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Status Of Yellow Perch And Walleye In Michigan Waters Of Lake Erie, 1989-93

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Abstract—We investigated the fish community and population dynamics of yellow perch *Perca flavescens* and walleye *Stizostedion vitreum* in Michigan waters of Lake Erie. This study was conducted from 1989 to 1993, but information from previous years was considered in the analyses. For yellow perch, index trap-net data suggested a decline in abundance with a slight increase in growth during the period. Catch-at-age analysis for yellow perch indicated an initial decline followed by an increase in abundance during the same period. Catch-at-age analysis produced mean estimates for survival (0.62), instantaneous fishing mortality (0.08), and annual exploitation (0.06) for yellow perch in Michigan waters of Lake Erie. For walleye, index trap-net data revealed no trend in walleye abundance during the period. However, index gill-net data suggested a sharp decline in walleye abundance from 1989 to 1993. Catch-at-age analysis for walleye indicated a decline in the abundance of age-2 and older fish from 1989 to 1991, and a slight increase in 1992 and 1993. Catch-at-age analysis produced mean estimates of annual survival (0.53), instantaneous fishing mortality (0.32), and annual exploitation (0.23). Possible explanations for the differences in abundance trends between index survey and catch-at-age analyses for both walleye and yellow perch included: a suspected increase in gear avoidance due to increased water clarity; an inherent weakness in catch-at-age analysis in estimating the numerical abundance of cohorts newly recruited to the fishery; an increase in growth rates for yellow perch, particularly for age-2 fish; and a suspected change in vertical distribution affecting walleye vulnerability to index gill nets. Analysis of walleye tag-recapture data also produced mean estimates of walleye annual survival (0.64) and exploitation rate (0.09), as well as instantaneous natural mortality (0.34). Possible factors in the differences between the two sets of parameter estimates for walleye were the longer time series of data and wider geographic area included in the tag recovery analysis. Walleye tag recovery data indicated strong northward and eastward movement patterns. Walleye tagged in the Huron River were recovered further north than those tagged at Monroe. Based on the results of this study, management actions recommended for Lake Erie percids included: no change in existing Michigan sport fishing regulations for yellow perch or walleye; and collection of spatially explicit fishing effort data for Lake Erie and the St. Clair River, Lake St. Clair, and Detroit River. Future research directions identified included: collection of yellow perch fecundity data from MDNR spring trap-net samples; continuation of the interagency $100.00 reward tag study; and continuation and support of genetic efforts to quickly and inexpensively identify stock of origin for walleye based on scale samples.

It is important to review historical records of Michigan's Lake Erie fishery to put current fisheries management into perspective. During most of the past 150 years the native fish community has been subjected to excessive commercial exploitation and forced to exist in severely degraded habitat. The changes in species structure and abundance have been dramatic (Appendix Figures 1 and 2). Lake sturgeon (species names are listed in Appendix 1), lake herring, lake whitefish, walleye, sauger, and yellow perch contributed substantially to commercial catches from 1890 to 1920, adding as much as three million pounds to the annual harvest. Most of these highly valued species were eliminated from the fishery by 1930 due to the combined effects of habitat degradation and overfishing (see Appendix Figure 1). Channel catfish and white bass are the highest valued species still contributing to commercial harvest (Appendix Figure 2), and they too have shown dramatically diminished production since 1960. A Strategic Plan, developed by the Fisheries Division of the Michigan Department of Natural Resources (MDNR), calls for rehabilitation and maintenance of the Lake Erie fish community and aquatic environments (MDNR 1994).

Yellow perch and walleye have been the primary sport and commercial species in Lake Erie this century. In Michigan waters of Lake Erie, walleye and yellow perch routinely account for over 80% of the total annual sport harvest (MDNR, unpublished records). Sport angling pressure in Michigan waters of Lake Erie has averaged over 1 million hours annually since the mid-1980s (Rakoczy and Rogers 1991; Rakoczy 1992). These percid fisheries clearly represent a resource of great importance to Michigan anglers, with significant socioeconomic benefits for all of southeast Michigan.

Since the mid-1970s, both yellow perch and walleye have been managed lake-wide under an interagency quota system. Under the auspices of the Great Lakes Fisheries Commission's (GLFC) Lake Erie Committee, biologists and administrators from Michigan, New York, Ohio, Ontario, and Pennsylvania work together to set annual harvest quotas for yellow perch and walleye that will ensure continued viability of both fisheries into the future. Success of this management system depends on accurate assessment of harvest and effort, abundance trends, and survival rates by each agency for fish populations within their waters of Lake Erie. Michigan began an annual assessment of walleye and yellow perch populations in Lake Erie in 1978. Bryant (1984) and Haas et al. (1988) have previously reported on various aspects of this assessment program. This report focuses on the assessment program from 1989 to 1993. The purpose was to examine trends in abundance, growth, and survival rates for yellow perch and walleye in Michigan's waters of Lake Erie. Movement patterns of walleye based on tag recovery data were also examined.

Methods

Net Samples

Trap nets were used to capture walleye for tagging and to provide an index of relative abundance and catch per unit effort (CPUE = number caught per 24 h or trap day) for walleye and yellow perch. We captured walleye and yellow perch with 1.8 m-deep trap nets fished at the same locations each year off Monroe, Michigan (Figure 1). Five nets were fished throughout each sample period and were normally tended 4 or 5 times each week. We tried to obtain a minimum of 50 net lifts each year. The nets were typically set in early April and fished through the end of the month.

The entire catch from each trap net was identified and enumerated. Size data and age samples (scales) were collected from walleye and yellow perch. The maximum time between net lifts was 72 h; most nets were lifted after 24 h.

Catch from gill nets set in the fall provided data on abundance of yearling and older walleye. We examined indices of relative year-class strength for walleye from both gear types because gear selectivity influences size distribution of the sample. We fished multifilament, graded-mesh gill nets at two stations also off Monroe (Figure 1) in October from 1978-93 as part of the interagency yearling walleye index program (GLFC, Lake Erie Committee, unpublished agreement). Replicate sets were made each year with nets, 1.8 m deep, each consisting of seven 30.5 m long panels that ranged from 51 to 127 mm stretched mesh by 13 mm intervals. In 1991-93, we also fished monofilament, graded-mesh gill nets at both stations in paired sets with standard multifilament nets. In 1991, the monofilament nets were 1.83 m deep, and included 12 panels 15.2 m long (182.4 m total length), that ranged from 32 mm to 76 mm stretched mesh by 6 mm intervals and 76 mm to 127 mm stretched mesh by 13 mm intervals. In 1992 and 1993, the monofilament nets also included two additional panels of 140 mm and 152 mm stretched mesh for a total length of 212.8 m. Both multifilament and monofilament gill nets were suspended from the surface on strings 0.9 m long. All walleye captured in gill nets each year were measured for length and scale samples were collected for age analysis.

For walleye, we also developed a ranking system for the 1974-92 year classes, some of which were not yet completely represented through their life. Each year class was ranked for three criteria: cumulative trap-net CPUE; cumulative gill-net CPUE; and cumulative harvest. The latter included all sport and commercial harvests for the Western and Central basins. For a given year class, ranks for the three criteria were averaged to arrive at a mean rank.

Catch-at-age analysis

We used CAGEAN (Deriso et al. 1985), a catch-at-age model, to estimate annual exploitation and survival rates for yellow perch and walleye. This model uses fishing mortality and catch-at-age data to arrive at stable and reliable estimates of historical and current stock sizes. It is an improvement over the traditional virtual population analysis since multiple gear types and auxiliary information on fishing effort are explicitly considered in the model. We used the IBM personal computer (PC) version of CAGEAN, which required that we input natural mortality rate as well as gear and age specific catches, fishing efforts, and individual weights. The program estimated abundance, catch, fishing mortality, selectivity, and catchability for each age of fish (CAGEAN-PC User Manual 1987). The CAGEAN program allows pooling of older age groups if uncertainty in the accuracy of the aging technique is a concern. Due to the short time series of data used in this analysis, we needed to assume constant age-specific selectivities and catchabilities through the time period analyzed.

For yellow perch, a two gear version of CAGEAN was implemented, using catch and effort data from spring trap-net surveys as well as sport fishery harvest and effort estimates. The natural mortality rate (M) was set at 0.4 (GLFC, Lake Erie Committee, unpublished report). We pooled all catch data for age 6 and older fish. We set the ages of full recruitment to the trap nets at 3 to 6. We set the ages of full recruitment to the sport fishery at 3 to 5, reflecting a decline in vulnerability to the sport fishery for older fish. Gear lambdas (λ) were set at 1.0 for the sport fishery and 0.5 for the trap-net survey. Effort lambdas (λ) used were 0.5 for both the sport fishery and trap-net survey.

We also used CAGEAN to analyze the interagency yellow perch catch-at-age data for Lake Erie's Western Basin (GLFC, Lake Erie Committee, unpublished data). These data included three gear types: commercial gill nets, commercial trap nets, and sport fishing. To standardize results from computer analyses, command files were structured as similarly as possible. The same ages of full selectivity and λ values were used for the sport fishery. Trap-net survey ages of full selectivity and λ values were used for the commercial trap-net data. Ages of full selectivity for the commercial gill-net data were set at 3 to 5, with gear $\lambda = 1.0$, and effort $\lambda = 0.5$. The natural mortality rate was again set at 0.4.

For walleye, a three gear version of CAGEAN was used with catch and effort data from spring trap-net surveys, fall gill-net surveys, and sport fishery harvest and effort estimates. We pooled all catch data for age 7 and older fish. We set the age of full recruitment to the trap nets, gill nets, and sport fishery at 3. We set the natural mortality rate at 0.32 (GLFC, Walleye Task Group, unpublished report). Gear λ was set at 1.0 for all three gear types, while effort λ was set at 0.5.

We also used CAGEAN to analyze interagency walleye catch-at-age data for all of Lake Erie. The interagency data included two gear types, gill nets and sport fishing. To standardize results from computer analyses, command files were structured as similarly as possible. The same age of full selectivity, gear λ and effort λ were used for the lakewide sport fishery and commercial gill-net fishery as for the Michigan sport fishery and index gill nets. The natural mortality rate was again set at 0.32.

Michigan sport fishery harvest and effort data for both species were available through an on-site creel survey conducted annually (for example, see Rakoczy and Rogers 1987). Biological data including length, weight, and scale samples for age analysis were collected from a representative subsample of the observed harvest by on-site creel clerks during all years except 1990. Age composition of Michigan's sport fishery harvest in 1990 was assumed to be the same as that of Ohio's sport fishery that year (Ohio Department of Natural Resources, personal communication). The sport fishery harvest-at-age and effort data used in the CAGEAN analysis for yellow perch and walleye are shown in Appendices 3 and 4.

Tag-recapture study

Walleye were tagged aboard the research vessel CHANNEL CAT by MDNR personnel during spring trap-net surveys near Monroe, Michigan from 1978-93. Fish were removed from trap nets and immediately placed in a live tank. Lake water was continuously circulated through the tank. Fish were removed individually from the live tank, tagged without anesthesia, and released at the net location. Total length was measured for all tagged fish, while total weight data and scale samples were taken from portions each year (36% to 100%). When scale samples were taken, all fish from that trap net were processed. Fish under 600 mm were tagged on the lower jaw with size 10 or 12 monel metal strap tags affixed by overlapping the tag snugly around the dentary bone; while fish over 600 mm were tagged with size 12 monel metal strap tags affixed around both the maxillary and premaxillary bones. All tags were inscribed with the Mt. Clemens MDNR address and an individual tag number. We tagged 31,902 walleye at Monroe from 1978 to 1993. Recaptures of tagged fish were submitted by anglers and commercial fishermen on a voluntary basis.

Walleye were also tagged by MDNR personnel during the spring spawning run in the Huron River near Flat Rock, Michigan (22 km upstream from Lake Erie). Fish were collected with pulsed DC electrofishing gear. Tagging and data collection were conducted as described above. A total of 930 fish were tagged in 1992 and 1993.

Tag recovery data were summarized by location and calendar day. Dates of tagging and tag recovery for recaptured walleye were coded by calendar day to facilitate seasonal analyses of recovery data. Geographical distributions of tag recoveries from the Monroe and Huron River tagging sites were analyzed and compared with Mardia's nonparametric two-sample test of the null hypothesis that two samples belong to the same bivariate distribution (Mardia 1967). Maps of monthly tag distribution were generated based on the numbers of tags recovered within zones including 10 minutes of latitude and longitude. We applied an analytical gridding method known as "Kriging" which uses a linear variogram to interpolate regularly spaced geographical data which was used to generate maps (Davis 1986).

A generalized stochastic model, ESTIMATE (Brownie et al. 1985), was used to analyze results of the tag-recapture study. This model provides unbiased maximum likelihood estimates of recovery and survival rates. Since the tag recovery rate is a product of exploitation rate and reporting rate (Krementz et al. 1987), total instantaneous mortality (natural logarithm of survival rate) may be partitioned into instantaneous fishing and natural mortality rates if an estimate of the tag reporting rate is available (Horsted 1963). Reward tags, carrying a reward inscription of $100 US, were randomly applied to 10% of the walleye tagged by Ontario, Ohio, and Michigan in 1990. The return rate of reward versus non-reward tags provide an estimate of the reporting rate for non-reward tags assuming that 100% of reward tags were reported.

Results

Net Samples

Mean catch per net lift for yellow perch during 1989-93 was 94.6, compared with a mean of 254.8 for the period from 1978-88 (Appendix 2). Based on catch per net lift, 1990-93 rank among the six lowest years for perch abundance since 1978. Yellow perch relative abundance declined sharply after 1989 and remained low through 1993 (Table 1). Relative abundance for ages 3 to 6 in 1989 were 5-10 fold higher than for any other age groups in any other year during 1989-93. Abundance of age 2 fish in 1992 and 1993 may have been 5-12 fold higher than during the period 1989-91.

