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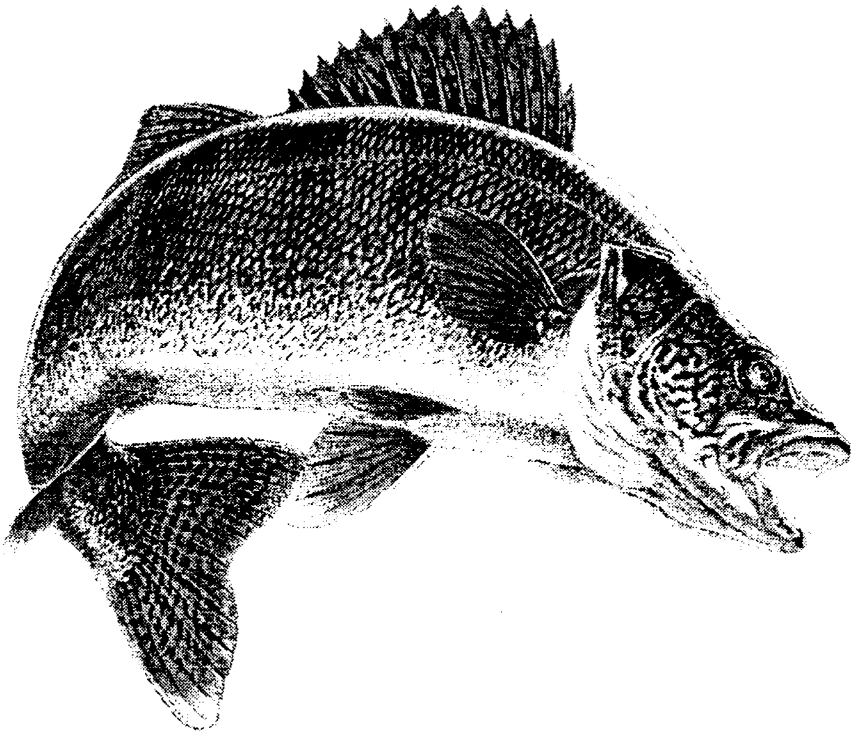

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Predator-prey and Competitive Interactions Among Walleye, Yellow Perch, and Other Forage Fishes in Saginaw Bay, Lake Huron

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Abstract.—We investigated predator-prey interactions among walleye *Stizostedion vitreum*, yellow perch *Perca flavescens*, and other forage fishes in Saginaw Bay, Lake Huron during May-October 1986-1988. We wanted to determine the extent of interactions between walleye and yellow perch and their impact on the forage fish community. Walleye primarily consumed cyprinids, young-of-the-year clupeids, and rainbow smelt *Osmerus mordax*, but age-2 and age-3 walleye relied on yellow perch during the summer of 1988 after a cold spring delayed clupeid recruitment. Although walleye diets varied among years, prey appeared to be abundant, and walleye growth was fast during each year of the study. Yellow perch consumed large numbers of chironomid larvae and zooplankton. Piscivory by yellow perch was rare, and represented opportunistic predation on benthic species such as trout-perch *Percopsis omiscomaycus*. Results of energetics modeling suggest that yellow perch subsist near a maintenance ration for much of the growing season and experience slow growth, energy depletion, and high natural mortality. The underlying reason appears to be a lack of large benthic invertebrates, which may be a result of eutrophic conditions in the inner Bay. Other forage fish populations were abundant and stable during the 3 years of the study. Predation on the forage fish community was low because walleye were rare. Most yellow perch died before attaining a size that would facilitate piscivory.

Saginaw Bay, Lake Huron presently supports an extensive sport fishery for walleye and a combined sport and commercial fishery for yellow perch (see Table 1 for a list of common and scientific names of fishes collected during this study). Since 1980, the populations of these two species have increased in response to stocking programs (walleye) and protection from overharvest (both species) (Keller et al. 1987). The management goal for Saginaw Bay was to produce large populations of both species with fast individual growth rates. While walleye growth was fast, growth of yellow perch was apparently slow. A shortage of large yellow perch caused dissatisfaction among user groups. The simultaneous resurgence of both species in recent times created a potential management problem in that increased predator density could tax the forage base. Additionally, competitive interactions between walleye and yellow perch could constrain growth rates and ultimate population size of either species. Alternatively, walleye predation on yellow perch could improve growth rates by reducing intraspecific interactions. However, the extent of interactions between walleye and yellow perch was unknown.

The lack of knowledge about the roles of these major predators in Saginaw Bay was exacerbated by large scale changes in the Saginaw Bay ecosystem. Overfishing, habitat loss, eutrophication, and species introductions had caused species abundance shifts, and an apparent shift by yellow perch from a predominantly benthic to predominantly pelagic food resource. Consequently, there was a strong possibility that the traditional roles of walleye and yellow perch in the ecosystem had been altered through these processes. In 1986, the Michigan Department of Natural Resources (MDNR), The University of Michigan (UM), and Michigan Sea Grant (MSG) initiated a 3-year study of predator-prey interactions between walleye, yellow perch, and other forage fishes in Saginaw Bay to define the roles of these species in the ecosystem and to develop management strategies that were ecologically consistent with processes occurring in this altered system.

The fish community of Saginaw Bay, Lake Huron, is the result of over 150 years of human disturbance. Overexploitation, habitat loss, cultural eutrophication, and invasion of exotic species have permanently altered the original aquatic community. Despite these changes, the Bay remains a valuable aquatic resource. Although Saginaw Bay represents less then 5% of the total surface area of Lake Huron, it may support as much as half the fishing effort directed at this system (Ryckman 1986).

Commercial fisheries were established in the Bay by the 1830s (Lanman 1839), and effort was focused on lake herring, walleye, yellow perch, and to a lesser extent lake trout, lake whitefish, and lake sturgeon. Individual yields of lake herring, walleye, and yellow perch usually exceeded 450,000 kg each year, making the walleye and yellow perch fisheries among the largest in the Great Lakes (Schneider 1977).

With the exception of lake sturgeon, which were extirpated by 1900, commercial yields from Saginaw Bay remained relatively stable until the 1930s, but yields of all species declined rapidly during the 1930-1945 period as the aquatic environment became degraded. Commercial production of walleye and yellow perch declined dramatically during this period (Figure 1). Rapid human population growth within the watershed caused habitat loss as wetlands were drained and tributary streams were dammed or channelized. Increases in industrial, domestic, and agricultural wastes caused the inner Bay to become highly eutrophic, and water quality became poor. During this period the invading sea lamprey, alewife, and rainbow smelt became established. Overexploitation of some existing fish stocks probably occurred during this time.

During the 1945-1955 period, stocks of walleye, lake trout, lake herring, and lake whitefish collapsed entirely through the effects of increasingly severe perturbations, and the loss of native piscivores allowed alewives and rainbow smelt to proliferate (Schneider and Leach 1977). Extensive changes were also observed in the benthic fauna. Before 1950, one of the predominant benthic invertebrates was the nymphal stage of the mayfly *Hexagenia limbata* (Insecta: ephemeroptera), but by 1955 they were extirpated and replaced by chironomids and oligochaetes (Schneider et al. 1969; Reynoldson et al. 1989), presumably due to anoxic conditions during the summer (Britt 1955). *Hexagenia* populations never recovered, and pollution tolerant organisms have comprised most of the benthic fauna since that time. By about 1960, Saginaw Bay had become nearly devoid of piscivorous predators, and this condition persisted through the mid-1970s. During these years, the inner Bay became highly eutrophic and nuisance blooms of blue-green algae became commonplace. Commercial fisheries were left without most traditional high value species, and fishermen redirected effort to yellow perch, rainbow smelt, white suckers, channel catfish, and common carp. Eshenroder (1977) suggested that yellow perch stocks, the last remaining species of value, became overexploited by the late 1960s.

Rehabilitation of the aquatic community of Saginaw Bay began during the late 1960s. Commercial harvests of most species declined because of more restrictive regulations. Improvements in water quality were observed following implementation of the Clean Water Act in 1972, and remaining wetlands received protection. Additionally, predator stocking has been used to offset the loss of native predators. Non-native salmonids have been stocked in the outer Bay area since about 1970. Salmonids inhabit the outer Bay throughout much of the year, but are excluded from the inner Bay during summer due to high temperatures. In the inner Bay, predator stocking has focused on the rehabilitation of walleye.

In 1970, the commercial fishery for walleye was closed, and in 1972 walleye fry were first stocked in the inner Bay and its tributaries. Some fry stocking continued through 1985, but by 1981, improvements in pond rearing techniques provided a large supply of 40-60 mm fingerling walleye. At least 200,000 fingerlings have been stocked each year since 1982, and annual stocking rates approached 1 million fingerlings per year during 1984-1986 (Figure 2).

Since 1980, large numbers of spawning walleye have been observed annually in the Saginaw and Tittibawassee rivers—the two largest tributary streams of the Bay. The source for all of these fish is not known, but many originated from the stocking programs. Natural reproduction of walleye in the rivers has occurred; however, natural recruitment to the population appears low (Jude 1992). Walleye larvae appear to die before reaching the Bay, young-of-the-year (YOY) are rarely collected before the annual fingerling stocking, and the population increased only after the stocking program was initiated. Stocking may be the primary source of YOY walleye in the inner Bay.

Some walleye in Saginaw Bay originate from other areas of the Great Lakes. Adult walleye tagged in Lake Erie and Lake St. Clair have often been recovered in Saginaw Bay (MDNR, Lake St. Clair Fisheries Research Station, unpublished data). These data suggest that adult walleye are capable of long distance dispersal; presumably significant spillover could occur into Saginaw Bay from dense populations in western Lake Erie and Lake St. Clair.

The stocking program, and possibly natural reproduction and immigration, resulted in the reestablishment of a sport fishery for walleye in Saginaw Bay, where none had existed previously. By 1988, over 100,000 walleye were being harvested each year during the summer fishery, and over 30,000 walleye were creeled in the river fishery (Ryckman 1986). Ice fishing for walleye is gaining popularity, and over 8,000 fish were creeled during the winter of 1987-1988. Growth of Saginaw Bay walleye is rapid. Walleye exceed 581 mm after two growing seasons, and exceed 536 mm by age 4. Fast growth rates have resulted in an abundance of large fish. Saginaw Bay is known for its trophy walleye, and angler satisfaction appears to be high, even though catch rates are relatively low.

In Saginaw Bay, walleye and yellow perch have fluctuated widely in abundance and growth during the past 65 years (Eshenroder 1977; Schneider and Leach 1977; El-Zarka 1959; Hile 1954; Hile and Jobes 1941). In some situations these predator fishes are known to compete for prey, especially in relatively small lakes with limited forage diversity and availability (Forney 1974; Forney 1976; Forney 1977a, 1977b; Ryder and Kerr 1978). Fall trawl studies by MDNR from 1971 through 1985 showed that walleye were growing rapidly with low natural recruitment while yellow perch were growing slowly with high natural recruitment.

Since 1970, yellow perch have increased in number, and they now are the most abundant species in trawl catches. Strong natural year classes were produced in 1975, 1979, and 1982-1985 (Figure 3). However, large individuals are rare, and angler dissatisfaction is great despite high catch rates.

The nature and strength of interactions between walleye and yellow perch in Saginaw Bay were unknown but of potential importance. The extent to which walleye preyed on yellow perch was important, because the primary management goal was to maintain large, fast-growing populations of both species. If walleye consumed enough yellow perch, perch growth rates might improve through a reduction in intraspecific competition. Under this scenario, the ultimate population size of walleye could be large, because yellow perch were abundant. Alternatively, if walleye and yellow perch shared limited food resources, growth rates and ultimate population size of either species might be constrained by food availability. Under this scenario, a large walleye population might lead to further reductions in yellow perch growth, and growth rates of walleye might decline quickly as the expanding population exerted high demand on a limited forage fish base. Which of these scenarios was correct was impossible to predict due to the perturbed nature of the Saginaw Bay environment and the lack of information on walleye-yellow perch interactions.

During 1986, a 3-year survey of the Saginaw Bay fish community was initiated. The purpose of this study was to: 1) examine the growth, diet, and distribution of walleye and yellow perch; 2) examine the abundance and distribution of forage fish; 3) examine predator-prey and possible competitive interactions between walleye and yellow perch; 4) estimate daily ration and total predatory demand of the walleye and yellow perch populations; and 5) use information gained from the study to evaluate alternative management strategies for Saginaw Bay.

Study Area

Saginaw Bay is a large, shallow embayment of Lake Huron. The Bay's 2,960 km^2 represent about 5% of the total surface area of the lake, and are evenly divided into inner and outer bays by a broad, shallow constriction that extends from Sand Point to Point Lookout. The inner Bay is shallow (mean depth = 4.5 m), peripherally marshy, with warm summer temperatures. The large surface to volume ratio of the inner Bay results in frequent wind mixing of the water column, and isothermal conditions are frequent. The outer Bay stratifies during the summer, and limnological conditions resemble those of Lake Huron proper, with cooler temperatures and high levels of dissolved oxygen below the thermocline. Consequently, the aquatic habitat differs between the two regions. The inner Bay experiences warm temperatures, while the outer Bay provides a cold-water environment below the summer thermocline.

