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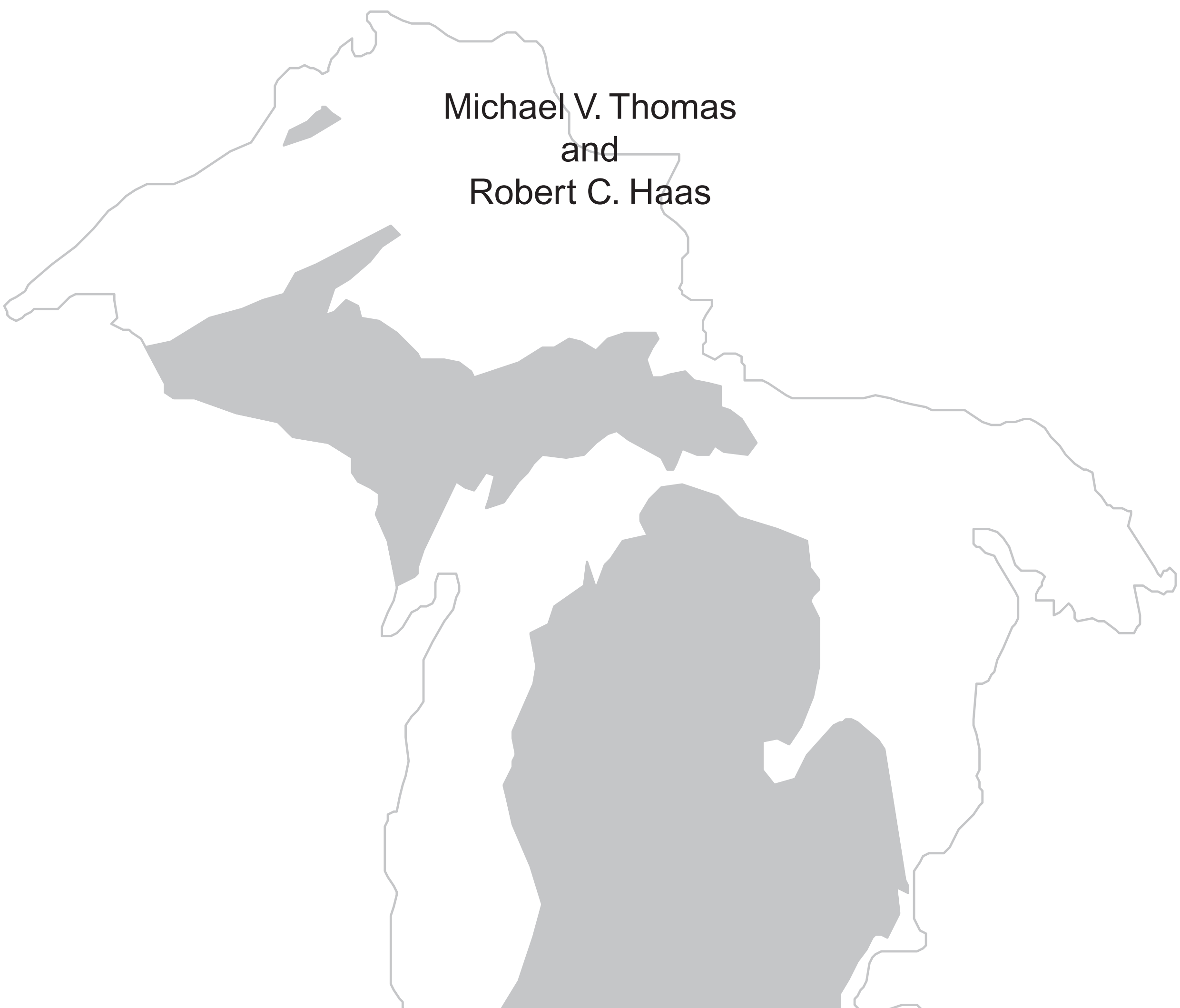

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Status of Yellow Perch and Walleye Populations in Michigan Waters of Lake Erie, 1994-98

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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 1994 to 1998, but information from previous years is considered in the analyses. Results of index trap-net and gill-net surveys, catch-at-age analysis of survey and sport fishery data, and analysis of walleye tag-recapture data were examined. For yellow perch, index trap-net data suggested a decline in abundance, while catch-at-age analysis indicated a period of decline with a slight recovery of abundance after 1996. Catch-at-age analysis produced mean estimates for annual survival (0.55), instantaneous fishing mortality (0.19), and annual exploitation (0.14) 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 steady decline in walleye abundance from 1994 to 1997. Catch-at-age analysis for walleye indicated a general decline in the abundance of age-2 and older fish from 1989 to 1994, and a slight recovery from 1995 to 1998. Catch-at-age analysis produced mean estimates of annual survival (0.65), instantaneous fishing mortality (0.27), and annual exploitation (0.21). Possible explanations for the differences between index survey and catch-at-age analysis abundance trends 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; and a suspected change in vertical distribution affecting walleye vulnerability to the index gill nets. Analysis of walleye tag-recapture data also produced mean estimates of walleye survival (0.74) and annual exploitation rate (0.11), as well as annual natural mortality (0.17). 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 were plotted showing obvious 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 include: no change in existing Michigan sport fishing regulations for yellow perch or walleye; collection of spatially-explicit fishing effort data for Lake Erie, the St. Clair River, Lake St. Clair, and the Detroit River; repeating an interagency reward tag study of walleye; and initiation of efforts to restore populations of native lake sturgeon, lake herring, and Great Lakes muskellunge. Future research directions identified include: continuation of genetic efforts to quickly and inexpensively identify stock of origin for walleye based on scale samples; and investigation of ecological effects of newly-introduced exotic species in Lake Erie.

Introduction

Walleye *Stizostedion vitreum* and yellow perch *Perca flavescens* have been the primary sport and commercial fish species in Lake Erie during this century. In Michigan waters of Lake Erie, walleye and yellow perch have routinely accounted for over 80% of the total number of fish harvested by the sport fishery. Sport angling pressure in Michigan waters of Lake Erie has averaged over 1 million hours annually since the mid-1980's (Rakoczy 1992; Rakoczy and Rogers 1987, 1988, 1990, 1991). 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-1970's, both species have been managed lakewide under an interagency quota system. Under the auspices of the Great Lakes Fisheries Commission's 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. The annual harvest allocations are largely based on stock assessment efforts of the Walleye Task Group and Yellow Perch Task Group. Success of this management system depends on accurate assessment by each agency of harvest and effort, abundance trends, and survival rates for fish stocks in its waters of Lake Erie.

Michigan began an annual assessment of walleye and yellow perch populations in Lake Erie in 1978. Bryant (1984), Haas et al. (1988), and Thomas and Haas (1994) have previously reported on various aspects of this assessment program. This report focuses on the assessment program from 1994 to 1998. 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 in Lake Erie and the connecting waters (Detroit River, Lake St. Clair, and St. Clair River) based on tag-recovery data were also examined.

Methods

Net Samples

Trap nets set in the spring provided abundance data on walleye and yellow perch, age-2 or older. Gill nets set in the fall provided data on abundance of yearling and older walleye, (useful as indices of relative year-class strength; Willis 1987). Impoundment gear (trap net) is generally considered to be superior for studying relative abundance of species (Yeh 1977; Craig 1980); however, traps must be fished for extended time periods, which is expensive. We examined relative year-class strength indices for walleye from both gear types because gear selectivity influences the size distribution of the sample.

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 hours or trap day) for walleye and yellow perch. This assumes that CPUE 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). We captured walleye and yellow perch with trap nets fished each year at the same locations off Monroe, Michigan (Figure 1). The trap nets have a 1.8 m deep pot of 5.1 cm stretch mesh, 7.6 cm stretch mesh heart and wings, and a 91.4 m long lead of 10.2 cm stretch mesh. 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. Nets were typically set in early April and fished through the end of the month, except for 1995 when vessel repairs delayed the survey period until April 24 to May 22.

The entire catch from each trap net was identified and enumerated. Size data were collected from all walleye and yellow perch. Scale samples were collected from all walleye and a subsample of 25 yellow perch per 2.54 cm group. Scale samples were used for age interpretation, which facilitated assessment of relative year-class strength. The maximum time between net lifts was 72 hours; most were lifted after 24 hours. Catch per net lift for yellow perch and walleye were standardized to catch per 24 hours.

We fished multi-filament, graded-mesh gill nets at two to four stations (Figure 1) in October during 1978-98 as part of the Great Lakes Fishery Commission, Lake Erie Interagency Yearling Walleye Index Program. Replicate sets were made each year with gangs of nets, 1.83 m deep, each consisting of seven 30.48 m long panels that ranged from 51 to 127 mm stretched mesh measure by 13 mm intervals. The gill nets were canned (suspended from the surface) on strings 0.91 m long. All walleye captured in gill nets each year were measured and aged using scale samples.

We also developed a mean ranking system for the 1974-97 walleye year classes. Each year class was ranked using three criteria: cumulative Michigan survey trap-net catch per effort; cumulative Michigan survey gill-net catch per effort; and cumulative harvest, including all sport and commercial harvests for the western and central basins. The ranks for the three criteria were equally weighted. For a given year class, ranks for the three criteria were averaged to arrive at a mean rank.

Catch-at-age analysis

Abundance, instantaneous fishing mortality rate, annual survival rate, and total annual exploitation rate were estimated for yellow perch and walleye in Michigan's waters of Lake Erie, from 1989 to 1998, with the CAGEAN catch-at-age model (Deriso et al. 1985). This model uses fishing mortality and catch-at-age data to arrive at stable and reliable estimates of historical and current stock size. It is an improvement of the traditional virtual population analysis because multiple gear types (including assessment, sport, and commercial fishing gear) and auxiliary information on fishing effort are explicitly considered in the model. Deriso et al. (1985) found that bias was substantially reduced when auxiliary information, such as effort data and survey catches, was included in the analysis. We used the IBM personal computer (PC) version of CAGEAN, which has inputs of natural mortality, gear-specific catch-at-age and weight-at-age, fishing effort, and gear and effort lambdas. The lambda values are weighting terms that govern how strongly the respective catch and effort observations influence the overall fit of the model. The model produces estimates of age-specific abundance, catch, fishing mortality, selectivity, catchability, and exploitation (CAGEAN-PC User Manual 1987). For yellow perch, we analyzed spring trap-net catch and effort data and sport-fishery harvest and effort data using a two-gear CAGEAN model. For walleye, a three-gear CAGEAN model was used to combine spring trap-net and fall gill-net catch and effort data with sport-fishery harvest and effort data. The sport-fishery harvest and targeted effort data for both species are shown in Appendices 3 and 4. Due to the short time series of data used in the analysis, we assumed constant age-specific selectivities and catchabilities through the time period analyzed.

For the analysis of yellow perch in Michigan's waters, we pooled all catch data for ages 6 and older due to the relatively low contribution of those cohorts to the harvest. We set the ages of full recruitment to the trap nets at 3 to 6, and to the sport fishery at 3 to 5. We set natural mortality at 0.4 (M=0.4), the value used by the Lake Erie Yellow Perch Task Group, as derived from catch curve analysis. Gear lambda's (λ) were set at 1.0 for the sport fishery and 0.5 for the trap-net survey. Effort λ's used were: sport fishery, 0.5; trap-net survey, 0.5.

We also used CAGEAN to analyze the interagency yellow perch catch-at-age data set for Lake Erie's Western Basin. This data set included three gear types: commercial gill nets, commercial trap nets, and sport fishing. To allow valid comparison of results, command files were structured as similarly as possible. The same sport fishery ages of full selectivity and λ's were used. Trap-net survey ages of full selectivity and λ's 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 $\lambda = 0.5$. Natural mortality rate was again set at 0.4 (M=0.4).

For walleye, a three-gear version of the program CAGEAN was used with catch and effort data from spring trap-net surveys and fall gill-net surveys, in addition to sport fishery harvest and targeted effort estimates. The annual natural mortality rate was set at 0.17 (M=0.17), based on survival and exploitation rates derived from the Monroe tag-recapture study. For walleye, we pooled all catch data for ages 7 and older due to relatively low contribution by those cohorts to the harvest. We set age of full recruitment to the trap nets, gill nets, and sport fishery at 3. Gear λ's were set at 1.0 for all three gear types, while effort λ's were set at 0.5.

We also used CAGEAN to analyze an interagency walleye catch-at-age data set for all of Lake Erie. The interagency data set included two gear types, gill nets and sport fishing. To allow valid comparison of results, command files were structured as similarly as possible. The annual natural mortality rate was set at 0.25 (M=0.25) based on analyses of interagency walleye tag data covering the whole lake. The same age of full selectivity, gear and effort λ's were used for the lakewide sport fishery and commercial gill-net fishery as for the Michigan sport fishery and index gill nets.