In general, growth rates appear to have increased significantly for yellow perch of ages 3-5 from 1989-93 for males (ANOVA, $F = 3.2$, $P = 0.014$) and females (ANOVA, $F = 11.3$, $P = 0.000$). The most notable increases in growth are evident in males of ages 3, 4, and 5 (Table 2). The presence of age-2 males in 1992 and 1993 was likely an indication of increased growth for that age group as well, resulting in some recruitment of age-2 fish to trap nets in those years.

Walleye abundance estimated from trap-net data varied over the study period with the highest abundance in 1991 (Table 3). Age specific CPUE values indicate that the 1982 (age 7 in 1989) and 1986 (age 3 in 1989) year classes were very strong. Mean age of trap-netted fish increased from 4.2 years in 1989 to 5.4 years in 1993 as these two year classes matured. Three relatively weak year classes were produced in 1987, 1988, and 1989. The 1990 year class appeared to be more abundant than the 1987-89 year classes. In fact, age-3 fish accounted for 32% of the trap-net catch in 1993, while the 1987-89 year classes combined to make up only 25% of the total. We believe our trap-net estimates of relative year-class strength reflect actual abundance trends because they also agree with independent year-class estimates from Ontario and Ohio trawls and gill nets (GLFC, Lake Erie Committee, unpublished data).

Overall, walleye growth rate, as indicated by length at age for trap-netted fish of each sex, exhibited no obvious trend (Table 4).

Walleye abundance estimated from gill-net data declined steadily from 1989 to 1993, but compared favorably with any other 5-year time period since 1978 (Table 5). Yearling walleye catch rates suggest that the 1990 and 1991 year classes were at least average in strength, while the 1992 year class appeared very weak.

Walleye growth rates, indicated by length at age (Table 6) for gill-netted fish of each sex, also exhibited no apparent trends over the study period. Mean length at age for the 1991 year class as age-1 and -2 fish in 1992 and 1993, respectively, was quite low. In fact, the 1991 year class was second lowest in mean length at age among yearlings of any year class since 1978 (Table 7). This may be an indication that the 1991 year class was rather robust. Only the 1982 year class, the strongest on record for Lake Erie, grew slower during its first two growing seasons.

Mean ranks were assigned to the 1974-92 year classes (Table 8). There was good agreement for estimates among the three gear types and a nonparametric statistical comparison showed no significant differences. The top five year classes were 1982, 1986, 1985, 1977, and 1984.

Catch-at-age analysis

The CAGEAN estimates of mean instantaneous fishing mortality, annual survival, exploitation, total abundance and catch for yellow perch in Michigan's waters of Lake Erie are presented in Table 9. Average parameter values during the study period (1989-93) were: survival, 0.62 (se = 0.02); instantaneous fishing mortality, 0.08 (se = 0.03); annual exploitation, 0.06 (se = 0.02); and average abundance, 14,480,695 (se = 4,536,241). Estimated annual survival increased during the study period, and exploitation decreased, but these changes were not statistically significant.

The CAGEAN estimates of mean instantaneous fishing mortality, annual survival, exploitation by gear type, total abundance and catch for yellow perch in the Western Basin (Michigan, Ohio, and Ontario waters) are presented in Table 10. Average parameter values during the study period were: survival, 0.54 (se = 0.04); instantaneous fishing mortality, 0.24 (se = 0.08); annual exploitation, 0.17 (se = 0.05); and average abundance, 65,775,694 (se = 18,767,256). Over the study period, estimated annual survival increased and exploitation decreased as for the Michigan waters estimates. Yellow perch in the Ohio and Ontario waters of the Western Basin experienced significantly higher exploitation and lower survival rates than those in Michigan waters (Kolmogorov-Smirnov two-sample test, $z = 2.2$, $P = 0.036$).

For walleye in Michigan waters of Lake Erie, estimates of instantaneous fishing mortality, annual survival, exploitation, total abundance and catch for walleye produced by the CAGEAN analysis are presented in Table 11. Average parameter values during the study period were: survival, 0.53 (se = 0.04); instantaneous fishing mortality, 0.32 (se = 0.08); annual exploitation, 0.23 (se = 0.05); and average abundance, 1,660,829 (se = 348,390). Estimated annual survival increased after 1990, while exploitation was lower. Variance for the mortality and exploitation estimates produced by CAGEAN were high so that null hypotheses of no change during the study were not rejected.

The lakewide CAGEAN estimates for walleye of instantaneous fishing mortality, annual survival, exploitation by gear type, total abundance and catch are presented in Table 12. Average parameter values during the study period were: survival, 0.60 (se = 0.01); instantaneous fishing mortality, 0.20 (se = 0.01); annual exploitation, 0.16 (se = 0.01); and average abundance, 40,145,918 (se = 9,907,772). Estimated survival declined significantly ($z = 3.3$, $P < 0.005$) in 1993, which must be attributed to increased exploitation since natural mortality was assumed constant. In contrast with yellow perch, these estimates indicate that walleye in Michigan waters of Lake Erie usually experience higher exploitation and lower survival than walleyes in the rest of Lake Erie.

Tag-recapture study

A total of 2,501 tagged fish (7.8% of total tagged) from the Monroe site were caught and reported by commercial and sport fishermen through 1993, while a total of 48 tagged fish from the Huron River site were caught and reported. The major portion (81.0%) of tag recoveries were reported by anglers. There appears to be ample angling harvest throughout the area to provide sufficient voluntary tag recoveries to adequately monitor movements of tagged stocks.

The geographical recapture distribution for fish tagged at Monroe shifted from 1989 to 1993 (Table 13). The percentage of recoveries reported from Lake Erie waters increased, with the largest portion of that increase occurring in the Central Basin. Recoveries were reported from March through December, with over 77% reported during May (33.5%), June (22.3%) and July (21.3%). The areal distribution of Monroe tag recaptures by month from 1987 to 1993 are shown in Figure 2.

The geographical recapture distribution of fish tagged in the Huron River in 1992 and 1993 was as follows: St. Clair River, 24.3%; Lake St. Clair, 8.1%; Detroit River, 27.0%;

Western Basin-Lake Erie, 24.3%; Central Basin-Lake Erie, 2.7%; Eastern Basin-Lake Erie, 8.1%; Lake Erie-Total, 35.1%. Recoveries were reported from March through July, with 43% reported caught in May. It appears walleye that spawn in the Huron River had a greater tendency to move northward, with significantly higher ($z = 8.8$, $P = 0.000$) proportions of recoveries in the Detroit River, Lake St. Clair, and St. Clair River. The areal distribution of tag recoveries from the two Michigan Lake Erie tag sites (Monroe and Huron River) is shown in Figure 3. Statistical comparisons of tag recovery locations from each tag site confirm that Huron River fish were recovered significantly further north than Monroe fish (Mardias $U = 26.9$, $P = 0.00$). The geographical centers (centroids) for these comparisons indicate the centroid for all tag recovery locations from the Huron River tag site was located 38 km north of the centroid of tag recoveries from the Monroe tag site (Figure 4). Comparisons within individual waterbodies showed that the Huron River fish were consistently recovered north of the Monroe tags; however, no within-lake differences between centroids (averaged 4.7 km apart) were significant.

Recovery data for tagged walleye were analyzed to estimate annual rates for tag recovery and survival from 1986 to 1993. Data on non-reward tag recovery for fish tagged at Monroe from 1978-93 are shown in Appendix 5. All parameter estimates were taken from Model 1 of the computer program ESTIMATE (Brownie et al. 1985) under the assumption that survival and reporting rates were year-specific. Model 0 assumes that first year recovery rate is different and models 2 and 3 assume constant survival and recovery rates. Model 1 was most compatible with all data sets compared to the three alternative models and produced the least biased estimates of annual survival and tag reporting rate. Another assumption was made that all tag recoveries attributable to the 1993 fishing year had been received so that recovery rate estimates for 1993 were comparable to those for prior years. Analysis of the tag recovery data produced an estimated mean annual survival of 63.58% and mean recovery rate of 3.27% (Table 14).

The reward tag study produced an estimate of reward/non-reward tag recovery ratio of 2.84 for walleye tagged at Monroe (Table 15).

These values were used to estimate instantaneous natural mortality (M) according to the relationship $M=Z-F$ [where $F=uZ/A$ for type II fisheries (Ricker 1975)]; where, Z is the instantaneous total mortality, u is the exploitation rate, A is the total mortality rate, and F is the instantaneous fishing mortality rate. A value for u of 9.3% was generated by multiplying the mean tag reporting rate produced by ESTIMATE (3.27) by the reward/non-reward ratio (2.84). The resulting value for M was 0.34. It is important to note that survival rate estimates, using ESTIMATE, are independent of recovery rates; thus, expansion of the tag recovery rate by reward/non-reward ratios will not alter survival rate estimates in any way.

The only statistically significant increase in tag recovery rate during the study period occurred in 1993 (Table 14).

Discussion

Net samples

We used trap nets and gill nets to investigate trends in abundance of yellow perch and walleye. Gill nets typically provide reasonable indices of relative year-class strength (Willis 1987). Trap nets are generally considered to be superior to gill nets for relative abundance studies (Yeh 1977; Craig 1980). This superiority assumes that CPUE in this gear is linearly related to fish abundance and that a percent change in abundance will be reflected in the same percent change in CPUE (Bannerot and Austin 1983). Trap-net CPUE for yellow perch suggests that yellow perch abundance in Michigan's waters of Lake Erie has declined in recent years. If the apparent increase in yellow perch growth is actually a density-dependent response, then it too suggests decreased abundance. However, several factors complicate this appraisal of yellow perch relative abundance. Lake Erie has undergone drastic biological changes during the past 10 years, including explosive increase in white perch abundance during the 1980s, appearance of the spiny water flea in the 1980s, establishment of zebra mussels in the late 1980s and early 1990s, and an apparent decline of white perch in recent years. Water clarity, possibly related to zebra mussel filtering, has increased dramatically across Lake Erie (Leach 1993). As a result, lower catchability of yellow perch due to gear avoidance may have also been a factor in the decline of survey trap-net catches of yellow perch and other species.

Zebra mussels may indirectly affect yellow perch growth in Lake Erie as well. Rautio (1994) found that benthic invertebrates were more abundant and that yellow perch grew faster in the presence of zebra mussels. Hayward and Margraf (1987) suggested that yellow perch in the Western Basin of Lake Erie, prior to the zebra mussel introduction, experienced restricted growth due to reduced size structure of the benthic prey base. Lake Erie yellow perch, in the presence of zebra mussels, may grow faster due to an improved benthic prey base, rather than as a response to lower yellow perch density. We suspect that the increase in CPUE of age-2 yellow perch in 1992 and 1993 (Table 1) was a result of improved growth and earlier vulnerability of yellow perch to the survey trap nets. The appearance of age-1 fish in the sport harvest (Appendix 2) may also be a function of improved growth and subsequent changes in angler selection of catch for harvest.

Trap-net CPUE for walleye was more stable than for yellow perch during the study period, but declined steadily from 1991 to 1993. Walleye gill-net CPUE declined across all years of the study. Lack of a strong year class in the late 1980's to replace the aging 1982 and 1986 year classes (both unusually strong) was certainly a factor in this decline. As with yellow perch CPUE, the effects of water clarity may also have been a factor, with a potential for increased net avoidance for both trap nets and gill nets leading to decreased CPUE. Our survey gill nets, which were suspended below surface on 0.9-m strings, may also have been sensitive to vertical shifts in walleye distribution in the water column due to water clarity changes. In recent years, many Ontario commercial fishermen have increased string lengths on their commercial gill nets due to a perceived shift in walleye vertical distribution (J. Payne, Ontario Ministry of Natural Resources, personal communication). The ranking system used for walleye year classes illustrates the dominance of the 1982, 1986, 1984, and 1985 year classes in the time series. Haas (1988) found that survey trap nets and gill nets used in Michigan waters of Lake Erie yielded similar relative abundance estimates for walleye. The mean ranking analysis used here confirms that finding.

Catch-at-age analysis

Based on catch-at-age analysis, yellow perch abundance in Michigan waters of Lake Erie declined from 1988 to 1991, but doubled from 1991 to 1992, and nearly doubled again from 1992 to 1993 (Table 9). The increases in predicted abundance in 1992 and 1993 were largely a result of the increased CPUE for age-2 perch in both the sport fishery and survey trap nets during 1992 and 1993. A notable increase in age-3 CPUE in the sport fishery in 1993 was also involved. Unfortunately, these changes in CPUE may not accurately reflect the changes in yellow perch abundance in Lake Erie. Increased growth rates and subsequent changes in age specific selectivities for both the sport fishery and survey trap nets may result in overestimation of abundance. We felt that a comparison of parameter estimates using catch-at-age analysis for data from Michigan waters with similar estimates using data from the entire Western Basin would be valuable due to the contrast in fisheries between these two areas. Of the three fishery management agencies on the Western Basin, Michigan is the only one limiting the yellow perch fishery to angling. Furthermore, Michigan's sport fishery is the only one restricted by a creel limit. Based on these differences, we suspected that yellow perch in Michigan waters would experience lower total exploitation rates and higher survival rates.

Annual estimates of total exploitation for yellow perch in the Western Basin ranged from 2.6- to 4.1-fold greater than estimates for Michigan waters alone. Annual estimates of survival ranged from 4 to 28 percent less for the Western Basin, compared with Michigan waters. In 1992 and 1993, survival estimates from the two data sets were closest, but exploitation rates differed the most. We can not explain this pattern. In general, we believe the higher exploitation rates and lower survival rates estimated for the Western Basin are an accurate reflection of the greater fishing pressure exerted on yellow perch in those areas with commercial fisheries.

