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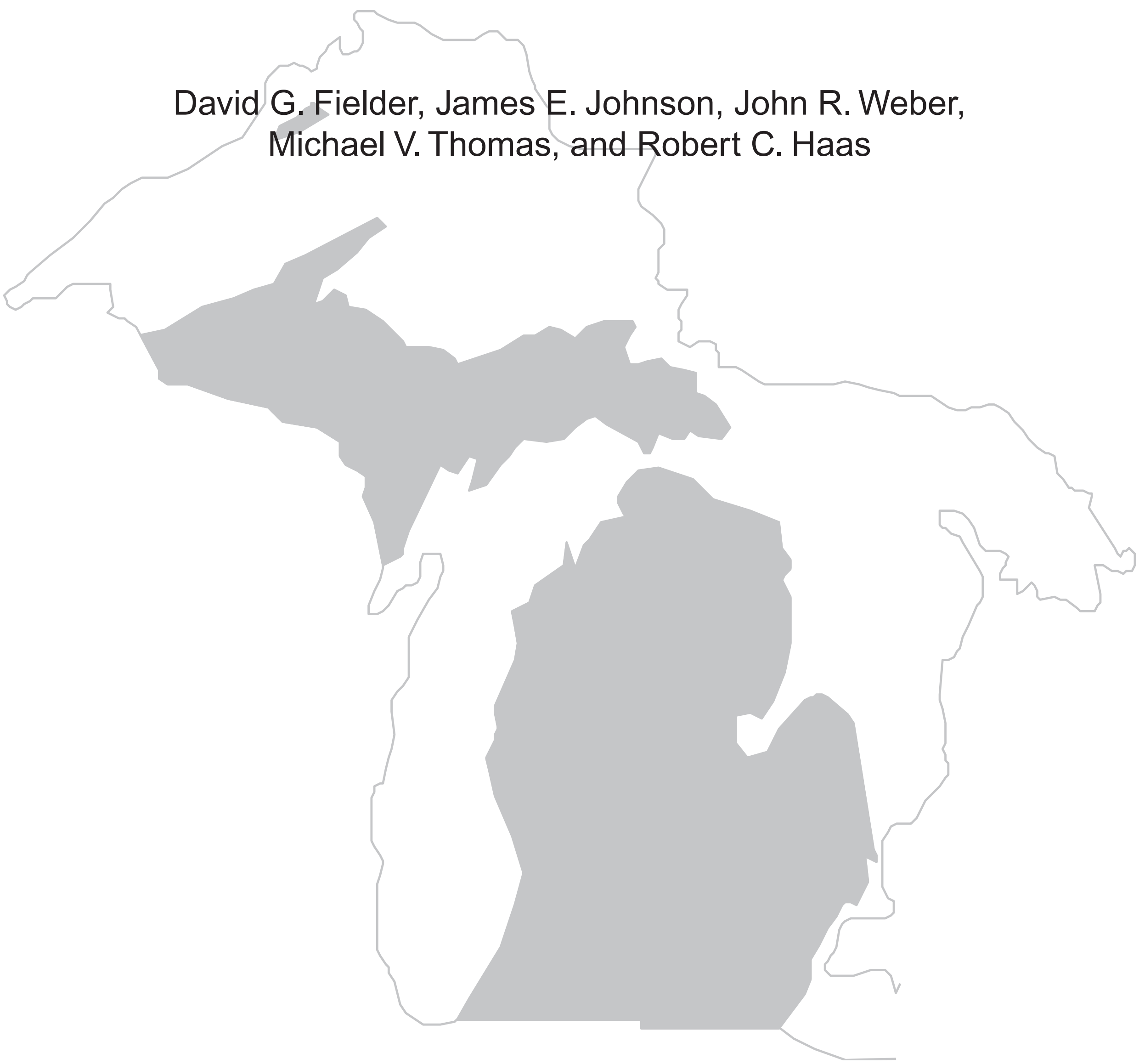

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Fish Population Survey of Saginaw Bay, Lake Huron, 1989-97

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Abstract.–In this study we investigated the overall fish community, and the population dynamics of yellow perch *Perca flavescens* and walleye *Stizostedion vitreum* in Saginaw Bay, Lake Huron. Field sampling was conducted from 1989 through 1997. Sampling was done by gill net, and bottom trawl. Spawning walleye were tagged in a bay tributary. In spite of the resurgence of walleye in the 1980s, Saginaw Bay remains an ecosystem characterized by an over abundance of forage fish and an under abundance of top predators. Trawl catch rates suggested that zebra mussel colonization of the bay in the early 1990s was accompanied by a shift in much of the forage fish community from pelagic planktivores towards benthic species. Despite this shift, abundance of walleye in Saginaw Bay did not change appreciably during the study. Declines in gill-net catch-per-unit-effort may be attributed to confounding effects of migration and changes in vulnerability to the gear, probably fueled by increased water clarity. No changes in distribution of walleye within the bay were evident as a result of zebra mussel colonization. Since the 1980s, walleye age structure has shifted towards older fish. Walleye growth was extremely fast and the population did not appear to be food limited. Walleye recruitment was relatively weak in 1992, 1993, and 1996. The latter two year classes corresponded to years of no stocking. This pattern of year class strength held up in the sport fishery and in the spawning run to the Tittabawassee River. Walleye exploitation was low, averaging 8.5%. Walleye total annual mortality for this time period was just 28.3%. We found evidence of both walleye immigration and emigration from the bay making interpretation of these statistics more difficult. During the study period, trawl catch rates documented a shift in yellow perch from high density and poor growth to a lower density with improved growth. Explanations for this shift may include decreased recruitment, improved food resources (larger, more abundant benthic invertebrates) as a result of zebra mussel colonization, and reduced infection by parasites. Walleye did not select yellow perch for a primary food source, but principally consumed alewife *Alosa pseudoharengus* and gizzard shad *Dorosoma cepedianum*, so the decline in yellow perch was not caused by

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walleye predation. Work towards full walleye recovery (population at carrying capacity) remains the single best means by which to restore balance to the bay's aquatic ecosystem. Other recommendations include dam removal or fish passage, to encourage natural reproduction of walleye and other river-spawning species.

Knowledge of the history of the fisheries of Saginaw Bay, Lake Huron is important for successful management. During 1912-40, Saginaw Bay accounted for over 28% of Lake Huron's commercial fish yield (Baldwin and Saafeld 1962). Commercial harvest in the bay dates back to the 1830s (Lanman 1839). Commercial harvest records indicate that the fish community was composed of walleye (see Appendix 1 for a complete list of all scientific and common names of fishes and aquatic organisms mentioned in this report), yellow perch, channel catfish, white sucker, northern pike, and several centrarchid species (Keller et al. 1987). In addition, harvest of lake trout, lake herring, and lake whitefish occurred both seasonally and in the outer portion of the bay (Baldwin and Saafeld 1962, Keller et al. 1987). Fishery production peaked in 1902 and declined steadily through the 1970s.

Historically, Saginaw Bay produced the second largest walleye fishery in the Great Lakes (Schneider and Leach 1977) but declined by the mid 1900s. Deterioration of habitat due to siltation, eutrophication, and industrial pollution have been identified as primary causes. Loss of spawning habitat was attributed principally to sedimentation of substrate. Construction of dams, which blocked spawning migrations, also contributed to loss of habitat. The invasion of exotic planktivores, such as rainbow smelt and alewives, further suppressed walleye recruitment. In the face of these perturbations, the remaining fishery was over-harvested during the 1940s by commercial operations (Schneider 1977; Schneider and Leach 1977). Attempts to stock walleye fry in the 1940s failed to establish significant recruitment. Many native species, such as lake herring, also declined with the loss of top predators and the invasion of exotics (Keller et al. 1987).

Recovery of the bay's fisheries began with passage of the Federal Clean Water Act in 1972. Partial control of exotic planktivores was achieved through stocking of salmonids in Lake Huron. The deteriorating commercial walleye fishery was formally closed in 1970, although this was primarily in response to concerns about mercury contamination. Commercial fishing in Saginaw Bay continues today for some species including yellow perch, common carp, lake whitefish, and channel catfish. Stocking of fry and fingerling walleye was resumed in 1972 by the Michigan Department of Natural Resources (MDNR). Fingerling stocking developed in earnest by 1982 and annual plantings approached 1 million fish during the 1990s (MDNR 1982).

Since the early 1980s, a major sport fishery has developed in the bay, largely in response to the re-establishment of walleye. From 1991-97, there was an annual average of 287,500 angler trips during the open water months of April through October (Rakoczy 1992; Rakoczy and Svoboda 1994; and G. Rakoczy, MDNR, personal communication). The average annual harvest during this period was 1,237,000 fish. Yellow perch dominated the harvest in numbers, making up over 90% in most years. The Saginaw Bay fishery accounted for 58% of the total fishing effort on the Michigan waters of Lake Huron for 1991-92. Saginaw Bay accounted for 86% of all the sport harvest by number on the Michigan waters of Lake Huron during that same time period (Rakoczy and Svoboda 1994).

Since 1980, large runs of spawning walleye have developed in the Tittabawassee River and other tributaries of the Saginaw River system. A current MDNR research priority is to determine the source of walleye recruitment to the bay. Three techniques have been employed to measure evidence of natural reproduction: fry sampling prior to stocking dates; interruptions in stocking in 1993 and 1996; and marking with oxytetracycline. All three approaches have indicated that at least some natural reproduction of walleye is occurring (Jude 1992, D.G. Fielder, MDNR, Alpena Fisheries Research Station, unpublished data).

A number of exotic fish and invertebrate species invaded the bay during the 1980s and 1990s, including white perch, zebra mussel, and round goby. This study will serve as an important source of information for gauging the impacts of exotic species invasions.

The MDNR began an index trawling program in 1970 to monitor trends in abundance of forage fish species, particularly yellow perch, in Saginaw Bay. The trawl survey has been conducted during fall. Previous research reports have summarized results of the index trawl program for various time periods. Weber (1985) summarized the trawling index results for 1970 to 1984. Haas and Schaeffer (1992) updated the results of the trawling program through 1991. Gill netting was begun in 1989 to provide biological and abundance information on adult fish and predator species, as well as to provide additional information on some forage species.

Regular monitoring of the status of the fish community is fundamental to management of Saginaw Bay's fisheries. This report, based on data from 1989 through 1997, provides information on abundance, recruitment, size and age structure, condition, and growth rates for many species collected. It also evaluates presence of invading exotic species, food habitats for select species; as well as movement, exploitation, and total mortality rate of walleye. The objectives of this study were to provide annual measurements and analysis of trends for the above parameters, to archive data for future use, and to provide an information base for formulating fishery management recommendations.

Study Area

Saginaw Bay lies entirely in Michigan's 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 industry and agriculture. There are several tributary systems to the bay, the largest being the Saginaw River. Water circulates in a counterclockwise direction in the bay (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 was detailed by Smith et al. (1977).

Methods

Trawling

Since the 1980s, trawling locations in the inner bay have been based on a 2-minute latitude x 2.8-minute longitude grid system. Data from the grids were then summarized for groups of girds constituting quadrants. Fish were collected in fall each year from the MDNR research vessel *Channel Cat* with trawls within three fixed index grids in the inner bay: Au Gres (north quadrant), Pinconning (south 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 was the closest to the mouth of the Saginaw River and substrate is comprised of 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 1 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 daylight between 15 September and 10 October are discussed in this report. Trawling gear was a 10.66-m headrope otter trawl with a 9-mm stretched mesh cod end, towed with a single warp and a 45.7-m bridle. A standard tow was made with the trawl on the bay bottom for 10 minutes at approximately 2.0 knots. Water temperature and Secchi disk depth were recorded at each trawling site. Some trawling data were supplemented with results from 1986-88 to facilitate interpretation and were either from Haas and Schaeffer (1992) or were MDNR, unpublished data.

Fish collected with trawls were identified and enumerated. Total weight and number for each species were recorded. Trawl tows with high forage fish catches were subsampled. Catches exceeding 10 kg were often subsampled by selecting 25% to 40% of the total catch for measurement of total number and weight (in g) for each species. Length-frequency distributions were developed for at least 150 individuals of each forage species, including young-of-the-year (YOY) yellow perch, at the fixed trawl stations.

Scale samples were taken from yellow perch for age and growth analysis. In addition, a maximum of 52 adult and 10 YOY 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.

Yellow perch were thawed in the laboratory, measured, and weighed. Fish were eviscerated, sexed, and checked for redworm, either *Eustrongilides tubifex* or *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 body water content, subsamples of yellow perch and their excised viscera were dried at 90^{o} C for 2 days in a drying oven and weighed to 0.0001 g. Stomach contents were evaluated by counting the number of organisms of each taxon. 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).

Gill Netting

Gill netting of walleye was based on the work of Isbell and Rawson (1989), who showed that gill-net catch could be effectively used as a measure of abundance and recruitment. Gill-net sampling was performed for a minimum of eight sites from the MDNR Research Vessel *Chinook* (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. The 38-mm mesh was added in 1993. Gill nets were fished on the bottom overnight in depths greater than 3 m. Two net sets were normally made at each sample site (Figure 1, Table 2). Catch-per-unit-effort (CPUE) was calculated and expressed as the number of each species per 305 m of net (excluding the 38-mm mesh). Certain sites were omitted from CPUE calculations to maintain comparability among years (Table 2). Catches from all sets were used in analysis of biological data such as length, weight, age, and growth. Yellow and white perch were subsampled from some catches. After 1994, yellow and white perch were subsampled for biological data by including specimens caught from every other net. Prior to 1995, subsampling of yellow and white perch was often done within individual net catches. The exclusion of the catch from the 38-mm mesh for recording and subsequent CPUE calculations for yellow and white perch were not uniformly done each year, requiring that age based abundance data be presented as percents as opposed to CPUE.

Additional netting was done in 1995 and 1996, in an effort to determine if walleye abundance was greater in shallower depths. These gill nets were 61 m long by 2 m deep and were constructed of multifilament mesh comprised of 7.6-m panels of the same mesh sizes used in the standard nets. Nets were fished overnight on the bottom in depths less than 3 m. Catch rate of both the standard (deep) nets and the exploratory (shallow) nets were standardized at 305 m (to compensate for the different net lengths) by extrapolating the catch per m of the short nets to the standard length. Specimens collected in the shallow nets were also included in analysis of age and growth for those years. Shallow-water net sets comprised 18 each year of the 38 total gill-net sets performed in 1995 and 36 in 1996 (Table 2).

Walleye, northern pike, yellow perch, and white perch were examined for total length in mm, weight in g, sex, and maturity. Scales were collected for age interpretation. Walleye were also examined for stomach contents. Percent-abundance for each prey species was calculated each year as the percent of all prey items (including unidentified fish) comprised by each species in all stomachs. All other species in the survey catch were examined for total length. Condition was examined by calculating 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 as reported by Merna et al. (1981).

Walleye Tagging

Walleye tagging was done annually at the Dow Dam site on the Tittabawassee River, a tributary of the Saginaw River system. Tagging was performed during the walleye spawning migration and typically spanned a one-week period in late March or early April. Since 1989, an average of 2,889 walleye was tagged each year. Walleye were collected with a 230-volt DC electrofishing boat, measured, and identified to sex; and scales were taken for age interpretation. Fish were selected for age analysis using a stratified-random design based on length groups. Beginning in 1994, in an effort to collect a more representative subsample, scales were collected from all captured fish, but only those scales from a single day of the run, thought to be most representative, were aged and analyzed to represent age structure. A day near the peak of the run was chosen that appeared to have approximately equal numbers of both sexes.

Tagging was limited to fish $\geq$ 381 mm to ensure vulnerability to the fishery. Serially-numbered monel metal tags with a return postal address were attached to the maxillary bone and walleye were released at the tagging site. Numbers tagged each year did not reflect magnitude of the run. A total of 26,000 walleye have been tagged since 1989.

No rewards were offered for tag returns. There was little formal promotion of the tagging program to encourage returns, however, walleye tagging of this type had been occurring in Saginaw Bay since 1981 and in other Michigan waters of the Great Lakes. Persons reporting tags were sent an informational letter.

Tag recovery data were analyzed for year-specific survival, fishing, and reporting rates using the tag-recovery computer program ESTIMATE, Model 1, (Brownie et al. 1985). The program also estimates mean recovery rate (exploitation rate) and mean survival rate (yielding total mortality estimates) based on both first-year returns and a matrix of returns from multiple years. Estimates for 1989 through 1997 derived added statistical power from return data for previous tagging years (1981-88). Results for that time period were presented by Keller et al. (1987) and Mrozinski et al. (1991). Exploitation was reported using a nonresponse multiplier of 2.72, a factor estimated for Lake Erie based on reward incentives for tag returns (Haas et al. 1988).