Michigan sport fishery harvest and effort data for both species were available through an annual on-site creel survey. 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. The age composition of Michigan's sport fishery harvest in 1990 was assumed to be the same as that estimated for Ohio's 1990 sport fishery based on creel survey data.

Tag-recapture study

Walleye were tagged by MDNR personnel during spring trap-net surveys during 1978-98, near Monroe, Michigan. Fish were removed from the trap nets and immediately placed in an on-board live tank equipped with continuously circulating lake water. Fish were removed individually from the live tank and tagged without anesthesia before release at the net location. Total length measurements were made on all tagged fish, while total weight measurements and scale samples were taken from portions (varying annually from 36% to 100%) of the total number tagged. Scale samples were taken, and ages subsequently estimated, for all walleye tagged from 1994-98. All 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. Fish over 600 mm were tagged with size 12 monel metal strap tags affixed by overlapping the tag snugly around both the maxillary and premaxillary bones. All tags were inscribed with the Mt. Clemens MDNR address and an individual tag number. We tagged 9,978 walleye at the Monroe site from 1994 to 1998. Tag-recapture data were solicited from anglers and commercial fishermen on a voluntary basis.

Tag recovery data were summarized by location and calendar day, and mapped using ArcView© and SURFER© geographic information system software. Dates of tagging and tag recovery for recaptured walleye were coded by calendar day and thus were independent of the calendar year. Geographical distributions of tag recoveries from the Monroe and Huron River tag sites were analyzed with Mardia's nonparametric two-sample test of the null hypothesis that two samples belong to the same bivariate distribution (Mardia 1967). Three-dimensional maps of tag recovery distributions were produced by applying a kriging algorithm to the mean number of tags or percent of tags recovered within 5 minute grids for the St. Clair system and Lake Erie. Kriging is a geostatistical gridding method used to produce contour and surface plots from irregularly spaced data (Keckler 1995). Mean values were positioned at grid centers prior to application of the kriging operation.

A generalized stochastic model, referred to as the ESTIMATE model (Brownie et al. 1985), was used to analyze the 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 the exploitation rate and the reporting rate (Krementz et al. 1987), total mortality (natural logarithm of survival rate) may be partitioned into fishing and natural mortality rates if an estimate of the tag reporting rate is available (Horsted 1963). The z-statistic (Brownie et al. 1985) was used to compare annual tag recovery rate estimates.

In many studies the reporting rate is assumed to be 100%, that is, all tags recovered by the fisheries are seen and subsequently reported. If 100% reporting is assumed, then the recovery rate is an estimate of the 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).

If an estimate of the exploitation rate is available, the fishing mortality rate may be estimated. However, fishing mortality rate is underestimated whenever the assumption of complete reporting is violated. Estimation of the exploitation and fishing mortality rates will be most reliable when reporting rates are high. 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 in other studies. A reward tag study, funded by the Ontario Ministry of Natural Resources, was begun in 1990 to provide an estimate of the non-reporting rate for traditional non-reward tags for Lake Erie walleye. 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 provided an estimate of the reporting rate for non-reward tags, assuming that 100% of reward tags were reported. In 1998, the 1990-98 cumulative non-reporting rate based on the 1990 tagging was 2.70 non-reward tags for every reward tag reported.

RESULTS

Net Samples

Forty-four species of fish have been identified from trap-net and gill-net catches in Lake Erie since the assessment program began in the late 1970s. Appendix 1 lists fish species collected with both types of nets since 1978.

Annual relative abundance of yellow perch, as indicated by trap-net CPUE, declined sharply after 1989 and remained low through 1998 (Table 1). Relative abundances for ages 3 to 6 in 1989 were much higher (5x-10x) than for any other age groups in any subsequent year. Similarly, the mean yellow perch catch per net lift since 1990 has been 6 times lower than the mean during tbe period from 1978 to 1989 (Appendix 1). Based on catch per net lift, the years 1994-98 rank among the seven lowest for perch abundance since 1978. Length-at-age for scale-sampled yellow perch caught in trap nets during 1992-98 is shown in Table 2. In general, no trend in length-at-age is obvious over this time period.

Walleye abundance as indicated by catch per 24-hour trap-net set varied over the study period with the highest abundance in 1991 (Table 3). The lowest abundance value for the period was in 1995 and probably was a result of the delayed sampling period that year. Age-specific CPUE values throughout the study period demonstrated the relative strength of the 1982 and 1986 year classes. Mean age of walleye captured in trap nets increased from 4.2 years in 1989 to 5.4 years in 1993 as these two strong year classes matured. CPUE values for age 11 and older walleye increased in 1993 and have remained above those of 1989-92. Two very poor year classes, 1992 and 1995 were also apparent based on low CPUE values for age 2 fish in 1994 and 1997. Overall, sex-specific length-at-age (Table 4) for trap-net caught walleye exhibited no apparent change over the study period.

Walleye abundance, as indicated by total catch per multi-filament gill-net lift, declined from 1994 to 1997 (Table 5). Yearling walleye catch rates suggested that the 1992 and 1995 year classes were the weakest of the two decades, and in combination are likely a primary reason for the record low total catch rates in 1996 and 1997.

Sex-specific length-at-age (Table 6) for walleye caught in gill nets also exhibited no apparent trends over the study period. However, mean length-at-age for the 1996 year class as age 1 fish in 1997 was quite low. In fact, the 1996 year class exhibited the lowest mean length-at-age for yearlings of any year class in the 1978-98 study period (Table 7).

Mean ranks were assigned to the 1974-97 year classes (Table 8). There was very good agreement between ranks from the three gear types and the nonparametric Friedman statistical comparison showed no significant differences (P=0.918). The top five year classes were 1982, 1986, 1985, 1984, and 1991.

Catch-at-age analysis

The program CAGEAN was used to estimate mean instantaneous fishing mortality, annual survival, and annual exploitation rates; as well as annual total abundance and catch for yellow perch and walleye. Average parameter values for yellow perch in Michigan's waters of Lake Erie during the study period (1989-98) were: annual survival rate, 0.55; instantaneous fishing mortality rate, 0.19; and annual exploitation rate, 0.14; while average annual abundance was 3,369,427 (Table 9).

Western basin yellow perch average parameter values during the study period (1989-98) were: annual survival rate, 0.47; instantaneous fishing mortality rate, 0.36; annual exploitation rate, 0.25; and annual abundance, 33,365,276 (Table 10).

Average parameter values for walleye in Michigan's water of Lake Erie during the study period (1989-98) were: annual survival rate, 0.65; instantaneous fishing mortality rate, 0.27; and annual exploitation rate, 0.21; while the average annual abundance was 1,277,474 (Table 11).

Lakewide average parameter values for walleye during the study period (1989-98) were: annual survival rate, 0.70; instantaneous fishing mortality rate, 0.10; annual exploitation rate, 0.08; and annual abundance, 66,212,233 (Table 12).

Tag-recapture study

A total of 658 tagged walleye from the Monroe site was reported by commercial and sport fishermen from 1994 through 1998. A total of 122 tagged fish from the Huron River site was reported through 1998. Most tag recoveries were reported by anglers. There appeared to be ample angling harvest throughout the area to provide enough voluntary tag recoveries to adequately monitor exploitation and movements of the tagged stocks.

The geographical distribution of Monroe tag recaptures varied slightly during the study period from 1994 to 1998 and remained very similar to the 1989-93 pattern (Table 13). The percentage of recoveries reported from Lake Erie waters stayed the same, with a modest switch from the West Basin to the Central and East basins. Recoveries were reported from all months, with 72% reported during the months of May (25.0%), June (21.9%) and July (24.5%). The areal distributions of Monroe tag recaptures from 1994 to 1998 by season are shown in Figure 2.

The geographical distribution of Huron River tag recaptures during 1992-98 was as follows: St. Clair River, 17.2%; Lake St. Clair, 10.7%; Detroit River, 27.0%; Western Basin-Lake Erie, 26.2%; Central Basin-Lake Erie, 7.4%; Eastern Basin-Lake Erie, 5.7%; Lake Erie-Total, 39.3%. Recoveries were reported from January through December, with 77% reported caught in May, June, and July. Comparison of the areal distribution of tag recoveries from the two Michigan Lake Erie tag sites (Monroe and Huron River) suggests that walleye spawning in the Huron River have a greater tendency to move northward, with higher proportions being recovered in the connecting waters (Figures 3-5). The centroid for all tag recovery locations from the Huron River tag site was significantly different (26 km north and slightly west) from the centroid of the Monroe tag recoveries (Figure 6; Mardias U = 44.5, P = 0.00). Comparisons of the two tag sites within individual waterbodies (Figure 7) showed that the Huron River tags were usually recovered north of the Monroe tags; however, Lake Erie was the only waterbody showing a within-lake difference between centroids (averaged 10.7 km apart: Lake Erie; Mardias U = 15.35, P = 0.00: Detroit River; Mardias U = 0.78, P = 0.68: Lake St. Clair; Mardias U = 0.58, P = 0.75: St. Clair River; Mardias U = 2.29, P = 0.32; Lake Huron; Mardias U = 0.26; P = 0.88).

Walleye tag-recovery data were analyzed to estimate annual rates for tag recovery and survival during the period from 1994 to 1998. Monroe site non-reward tag recovery data for the period from 1994 to 1998 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 1 was more compatible with all data sets than three alternative models and probably produced the least-biased estimates. We also assumed that all tag recoveries attributable to the 1998 fishing year had been received so that the recovery rate estimates for 1998 were comparable to those for prior years (occasionally some tags are reported a year or two after the fish were caught). Analysis of the tag recovery data produced an estimate for mean annual survival of 74.15% and mean recovery rate of 3.65% (Table 14). The reward tag study produced an estimated reward/non-reward tag recovery ratio of 2.95 for Monroe site tagged walleye (Table 15).

Instantaneous natural mortality (M) was estimated according to the relationship M=Z-**u**Z/A where (**u**Z/A=F) for type II Fisheries; and 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 (Ricker 1975). A value for **u** of 10.8% was generated by multiplying the mean recovery rate (3.65) by the reward/non-reward ratio (2.95). The resulting value for M was 0.17. It is important to note that survival rate estimates from the program "ESTIMATE" are independent of recovery rates; thus, expansion of the tag recovery rate by reward/non-reward ratios did not alter survival rate estimates in any way. The estimated annual tag recovery rate (and exploitation) varied without trend from 1994 to 1998 (Table 16). Z-statistics were significantly different for 6 of 10 comparisons.

DISCUSSION

Net samples

Trap-net CPUE for yellow perch suggested that yellow perch abundance in Michigan's waters of Lake Erie has been much lower during the 1990’s than during the previous decade. However, several factors complicate this appraisal. Lake Erie has undergone drastic biological changes during the past 20 years, including the explosive increase in white perch abundance in the 1980's, the establishment of zebra mussels in the late 1980's and early 1990's, and an apparent decline of white perch in recent years. Water clarity, possibly related to filtering by zebra mussels, has increased dramatically across Lake Erie (Leach 1993). As a result, we suspect lower catchability due to gear avoidance may have been a factor in the decline of survey trap-net catches of yellow perch and other species.

Trap-net CPUE for walleye declined from 1994 to 1998 and walleye gill-net CPUE declined from 1994 to 1996. This was likely the combined effect of the two weakest year classes in recent times, 1992 and 1995, progressing through the population. As with yellow perch, the effects of water clarity may also have been a factor in lower walleye CPUE, with a potential for increased net avoidance for both trap nets and gill nets. Catches in our survey gill nets, which were suspended below surface on 0.91-m strings, may also be 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, Wheatley, Ontario, personal communication).

The mean ranking system used for walleye year classes illustrated the dominance of the 1982, 1986, 1985, 1984, and 1991 year classes in the time series. Haas et al. (1988) and Thomas and Haas (1994) found that Michigan's Lake Erie survey trap nets and gill nets yielded similar relative abundance estimates for walleye. The mean ranking analysis used here confirmed that finding.

Catch-at-age analysis

Based on catch-at-age analysis, yellow perch abundance in Michigan waters of Lake Erie was highest in 1989 and declined to its lowest level in 1994. The population recovered and remained at over 3 million fish after 1996. Strong year classes in 1984 and 1986 and again in 1993-95 produced this pattern.

We felt comparison of parameter estimates of the catch-at-age analysis for the Michigan waters data set with estimates for the entire Western Basin would be valuable due to the contrast in fisheries between the two areas. Of the three fisheries management agencies on the Western Basin, Michigan is the only one limiting the yellow perch fishery to angling. Based on this difference, we suspected that yellow perch in Michigan waters would experience lower total exploitation rates and higher survival rates.

Annual estimates of total exploitation rate for the Western Basin exceeded the estimates for Michigan waters throughout the period 1989 to 1997. Only in 1998 did the CAGEAN estimates of annual total exploitation rate for the Western Basin fall below the estimate for Michigan waters. Similarly, annual estimates of survival rate were less for the Western Basin compared with Michigan waters, from 1989 to 1997. In general, we believe the higher exploitation rates and lower survival rates estimated for the Western Basin were an accurate reflection of the greater fishing pressure exerted on yellow perch in those areas with commercial fisheries.