This study examined fish collected from inner Saginaw Bay at four primary locations: Wildfowl Bay, North Island, Pinconning, and Au Gres (Figure 4). Wildfowl Bay is a shallow and productive sub-bay which serves as a nursery area for many fish species. North Island is slightly deeper and less protected than Wildfowl Bay, but water quality is similar. The Pinconning Station is located at a bottom depression known locally as the "Black Hole". This station is the closest to the mouth of the Saginaw River and the substrate is comprised of organic sediments rich in pollution tolerant benthic macroinvertebrates. The Au Gres Station is located near the City of Au Gres, and conditions here more closely resemble those of the less eutrophic outer Bay.

Methods

Field Sampling

Trawl and gill-net catches from all sites were used to describe the fish community of the inner portion of Saginaw Bay during 1986-1988. Gill nets were a valuable sampling tool because they provided information on the vertical distribution of fish and also were used to validate that the trawl was catching a representative set of fish species and sizes which we needed to adequately describe the community.

All field sampling was conducted from the MDNR research vessel *Channel Cat.* We made concurrent monthly collections of walleye, yellow perch, and forage fishes during May through October, 1986-1988 using bottom trawls and gill nets at the four primary fixed stations and numerous randomly sampled stations located throughout inner Saginaw Bay. When this study was planned it was anticipated that Analysis of Variance (ANOVA) could be applied to extract the maximum amount of information from the data. However, the trawl catches should be normally distributed and their variances homogeneous for valid application of ANOVA. The trawl data was examined for normality (Lilliefors test) and homogeniety of variance (Bartlett's test). The ANOVA procedure is quite robust against violation of the normality assumption (Steel and Torrie 1960). Therefore, random and fixed trawl stations were compared spatially and temporally with the parametric ANOVA and nonparametric Kruskal-Wallis (K-W) statistical tests to determine whether they were providing similar measures of fish abundance. All statistical tests for this study were performed at a significance level of $P_\alpha = 0.05$.

Trawling gear consisted of a 10.66-m headrope otter trawl towed with single warp and a 45.7-m bridle. The standard tow was made with the trawl on the lake bottom underway for 10 minutes at approximately 3.0 knots vessel speed. Some random trawl sites were characterized by hard, rocky bottom which necessitated tows of shorter duration. A series of predetermined, timed tows were made to test whether length of trawl drag affected fish catch rate.

The trawl opening was measured during fishing operations on Lake St. Clair (MDNR, Lake St. Clair Fisheries Research Station, unpublished data). The trawl mouth extended approximately 5.5 m in width and 2.4 m in height. The distance that the trawl was towed at the average vessel speed on Saginaw Bay was 626 m and the area swept was 3,442 m^2.

We conducted an ancillary trawl study in Lake St. Clair during 1989 to estimate the efficiency of the trawl in capturing yellow perch. A series of trawl tows were made within a net enclosure which had been stocked with a known population of marked yellow perch. The catchability of our trawl for yellow perch was estimated to be 42%. Nielsen (1983) estimated that the catchability of adult yellow perch in a smaller bottom trawl in Oneida Lake ranged from 8% to 26% based on independent population estimates for perch.

The gill nets used during the survey were 518.2 m long, 1.8 m deep, and individual net gangs consisted of 15.3-m panels of 1.9-, 2.5-, 3.8-, 5.0-, and 6.3-cm, and 60.1-m panels of 7.6-, 8.9-, and 10.2-cm stretched nylon mesh. The top and bottom half of each gill net was delineated with colored thread running its full length. Gill net catches were standardized to the number caught per 304.8 m of net fished (CPUE).

Two types of gill nets were employed, a sinking and a floating variety. Floating and sinking nets were identical in all respects except that lead weights were reduced on the floating nets allowing them to hang suspended vertically with the floats at the surface.

All gill-net catches were recorded by mesh size and depth strata according to whether they were caught in the top or bottom half. Floating and sinking gill nets were fished at all gill-net sites providing 3.6 m of vertical capture data. Many of the net sites were no deeper than 4 m so the gill-net data should represent the entire vertical distribution quite well. The purpose of vertical stratification of gill-net catches was to provide data on vertical distribution of prey species in the environment allowing more thorough interpretation of predator diet and trawl catch information.

Each monthly survey was initiated with a diel sample. This consisted of serial trawls every 3 hours for 24 hours at a fixed station. During 1986, the diel station was located near Sand Point, but during 1987 and 1988 it was shifted several miles to Wildfowl Bay where sampling was less affected by bad weather and catch rates of yellow perch were higher. Serial trawl collections at the diel station were supplemented with collections from floating and sinking experimental gill nets. One floating and one sinking gill net temporally bracketed each diel trawl collection. Most gill nets were fished for 6 hours, but during 1986 some 2-hour and 24-hour gill-net collections were attempted during the initial phases of the study.

Walleye collected during diel sampling were measured (mm), weighed (g), and sexed. Scale samples were collected for aging.

Stomach contents were removed and immediately preserved in 10% buffered formalin. Forage fish were sorted by species, counted, and weighed. A total of 52 adult and 10 YOY yellow perch were sampled from each diel trawl. Fish were sampled randomly, but exceptionally large individuals were always included. These represented no more than three individuals per trawl collection. After removal from the trawl, the yellow perch were stunned on ice, immediately frozen with liquid nitrogen to stop digestion, and held in a plastic cooler until transfer to a land-based freezer unit. Fish were kept frozen until processing. Walleye and yellow perch collected with gill nets were processed in a similar manner. Forage fish and other species were counted and assigned into length groups.

Following the diel survey, sampling continued for 5 to 7 d at three fixed and eight randomly selected stations located throughout the inner Bay. Fixed stations were located near North Island, Pinconning (Black Hole), and Au Gres. Fixed stations were sampled during every monthly survey between 0700-1700 h by making three replicate trawls, and 6-h collections with floating and sinking gill nets. Walleye, yellow perch, and forage fish were processed in the manner described for diel surveys, but length frequency and length-weight data on forage fish were also collected at these sites.

Random sampling was carried out throughout the inner Bay during each monthly survey. Stations were randomly selected based on a grid system (Figure 5) and sampled with three replicate bottom trawls, and fish were processed in the manner described for the diel station. All sampling at fixed and random stations was carried out between the hours of 0700 and 1800.

Stomach contents were collected from walleye and yellow perch at all fixed trawl and gill-net stations and from four of the eight randomly selected trawl stations during each month. Benthos samples (1986-1988), and zooplankton samples (1987-1988) were collected from each of the trawl sites whenever fish stomach contents data were collected. Zooplankton were sampled with one vertical tow of a 0.5-m plankton net made of 353-μm nylon mesh and preserved in a 4% sugared formalin solution. Three replicate benthos samples were taken with a standard-sized Ponar and preserved in 10% buffered formalin.

Laboratory Methods

Stomach contents of walleye were identified to the lowest practical taxon, usually species. Partially digested prey were identified through structures resistant to digestion such as spines, scales, and vertebrae (Table 2). Total length, standard length, or backbone length were measured depending on the condition of the specimen. Where standard or backbone lengths were measured, we estimated total length using regression equations developed by Knight et al. (1984). Prey weights at capture were then back calculated using total length/wet weight relationships of forage fishes captured at the fixed stations. Length measurements could not be obtained from 2% of prey items because digestion had progressed too far. They were excluded from the data set, which should not bias the results because all prey digest at similar rates (Swenson and Smith 1973).

Walleye were aged from scales using standard methods by personnel from the MDNR, Lake St. Clair Fisheries Research Station.

Yellow perch were thawed in the laboratory, measured, and weighed. Fish were slit from anus to gills, sexed, and checked for redworm *Eustrongilides tubifex* infestation. Viscera were removed and weighed after removal of stomach contents which were weighed separately. Somatic weights (total weight of an eviscerated individual) were also recorded. Stomach contents were preserved in ethanol. Subsamples of yellow perch and their excised viscera were dried at 90 °C for 2 d in a drying oven and weighed. Stomach contents of yellow perch were evaluated by counting the number of organisms of each taxon.

Zooplankton samples collected in 1988 were analyzed to determine species density and average size using a computer-based digitizing and measuring system. These zooplankton samples were used to describe the potential zooplankton population available for grazing by yellow perch.

All benthos samples collected in 1986 were sorted to the lowest taxon possible, and counted. These benthos data were used to describe the potential population available for grazing by yellow perch. Benthos samples collected in 1987 at the fixed stations were sorted and grouped according to whether they were potential food types for yellow perch. The potential food types were sampled for size and weight data.

Energetics Modeling

Although we collected 1,433 walleye during the 3 years of the study, sample sizes were too small to directly estimate food consumption by the population. Consequently, we estimated walleye food consumption using the bioenergetics model originally proposed by Kitchell et al. (1977) and more recently adapted for micro-computers (Hewett and Johnson 1989). Required inputs are temperature (representing the thermal experience of the species), the proportional contribution of each prey type to the total wet weight of the diet, predator and prey caloric densities ($cal \bullet g^{-1}$ wet weight), and initial and final weights of the species being examined.

Temperature was recorded concurrently with each trawl and gill-net collection at a depth of 1 m. Saginaw Bay has a large surface to volume ratio, and rarely shows any vertical temperature stratification. Water temperature regimes varied little between years and months (Table 3) and between stations within a given month. The proportional contribution of each prey type to the total wet weight of the diet was estimated from the back-calculated weight at capture. Data from the literature were used for model inputs of caloric densities of predators and prey (Table 4); we assumed that caloric densities did not vary throughout the year. Data on trout-perch and other rarely consumed species were not available. In these cases, we assumed a value of 1,000 $cal \bullet g^{-1}$ (wet weight). Growth of walleye was modeled by dividing the growing season into growing periods of 1 or 2 months, and fitting a separate proportion of maximum consumption (P-value) to each interval. Growth was measured as the mean increase in wet weight during each time interval for members of a particular cohort.

Food consumption by yellow perch was estimated directly through the diel trawl surveys at Wildfowl Bay. To minimize bias associated with variable capture times, we excluded perch captured in gill nets from this analysis. For each age class where sufficient numbers of fish were collected by the trawl, median amounts of food from each diel survey were entered into the algorithm developed by Elliott and Persson (1978). The use of this model also required an estimate of the instantaneous gastric evacuation rate (R). Because no data exist regarding estimates of R for yellow perch, we used the gastric evacuation rate for *Perca fluviatilis* developed by Persson (1979).

During 1986 and early 1987, eight diel trawl surveys were performed. During late 1987 and 1988, nine trawl tows were made. In cases where only eight serial trawl tows were made, we had to approximate amounts of food in stomachs at the end of the diel survey by assuming that median amounts of food in stomachs were identical to those observed from the first tow. This assumption was not needed after June, 1987 because the endpoint was estimated directly. Data were adequate to directly estimate consumption for age-1 through age-4 perch for the years 1987 and 1988.

Food consumption estimates could not be made for yellow perch collected during 1986 due to small sample sizes, and bad weather which forced us to abandon several diel surveys.

Food consumption for yellow perch collected from the diel station at Wildfowl Bay were also estimated using an energetics model (Hewett and Johnson 1989), however, some inputs differed from those used for walleye. Growth was measured as the mean increase in wet weight during each month of the growing season for members of a particular year class (Figure 6). Temperature was recorded concurrently with each trawl collection at the diel station, and varied little between collections during a given month. To estimate the proportional contribution of each prey type to the total wet weight of the diet we converted counts of individual taxa to wet weights using median dry weights of taxa from Hayward and Margraf (1987) and percent water data from Cummins and Wuycheck (1971), Rottiers and Tucker (1982), Hewett and Johnson (1989). While conversion of prey counts to wet weights is clearly an imprecise method for estimating the weight of food in stomachs, this method appears unbiased for estimating the proportional contribution of the prey types we encountered. We used data from the literature to estimate caloric densities of individual prey items, and prey caloric densities were assumed to be constant.

Body energy density of yellow perch in Saginaw Bay varies during the growing season (Salz 1989; Diana and Salz 1990). Therefore, we believed that assuming a constant predator caloric density would be unrealistic, however we did not have seasonal estimates of caloric density. Consequently, we used the regression developed by Craig (1977) which predicts caloric density from percent water data, which were available to us. We believe this regression provided realistic estimates of seasonal trends in caloric density of Saginaw Bay yellow perch (Figure 7) for three reasons: 1) estimates of caloric density were within the range estimated by Diana and Salz (1990); 2) caloric densities increased whenever yellow perch were experiencing somatic growth; and 3) caloric densities declined during months when yellow perch experienced no growth or actual loss of weight.

Food consumption by yellow perch was modeled by dividing the growing season (May through October) into growing periods of about one or occasionally 2 months, and fitting a separate proportion of maximum consumption (P-value) to each interval.

Cumulative food consumption by walleye and yellow perch were estimated using the bioenergetics model. Maintenance rations were estimated with the bioenergetics model by simulating growth of fish for one day each month, the minimum amount possible in the model.