Walleye movement was determined by plotting tag return locations. Tag return location was assigned latitude and longitude based on capture location provided by the angler. This information was overlaid as various groupings on a geographic information system. Groups included pre- and post-zebra mussel years, season, and sex. Inferences about movement patterns were made by visual inspection of the spatially mapped output.

Statistical Analysis

Trawl catches should be normally distributed and their variances homogenous for valid applications of ANOVA procedures. Trawl and gill-net data were examined for normality (Lilliefors test) and homogeneity of variance (Bartlett's Test). We used either parametric ANOVA procedures and nonparametric Mann-Whitney and Wilcoxon procedures to test for statistical differences in mean trawl CPUE between a pre-zebra mussel time period (1986-90) and post-zebra mussel period (1993-96).

Gill-net CPUE distributions often failed tests for homogeneity of variance. In those instances, confidence limits for each mean CPUE were estimated using the bootstrap percentile method (Buckland 1984; Effron and Tibshirani 1993).

Scheffé multiple-comparison procedures were used to further evaluate some significant differences detected by ANOVA. ANOVA procedures were also used to test for differences in yellow perch mean length-at-age among years for trawl data, and for walleye, yellow perch and white perch mean length-at-age data from gill-net data. Simple linear regression analysis was used to develop length-weight relationships for some species and to examine correlations within some other data sets. All statistical tests for this study were performed according to Sokal and Rohlf (1981) and conducted at a significance level of P_{α}=0.05. SPSS computer software was used for statistical analyses (SPSS 1997).

Results

Species Composition and Catch Rates for Trawls

From 1986 to 1997, a total of 360 trawl tows were made during daylight hours between 15 September and 10 October (Table 1). Mean annual water temperatures at the trawling sites ranged from 12.4 °C to 18.0 °C, with the coolest temperatures during 1989 and 1990 and the warmest temperatures in 1996 and 1997 (Table 3). Mean Secchi depths ranged from 0.74 to 1.49 m, with the smallest Secchi depth during 1990 and the greatest Secchi depth in 1991 (Table 3).

Species composition of trawl tows varied considerably among years (Table 4). The six most abundant species were alewife, rainbow smelt, spottail shiner, trout-perch, white perch, and yellow perch. In combination, these six species accounted for at least 88% of the total catch each year.

Catch-Per-Unit-Effort, expressed as mean catch per 10-minute tow, also varied considerably among years (Table 5). A few trends in CPUE were apparent. Yellow perch CPUE dropped dramatically after 1989, and remained relatively low through 1997. White perch CPUE increased greatly from 1986 to 1989, declined from 1989 to 1993, and then increased again from 1993 to 1995. Johnny darter CPUE after 1991 was markedly higher than during the 1986 to 1991 period. In general however, consistent trends in annual mean CPUE were not apparent for most species.

Comparison of Trawl Catch Rates During Pre- and Post-Zebra Mussel Periods

Comparison of mean CPUE between two time periods, pre- (1986-90), and post-zebra mussels (1993-97) indicated a consistent decline in catch rates for planktivorous species and increased catch rates for benthivorous species after the zebra mussel invasion (Table 6). Emerald shiner, gizzard shad, and spottail shiner all had lower CPUE during 1993-97. In contrast, mean catch rates for freshwater drum, johnny darter, trout-perch, and white sucker were significantly higher during 1993-97. Catch rates for yellow perch also declined significantly in 1993-97. However, catch rates of all age groups of yellow perch declined dramatically in 1990, prior to zebra mussel colonization (Table 7), and remained depressed thereafter. Three very poor cohorts were produced consecutively after zebra mussel colonization, 1992-94, but recruitment rebounded somewhat in 1995 and 1997.

Mean total length for the major forage species also differed between the pre- and post-zebra mussel periods (Table 8). Alewife, gizzard shad, rainbow smelt, spottail shiner, trout-perch, and white perch experienced significant declines in mean length during the post zebra mussel period. No forage species exhibited an increase in mean length between the two time periods.

Growth, Condition, and Diet of Yellow Perch from Trawls

The length-frequency distribution of yellow perch captured in fall trawls shifted towards larger size groups during the 1990s (Table 9). The proportion of yellow perch in the catch exceeding 200 mm in total length was greater than 10% for five out of seven years after 1990, compared to less than 3% prior to 1991. Similarly, the proportion of yellow perch exceeding 216 mm in total length (the current minimum length limit for the commercial yellow perch fishery in the bay) was much higher in 1991 and 1993-97, than in 1986-90.

A gradual increase in mean length-at-age of yellow perch has been underway since 1989 (Table 10). The increase is particularly evident for age 1-4 fish. Mean length-at-age for the sexes combined exceeded the statewide average for age 1-3 yellow perch for five consecutive years from 1993 to 1997.

Both male and female yellow perch experienced steadily-increasing rates of infection by redworm from 1986-88 (Table 11). The mean infection rate for this period was 72% for males and 70% for females. However, the infection rate declined in the 1990s; we found an infection rate of 53% for males and 56% for females during 1993-97.

Yellow perch condition, as reflected by body water content, improved in the post-zebra mussel period. For males, percent water for ages 2-6 exhibited statistically-significant declines for ages 4-6, indicating higher lipid content during 1993-97 (Table 12). Females of ages 2-6 showed a decline in percent water, with statistically-significant declines for ages 2-6. For both sexes, the greatest improvement in condition occurred in age 4 and older fish.

Stomach contents were examined from 864 yellow perch from fall trawls beginning in 1991 (no yellow perch were collected for diet analysis in 1989, 1990, or 1993). Since sample sizes have been limited since 1991, it was not practical to analyze differences between sexes or age groups. There were few trends or patterns across years in frequency-of-occurrence (Table 13). Zooplankton continued to be numerically dominant, occurring in 60% or more of the non-empty stomachs each year. Similarly, chironomid larvae occurred in a high proportion of the non-empty stomachs each year. Other large food items, such as fish and larger invertebrates (mayfly and caddis fly larvae) continued to occur at much lower frequencies.

Colonization of the bay by zebra mussels and spiny water fleas was reflected in the diet. Zebra mussels were first found in perch stomachs in 1991 and have been observed in the diet each year since. Spiny-water fleas were first found in perch stomachs in 1992, and were quite common in the diet during 1992, 1994, and 1995.

Species Composition and Catch Rates for Gill Netting

A total of 142 net sets were made between 1989 and 1997, yielding 18,787 fish. CPUE of walleye has generally declined in recent years while yellow perch CPUE fluctuated over the study period (Table 14). White perch have fluctuated in CPUE as well. Other relatively abundant species included channel catfish, freshwater drum, gizzard shad, and white sucker. Northern pike occurred in very low numbers. Species making seasonal appearances in the bay, or those with a more pelagic existence, were probably under represented in this sampling.

Catch rates for select species were compared between shallow (<3m) and standard (>3m) depths in 1995 and 1996 (Table 15). Consistent differences could only be found for yellow perch, which were more abundant at shallower depths, and channel catfish, which were more abundant at deeper depths. No difference in catch rate was found for walleye.

Comparisons of outer- and inner-bay catch rates showed no consistent difference for any species (Table 16). Yellow perch catch rate was significantly greater in the inner bay in 1996 but not in 1995. Walleye catch rates were significantly greater in the inner bay only in 1995.

Recruitment and Year-Class Strength Based on Gill-Net Catch

Gill-net catch rates for most species generally declined sharply after 1991 (Table 14). The decline was most pronounced in walleye, white suckers, and channel catfish. Even catch rates of large cohorts of walleye declined sharply after 1991 (Table 17). For example, the CPUE of the 1988, 1989, and 1990 year classes declined by 81%, 88%, and 75% (respectively) in 1991-92 (relative to an expected decline of approximately 30%). This sharp decline across species and among walleye cohorts suggests a change in gill-net vulnerability, which compromises the utility of CPUE as an index of abundance. It also precludes catch curve or cohort-based CPUE analysis, one assumption for which is that gear vulnerability is equal across fish sizes and sampling years (Ricker 1987). Therefore, we considered both CPUE and the percent-contribution of yearling walleye as indicators of year class strength (Table 17, Figure 2). Both indices indicate the 1989 and 1990 year classes to be exceptionally strong. Similarly, they both indicate moderate strength of the 1988 year class. The CPUE and percent-contribution indices, however, diverge over certain year classes starting with the 1992 survey year (Table 17). The indices both strongly disagree over the 1991, 1994, and 1995 year classes, with the percent-contribution index indicating each as moderate to strong.

This measure (percent-contribution) of local recruitment appears to reflect the pattern of strong and weak year classes in the fishery and in the spawning run at the Tittabawassee River. Regression analysis indicated that the percent of yearling walleye in the gill-net catch accounted for 77% of the variability of the same year classes in the bay fishery at age 3 and 58% at age 4 (Figure 3). The same data accounted for 89% of the variability of age-4 fish in the spawning run in the Tittabawassee River (Figure 3). The weak year classes at least partially account for a significant increase in mean age in recent years.

Confidence in CPUE of Yellow perch was similarly compromised by the change in gear vulnerability and further complicated by some inconsistencies in data collection over the span of the survey. Proportions of yellow perch and white perch by age, however, do allow some examination of age-specific abundance changes and also suggest some variability in recruitment (Table 18). However, these species are not fully recruited to the gill nets until later ages. Mean age of yellow perch declined over the survey period but was probably an artifact of the addition of the 38-mm mesh. Accelerated recruitment to the sampling gear by faster-growing young yellow perch could also account for the observed changes. White perch showed no trend in mean age (Table 18).

Age interpretation of channel catfish has just recently been added to this study. Data for survey year 1997 suggests these fish recruited to the gill nets at age 2 (Table 19). There were not enough data to develop recruitment patterns or estimate mortality rates.

Growth, Condition, and Diet of Selected Species Based on Gill-Net Data

Walleye growth in Saginaw Bay was very fast. Since 1989 the mean length of walleye at nearly every age in every survey year has exceeded state average (Table 20). Growth rates also greatly exceeded those exhibited historically in Saginaw Bay (Hile 1954). This fast growth indicates the population exists at levels below the carrying capacity of the bay. Increases in number of year classes and mean length reflected the expansion of this population after its resurgence in the 1980s.

Similar analysis for yellow perch (Table 20) indicated a situation opposite that of walleye. Growth rates of yellow perch were below state average for nearly all ages. There has, however, been some improvement in growth rate in recent years. The slow growth was less pronounced for younger perch (ages 1-3).

Condition of walleye, as indicated by relative weight, showed no appreciable trend over the survey years (Table 21). Length/weight regression equations for walleye, yellow perch, and white perch are shown in Appendix 2. Higher overall condition of walleye in 1989 and 1990 probably resulted from the better condition of smaller sized fish. Yellow perch exhibited average condition in recent years, despite slow growth. Two years of lower condition were apparent in 1991 and 1992 (Table 21).

Gizzard shad and alewife were the most frequent items in the diet of walleye at the time of the survey (Table 22). Other species regularly consumed over the survey years were yellow perch and spottail shiners.

Population Size Structure Based on Gill-Net Catch

The PSD of the walleye population exceeded that normally recommended (30-60) for a balanced walleye population (Table 23; Anderson and Weithman 1978). A substantial proportion of walleye was in the preferred and memorable size ranges (Figure 4). This is probably attributable to the fast growth in combination with relatively low local recruitment. The PSD of yellow perch declined greatly after 1994, falling back to within the recommended range of 30-50 (Table 23; Anderson and Weithman 1978).

Abundance of younger yellow perch in the population (less than 160 mm) increased after 1994 (Figure 5), most likely indicating improved recruitment. There is no sport fishing length limit for this species; however, the commercial trap net fishery is limited to fish 216 mm and larger.

Walleye Mortality, Exploitation and Movement Based on Tag Returns

Between 1989 and 1997, 25,999 walleye were tagged at Dow Dam (Table 24). The age structure of the tagged population was dominated by age 4-7 fish but mean age increased from 2.7 to 8.0 during 1981-97 (Table 25). Walleye exploitation rate was estimated from tag returns and averaged only 8.5% between 1989 and 1997, after adjustment for nonreporting (Table 26). The greatest exploitation rate in any year was 14.5% for 1992 (recovery rate = 5.4; Table 24). Annual harvest of walleye from the open water fishery (as estimated by creel survey, usually April through October) averaged 68,594 walleye between 1989 and 1997 (Table 26). Total annual mortality rate during these same years averaged just 28.3%.

No appreciable difference could be discerned between long-range movements of male and female walleye (Figure 6). Slightly more female walleye migrated north of Saginaw Bay than males. Spatial patterns of tag returns were partially a function of the distribution of angler fishing pressure, which heavily influenced seasonal return locations. Winter return locations (Figure 7) reflected the primary usage of the inner bay and Saginaw/Tittabawassee rivers as fishing locations. The abundance of tag returns from the Saginaw River system in the spring reflected proximity of walleye spawning locations. Most of the spring returns depicted in Figure 7 represented post-spawn catches. Later in spring, walleye tagged at Dow Dam were already being caught as far north as Thunder Bay. Tag returns in summer indicated a fairly uniform distribution throughout the bay, including the outer bay. Summer returns included some harvest from the Saginaw River system but much less so than in winter and spring. There were far fewer tag returns in fall, although their distribution spanned the same geographic area as summer returns (Figure 7). There was no apparent difference in return locations between pre- and post-zebra mussel colonization periods (Figure 8).

Discussion

Walleye

There are several possible explanations for the decline in gill-net CPUE for walleye over time (Table 14). Those declines were not fully mirrored in the harvest by the fishery (Table 26; Rakoczy 1992; Rakoczy and Svoboda 1994; G. P. Rakoczy, MDNR, unpublished data). It has been difficult to determine if declines in CPUE were genuine trends in abundance or artifacts of changing gear vulnerability. Zebra mussels were colonizing Saginaw Bay during the decline in gill-net CPUE (Nalepa et al. 1995). Zebra mussel colonization has resulted in increased light penetration in some parts of Saginaw Bay (Skubinna et al. 1995), although Secchi disk depth did not vary among years at the time of our survey sampling (Table 3). Hansson and Rudstam (1995) demonstrated that changing visibility can affect vulnerability to gill nets. No such change in gill-net CPUE has been attributed to zebra mussel colonization in Lake Erie (R.C. Haas, MDNR, unpublished data).

Another possible explanation for this discrepancy between walleye gill-net CPUE and the fishery would be migration. Summer abundance of adult walleye in Saginaw Bay can be heavily influenced by immigration from Lake Erie (R. C. Haas, MDNR, Mt. Clemens Fisheries Research Station, unpublished data). Tag return data have verified the presence of these fish in the bay. Regression analysis indicated that walleye population size in Lake Erie (Lake Erie Walleye Task Group, Great Lakes Fishery Commission, Ann Arbor, unpublished data) accounted for 58% of the variability of angler walleye CPUE in open water of Saginaw Bay. The migration of walleye from Lake Erie into Saginaw Bay appears to be seasonal in nature. It is possible that Lake Erie walleye left the bay prior to sampling in some years.

Movement by walleye from within the bay to locations outside did not appear to explain declines in gill-net CPUE. Exploratory sampling and testing did not find a significantly greater catch of walleye in shallower areas or outer bay sites (Table 15 and 16). There was some emigration of walleye to the main basin of Lake Huron. If a large migration occurred seasonally, then movement could help account for the discrepancy of trends in fall gill-net CPUE and annual recreational harvest. However, catch rates of gill nets since 1993 indicate a population that is static in abundance and this is consistent with the fishery. Whatever factors were affecting the change in gill-net CPUE during early 1990s, the catch rate today can still serve as a measure of relative abundance. However, caution is necessary when comparing long term trends in gill-net CPUE.

Year-class strength of yearling walleye expressed as percentage of total catch, lessens the effects of changes in vulnerability to gear or migration discussed above. Based on this analysis, the cohorts of 1992, 1993, and 1996 were weak year classes relative to other survey years (Table 17, Figure 2). An assumption behind the percent-contribution index is that the population was largely static (as indicated by the stable fishery and exploitation rate; Table 26) and the individual age percentages therefore represent year class strength. While not ideal, the percentage approach provided a measure of recruitment of age-1 fish to the population, based on local production, that was also consistent with age data from the sport fishery and spawning run.

Local walleye production includes contributions from both natural reproduction and stocking. Stocking of walleye fingerling has occurred in Saginaw Bay since 1979 (Table 27). Years of no stocking (1993 and 1996) both produced weak year classes, although some natural recruitment did occur (Figure 2; Table 17). However, it is not clear if wild recruits have completed migration from the Saginaw River system nursery areas to the bay even by age 1. Stocking alone cannot insure relatively strong recruitment every year, as evidenced by the weak 1992 year class that included significant stocking. Regression analysis indicated fingerling stocking accounted for only 32% of the variability in year class strength (based on the percent yearling index from gill-net data). The exact proportions of hatchery fish and locally-produced wild fish in the bay remain unclear, but both sources appear to contribute to the bay in most years.