The estimated mean annual survival for yellow perch (0.62) produced by catch-at-age analysis for Michigan waters was considerably higher than those recently reported from other areas of the Great Lakes. Annual survival for yellow perch in southern Lake Michigan ranged from 0.40-0.44 (Rybicki 1985), while perch from the Les Cheneaux Island area (northern Lake Huron) experienced a survival rate of 0.45 (Lucchesi 1988). The estimate of mean annual survival for the Western Basin analysis (0.54) was also comparatively high.

Yellow perch abundance estimates generated by the catch-at-age analysis for the Western Basin were much higher than for the analysis on Michigan waters. However, both showed the same trend of large increases in 1992 and 1993. This trend is probably a function of increased growth rates, as we also suspected for the abundance estimates for Michigan waters. Additionally, estimation of abundance for the most recent cohorts entering the catch is risky, because the regression methods are not able to determine if a given cohort is small and being fished hard or is large and being subjected to lower fishing rates (Hilborn and Walters 1992). The analysis of catch-at-age data for Michigan walleye produced catch estimates surprisingly similar to those actually observed for the fishery. This level of similarity is even more surprising considering our decision to use only one set of selectivities and catchabilities for the analysis due to the short time series under consideration. This suggests that the CAGEAN model estimates of survival and exploitation should also be close to the actual values for the Michigan analysis.

Our analysis indicates that walleye abundance declined rather sharply from 1989 to 1991, coincident with entry of the weak 1987 to 1989 year classes into the fishery as age-2 fish. The entry of the stronger 1990 year class into the fishery in 1992 stabilized abundance, but levels remained about 50% less than those in 1988 and 1989. This is again a reflection of the high abundance levels that existed in the mid and late 1980s, a combined effect of several strong year classes (1982, 1986, 1984, 1985).

Estimates of exploitation for walleye in Michigan waters, based on the CAGEAN analysis, showed an interesting pattern. Total exploitation rate was quite high from 1988-90, then declined to a level about 50% lower for 1990-93. The reason for this change is not clear. Michigan sport harvest greatly exceeded the allowable catch quota during the three years of analysis when high exploitation rates were found (1988-90, Appendix 6). In response to exceeding quotas in 1988 and 1989, Michigan reduced the daily creel limit in 1990 for its Lake Erie walleye fishery from 10 fish to 6 fish. Sport fishing effort also dropped dramatically after 1990 for the Michigan sport fishery (Appendix 4). Since 1991, the Michigan sport harvest has not exceeded total allowable catch. Estimated abundance levels since 1990 were 50% lower than in 1988 and 1989. It is possible that declining abundance, a disproportionate decline in fishing effort, and a reduced bag limit were all involved in the decline in exploitation. However, we are unable to distinguish the relative importance of these factors in the observed change. In addition, a major change in walleye catchability due to changes in walleye distribution or feeding behavior could also be involved.

We felt that comparison of parameter estimates using catch-at-age analysis for the data from Michigan waters with analysis using data from Lake Erie would be valuable due to differences in the fisheries between the areas. Michigan and Ohio limited walleye fishing to angling, while Ontario's fishery was based on commercial gill nets. Exploitation in Michigan waters was likely higher than exploitation lake wide due to the intensity of the sport fishery in Michigan's limited jurisdiction.

Estimates of exploitation generated using the lakewide data were about two-thirds less than those estimated using the Michigan data for 1988 to 1990. Estimated exploitation rates were nearly the same for the two areas in 1991 and 1992. The lakewide estimate of exploitation was higher than that estimated for Michigan waters in 1993, the last year of analysis. In fact, the lakewide estimate of exploitation increased nearly 100% from 1992 to 1993. Review of the CAGEAN output files indicated this increase was the result of a 50% increase in exploitation by the sport fishery, and a 100% increase in exploitation by the gill-net fishery.

Many Michigan anglers believed that the commercial gill-net fishery in Ontario for walleye was exploiting Lake Erie walleye at a much higher rate than a sport fishery could. Regrettably, direct comparison of the exploitation rates of the Michigan sport fishery with the Ontario commercial fishery are not possible through this analysis. However, it is evident from analysis using Michigan data that the Michigan sport fishery was exploiting walleye in Michigan waters at a rate much higher than the lakewide rate during 1988-90, which included the Ontario commercial fishery.

Tag-recapture study

Haas et al. (1988) reported that tag recovery data from 1978-87 for the Monroe tag site demonstrated a strong tendency for upstream movement after spawning, with substantial movement of Lake Erie walleye into the Detroit River, Lake St. Clair, and the St. Clair River. They found that 29% of all Monroe tags recovered came from the Detroit River or further north. Tag recovery data from 1989-93 continued to show a strong tendency for upstream movement, with 26% of all tags recovered from the Detroit River or further north. The areal distribution of tag recoveries by month (Figure 2) further illustrate the northward movement of fish from the Monroe tag site into the connecting waters. An eastward movement pattern is also evident. We believe that the majority of walleye tagged in Lake Erie at Monroe originated from the Maumee River stock, with sexually mature fish being caught and tagged after spawning.

Areal distribution of tag recoveries is at least partially dependent on areal distribution of fishing effort. Unfortunately, distribution of effort is poorly understood and has not been factored into distribution of tag recoveries for walleye from Lake Erie. Although sample size is quite small, tag recoveries from walleye tagged in the Huron River appear to differ in areal distribution compared to walleye tagged at Monroe. Walleye tagged in the Huron River were recovered significantly further north of the fish tagged at Monroe. This difference may be due to the relative geographical location of the tag sites (Huron River site was 27 km north of the Monroe site) or to possible differences in the sex and age structure of the tagged populations. Alternatively, walleye spawning in the Huron River may represent a separate stock. Separate stocks may exhibit different movement patterns, experience different growth, mortality, and exploitation rates, and respond differently to environmental perturbations (Ihssen et al. 1981, Colby and Nepszy 1981). While the Maumee River spawning stock is likely the single largest walleye stock in Lake Erie, inclusion of as many separate stocks as possible in the interagency tag-recapture study, including comparatively small stocks, will provide a broader understanding of walleye population dynamics in the lake.

Although ESTIMATE provided unbiased estimates of recovery and survival rates, we needed to determine the tag reporting rate to estimate instantaneous natural mortality. In many studies reporting rate is assumed to be 100%, that is, all tags taken in fisheries are assumed to be seen and subsequently reported. If 100% reporting is assumed, then recovery rate is an estimate of exploitation rate. More likely, reporting rate is less than 100% and may vary over time (Rawstron 1971), space (Chadwick 1968; Henny and Burnham 1976; Reeves 1979; Green et al. 1983), or other factors (Rawstron 1971, Green et al. 1983). Unfortunately, high reporting rates are difficult to ensure. Rewards, ranging from money to books to chances in a lottery, have been offered for the return of tags. Presumably the monetary reward or prize is a further incentive to the angler or commercial fisherman to report the catch.

The reward tag study carried out by Ontario, Ohio, and Michigan in 1990 provided critical information on non-reporting of tagged walleye in Lake Erie. This information has greatly increased our confidence in estimates of walleye survival and natural mortality derived from tag recovery data. However, the behavior of fishermen may change over time and we do not know how this might alter their tag reporting rate. Further, differing non-reporting rates for groups of fish tagged at different sites provide valuable insight into the behavior of anglers and commercial fishermen.

The estimate of mean annual survival (0.64) produced by ESTIMATE was higher than the estimated mean annual survival produced by CAGEAN analysis on the Michigan data set (0.53). We believe the additional years included in the tag recovery analysis with ESTIMATE, 1978 to 1987, are part of the reason for this difference. In addition, the tag recovery data reflect survival across the full geographical distribution of the tagged population, while the CAGEAN estimate of survival based on the Michigan waters of Lake Erie. As discussed above, during the period 1988-90, exploitation rates in Michigan waters were considerably higher than those estimated for the lakewide data set.

Recommendations

Catch-at-age modeling of yellow perch has proved to be a useful technique. However, it could be significantly improved by collecting data on fecundity to incorporate into the analyses. We recommend that MDNR collect yellow perch fecundity data, including maturity schedules and egg production, from spring trap-net samples. Other Lake Erie management agencies should be encouraged to do likewise.

Yellow perch are a critically important sport and commercial species in Lake Erie. Recently, fisheries biologists around Lake Erie have grown concerned about the status of yellow perch. Many index survey programs, as well as the commercial fisheries, suggest that yellow perch abundance has declined greatly. However, abiotic changes in Lake Erie during the past decade confound assessment of their status. All management agencies around the lake should be strongly encouraged to closely monitor the status of yellow perch stocks and fisheries. This study indicates that current sport fishing regulations in Michigan (no closed season, no size limit, 100 fish creel limit) are not resulting in substantial exploitation of yellow perch in Michigan waters of Lake Erie at this time. Thus, there is no biological basis for changing yellow perch regulations in Michigan.

The current suite of regulations on the Michigan sport fishery for Lake Erie walleye includes no closed season, a 330-mm minimum size limit, and a 6 fish daily creel limit. Current exploitation and survival rates indicate these regulations provide ample protection for Lake Erie walleye. During the last three fishing seasons (1991-93) Michigan sport harvest has not exceeded recommended allowable catch. At this time, there appears to be no biological reason to consider any changes in these regulations.

The reward study for tagged walleye that was carried out in 1990 by Ontario, Ohio, and Michigan demonstrated consistent tag reporting by anglers and commercial fishermen from 1990 through 1993. We are in debt to the Ontario Ministry of Natural Resources for paying all of the $100.00 rewards and thereby contributing much more than their fair share to this project. However, the majority of walleye tagged in 1990 have now passed through the population and fishery. We recommend that the interagency $100.00 reward study be continued by tagging another group of walleye with reward tags in 1995 or 1996 and that either Michigan or Ohio pay the rewards.

All agencies involved in walleye management on Lake Erie recently agreed that identification, description, and regulation of genetic stocks will be necessary for effective management. Preliminary genetic investigations conducted at Case Western Reserve University indicate that it may be possible to develop a quick and inexpensive technique to identify stock of origin for individual walleye from their scales. Since this technique would be useful in Lake Erie walleye management, this research should be continued and supported.

A grid system should be developed for collecting fishing effort data by appropriate fishery management agencies on the St. Clair and Detroit rivers, Lake St. Clair, and Lake Erie. Monthly estimates of effort should also be generated throughout this area each year. Small grids would allow more precise analyses of catch and tag recovery data and better resolution for geographically referenced fish population data. Grid size for Lake Erie should be no larger than 10 minutes of latitude and longitude while grids for Lake St. Clair and the two connecting rivers should be no larger than 5 minutes.

Acknowledgments

The following MDNR employees were instrumental in data collection and tabulation: biologist, W. Bryant; boat captains, L. Shubel and J. Hodge; technicians, K. Koster and J. Clevenger; fisheries assistant, S. Rautio. Michigan DNR employee B. Menovske diligently collected and tabulated walleye tag data. P. Schneeberger and J. Diana provided helpful comments on the manuscript.

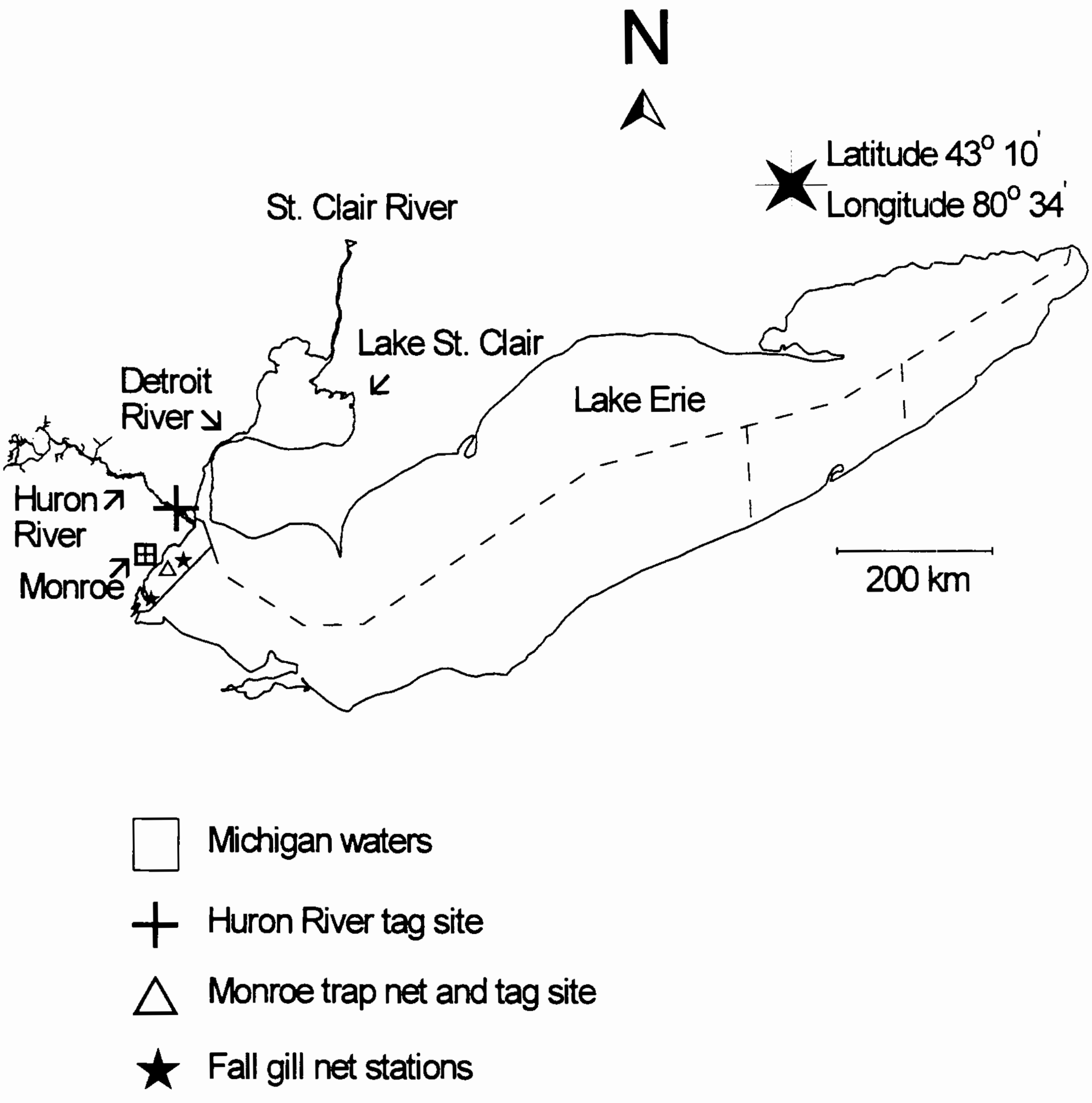


Figure 1.—Map of Lake Erie, Lake St. Clair, and the Detroit and St. Clair rivers showing net stations and walleye tag sites.