Total predatory demand by walleye and yellow perch on forage fish was estimated using energetics models. We restricted our analysis to the growing season of 1988 because we had adequate growth and diet information for all significant age classes of both species, and predators appeared to be more abundant than during other years. For population level modeling of walleye, we assumed a population of 1,000,000 fish, and an annual survival of 62% (Mrozinski et al. 1991). Mrozinski et al. (1991) suggested that the population of adult walleye had reached 1-2 million fish by the late 1980s. We partitioned the total population into age classes based on the proportion of individual age classes in our samples. Yellow perch population size was estimated from trawl catches adjusted for total area of the Bay and catchability of perch in the net. Population size was partitioned into individual age classes based on the proportion of individual age classes in our samples. Survival of yellow perch was estimated to be 32% from trawl catch curves.

One difficulty we encountered in performing this analysis was that we could not identify a large proportion of prey fish found in yellow perch stomachs. In many other studies on yellow perch, unidentified fish were excluded from analyses. The presumption was been that fish tended to digest at similar rates so results were not biased. However, during this study, unidentified fish comprised a significant proportion of the diet in some months, and to ignore them would have caused the bioenergetics model to overestimate the quantity of invertebrates consumed by yellow perch. Most of the unidentified fish found in perch stomachs were probably spottail shiners or rainbow smelt because these species exhibit a high degree of spatial overlap with yellow perch, are vulnerable to predation due to their small size and lack of spines, and small individuals lack distinguishing features that would render them quickly identifiable after digestion. Consequently we retained them in the analysis and assumed they had a caloric density of 1,191 $cal \bullet g^{1}$ wet weight. Kelso (1972) reported this value as the caloric density of emerald shiners, which should be reasonably similar to spottail shiners and rainbow smelt.

Density of major benthic food groups was determined by expanding mean numbers found in Ponar samples at random and fixed trawl stations in 1986. Individual weights for major benthic food items were taken from Ponar samples collected at fixed stations in 1987. Mean weight data for these benthic organisms was used to expand density information to estimate mean biomass. Production of chironomids was extrapolated from our biomass estimates using a mean P/B ratio of 14.6 determined for the most eutrophic station in Bay of Quinte by Johnson and Brinkhurst (1971).

We estimated forage fish production using Chapman's tabular method (Ricker 1971), and monthly estimates of biomass and weight of each individual age class of each species of forage fish. This produced an extremely conservative estimate of forage fish production because: 1) biomass estimates from trawl samples did not sample individuals up in the water column; 2) small individuals could pass through the trawl mesh; and 3) we only computed production for the seven most abundant species known to be consumed by walleye or yellow perch. Additionally, in some cases true growth rates were obscured by influxes of new recruits resulting from multiple spawning by some forage species. Where this occurred, and true growth could not be estimated, we assumed that no production took place until a positive growth rate was reestablished. Again, this kept our estimates extremely conservative.

Results

Fish Community

The inner Bay was characterized by a very abundant fish community dominated by small, secondary predators such as yellow perch and forage species such as rainbow smelt and spottail shiners. A total of 30 fish species were sampled with the trawl. Based on trawl catches at the fixed and random sites, yellow perch were numerically the most abundant species in the inner Bay followed by rainbow smelt, spottail shiner, trout-perch, and alewife (Table 5). These five most abundant species averaged 1,952 individuals per 10-minute trawl tow (CPUE) and each had a CPUE greater than 200.

Statistical comparisons showed that trawl catches for most fish species at fixed stations were not different ($P_\alpha < 0.05$) from random stations (Table 6). The high similarity in catch rates for most species was unexpected and suggested that the distribution of fish schools or aggregations in the inner Bay was quite uniform. The mean CPUE for all fish except yellow perch was 1,784 at fixed stations compared to 1,753 at random stations which were nearly identical (ANOVA $P = 0.91$, K-W $P = 0.69$). However, the distributions of these combined catches were examined and found to be significantly different from normal ($P = 0.00$). Their variance was also examined and found to be homogenous ($P = 0.62$).

The trawl catch of YOY yellow perch at the fixed and random stations was not different. However, the mean CPUE for yearlings and adults at fixed stations (539.21) was significantly greater than random stations (377.76) (ANOVA $P = 0.003$, K-W $P = 0.000$). Variances for these CPUE data were found to be homogeneous (Bartlett's test $P = 0.175$). Greater catches of yellow perch at fixed stations was not unexpected. They had been selected in the early 1970s, because they provided relatively high trawl catches of yellow perch.

Gill nets were not as efficient as bottom trawls at determining the presence of species in the fish community. Gill nets caught only 53% of the 30 species represented in trawl catches. Gill nets did not capture any species of fish that were not found in the trawl. Total CPUEs of fish in gill nets were very consistent across years averaging 549, 560, and 486 fish for 1986, 1987, and 1988 respectively. Yellow perch were the most abundant fish in gill nets, making up 34.0%, 33.7%, and 32.2% of the catch by number (Appendices 1-3). Because yellow perch were also the most abundant fish taken in bottom trawls, there was little question that they were truely the major species in numerical abundance. Alewife, spottail shiner, channel catfish, and white sucker were the next most abundant species averaging 23.7%, 8.1%, 7.8%, and 7.1% of the gill net catch.

Length-frequency histograms for the eight important forage species taken from combined trawl catches are shown in Figure 8. Very large numbers of these species in the length range from 20-100 mm were found in the inner Bay. The monthly changes in length frequency show that the majority of available forage fish were 50-130 mm total length during May, June, September, and October (Figures 9-16). There were significant numbers of all eight species in the length range from 20-50 mm only during July and August. Virtually no gizzard shad were caught in the trawl during May and June indicating that YOY were being subjected to severe natural mortality either from predation and/or overwinter temperature stress. Very few white perch were captured during the early months either and they are also known to be quite sensitive to cold-stress. In other months, white perch catches fluctuated widely because the population was expanding.

Length-frequency data collected from gill-net catches suggested that the trawl was capturing a representative size range of most species (Table 7 and Appendix 4). Concern is often expressed that bottom trawls are selective for smaller sized fish and tend to underestimate density of larger individuals. In the case of yellow perch from gill nets, 87.1% were in the range from 101-201 mm, even though gill net meshes were used that effectively capture all sizes of yellow perch. Trawl samples contained a larger percentage of yellow perch longer than 200 mm in spite of the fact that they also contained many more YOY.

Depth stratification of the gill-net catches showed that most species were caught primarily within 1.8 m of the bottom with the exception of emerald shiners; and to a lesser extent, alewife and gizzard shad (Figure 17 and Appendix 5). Emerald shiners were the only species that appeared to be oriented enough to surface waters to be unavailable to the trawl for adequate population sampling. During October, emerald shiners tended to be much lower in the water column where they were more vulnerable to the trawl (Appendix 6).

The MDNR fall index trawling program in the inner Bay, conducted from 1971 through 1991, showed some important trends in species abundance (Table 8). Yellow perch showed a dramatic increase in population level during the first 4 years and remained at very high abundance levels until 1990. White perch were absent from the Bay until 1984 but quickly rose in abundance to become one of the most abundant members of the fish community by 1989. There appear to have been increases of several other species such as trout-perch, emerald shiner, white sucker, and freshwater drum, until recently. A number of species, including yellow perch, rainbow smelt, and emerald shiner, have declined substantially in abundance since 1989 (Table 9).

On a monthly basis the trawl catches for most species peaked in August or September with the lowest catches occurring in May and October (Table 10 and Appendix 6). The declines in apparent abundance from September to October cannot entirely be explained by mortality expectations and probably have some relationship to dramatically cooling water temperatures and associated changes in behavior. Likewise, the apparent increase in abundance from May to June must be due to increased catchability in trawls since YOY are not yet vulnerable to capture.

The trawl CPUE data were also used to describe the areal distribution of major species around the inner Bay (Figure 18). The only pattern general to most species was that the very center of the inner Bay tends to have lower stock density. Some species, such as yellow perch, white sucker, and common carp were abundant throughout the inner Bay, while the distribution of others such as white bass, white perch, and walleye was quite patchy.

Biomass estimates were generated for all species in the inner Bay based on their CPUE and length-weight regressions from trawl samples at random and fixed stations during 1986-1988 (Figures 19-22 and Appendix 7). The resulting estimates for trawl biomass were expanded by the ratio of the area swept by the trawl to the total area of the inner Bay to obtain estimates of total biomass. The biomass of yellow perch averaged 91.5 kg•hectare^{-1}, nearly 50% of the total trawlable biomass of 214.3 kg•hectare^{-1} for all species. Spottail shiners and trout-perch were the forage species with the next highest biomass estimates.

Yellow Perch Abundance Indices and Growth

Reproductive success of yellow perch, as reflected in fall trawl catches, has been high in the inner portion of Saginaw Bay during the period from 1970 through 1991. The average cumulative CPUE for individual year classes (1970-1987) of yearling and older yellow perch over their history of vulnerability to trawling (generally ages 1-5) was 297.6. Their abundance ranged from a low cumulative CPUE of 114.8 for the 1972 year class to a high of 776.4 for the 1979 year class (Table 11). Fall trawl catch of YOY has averaged 137.6 per 10-minute tow and ranged from a low CPUE of 11.1 for the 1976 year class to a high of 686.7 for the 1982 year class. High trawl catches at age-0 have not necessarily been associated with high cumulative CPUEs for that year class at ages 1-5. This lack of a relationship suggests that competitive interactions may induce high natural mortality on YOY during the first winter which significantly reduces recruitment to older ages.

Observed length at age for yellow perch in fall trawl samples did not appear to change during the 1986-1988 time period (Table 12). However, there appears to have been substantial increases in growth rates of both males and females, most evident at ages 1-3, since 1989 (Tables 13-16). Monthly length-frequency data on yellow perch from gill nets, shown in Table 17, indicated that the trawl was adequately sampling all sizes present in the population.

Monthly trawl CPUEs of yearling and older yellow perch during 1986-1988 averaged 381 and ranged from 281 in October to 477 in June indicating that the overall population level was not changing very much (Table 18 and Figure 23). Estimated monthly biomass of yearling and adult showed that the population was quite stable at about 100 kg•hectare^{-1} (Figure 24). Apparently there was a substantial decline in the population after 1989 resulting in biomass estimates less than 40 kg•hectare^{-1}. Trawl catches of age-0 yellow perch peaked in August (Figure 25).

Age analysis of yellow perch from trawl samples showed low mortality from ages 1-4 for males (22%) and from ages 1-3 for females (28%) (Table 19). However, there apparently was high mortality following those ages (66% for males) which suggested that yellow perch may have been dying from starvation-related causes since no other source of extensive mortality was evident.

During 1986-1988, the male to female (M:F) sex ratio in monthly trawl samples ranged from 1.6 to 2.1, which was similar to the longer-term (1970-1991) average of 2.5, (Table 20). As expected, the M:F ratio increased to 3.5 at age-4 and then declined to slightly more than 1.0 at ages greater than 6. We hypothesized that if female yellow perch were dying faster than males because of their greater energetic demands, then the sex ratio should be biased heavily to males. The fact that heavy mortality occurs one year earlier in females is seen to support this concept since female yellow perch typically demonstrate greater energy turnover due to their relatively high reproductive demand.

Yellow perch age data from fall trawl samples were combined for the period from 1970-1991 and used to calculate average annual survival rates. Yellow perch abundance during the early years was considerably lower and survival probably higher. However, it is important to use a long series of years for calculating mortality since annual variation in trawl CPUE is high. The survival rate for males aged 1-3 was 47.9% (± 0.4%) and for ages 4-8 it was 31.4% (± 1.0%). Annual survival for females was more consistent being 41.3% (± 0.6%) for ages 1-3 and likewise 41.3% for ages 4-8 (± 1.5%). A statistical comparison between male and female survival rates using the z-test ($P < 0.01$) showed that male survival was significantly higher than female survival during ages 1-3 and significantly lower during ages 4-8. These observed differences in survival rate possibly explain the biased sex ratio observed in all trawl collections. Female survival rate may not have dropped because they were larger than males and might have been able to better utilize abundant forage fish populations.

Growth of YOY yellow perch has significantly declined during the period 1970-1991 based on empirical lengths from fall-trawl collections. The long-term average was 82.7 mm total length compared to 88.7 mm during the 11-year period from 1970-1980 and 76.7 mm during the 11-year period from 1981-1991. This decline in growth rate probably resulted from increased density of yellow perch in the inner Bay over the long-term (1971-1989), and more recently (1987-1989), to the expansion of the white perch population. There have not been other obvious changes in productivity of the inner Bay which might explain the decline. The white perch population has consisted primarily of age-0 individuals which may have competed directly with young yellow perch.

Zooplankton

The zooplankton population in the inner portion of Saginaw Bay was characterized by relatively low densities of very small planktonic crustaceans (Tables 21-23). Overall density was 19 organisms per liter (± 7 organisms per liter) and they averaged 0.8 mm (± 0.03 mm) in length. Bosminids were the most abundant cladocerans and they averaged 0.4 mm (± 0.01 mm) in length. Generally, the zooplankton population shows species composition and size ranges which are typical of heavy predation pressure from abundant foraging fishes such as alewife, rainbow smelt, and emerald shiners.