The walleye population and fishery began to show signs of resurgence in the mid 1980s (Keller et al. 1987). The population during the study period sustained a substantial sport fishery with exploitation averaging only 8.5% and total mortality averaging 28.3% (Table 26). Total mortality rates between 40 and 55% are common for exploited walleye populations (Colby et al. 1979). The exploitation rate in Saginaw Bay is based on returns of walleye tagged from a single spawning site, Dow Dam (Tittabawassee River). Walleye from this segment of the population inhabit the Tittabawassee River much of the year, providing a riverine sport fishery (Figure 7; Rakoczy and Rogers 1988). These exploitation estimates thus may not reflect exploitation rates for other walleye stocks such as those spawning on reefs in the bay or for the immigrant portion of the population.

The walleye growth rate was much faster than the average for walleye in Michigan (Table 20), exceeding even that of Lake Erie (Thomas and Haas 1994). The modern growth rate was also much faster than that for walleye in Saginaw Bay from 1926 through 1938 (Table 20). The fish community continued to appear unbalanced, with too few predators for the abundant forage available as originally reported by Keller et al. (1987), and the fast walleye growth rate reflected this. Walleye principally consumed gizzard shad and alewife in Saginaw Bay (Table 22). Soft-rayed forage fish were consumed by walleye almost to the exclusion of abundant spiny-rayed species such as yellow perch (Table 22), but the frequency of yellow perch and white perch in the diet increased in recent years. Gizzard shad were less frequent in trawl catches after 1991 (Table 5), suggesting decreased abundance. Walleye probably switched to alternate prey during this decline. Alewife appeared in the walleye diet during years of highest alewife trawl catch rates (Table 5). Similarly, an increase in empty stomachs in recent years coincides with the post zebra mussel decline in abundance of soft-rayed species including alewife, gizzard shad, emerald shiner, spottail shiner, and rainbow smelt.

The age and size structure of the walleye population in Saginaw Bay increased as rehabilitation progressed. The mean age steadily increased in the open water population (Table 17), in the spawning run (Table 25), and in the fishery (Table 28). Weak year classes in 1992, 1993, and 1996 also fueled the increase in mean age. Walleye have been reported to live as long as 20 years (Colby et al. 1979). In a fast growing and exploited population like Saginaw Bay, fish are unlikely to be that old but if the low rate of exploitation continues, the walleye population may continue to add year classes. The size structure of the walleye population was dominated by large individuals (Table 23). This was again a function of fast growth and low exploitation rate. A large proportion of walleye were harvested in the preferred and memorable angling size categories (Table 23). Between 1992 and 1997, walleye harvested by anglers averaged over 1.8 kg (Table 28). Both mean and modal lengths of the walleye harvest reached above 500 mm, well past the 381-mm minimum length limit (Figure 4). From this, it appears that anglers either do not catch many fish around the minimum length limit or they do not choose to harvest them. This phenomenon could also have been fueled by the seasonal influx of adult Lake Erie walleye.

Yellow Perch

Survey trawl CPUE indicated that yellow perch abundance changed dramatically over the past 10 years. The yellow perch population during the mid- to late-1980s in Saginaw Bay was characterized by high abundance, slow growth, and poor condition (Salz 1989; Haas and Schaeffer 1992). The yellow perch population during the mid- to late-1990s in Saginaw Bay exhibited much lower abundance, and improved growth and condition. At the same time, redworm infection rates declined, and perch over 200 mm became more common in trawl catches.

Some interesting disparities existed between abundance and growth of yellow perch estimated from trawl and gill-net data. Gill-net CPUE for yellow perch (Table 14) indicated no major change in abundance, while trawl CPUE indicated a dramatic decline in abundance. Similarly, growth rate of yellow perch estimated from gill-net samples changed little (Table 20), while trawl samples indicated a substantial increase in growth rate for younger ages. The factors behind this disparity are not clear, but gear selectivity may be involved. Haas and Schaeffer (1992) found that size distribution of yellow perch from trawl collections compared favorably to gill-net collections and their nets included smaller mesh than ours. Low sample sizes of smaller yellow perch from the gill-net catch before 1994 (when the 38-mm mesh was added), may have also added to the problem. For example; prior to 1995, age-1 and -2 yellow perch were uncommon in gill nets, but in 1996, they combined to account for 42.7% of the catch (34.3% in 1997). While this increase is likely due to the inclusion of the 38-mm mesh in 1994, their increased growth rate and improved condition probably also made yellow perch more vulnerable to gill nets in later years. This situation illustrates the value of including more than one gear type in a community survey such as this.

The parasitic nematodes *Eustrongylides tubifex* and *Philometra cylindracea*, commonly referred to as redworms, are parasites of yellow perch in the Great Lakes. Rosinski et al. (1997) found that *E. tubifex* infected 76% of yellow perch examined from Saginaw Bay in

September 1992, while 17% were infected by *P. cylindracea*. Salz (1989) found that redworm-infected yellow perch had higher body water content than uninfected fish, suggesting that redworm infection was a drain on energy resources of the fish. Several factors could be involved in the decreased rates of infection seen in the mid-90s. Disease and parasitism rates are believed to be lower at low host population density. Additionally, yellow perch in better condition may be more resistant to infection by redworms. Furthermore, a reduction in population density of the parasites' other intermediate or definitive hosts could reduce infection rate. Finally, a change in the diet of yellow perch could also play a role. While the reason for the decreased infection rate is unclear, it is certainly a good sign for yellow perch in the bay.

Several events have occurred in Saginaw Bay since the late 1980s that could have caused major changes in the food web. First, yellow perch densities in Saginaw Bay declined dramatically between 1989 and 1990 and remained at a reduced level through 1997. Previous studies documented that yellow perch in Saginaw Bay were subsisting near a maintenance ration; with slow growth, energy depletion, high natural mortality, and high density during the 1980s (Salz 1989; Haas and Schaefer 1992). Thus, the decline in density likely resulted in decreased competition among yellow perch for food; and subsequent improved growth and condition (Diana 1995).

Another event that should have major implications for the Saginaw Bay food web was zebra mussel colonization of the bay in the early 1990s. Zebra mussels have been implicated in other areas as causing a major shift of energy flow from the pelagic communities of food webs to benthic communities (Griffiths 1993; Leach 1993). This shift of energy to benthos should improve the diversity and abundance of desirable benthic food items, thus benefiting yellow perch growth (Rautio 1995). White perch and spiny water fleas invaded the bay in the late-1980s, and further increased the likelihood of major changes in the food web. White perch in Lake Erie have been shown to feed extensively on zooplankton as well as on benthic invertebrates (Parrish and Margraf 1990). Small yellow perch may avoid consumption of the large zooplankton *B. cederstoemi* (Barnhisel 1991), but yellow perch over 150 mm readily preyed on *B. cederstoemi* in Lake St. Clair (Synnestvedt 1997). While diet data collected for yellow perch during this study documented the presence of zebra mussels and spiny water fleas in the diet, other zooplankton remained an important component of the fall diet, and large benthic macroinvertebrates were still relatively uncommon. This study, however, only provided a snapshot of the diet during a short period in the fall. A complete assessment of the current yellow perch diet in Saginaw Bay would require sampling at intervals throughout the year.

The commercial fishery for yellow perch has been regulated by a 216-mm minimum length limit since 1982. During the high density, slow growth, and poor condition period of the 1980s, few yellow perch grew large enough or survived long enough to reach that size. After growth and condition improved, the commercial trap-net fishery should have experienced higher catch rates. In fact, CPUE for the Saginaw Bay trap net fishery was higher in the 1990s than during the years from 1982 to 1989 (Figure 9; MDNR, unpublished data). While this increased catch rate reflects a positive change in growth, it may also signal potential competition between the commercial and sport fishery for larger perch. At this point, there is no direct evidence of such a problem. Given the cyclical nature of perch density and growth in Saginaw Bay, it seems probable that a period of high density and slow growth may occur again.

White Perch

White perch were first collected in fall trawl tows on Saginaw Bay in 1984 and increased in abundance through 1989. After 1989, catch rates of white perch in both trawls and gill nets fluctuated at a lower level (Tables 5 and 14). Young-of-the-year accounted for nearly the entire trawl catch each year, while the gill-net catch was dominated by age-1 fish most years. It appears that few white perch survived beyond 3 years of age in Saginaw Bay.

Channel Catfish

Channel catfish are an opportunistic omnivore that likely play an important ecological role in Saginaw Bay. Their abundance (as indicated by gill-net CPUE) has declined recently, perhaps also in response to changes in vulnerability to the gear. Like walleye, these recent declines in gill-net CPUE may not reflect true changes in abundance. Both sport anglers and the commercial fishery harvest channel catfish.

Lengths-at-age for channel catfish sampled in 1997 (Table 19) represented a greatly increased growth rate compared to those reported for 1985 by Haak (1987) from back calculation. This difference, however, probably stems from the extra period of growth during the summer before fall capture compared to length at annulus as determined by back calculation. The growth rates for 1997 were more characteristic of those reported for Saginaw Bay in the early 1970s (Eshenroder and Haas 1974). During that period total mortality rate of channel catfish was 67% compared to 45% in 1985.

Other Important Forage Species

Alewife, rainbow smelt, spottail shiner, and trout-perch remained the most abundant species in the forage fish community of Saginaw Bay. Our data suggested that abundance of the pelagic zooplanktivores (alewife, gizzard shad, and rainbow smelt) declined after the zebra mussel invasion. Concurrently, trout-perch (a benthivore) abundance increased and spottail shiner (a benthivore) appeared to vary without obvious trend. Annual variation in trawl CPUE for these species was high, however, and these trends will require further monitoring.

The apparent decline in mean length for all these species since zebra mussel colonization is perplexing. Reduced growth due to competition with zebra mussels for planktonic food resources is a possibility. Alternatively, Haas and Schaeffer (1992) speculated that yellow perch predation on small spottail shiners, rainbow smelt, and trout-perch could have been strong enough to suppress their abundance during the 1980s. Perhaps the dramatic decline in yellow perch abundance after 1990 caused reduced predation on smaller individuals of these species, resulting in an overall shift in length-frequency towards a smaller size. In either case, a shift towards smaller prey sizes would seem to favor yellow perch, while forcing walleye to feed more frequently, utilize alternative prey species, or move to alternative foraging areas where larger individuals of these species are more abundant. It should be noted however, that in most years gizzard shad or alewife dominated the walleye diet (Table 22), despite relatively low trawl CPUE. These and other pelagic species may be under represented in trawl catches.

Recommendations

The primary objective of management and research should remain the reestablishment of an abundant top predator so as to restore balance to the ecosystem. Full recovery of the walleye population to the bay's carrying capacity is likely to be the best means to achieve this. Removal of dams or the establishment of fish passage on the Saginaw River system should be encouraged as a means to enhance natural reproduction of walleye and benefit other species as well.

Walleye stocking appears to be making some contribution to the walleye population in Saginaw Bay. An assessment of its role in future management is the subject of the MDNR stocking evaluation (Study 468) presently underway.

The minimum length limit for the walleye fishery appears to have little biological benefit in most years; however given the excellent growth of walleye and the statewide nature of the regulation, removal is neither necessary nor desirable.

While full walleye recovery remains the best means to achieve ecological balance, restoration of other native predators could also be useful. These include reintroductions of Great Lakes muskellunge, and habitat improvement or stocking for lake sturgeon and northern pike. Lake herring, while not a predator, was a native inhabitant of Saginaw Bay, and has been largely displaced by alewives. Now, with partial alewife control realized in the Great Lakes, reintroduction should be pursued. In all, increased diversity of the fish community via enhancement of native species will help strengthen the ecosystem's resistance to invasion of more exotic species.

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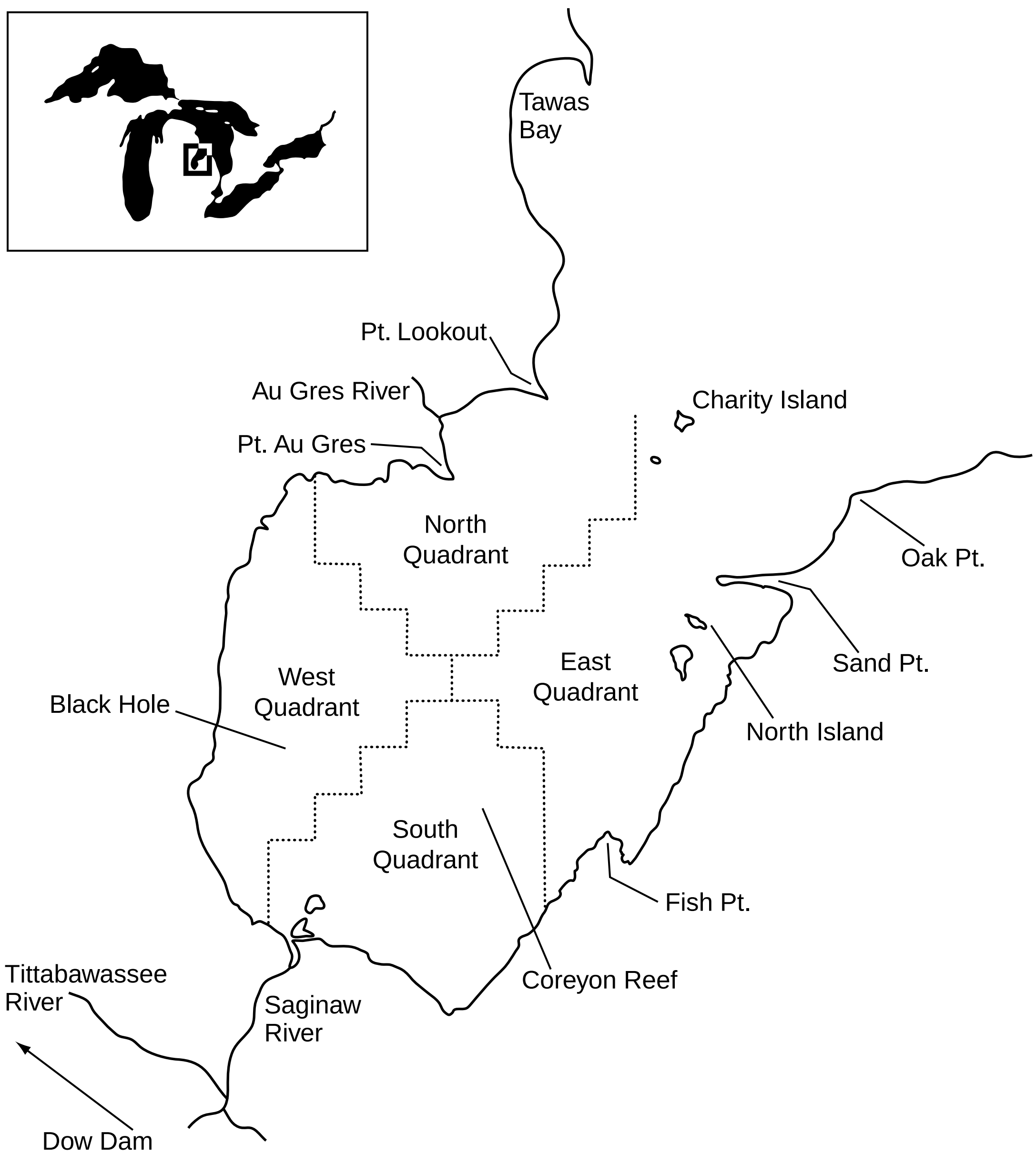


Figure 1.–Saginaw Bay gill-net sampling locations, trawling quadrants, and tagging site at Dow Dam.