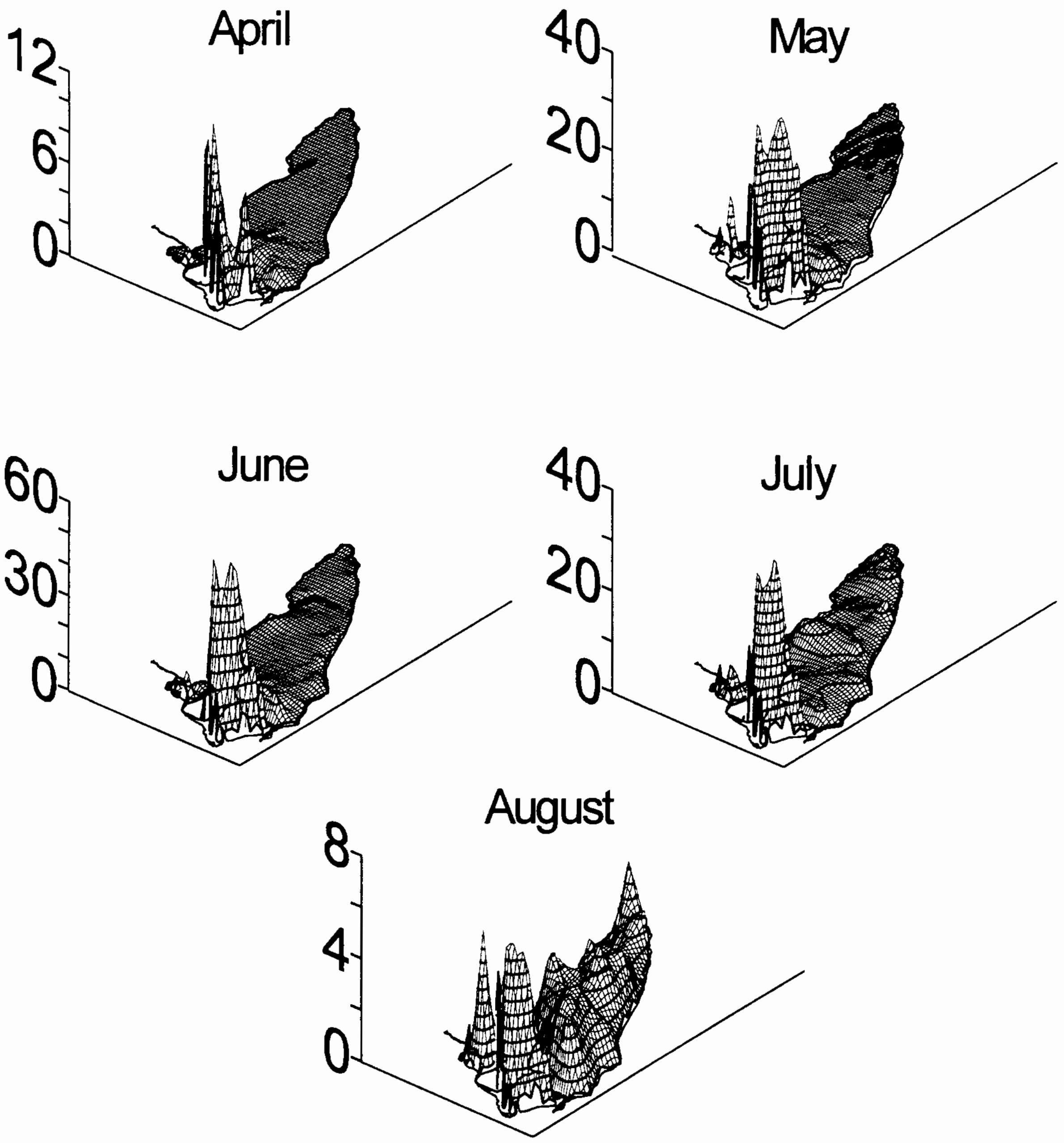
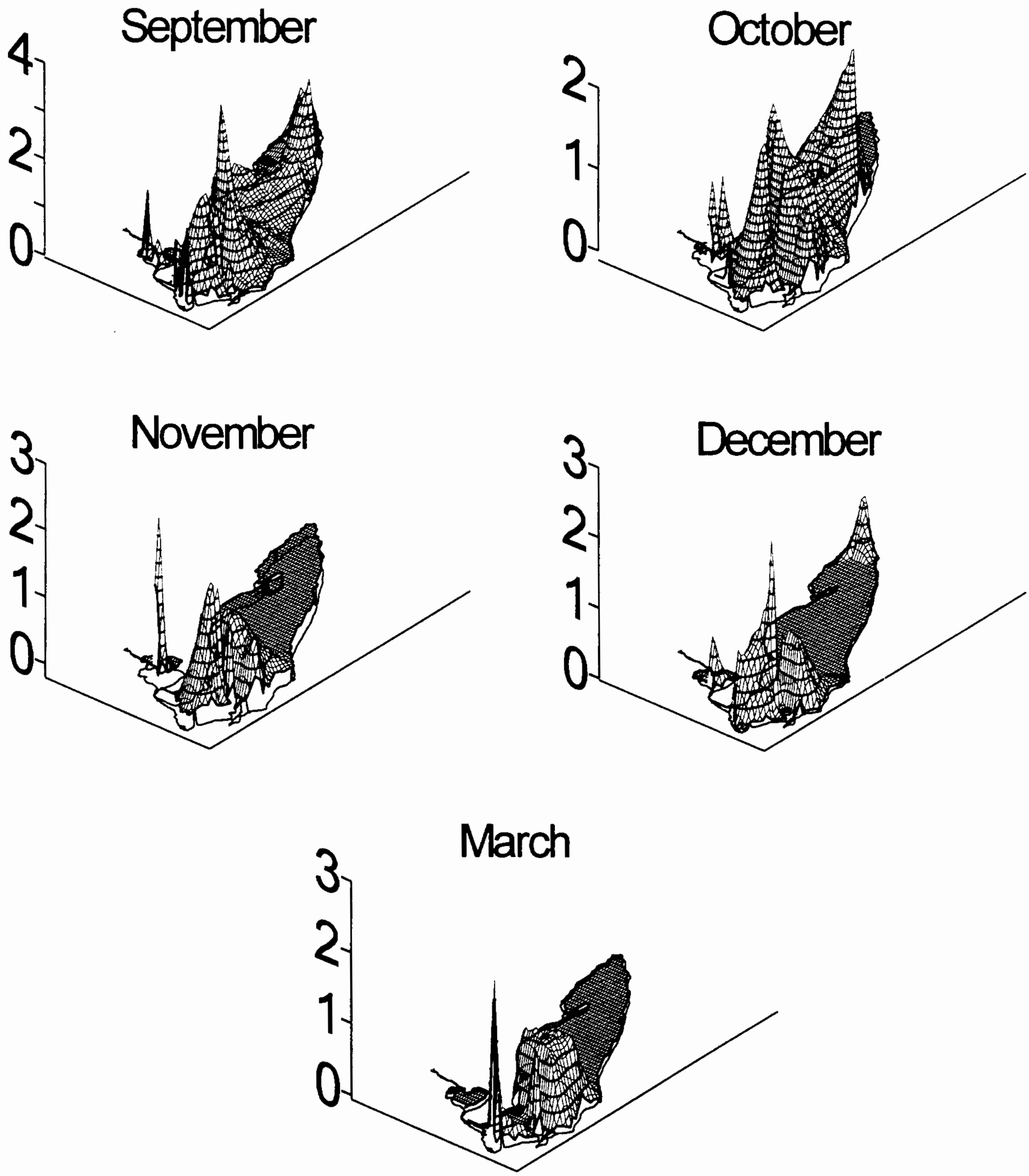


Figure 2.–Three-dimensional maps of the monthly distribution of 1,900 tag recoveries from walleyes caught by anglers and commercial fishermen during 1978-1993. All walleyes were tagged at the Monroe trap net station during spring. Mapped data was estimated by applying a kriging algorithm to mean number of tags recovered within grids of 10 minutes of latitude by 10 minutes of longitude. Mean values were positioned at grid centers prior to the kriging operation.



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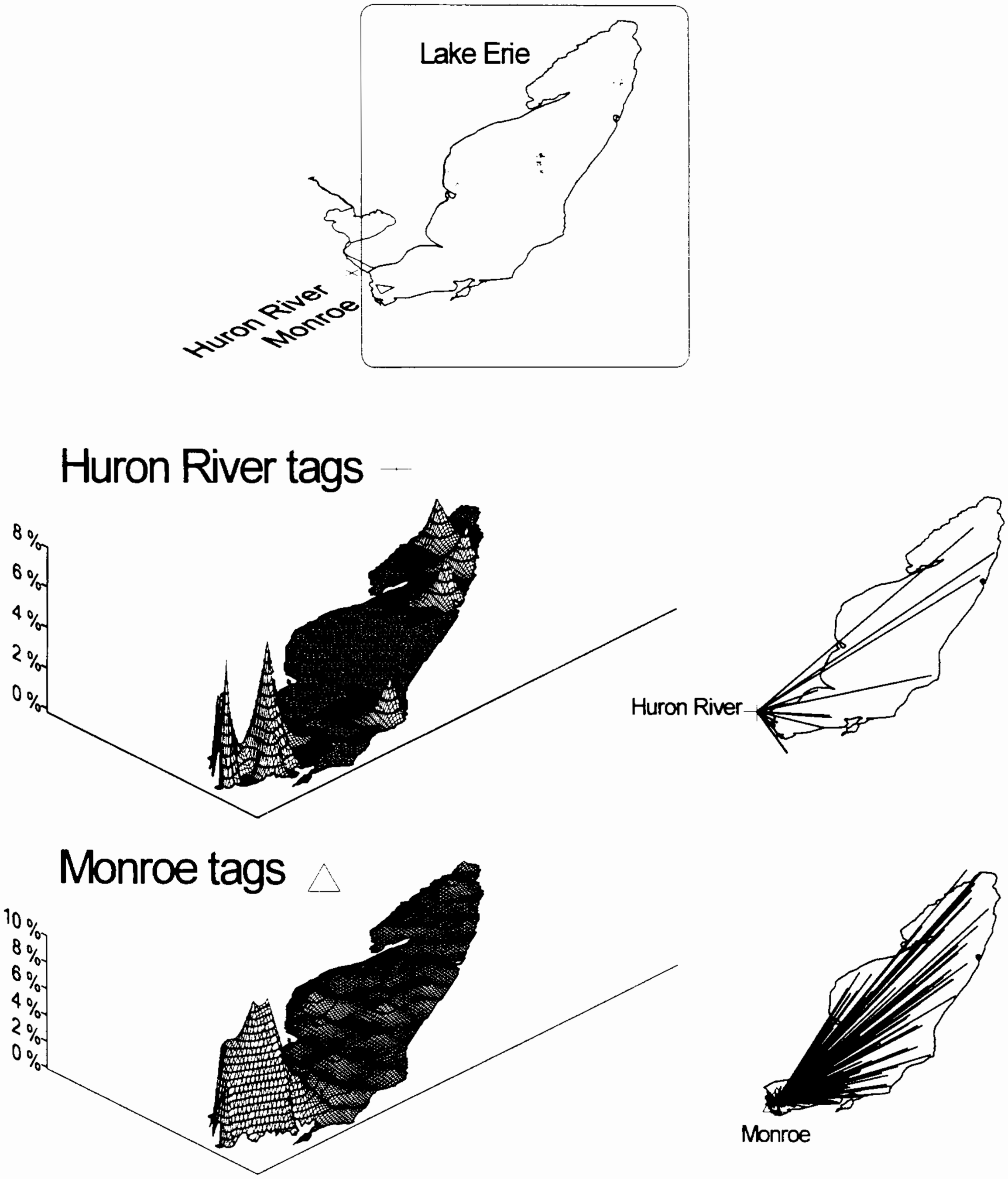
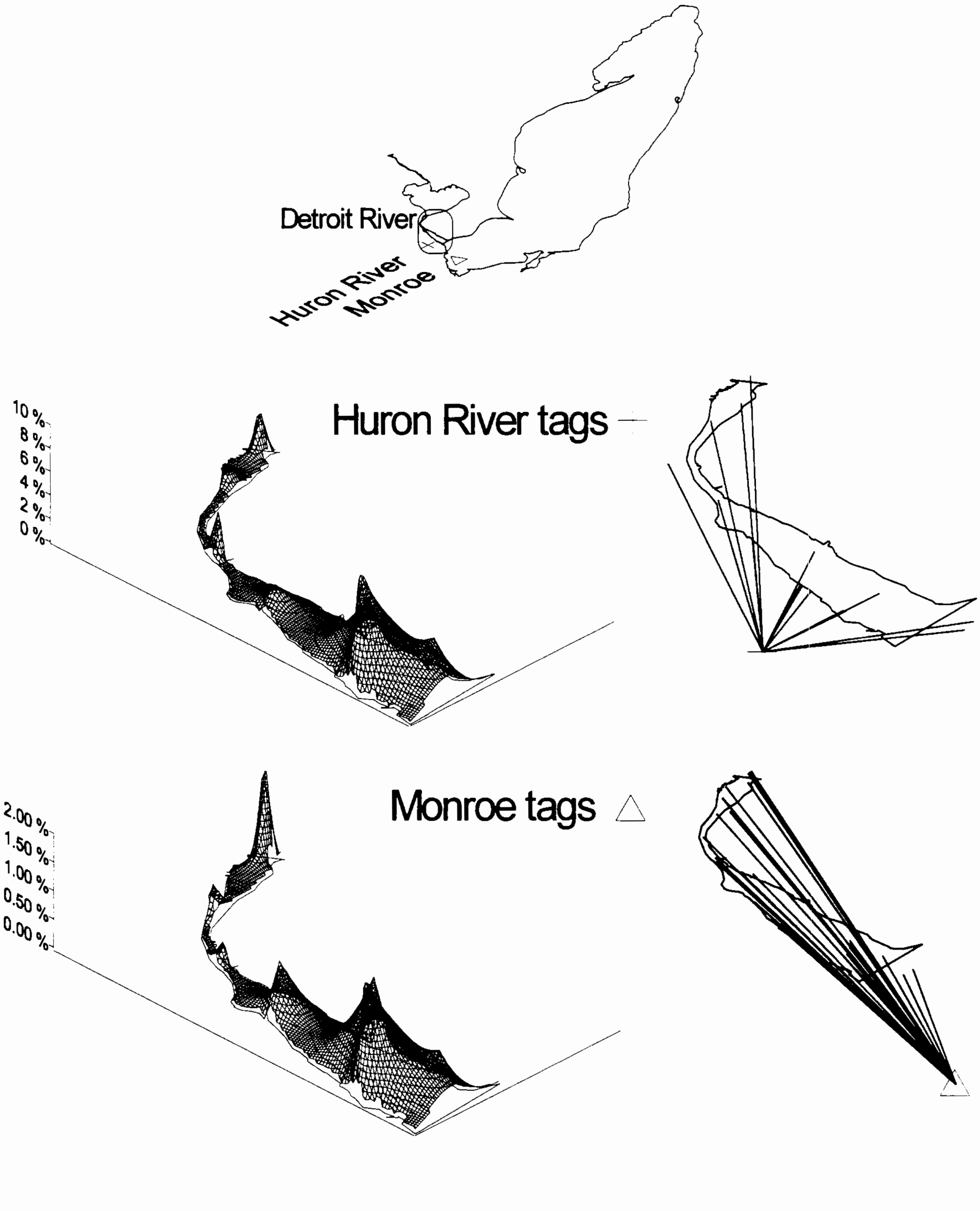