Benthos

The benthos populations sampled at random and fixed trawl stations during 1986 were characterized by high densities of oligochaetes and meiobenthic copepods (Table 24). Large benthic organisms were rare. Chironomids were the most abundant benthic food item for yellow perch. However, a large fraction were small species which offerred relatively little food value per item. Benthos data from the replicate ponar samples at trawl stations were converted to mean number•m^{-2} and plotted on a 3-dimensional map projection to show areal distribution. Benthos density estimates for the 10 taxa most often utilized as food by yellow perch were compared with their frequency in the diet of yellow perch in Figure 26. Visual inspection of these maps suggests yellow perch were utilizing benthic food items in proportion to their availability. Chironomid pupae and amphipoda were exceptions, which suggests that yellow perch may have difficulty locating and catching those items.

Walleye

Gear bias.—During the three field seasons, we captured 1,433 walleye with bottom trawls and experimental gill nets. Length-frequency distributions differed significantly between the gear types (Kolmogorov-Smirnov test, $P < 0.05$), suggesting that vulnerability to capture in our gill nets increased with size, or that small walleye preferred the benthic habitat. Generally, gill nets captured walleye larger than 350 mm in size, while the bottom trawl captured all sizes of walleye (Figure 27). In spite of this, no significant differences were observed in mean length at age of walleye captured in the two gear types (ANOVA, $P < 0.05$). Significantly greater numbers of empty stomachs were found among walleye captured in gill nets, presumably due to a combination of digestion after capture, higher activity rate for unsatiated fish, and occasional regurgitation of prey during gill net lifts. Because gear type did not appear to bias the proportions of items in the diet, and we had no reason to assume that prey were selectively regurgitated, we pooled walleye from all gear types for diet analysis.

Age and growth.—Although we collected walleye as old as age 10 from the 1976 year class, our samples were dominated by age-1, age-2, and age-3 fish from the 1984, 1985, and 1986 year classes. Walleye were relatively rare in our samples compared to most other species, but sample sizes were adequate to examine growth differences among years for age-1 fish during 1986, 1987, and 1988, and for age-2 fish for 1987 and 1988. We were also able to examine seasonal growth trends for ages 1 and 2, as well as age-3 fish during 1988. We detected no significant differences in mean length at age between years (ANOVA, $P < 0.05$). Saginaw Bay walleye grew quickly, with age-1 fish attaining mean lengths of 352-369 mm and mean weights of 414-470 g by October of each year (Tables 25 and 26). Age-2 fish averaged 440 mm and 820 g, while age-3 fish exceed 500 mm and 1 kg by the end of their fourth growing season. These growth rates are the fastest recorded for any walleye population in Michigan, and are exceeded by only a few southern populations with longer growing seasons.

Seasonal trends in growth varied by age and year. Age-1 and age-2 fish did not show much somatic growth before June, but grew steadily from July through October (Figure 28). Age-3 walleye grew only slowly throughout the growing season during 1988, but achieved a large somatic gain during September. This was most likely due to a cold spring which delayed clupeid (alewife and gizzard shad) recruitment until the fall.

Diets.—Walleye diets varied with age, and between years. Diets of age-1 walleye were similar during 1986 and 1987; these fish consumed shiners and rainbow smelt during the spring, but switched to newly recruited clupeids during the fall (Figure 29 and Appendix 8). Sample sizes during 1988 were inadequate to define spring diets. Fish collected during May, June, and July contained unidentifiable prey items or had empty stomachs. However, the late summer and fall trend of clupeid consumption was evident. Age-1 walleye consumed some yellow perch during August and September, but perch never comprised a large proportion of the diet of this age class. Diets of age-2 walleye appeared to differ between 1987 and 1988. During 1987, these individuals consumed rainbow smelt during May, but clupeids became important from June through September (Figure 30 and Appendix 9). Rainbow smelt increased in importance during October. Although sample sizes were small for the early portion of 1988, we note that rainbow smelt were absent from the diet, and appear to have been replaced by cyprinids. The summer diet during 1988 differed substantially from the 1987 diet in that age-2 walleye relied extensively on yellow perch during July and August, with clupeids becoming important only during September and October. Diets of age-3 fish during the spring months of 1988 were dominated by adult clupeids, particularly alewives, which migrate into the inner Bay during May in large numbers to spawn (Figure 31 and Appendix 10). As with age-2 fish during 1988, yellow perch comprised a significant proportion of the diet during July and August while clupeids became important during September and October.

We used the energetics model to examine the nutritional contribution of individual prey types to walleye during the growing seasons of 1987 and 1988 (Table 27 and Appendices 11-12). These data indicate that although walleye consumed similar amounts of prey each year, the proportion of individual prey types varied among years for age-2 walleye. During all 3 years of the study, clupeids contributed about half the total prey biomass eaten, suggesting that most prey consumption is occurring during the summer and fall when these prey types are available as young of the year. Because clupeids have a higher caloric density than other prey types, an even greater fraction of the total caloric intake is occurring at this time. However, prey types comprising the remaining half of the diet varied considerably. During 1987, 23% of the diet of age-2 walleye was comprised of rainbow smelt, but this prey type was absent during 1988, and was evidently offset by a large increase in the consumption of *Notropis* spp. For age-2 walleye, we observed an apparent decline in the proportion of total consumption comprised of both rainbow smelt and clupeids in 1988 compared with 1987 data. However, these fish apparently maintained total consumption by increasing predation on *Notropis* spp. and yellow perch. While no between year comparisons are possible for age-3 walleye, they followed a similar pattern to that observed in age-2 fish.

Walleye seasonal patterns of predation and consumption were consistent with trends in forage fish abundance. Rainbow smelt were significantly more abundant during 1987 than 1988, while shiners were significantly more abundant during 1988 than 1987 (Kruskal-Wallis test, $P < 0.05$). No significant differences in yellow perch or clupeid abundance were observed between years, but the temporal abundance of these two prey types varied. A cold spring during 1988 evidently delayed clupeid recruitment by approximately 1 month. This might explain why age-2 and age-3 walleye consumed more yellow perch during July and August until clupeids became available during September and October.

Did changes in prey availability affect walleye in any way? For age-1 and age-2 fish we observed no differences in total consumption between years, and seasonal growth patterns were similar. In fact, seasonal growth was slightly faster for age-2 fish during 1988—the year when clupeid recruitment was delayed and walleye may have been forced to subsist on yellow perch. Although multi-year comparisons are not possible for older age classes, we observed that age-3 walleye accumulated most of their seasonal growth during September and October of 1988, which suggests that clupeid availability may be important for this age class. Unfortunately, the mechanism underlying the observed seasonal growth pattern is not clear. Age-3 walleye may exhibit marked prey preferences for clupeids, enjoy greater capture success on these forms, or have lower energetic costs associated with search, pursuit, and handling. Clupeids also have higher energy densities than other prey types, and would confer more energy per bite at fixed capture costs.

Walleye in inner Saginaw Bay exhibit fast growth rates because they have an abundance of food. Although total food consumption varied little between years, the proportion of individual prey types varied, which reflected changes in forage fish abundance and timing of recruitment. This suggests that stochastic processes regulating prey abundance may be important even at low predator density. Walleye show strong preferences for soft-rayed prey (Knight et al. 1984), but in Saginaw Bay younger age classes maintained fast growth rates on spiny-rayed species in the absence of preferred prey types. Growth of age-3 fish was maintained only through high consumption rates of clupeids during fall 1988.

The results from this study suggest that walleye predation is unlikely to be a significant source of mortality for yellow perch under present conditions. Walleye are still relatively rare in Saginaw Bay, they consumed yellow perch only for short-time periods when other prey types were rare, yellow perch never comprised more than half the total wet weight of the diet during months they were consumed, and predation on yellow perch ceased as soon as alternate prey became available. Furthermore, the conditions under which moderate predation occurred did not appear to be related to any of the observed changes in the fish community. Thus, walleye predation is unlikely to result in significant reductions in yellow perch abundance, even under higher population densities.

Yellow Perch Diets

The diet of yellow perch varied greatly with age, but little across years. Diets were qualitatively restricted in the sense that only a few prey items comprised most of the wet weight of the diet. Age-1 yellow perch consumed large numbers of zooplankton, and they sometimes comprised up to half the total wet weight of the diet during May, June, or July (Table 28). However, chironomid larvae (Insecta:chironomidae) were the most abundant food item for this age class for most months during each year of the study. Although age-2 individuals also took large numbers of zooplankton, chironomids were the only food item that contributed significantly to the total wet weight of the diet during most months (Table 29). Fish were important to this age class only during October in 1986 and 1988. By age-3 yellow perch had become more piscivorous, but chironomid larvae remained important components of the diet (Table 30). Age-4 and age-5 yellow perch exhibited greater trends toward piscivory (Tables 31 and 32). Fish contributed up to 90% of the total wet weight of the diet during the summer and fall, but chironomids remained important dietary components during the spring months of each year.

Unlike walleye, consumption of forage fish by yellow perch was not related to the abundance and timing of forage fish recruitment. This is undoubtedly due in part to a greater degree of uncertainty regarding their diet—most of the forage fish found in perch stomachs could not be identified. It appears that piscivory by yellow perch may be regulated by spatial overlap of predator and prey. Yellow perch rarely consumed gizzard shad or alewives, which are pelagic foragers as young of the year. Instead, they consumed trout-perch, YOY yellow perch, and cyprinids. It is possible that the large proportion of unidentified fish in the diet may represent predation on YOY spottail shiners. This species is abundant in the benthic habitat, lacks distinguishing features that resist digestion, and has a small fine-scaled body that might be quickly rendered unidentifiable after a short period of digestion. If this were the case, then nearly all the fish consumed by yellow perch represent benthic dwelling forms which would have a high degree of spatial overlap with adult yellow perch. Cannibalism by yellow perch was observed, but it's effect on abundance of YOY yellow perch is probably minimal. Cannibalism only occurred during the fall among age-4 and age-5 fish, which represent only a minor component of the yellow perch population.

Yellow perch in Saginaw Bay appear to be strongly constrained by prey availability. During their growth history they pass through three basic stages which are known to be dependent upon adequate supplies of zooplankton, benthos, and prey fish. Yellow perch typically display growth-related problems when some of these are deficient. Although they become increasingly piscivorous with age, all age classes of yellow perch in Saginaw Bay consumed large numbers of extremely small invertebrate prey. Additionally, forage fish were extremely rare by number in the diet. Although forage fish comprised most of the wet weight of the diet during some months for age-3 and older perch, on average fewer than one in seven individuals had captured fish prey. This suggests that yellow perch in Saginaw Bay rarely are able to utilize large prey items which are critical to good growth.

Stomachs of male yellow perch were found to contain less food weight than stomachs of females and the sexes displayed different patterns of food containment across months (Tables 33-34 and Appendices 13-14). Absolute food weight in males declined during May through July; whereas, food weight increased in females. Both sexes contained the greatest food weight during September. Females had significantly larger absolute food weight (mean = 0.04 g) present in their stomachs per gram of body weight compared to males (mean = 0.02 g) (Tables 35 and 36).

Validation of the Energetics Model

We validated the energetics model by comparing its predictions to those of the Elliott and Persson (1978) consumption model (hereafter referred to as the consumption model). Estimates of food consumption from the consumption model showed good agreement with food consumption estimates derived from the energetics model during the spring and fall. However, estimates from the consumption model were considerably greater than those from the energetics model during the summer. Plotting of the absolute value of the differences between two models versus temperature indicated that this was a temperature related phenomenon, and that the two models were in agreement below temperatures of 22°C, but not at higher temperatures (Figure 32).

Persson (1979) developed estimates of gastric evacuation rates for Eurasian perch (*Perca fluviatilis*), over a temperature range of 4-21°C. However, at temperatures greater than 22°C estimates of R must be derived through extrapolation (Figure 33). Virtually all discrepancies between the two models resulted from observations in the 22-27°C range, where the consumption model required an extrapolated value of *R*. Consequently, we concluded that discrepancies between the models above may be the result of inappropriate predictions of *R* at high temperatures. Additionally, despite these discrepancies, estimates of cumulative consumption by the two models differed by only a factor of 1.3. We concluded that the energetics model may provide an accurate representation of consumption at temperatures below 22°C, and that discrepancies between the two models at higher temperatures are most likely the result of overestimates of *R* used in the consumption model. Therefore, the energetics model was used to examine seasonal trends in consumption by yellow perch.

Energetics Modeling of Yellow Perch

Results of energetics modeling suggest that yellow perch become increasingly food limited with age, and that this could be responsible for their relatively slow growth. For age-1 fish, we observed high consumption rates during June and July of both 1987 and 1988, but steady declines in consumption during the rest of the growing season. High consumption rates early in the season were associated with an abundance of zooplankton and chironomids. During 1987, consumption was adequate to maintain growth until about mid-September, but during 1988, age-1 fish appeared to be feeding at close to a maintenance ration during the August-October period, presumably due to a lack of invertebrate prey (Figure 34). Age-2 fish followed a similar pattern during both years, with the highest consumption rates occurring during early summer, followed by poor feeding conditions after August (Figure 35). During Both years, age-2 fish apparently subsisted at or below a maintenance ration during the month of September, although conditions appear to be more severe during 1988 than 1987. The ration of age-3, age-4, and age-5 fish was similar for both years in that both age classes appeared to subsist just above a maintenance ration for much of the year (Figures 36-38). During 1987, we observed a peak in the consumption rate during late July which may have been associated with increased availability of YOY forage fishes, while during 1988 the highest consumption rates above maintenance occurred during June.