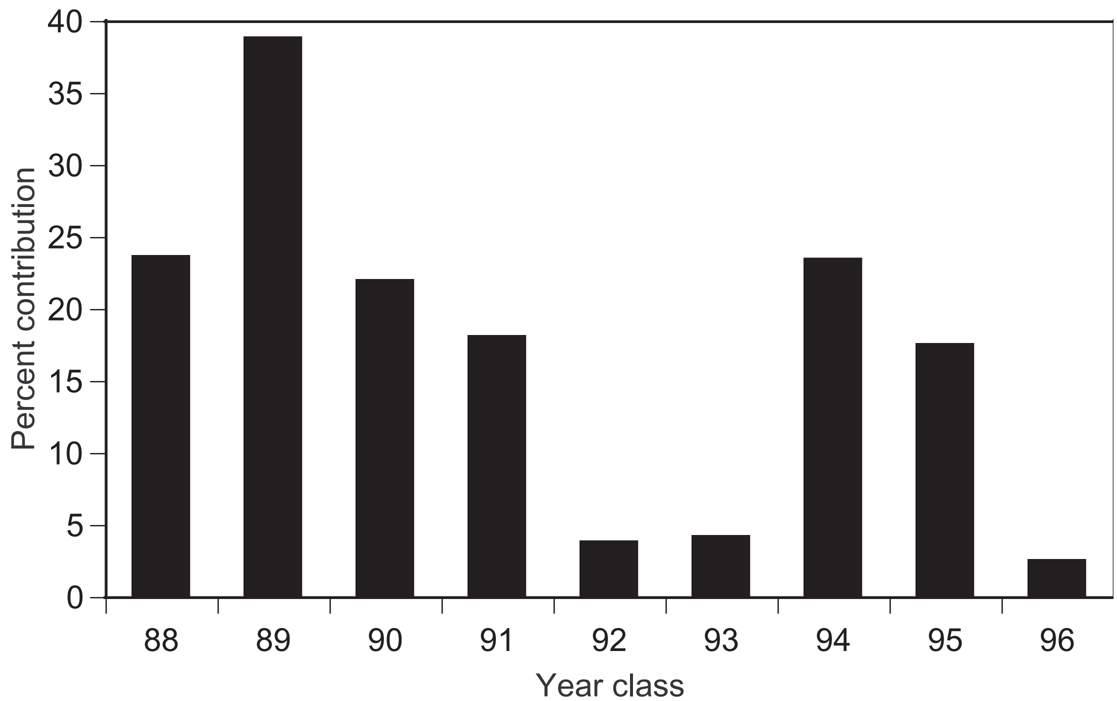


Figure 2.–Percentage of yearling walleye from the gill-net catch as an indicator of year class strength for Saginaw Bay, 1989-97.

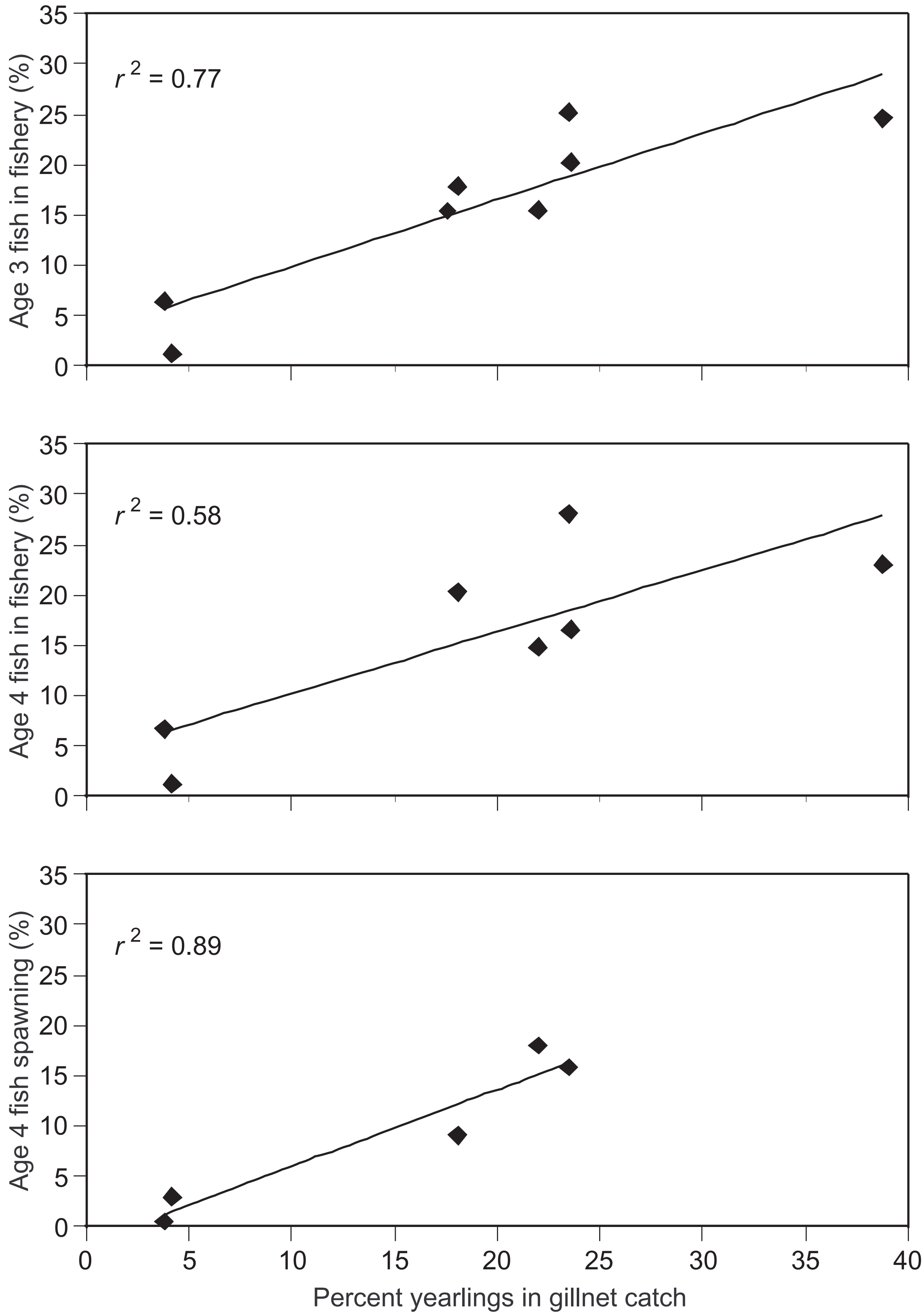


Figure 3.–Relationships between percent yearling walleye from gill net catch and relative year class strength of age-3- and age-4-fish in the open water fishery of Saginaw Bay and age-4-fish in the spawning run in the Tittabawassee River.

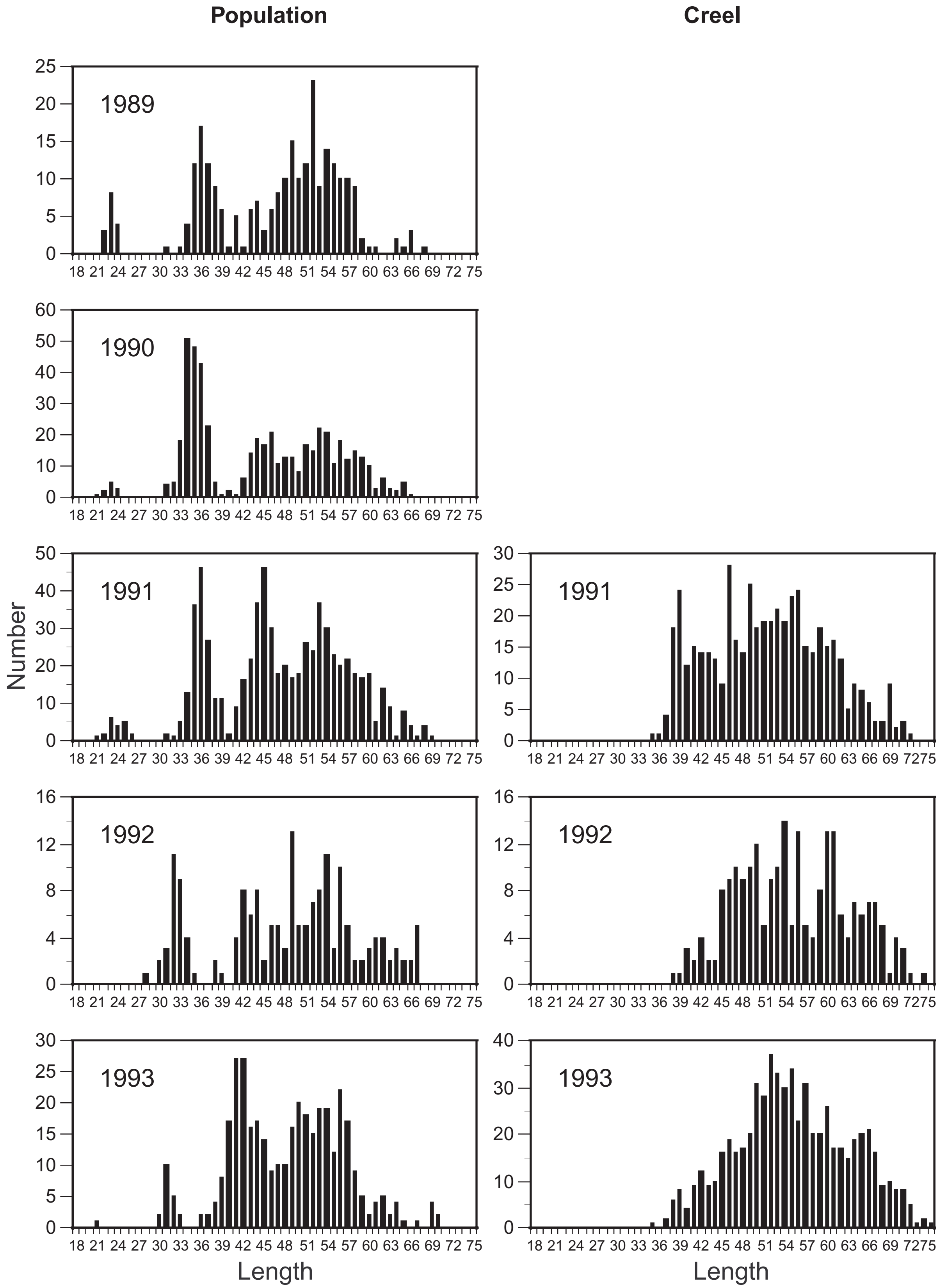
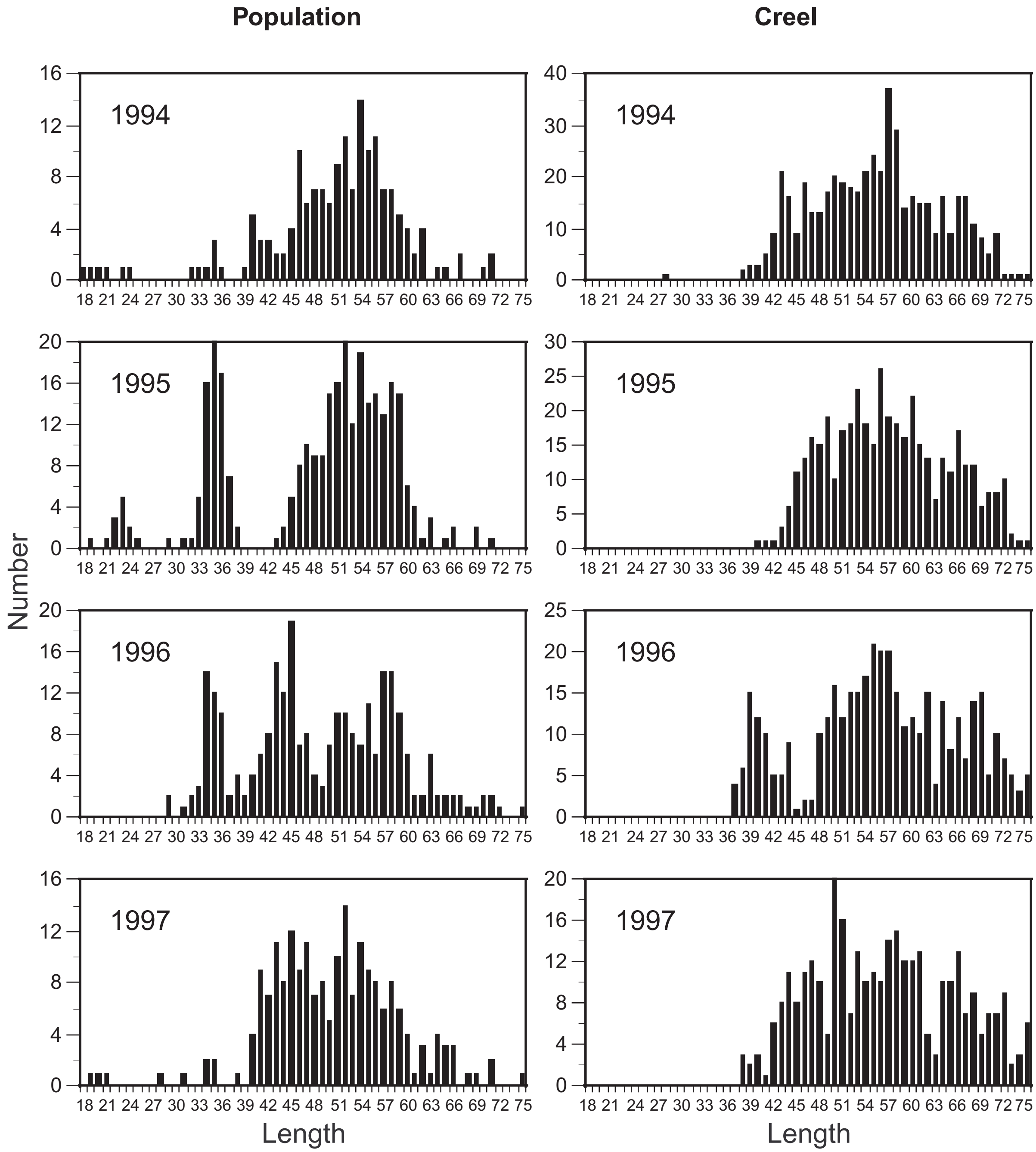


Figure 4.–Length frequencies of walleye from gill net (population) and creel for Saginaw Bay, 1989-97. All lengths are in cm. Sport fishery minimum length limit is 38 cm.