Figure 3.–Two and three-dimensional maps, by waterbody, comparing the distribution of walleye tag recoveries from the Monroe versus the Huron River tag sites. Tagged walleye were caught and reported by sport and commercial fishermen during 1991-1993. All walleyes were tagged at the two locations during spring. Three-dimensional mapped data was estimated by applying a kriging algorithm to percent of tags recovered within grids of 10 minutes of latitude by 10 minutes of longitude. Percent values were positioned at grid centers prior to the kriging operation. Two-dimensional maps show a straight-line trace for each walleye between tag and recapture location.



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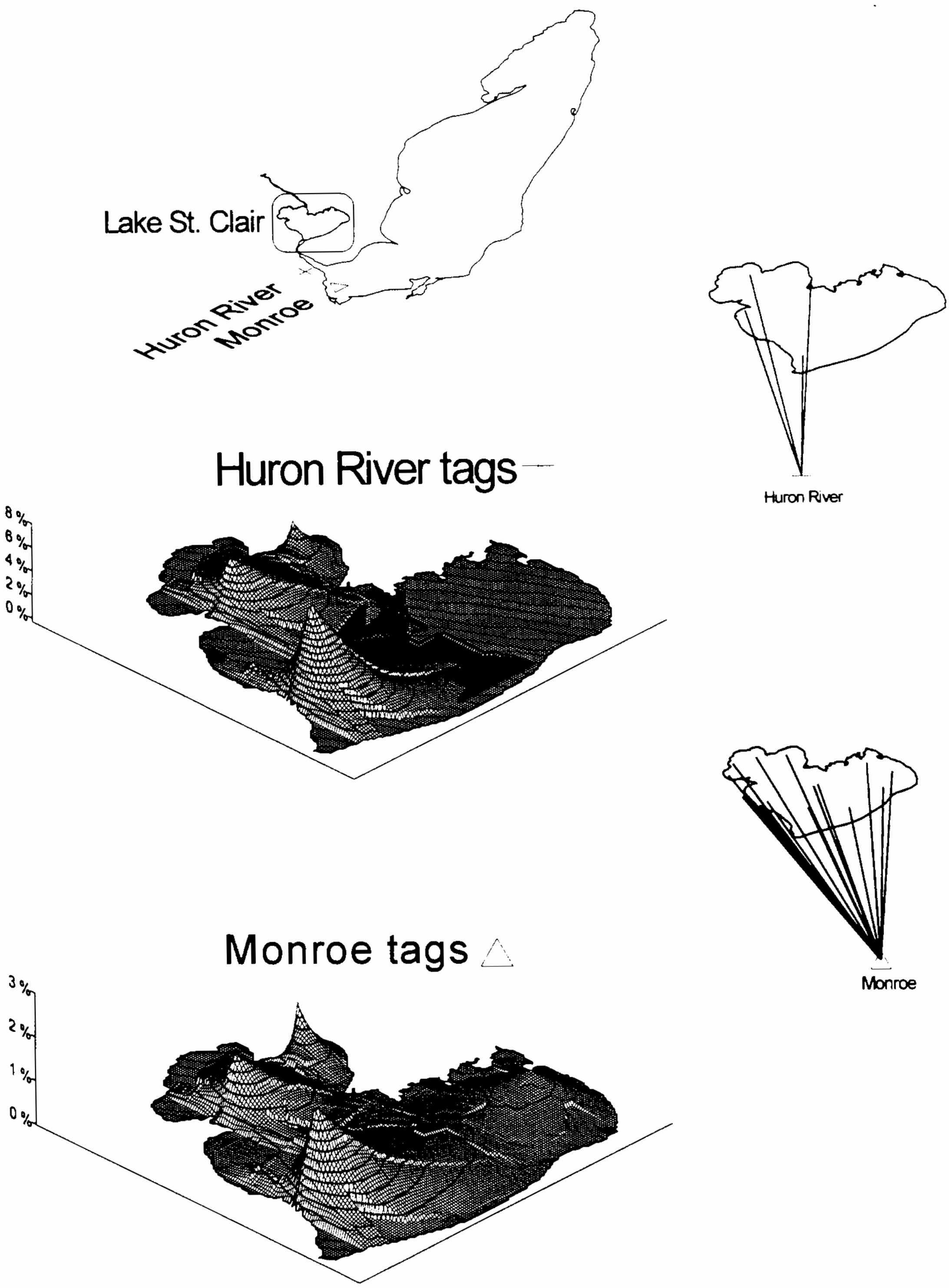

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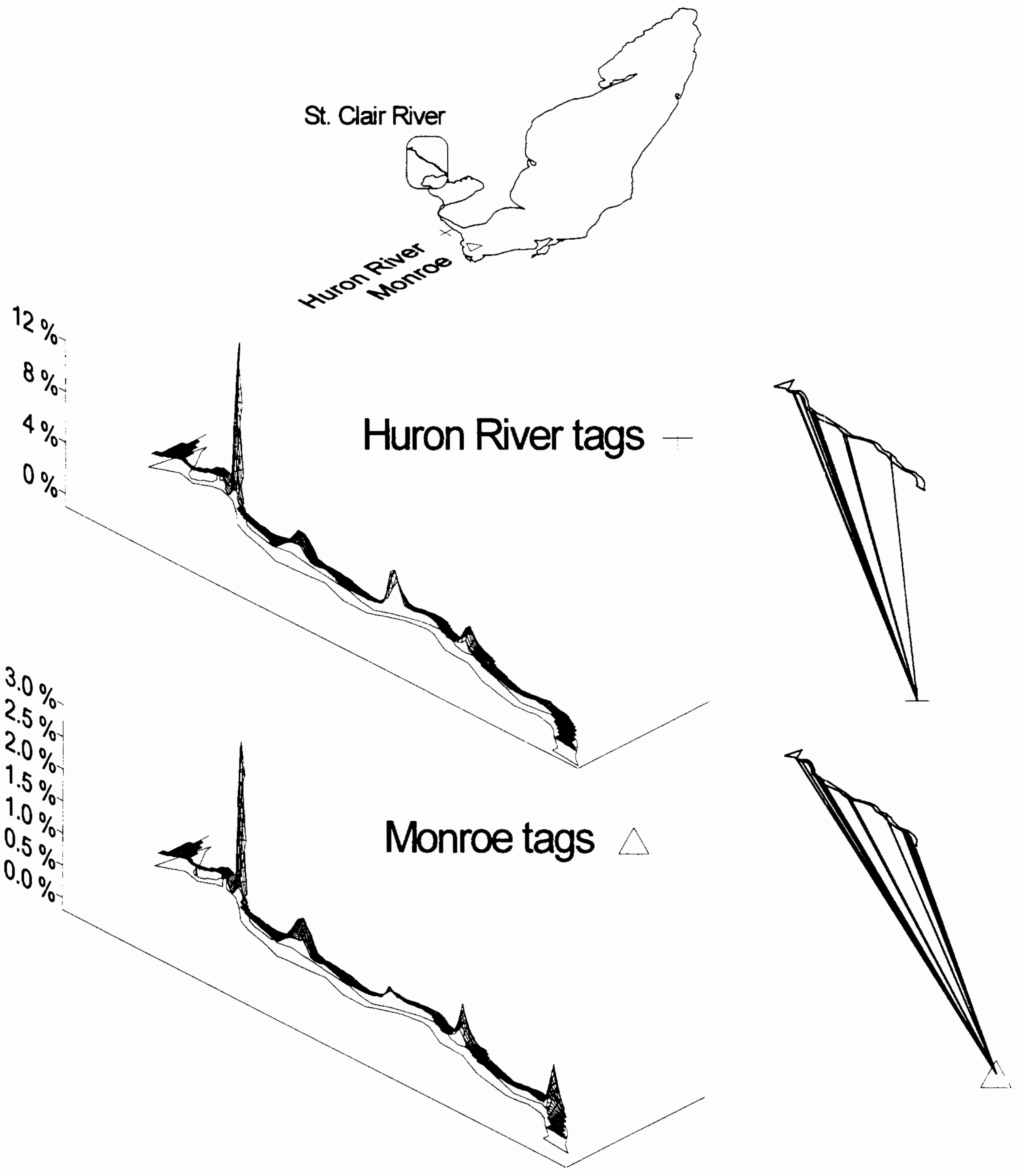

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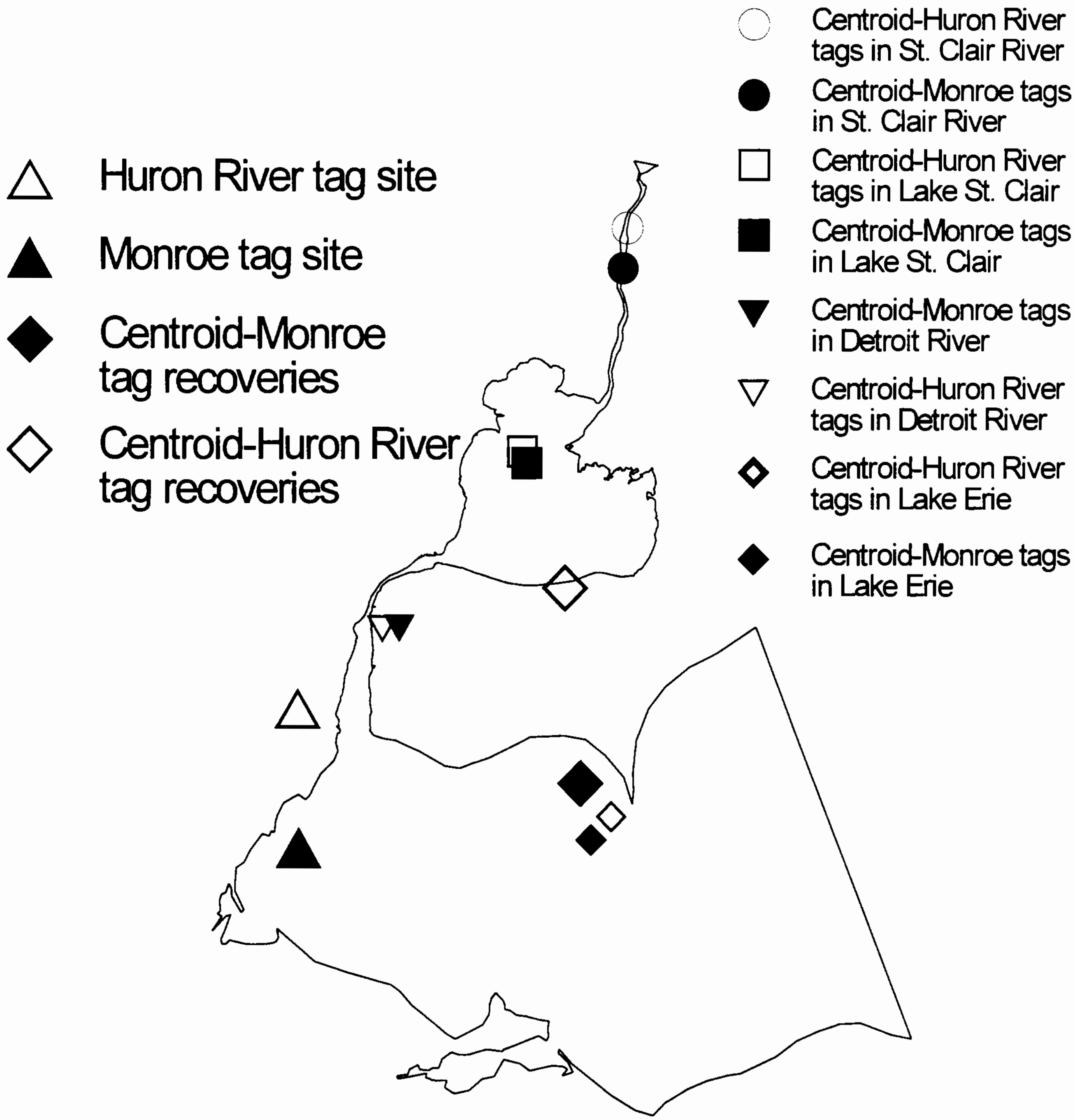

Figure 4.–Two-dimensional map comparing the geographical centroids of walleye tag recovery distributions for the Monroe versus the Huron River tag sites. Tagged walleye were caught and reported by sport and commercial fishermen during 1991-1993. All walleyes were tagged at the two locations during spring. Large map symbols denote tag site locations and centroids for all recoveries from each tag site. Small map symbols denote centroids for recoveries from each tag site within a particular waterbody.

