1981	0.1	–	–	–	–	–	–	–	–	–	–	–	–
1982	0.6	0.1	–	–	–	–	–	–	–	–	–	–	–
1983	1.4	0.1	0.4	–	–	–	–	–	–	–	–	–	–
1984	3.9	0.9	0.9	0.4	–	–	–	–	–	–	–	–	–
1985	10.3	2.6	2.3	0.9	–	–	–	–	–	–	–	–	–
1986	18.4	5.9	3.7	2.3	0.3	–	–	–	–	–	–	–	–
1987	24.3	14.7	7.1	3.7	0.6	–	–	–	–	–	–	–	–
1988	24.5	20.4	11.7	7.1	1.7	–	0.2	–	0.1	–	–	–	–
1989	13.4	23.2	22.8	11.7	3.6	0.3	0.2	0.1	0.3	–	–	–	–
1990	3.1	21.6	34.6	22.8	10.3	1.3	0.5	0.1	0.5	–	–	–	–
1991	–	10.2	11.7	34.6	22.6	3.9	1.7	0.1	1.6	–	–	–	–
1992	–	0.2	2.8	11.7	17.8	3.0	1.5	0.4	2.1	–	–	–	–
1993	–	–	–	4.5	24.5	6.0	3.3	0.8	5.1	0.4	0.2	–	–
1994	–	–	–	0.2	18.4	34.7	16.3	4.3	6.4	0.8	0.1	0.1	–
1995	–	–	–	–	0.2	50.0	56.3	17.6	10.0	2.2	0.2	–	0.1
1996	–	–	–	–	–	0.9	19.4	26.1	20.0	7.6	0.7	0.3	0.4
1997	–	–	–	–	–	–	0.5	48.4	29.6	27.8	9.9	2.6	1.0
1998	–	–	–	–	–	–	–	2.2	23.5	49.2	36.3	10.0	2.7
1999	–	–	–	–	–	–	–	–	0.8	11.9	35.4	13.7	4.0
2000	–	–	–	–	–	–	–	–	–	0.2	11.7	22.4	9.8
2001	–	–	–	–	–	–	–	–	–	–	5.3	49.6	58.5
2002	–	–	–	–	–	–	–	–	–	–	0.3	1.3	19.6
2003	–	–	–	–	–	–	–	–	–	–	–	–	3.9
No. aged	1,759	1,451	1,228	1,373	1,239	880	959	1,659	1,535	1,160	1,217	1,039	957
Mean weight (grams) [a]	155	129	142	122	94	93	117	102	115	128	142	112	165
Harvest (no) [a]	1,126,014	737,257	1,432,819	775,749	536,640	1,102,064	782,785	955,889	323,986	590,123	287,233	358,789	99,612
2 SE harvest number	134,539	102,792	213,852	138,141	84,949	154,811	108,126	218,871	134,211	211,210	129,229	160,092	56,636
Harvest (kgs)	174,532	95,106	203,460	94,641	50,444	102,492	91,586	97,501	37,258	75,536	40,787	40,184	16,436

[a] Numbers of fish, from previous MDNR sport fishing survey reports.

Table 33.–Annual total effort, total catch, and CPUE for the small-mesh trap-net commercial fishery on Saginaw Bay (unpublished data from MDNR commercial fish reporting system).

Year	Annual total effort (lifts)	Annual total catch (kg)	CPUE (kg/lift)
1971	396	8,693	22.0
1972	6,250	136,024	21.8
1973	6,963	135,309	19.4
1974	6,375	103,088	16.2
1975	7,461	121,314	16.3
1976	7,112	145,736	20.5
1977	6,423	116,205	18.1
1978	5,603	74,631	13.3
1979	5,150	76,124	14.8
1980	4,901	88,003	18.0
1981	5,440	82,781	15.2
1982	5,721	68,498	12.0
1983	7,435	60,999	8.2
1984	6,815	53,359	7.8
1985	5,282	35,918	6.8
1986	5,482	30,659	5.6
1987	5,855	44,127	7.5
1988	4,763	40,024	8.4
1989	5,249	33,118	6.3
1990	5,110	40,456	7.9
1991	4,367	51,386	11.8
1992	4,968	45,862	9.2
1993	4,202	34,212	8.1
1994	4,733	45,065	9.5
1995	4,708	55,276	11.7
1996	4,161	48,470	11.6
1997	4,800	42,178	8.8
1998	3,910	33,544	8.6
1999	3,943	46,688	11.8
2000	3,344	41,898	12.5
2001	3,731	50,543	13.5
2002	3,088	33,123	10.7
2003	1,704	20,337	11.9
2004	2,069	20,661	10.0