As yellow perch increase in age and size in the inner Bay, they appear to spend progressively more time at or below a maintenance ration. We expected to see major peaks in consumption during July, August, or September associated with recruitment of forage fishes, but only minor increases in consumption were observed for the older age classes during August 1987. All age classes we examined exhibited their highest consumption rates during June or July-a time when forage fish are not yet abundant, and fish are primarily consuming invertebrates (Figure 39). These results in combination with the overall rarity of forage fish in stomachs, suggest that yellow perch in Saginaw Bay cannot take advantage of an apparently abundant supply of forage fish, and obtain too much of their caloric intake through predation on large numbers of small invertebrates.

Energetics Modeling of Walleye

Population level energetics modeling indicates that 1 million age-1, age-2, and age-3 walleye would have consumed about 750,000 kg of prey during 1988 (Table 37). Although predation by older age classes was not modeled, these age classes represent about 87% of the walleye in the inner Bay. Clupeids, *Notropis* spp., and yellow perch comprised the majority of the prey biomass consumed by walleye.

Predation by yellow perch during 1988 was clearly far more important to the forage fish community than was predation by walleye. Each individual age class of yellow perch consumed substantial amounts of fish, and some individual age classes consumed more fish than were consumed by the entire walleye population. In fact, the total predatory impact of ages 1-5 yellow perch was more than seven times greater than that of walleye. Although yellow perch are not as piscivorous as walleye, they are far more abundant and consequently have a greater effect on the forage community. Unfortunately, their effect on individual forage species is not clear, because the majority of the fish found in yellow perch stomachs could not be identified. Although yellow perch consumed more forage fish than walleye, this was not their most important food source. Chironomid larvae and pupae comprised about 85% of the total amount of prey consumed by age 1-5 yellow perch, and were important to each age class. Our estimates of benthic biomass (Table 38) agree well with data for shallow stations in Bay of Quinte which provided Great Lakes habitat similar to Saginaw Bay (Johnson and Brinkhurst 1971). We found mean biomass of chironomids to be 4.56 $g \bullet m^{-2}$ in Saginaw Bay compared to 4.88 $g \bullet m^{-2}$ in Bay of Quinte. Good agreement in biomass values supported our use of the P/B ratio from Bay of Quinte. We estimated that yellow perch consumed about 41,000,000 kg of chironomids in 1988 which was 39% of the production estimate of 105,000,000 kg (Table 39). This suggests heavy predation pressure on major components of the benthic community.

Walleye and yellow perch did not appear to be consuming a large proportion of the available forage fish production. Although their combined total predatory impact during the growing season of 1988 exceeded 6,000,000 kg, extremely conservative estimates of production by the most abundant forage species indicate that production during this time exceeded 22,000,000 kg, and was likely far greater, because we restricted our analyses to age classes clearly vulnerable to predation. Nor did we include less common species that could serve as forage (Table 40). In addition, since forage biomass estimates were based on catches in bottom trawls, production of pelagic species such as clupeids and rainbow smelt are likely to be far too low.

Predation by walleye and yellow perch probably has only a minor effect on production or abundance of most fish species, because production far exceeded predation for all species. However, most of the fish prey consumed by yellow perch could not be identified with certainty. If yellow perch were specializing on rainbow smelt, trout-perch, or *Notropis* spp., then yellow perch could be consuming a significant proportion of the production of these species. The low production of rainbow smelt and trout-perch may reflect intense predation by yellow perch, and both *Notropis* spp. and trout-perch were found in yellow perch stomachs. Rainbow smelt were never observed, but YOY smelt may digest quickly due to their small size.

Prey can be unavailable through their absence, inaccessibility, or size. Our analysis does not specifically account for size selection by walleye and yellow perch, because fish found in yellow perch stomachs were not measured, and walleye did not exhibit much prey size selectivity. However, our production estimates were made to exclude age classes of forage species that might have been invulnerable to walleye or yellow perch predation. Thus, even if prey size selectivity were operating, forage fish production would be likely to exceed predation.

Discussion

Our results suggest that walleye and yellow perch experience extremely different ecological conditions in inner Saginaw Bay. Walleye grow fast because prey abundance and consumption rates are high. Stochastic effects that influence the recruitment of forage fish are important in that variation in forage fish abundance appears to influence which prey species are consumed. Walleye appear to prefer soft-rayed prey such as clupeids and rainbow smelt, but did consume yellow perch during times when these prey were scarce. Yellow perch are probably important to walleye only during times when preferred prey are unavailable.

In Lake Erie, expansion of the walleye population has led to declines in native cyprinids, and walleye somatic growth appears to depend on the availability of YOY clupeids during late summer (Parsons 1971; Hartman and Margraf 1992). This phenomenon was not observed in Saginaw Bay for age-1 or age-2 walleye, but we found that age-3 fish collected during 1988 exhibited most of their somatic growth during September and October, when the YOY clupeids recruited late in the year after a cold spring. However, growth of this age class during 1988 did not appear to be suppressed, and it is unlikely that walleye experienced any food shortages that year.

Although the importance of individual prey species varied among years, there is no evidence at the present time to suggest that prey is limiting for age-1, age-2, or age-3 walleye. Although we have little information about older age classes, these fish appear to be large enough to consume almost any forage species in the inner Bay including adult yellow perch. Walleye remain relatively sparse in Saginaw Bay, and we believe that large increases in the population would have to occur before walleye have a significant impact on the forage base, and good growth rates are likely to continue.

The prediction of good walleye growth is based on the assumption that the primary source of walleye recruitment is the fingerling stocking program, which provides a relatively constant influx of new recruits each year. Natural reproduction resulting in a large year class could have profound effects on the forage base, and might lead to reduced growth. Unfortunately, at the present time there is no way to differentiate wild versus stocked fish. Understanding the dynamics of walleye recruitment in Saginaw Bay is critical to the long-term success of the walleye rehabilitation program, and the maintenance of fast growth rates that maintain the trophy fishery. Additionally, knowing the relative importance of stocked versus wild fish could also be used to increase the number of walleye in the inner Bay, and tradeoffs between fast growth and increased abundance could be evaluated.

In contrast, yellow perch in Saginaw Bay now experience high natural mortality associated with energy depletion. Only the largest individuals of each year class survive to older ages, and after maturity, adults appear to have difficulty meeting the combined costs of maintenance, growth, and reproduction (Salz 1989). As a result, most yellow perch inhabiting the Bay reach a terminal size of about 175 mm, then sustain a high mortality. Few males live beyond age 5 and few females live beyond age 4. Females grow faster and have higher energetic costs associated with spawning, thus death occurs earlier than males. Consequently, few large individuals are available for harvest. Although the severity of energy depletion probably varies between different sites, the phenomenon appears to be ubiquitous throughout the inner Bay. Most yellow perch appear to die of energy depletion before they reach the 216 mm commercial minimum length limit, and those reaching the 175-200 mm range are only marginally acceptable to anglers.

The mechanism underlying energy depletion in yellow perch appears to be food limitation. Yellow perch from the inner Bay exhibit a qualitatively restricted diet in that zooplankton, chironomids, and fish were the major prey items that were represented in the diet. Although fish comprised a significant proportion of the diet of older individuals, they continued to take large numbers of small prey. Piscivory by yellow perch was rare, and appears to represent opportunistic predation on benthic dwelling species. Results of the energetics modeling suggest that as yellow perch increase in age and size, they spend progressively more time during the growing season near a maintenance ration. The highest consumption rates above a maintenance ration were associated with early summer invertebrate abundance, while increases in consumption associated with times of high forage fish abundance occurred only sporadically among the older age classes, and provided little energetic relief.

Energy depletion suggested by energetics modeling was consistent with seasonal trends in somatic growth, percent water content, and condition observed by Salz (1989). Nearly all somatic growth occurred during the short interval between spawning (May) and the onset of gonad production (August). This represents a much shorter period of somatic addition than historical yellow perch populations in the inner Bay. Hile and Jobes (1940) found that 77% of the total yellow perch production in Saginaw Bay (1936-1938) took place between September and December. Additionally, trends in visceral and somatic percent water and condition factor suggested that yellow perch shunt much of the energy stored over the summer into gonad production after August into metabolism and reproduction (Diana and Salz 1990). We found that somatic growth and lipid storage occurred only during the summer when predicted daily ration was the highest. Evidence of energy depletion (shunting) during the fall was associated with a daily ration that was near, or even below, the calculated maintenance ration. We suggest that yellow perch in the inner Bay gain much of their yearly caloric intake during a short period during early summer when zooplankton densities are high and the seasonal chironomid emergence is occurring. Food resources may be inadequate during other times.

Food limitation and energy depletion could be the result of intraspecific competition, because growth rates of yellow perch in Saginaw Bay have varied inversely with abundance. Hile (1954) found fast growth rates during 1929-1930 during a period of exceptionally low abundance, but El-Zarka (1959) found slower growth during the 1944-1955 period when abundance was higher by a factor of 7 over the 1929-1930 period. Eshenroder (1977) observed increased growth rates during a period of apparent overexploitation during the 1960s, while Weber (1985) found an inverse correlation between yellow perch density and growth during the years 1970-1985 (Weber 1985). These data suggest that growth rates of yellow perch in Saginaw Bay are strongly density dependent.

Weber (1985), using back-calculated length at age data, concluded that growth rates of yellow perch from inner Saginaw Bay had declined, but were similar to those reported by El-Zarka (1959) during 1944-1955. These data suggested that the lack of large yellow perch might be the result of over-harvest. However, comparison of empirical with back-calculated lengths by Salz (1989) indicated that Saginaw Bay yellow perch exhibit reversed Lee's phenomenon due to selective mortality of smaller fish in each year class. Positive correlations between first year growth and age of capture suggested that only the largest individuals of each year class survived. Consequently, Weber's (1985) estimates based on back-calculated length may have overestimated length at age. While this bias appears to be negligible, it had important consequences.

During 1982, a 216 mm minimum length limit was established for the commercial trap net fishery in the inner Bay. During the next several years, MDNR personnel performed age and growth analyses on samples of yellow perch taken from commercial trap nets, and mean length at age was estimated using back-calculation from scales. They observed a truncated age distribution with an apparent high mortality after age 5 (MDNR, unpublished data). Because back-calculated length-at-age was used, high mortality was associated with a length range of 203-223 mm suggesting that yellow perch were being heavily cropped as they became vulnerable to the commercial minimum size limit of 216 mm.

In reality, yellow perch were probably not being over-harvested by the commercial fishery, because they had not attained a length range of 203-223 mm. Instead, the mortality was occurring over a length range of 180-200 mm (their true length when corrected for the bias caused by reversed Lee's phenomenon). Thus, high mortality was occurring in yellow perch that were up to 36 mm smaller than the commercial minimum length limit. While commercial fishermen do take a small proportion of undersized fish in their catch, this difference seems far too large to be a result from that practice. Based on Weber (1985) and results of this study, the sport and commercial harvest during 1980-1984 (389,000 kg•year^{-1}) was about 3.0% of the average stock biomass (13.5 million kg) of age-1 and older yellow perch during 1986-1988 suggesting again that harvest was probably having a minimal impact. This reanalysis of the data suggests that natural mortality was the dominant factor and fishing mortality probably was much less forceful than first thought.

The true growth rate of yellow perch in Saginaw Bay may have been approaching an all time historical low in 1988. While no comparable density estimates are available for earlier times, yellow perch were the most abundant species in our trawl catches, and comprised a large proportion of total biomass.

We believe that abundance may have been at an all time high during 1986-1988. Consequently, intraspecific effects, if they exist, would have had maximum effect.

Intraspecific effects may be severe, but a lack of large benthic prey could be of equal importance. Hayward and Margraf (1987, 1988) found that yellow perch from Lake Erie's more eutrophic western basin had lower consumption rates than fish from the less eutrophic central basin. They attributed low consumption rates of the western basin fish to a lack of large benthic prey induced by eutrophication. Direct evidence for this hypothesis also exists in Saginaw Bay. Prior to 1950, Saginaw Bay was much less eutrophic than it is today and one of the predominant benthic invertebrates was the nymphal stage of the mayfly *Hexagenia limbata* (Reynoldson et al. 1989). By 1955, *Hexagenia* had been extirpated, and chironomids and oligochaetes predominated in the benthos. Yellow perch in Saginaw Bay formerly consumed *Hexagenia* (Tharratt 1959), but this prey item became unavailable after their extirpation. Furthermore, we have learned that growth rates of yellow perch declined sharply during 1952 (El-Zarka 1959). The loss of *Hexagenia* is believed to have occurred as a catastrophic extirpation during 1950-1955 (Reynoldson et al. 1989). Severe declines in mean length at age and mean weight of adult age classes from the average growth during the 1944-55 period were observed (Figure 40).

We do not know why the absence of large benthic prey was associated with slower growth of yellow perch in Saginaw Bay (Figure 41). This is particularly vexing because other benthivores such as common carp, channel catifsh, and white suckers appear to have been unaffected by the loss of *Hexagenia*. Yellow perch are most likely visual predators that select individual prey organisms. Consequently, reductions in light intensity associated with phytoplankton blooms during times of high eutrophication could impair their ability to locate prey. Some evidence for this exists. Yellow perch from the inner Bay occasionally ingested large amounts of sediment in addition to benthic organisms (MDNR, Lake St. Clair Fisheries Research Station, unpublished data). These individuals may have been filter feeding. However, the majority of the perch we collected did not contain sediment. This strongly suggests that they were locating and consuming individual prey.