Table 1.—Yellow perch catch per unit effort (CPUE) by age for trap net surveys from 1989-93 (expressed as number caught per net per 24 h).

		Age							
Year	Days	2	3	4	5	6	7	8+	Total
1989	95.5	0.02	26.64	50.02	39.27	24.63	2.89	1.28	144.83
1990	139.2	0.04	0.35	4.20	8.72	5.82	2.90	1.73	24.58
1991	86.0	0.03	2.74	2.41	9.29	7.99	6.29	1.79	31.91
1992	98.6	0.22	2.31	2.47	1.68	5.04	4.47	2.41	19.50
1993	99.1	0.25	6.28	5.34	2.31	1.58	2.51	0.81	20.24
Mean		0.10	6.60	11.33	10.43	8.29	3.46	1.42	42.35

Table 2.—Mean length and standard error (SE) in mm for yellow perch caught in trap nets during spring surveys. Sample size in parentheses.

	1989		1990		1991		1992		1993	
Age	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
					Males					
2	—	—	—	—	—	—	159 (7)	9.7	177 (4)	2.5
3	169 (29)	2.9	175 (3)	6.7	189 (12)	4.7	181 (31)	2.3	185 (48)	2.1
4	190 (24)	3.3	185 (38)	3.4	196 (11)	6.6	208 (16)	7.0	212 (25)	3.6
5	215 (21)	3.4	205 (29)	3.3	210 (31)	4.7	221 (8)	6.7	233 (10)	7.2
6	221 (20)	4.4	230 (25)	4.9	229 (21)	4.8	243 (34)	4.1	238 (8)	3.9
7	251 (14)	7.3	233 (10)	5.7	244 (21)	5.0	238 (25)	4.2	250 (23)	5.4
8	248 (4)	5.2	252 (22)	2.7	258 (8)	5.5	247 (13)	7.2	258 (6)	7.5
9	—	—	266 (4)	9.8	255 (6)	4.4	278 (4)	12.9	260 (10)	4.2
10	—	—	—	—	—	—	—	—	248 (3)	14.4
					Females					
3	189 (10)	4.5	—	—	237 (4)	13.0	233 (13)	6.8	224 (31)	4.4
4	207 (28)	2.1	213 (17)	7.1	255 (3)	10.2	243 (22)	6.7	239 (32)	3.8
5	236 (39)	4.5	233 (36)	3.3	250 (21)	5.8	254 (14)	6.8	267 (24)	5.7
6	272 (32)	5.2	252 (28)	5.5	253 (18)	5.5	276 (23)	4.3	281 (14)	5.0
7	279 (15)	4.8	278 (22)	6.7	272 (24)	4.4	283 (23)	5.8	290 (12)	6.8
8	284 (15)	4.3	290 (17)	3.9	279 (7)	13.4	296 (21)	6.0	311 (13)	6.6
9	—	—	292 (15)	6.2	300 (6)	8.8	294 (3)	8.1	307 (10)	5.8
10	—	—	279 (3)	28.1	—	—	—	—	305 (5)	4.8

Table 3.—CPUE (number caught per net per 24 h) for walleye by age for trap net surveys from 1988-93.

Year class	Year				
	1989	1990	1991	1992	1993
1980	0.01	0.01	—	—	—
1981	0.35	0.13	—	—	—
1982	3.37	1.92	0.89	0.56	0.31
1983	0.85	0.37	1.19	0.46	0.26
1984	1.88	2.11	3.60	2.16	0.63
1985	2.90	1.78	2.52	2.11	1.23
1986	9.90	5.90	13.37	7.00	3.66
1987	1.10	1.06	3.91	2.58	1.75
1988	0.01	0.59	4.90	2.38	1.46
1989	—	—	1.87	1.42	0.72
1990	—	—	—	2.32	5.01
1991	—	—	—	—	0.52
Total	20.69	14.05	32.35	21.03	15.57
Mean age	4.2	4.9	4.9	5.5	5.4
24 hour sets	96	139	86	99	99

Table 4.—Mean length and standard error (SE) in mm for walleye caught in trap nets during spring surveys. Sample size in parentheses.

Age	1989		1990		1991		1992		1993	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
					Males					
2	339 (48)	3.0	346 (45)	2.4	358 (145)	1.5	365 (207)	1.2	334 (31)	4.5
3	401 (831)	0.7	400 (117)	2.2	413 (379)	1.0	433 (135)	2.0	418 (460)	1.0
4	451 (246)	1.5	442 (674)	0.9	448 (280)	1.6	462 (200)	1.7	468 (57)	3.4
5	487 (147)	2.3	478 (214)	1.9	480 (933)	0.9	493 (215)	1.9	495 (127)	2.8
6	513 (73)	4.0	521 (263)	1.9	520 (183)	2.4	514 (614)	1.2	517 (151)	2.5
7	522 (269)	1.8	531 (49)	5.6	541 (254)	1.8	546 (184)	2.2	532 (270)	2.0
8	561 (25)	7.2	540 (215)	2.1	566 (84)	3.2	563 (190)	2.3	564 (89)	3.5
9	577 (5)	20.4	570 (14)	12.9	561 (43)	5.2	579 (37)	4.8	578 (34)	5.5
10	607 (8)	12.5	589 (6)	10.5	—	—	588 (35)	5.1	586 (13)	7.5
11	—	—	—	—	—	—	—	—	579 (16)	6.6
					Females					
2	—	—	—	—	—	—	—	—	317 (3)	5.3
3	439 (19)	4.8	435 (6)	12.7	421 (6)	7.8	—	—	430 (3)	30.2
4	479 (15)	6.8	494 (103)	2.8	496 (32)	4.4	501 (23)	5.6	515 (4)	11.6
5	531 (32)	5.5	520 (27)	21.6	534 (160)	1.9	536 (21)	6.5	550 (12)	11.2
6	585 (6)	24.1	577 (25)	8.0	584 (28)	4.9	577 (57)	4.7	569 (14)	9.6
7	599 (47)	6.6	—	—	600 (36)	6.1	607 (17)	6.3	598 (67)	3.9
8	636 (8)	9.2	620 (48)	7.1	647 (12)	13.4	654 (19)	8.5	639 (25)	10.4
9	671 (3)	14.8	651 (4)	26.0	654 (28)	5.8	671 (7)	12.3	660 (23)	6.7
10	610 (3)	23.2	672 (5)	15.2	672 (3)	40.2	681 (16)	8.5	667 (12)	10.7
11	694 (3)	53.2	707 (3)	23.5	—	—	—	—	702 (14)	7.7
12	—	—	700 (3)	23.8	—	—	—	—	—	—

Table 5.—Walleye CPUE (number per net lift) in multi-filament gill nets during fall surveys on Michigan waters of Lake Erie.

Year class	Total CPUE	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1972	0.9	0.8	0.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1973	0.9	0.5	0.3	0.2	—	—	—	—	—	—	—	—	—	—	—	—	—
1974	13.6	8.3	3.5	0.3	1.5	—	—	—	—	—	—	—	—	—	—	—	—
1975	42.8	25.8	10.5	3.5	2.0	0.5	0.5	—	—	—	—	—	—	—	—	—	—
1976	18.3	7.0	5.3	2.8	1.0	1.5	0.3	0.0	0.5	—	—	—	—	—	—	—	—
1977	170.9	91.0	37.0	22.7	9.0	5.0	2.5	3.0	0.5	0.3	—	—	—	—	—	—	—
1978	61.5	—	19.0	25.0	6.0	5.5	2.5	1.8	0.5	1.3	—	—	—	—	—	—	—
1979	72.3	—	—	44.0	13.5	5.0	4.3	2.3	2.0	0.5	0.5	0.3	—	—	—	—	—
1980	92.5	—	—	—	43.0	21.5	14.5	5.0	5.3	2.3	0.5	0.3	0.0	0.3	—	—	—
1981	72.0	—	—	—	—	33.5	21.3	7.8	3.8	2.8	2.3	0.5	0.3	0.0	—	—	—
1982	306.0	—	—	—	—	—	29.0	91.8	95.8	44.3	28.5	5.3	7.5	3.5	0.5	—	—
1983	34.5	—	—	—	—	—	—	4.5	12.0	4.0	5.0	3.5	1.8	1.8	2.0	—	—
1984	147.1	—	—	—	—	—	—	—	69.8	34.3	20.5	3.5	8.0	8.3	2.0	0.5	0.3
1985	176.1	—	—	—	—	—	—	—	—	98.0	42.5	9.3	14.3	8.5	1.5	1.3	0.8
1986	295.1	—	—	—	—	—	—	—	—	—	96.8	30.3	90.3	43.5	19.5	11.0	3.8
1987	121.3	—	—	—	—	—	—	—	—	—	—	4.5	53.8	26.8	20.0	13.8	2.5
1988	118.3	—	—	—	—	—	—	—	—	—	—	—	61.5	35.8	9.3	7.3	4.5
1989	45.8	—	—	—	—	—	—	—	—	—	—	—	—	16.0	17.0	10.0	2.8
1990	115.5	—	—	—	—	—	—	—	—	—	—	—	—	—	54.5	48.0	13.0
1991	110.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	63.0	47.3
1992	2.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.0
Total		133.3	75.5	98.7	76.0	72.5	74.3	116.5	190.0	187.5	196.5	57.0	237.5	144.3	126.3	91.8	76.8
Net lifts		4	4	6	2	2	4	4	4	4	4	4	4	4	4	4	4

Table 6.—Mean total length (mm) at age for walleye caught during fall in survey multi- and monofilament gill nets (sample size in parentheses).

Age	1989		1990		1991		1992		1993	
					Sexes combined					
1	335	(246)	351	(64)	345	(218)	309	(252)	331	(13)
2	410	(215)	418	(143)	434	(68)	414	(192)	389	(246)
3	452	(361)	461	(107)	463	(37)	459	(40)	445	(62)
4	489	(57)	487	(174)	489	(40)	487	(29)	462	(11)
5	509	(32)	509	(34)	500	(78)	504	(55)	501	(23)
6	519	(7)	532	(33)	520	(6)	530	(44)	510	(13)
7	534	(30)	530	(7)	544	(8)	542	(5)	548	(22)
8	626	(1)	568	(14)	570	(8)	627	(2)	539	(3)
9	—	—	—	—	—	—	—	—	541	(2)
10	669	(1)	637	(1)	—	—	—	—	—	—
Mean	420	(950)	457	(577)	415	(463)	395	(619)	418	(399)
					Males					
1	337	(112)	354	(33)	342	(97)	305	(153)	337	(5)
2	401	(134)	411	(95)	418	(26)	408	(139)	385	(161)
3	436	(232)	452	(68)	444	(17)	449	(27)	429	(39)
4	470	(37)	472	(117)	472	(27)	477	(22)	447	(9)
5	498	(26)	500	(29)	489	(63)	492	(46)	487	(18)
6	505	(6)	519	(28)	504	(4)	511	(26)	510	(13)
7	520	(26)	530	(7)	542	(7)	542	(5)	529	(16)
8	—	—	558	(11)	550	(6)	556	(1)	539	(3)
9	—	—	—	—	—	—	—	—	541	(2)
Mean	418	(573)	452	(388)	422	(247)	394	(419)	416	(268)
					Females					
1	337	(113)	348	(31)	348	(121)	316	(98)	328	(8)
2	426	(81)	432	(48)	444	(42)	430	(52)	398	(85)
3	481	(128)	477	(39)	479	(20)	478	(12)	472	(23)
4	525	(20)	519	(57)	525	(13)	518	(5)	532	(2)
5	557	(6)	563	(5)	550	(15)	577	(7)	550	(5)
6	604	(1)	602	(5)	552	(2)	558	(18)	—	—
7	621	(4)	604	(3)	560	(1)	—	—	599	(6)
8	626	(1)	637	(1)	629	(2)	698	(1)	—	—
10	669	(1)	—	—	—	—	—	—	—	—
Mean	429	(355)	465	(189)	408	(216)	396	(193)	422	(129)

Table 7.—Mean total length (mm) for yearling walleye caught in Michigan fall gill net surveys. Sample size in parentheses.