Table 34.–Proportional contribution of stocked walleyes to the 1997–2004 walleye year classes of Saginaw Bay, as determined by oxytetracycline mark detection analysis for two ages of juveniles.

Year class	Age-0	Age-1	Composite
1997	81	50	69
1998	81	83	82
1999	85	84	85
2000	96	94	95
2001	61	61	61
2002	85	91	88
2003	28	21	24
2004	19	–	19

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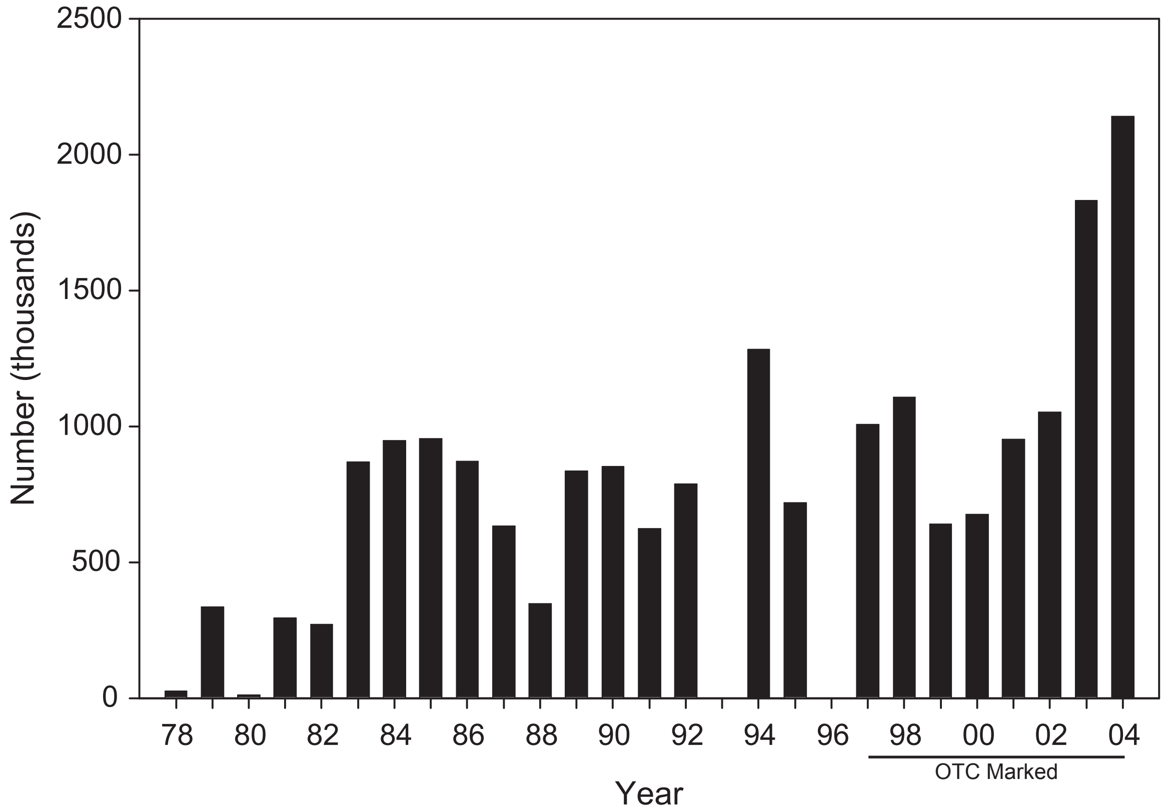
Appendix 1.–Common and scientific names of fishes and other aquatic organisms mentioned in this report. The age groups for those species considered forage in this report are designated with "All" for all ages, or "YOY" for young of year.