The estimate of mean annual survival for yellow perch, 0.55, produced by the catch-at-age analysis for Michigan waters was within the range of 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 Les Cheneaux Island perch (northern Lake Huron) experienced a survival rate of 0.45 (Lucchesi 1988) during the 1980's and 0.55 in 1995 (Schneeberger and Scott 1997). Schneeberger (2000) estimated mean annual survival for Little Bay De Noc yellow perch at 0.42 for 1996. The estimate of mean annual survival for the Western Basin analysis, 0.47, was also within the reported range.

As expected, yellow perch abundance estimates generated by the catch-at-age analysis on the Western Basin catch-and-effort data set were much higher than for the analysis on Michigan waters, but showed a similar pattern of highest abundances in 1989 and 1998. However, as Hilborn and Walters (1992) point out, estimation of abundance for the most recent cohorts with catch-at-age analysis 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. Therefore, it remains uncertain if yellow perch abundance truly increased during 1998.

Estimates of annual total exploitation rates for walleye in Michigan waters, based on the CAGEAN analysis, showed an interesting pattern. Total exploitation rate was quite high in 1989 and 1990, then declined and remained 40% to 85% lower through 1998. A dramatic decline in fishing effort (Appendix 4) combined with a reduced bag limit were likely involved in the decline in exploitation rate. In response to the quota being exceeded in 1987, 1988, and 1989 (Appendix 6), Michigan reduced the daily creel limit for its Lake Erie walleye fishery from 10 fish to 6 fish daily in 1990. Since 1991, the Michigan sport harvest has not exceeded the total allowable catch, despite a return to a 10-fish daily creel limit in 1997. It is also possible that a major change in walleye catchability due to water clarity-driven changes in walleye distribution or feeding behavior could be involved. Unfortunately, we were unable to distinguish the relative importance of these factors in the observed decline in exploitation rate.

Our analysis indicated that walleye abundance in Michigan waters declined rather sharply from 1989 to 1991, coincident with the aging of the strong 1982, 1984, 1985, and 1986 year classes. A series of average and weak year classes from 1987 to 1995, except 1991, resulted in lower (but fairly stable) abundance from 1992 through 1997. Despite the entry of the rather robust 1996 year class to the fishery in 1998, the estimated abundance remained lower than in 1989. This was a reflection of the magnitude of abundance levels in the mid and late 1980's, a combined effect of four strong year classes.

We felt comparison of parameter estimates of the catch-at-age analysis for the Michigan waters data set with estimates from similar analysis of the entire Lake Erie data set would be valuable due to the difference in fisheries in different areas. Walleye were harvested only by sport anglers in Michigan and Ohio, but commercial gill nets harvested most walleye in Ontario waters. We suspected that exploitation rates in Michigan waters would likely have been higher than exploitation rates lake wide during the late 1980s due to the intensity of the sport fishery in Michigan's limited jurisdiction, but that exploitation rates would be similar after the sport effort in Michigan waters declined.

Estimates of exploitation rates generated by the analysis of the lakewide data set were about half to two-thirds less than those estimated by the Michigan waters analysis for 1989 to 1994. However, lakewide estimates of exploitation were similar to those estimated for Michigan waters from 1995 to 1998. Review of the CAGEAN output files indicated this shift was a result of both a 40% to 50% decrease in exploitation by the sport fishery and a 60% to 90% increase in exploitation by the gill-net fishery after 1994.

Tag-recapture study

Haas et al. (1988) and Thomas and Haas (1994) reported that tag-recovery data from the period 1978-93 for the Monroe and Huron River tag sites demonstrated a strong tendency for upstream movement after spawning, with substantial movement of Lake Erie walleye into the connecting waters. These investigators found that 29% and 23% of all Monroe tags recovered, during their respective study time periods, came from the Detroit River or further north. Tag-recovery data from the study period 1994-98 continued to show a strong tendency for northward movement, with 23% of all tags again recovered from the Detroit River or further north. The areal distribution of tag recoveries by season (Figure 2) further illustrated the northward movement of fish from the Monroe tag site into the connecting waters. An eastward movement pattern was also evident. We found an even stronger tendency for tagged fish to be recovered in the Central and East basins than previously known. This may be a reflection of a relative increase in walleye exploitation in these eastern areas rather than to changes in walleye movements per se.

Although the sample size was quite small, tag recoveries from walleye tagged in the Huron River differed in areal distribution from those of the Monroe tag site. Walleye tagged in the Huron River were recovered significantly northward of the Monroe tagged fish. This difference probably resulted from the relative geographical location of the tag sites (Huron River site was 27 km north of the Monroe site) since the relative locations of centers of the respective tag distributions (Huron River centroid 26 km north of Monroe centroid) were very similar. Alternatively, Huron River spawning walleye may represent a separate stock.

The estimate of mean annual survival, 0.74, produced by the program ESTIMATE, was higher than the estimate of mean annual survival produced by the CAGEAN analysis on the Michigan data set, 0.65. We believe the additional years included in the tag-recovery analysis with ESTIMATE, particularly 1987, were part of the reason for this difference. Walleye abundance and survival were considerably higher during the mid to late 1980's (Thomas and Haas 1994). In addition, the tag-recovery data reflected survival across the full geographical distribution of the tagged population, while the CAGEAN estimate of survival based on the Michigan data set was limited to Michigan waters of Lake Erie. As discussed above, during the period 1989-94, exploitation rates in Michigan waters were estimated to be much higher than those estimated for the lakewide data set.

The reward tag study carried out by Ontario, Ohio, and Michigan in 1990 has provided critical information on non-reporting of tagged Lake Erie walleye. This information has greatly increased our confidence in the estimates of walleye survival and natural mortality derived from the tag-recovery data. Further, differing non-reporting rates for groups of fish tagged at different tag sites provided valuable insight into the behavior of anglers and commercial fishermen.

Recommendations

1) Yellow perch are a critically important sport and commercial species in the Lake Erie fishery. While yellow perch abundance has recovered in recent years, from the low levels of the early 1990's, abiotic changes in Lake Erie during the past decade confound the 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 indicated that current Michigan sport fishing regulations (no closed season, no size limit, 50 fish creel limit) are not resulting in over-exploitation of yellow perch in Michigan waters of Lake Erie at this time. Thus, we find no biological basis for changing yellow perch regulations for Michigan sport anglers.

2) The current suite of regulations on the Michigan sport fishery for Lake Erie walleye include no closed season, a 330 mm minimum size limit, and a 10 fish daily creel limit. Current exploitation and survival rates indicated that these regulations have provided ample protection for the Lake Erie walleye stock. Since 1991, Michigan sport harvest has not exceeded the recommended allowable catch. At this time, we see no biological reason to consider any changes in these regulations.

3) The interagency reward tag study initiated in 1990 with a $100.00 US tag applied to 10% of the walleye was crucial to interagency walleye management during 1990-97. Walleye tagged in 1990 have passed through the population and therefore, managers currently have reduced ability to estimate important walleye population parameters. We recommend that the interagency reward tag study be repeated periodically.

4) All agencies, including the Michigan DNR, involved in management of Lake Erie walleye recently agreed that identification, description, and regulation of genetic stocks will be necessary for effective management. Preliminary genetic investigations at Case Western Reserve University in Cleveland, Ohio have indicated that it may be possible to develop a quick and cheap genetic technique for identifying the stock of origin for individual walleye from their scales. Since this technique would provide a giant stride forward in Lake Erie walleye management, we recommend that this research be continued and supported.

5) Separate walleye stocks may exhibit different movement patterns, experience different growth, mortality, and exploitation rates; and respond differently to environmental perturbations. Although the Maumee River spawning stock was likely the single largest walleye stock in Lake Erie, inclusion of as many separate stocks as possible in future interagency tag-recapture studies, including comparatively small stocks, would provide a broader understanding of walleye population dynamics in the lake.

6) We recommend that a grid system be developed for collecting sport fishing effort data by appropriate fisheries management agencies on the St. Clair and Detroit rivers, Lake St. Clair, and Lake Erie and that monthly estimates of fishing effort be generated throughout this area each year. No harvest or effort estimates for the sport fishing in the connecting waters have been produced since the mid 1980s. The lack of current sport-fishery statistics weakens habitat protection efforts. Such data are also critical in understanding ecological changes that occur in this system. Small grids would allow more precise analyses of catch and tag-recovery data and better resolution for all geographically referenced fish population data and eventually contribute to a better understanding of habitat relationships. Grid size for Lake Erie should be no larger than 10 minutes of latitude and longitude and no larger than 5 minutes for Lake St. Clair and the two connecting rivers. Remote sensing should also be investigated as a potential source for counts of boating activity and instantaneous effort estimates.

Acknowledgments

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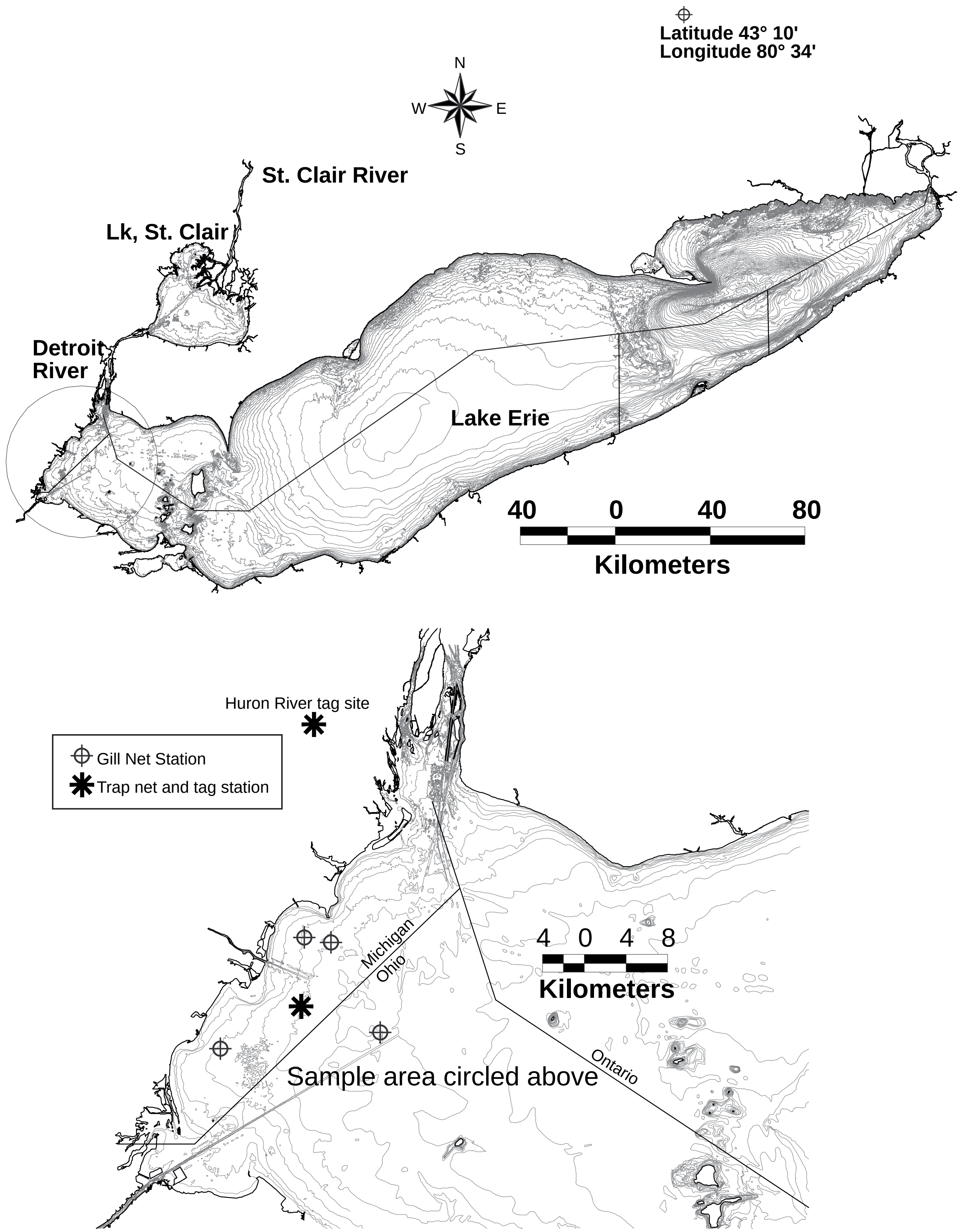

Figure 1.–Map of Lake Erie, Lake St. Clair, and the Detroit and St. Clair rivers showing net stations and the Huron River and Monroe (Raisin River) walleye tag sites. The Huron River site is the farther north location and the Monroe site is also the spring trap-net location.