It is more likely that yellow perch can not maintain a positive energy balance on a diet of small benthic prey and zooplankton. Search, pursuit, and handling costs might be high even at high prey densities because individual prey are consumed one at a time. This would constrain the overall foraging rate, and a diet of small prey would confer little energy per bite. As yellow perch increase in size, their total metabolic demand also increases; thus, they must ingest more calories than smaller conspecifics. This problem would be exacerbated after maturation when gamete production becomes an additional metabolic cost. Large benthic prey may have conferred an energetic advantage by providing a better return from a foraging strategy that focuses on one prey item at a time.

Further energetic advantages could have existed if large benthic prey were especially abundant, or highly available. During 1956, *Hexagenia* were present at an average density of $7.6 \bullet m^{-2}$ (Schneider et al. 1969), but were probably much more abundant prior to the 1950s.

Leach et al. (1977) suggested that moderate eutrophication enhances percid growth and yield by increasing primary production; however, beyond a critical threshold, percid biomass declines as energy becomes channeled into unharvestable food webs. Thus, under severe eutrophication percid biomass declines. Our results support this hypothesis. In Saginaw Bay, eutrophication has induced a shift from a benthic community comprised of large forms such as *Hexagenia* to one dominated by chironomids and oligochaetes. Although yellow perch can consume chironomids, they appear to be an inadequate energy source due to their small size, poor dietary quality, or restricted seasonal availability. We hypothesize that food webs do not become unharvestable by yellow perch after eutrophication, but that eutrophication causes a reduction in prey size or quality that creates energetic constraints. In Saginaw Bay, this apparently has resulted in energy depletion and high natural mortality for yellow perch.

This problem appears to be exacerbated by high yellow perch density. During 1968-1971, yellow perch from the inner Bay grew faster (Eshenroder 1977), in spite of an absence of large benthic prey and severe eutrophication. Density was lower because commercial gill net harvests were high, and natural mortality from energy depletion may have also occurred. Presumably, growth improved because intraspecific effects such as competition for limited food resources were reduced. This raises the possibility that yellow perch growth could be improved by increasing harvest mortality, but the relationship between density and growth remains undefined.

We hypothesize that yellow perch cannot take full advantage of an abundant supply of forage fish because they do not achieve a size where they can become efficient piscivores. Yellow perch tend to become piscivorous only after attaining a length of 175 mm (Ney 1978). This is close to the terminal size achieved by age-4 yellow perch before they succumb to energy depletion in Saginaw Bay. These yellow perch may be caught in an ecological trap, assuming that they strive to reach large size. As the fish grow, they become too large to maintain energy reserves while subsisting on chironomids and zooplankton, but they are not yet large enough to be efficient piscivores. In the past, large prey types such as *Hexagenia* may have provided a high energy food source that sustained growth to sizes beyond 175 mm where perch could become more efficient piscivores.

From a management perspective, the problem is exacerbated because yellow perch in the inner Bay appear to shunt their available reserves into reproduction rather than growth (Salz 1989). This may represent a population specific life history strategy. Natural selection in Saginaw Bay may have favored individuals that, when physiologically stressed by chronic resource shortages, allocated available reserves into reproduction despite almost certain post spawn mortality. This is probably not a response to overharvest because yellow perch die well below the minimum commercial limit (216 mm) and the sport fishing yield has been relatively small compared to stock size.

We hypothesize that many yellow perch from the inner Bay may be semelparous. Consequently, traditional approaches to harvest regulation such as protection of individuals until after first spawn or growth to a specific harvestable size may be inappropriate for the inner Bay population because the lifespan of most individuals appears restricted to 4 to 5 years. In this case, commercial harvest of age-3 and age-4 yellow perch would provide an economic return on fish that will almost certainly die of energy depletion before they become acceptable to sport anglers.

Unfortunately, increased harvest of yellow perch from Saginaw Bay may not improve individual growth rates. This is an extremely dense population, and it is unlikely that even large increases sport or commercial landings would significantly reduce perch density. Additionally, even if the existing food resources become more abundant through a reduction in intraspecific effects, we believe that a lack of large benthic prey will remain a problem.

Did walleye and yellow perch have a significant impact on the forage fish community of Saginaw Bay? Estimates of production and consumption suggest that the two predatory species consumed at most 25% of the annual production of the forage fish community. This estimate is liberal, because we chose parameters that maximized the impact of predation, while our estimates of forage biomass and production were very conservative. Predation is probably not limiting any forage species, with the possible exceptions of trout-perch and rainbow smelt. At the time of this study, other warmwater predatory species were rare, and salmonids were excluded from the inner Bay by warm temperatures. White perch colonized the Bay during the study, and older individuals will undoubtedly be piscivorous (Schaeffer and Margraf 1986). However, adult white perch remain rare despite apparently strong year classes during the past 5 years. Thus, piscivory is not likely to increase or become a limiting factor during the immediate future.

However, yellow perch appear to have a strong impact on the benthic community, and probably consume much of the available production. Abundant stocks of other benthivorous species such as white sucker, common carp, channel catfish, and white perch also forage on the benthos. This strongly suggests that the availability of benthic organisms could be limiting, and that prey shortages may have been the mechanism limiting growth of yellow perch.

Our results suggest that the simultaneous resurgence of walleye and yellow perch is not a barrier to the management goal of maintaining large fast growing populations of both species for harvest. Walleye and yellow perch have almost no diet overlap, thus competition for food resources is unlikely. Yellow perch are seasonally important to walleye, but only at times when alternate prey are lacking and walleye predation is probably not a significant source of mortality on perch. Were walleye to increase, more yellow perch would be consumed, but it is doubtful that even a large walleye population would control them. Consequently, interspecific interactions through competition or predation are presently minimal, and the growth and abundance of either species is not constrained by the other.

No easy solution exists to deal with the problem of slow yellow perch growth rates. Increasing harvest rates on 150-203 mm yellow perch through the removal of restrictions on sport or commercial fisheries is probably a prerequisite, although mortality would have to increase substantially to reduce intraspecific effects, and growth may not improve because of a lack of large, benthic prey. The long-term solution to this problem is the restoration of ecological conditions that would permit *Hexagenia* and other pollution intolerant large invertebrates to recolonize the inner Bay. The restoration of this food web would benefit not only yellow perch, but other species as well. Until this is achieved, it is likely that adult yellow perch will experience an energetic bottleneck.

The major prerequisite for restoration of large benthic prey types will be a return to the more pristine ecological conditions present in the Bay before the 1950s. Continued reductions in nutrient and sediment loading must occur, as well as stabilization of flow regimes in tributaries. We are particularly concerned with non-point sources that result from poor land use practices within the watershed. Meeting this objective will require an integrated whole-watershed approach in conjunction with fish management.

Management Recommendations

1. Remove the existing bag limit for sport anglers. Regulations on the commercial fishery should be relaxed such that age-3 and age-4 yellow perch could be harvested. A slot limit of 6 to 8 inches may achieve this goal.

2. Based on the results of this study, we feel that walleye are only consuming a small proportion of the forage fish production, and that the general availability of prey fish remains high. Fishery managers need not be concerned that predator stocking will result in predation rates that threaten forage fish populations. The apparent high availability of forage strengthens the justification for reestablishing additional native predator species such as the Great Lakes muskellunge and sauger. Additional predation pressure on yellow perch stocks also would be valuable since it would tend to relieve predation pressure on the benthic community and improve growth of the perch.

   Rehabilitation of the fish community of Saginaw Bay appears to depend heavily upon restoration of benthic diversity. This will require management on a whole-watershed basis to improve the quality of the benthic habitat and also reduce the overwhelming predator com-munity that now preys upon it. We feel that current efforts to monitor and improve water quality in Saginaw Bay should be supported to the fullest extent possible. In addition, increased harvest of benthivorous species and sizes of fish, especially yellow perch and white perch, should be encouraged.

3. Monitoring of yellow perch growth should continue, but programs that rely on sampling commercial gear and using back calculated length at age should not be undertaken. Because yellow perch exhibit reversed Lee's phenomenon, only the largest individuals of each age class are surviving to maturity. This causes overestimation of back-calculated mean length at age. Direct estimates of mean length at age should be performed using bottom trawl samples, which appear to be less biased.

4. The dynamics of walleye recruitment will not be understood until there is a reliable method to differentiate wild and stocked fish. In the absence of any proven method, strong consideration should be given to alternate year stocking of fingerling walleye. The primary objection to this approach is that sport angling groups enjoy participation in pond-rearing projects. During non-stocking years, these groups could assist in the rearing of an additional predator for stocking in Saginaw Bay, such as the Great Lakes muskellunge (*Esox masquinongy*). Alternatively, fingerling walleye reared in the ponds could be used for stocking in inland lakes. Sport angler groups could contribute a substantial proportion of the fish used for inland stocking on alternate years. Monitoring of the age and growth of Saginaw Bay walleye should be continued, particularly if the alternate year stocking strategy is adopted. In particular the growth of older age classes should be examined.

5. There is a strong public perception that the lack of large yellow perch in Saginaw Bay is the result of legal and illegal commercial overharvest. MDNR should take a leadership role in correcting this perception through its information dissemination capabilities.

6. There should be no restrictions on the sport or commercial harvest of white perch, and some research effort should be expended to determine the locations where adult white perch spawn. These fish are highly vulnerable to exploitation during spawning, and could furnish a new angling experience for sport anglers.

7. Yearly monitoring of Saginaw Bay should continue. This will enhance the existing data base, and provide data regarding age and growth of yellow perch. Continued monitoring is especially important in that large changes in the ecosystem may occur as zebra mussels proliferate in the inner Bay over the next 5 years.

8. The MDNR Fisheries Division should evaluate the activities of other agencies involved in watershed management of Saginaw Bay to determine their jurisdictions, goals and objectives, and ongoing programs. This information should be synthesized, management plans developed, and information exchanged. Fisheries Division should develop a watershed management plan for the Saginaw basin, with the other agencies, with consistent goals and targets for restoration of the Saginaw Bay ecosystem.

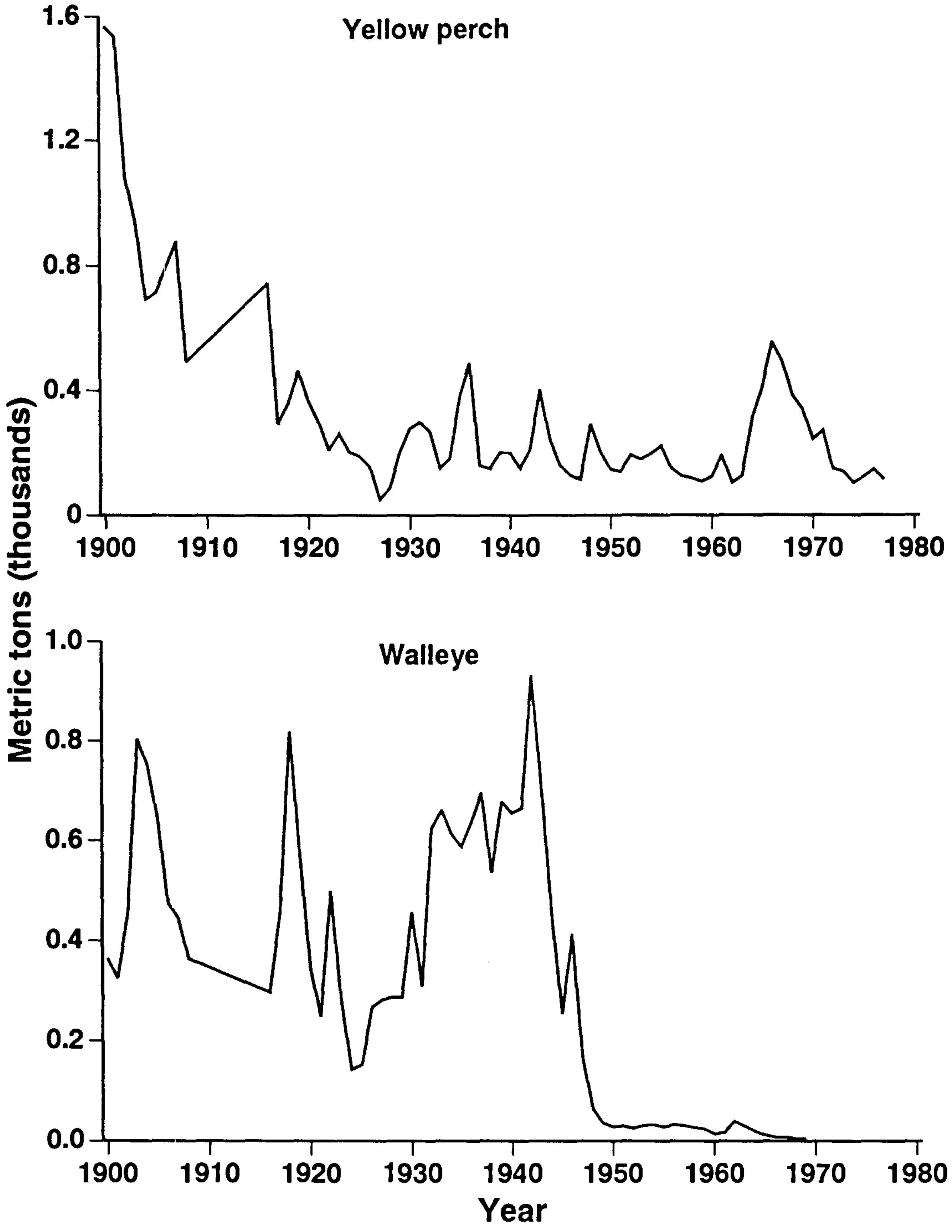


Figure 1.—Commercial landings of yellow perch and walleye from Saginaw Bay, Lake Huron.