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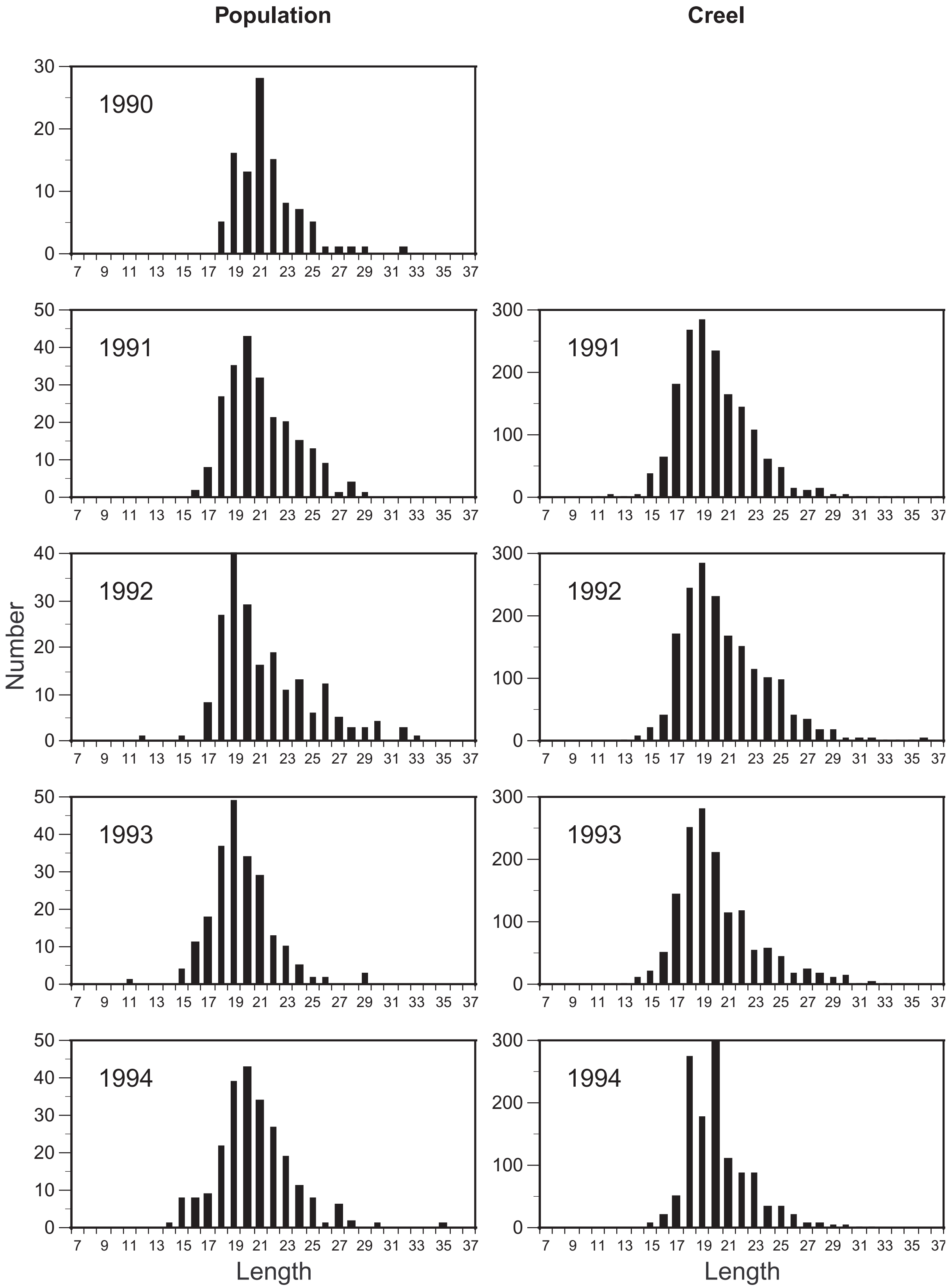
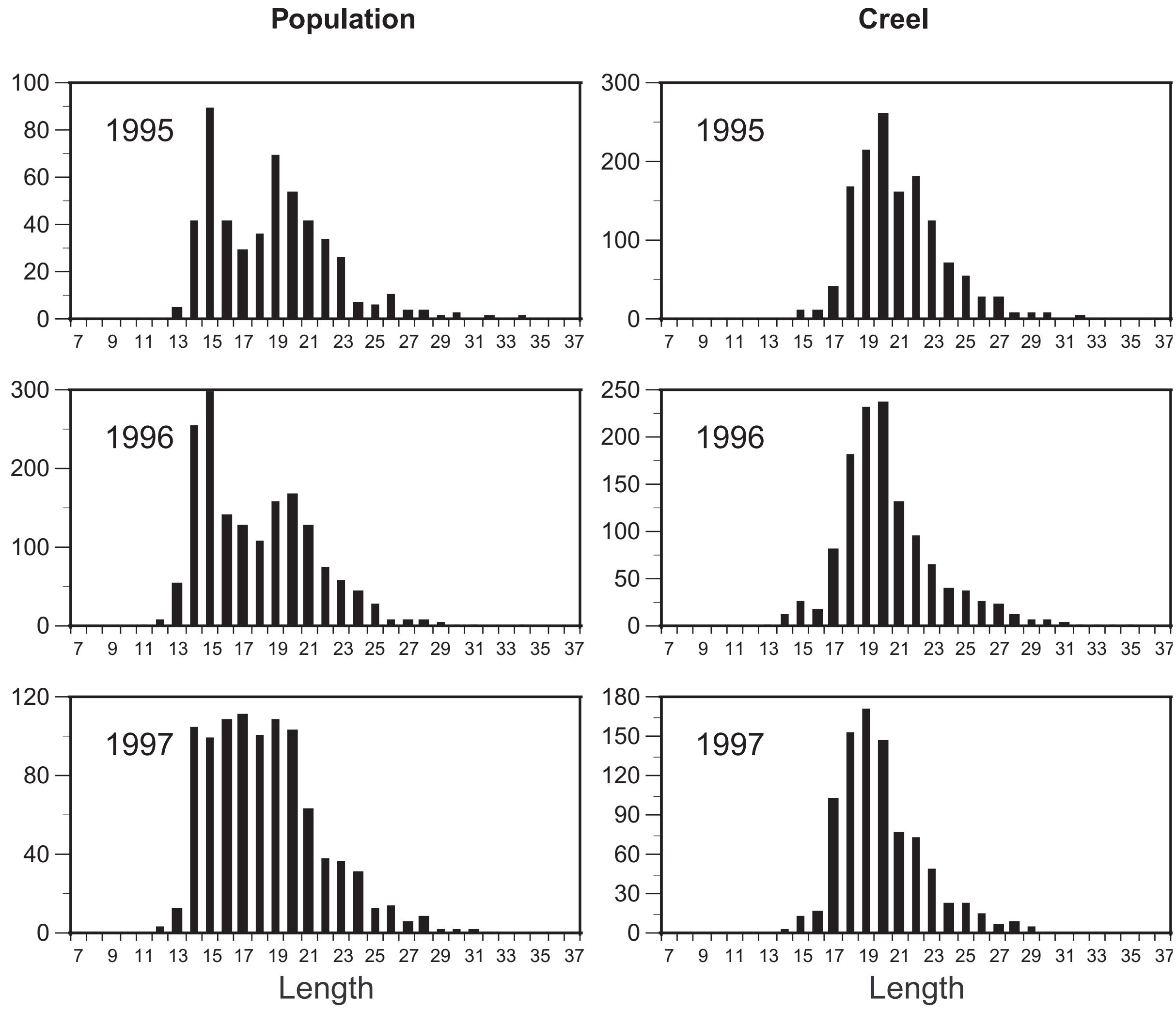


Figure 5.–Length frequencies of yellow perch from gill net (population) and creel for Saginaw Bay, 1990-97. All lengths are in cm.



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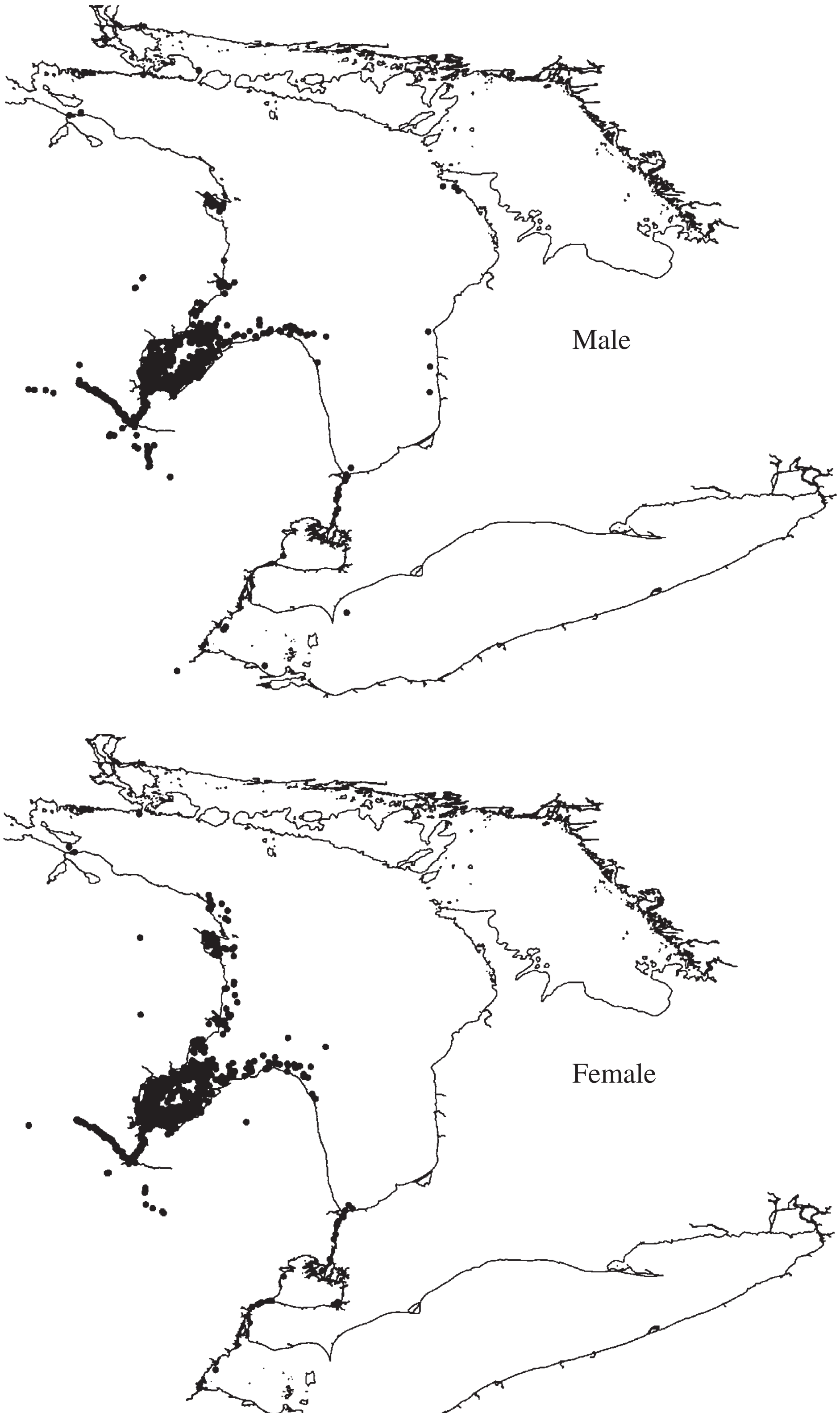

Figure 6.–Locations, by sex, of returns from walleye tagged at Dow Dam 1989-97.

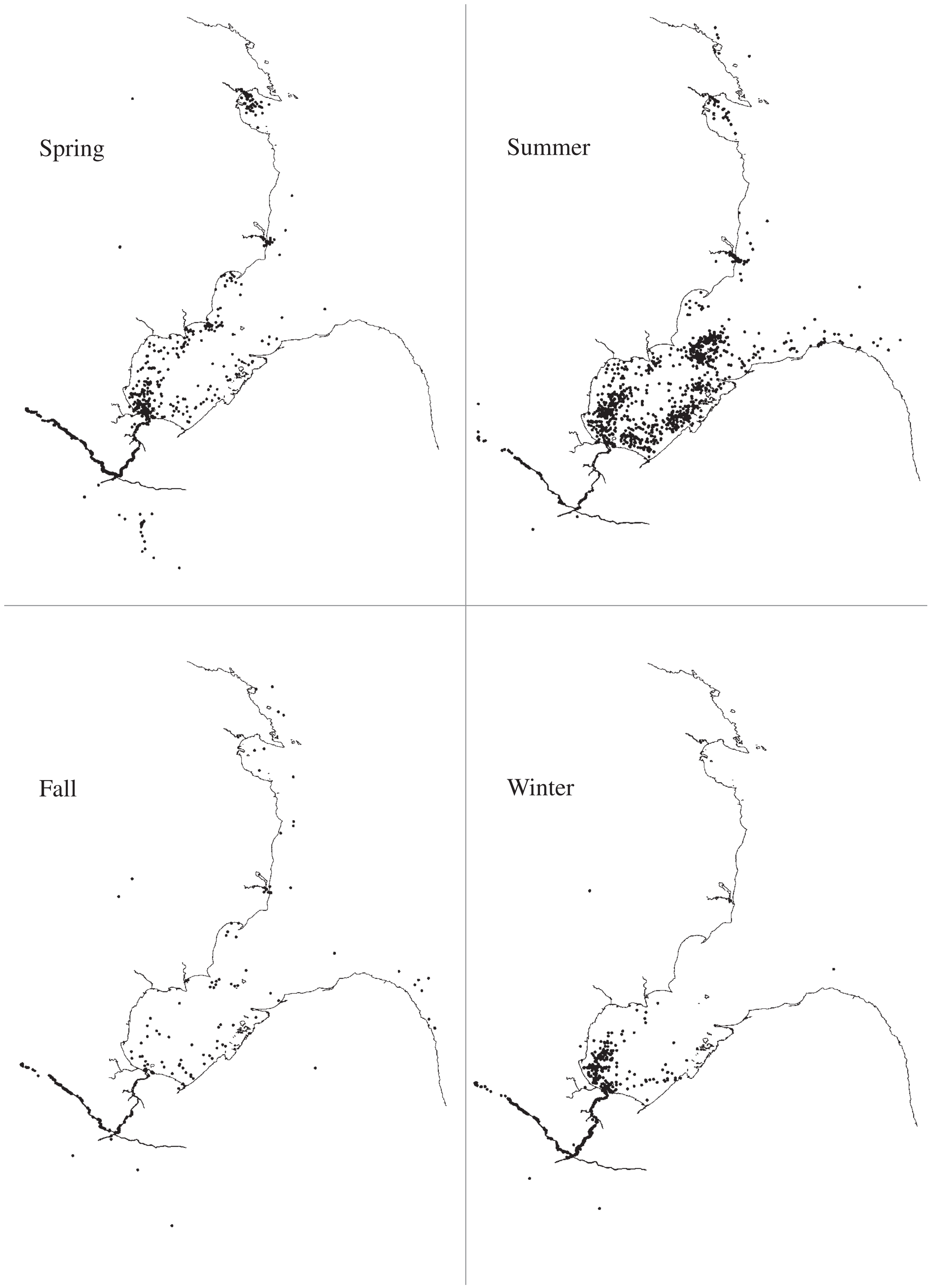

Figure 7.–Locations, by season, of returns from walleye tagged at Dow Dam and recaptured in Saginaw Bay, 1989-97.

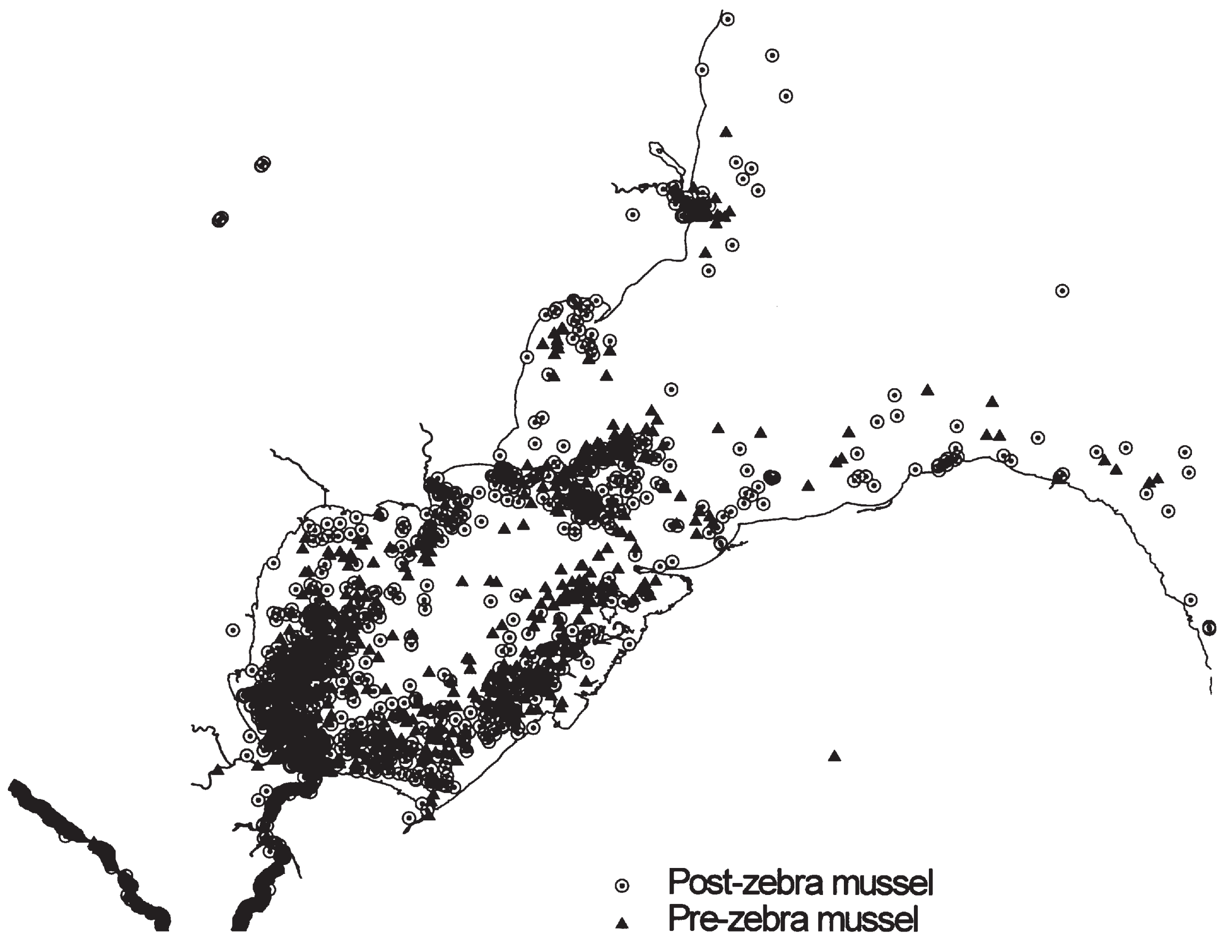

Figure 8.–Returns of walleye tagged at Dow Dam and recaptured in Saginaw Bay pre- (1989-90) and post- (1993-97) zebra mussel colonization.