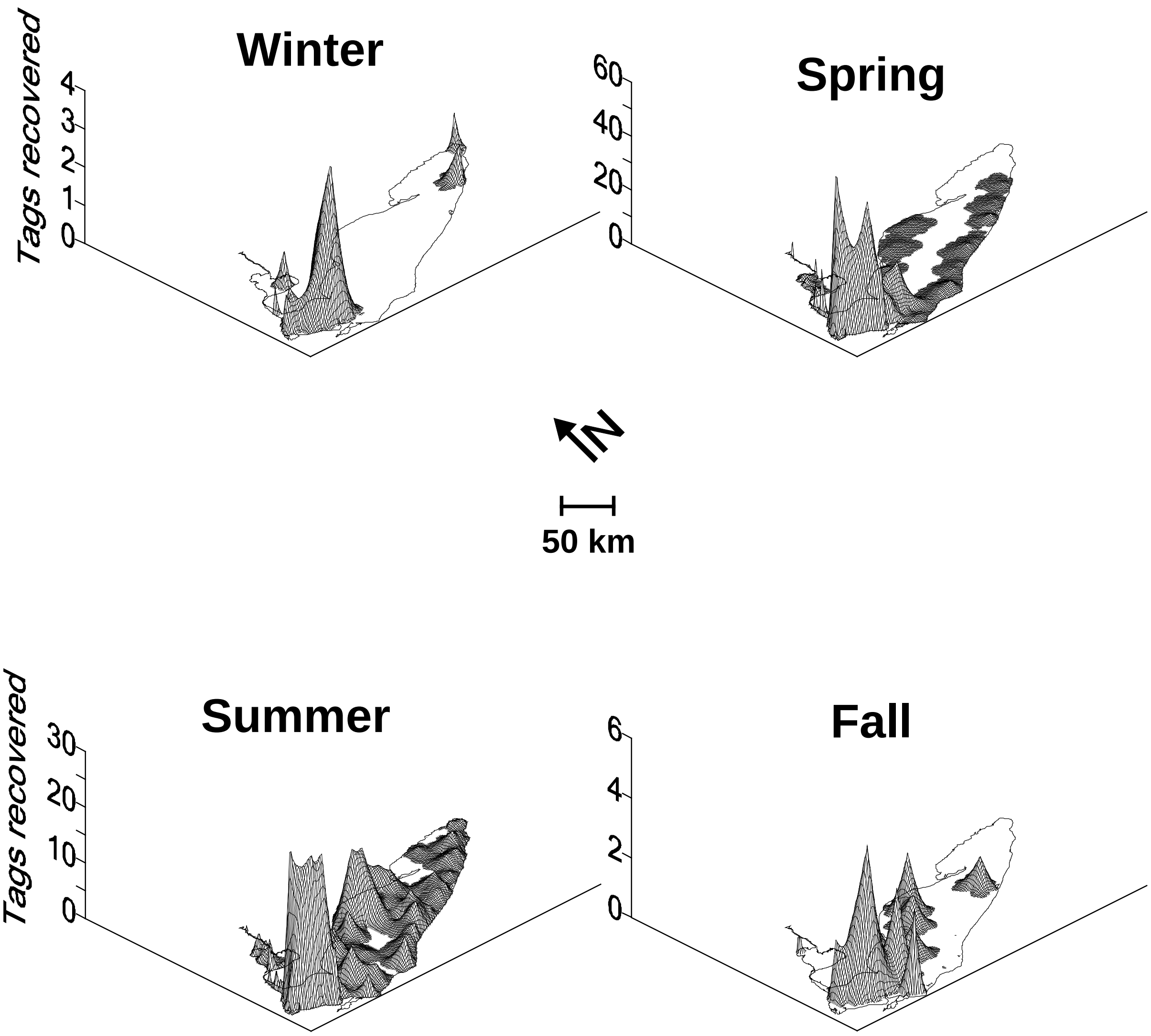

Figure 2.–Three-dimensional maps of the seasonal distribution within Lake Erie and the connecting waters of 658 tag recoveries from walleye caught by anglers and commercial fishermen during 1994-98. All walleye were tagged at the Monroe trap-net station during spring. Mapped data was estimated by applying a kriging algorithm to mean number of tags recovered within 5 minute grids for Lake St. Clair and 10 minute grids for Lake Erie. Mean values were positioned at grid centers prior to application of the kriging operation.

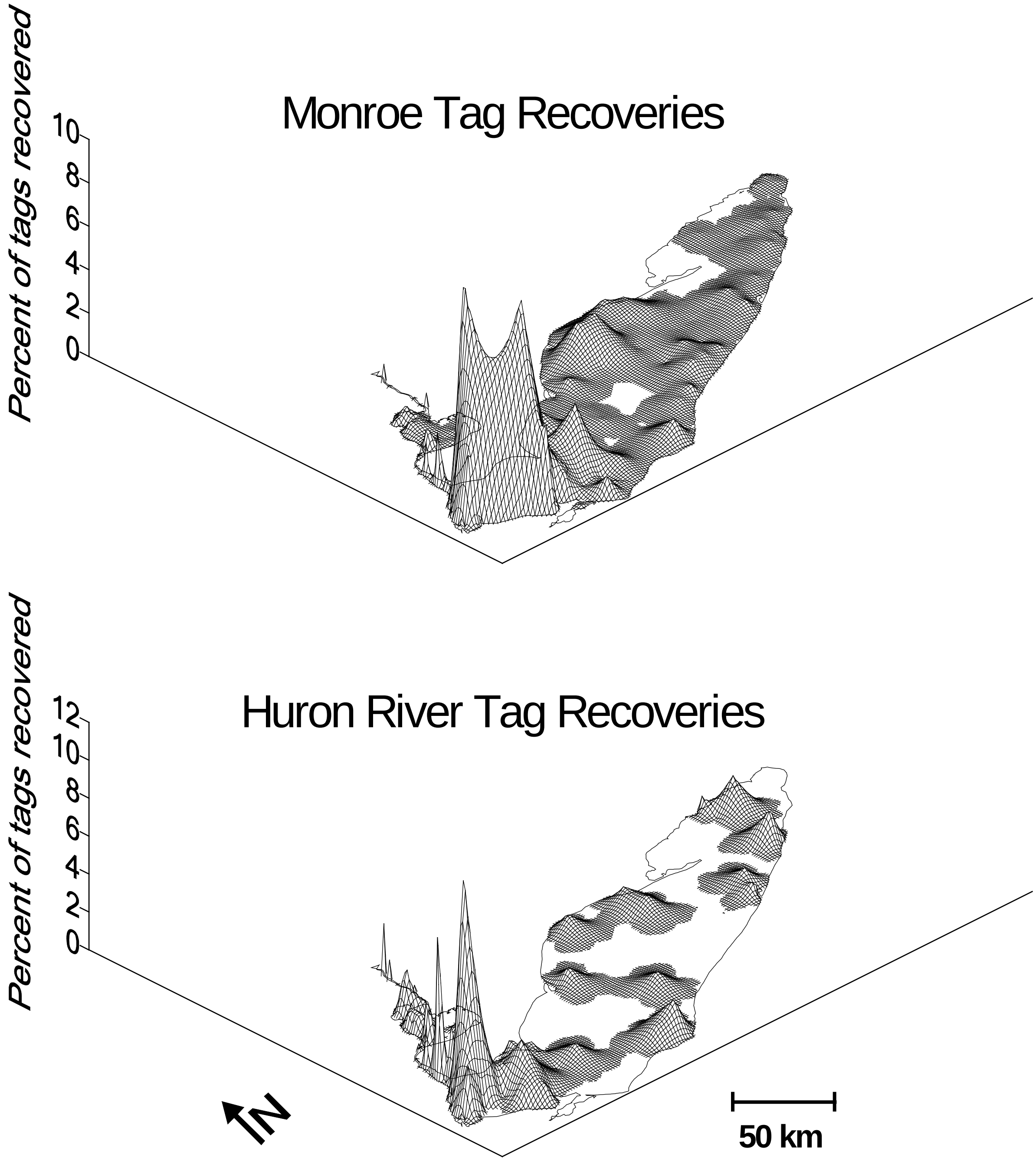

Figure 3.–Three-dimensional maps of Lake Erie, Lake St. Clair, and the Detroit and St. Clair rivers comparing the distribution of walleye tag recoveries from the Monroe versus the Huron River tag sites. Tagged walleye were caught and voluntarily reported by sport and commercial fishermen during 1994-98. All walleye were tagged during spring. Three-dimensional map data was estimated by applying a kriging algorithm to percent of tags recovered within 5 minute grids on Lake St. Clair and 10 minute grids on Lake Erie. Percent values were positioned at grid centers prior to the kriging operation.

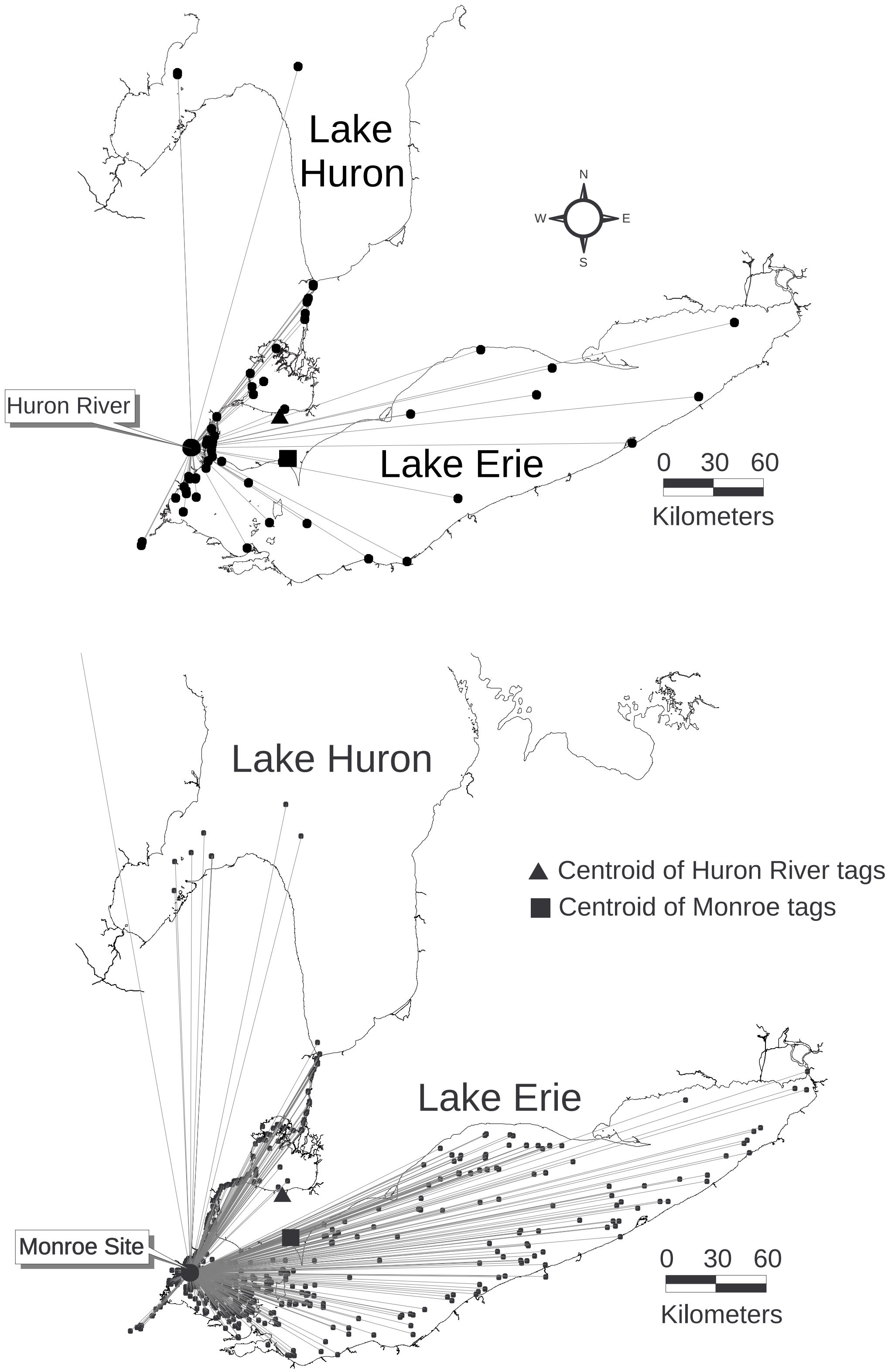

Figure 4.–Two-dimensional maps of Lake Erie, Lake St. Clair, and the Detroit and St. Clair rivers comparing the distribution of walleye tag recoveries from the Monroe versus the Huron River tag sites. Tagged walleye were caught and voluntarily reported by sport and commercial fishermen during 1994-98. All walleye were tagged during spring. Circular symbols denote tag sites and the diamond (Huron River) and square (Monroe) symbols are located at the centroid of the tag recovery distribution. Small circles and lines indicate individual tag recoveries.