Figure 2.—Stocking rates of fingerling walleye during 1978-1986 in Saginaw Bay, Lake Huron.

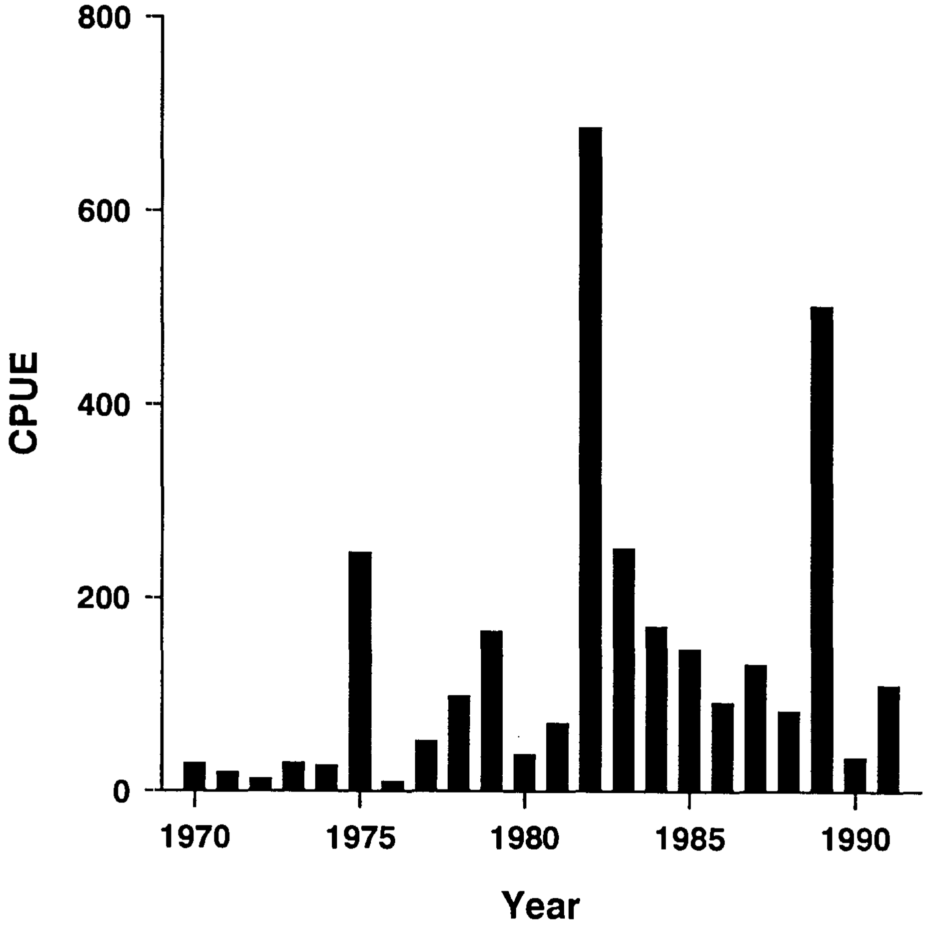


Figure 3.—Mean catch per 10-minute trawl tow (CPUE) of young-of-the-year yellow perch from Saginaw Bay, Lake Huron during 1970-1991.

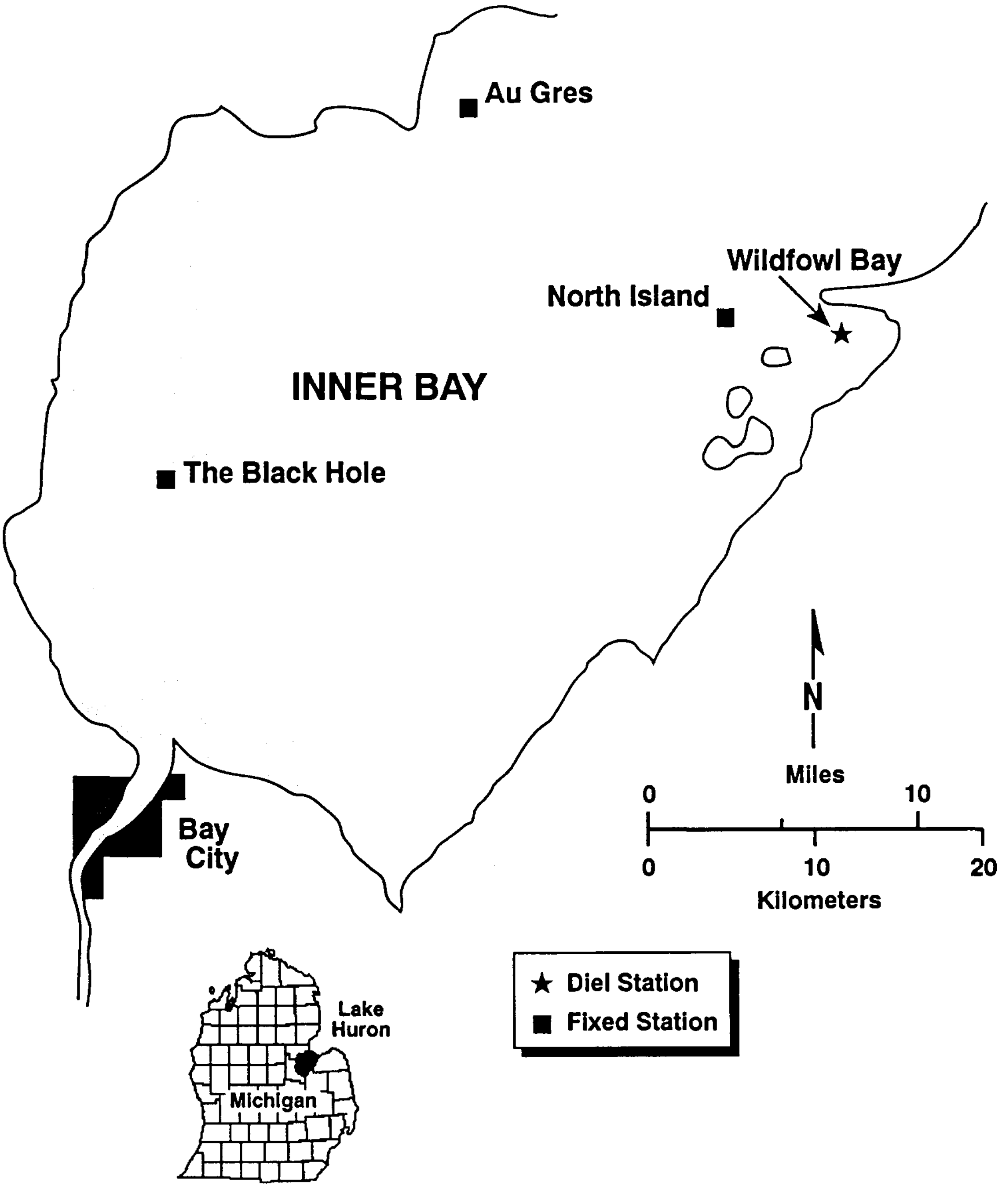


Figure 4.—Map of inner Saginaw Bay, Lake Huron showing diel station (Wildfowl Bay) and fixed stations (North Island, Black Hole, and Au Gres).

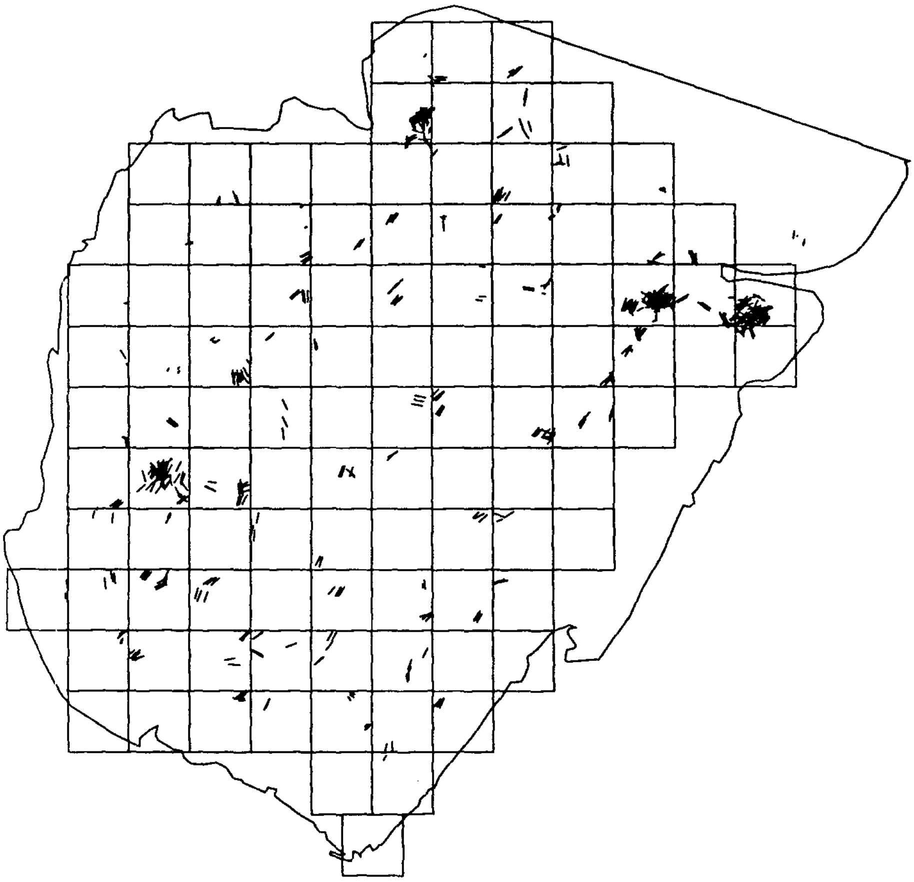


Figure 5.—Map traces of trawl tows made at random and fixed stations in the inner portion of Saginaw Bay, Lake Huron during 1986-1988.

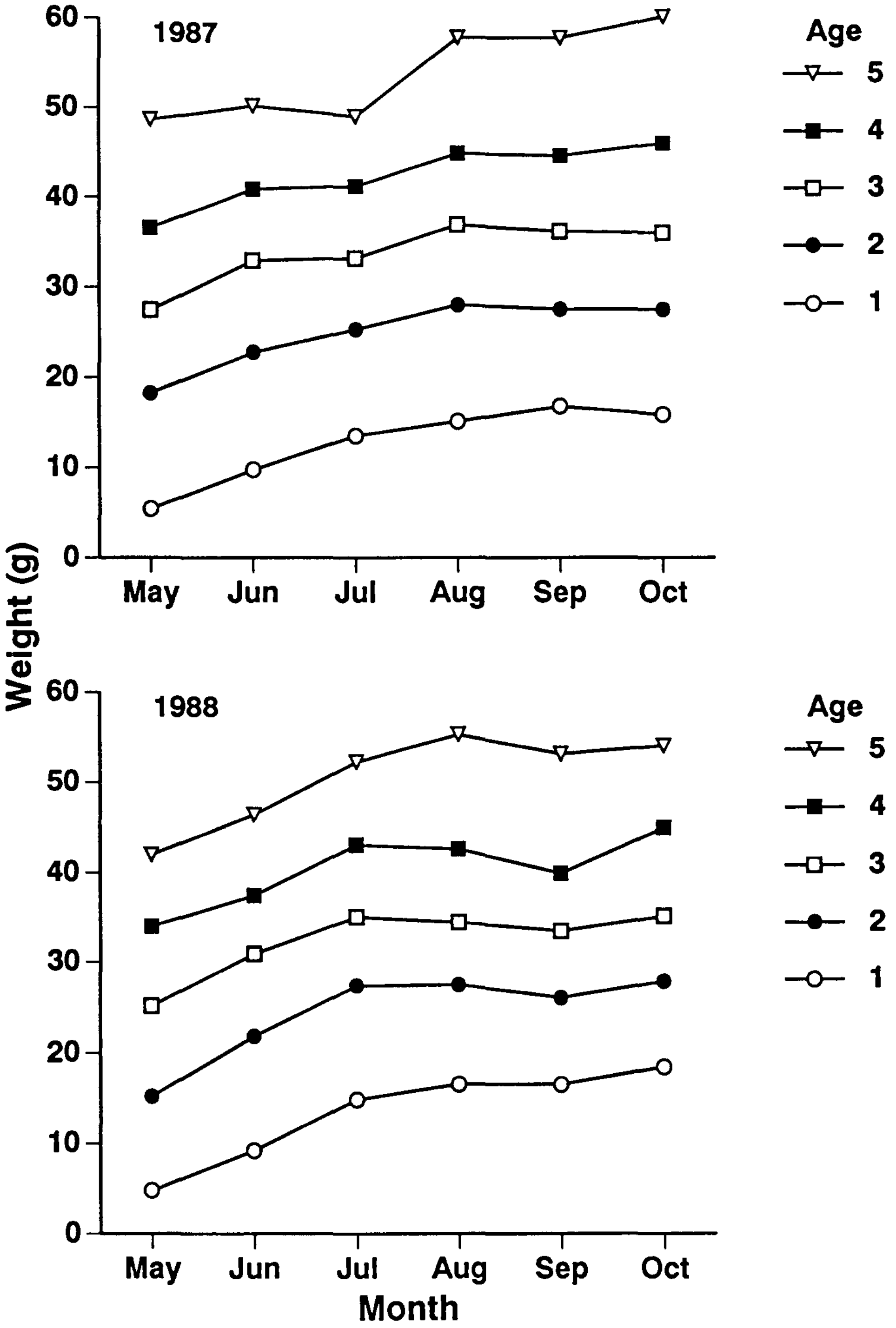


Figure 6.—Seasonal changes in mean weight (g) of age 1-5 yellow perch collected with bottom trawls during 1987-1988 from the Wildfowl Bay station, Saginaw Bay, Lake Huron.