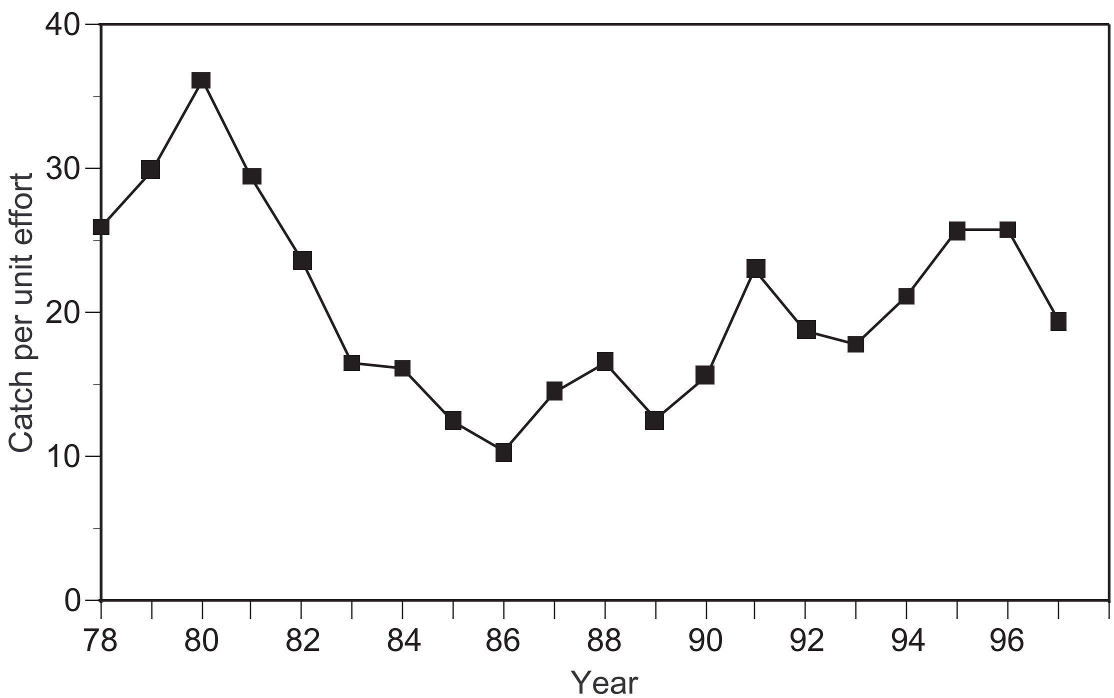

Figure 9.–Annual catch per unit effort (pounds per 24-hours fished) of yellow perch, for small mesh, commercial trap nets in Saginaw Bay, 1978-97.

Table 1.–Number and location of fall trawl tows on Saginaw Bay from 1986-97.

	Number of fall trawl tows											
Quadrant	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
East	16	35	3	6	5	6	16	5	6	6	6	7
South	3	5	6	0	4	3	6	5	9	9	6	7
West	7	11	6	3	4	3	3	13	8	9	12	10
North	11	9	8	3	0	3	11	15	6	9	6	10
Total	37	60	23	12	13	15	36	38	29	33	30	34

Table 2.–Total number of 305 m (effort) fall gill-net sets by location for Saginaw Bay, Lake Huron, 1989-97. Total effort each year was used in calculations of CPUE except 1994 through 1997 where number of net sets used in CPUE calculations are in parentheses.

	Total gill-net effort								
Station	1989	1990	1991	1992	1993	1994	1995	1996	1997
Saginaw River	2	–	–	–	–	–	–	–	–
Point Lookout	1	–	–	1	1	1(1)	4(1)	3(1)	1(1)
AuGres River	–	–	2	1	1	1(1)	1(1)	1(1)	1(1)
Point AuGres	2	–	2	2	1	2(2)	6(2)	6(2)	2(2)
Black Hole	2	3	2	2	2	2(2)	6(2)	5(2)	2(2)
Coreyon Reef	–	2	2	2	2	2(2)	3(2)	2(2)	2(2)
Fish Point	–	–	–	–	2	2(2)	1	5(2)	2(2)
North Island	–	–	–	–	–	1	6(2)	5(2)	2(2)
Oak Point	–	–	–	–	1	1(1)	6(2)	5(2)	2(2)
Charity Island	–	–	–	–	–	–	3	2	2
Tawas	–	–	–	–	–	–	2	2	2
Total	7	5	8	8	10	12(11)	38(12)	36(14)	18(14)

Table 3.–Mean and two standard errors (2SE) for water temperature and Secchi depth at trawling sites in Saginaw Bay, 1987-97.

Year	Water temperature (^{o}C)	2SE	Secchi depth (m)	2SE
1987	16.7	1.9	1.04	0.20
1988	16.8	1.3	1.23	0.29
1989	12.4	1.9	–	–
1990	13.0	1.2	0.74	0.22
1991	15.5	1.0	1.49	0.22
1992	14.7	1.2	1.29	0.26
1993	14.0	0.7	1.26	0.30
1994	16.3	1.4	0.92	0.19
1995	14.9	1.1	1.33	0.33
1996	16.9	1.9	1.00	0.19
1997	18.0	0.7	1.33	0.30

Table 4.–Percent species composition of Saginaw Bay fall trawl catches from 1986-97.

	Percent composition												
Species	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Avg.
Alewife	12.88	8.47	19.22	6.67	1.38	7.27	26.04	14.90	3.80	14.98	7.97	7.53	11.75
Black crappie	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Bluegill	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00
Carp	0.29	0.24	0.11	0.15	0.39	0.28	0.25	0.27	0.81	0.36	0.36	0.11	0.25
Channel catfish	0.17	0.24	0.04	0.02	0.41	0.04	0.02	0.07	0.54	0.18	0.54	0.06	0.16
Freshwater drum	0.75	0.29	0.10	0.10	1.14	2.22	0.24	0.66	2.41	1.51	1.36	0.12	0.63
Emerald shiner	7.05	0.85	0.47	1.68	4.29	1.33	0.80	0.06	0.00	0.00	0.07	0.30	1.12
Gizzard shad	0.44	1.32	3.70	4.99	4.37	4.45	0.03	1.48	0.54	0.32	1.87	0.48	1.68
Johnny darter	0.14	0.17	0.04	0.01	0.12	0.04	0.99	0.78	0.81	1.41	1.79	0.48	0.52
Logperch	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Longnose gar	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Northern shorthead redhorse	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Pumpkinseed sunfish	0.01	0.09	0.00	0.00	0.01	0.02	0.00	0.01	0.00	0.00	0.01	0.00	0.02
Quillback carpsucker	0.00	0.11	0.00	0.02	0.02	0.03	0.01	0.05	0.05	0.03	0.07	0.00	0.03
Rainbow smelt	19.32	17.82	28.02	6.52	3.96	3.93	24.12	36.35	5.07	1.07	1.23	39.60	20.46
Rock bass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Spottail shiner	16.49	27.51	16.19	9.24	12.80	11.16	15.67	7.26	18.87	20.69	16.44	19.54	17.64
Stonecat	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trout-perch	11.83	12.14	8.11	6.28	7.51	14.89	17.21	31.55	46.33	24.86	38.53	17.98	18.14
Walleye	0.11	0.11	0.04	0.07	0.12	0.49	0.10	0.10	0.17	0.05	0.12	0.08	0.10
White bass	0.44	0.21	0.30	0.09	0.31	0.54	0.01	0.13	0.59	0.05	0.03	0.12	0.20
White perch	0.51	2.14	5.47	43.01	51.84	36.35	7.88	2.12	17.10	27.60	22.01	10.04	13.53
White sucker	0.46	0.38	0.08	0.09	0.68	1.10	0.65	1.03	0.92	0.36	0.64	0.68	0.50
Whitefish	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.01	0.01
Yellow perch	29.04	27.89	18.12	21.05	10.65	15.83	5.97	3.16	1.96	6.47	6.93	2.84	13.25
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 5.–Mean CPUE (catch per 10-minute tow) for major species in Saginaw Bay trawl tows, 1986-97.

	Mean CPUE												Overall
Species	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	mean
Alewife	247.6	149.2	1,588.9	281.9	17.5	86.2	302.5	191.2	42.2	306.8	98.7	300.7	282.3
Channel catfish	2.7	4.9	3.9	0.7	5.2	0.5	0.3	0.9	6.2	3.3	6.3	2.35	3.3
Common carp	5.0	4.3	7.3	6.4	5.0	3.3	2.9	3.3	9.2	6.9	4.4	4.45	5.1
Emerald shiner	151.7	17.1	24.7	71.1	54.5	15.8	9.3	0.7	0.0	0.0	0.9	12.63	28.8
Freshwater drum	12.1	5.3	7.9	4.1	14.5	26.3	2.8	8.7	27.9	28.3	16.3	4.61	13.0
Gizzard shad	8.6	30.1	192.5	211.0	55.5	52.7	0.3	19.3	6.2	6.7	22.9	17.8	38.1
Johnny darter	2.6	3.3	3.7	0.4	1.5	0.5	11.5	10.3	8.9	28.9	20.7	20.0	9.4
Rainbow smelt	367.8	298.2	2,445.2	275.7	50.3	46.6	280.2	467.9	56.9	22.4	15.2	1,584.6	377.6
Spottail shiner	287.9	508.1	1,271.8	390.4	162.7	132.3	182.0	96.8	218.2	372.6	209.5	808.5	350.7
Trout-perch	194.7	220.7	738.6	265.3	95.4	176.5	199.9	416.4	534.2	513.5	474.1	740.6	350.3
Walleye	1.9	1.9	1.8	3.2	1.5	5.9	1.1	1.3	2.0	0.9	1.3	2.9	1.8
White perch	10.1	42.2	386.0	1,817.9	658.6	430.9	91.5	27.9	192.7	528.2	277.2	409.1	258.6
White sucker	7.3	7.2	6.7	3.7	8.6	13.1	7.6	10.3	10.3	7.0	7.7	28.4	8.1
Yellow perch	530.0	530.9	1,525.3	889.6	135.3	188.2	69.3	37.8	21.7	125.8	85.0	122.0	346.8

Table 6.–Mean and two standard errors (SE) for CPUE (catch per 10-minute tow) of common forage species in Saginaw Bay fall trawls over two time periods, pre-zebra mussel (1986-90), and post-zebra mussel (1993-97).

	Pre-zebra mussel		Post-zebra mussel	
Species	Mean CPUE	2SE	Mean CPUE	2SE
Alewife	401.84	200.11	191.92	60.95
Common carp	5.17	1.20	5.54	0.97
Channel catfish	3.84	1.37	3.63	0.99
Freshwater drum	8.14	2.66	16.81	3.97
Emerald shiner	60.49	24.30	2.77	1.82
Gizzard shad	67.65	28.09	14.75	4.84
Johnny darter	2.77	0.96	17.68	4.43
Rainbow smelt	632.42	290.14	433.21	201.73
Spottail shiner	532.34	123.69	333.23	98.96
Trout-perch	288.65	84.11	530.70	140.15
Walleye	1.97	0.48	1.67	0.38
White perch	290.76	113.21	281.40	44.40
White sucker	7.00	1.54	12.61	3.92
Yellow perch	682.61	166.24	77.91	10.90

Table 7.–Mean CPUE (catch per 10-minute tow) by age class for yellow perch from fall trawls in Saginaw Bay, 1986-97.

	Mean CPUE											
Age	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
0	117.6	258.0	458.9	280.2	34.0	106.5	7.1	0.5	3.5	100.6	37.9	89.1
1	132.8	61.0	263.8	168.7	37.8	14.4	42.2	2.2	1.4	12.0	30.9	11.3
2	125.9	98.6	248.6	180.3	20.2	27.8	8.4	20.7	2.8	2.6	5.9	16.9
3	128.4	66.8	309.4	128.0	20.5	17.3	5.3	7.6	10.1	3.5	3.7	2.9
4	21.2	37.6	171.6	81.1	12.6	12.0	3.4	4.4	2.5	5.2	2.7	0.5
5	3.0	6.6	56.8	33.3	6.1	7.6	2.0	1.9	1.0	1.1	3.2	0.5
6	0.7	1.8	13.5	12.9	2.8	2.3	0.6	0.3	0.2	0.6	0.8	0.4
7	0.5	0.4	1.7	4.4	0.9	0.3	0.2	0.1	0.2	0.1	0.0	0.2
8	0.0	0.0	0.9	0.3	0.3	0.0	0.0	0.2	0.0	0.1	0.0	0.0
9	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	530.0	530.9	1,525.3	889.6	135.3	188.2	69.3	37.8	21.7	125.8	85.0	122.0
Yearling and older	412.4	272.9	1,066.4	609.4	101.3	81.7	62.2	37.3	18.2	25.2	47.1	32.8

Table 8.–Mean and two standard errors (SE) for total length (mm) of common forage species in fall trawls in Saginaw Bay for two time periods, pre-zebra mussel (1986-90), and post-zebra mussel (1993-97).

	Pre-zebra mussel		Post-zebra mussel	
Species	mean total length	2SE	mean total length	2SE
Alewife	77.53	0.48	69.12	0.60
Freshwater drum	137.12	8.20	103.26	1.78
Gizzard shad	98.35	1.12	95.53	2.30
Rainbow smelt	57.79	0.74	52.52	0.39
Spottail shiner	80.39	0.56	73.27	0.62
Trout-perch	80.92	0.64	66.57	0.68
White perch	80.11	0.70	66.07	0.62

Table 9.–Length-frequency distribution for yellow perch collected in fall trawls on Saginaw Bay, 1986-97.

Length	Number per length group											
interval	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
31-35mm	0	0	0	0	0	0	0	0	0	0	2	0
36-40mm	0	1	2	0	0	0	0	0	0	5	0	0
41-45mm	0	13	4	0	0	0	0	0	0	1	0	0
46-50mm	0	25	29	0	0	0	0	0	0	2	0	0
51-55mm	7	60	70	1	0	1	0	0	0	2	0	0
56-60mm	5	83	89	10	0	14	0	0	0	6	0	2
61-65mm	4	50	96	131	0	126	1	0	0	29	0	32
66-70mm	66	54	189	285	9	274	16	0	0	97	3	103
71-75mm	221	180	455	271	97	243	48	0	0	168	22	138
76-80mm	240	490	401	106	236	101	40	2	3	113	70	117
81-85mm	122	429	195	15	145	24	14	1	7	43	102	47
86-90mm	24	278	63	1	58	6	1	8	5	12	57	12
91-95mm	8	103	14	0	9	3	3	6	4	1	9	6
96-100mm	2	49	15	0	0	3	0	5	4	0	1	0
101-105mm	7	36	9	1	1	0	1	5	3	0	0	0
106-110mm	65	71	82	16	2	1	12	2	5	1	0	1
111-115mm	222	134	198	56	33	17	45	2	1	2	1	2
116-120mm	447	184	234	118	109	39	162	1	0	5	6	9
121-125mm	318	240	255	140	209	55	330	4	0	25	23	39
126-130mm	278	297	244	138	154	65	280	18	2	32	55	52
131-135mm	312	260	280	102	94	99	130	19	4	42	84	57
136-140mm	360	325	238	86	51	94	50	18	6	75	73	62
141-145mm	394	382	299	142	65	83	44	28	15	71	44	32
146-150mm	271	327	301	170	78	110	70	53	35	59	31	14
151-155mm	177	303	265	144	97	106	63	86	31	37	19	25
156-160mm	147	224	284	157	97	105	71	105	51	20	7	45
161-165mm	127	161	230	106	107	106	63	92	52	17	5	53
166-170mm	90	95	178	95	95	111	74	97	67	21	7	47
171-175mm	77	69	143	51	80	86	35	83	77	40	11	62
176-180mm	61	44	96	57	74	72	40	65	98	41	15	48
181-185mm	76	54	75	45	66	53	30	63	89	52	9	49
186-190mm	45	49	41	37	58	44	22	42	80	51	11	41
191-195mm	29	29	47	29	39	37	12	39	73	41	12	33
196-200mm	19	23	21	23	29	39	16	27	59	43	12	22
201-205mm	14	15	20	14	25	31	14	20	67	43	18	14
206-210mm	12	13	13	12	22	33	9	24	40	32	16	13
211-215mm	6	9	11	14	23	26	6	17	35	28	13	6
216-220mm	3	15	6	7	13	25	7	5	21	11	11	8
221-225mm	8	3	7	7	8	17	2	11	12	3	4	6
226-230mm	4	1	7	5	6	9	3	9	13	9	8	6
231-235mm	2	4	3	0	7	16	2	4	8	10	4	1
236-240mm	1	6	3	4	7	5	4	4	6	4	3	1
241-245mm	4	2	4	0	1	7	6	3	4	5	3	3
246-250mm	1	2	1	2	2	12	2	2	4	3	1	4
251-255mm	1	1	0	2	0	6	2	1	1	1	3	2
256-260mm	0	1	1	1	0	7	1	2	2	1	0	2
261-265mm	1	0	1	0	0	2	1	1	3	0	1	1
266-270mm	0	1	2	0	1	1	2	2	1	1	1	0
Total	4278	5195	5221	2601	2207	2314	1734	976	988	1305	777	1217
# > 100mm	3579	3380	3599	1781	1653	1519	1611	954	965	826	511	760
# > 200mm	57	73	79	68	115	197	61	105	217	151	86	67
% > 200mm	1.6	2.2	2.2	3.8	7.0	13.0	3.8	11.0	22.5	18.3	16.8	8.8
# > 8.5in	25	36	35	28	45	107	32	44	75	48	39	34
% > 8.5%	0.7	1.1	1.0	1.6	2.7	7.0	2.0	4.6	7.8	5.8	7.6	4.5

Table 10.–Mean total length (mm) at age for yellow perch from Saginaw Bay fall trawls, 1986-97.