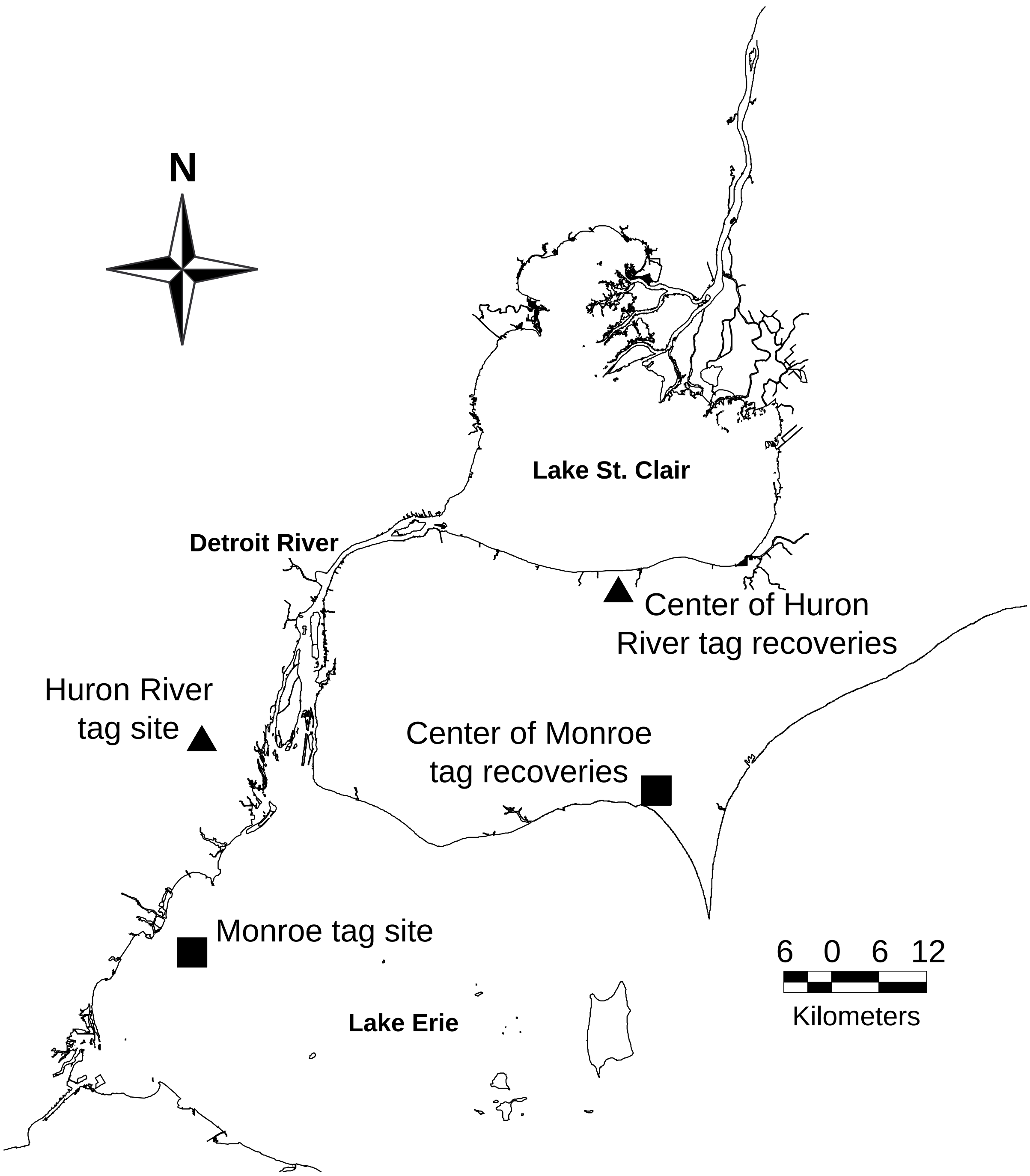

Figure 5.–Two-dimensional map of portions of Lake Erie, Lake St. Clair, and the Detroit rivers comparing the tag locations and center of respective walleye tag recovery distributions from the Monroe versus the Huron River tag sites. Tagged walleye were caught and voluntarily reported by sport and commercial fishermen during 1994-98. All walleye were tagged during spring.

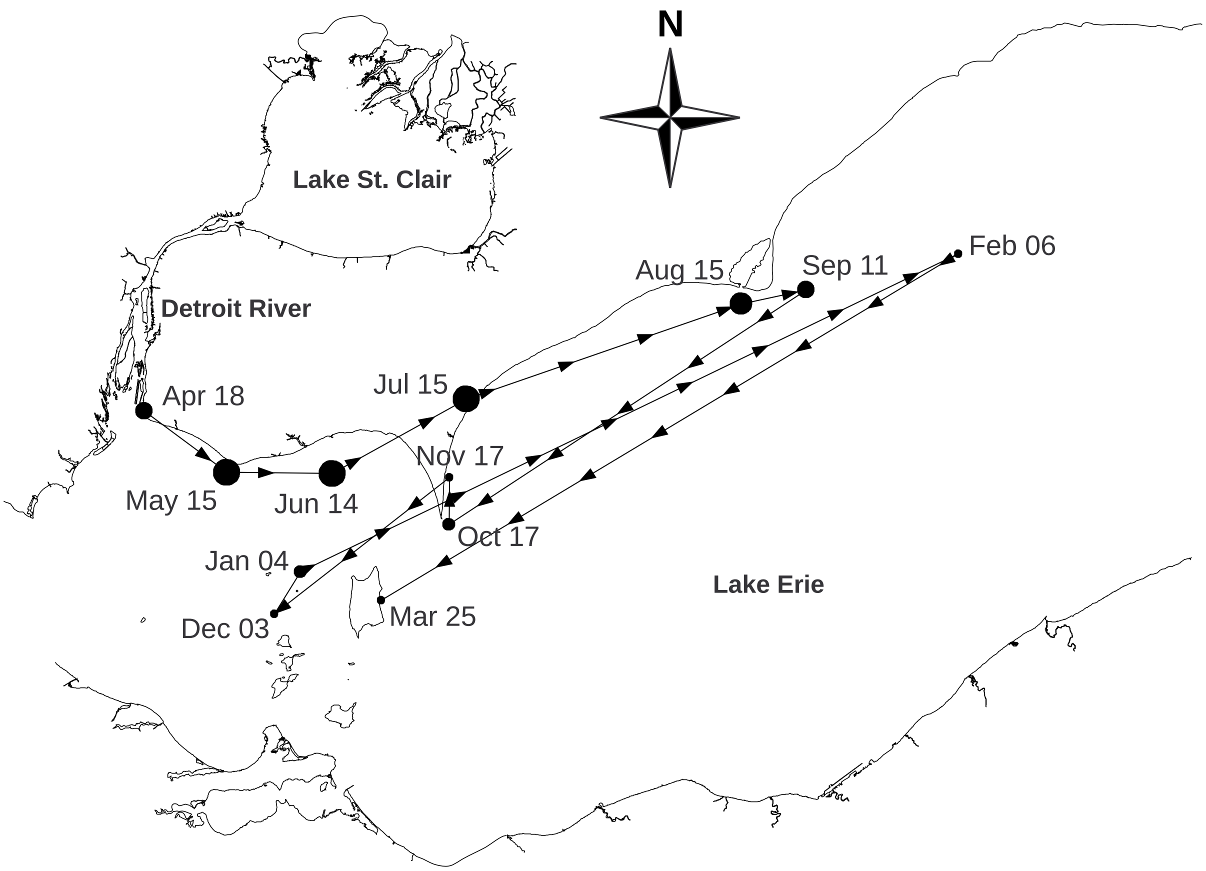

Figure 6.–Two-dimensional map of portions of Lake Erie, Lake St. Clair, and the Detroit rivers showing the monthly position of the centroid of the Monroe recoveries. Tagged walleye were caught and voluntarily reported by sport and commercial fishermen during 1994-98. All walleye were tagged during spring.

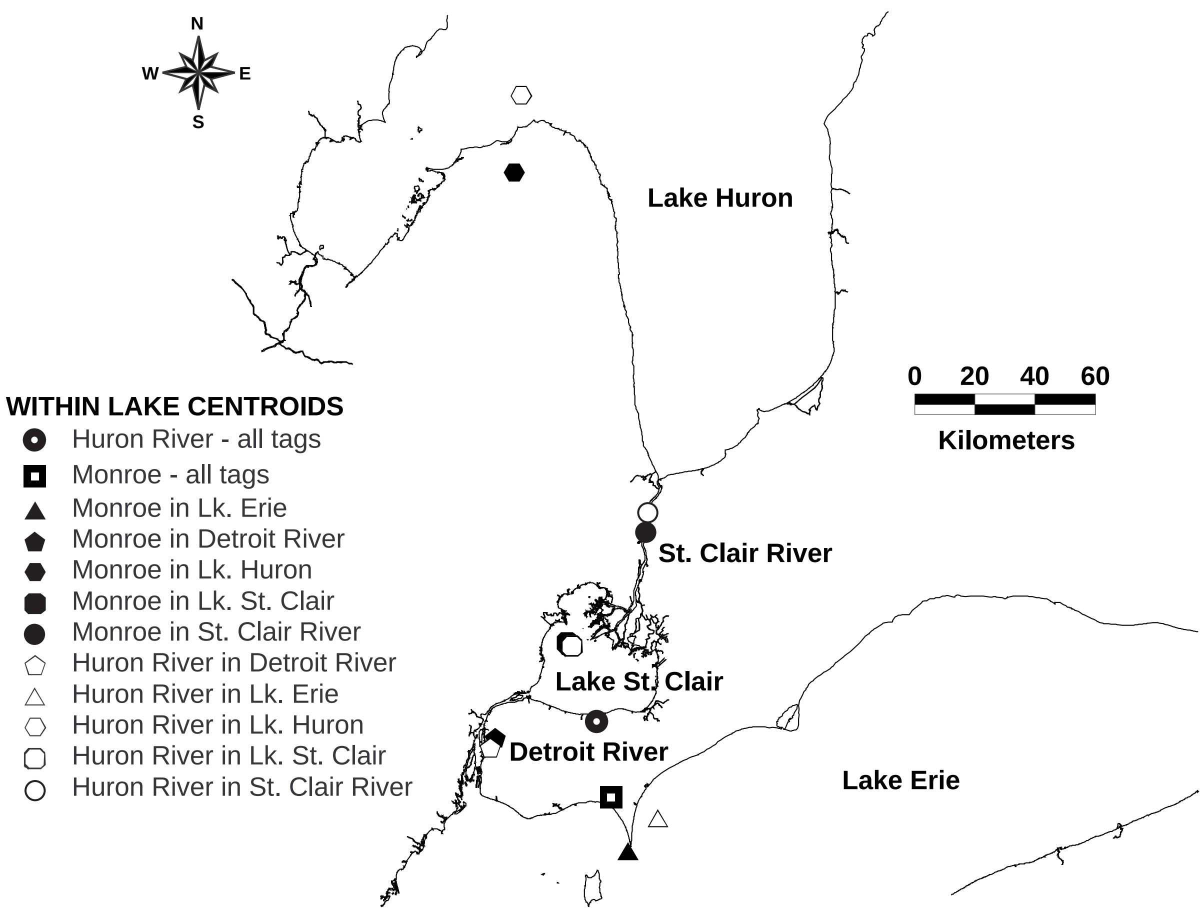

Figure 7.–Map of Lake Erie, Lake St. Clair, and the Detroit and St. Clair rivers showing within lake centroids of tag recoveries from the Huron River and Monroe (Raisin River) walleye tag sites. The Huron River site is the farther north location and the Monroe site is also the spring trap-net location.

Table 1.–Yellow perch catch-per-unit effort (CPUE; expressed as number caught per net in 24 hours) by age for trap-net surveys in Michigan waters of Lake Erie, 1989-98.

		Age							Total
Year	Days	2	3	4	5	6	7	8+	CPUE
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
1994	95.0	0.20	1.70	4.39	2.20	1.29	0.52	0.65	10.95
1995[1]	88.9	0.01	0.09	1.39	1.60	0.84	0.15	0.09	4.16
1996	100.7	0.20	2.42	2.87	4.38	2.82	2.24	0.67	15.60
1997	93.0	0.00	4.87	6.11	2.82	2.67	1.66	0.68	18.82
1998	88.0	0.42	6.30	4.70	2.39	1.68	0.65	0.38	16.51

[1]Sampling period delayed by two weeks.

Table 2.–Mean length (mm) and standard error (SE) of yellow perch caught in trap-nets in Michigan waters of Lake Erie during spring surveys, 1994-98. Sample size in parentheses.