Survey year	Year class	Mean length	Standard error
1978	1977	343 (410)	1.0
1979	1978	330 (115)	1.9
1980	1979	344 (222)	1.3
1981	1980	336 (86)	2.0
1982	1981	333 (143)	1.9
1983	1982	308 (116)	1.7
1984	1983	311 (18)	4.7
1985	1984	329 (279)	1.2
1986	1985	339 (392)	1.0
1987	1986	332 (387)	1.1
1988	1987	347 (18)	4.2
1989	1988	336 (246)	1.2
1990	1989	352 (64)	2.4
1991	1990	345 (218)	1.3
1992	1991	309 (252)	1.4
1993	1992	331 (13)	6.5
All years		334 (2979)	0.4

Table 8.—Mean rank of year classes for Lake Erie walleye based on measured harvest and survey catch per effort.

Year class	Total harvest[1]	Harvest rank	Trap-net CPUE	Trap-net rank	Gill-net CPUE	Gill net rank	Mean rank
1974	2,728,065	11	4.59	15	13.6	18	14.67
1975	3,486,656	8	12.01	8	42.8	15	10.33
1976	887,337	17	1.77	17	18.3	17	17.00
1977	7,039,127	4	36.44	3	170.9	4	3.67
1978	3,583,839	7	8.93	13	61.5	13	11.00
1979	2,666,167	13	8.99	12	72.3	11	12.00
1980	5,658,052	6	21.86	6	92.5	10	7.33
1981	3,112,162	9	17.85	7	72.0	12	9.33
1982	21,937,782	1	111.93	1	306.0	1	1.00
1983	2,230,181	14	9.01	11	34.5	16	13.67
1984	6,872,904	5	33.25	4	147.1	5	4.67
1985	7,874,633	3	29.87	5	176.1	3	3.67
1986	11,862,682	2	49.87	2	295.1	2	2.00
1987	2,687,523	12	10.40	9	121.3	6	9.00
1988	1,931,505	15	9.34	10	118.3	7	10.67
1989	862,798	18	4.02	16	45.8	14	16.00
1990	2,745,045	10	7.33	14	115.5	8	10.67
1991	1,358,534	16	0.52	18	110.3	9	14.33
1992	8,760	19	0.00	19	2.0	19	19.00
Mean	4,712,355		19.89		106.1		

[1] Total harvest determined by summing each agency's sport and commercial age specific harvest estimates.

Table 9.—Population statistics for yellow perch in Michigan waters of Lake Erie, 1988-93, from the CAGEAN model (Deriso et al. 1985).

Fishing year	Instantaneous fishing mortality rate	Annual survival rate	Total exploitation rate	Estimated numerical abundance	Estimated numerical catch
1988	0.0823	0.6174	0.0654	14,126,448	923,170
1989	0.1565	0.5732	0.1201	9,771,933	1,173,561
1990	0.1287	0.5894	0.1002	7,741,327	775,462
1991	0.0629	0.6295	0.0504	7,317,376	368,718
1992	0.0205	0.6567	0.0167	16,058,162	268,748
1993	0.0197	0.6572	0.0161	31,514,676	507,372

Table 10.—Population statistics for yellow perch in Lake Erie's Western Basin, 1988-93, from the CAGEAN model (Deriso et al. 1985).

Fishing year	Instantaneous fishing mortality rate	Annual survival rate	Total exploitation rate	Estimated numerical abundance	Estimated numerical catch
1988	0.2570	0.5184	0.1892	98,798,574	18,697,178
1989	0.4788	0.4153	0.3192	54,185,587	17,298,100
1990	0.3766	0.4599	0.2641	29,410,276	7,767,765
1991	0.1848	0.5572	0.1412	35,713,375	5,041,386
1992	0.0856	0.6153	0.0682	76,146,450	5,189,707
1993	0.0633	0.6292	0.0508	133,422,781	6,778,000

Table 11.—Population statistics for walleye in Michigan waters of Lake Erie, 1988-93, from the CAGEAN model (Deriso et al. 1985).

Fishing year	Instantaneous fishing mortality rate	Annual survival rate	Total exploitation rate	Estimated l numerica abundance	Estimated numerical catch
1988	0.3703	0.5014	0.2686	4,601,245	1,235,781
1989	0.4481	0.4639	0.3139	2,956,600	928,175
1990	0.5812	0.4061	0.3842	1,703,699	654,495
1991	0.1837	0.6043	0.1445	900,606	130,150
1992	0.1715	0.6117	0.1358	1,398,368	189,917
1993	0.2101	0.5885	0.1636	1,344,870	219,995

Table 12.—Population statistics for walleye in all waters of Lake Erie, 1988-93, from the CAGEAN model (Deriso et al. 1985).

Fishing year	Instantaneous fishing mortality rate	Annual survival rate	Total exploitation rate	Estimated numerical abundance	Estimated numerical catch
1988	0.1426	0.6296	0.1142	84,358,515	9,635,910
1989	0.1664	0.6149	0.1318	62,988,647	8,299,344
1990	0.1424	0.6298	0.1140	46,751,790	5,330,234
1991	0.1457	0.6277	0.1165	33,012,261	3,846,542
1992	0.1846	0.6037	0.1450	31,810,656	4,613,284
1993	0.3726	0.5003	0.2691	26,166,235	7,041,954

Table 13.—Geographical distribution of tag recoveries from walleye tagged at Monroe, Michigan, Lake Erie (expressed as a percentage of the total number recovered each year).

Geographical area	Percent of tags recovered by location					Total percent by location
	1989	1990	1991	1992	1993	
Lake Huron - Saginaw Bay	0.5	0.5	0.4	0.5	1.6	0.6
St. Clair River	7.2	4.9	7.1	2.7	6.1	5.2
Lake St. Clair	3.8	8.3	3.1	4.1	2.6	4.6
Detroit River	13.0	14.7	17.3	9.5	8.1	12.3
Western Basin-Lake Erie	55.3	54.2	56.9	64.5	58.7	60.6
Central Basin-Lake Erie	10.6	12.8	11.6	13.1	17.7	14.4
Eastern Basin-Lake Erie	3.8	3.0	1.8	2.7	3.5	2.3
Lake Erie-total	69.7	70.0	70.3	80.3	79.9	77.3

Table 14.—Annual survival and recovery rate (percent) produced by program "ESTIMATE" (Brownie et al. 1985) for 1986-93 from Lake Erie walleye tagged at Monroe, Michigan.

Fishing year	Tag recovery rate	Standard error	Walleye survival rate	Standard error
1986	3.62	0.28	54.62	5.17
1987	3.47	0.32	108.52	10.37
1988	3.19	0.23	43.99	4.77
1989	3.33	0.32	43.70	5.15
1990	4.49	0.41	78.95	9.01
1991	2.20	0.22	56.90	6.45
1992	3.77	0.35	67.85	9.70
1993	5.31	0.57	--[1]	--
Mean	3.27	0.09	63.58	1.28

[1]Survival rate for last year cannot be estimated.

Table 15.—Recovery rates for reward and non-reward walleye tags from four tag sites in Lake Erie, 1990 through 1993. Non-reporting rate is the ratio of reward tags to non-reward tags reported.

Tag Site	Number Tagged	Returns				Percent reported caught				
		1990	1991	1992	1993	1990	1991	1992	1993	Total
Chicken/Hen Islands[1]										
Reward	400	37	18	18	9	9.25	4.50	4.50	2.25	20.50
Non-reward	1,972	65	32	23	23	3.30	1.62	1.17	1.17	7.25
Non-reporting rate						2.81	2.77	3.86	1.93	2.83
Sandusky Bay[2]										
Reward	149	5	2	3	1	3.36	1.34	2.01	0.67	7.38
Non-reward	1,344	31	15	12	12	2.31	1.12	0.89	0.89	5.21
Non-reporting rate						1.45	1.20	2.26	0.75	1.42
Sugar Rock[2]										
Reward	178	19	10	6	9	10.67	5.62	3.37	5.06	24.72
Non-reward	1,333	40	36	17	18	3.00	2.70	1.28	1.35	8.33
Non-reporting rate						3.56	2.08	2.64	3.74	2.97
Monroe[3]										
Reward	218	26	13	10	16	11.93	5.96	4.59	7.34	29.82
Non-reward	1,675	71	46	28	31	4.24	2.75	1.67	1.85	10.51
Non-reporting rate						2.81	2.17	2.74	3.97	2.84
All tag sites										
Reward	945	87	43	37	35	9.21	4.55	3.92	3.70	21.38
Non-reward	6,324	207	129	80	84	3.27	2.04	1.27	1.33	7.91
Non-reporting rate						2.81	2.23	3.10	2.79	2.70

[1]=Ontario tag site
[2]=Ohio tag sites
[3]=Michigan tag site

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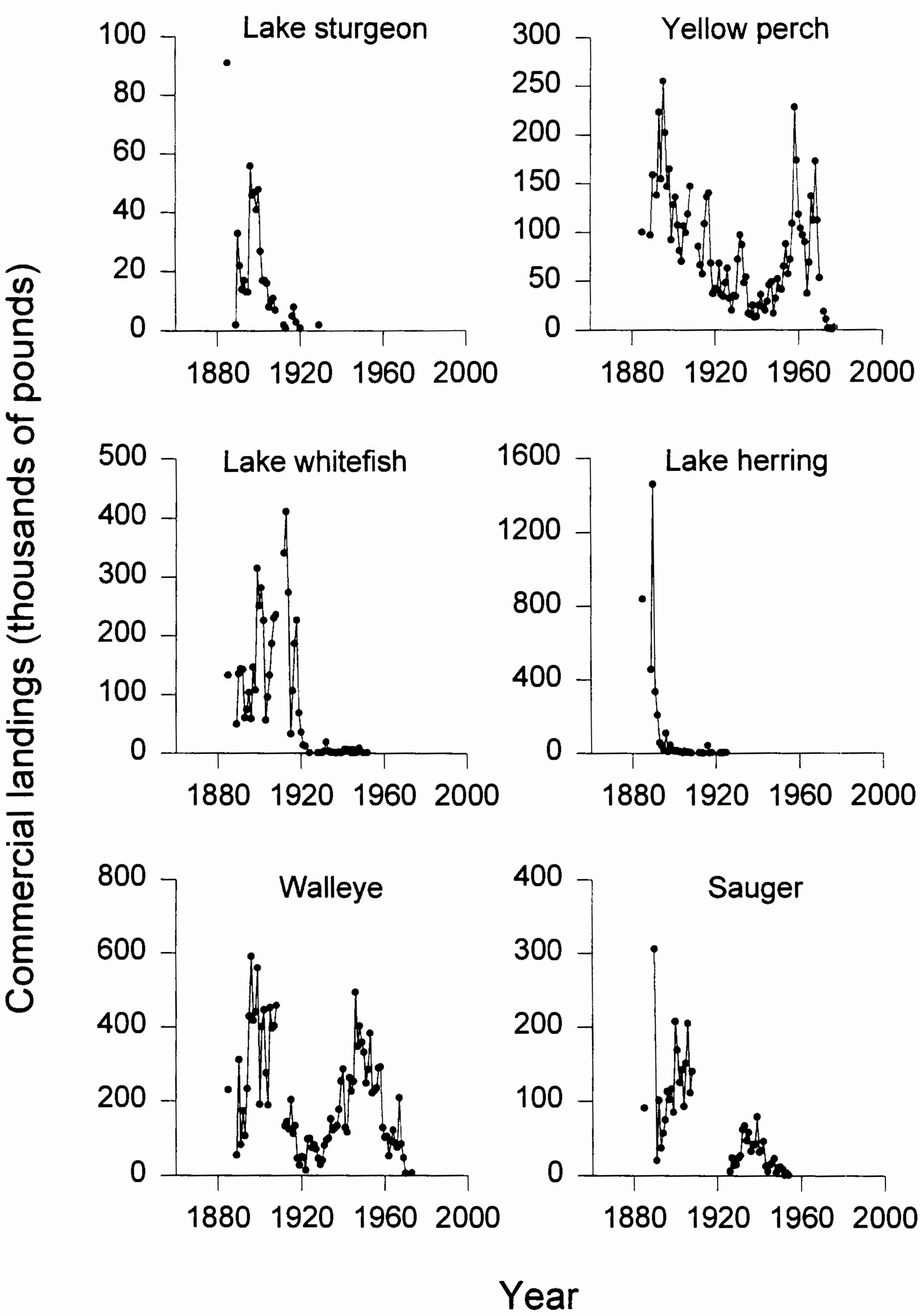
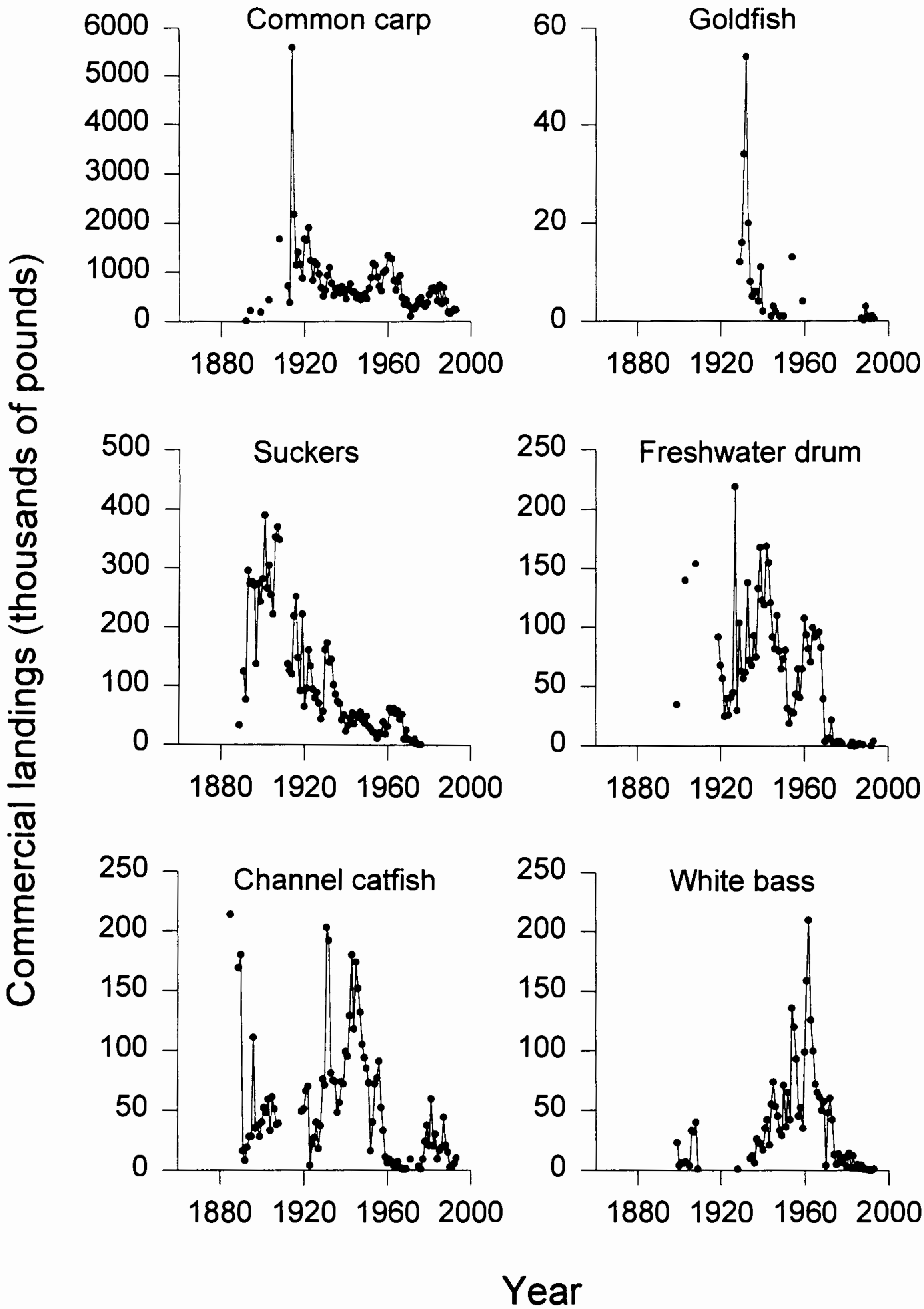