Age	State average	Mean length-at-age											
		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Males													
1		118.1	119.7	118.1	119.8	123.8	123.7	124.0	131.4	144.8	134.6	131.9	130.7
2		135.2	134.6	136.1	140.9	145.6	146.0	149.3	154.7	158.8	168.8	166.4	165.6
3		152.6	150.4	147.4	157.2	165.3	166.9	163.7	178.3	175.7	179.2	189.1	195.0
4		180.9	165.6	164.2	169.6	175.1	184.1	180.8	193.5	190.9	192.1	200.0	201.8
5		193.6	187.8	178.4	184.9	186.1	201.6	186.7	202.2	200.1	203.1	211.4	219.4
6		211.3	191.0	196.7	194.4	195.3	212.1	208.6	213.5	200.5	210.5	218.8	218.3
Females													
1		119.8	121.3	121.6	122.7	126.0	127.1	126.9	132.4	148.1	142.1	136.7	136.1
2		143.7	141.2	142.7	148.7	156.9	155.1	158.6	168.7	172.0	179.0	183.2	179.4
3		169.3	163.1	157.8	168.5	176.0	178.7	173.3	188.2	195.4	193.3	203.4	209.9
4		194.6	187.0	180.9	184.4	200.7	202.2	204.3	209.6	213.7	211.4	219.5	231.5
5		228.4	207.5	202.9	208.1	214.9	220.7	236.0	242.3	235.3	225.2	233.4	230.3
6		262.2	220.9	217.3	228.9	234.5	246.4	249.3	245.2	246.0	246.7	260.0	286.0
Sexes combined													
1	127	118.8	120.5	119.7	121.4	124.8	125.1	125.5	131.8	146.2	138.5	133.9	132.9
2	160	139.4	138.0	139.4	145.1	151.2	151.0	153.8	161.1	163.3	173.0	174.4	173.2
3	183	159.8	156.0	152.6	162.4	170.8	173.3	167.5	183.3	185.3	183.8	197.5	201.7
4	208	185.5	173.9	170.6	177.8	192.1	194.2	187.4	200.9	200.2	196.9	204.9	216.7
5	234	208.3	195.8	187.7	194.8	197.3	211.5	196.8	215.2	208.9	209.8	215.9	222.2
6	257	240.4	202.8	205.4	208.8	201.8	232.3	217.3	236.1	212.9	226.0	234.5	238.6

Table 11.–Rate of redworm infestation in yellow perch collected from fall trawl tows in Saginaw Bay, 1986-97. Pre-Zebra Mussel is delineated as "Pre-ZM", and post-Zebra Mussel is delineated as Post-ZM.

	Percent of perch infected													
Sex	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Pre-ZM 1986-88	Post-ZM 1993-97
Male	59.7	70.7	80.7	–	–	69.0	23.1	68.2	38.5	55.9	48.6	37.0	72.0	53.0
Female	51.2	65.7	83.1	–	–	65.8	31.0	53.7	47.0	47.2	43.7	37.5	70.0	56.0

Table 12.–Mean and two standard error (2SE) for percent water by weight of yellow perch collected from fall trawl tows in Saginaw Bay during pre-Zebra Mussel and post-Zebra Mussel periods.

	Pre-Zebra Mussel		Post-Zebra Mussel	
Age	Mean % water	2SE	Mean % water	2SE
Males				
1	72.80	0.34	73.23	0.22
2	73.22	0.18	72.92	0.12
3	72.61	0.17	72.30	0.18
4	72.96	0.26	71.40	0.25
5	72.73	0.34	71.32	0.33
6	73.27	0.60	71.01	0.46
Females				
1	73.24	0.40	73.37	0.26
2	73.83	0.20	72.88	0.12
3	73.43	0.22	72.51	0.22
4	73.63	0.36	71.94	0.61
5	73.39	0.50	71.70	0.61
6	73.44	1.02	71.32	0.70

Table 13.–Frequency of occurrence (percent) for food items in yellow perch for fall trawl surveys from Saginaw Bay, 1986-96.

	Frequency of occurrence								
Taxa	1986	1987	1988	1991	1992	1994	1995	1996	
Bosmina	5.50	1.59	3.37	2.73	17.65	5.81	0.80	1.72	3.61
Daphnia	1.26	0.32	0.59	0.00	1.96	0.00	0.00	0.00	0.61
Chydorid	67.14	25.50	27.16	19.09	61.76	41.86	8.00	18.97	34.96
Macrothricid	13.99	4.44	13.48	16.36	27.45	18.60	12.80	5.17	11.22
Leptadora	0.16	2.01	0.10	0.00	0.00	0.00	0.00	0.00	0.67
Copepod	37.58	51.32	45.49	57.27	46.08	39.53	41.60	53.45	46.05
Ostracod	27.36	25.61	34.39	39.09	63.73	45.35	48.80	50.86	32.92
Sida	23.27	16.51	3.17	1.82	38.24	24.42	3.20	8.62	13.17
Bythotrephes	0.00	0.00	0.00	0.00	21.57	13.95	20.80	0.00	1.92
All plankton	73.27	62.54	59.66	65.45	78.43	68.60	78.40	63.79	65.26
Pelecepod	7.39	3.60	3.77	9.09	3.92	0.00	5.60	11.21	4.89
Gastropod	3.30	0.74	0.50	0.00	0.00	0.00	0.80	0.86	1.12
Zebra mussel	0.00	0.00	0.00	0.91	16.67	20.93	1.60	12.93	1.69
Isopod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.86	0.03
Hydracarina	8.49	2.54	9.42	0.91	2.94	1.16	0.80	0.00	5.72
Amphipod	4.40	1.90	1.29	0.00	28.43	15.12	0.00	4.31	3.39
Total Others	19.18	8.57	13.97	10.91	41.18	33.72	8.80	21.55	14.80
Ephemerida	3.46	0.21	0.69	0.00	0.00	0.00	0.00	1.72	1.05
Tricoptera	5.82	1.38	0.10	0.00	4.90	6.98	8.00	29.31	3.39
Chironomid pupae	28.30	30.16	33.89	3.64	25.49	3.49	12.80	26.72	28.35
Chironomid larvae	66.67	78.41	77.40	71.82	69.61	47.67	60.00	68.10	73.22
All insects	71.07	82.33	81.27	72.73	80.39	54.65	67.20	75.00	77.66
All fish	18.08	7.41	7.33	10.00	10.78	9.30	12.00	16.38	10.32
Number of Non-empty stomachs	636	945	1009	110	102	86	125	116	3129

Table 14.–Mean CPUE (number per 305 m net lift) for gill-net catches by species from Saginaw Bay 1989-97. Means with no letter in common are significantly different.

	Mean CPUE								
Species	1989	1990	1991	1992	1993	1994	1995	1996	1997
Alewife	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.1	0.0
Bigmouth Buffalo	0.1	0.0	0.0	0.4	0.7	0.1	0.0	0.0	0.0
Black Crappie	0.0	0.2	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	0.1	0.1
Brown trout	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0
Burbot	0.0	0.0	0.0	0.0	0.3	0.1	0.2	0.1	0.1
Carp	0.7	1.4	0.1	2.1	0.5	1.2	0.2	0.6	0.1
Channel catfish	5.3abde	19.4a	15.2ac	3.2bde	5.8bcd	3.6de	1.4e	8.8abd	4.9bd
Chinook salmon	0.0	0.0	0.0	0.8	0.5	0.1	0.2	0.1	0.0
Freshwater drum	4.3	12.6	3.4	11.1	5.3	7.8	8.8	28.4	19.0
Gizzard shad	8.1acd	22.4ab	44.6b	2.6cd	9.2acd	4.1acd	3.9acd	14.8abc	2.2d
Goldfish	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.1
Lake trout	0.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1
Lake whitefish	0.3	0.0	0.0	0.5	0.1	0.0	0.1	0.0	0.1
Longnose gar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Longnose sucker	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.1	0.1
Northern pike	0.1	1.6	0.5	0.8	0.0	0.4	0.3	0.1	0.1
Northern redhorse	0.0	0.2	0.9	0.0	0.0	0.0	0.2	0.8	0.1
Quillback	0.3	4.0	1.0	0.4	0.3	0.4	0.8	1.1	0.7
Rainbow smelt	0.0	1.0	0.0	0.8	0.5	0.2	0.0	0.0	1.5
Rainbow trout	0.0	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0
Rock bass	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.3	0.0
Round whitefish	0.4	0.0	0.0	0.0	0.3	0.0	0.1	0.0	0.0
Smallmouth bass	0.0	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0
Stone cat	0.4	0.8	0.4	0.2	0.4	0.3	0.2	1.0	0.4
Tiger musky	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Walleye	37.0ad	101.6b	86.1ab	21.4ac	38.0a	14.8c	13.4cd	12.9c	11.3c
White bass	0.3	4.0	2.3	1.8	1.0	0.1	1.1	0.5	0.6
White perch	51.6a	18.4b	28.6ab	1.9c	2.8c	28.9bc	8.8bc	28.4ab	19.0b
White sucker	42.6	81.0	62.4	121.9	35.8	40.3	18.2	33.1	18.8
Yellow perch	46.6ac	115.0bc	5.4ac	33.4ac	62.1abc	31.2ac	26.4a	59.4c	30.7ac

Table 15.–Mean CPUE (number per 305 m net lift) comparisons and P values between shallow and standard sets of gill nets for select fish species in Saginaw Bay, 1995 and 1996.

	1996 CPUE			1995 CPUE		
Species	Shallow	Standard	P	Shallow	Standard	P
Northern pike	0.61	0.78	.848	1.22	0.25	.202
Channel catfish	0.00	7.61	.009	–	–	–
Walleye	15.28	11.89	.325	12.22	11.31	.848
Yellow perch	87.89	29.18	.002	36.97	18.50	.022
White perch	25.78	7.64	.017	0.92	4.00	.058

Table 16.–Mean CPUE (number per 305 m net lift) comparisons and P values between inner and outer bay for gill-net catches of select species in Saginaw Bay, 1995 and 1996.

	1996 CPUE			1995 CPUE		
Species	Inner	Outer	P	Inner	Outer	P
Northern pike	0.09	1.86	.379	0.40	0.00	.223
Channel catfish	11.18	2.00	.041	–	–	–
Walleye	14.45	7.86	.132	15.80	3.83	.023
Yellow perch	118.45	39.86	.007	19.40	17.00	.805
White perch	37.00	8.14	.025	5.20	2.00	.232

Table 17.–CPUE (number per 305 m net lift) and percent-contribution of year classes for walleye from fall gill-net surveys, Saginaw Bay, 1989-97. Mean ages with no letter in common are significantly different.

Year class	Age	Percent	CPUE	Age	Percent	CPUE	Age	Percent	CPUE
	1989			1990			1991		
1994	–	–	–	–	–	–	–	–	–
1993	–	–	–	–	–	–	–	–	–
1992	–	–	–	–	–	–	–	–	–
1991	–	–	–	–	–	–	0	2.9	2.9
1990	–	–	–	0	2.2	2.2	1	22.0	18.9
1989	0	5.8	2.1	1	38.8	39.4	2	25.5	21.9
1988	1	23.6	8.7	2	14.6	14.8	3	12.4	10.6
1987	2	9.3	3.4	3	9.4	9.6	4	9.9	8.5
1986	3	20.8	7.7	4	14.6	14.8	5	10.1	8.6
1985	4	28.6	10.5	5	11.8	12.0	6	9.9	8.5
1984	5	8.1	3.0	6	6.3	6.4	7	3.8	3.3
1983	6	2.7	1.0	7	1.8	1.8	8	3.1	2.6
1982	7	1.2	0.4	8	0.6	0.6	9	0.3	0.2
1981	8	0.0	0.0	9	0.0	0.0	10	0.1	0.1
Mean	2.8ab			2.7a			3.2bc		
Total		100	37.0		100	101.6		100	86.1
	1992			1993[1]			1994		
1994	–	–	–	–	–	–	0	3.0	0.2
1993	–	–	–	0	–	–	1	4.2	0.7
1992	0	–	–	1	3.8	1.6	2	7.9	1.2
1991	1	18.1	3.9	2	28.7	11.8	3	19.4	2.7
1990	2	25.1	5.4	3	17.9	7.4	4	21.8	3.2
1989	3	14.6	3.1	4	20.9	8.6	5	15.8	2.5
1988	4	11.1	2.4	5	8.1	3.3	6	15.8	2.4
1987	5	10.5	2.2	6	6.5	2.6	7	9.1	1.4
1986	6	7.0	1.5	7	7.9	3.2	8	3.0	0.5
1985	7	8.2	1.7	8	4.9	2.0	9	0.0	0.0
1984	8	3.5	0.8	9	0.8	0.3	10	0.0	0.0
1983	9	0.6	0.1	10	0.0	0.0	11	0.0	0.0
1982	10	1.2	0.2	11	0.0	0.0	12	0.0	0.0
1981	11	0.0	0.0	12	0.3	0.1	13	0.0	0.0
Mean	3.5cd			3.9de			4.3efg		
Total		100	21.4		100	42.3		100	14.8
	1995[2]			1996[2]			1997[2]		
1997	–	–	–	–	–	–	0	1.0	0.1
1996	–	–	–	0	–	–	1	2.5	0.2
1995	0	3.3	0.4	1	17.6	1.9	2	16.9	1.7
1994	1	23.5	2.7	2	28.0	3.0	3	28.9	2.9
1993	2	0.7	0.1	3	4.6	0.5	4	4.0	0.4
1992	3	8.6	1.0	4	3.1	0.3	5	5.0	0.5
1991	4	16.9	2.0	5	11.9	1.3	6	10.9	1.1
1990	5	18.5	2.1	6	12.3	1.3	7	8.5	0.8
1989	6	12.9	1.5	7	11.1	1.2	8	10.9	1.1
1988	7	8.3	0.9	8	5.4	0.6	9	8.5	0.8
1987	8	5.6	0.6	9	4.6	0.5	10	2.0	0.2
1986	9	0.7	0.1	10	1.5	0.2	11	0.5	0.1
1985	10	0.3	<0.1	11	0.0	0.0	12	0.5	0.1
1984	11	0.7	0.1	12	0.0	0.0	13	0.0	0.0
Mean	4.1df			4.1dgf			4.8g		
Total		100	11.5		100	10.6		100	10.1

[1] Age distribution includes one age-13 fish, eleven walleyes un-aged. Percent-contribution based on aged fish only.

[2] Data based on expanded netting effort catch to provide a larger sample size. Total catch per 1000m therefore differs slightly from value reported in Table 3 which is based solely on catch from traditional netting locations.

Table 18.–Percent age composition of white perch and yellow perch from the gill-net catch, Saginaw Bay, 1989-97. Means with no letter in common are significantly different.

	Percent composition								
Age	1989	1990	1991	1992	1993	1994[1]	1995[1]	1996[1]	1997[1]
White perch									
0	13.3	–	1.0	–	–	12.6	4.9	–	1.6
1	68.8	7.5	93.9	86.7	17.9	70.6	93.4	73.9	33.3
2	17.2	47.5	4.1	13.3	53.6	7.0	1.6	22.5	42.6
3	0.8	42.5	1.0	–	14.3	5.1	–	2.2	16.3
4	–	–	–	–	10.7	1.9	–	1.4	3.1
5	–	2.5	–	–	3.6	2.8	–	–	0.8
6	–	–	–	–	–	–	–	–	0.8
7	–	–	–	–	–	–	–	–	1.6
8	–	–	–	–	–	–	–	–	–
9	–	–	–	–	–	–	–	–	–
Mean age	1.06a	2.42c	1.05ab	1.13abd	2.29c	1.21ad	0.97b	1.31d	1.99c
Yellow perch									
0	na	–	–	–	–	–	–	–	0.2
1	na	–	–	0.5	2.3	–	28.4	6.4	6.6
2	na	1.0	1.3	4.0	5.0	2.5	13.4	36.3	27.7
3	na	7.9	24.9	30.2	36.7	12.1	14.3	17.1	33.6
4	na	27.7	44.4	34.2	32.6	40.8	30.8	16.0	13.5
5	na	30.7	23.1	18.3	12.8	34.2	9.8	15.4	8.8
6	na	13.9	4.9	9.9	7.3	8.8	3.0	5.8	5.1
7	na	12.9	1.3	2.0	2.3	0.8	–	2.3	2.9
8	na	5.9	–	0.5	0.9	0.4	0.3	0.4	1.6
9	na	–	–	0.5	–	0.4	–	–	–
Mean age	na	5.11a	4.09b	4.09bc	3.84b	4.41c	2.91d	3.27e	3.25e

[1] Includes the catch of 38 mm mesh. Ages includes one age 10 fish in 1996.