	1994		1995		1996		1997		1998	
Age	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
					Males					
2	168	3.5	187	–	173	2.2	–	–	–	–
	(11)		(1)		(8)					
3	189	3.9	194	0.7	191	1.9	191	1.9	206	12.6
	(24)		(4)		(33)		(30)		(7)	
4	207	2.8	243	4.6	216	4.5	212	3.1	207	2.3
	(45)		(11)		(21)		(25)		(72)	
5	217	5.7	250	2.4	244	4.0	231	5.6	226	3.9
	(26)		(12)		(26)		(16)		(26)	
6	239	6.2	256	5.0	258	3.8	257	4.8	250	7.8
	(8)		(7)		(22)		(17)		(8)	
7	252	3.4	265	13.5	258	6.4	255	1.8	268	5.0
	(8)		(2)		(10)		(18)		(12)	
8	277	–	273	–	277	12.8	266	2.0	290	–
	(1)		(1)		(4)		(2)		(1)	
9	257	4.1	286	7.0	284	12.4	–	–	–	–
	(3)		(2)		(3)					
10	250	–	–	–	–	–	–	–	–	–
	(1)									
					Females					
3	216	3.7	251	–	223	6.7	215	3.7	199	14.4
	(25)		(1)		(8)		(14)		(5)	
4	239	3.4	278	4.2	243	3.3	238	3.0	240	3.8
	(47)		(31)		(21)		(48)		(53)	
5	248	5.6	287	3.0	282	4.2	261	5.8	254	4.9
	(19)		(39)		(33)		(23)		(38)	
6	286	5.8	288	5.6	287	4.2	295	3.7	279	5.6
	(16)		(20)		(17)		(27)		(15)	
7	297	8.0	290	4.2	302	3.5	305	6.2	308	5.8
	(3)		(3)		(23)		(10)		(9)	
8	306	8.0	–	–	351	–	317	6.3	305	10.2
	(4)				(1)		(10)		(4)	
9	308	20.0	–	–	316	30.0	–	–	320	–
	(3)				(2)				(1)	
10	–	–	–	–	344	–	–	–	–	–
					(1)					

Table 3.–Walleye catch-per-unit effort (CPUE; expressed as number caught per net in 24 hours) by age for trap-net surveys in Michigan waters of Lake Erie, 1989-98.

Survey year	24 hr. sets	Age 1	2	3	4	5	6	7	8	9	10	11+	All ages	Mean age
1989	96	0.01	1.10	9.90	2.90	1.88	0.85	3.37	0.35	0.01	0.12	0.03	20.69	4.2
1990	139	0.00	0.59	1.06	5.90	1.78	2.11	0.37	1.92	0.13	0.01	0.01	14.05	4.9
1991	86	0.00	1.87	4.90	3.91	13.37	2.52	3.60	1.19	0.89	0.00	0.00	32.35	4.9
1992	99	0.00	2.32	1.42	2.38	2.58	7.00	2.11	2.16	0.46	0.56	0.00	21.03	5.5
1993	99	0.00	0.52	5.01	0.72	1.46	1.75	3.66	1.23	0.63	0.26	0.31	15.57	5.4
1994	88	0.00	0.21	8.37	6.33	1.14	1.75	3.79	3.15	1.43	0.59	0.33	27.14	5.0
1995	89	0.00	7.33	0.01	1.52	0.56	0.18	0.57	0.76	0.29	0.17	0.00	11.53	3.3
1996	101	0.00	1.29	5.90	0.36	4.61	3.63	1.25	2.18	1.97	1.36	0.69	23.28	5.5
1997	93	0.00	0.18	6.06	4.19	0.37	2.84	1.54	1.08	0.98	0.92	0.42	18.74	4.8
1998	88	0.00	5.50	0.59	4.04	2.39	0.47	1.80	0.76	0.61	0.73	0.46	17.44	4.3
Mean	97.8	0.00	2.09	4.32	3.23	3.01	2.31	2.21	1.48	0.74	0.47	0.23	20.18	4.8

Table 4.–Mean length (mm) and standard error (SE) of walleye caught in trap-nets during spring surveys, 1994-98. Sample size in parentheses.

	1994		1995		1996		1997		1998	
Age	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
					Males					
2	353	6.7	342	2.0	346	2.5	354	6.0	337	0.9
	(6)		(57)		(75)		(13)		(301)	
3	409	0.9	420	1.5	410	1.0	411	0.9	408	3.5
	(621)		(2)		(500)		(513)		(49)	
4	464	1.5	450	2.6	459	5.4	456	1.4	446	1.4
	(365)		(81)		(26)		(307)		(323)	
5	494	3.1	488	3.6	482	1.4	491	5.8	478	2.1
	(80)		(35)		(408)		(30)		(198)	
6	520	2.5	518	7.4	510	1.6	508	1.8	512	5.3
	(127)		(13)		(304)		(241)		(37)	
7	536	1.8	537	5.3	534	3.0	533	2.6	521	2.3
	(291)		(40)		(113)		(127)		(147)	
8	551	2.3	560	5.1	551	2.3	558	3.4	549	4.3
	(212)		(51)		(194)		(94)		(58)	
9	569	3.9	560	5.4	568	2.8	579	3.7	575	5.6
	(85)		(18)		(165)		(86)		(46)	
10	584	6.4	5804	8.5	577	3.7	580	4.8	585	5.4
	(27)		(9)		(107)		(71)		(45)	
11	597	8.2	600		609	6.2	581	7.8	593	9.0
	(14)		(2)		(31)		(29)		(13)	
					Females					
2	349	9.8	–	–	–	–	–	–	332	–
	(6)								(1)	
3	416	3.6	–	–	453	17.5	443	3.7	518	–
	(66)				(5)		(14)		(1)	
4	511	2.2	501	6.2	517	14.0	497	3.7	488	4.8
	(172)		(17)		(8)		(41)		(29)	
5	537	7.8	509	25.3	539	4.6	511	20.4	532	12.3
	(19)		(4)		(37)		(3)		(7)	
6	578	7.4	–	–	572	4.8	517	11.0	588	16.2
	(24)				(55)		(16)		(4)	
7	613	7.1	–	–	593	12.7	586	11.6	605	10.1
	(34)				(12)		(13)		(11)	
8	611	6.8	636	21.1	637	10.4	614	9.0	636	11.7
	(56)		(7)		(22)		(2)		(9)	
9	646	7.5	663	30.0	652	9.6	645	25.9	648	7.8
	(35)		(3)		(29)		(3)		(8)	
10	672	9.3	682	13.4	662	6.5	667	16.6	677	8.2
	(24)		(3)		(29)		(12)		(18)	
11	644	21.6	690	–	685	8.3	687	17.3	688	17.3
	(6)		(1)		(15)		(7)		(6)	
12	683	14.1	685	–	720	15.4	709	25.9	726	10.4
	(8)		(1)		(9)		(3)		(8)	

Table 5.–Walleye catch in multi-filament gill-net gangs (expressed as number caught per net lift) during fall surveys in Michigan waters of Lake Erie, 1981-98.

Year class	Total CPUE	Survey year 1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1972	1.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1973	1.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1974	13.6	1.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1975	42.8	2.0	0.5	0.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1976	18.4	1.0	1.5	0.3	0.0	0.5	–	–	–	–	–	–	–	–	–	–	–	–	–
1977	171.0	9.0	5.0	2.5	3.0	0.5	0.3	–	–	–	–	–	–	–	–	–	–	–	–
1978	61.6	6.0	5.5	2.5	1.8	0.5	1.3	–	–	–	–	–	–	–	–	–	–	–	–
1979	72.4	13.5	5.0	4.3	2.3	2.0	0.5	0.5	0.3	–	–	–	–	–	–	–	–	–	–
1980	92.7	43.0	21.5	14.5	5.0	5.3	2.3	0.5	0.3	0.0	0.3	–	–	–	–	–	–	–	–
1981	72.3	–	33.5	21.3	7.8	3.8	2.8	2.3	0.5	0.3	0.0	–	–	–	–	–	–	–	–
1982	306.2	–	–	29.0	91.8	95.8	44.3	28.5	5.3	7.5	3.5	0.5	–	–	–	–	–	–	–
1983	34.6	–	–	–	4.5	12.0	4.0	5.0	3.5	1.8	1.8	2.0	–	–	–	–	–	–	–
1984	147.7	–	–	–	–	69.8	34.3	20.5	3.5	8.0	8.3	2.0	0.5	0.3	0.5	–	–	–	–
1985	177.2	–	–	–	–	–	98.0	42.5	9.3	14.3	8.5	1.5	1.3	0.8	1.0	–	–	–	–
1986	297.5	–	–	–	–	–	–	96.8	30.3	90.3	43.5	19.5	11.0	3.8	2.0	0.3	–	–	–
1987	127.5	–	–	–	–	–	–	–	4.5	53.8	26.8	20.0	13.8	2.5	3.8	1.0	0.5	0.8	–
1988	125.0	–	–	–	–	–	–	–	–	61.5	35.8	9.3	7.3	4.5	4.5	0.5	0.8	0.8	–
1989	52.3	–	–	–	–	–	–	–	–	–	16.0	17.0	10.0	2.8	3.3	1.3	0.8	0.8	0.3
1990	136.1	–	–	–	–	–	–	–	–	–	–	54.5	48.0	13.0	16.5	1.5	1.3	1.3	0.0
1991	194.0	–	–	–	–	–	–	–	–	–	–	–	63.0	47.3	61.5	11.3	6.8	2.8	1.3
1992	15.4	–	–	–	–	–	–	–	–	–	–	–	–	2.0	7.3	2.0	0.3	1.5	2.3
1993	167.4	–	–	–	–	–	–	–	–	–	–	–	–	–	73.3	71.0	11.8	8.08	3.3
1994	125.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	63.3	43.0	14.0	4.8
1995	5.4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3.3	1.3	0.8
1996	121.8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	37.5	84.3
1997	54.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	54.3
Total		76.0	72.5	74.9	116.2	190.2	187.8	196.6	57.5	237.5	144.5	126.3	154.9	77.0	173.7	152.2	68.6	68.8	151.4
Net lifts		2	4	4	4	4	4	4	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 gill-nets (standard error in parentheses), 1994-98.

Age	Survey year 1994		1995		1996		1997		1998	
Sexes combined										
1	328	(1.0)	318	(1.1)	326	(4.0)	306	(1.3)	319	(1.0)
2	407	(4.6)	401	(1.1)	404	(1.1)	380	(17.4)	404	(0.9)
3	440	(1.4)	443	(7.2)	452	(4.0)	443	(4.1)	439	(11.4)
4	476	(3.4)	478	(3.8)	504	(48.5)	475	(5.5)	487	(5.2)
5	505	(8.4)	513	(8.2)	488	(5.2)	523	(23.3)	514	(8.9)
6	523	(5.0)	536	(17.7)	533	(16.7)	521	(13.1)	525	(8.7)
7	545	(10.8)	563	(22.1)	568	(19.7)	556	(15.5)	517	(2.7)
8	556	(6.3)	566	(20.8)	550	(30.9)	572	(14.0)	525	(–)
9	548	(14.4)	550	(11.5)	640	(61.5)	581	(44.4)	525	(–)
10	578	(50.5)	–	(–)	–	(–)	604	(50.2)	586	(–)
Mean	402	(2.5)	380	(2.0)	422	(2.5)	372	(4.9)	382	(1.8)
Males										
1	324	(1.2)	314	(1.7)	325	(2.6)	302	(1.9)	317	(2.0)
2	402	(3.6)	394	(1.2)	397	(1.4)	372	(25.0)	396	(1.0)
3	434	(1.2)	436	(5.1)	435	(2.9)	429	(3.4)	428	(6.2)
4	469	(2.8)	463	(3.4)	456	(–)	462	(4.2)	473	(4.3)
5	498	(6.7)	494	(4.4)	484	(4.0)	475	(5.6)	502	(8.1)
6	523	(5.0)	513	(12.7)	500	(7.6)	499	(9.0)	525	(8.7)
7	536	(9.7)	534	(9.8)	533	(–)	542	(8.2)	517	(2.7)
8	553	(5.5)	548	(6.0)	523	(26.0)	572	(14.0)	525	(–)
9	548	(14.4)	550	(11.5)	578	(–)	537	(2.0)	525	(–)
10	578	(50.5)	–	(–)	–	(–)	554	(2.5)	586	(–)
Mean	413	(2.9)	380	(2.5)	419	(2.9)	380	(6.4)	388	(2.5)
Females										
1	333	(1.5)	322	(1.4)	327	(7.1)	310	(1.7)	321	(1.1)
2	421	(14.7)	412	(2.0)	410	(1.6)	392	(27.0)	413	(1.4)
3	468	(3.5)	472	(26.2)	480	(6.0)	463	(7.4)	447	(19.4)
4	517	(12.1)	515	(5.8)	553	(–)	519	(8.2)	522	(7.3)
5	564	(32.0)	551	(14.9)	522	(36.6)	586	(15.1)	550	(19.1)
6	–	(–)	595	(10.0)	577	(11.6)	571	(23.1)	–	(–)
7	629	(1.5)	637	(42.0)	586	(15.0)	612	(–)	–	(–)
8	610	(–)	584	(43.5)	604	(–)	670	(–)	–	(–)
9	–	(–)	–	(–)	701	(–)	704	(–)	–	(–)
Mean	378	(4.5)	379	(3.3)	425	(4.2)	364	(7.5)	376	(2.5)

Table 7.–Mean total length (mm), standard error, and sample size for yearling walleye caught in Michigan fall gill-net surveys, 1978-98.