Common name	Scientific name	Forage
Alewife	*Alosa pseudoharengus*	All
Bigmouth buffalo	*Ictiobus cyprinellus*	
Black crappie	*Pomoxis nigromaculatus*	
Bluegill	*Lepomis macrochirus*	
Bowfin	*Amia calva*	
Brown bullhead	*Ameiurus nebulosus*	
Brown trout	*Salmo trutta*	
Burbot	*Lota lota*	
Common carp	*Cyprinus carpio*	
Channel catfish	*Ictalurus punctatus*	YOY
Chinook salmon	*Oncorhynchus tshawytscha*	
Emerald shiner	*Notropis atherinoides*	
Freshwater drum	*Aplodinotus grunniens*	YOY
Gizzard shad	*Dorosoma cepedianum*	YOY
Goldfish	*Carassius auratus*	
Johnny darter	*Etheostoma nigrum*	All
Lake herring	*Coregonus artedi*	
Lake sturgeon	*Acipenser fulvescens*	
Lake trout	*Salvelinus namaycush*	
Lake whitefish	*Coregonus clupeaformis*	
Longnose gar	*Lepisosteus osseus*	
Longnose sucker	*Catostomus catostomus*	
Muskellunge	*Esox masquinongy*	
Northern pike	*Esox lucius*	
Shorthead redhorse	*Moxostoma macrolepidotum*	
Pink salmon	*Oncorhynchus gorbuscha*	
Quagga mussel	*Dreissena bugensis*	
Pumpkinseed	*Lepomis gibbosus*	
Quillback	*Carpoides cyprinus*	
Rainbow smelt	*Osmerus mordax*	All
Rainbow trout	*Oncorhynchus mykiss*	
Redhorse spp.	*Moxostoma* spp.	
Rock bass	*Ambloplites rupestris*	
Round goby	*Neogobius melanostomus*	All
Round whitefish	*Prosopium cylindraceum*	
Shortnose gar	*Lepisosteus platostomus*	
Smallmouth bass	*Micropterus dolomieui*	
Spottail shiner	*Notropis hudsonius*	All
Stonecat	*Noturus flavus*	
Sunfish spp.	*Lepomis* spp.	
Trout-perch	*Percopsis omiscomaycus*	All
Walleye	*Sander vitreus*	YOY
White bass	*Morone chrysops*	YOY
White perch	*Morone americana*	All
White crappie	*Pomoxis annularis*	
White sucker	*Catostomus commersoni*	YOY
Yellow perch	*Perca flavescens*	All
Zebra mussel	*Dreissena polymorpha*	

Appendix 2.–Walleye fingerling stocking in Saginaw Bay by the MDNR, 1978–2004. Fingerlings were pond-reared "spring fingerlings" approximately 42 mm in total length.



Appendix 3.–Mean CPUE (number of fish per 10-minute sample) for common species collected during fall bottom trawling in Saginaw Bay, 1971–2004, including data previously reported by Weber (1985), Haas and Schaeffer (1992), Fielder et al. (2000). Dash (–) = data not available.