Table 19.–Percent age and mean length-at-age for channel catfish, 1997. N denotes sample size and means limited to a sample size of at least 5 fish.

Age	N	Percent	Mean length
0	0	0.0	–
1	0	0.0	–
2	15	27.8	236
3	13	24.1	328
4	4	7.4	–
5	6	11.1	404
6	7	13.0	411
7	3	5.6	–
8	1	1.9	–
9	0	0.0	–
10	0	0.0	–
11	1	1.9	–
12	2	3.7	–
13	2	3.7	–
Total	54	100.0	348

Table 20.–Annual mean total lengths at age (mm) of walleye and yellow perch from Saginaw Bay, using fall gill-net data for 1989-97, as well as Michigan average lengths (Merna et al. 1981) and bay historic averages for 1926-38 (Hile 1954). Standard error of the mean is shown in parentheses. Mean lengths with no letter in common are significantly different. No means included for sample sizes less than 5 fish.

	Mean length									Michigan	Bay historic
Age	1989	1990	1991	1992	1993	1994	1995	1996	1997	average	average
Walleye											
0	230(1.6)	228(2.8)	238(3.0)	–	–	207(10.4)	224(4.6)	–	–	180	–
1	362(2.0)	348(1.3)	361(2.5)	320(2.6)	306(7.7)	348(8.8)	346(3.0)	352(4.9)	330(13.5)	264	254
2	441(4.2)	444(3.6)	444(1.4)	438(4.3)	410(3.4)	426(13.9)	–	437(3.7)	419(4.2)	353	320
3	498(5.4)	495(6.0)	504(3.3)	500(5.0)	465(4.9)	473(6.0)	470(3.8)	478(11.6)	468(3.8)	401	371
4	523(4.3)	537(5.5)	536(4.5)	535(6.1)	516(4.3)	521(5.3)	501(7.2)	537(16.4)	504(5.6)	447	411
5	568(9.3)	553(5.4)	557(4.3)	548(6.8)	537(4.8)	537(5.1)	543(4.3)	517(9.0)	536(11.6)	488	457
6	585(24.6)	552(9.2)	571(4.9)	588(12.2)	552(5.7)	564(6.0)	555(5.3)	582(8.6)	547(6.2)	523	483
7	–	580(17.0)	590(9.3)	611(11.6)	580(9.5)	613(15.7)	572(8.3)	568(6.5)	576(11.9)	549	505
8	–	–	611(8.7)	638(9.8)	601(10.4)	612(17.0)	590(12.2)	579(14.2)	586(12.9)	569	533
9	–	–	–	–	–	–	–	619(27.4)	579(11.5)	586	582
Mean length	462ab	443a	472b	483bc	483bc	506c	480bc	487bc	502c		
Yellow perch											
0	na	–	–	–	–	–	–	–	–	84	–
1	na	–	–	–	153(11.0)	–	148(0.9)	150(2.2)	141(1.2)	133	–
2	na	–	–	176(3.6)	185(8.2)	148(1.6)	161(2.3)	151(1.0)	155(1.1)	165	–
3	na	196(7.0)	197(2.3)	196(2.6)	189(2.3)	176(3.3)	187(3.5)	184(1.8)	189(2.2)	191	–
4	na	204(2.6)	208(2.2)	211(3.2)	195(2.8)	198(1.8)	205(2.3)	196(1.6)	202(1.9)	216	–
5	na	217(4.4)	220(4.1)	235(5.6)	208(3.4)	214(2.1)	220(4.6)	211(1.9)	227(3.3)	240	–
6	na	218(4.9)	218(5.9)	237(9.4)	213(5.2)	243(8.1)	248(9.2)	232(4.4)	239(4.4)	262	–
7	na	213(3.7)	–	–	216(8.1)	–	–	244(7.2)	247(6.4)	282	–
8	na	244(16.7)	–	–	–	–	–	–	256(16.5)	295	–
Mean Length		213a	210a	214a	195c	207a	186b	177d	182b		

Table 21.–Mean relative weight by length class and all sizes combined for walleye and yellow perch collected in gill nets in Saginaw Bay, fall 1989-97. N denotes sample size for that year. Means with no letter in common are significantly different.

	Relative Weight				
Year	Stock-quality	Quality-preferred	Preferred-memorable	All sizes combined	N
Walleye					
1989	100	96	95	96ab	259
1990	98	101	97	98a	508
1991	95	96	95	96b	689
1992	87	88	90	89c	171
1993	91	91	88	90c	380
1994	88	88	90	89c	166
1995	92	93	92	95ab	302
1996	90	92	90	90bc	267
1997	95	90	91	91c	204
Yellow perch					
1989	NA	NA	NA	NA	NA
1990	98	97	92	97ab	101
1991	82	80	86	81c	231
1992	82	87	86	84c	202
1993	96	95	94	96ab	218
1994	96	96	92	96ab	241
1995	91	87	90	89d	501
1996	103	93	91	101a	1677
1997	94	95	93	95b	962

Table 22.–Incidence of void stomachs and percent-abundance of food items found in stomachs of walleye from fall gill nets in Saginaw Bay, 1989-97.

			Percent-Abundance								
Year	Stomachs examined	% void	Unidentified fish remains	Gizzard shad	Yellow perch	Spottail shiner	Rainbow smelt	Alewife	Ninespine stickleback	White sucker	White perch
1989	257	26	27	63	0	0	<1	8	1	0	<1
1990	508	37	22	76	0	0	<1	1	<1	0	<1
1991	669	36	34	63	<1	<1	0	2	0	<1	0
1992	171	56	62	2	2	2	14	17	0	2	0
1993	371	52	39	59	0	0	<1	2	0	0	0
1994	84	45	24	70	3	3	0	0	0	0	0
1995	291	45	31	28	1	<1	0	37	0	<1	1
1996	148	61	72	23	4	0	0	1	0	0	0
1997	204	35	59	12	3	7	0	17	0	0	2

Table 23.–Proportional-stock-density for walleye and yellow perch and RSD of preferred and memorable fish (respectively, in parentheses) from fall gill-net data from Saginaw Bay, 1989 - 1997.

	PSD and RSD								
Species	1989	1990	1991	1992	1993	1994	1995	1996	1997
Walleye	79(44,3)	61(34,2)	79(40,3)	81(46,8)	93(40,3)	96(58,5)	76(55,3)	83(46,6)	96(51,8)
Yellow perch	na	79(9,1)	69(12,0)	62(18,4)	45(3,0)	73(9,1)	38 (6,1)	22 (2,0)	33 (5,1)

Table 24.–Number of walleye tagged at Dow Dam on the Tittabawassee River and recovered, 1989-97.

Tag year	Number tagged	Number recovered									Total recovered
		1989	1990	1991	1992	1993	1994	1995	1996	1997	
1989	2,494	71	47	37	51	18	15	6	3	4	252
1990	2,488		60	55	53	34	9	8	4	5	228
1991	3,079			75	113	51	16	9	11	11	286
1992	2,995				170	83	30	19	14	10	326
1993	2,989					154	52	31	24	17	278
1994	2,999						76	49	44	36	205
1995	2,970							54	54	45	150
1996	2,992								71	71	142
1997	2,993									80	80
Mean	2,889										
Total	25,999										1,947

Table 25.–Age composition (percent) of walleye sampled from Saginaw Bay tributaries during spring electrofishing, 1981-97.

	Age composition														Mean
	1	2	3	4	5	6	7	8	9	10	11	12	13	14+	Age[1]
1981	0.3	56.0	22.6	20.0	1.1	–	–	–	–	–	–	–	–	–	2.7
1982	–	–	79.2	13.6	7.2	–	–	–	–	–	–	–	–	–	3.3
1983	–	–	0.7	85.3	4.4	3.7	3.7	1.5	0.0	0.7	–	–	–	–	4.3
1984	–	14.7	18.2	22.1	33.8	8.2	3.0	–	–	–	–	–	–	–	4.1
1985	0.1	8.6	48.3	20.3	19.2	3.3	0.2	–	–	–	–	–	–	–	3.6
1986	–	3.1	28.4	39.1	17.3	5.9	5.2	1.0	0.1	–	–	–	–	–	4.2
1987	–	10.4	1.9	46.9	29.9	5.0	3.7	1.9	0.3	–	–	–	–	–	4.4
1988															
Female	–	–	4.0	18.5	32.8	25.7	10.5	5.7	3.0	–	–	–	–	–	5.5
Male	–	0.5	29.5	22.8	25.5	14.5	3.8	2.3	1.1	–	–	–	–	–	4.5
1989															
Female	–	–	1.5	41.4	27.3	23.1	5.7	1.1	–	–	–	–	–	–	4.9
Male	–	0.8	5.8	58.5	20.4	8.2	4.4	1.2	0.6	–	–	–	–	–	4.5
1990															
Female	–	0.1	0.1	1.2	37.1	34.7	22.9	3.6	0.4	–	–	–	–	–	5.9
Male	–	3.1	5.0	14.0	49.2	21.1	7.1	0.5	0.1	–	–	–	–	–	5.0
1991															
Female	–	–	0.1	18.8	19.2	45.7	11.5	2.6	1.5	0.6	–	–	–	–	5.7
Male	–	0.1	43.8	9.6	19.6	20.5	3.6	2.6	0.2	–	–	–	–	–	4.4
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	–	–	8.0
Male	–	–	–	1.5	0.3	15.2	23.6	27.3	16.1	9.2	4.0	2.0	–	0.6	8.0

[1]Mean age of all fish collected on the date when the sex ratio in the run was 1:1.

Table 26.–Percent composition of walleye year classes in the Saginaw Bay sport fishery, plus total harvest (2 SE in parentheses), adjusted annual exploitation rate (from tag data), and total annual mortality rate, 1989-97.

	Percent composition of harvest									
Year class	1989	1990	1991	1992	1993	1994	1995	1996	1997	Mean
1981	–	–	0.8	1.3	0.6	0.2	–	–	–	
1982	5.1	–	2.4	3.1	2.1	–	0.7	0.2	–	
1983	5.1	–	6.5	4.5	4.1	1.8	1.4	2.2	0.6	
1984	13.6	–	8.4	4.9	4.8	4.4	4.2	2.7	2.4	
1985	28.8	–	14.5	10.7	12.7	8.4	8.7	7.7	3.6	
1986	45.7	–	16.1	18.3	10.6	11.6	9.7	10.2	6.7	
1987	1.7	–	12.0	11.6	7.6	9.2	8.3	6.2	6.1	
1988	–	–	20.2	16.5	14.1	13.8	11.1	7.0	6.7	
1989	–	–	19.1	24.6	23.0	17.6	16.3	11.7	5.2	
1990	–	–	–	4.5	15.5	14.8	12.7	9.2	9.7	
1991	–	–	–	–	4.9	17.8	20.3	19.0	18.2	
1992	–	–	–	–	–	0.4	6.4	6.7	11.5	
1993	–	–	–	–	–	–	0.2	1.2	1.2	
1994	–	–	–	–	–	–	–	15.7	25.2	
1995	–	–	–	–	–	–	–	–	3.0	
1996	–	–	–	–	–	–	–	–	–	
1997	–	–	–	–	–	–	–	–	–	
No. aged	59	–	491	224	631	500	424	401	330	
Harvest	56,337	–	61,028	64,447	125,160	68,170	47,887	47,566	78,128	68,594
	(10,580)	–	(10,817)	(8,702)	(18,357)	(11,907)	(9,208)	(9,990)	(15,109)	
Exploitation	9.5	6.5	7.2	14.5	13.1	7.4	5.3	6.6	7.2	8.5
Total Mortality	28.5	27.9	39.3	41.2	35.7	19.7	36.0	15.5	–	28.3

Table 27.–Number of fingerling walleye stocked in Saginaw Bay between 1979 and 1997.

Year	Number stocked
1979	334,427
1980	9,989
1981	294,656
1982	269,540
1983	869,000
1984	947,796
1985	954,218
1986	871,263
1987	632,204
1988	345,537
1989	834,375
1990	850,085
1991	622,687
1992	787,675
1993	0
1994	1,282,992
1995	717,519
1996	0
1997	1,006,377
Total	11,630,340

Table 28.–Mean age (years), total length (mm), and weight (g) of sampled walleye and yellow perch taken by sport anglers during open water fishing season (typically April - October) in Saginaw Bay, 1989-97. Specimens are randomly subsampled by creel clerks based on a monthly quota. Standard error of the mean in parentheses.

	Walleye				Yellow perch			
Year	N	Age	Length	Weight	N	Age	Length	Weight
1989	59	3.9 (.15)	534 (9.7)	1,659 (100)	1,252	4.1 (.03)	187 (.8)	83 (1.9)
1990	–	–	–	–	–	–	–	–
1991	488	4.6 (.09)	516 (3.8)	1,518 (37)	1,658	4.4 (.02)	198 (.7)	257 (3.4)
1992	224	5.2 (.14)	554 (5.3)	1,827 (56)	1,760	5.0 (.04)	206 (.8)	155 (3.7)
1993	628	5.6 (.09)	552 (3.2)	1,740 (31)	1,451	4.4 (.04)	200 (.8)	129 (3.6)
1994	497	5.8 (.10)	553 (3.6)	1,831 (38)	1,228	4.7 (.05)	201 (.7)	142 (3.4)
1995	423	6.5 (.12)	570 (3.8)	1,961 (42)	1,373	4.8 (.04)	209 (.7)	122 (2.9)
1996	398	6.6 (.15)	561 (4.9)	1,867 (49)	1,239	4.0 (.04)	202 (.8)	94 (2.6)
1997	330	6.4 (.17)	569 (6.2)	1,845 (49)	882	2.8 (.04)	198 (.9)	93 (5.8)

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Appendix 1.–Common and scientific names of fishes and other aquatic organisms mentioned in this report.

Common name	Scientific name
Alewife	*Alosa pseudoharengus*
Bigmouth buffalo	*Ictiobus cyprinellus*
Black crappie	*Pomoxis nigromaculatus*
Bluegill	*Lepomis macrochirus*
Bowfin	*Amia calva*
Brown trout	*Salmo trutta*
Burbot	*Lota lota*
Channel catfish	*Ictalurus punctatus*
Chinook salmon	*Oncorhynchus tshawytscha*
Common carp	*Cyprinus carpio*
Emerald shiner	*Notropis atherinoides*
Eurasian ruffe	*Gymnouphalus cernuus*
Freshwater drum	*Aplodinotus grunniens*
Gizzard shad	*Dorosoma cepedianum*
Goldfish	*Carassius auratus*
Great Lakes muskellunge	*Esox masquinongy*
Johnny darter	*Etheostoma nigrum*
Lake herring	*Coregonus artedii*
Lake sturgeon	*Acipenser fulvescens*
Lake trout	*Salvelinus namaycusn*
Lake whitefish	*Coregonus clupeaformis*
Longnose sucker	*Catostomus catostomus*
Mayfly	*Hexagenia sp.*
Ninespine stickleback	*Pungitius pungitius*
Northern pike	*Esox lucius*
Northern shorthead redhorse	*Moxostoma macrolepidotum*
Pumpkinseed	*Lepomis gibbosus*
Quillback	*Carpiodes cyprinus*
Rainbow smelt	*Osmerus mordax*
Rainbow trout	*Oncorhyhus mykiss*
Rockbass	*Ambloplites rupestris*
Round goby	*Neogobius melanostomus*
Round whitefish	*Prosopium cylindraceum*
Shorthead redhorse	*Moxostoma macrolepidotum*
Smallmouth bass	*Micropterus dolomieui*
Spiny water flea	*Bythotrephes cederstroemi*
Spottail shiner	*Notropis hudsonius*
Stone cat	*Noturus flavus*
Tiger musky	*Esox masquinongy*
Trout-perch	*Percopsis omiscomaycus*
Tubenose goby	*Proterorhinus marmoratus*
Walleye	*Stizostedion vitreum*
White bass	*Morone chrysops*
White perch	*Morone americana*
White sucker	*Catostomus commersoni*
Yellow perch	*Perca flavescens*
Zebra mussel	*Dreissena polymorpha*

Appendix 2.–Length/weight regression equations for select species based on 1997 fall gill-net collections in Saginaw Bay. Logs are base 10 and weight (wt) is in grams, 1ength (len) is in mm.

Species	Equation	r^2
Walleye	log(wt)=3.171 log(len)-5.473	0.98
Yellow perch	log(wt)=3.223log(1en)-5.406	0.82
White perch	log(wt)=2.904log(1en)-4.573	0.90