Survey year	Year class	Mean length	Standard error	Sample size
1978	1977	343	1.0	410
1979	1978	330	1.9	115
1980	1979	344	1.3	222
1981	1980	336	2.0	86
1982	1981	333	1.9	143
1983	1982	308	1.7	116
1984	1983	311	4.7	18
1985	1984	329	1.2	279
1986	1985	339	1.0	392
1987	1986	332	1.1	387
1988	1987	347	4.2	18
1989	1988	336	1.2	246
1990	1989	352	2.4	64
1991	1990	345	1.3	218
1992	1991	309	1.4	252
1993	1992	331	6.5	13
1994	1993	328	1.0	415
1995	1994	318	1.1	444
1996	1995	326	4.0	18
1997	1996	306	1.3	210
1998	1997	319	1.0	357

Table 8.–Mean rank of walleye year classes in Lake Erie based on measured harvest and survey catch per effort, 1974-97.

Year class	Total harvest[1]	Harvest rank	Trap CPUE	Trap rank	Gill CPUE	Gill-net rank	Mean rank
1974	2,728,109	17	0.39	23	13.6	23	21.00
1975	3,487,115	14	1.32	20	42.8	19	17.67
1976	888,028	22	0.81	21	18.4	21	21.33
1977	7,045,673	5	10.23	14	171.0	5	8.00
1978	3,596,299	13	8.91	15	61.6	16	14.67
1979	2,683,484	18	8.65	16	72.4	14	16.00
1980	5,705,365	9	21.54	6	92.7	13	9.33
1981	3,108,403	16	16.93	11	72.3	15	14.00
1982	22,011,721	1	98.64	1	306.2	1	1.00
1983	2,262,177	19	21.43	7	34.6	20	15.33
1984	7,090,702	4	28.10	3	147.7	7	4.67
1985	7,604,884	3	27.02	5	177.2	4	4.00
1986	13,942,269	2	56.57	2	297.5	2	2.00
1987	4,189,711	11	27.29	4	127.5	9	8.00
1988	4,041,153	12	15.54	12	125.0	11	11.67
1989	2,225,224	20	8.26	17	52.3	18	18.33
1990	5,666,003	10	20.14	8	136.1	8	8.67
1991	6,669,951	7	19.65	10	194.0	3	6.67
1992	1,085,236	21	1.41	19	15.4	22	20.67
1993	5,806,348	8	19.79	9	167.4	6	7.67
1994	6,713,725	6	11.37	13	125.1	10	9.67
1995	319,070	23	0.77	22	5.4	24	23.00
1996	3,452,544	15	5.50	18	121.8	12	15.00
1997	13,302	24	0.00	24	54.3	17	21.67
Mean	5,097,354		17.93		109.7		

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

Table 9.–Population statistics for yellow perch in Michigan waters of Lake Erie, 1989-98, from the CAGEAN[1] model.

Fishing year	Instantaneous fishing mortality rate	Annual survival rate	Total exploitation rate	Estimated numerical abundance	Estimated numerical catch
1989	0.2656	0.5140	0.1944	6,511,622	1,266,060
1990	0.2686	0.5124	0.1970	4,062,500	800,430
1991	0.1562	0.5734	0.1204	2,796,450	336,653
1992	0.1023	0.6052	0.0807	3,108,551	250,745
1993	0.2071	0.5449	0.1558	2,500,252	389,660
1994	0.1815	0.5591	0.1378	2,023,897	278,872
1995	0.1451	0.5798	0.1119	2,607,485	291,900
1996	0.1932	0.5526	0.1458	3,560,163	519,086
1997	0.2105	0.5431	0.1576	3,212,626	506,468
1998	0.1936	0.5523	0.1461	3,310,725	483,546

[1]Deriso et al. 1985

Table 10.–Population statistics for yellow perch in Lake Erie's Western Basin, 1989-98, from the CAGEAN[1] model.

Fishing year	Instantaneous fishing mortality rate	Annual survival rate	Total exploitation rate	Estimated numerical abundance	Estimated numerical catch
1989	0.5889	0.3720	0.3746	38,993,400	14,608,647
1990	0.5544	0.3851	0.3603	19,352,067	6,972,083
1991	0.4331	0.4347	0.2978	18,039,660	5,372,323
1992	0.3527	0.4711	0.2511	20,719,881	5,203,683
1993	0.5208	0.3982	0.3440	16,235,920	5,584,930
1994	0.2726	0.5104	0.2008	19,945,437	4,004,621
1995	0.1948	0.5517	0.1480	37,196,389	5,505,799
1996	0.2289	0.5332	0.1712	53,692,877	9,191,722
1997	0.2959	0.4986	0.2145	45,248,601	9,704,145
1998	0.1907	0.5539	0.1455	64,228,524	9,342,355

[1]Deriso et al. 1985

Table 11.–Population statistics for walleye in Michigan waters of Lake Erie, 1989-98, from the CAGEAN[1] model.

Fishing year	Instantaneous fishing mortality rate	Annual survival rate	Total exploitation rate	Estimated numerical abundance	Estimated numerical catch
1989	0.5406	0.4913	0.3876	3,060,327	1,186,204
1990	0.5183	0.5024	0.3754	1,747,340	655,911
1991	0.1601	0.7189	0.1364	981,502	133,885
1992	0.2960	0.6275	0.2369	1,037,684	245,846
1993	0.3041	0.6224	0.2425	1,045,682	253,602
1994	0.3412	0.5998	0.2674	707,385	189,158
1995	0.1157	0.7515	0.1007	819,532	82,535
1996	0.1755	0.7079	0.1485	1,023,804	152,028
1997	0.1649	0.7154	0.1402	781,113	109,519
1998	0.0851	0.7748	0.0752	1,570,371	118,024

[1]Deriso et al. 1985

Table 12.–Population statistics for walleye in all waters of Lake Erie, 1989-98, from the CAGEAN[1] model.

Fishing year	Instantaneous fishing mortality rate	Annual survival rate	Total exploitation rate	Estimated numerical abundance	Estimated numerical catch
1989	0.1127	0.6958	0.0945	86,637,600	8,188,592
1990	0.0842	0.7159	0.0716	74,178,675	5,309,965
1991	0.0739	0.7233	0.0632	60,253,120	3,805,560
1992	0.0877	0.7134	0.0744	61,603,334	4,583,232
1993	0.1176	0.6924	0.0984	66,588,731	6,553,184
1994	0.1076	0.6994	0.0904	50,360,529	4,554,805
1995	0.0969	0.7069	0.0819	58,331,431	4,774,978
1996	0.1109	0.6971	0.0931	72,752,325	6,773,108
1997	0.1040	0.7019	0.0876	52,622,783	4,608,611
1998	0.1075	0.6994	0.0904	78,793,805	7,125,177

[1]Deriso et al. 1985

Table 13.–Geographical distribution of tag recoveries for walleye tagged at Monroe, Michigan, Lake Erie (expressed as a percentage of the total number recovered each year), 1989-98.

	Recovery Year						
Geographical Area	1989-93	1994	1995	1996	1997	1998	1994-98
Lake Huron – Saginaw Bay	0.6	2.7	0.7	1.5	0.0	2.4	1.5
St. Clair River	5.2	6.5	7.7	2.6	4.1	7.9	5.5
Lake St. Clair	4.6	2.7	2.1	3.6	5.2	7.1	4.0
Detroit River	12.3	8.7	11.3	11.3	12.4	6.3	10.2
Lake Erie-Total	77.3	78.8	76.1	78.5	75.2	73.2	77.0
Western Basin	60.6	53.8	45.1	52.3	53.9	56.7	52.4
Central Basin	14.4	20.7	26.8	23.6	19.2	16.5	21.4
Eastern Basin	2.3	4.3	4.2	2.6	2.1	3.1	3.2

Table 14.–Tag recovery rate and annual survival estimates (percent) produced by program "ESTIMATE"[1] for walleye tagged at Monroe, Michigan, Lake Erie, 1986-98.

	Tag Recovery rate		Walleye Survival rate	
Fishing year	Estimate	Standard error	Estimate	Standard error
1986	3.18	0.32	61.13	5.65
1987	3.31	0.33	110.40	10.00
1988	3.15	0.23	45.42	4.41
1989	3.25	0.30	32.93	3.05
1990	5.76	0.45	114.84	8.89
1991	4.12	0.30	55.89	4.60
1992	5.00	0.37	72.64	6.97
1993	5.47	0.45	69.71	7.68
1994	3.05	0.29	114.82	19.52
1995	1.75	0.29	37.00	6.37
1996	3.68	0.33	112.52	14.75
1997	2.05	0.21	62.52	15.28
1998	1.71	0.36	—[2]	—[2]
Mean	3.65	0.10	74.15	1.96

[1]Brownie et al. 1985

[2]Survival rate for last year is not estimable.

Table 15.–Recovery rates for reward and non-reward walleye tags from four tag sites in Lake Erie, 1990-98.

		Returns								Reporting rate									
Tag Site	Tagged	1990	1991	1992	1993	1995	1996	1997	1998	1990	1991	1992	1993	1994	1995	1996	1997	1998	Total
Chicken/Hen Islands[1]																			
Reward	400	37	18	18	11	5	3	2	0	9.25	4.50	4.50	2.75	1.75	1.25	0.75	0.50	0.00	25.25
Non-reward	1,972	65	32	23	25	6	6	1	1	3.30	1.62	1.17	1.27	0.51	0.30	0.30	0.05	0.05	8.57
Non-reporting rate	–	–	–	–	–	–	–	–	–	2.81	2.77	3.86	2.17	3.45	4.11	2.47	9.86	0.00	2.95
Sandusky Bay[2]																			
Reward	149	5	2	3	1	0	0	1	0	3.36	1.34	2.01	0.67	1.34	0.00	0.00	0.67	0.00	9.40
Non-reward	1,344	31	15	12	13	4	3	1	0	2.31	1.12	0.89	0.97	0.45	0.30	0.22	0.07	0.00	6.32
Non-reporting rate	–	–	–	–	–	–	–	–	–	1.45	1.20	2.26	0.69	3.01	0.00	0.00	9.02	0.00	1.49
Sugar Rock[2]																			
Reward	178	19	10	6	9	1	2	1	2	10.67	5.62	3.37	5.06	0.56	0.56	1.12	0.56	1.12	28.65
Non-reward	1,333	40	36	17	19	8	4	5	4	3.00	2.70	1.28	1.43	1.05	0.60	0.30	0.38	0.30	11.03
Non-reporting rate	–	–	–	–	–	–	–	–	–	3.56	2.08	2.64	3.55	0.53	0.94	3.74	1.50	3.74	2.60
Monroe[3]																			
Reward	218	26	13	10	16	2	4	0	2	11.93	5.96	4.59	7.34	2.75	0.92	1.83	0.00	0.92	36.24
Non-reward	1,675	71	46	28	32	9	7	2	1	4.24	2.75	1.67	1.91	0.60	0.54	0.42	0.12	0.06	12.30
Non-reporting rate	–	–	–	–	–	–	–	–	–	2.81	2.17	2.74	3.84	4.61	1.71	4.39	0.00	15.37	2.95
All tag sites																			
Reward	945	87	43	37	37	8	9	4	4	9.21	4.55	3.92	3.92	1.69	0.85	0.95	0.42	0.42	25.93
Non-reward	6,324	207	129	80	89	27	20	9	6	3.27	2.04	1.27	1.41	0.63	0.43	0.32	0.14	0.09	9.60
Non-reporting rate	–	–	–	–	–	–	–	–	–	2.81	2.23	3.10	2.78	2.68	1.98	3.01	2.97	4.46	2.70

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

Table 16.–Statistical comparison (*z*-statistic) between annual tag recovery rates for walleye tagged at the Monroe site during 1994-98.

Fishing year	Recovery rate	Standard error	*z*-statistic Comparing 1994	Comparing 1995	Comparing 1996	Comparing 1997
1994	3.05	0.29				
1995	1.75	0.29	3.17[1]			
1996	3.68	0.33	1.43	4.39[1]		
1997	2.05	0.21	2.79[1]	0.84	4.17[1]	
1998	1.71	0.36	2.90[1]	0.09	4.03[1]	0.82

[1]Significantly different at the 95% level.

Literature Cited

Bannerot, S. P., and C. B. Austin. 1983. Using frequency distributions of catch-per-unit effort to measure stock abundance. Transactions of the American Fisheries Society 112:608-617.