Appendix Figure 1.–Historical commercial catch from Michigan's waters of Lake Erie for major species that are no longer available to the fishery.



Appendix Figure 2.–Historical commercial catch from Michigan's waters of Lake Erie for major species that are currently available to the fishery. Suckers are presented as catch of *Catostomus* and *Moxostoma spp.* combined.

Appendix 1.—Fish species collected from Lake Erie with survey trap nets and gill nets, 1978-93.

Common name	*Scientific name*
Lake sturgeon	*Acipenser fulvescens Rafinesque*
Longnose gar	*Lepisosteus osseus (Linnaeus)*
Bowfin	*Amia calva Linnaeus*
Mooneye	*Hiodon tergisus Lesueur*
Alewife	*Alosa pseudoharengus (Wilson)*
Gizzard shad	*Dorosoma cepedianum (Lesueur)*
Goldfish	*Carassius auratus (Linnaeus)*
Common carp	*Cyprinus carpio Linnaeus*
Silver chub	*Macrhybopsis storeriana (Kirtland)*
Quillback	*Carpiodes cyprinus (Lesueur)*
White sucker	*Catostomus commersoni (Lacepde)*
Bigmouth buffalo	*Ictiobus cyprinellus (Valenciennes)*
Black buffalo	*Ictiobus niger (Rafinesque)*
Spotted sucker	*Minytrema melanops (Rafinesque)*
Silver redhorse	*Moxostoma anisurum (Rafinesque)*
Golden redhorse	*Moxostoma erythrurum (Rafinesque)*
Shorthead redhorse	*Moxostoma macrolepidotum (Lesueur)*
Black bullhead	*Ameiurus melas (Rafinesque)*
Yellow bullhead	*Ameiurus natalis (Lesueur)*
Brown bullhead	*Ameiurus nebulosus (Lesueur)*
Channel catfish	*Ictalurus punctatus (Rafinesque)*
Stonecat	*Noturus flavus Rafinesque*
Northern pike	*Esox lucius Linnaeus*
Muskellunge	*Esox masquinongy Mitchill*
Rainbow smelt	*Osmerus mordax (Mitchill)*
Lake whitefish	*Coregonus clupeaformis (Mitchill)*
Coho salmon	*Oncorhynchus kisutch (Walbaum)*
Rainbow trout	*Oncorhynchus mykiss (Walbaum)*
Chinook salmon	*Oncorhynchus tshawytscha (Walbaum)*
Brown trout	*Salmo trutta Linnaeus*
Burbot	*Lota lota (Linnaeus)*
White perch	*Morone americana (Gmelin)*
White bass	*Morone chrysops (Rafinesque)*
Rock bass	*Ambloplites rupestris (Rafinesque)*
Pumpkinseed	*Lepomis gibbosus (Linnaeus)*
Bluegill	*Lepomis macrochirus Rafinesque*
Smallmouth bass	*Micropterus dolomieu Lacepde*
Largemouth bass	*Micropterus salmoides (Lacepde)*
White crappie	*Pomoxis annularis Rafinesque*
Black crappie	*Pomoxis nigromaculatus (Lesueur)*
Yellow perch	*Perca flavescens (Mitchill)*
Sauger	*Stizostedion canadense (Smith)*
Walleye	*Stizostedion vitreum (Mitchill)*
Freshwater drum	*Aplodinotus grunniens Rafinesque*

Appendix 2.—Mean catch per trap net lift for all species commonly taken during spring trap net surveys in Michigan waters of Lake Erie.

Species	Survey year 1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1978-88 mean	1989-93 mean	Overall mean
Walleye	28.1	49.0	18.1	20.6	38.8	26.1	36.6	75.5	61.7	33.9	83.1	35.9	23.8	95.9	37.7	39.2	42.9	46.5	44.0
Smallmouth bass	0.1	0.0	0.0	0.1	0.2	0.1	0.1	0.1	0.1	0.0	0.1	0.3	0.1	0.2	0.1	0.2	0.1	0.2	0.1
Yellow perch	377.0	320.0	669.0	512.0	146.0	257.0	129.0	156.0	40.3	174.0	22.9	251.5	41.7	94.6	35.0	50.2	254.8	94.6	204.8
Rock bass	1.2	0.8	1.9	0.9	1.5	1.3	1.0	1.5	0.7	1.5	0.9	0.8	0.3	0.8	0.5	1.2	1.2	0.7	1.0
White bass	1.5	1.5	3.7	1.4	10.5	4.9	2.5	2.8	7.6	0.4	5.3	4.7	0.9	1.6	0.5	0.1	3.8	1.6	3.1
White perch	0.0	0.1	0.3	0.5	24.6	35.0	10.9	38.9	30.3	43.5	63.1	233.0	40.5	56.8	5.1	0.0	22.5	67.1	36.4
Pumpkinseed	0.1	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.1
Bluegill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Black crappie	0.2	0.0	0.2	0.0	0.1	0.0	0.1	0.1	0.2	0.2	0.4	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.1
Channel catfish	3.5	9.7	5.4	5.8	4.9	10.6	4.6	5.5	5.4	2.7	3.5	4.1	9.0	6.0	4.6	4.6	5.6	5.7	5.6
Brown bullhead	0.2	1.1	1.6	1.9	1.7	4.2	2.5	1.5	4.1	0.9	9.2	3.9	13.1	4.3	4.0	1.6	2.6	5.4	3.5
White sucker	7.8	8.3	7.9	12.2	8.7	6.7	10.2	33.0	10.2	7.0	6.7	2.8	4.3	13.5	14.6	9.0	10.8	8.8	10.2
Redhorse sp.	2.4	1.2	0.6	1.0	0.8	1.5	1.7	1.4	1.3	1.7	1.8	0.6	0.4	0.6	3.1	3.6	1.4	1.7	1.5
Freshwater drum	37.4	66.8	14.0	42.9	13.4	23.5	25.1	30.6	25.3	9.1	15.6	6.4	5.1	25.6	8.9	20.7	27.6	13.3	23.2
Common carp	5.1	26.1	4.7	8.2	6.9	14.9	3.5	2.0	1.9	0.6	6.0	0.6	2.3	2.3	1.3	1.4	7.3	1.6	5.5
Goldfish	4.8	2.4	0.3	0.4	0.4	2.5	0.6	0.2	0.1	0.0	0.2	0.1	0.1	0.1	0.1	0.0	1.1	0.1	0.8
Gizzard shad	4.4	4.7	2.3	3.9	17.8	28.4	18.1	17.4	2.7	2.3	15.9	0.3	2.3	0.0	0.6	0.3	10.7	0.7	7.6
Longnose gar	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	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	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quillback	4.0	18.6	1.8	2.0	2.4	5.6	2.0	1.9	1.7	1.8	1.5	0.7	1.9	2.9	4.4	3.2	3.9	2.6	3.5
Stonecat	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Total	477.9	510.3	731.8	613.9	278.8	422.4	248.7	368.5	193.6	279.7	236.4	546.2	145.8	305.5	120.5	135.2	396.5	250.6	351.0
Percent Yellow perch	78.9	62.7	91.4	83.4	52.4	60.8	51.9	42.3	20.8	62.2	9.7	46.0	28.6	31.0	29.0	37.1	56.0	34.4	49.3
Percent White perch	0.0	0.0	0.0	0.1	8.8	8.3	4.4	10.6	15.7	15.6	26.7	42.7	27.8	18.6	4.2	0.0	8.2	18.7	11.5
Net lifts	50	46	48	36	37	53	57	51	49	55	51	55	82	29	55	40	48	52	50

Appendix 3.—Sport fishing targeted effort[1] and catch at age for yellow perch in Michigan's waters of Lake Erie, 1988-93.

Year	Harvest by age (numbers)						Total harvest	Total effort	Total CPUE
	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6+	(numbers)	(angler hours)	(# fish/ang. hr.)
1988	0	97,739	362,137	295,914	25,994	62,511	844,294	494,158	1.71
1989	0	7,332	447,243	605,612	316,736	90,915	1,467,838	696,973	2.11
1990	5,653	51,409	79,769	320,153	180,686	145,241	782,911	634,255	1.23
1991	695	31,602	130,295	94,645	62,865	58,552	378,654	164,517	2.30
1992	1,202	69,477	52,931	22,894	26,381	81,932	254,817	120,979	2.11
1993	4,868	83,450	264,259	83,450	27,817	9,736	473,580	244,455	1.94

[1]Targeted effort estimated from monthly distribution of effort.

Appendix 4.—Sport fishing targeted effort[1] and catch at age for walleye in Michigan's waters of Lake Erie, 1988-93.

Year	Harvest by age (numbers)						Total harvest (numbers)	Total effort (angler hours)	Total CPUE (# fish/ang. hr.)
	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7+			
1988	873,147	418,736	194,333	34,332	445,729	30,511	1,996,788	4,362,450	0.458
1989	146,149	599,508	101,409	62,635	29,826	152,114	1,091,641	3,794,000	0.288
1990	19,558	117,350	340,315	78,233	89,968	101,704	747,128	1,803,000	0.414
1991	12,618	14,938	15,985	37,670	13,050	37,786	132,047	440,393	0.300
1992	130,313	27,571	28,720	16,126	24,916	21,872	249,518	714,917	0.349
1993	58,138	95,962	10,507	16,811	19,613	69,345	270,376	690,797	0.391

[1]Targeted effort estimated from monthly distribution of catch.

Appendix 5.—Tag recovery data (non-reward) for walleye tagged at the Monroe site, Lake Erie, 1978-93.

Year tagged	Number tagged	Year recovered															
		1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1978	1,396	46	54	27	6	8	3	2	4	1	2	3	1	0	1	0	0
1979	2,349	—	61	54	19	19	3	7	7	2	0	3	2	0	0	0	0
1980	842	—	—	24	19	8	6	5	0	0	0	0	0	0	0	0	0
1981	725	—	—	—	19	11	2	1	1	1	1	1	0	0	0	0	0
1982	1,097	—	—	—	—	38	22	15	5	3	0	0	0	1	0	0	0
1983	1,320	—	—	—	—	—	54	23	8	1	2	1	1	0	0	0	0
1984	1,664	—	—	—	—	—	—	51	25	15	7	6	3	2	1	0	0
1985	3,763	—	—	—	—	—	—	—	132	98	44	37	17	17	7	0	0
1986	2,959	—	—	—	—	—	—	—	—	94	56	53	31	19	12	3	11
1987	1,842	—	—	—	—	—	—	—	—	—	65	72	22	14	6	10	6
1988	3,918	—	—	—	—	—	—	—	—	—	—	126	59	30	10	18	13
1989	1,866	—	—	—	—	—	—	—	—	—	—	—	66	36	15	13	11
1990	1,675	—	—	—	—	—	—	—	—	—	—	—	—	76	28	29	28
1991	2,730	—	—	—	—	—	—	—	—	—	—	—	—	—	56	66	54
1992	2,010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	70	79
1993	1,526	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	81

Appendix 6.—Michigan total allowable catch and estimated harvest of Lake Erie walleye, 1976-93 (expressed as numbers of fish).

Year	Total allowable catch	Harvest
1976	80,500	10,000
1977	87,600	40,000
1978	73,000	44,000
1979	207,000	89,337
1980	261,700	183,140
1981	367,400	117,900
1982	504,100	75,700
1983	572,000	85,000
1984	676,500	168,800
1985	430,700	181,300
1986	660,000	605,700
1987	490,100	902,400
1988	397,500	1,996,800
1989	383,000	1,092,000
1990	616,000	743,000
1991	440,000	132,000
1992	329,000	250,000
1993	556,500	270,000