Year \ Species	Alewife	Channel catfish	Carp	Emerald shiner	Freshwater drum	Gizzard shad	Johnny darter	Lake whitefish	Pumpkinseed	Quillback	Smelt	Rock bass	Round goby	Shorthead redhorse	Spottail shiner	Trout-perch	Walleye	White bass	White perch	White sucker	Yellow perch	Number of tows
1971	126	1	2	4	0	3	–	–	–	–	392	–	0	–	94	45	0	0	0	1	196	30
1972	109	1	4	3	0	1	–	–	–	–	375	–	0	–	419	100	0	0	0	1	151	15
1973	3	3	2	0	0	2	–	–	–	–	287	–	0	–	16	11	0	0	0	1	104	17
1974	8	14	9	1	0	22	–	–	–	–	139	–	0	–	192	120	0	0	0	1	256	30
1975	22	17	2	1	1	17	–	–	–	–	220	–	0	–	435	47	0	0	0	1	573	20
1976	41	1	1	0	0	370	–	–	–	–	780	–	0	–	94	9	0	0	0	0	272	20
1977	13	1	2	19	1	4	–	–	–	–	65	–	0	–	449	28	0	0	0	9	392	21
1978	72	1	1	0	0	147	–	–	–	–	499	–	0	–	563	25	0	0	0	5	286	18
1979	353	4	3	1	1	5	–	–	–	–	337	–	0	–	712	177	0	0	0	9	661	18
1980	84	11	1	0	1	48	–	–	–	–	802	–	0	–	442	45	0	0	0	1	703	20
1981	289	5	3	0	0	3	–	–	–	–	98	–	0	–	849	56	0	0	0	5	393	17
1982	127	1	0	3	4	2	–	–	–	–	266	–	0	–	212	30	1	3	0	15	1,319	13
1983	1,030	1	1	54	11	39	–	–	–	–	58	–	0	–	1,237	255	0	0	0	7	384	17
1984	58	3	1	3	8	7	–	–	–	–	250	–	0	–	787	148	0	10	0	14	444	12
1985	18	3	1	11	15	11	–	–	–	–	202	–	0	–	165	315	2	4	1	6	362	24
1986	304	3	6	242	17	11	3	0	0	0	366	0	0	0	285	157	1	13	11	6	420	46
1987	57	4	3	42	4	29	3	0	1	2	210	0	0	0	470	167	1	1	58	6	476	67
1988	86	4	5	55	1	41	3	0	0	7	176	0	0	0	107	54	3	10	168	4	258	38
1989	226	2	6	57	9	169	0	0	0	1	221	0	0	0	340	232	3	3	2,321	3	799	15
1990	16	5	5	45	23	46	1	0	0	0	48	0	0	0	198	135	2	4	682	11	151	16
1991	81	0	3	15	25	49	1	0	0	0	44	0	0	0	124	166	6	6	412	12	192	16
1992	302	0	3	9	3	0	11	0	0	0	280	0	0	0	182	200	1	0	92	8	75	36
1993	226	1	3	1	10	20	11	0	0	1	562	0	0	0	101	438	1	2	30	11	41	37
1994	48	6	9	0	28	9	11	0	0	1	58	0	0	0	203	513	2	6	183	10	24	32
1995	307	3	7	0	28	7	29	1	0	1	22	0	0	0	373	513	1	1	528	7	125	33
1996	99	6	4	1	16	23	21	0	0	1	15	0	0	0	209	474	1	0	277	8	85	30
1997	301	2	4	13	5	18	20	1	0	0	1,585	0	0	0	808	741	3	4	416	28	122	31
1998	1,592	3	8	2	28	23	5	0	0	0	50	0	0	0	549	1,175	7	2	303	11	149	27
1999	82	5	6	1	9	3	6	0	2	4	32	5	4	0	1,935	406	7	0	141	10	87	27
2000	363	7	6	1	18	3	4	0	0	1	433	0	137	0	1,019	685	2	0	984	7	39	30
2001	1,101	8	8	1	10	10	1	0	0	4	349	0	306	0	691	411	2	0	600	22	157	25
2002	369	5	6	1	12	20	0	1	0	2	161	0	368	0	1,036	439	4	0	330	28	70	35
2003	733	3	5	1	10	18	0	0	0	4	449	0	156	0	1,367	545	44	14	502	42	2,471	27
2004	9	1	6	2	7	2	0	1	0	1	213	0	365	0	213	450	28	40	287	19	490	36

Appendix 4.–Length-weight regression equations and von Bertalanffy growth equations for select species derived from Saginaw Bay fall gill net data collected in 2004 and 1998–2004, respectively. *W* = Weight in grams; L = 1ength in mm; and *t* = age in years.

Species	Length-weight equation	r^2	Von Bertalanffy equation	K	L∞	t_o
Walleye	$Log_{10}(W) = 3.123\ log_{10}(L) - 5.375$	0.97	$L_t = 622[1\text{-}e^{-0.3481(t+1.95)}]$	0.3481	622	-1.95
Yellow perch	$Log_{10}(W) = 2.888\ log_{10}(L) - 4.627$	0.92	$L_t = 351[1\text{-}e^{-0.1336(t+2.95)}]$	0.1336	351	-2.96
Channel catfish	$Log_{10}(W) = 3.197\ log_{10}(L) - 5.565$	0.94	$L_t = 632[1\text{-}e^{-0.1943(t+0.62)}]$	0.1943	632	-0.62