Brownie, C., D. R. Anderson, K. P. Burnham, and D. S. Robson. 1985. Statistical inference from band recovery data—A handbook (2nd edition). U. S. Department of the Interior, Fish and Wildlife Service, Resource Publication 156, Washington D. C.

Bryant, W. C. 1984. Status of the walleye in Michigan waters of Lake Erie and connecting waters, 1980-1983. Michigan Department of Natural Resources, Fisheries Research Report 1918, Ann Arbor.

CAGEAN-PC User Manual. 1987. International Pacific Halibut Commission, Seattle, Washington.

Chadwick, H. K. 1968. Mortality rates in the California striped bass population. California Fish and Game 54:228-246.

Craig, J. F. 1980. Sampling with traps. Pages 55-70 *in* T. Backiel and R. L. Welcomme, editors. Guidelines for sampling fish in inland waters. Food and Agriculture Organization, Report 33, Rome, Italy.

Deriso, R. B., T. J. Quinn II, and P. R. Neal. 1985. Catch-age analysis with auxiliary information. Canadian Journal of Fisheries and Aquatic Sciences 42:815-824.

Green, A. W., G. C. Matlock, and J. E. Weaver. 1983. A method for directly estimating the tag-reporting rate of anglers. Transactions of the American Fisheries Society 112:412-415.

Haas, R. C., M. C. Fabrizio, and T. N. Todd. 1988. Identification, movement, growth, mortality, and exploitation of walleye stocks in Lake St. Clair and the western basin of Lake Erie. Michigan Department of Natural Resources, Fisheries Research Report 1954, Ann Arbor.

Hayward, R. S., and F. J. Margraf. 1987. Eutrophication effects on prey size and food available to yellow perch in Lake Erie. Transactions of the American Fisheries Society 116:210-223.

Henny, C. J., and K. P. Burnham. 1976. A reward band study of mallards to estimate band reporting rates. Journal of Wildlife Management 40:1-14.

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

Horsted, S. A. 1963. On non-reported recaptures from Danish tagging experiments on cod, Subarea 1. Pages 22-25 *in* North Atlantic
Fish Marking Symposium. International Commission for the Northwest Atlantic Fisheries, Special Publication 4. ICNAF Headquarters, Dartmouth, Nova Scotia, Canada.

Keckler, Doug. 1995. Surfer for Windows version 6: contouring and 3D surface mapping - user's guide. Golden Sofware, Inc., Golden, Colorado

Krementz, D. G., M. J. Conroy, J. E. Hines, and H. F. Percival. 1987. Sources of variation in survival and recovery rates of American black ducks. Journal of Wildlife Management 51:689-700.

Leach, J. H. 1993. Impacts of the zebra mussel (Dreissena polymorpha) on water quality and fish spawning reefs in western Lake Erie. Pages 381-397 *in* T. F. Nalepa and D. W. Schloesser, editors. Zebra mussels: Biology, impacts, and control. CRC Press, Boca Raton, Florida.

Lucchesi, D. O. 1988. A biological analysis of the yellow perch population in the Les Cheneaux Islands, Lake Huron. Michigan Department of Natural Resources, Fisheries Research Report 1958, Ann Arbor.

Mardia, K. V. 1967. A nonparametric test for the bivariate two-sample location problem. Journal of the Royal Statistical Society, Series B 29:320-342.

Rackoczy, G. P. 1992. Sportfishing catch and effort from the Michigan waters of lakes Michigan, Huron, Erie, and Superior, April 1, 1990 - March 31, 1991. Michigan Department of Natural Resources, Fisheries Technical Report 91-10a, Ann Arbor.

Rackoczy, G. P., and R. D. Rogers. 1987. Sportfishing catch and effort from the Michigan waters of lakes Michigan, Huron, and Erie, and their important tributary streams, April 1, 1986 - March 31, 1987. Michigan Department of Natural Resources, Fisheries Technical Report 87-6a, Ann Arbor.

Rackoczy, G. P., and R. D. Rogers. 1988. Sportfishing catch and effort from the Michigan waters of lakes Michigan, Huron, Superior, and Erie, and their important tributary streams, April 1, 1987 - March 31, 1988. Michigan Department of Natural Resources, Fisheries Technical Report 88-9a, Ann Arbor.

Rackoczy, G. P., and R. D. Rogers. 1990. Sportfishing catch and effort from the Michigan waters of lakes Michigan, Huron, Erie, and Superior and their important tributary streams, April 1, 1988 - March 31, 1989. Michigan Department of Natural Resources, Fisheries Technical Report 90-2a, Ann Arbor.

Rackoczy, G. P., and R. D. Rogers. 1991. Sportfishing catch and effort from the Michigan waters of lakes Michigan, Huron, Erie, and Superior, and their important tributary streams, April 1, 1989 - March 31, 1990. Michigan Department of Natural Resources, Fisheries Technical Report 91-10a, Ann Arbor.

Rawstron, R. R. 1971. Nonreporting of tagged white catfish, largemouth bass, and bluegills by anglers at Folsom Lake, California. California Fish and Game 57:246-252.

Reeves, H. M. 1979. Estimates of reporting rates for mourning dove bands. Journal of Wildlife Management 43:36-41.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Resources Board of Canada 191: 382 p.

Rybicki, R. W. 1985. Feasibility of trap nets for harvesting, and observations on distribution, growth, and survival of yellow perch in southern Lake Michigan, 1978-79. Michigan Department of Natural Resources, Fisheries Research Report 1930, Ann Arbor.

Schneeberger, P. J., and S. J. Scott. 1997. Population dynamics and fishery statistics for yellow perch in Lex Cheneaux Islands area. Pages 26-41 *in* J. S. Diana, G. Y. Belyea, and R. D. Clark, editors. History, status, and trends in populations of yellow perch and double-crested cormorants in Les Cheneaux Islands, Michigan. Michigan Department of Natural Resources, Fisheries Special Report 17, Ann Arbor.

Schneeberger, P. J. 2000. Population dynamics of contemporary yellow perch and walleye stocks in Michigan waters of Green Bay, Lake Michigan, 1988-96. Michigan Department of Natural Resources, Fisheries Research Report 2055, Ann Arbor.

Thomas, M. V., and R. C. Haas. 1994. Status of yellow perch and walleye in Michigan waters of Lake Erie, 1989-93. Michigan Department of Natural Resources, Fisheries Research Report 2011, Ann Arbor.

Willis, D. W. 1987. Use of gill-net data to provide a recruitment index for walleyes. North American Journal of Fisheries Management 7:591-592.

Yeh, C. F. 1977. Relative selectivity of fishing gear used in a large reservoir in Texas. Transactions of the American Fisheries Society 106:309-313.

Appendix 1.–Fish species collected from Lake Erie with survey trap-nets and gill-nets since 1978.

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

Appendix 2.–Mean catch per trap-net lift for all species taken during spring trap-net surveys in Michigan waters of Lake Erie, 1978-98.

	Survey year											
Species	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
% 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
% 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
Net lifts	50	46	48	36	37	53	57	51	49	55	51	55

Appendix 2.–Continued.

Species	Survey year									78-89	90-98	Overall
	1990	1991	1992	1993	1994	1995[1]	1996	1997	1998	Mean	Mean	Mean
Walleye	23.8	95.9	37.7	39.2	53.0	26.2	52.0	30.2	34.8	42.3	43.6	42.9
Smallmouth bass	0.1	0.2	0.1	0.2	0.8	2.2	2.1	1.2	1.9	0.1	1.0	0.5
Yellow perch	41.7	94.6	35.0	50.2	23.2	10.3	36.6	30.7	33.3	254.6	39.3	162.3
Rock bass	0.3	0.8	0.5	1.2	1.0	4.1	1.1	0.9	1.0	1.2	1.2	1.2
White bass	0.9	1.6	0.5	0.1	1.1	2.1	0.6	2.6	1.3	3.9	1.2	2.7
White perch	40.5	56.8	5.1	0.0	14.7	72.8	5.9	10.2	8.7	40.0	23.9	33.1
Pumpkinseed	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0
Bluegill	0.0	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Black crappie	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.1
Channel catfish	9.0	6.0	4.6	4.6	5.4	3.7	8.8	4.4	11.4	5.5	6.4	5.9
Brown bullhead	13.1	4.3	4.0	1.6	1.1	0.2	1.1	0.4	0.0	2.7	2.9	2.8
White sucker	4.3	13.5	14.6	9.0	5.8	7.4	14.0	4.7	15.0	10.1	9.8	10.0
Redhorse sp.	0.4	0.6	3.1	3.6	1.8	1.0	5.5	1.9	3.3	1.3	2.4	1.8
Freshwater drum	5.1	25.6	8.9	20.7	8.8	13.0	15.4	6.8	28.3	25.8	14.7	21.1
Common carp	2.3	2.3	1.3	1.4	3.7	2.9	8.2	0.6	3.1	6.7	2.9	5.1
Goldfish	0.1	0.1	0.1	0.0	4.4	0.1	0.5	0.1	0.0	1.0	0.6	0.8
Gizzard shad	2.3	0.0	0.6	0.3	0.3	1.7	0.3	0.0	0.0	9.9	0.6	5.9
Longnose gar	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	0.0
Quillback	1.9	2.9	4.4	3.2	4.6	6.7	8.9	2.2	7.9	3.7	4.7	4.1
Stonecat	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	145.8	305.5	120.5	135.2	129.6	155.2	161.2	96.9	150.0	409.0	155.3	300.3
% yellow perch	28.6	31.0	29.0	37.1	17.9	6.2	22.7	31.7	22.2	55.2	25.1	42.3
% white perch	27.8	18.6	4.2	0.0	11.3	46.9	3.6	10.5	5.8	11.1	14.3	12.5
Net lifts	82	29	55	40	45	39	45	57	44	49	49	49

[1]Sampling period delayed by two weeks.

Appendix 3.–Sport fishing catch-at-age and targeted effort[1] for yellow perch in Michigan waters of Lake Erie, 1988-98.

Year	Harvest by age (numbers)						Total harvest (numbers)	Targeted effort (angler hours)	Total CPUE (#fish/ang.hr.)
	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6+			
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
1994	11,461	103,546	41,186	61,830	20,097	8,208	246,327	224,699	1.10
1995	14,351	225,789	59,554	17,621	21,007	4,918	343,240	123,616	2.77
1996	7,455	301,487	283,797	28,223	7,872	6,398	635,233	193,733	3.27
1997	0	92,269	277,609	134,728	21,001	3,828	529,435	192,605	2.74
1998	761	183,936	234,283	142,877	22,087	2,334	586,277	183,882	3.18

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

Appendix 4.–Sport fishing catch-at-age and targeted effort[1] for walleye in Michigan waters of Lake Erie, 1988-98.

Year	Harvest by age (numbers)						Total harvest	Targeted effort	Total CPUE
	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7+	(numbers)	(angler hours)	(#fish/ang.hr.)
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
1994	7,407	122,114	36,707	3,768	8,526	37,516	216,040	787,896	0.274
1995	48,800	5,848	34,317	7,904	1,609	9,431	107,909	276,852	0.390
1996	39,302	93,468	5,364	20,669	5,851	9,953	174,607	521,011	0.335
1997	1,494	56,365	43,466	4,546	7,291	9,238	122,400	374,437	0.327
1998	52,561	20,113	30,045	5,846	2,350	3,691	114,607	374,218	0.306

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

Appendix 5.–Tag recovery data (non-reward) for walleye tagged at the Monroe site, Lake Erie, 1986-98.

Year tagged	Number tagged	Year recovered												
		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1986	2,959	94	56	53	31	20	27	5	9	4	2	2	2	0
1987	1,842	–	65	72	24	13	12	12	7	3	6	0	0	0
1988	3,918	–	–	126	58	30	25	25	13	6	2	3	5	1
1989	1,866	–	–	–	66	33	33	18	10	9	4	1	4	0
1990	1,675	–	–	–	–	105	78	50	44	16	10	11	3	2
1991	2,730	–	–	–	–	–	103	85	57	21	16	15	13	5
1992	2,010	–	–	–	–	–	–	95	85	34	12	23	12	5
1993	1,526	–	–	–	–	–	–	–	90	28	22	18	9	5
1994	2,006	–	–	–	–	–	–	–	–	63	46	32	15	10
1995	965	–	–	–	–	–	–	–	–	–	21	12	7	3
1996	2,269	–	–	–	–	–	–	–	–	–	–	77	57	31
1997	3,448	–	–	–	–	–	–	–	–	–	–	–	66	43
1998	1,290	–	–	–	–	–	–	–	–	–	–	–	–	22

Appendix 6.–Michigan total allowable catch and estimated harvest of Lake Erie walleye, 1976-98 (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
1994	400,000	216,038
1995	477,000	107,909
1996	583,000	174,607
1997	514,000	122,400
1998	546,000	114,606