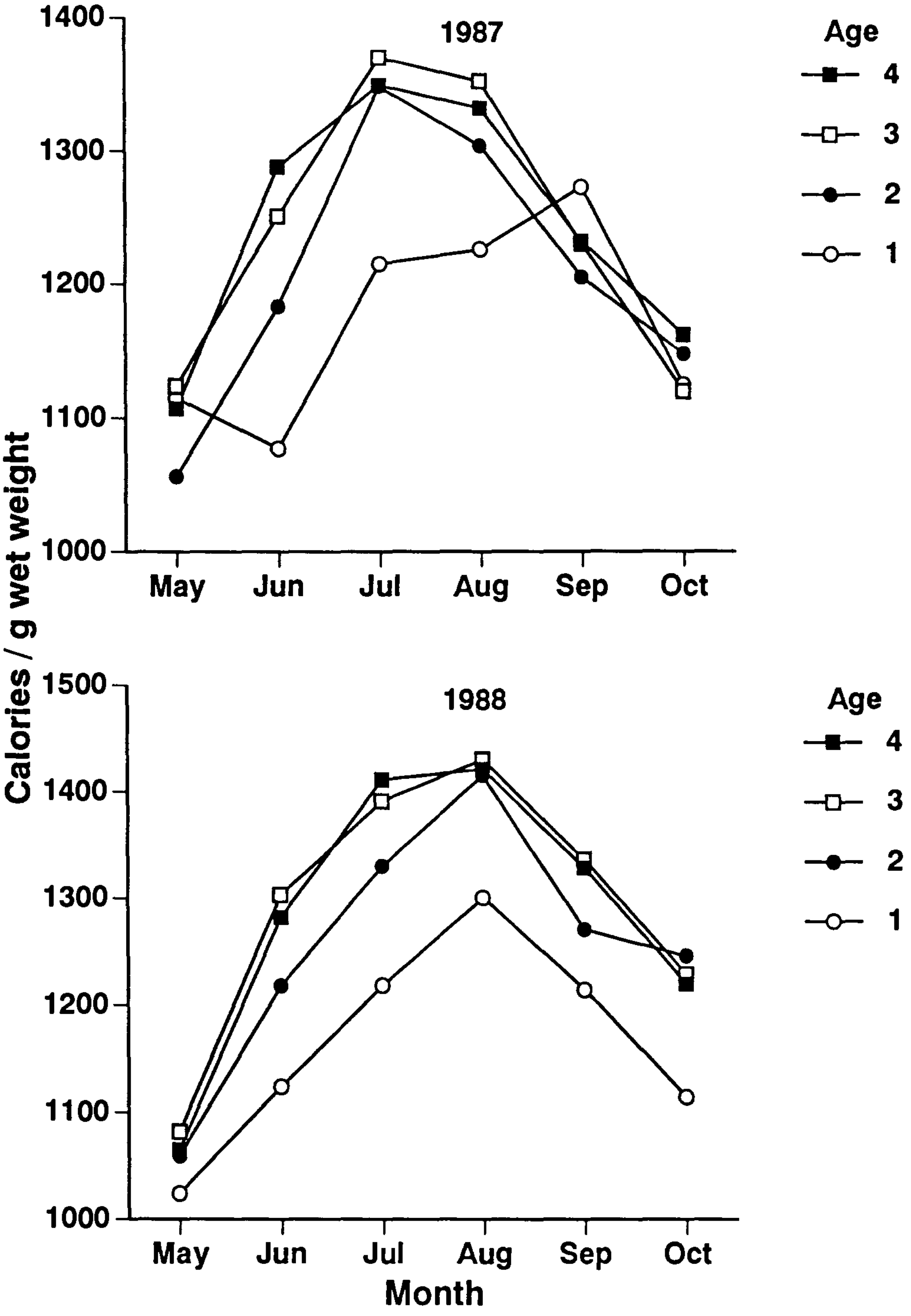


Figure 7.—Caloric densities of yellow perch in Saginaw Bay, Lake Huron, during 1987-1988, estimated from percent water data and Craig (1977).

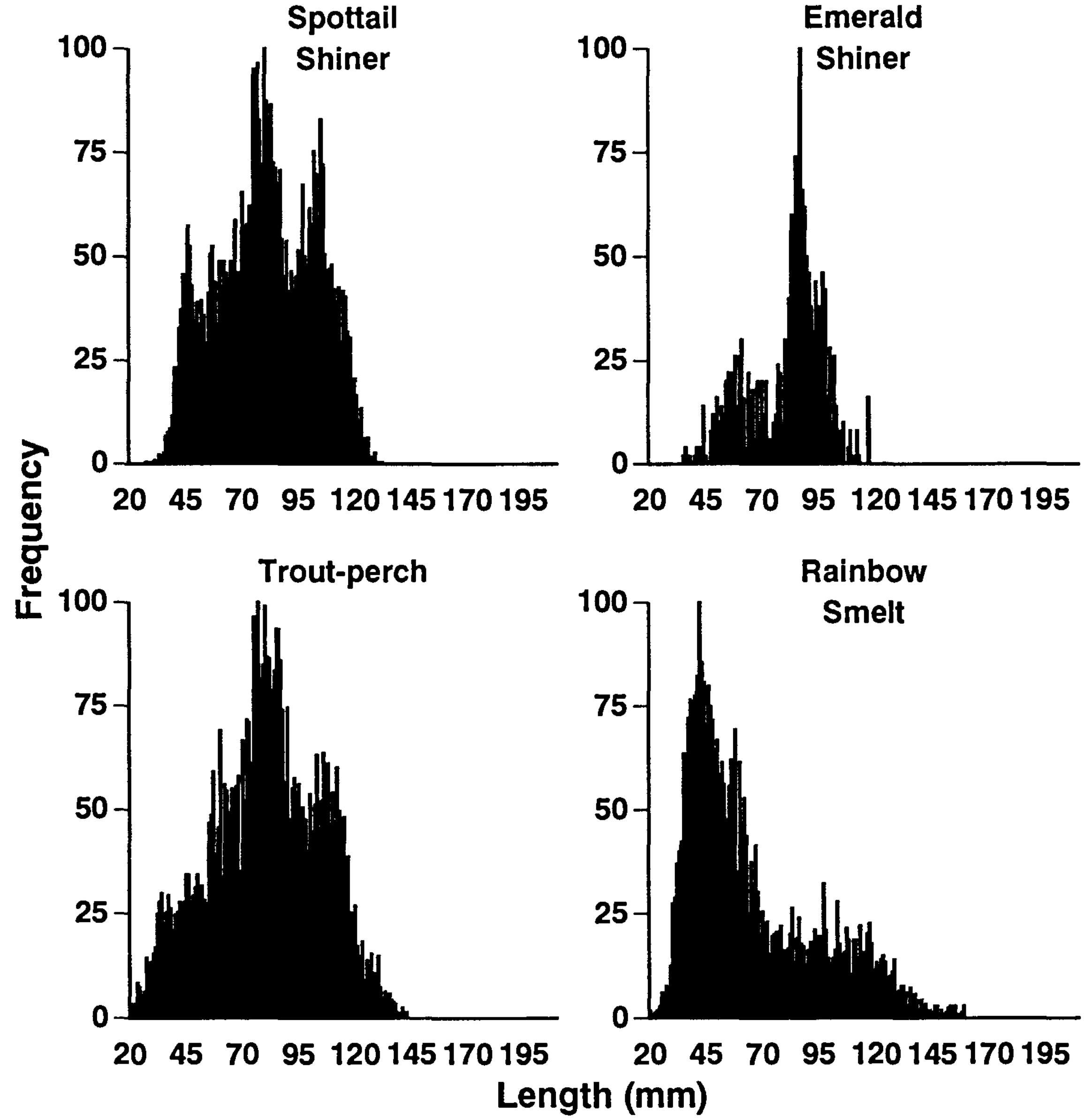
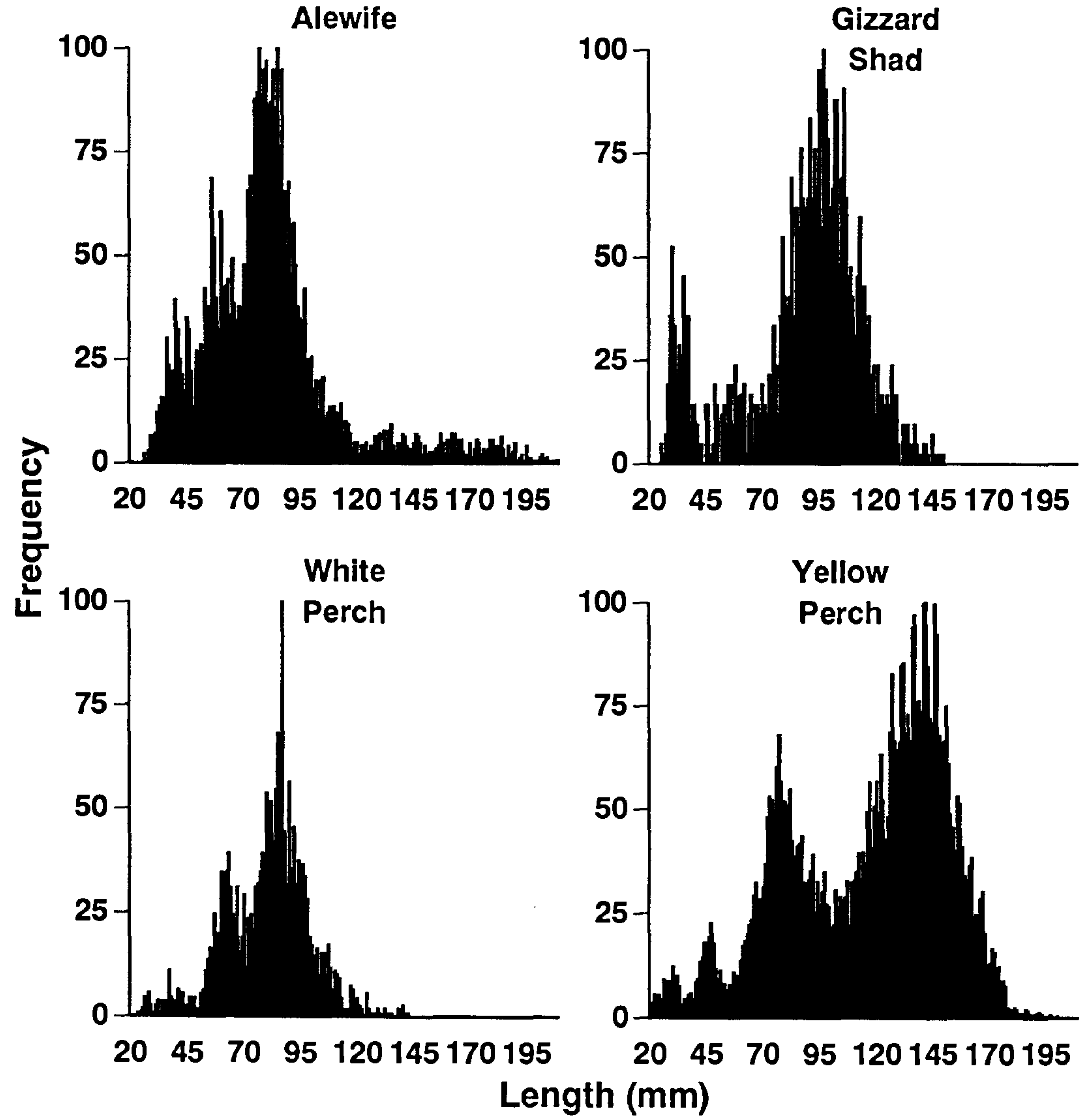


Figure 8.—Combined length frequency for major forage species caught in bottom trawls in Saginaw Bay, Lake Huron during 1986-1988. Frequencies were standardized to peak at 100.



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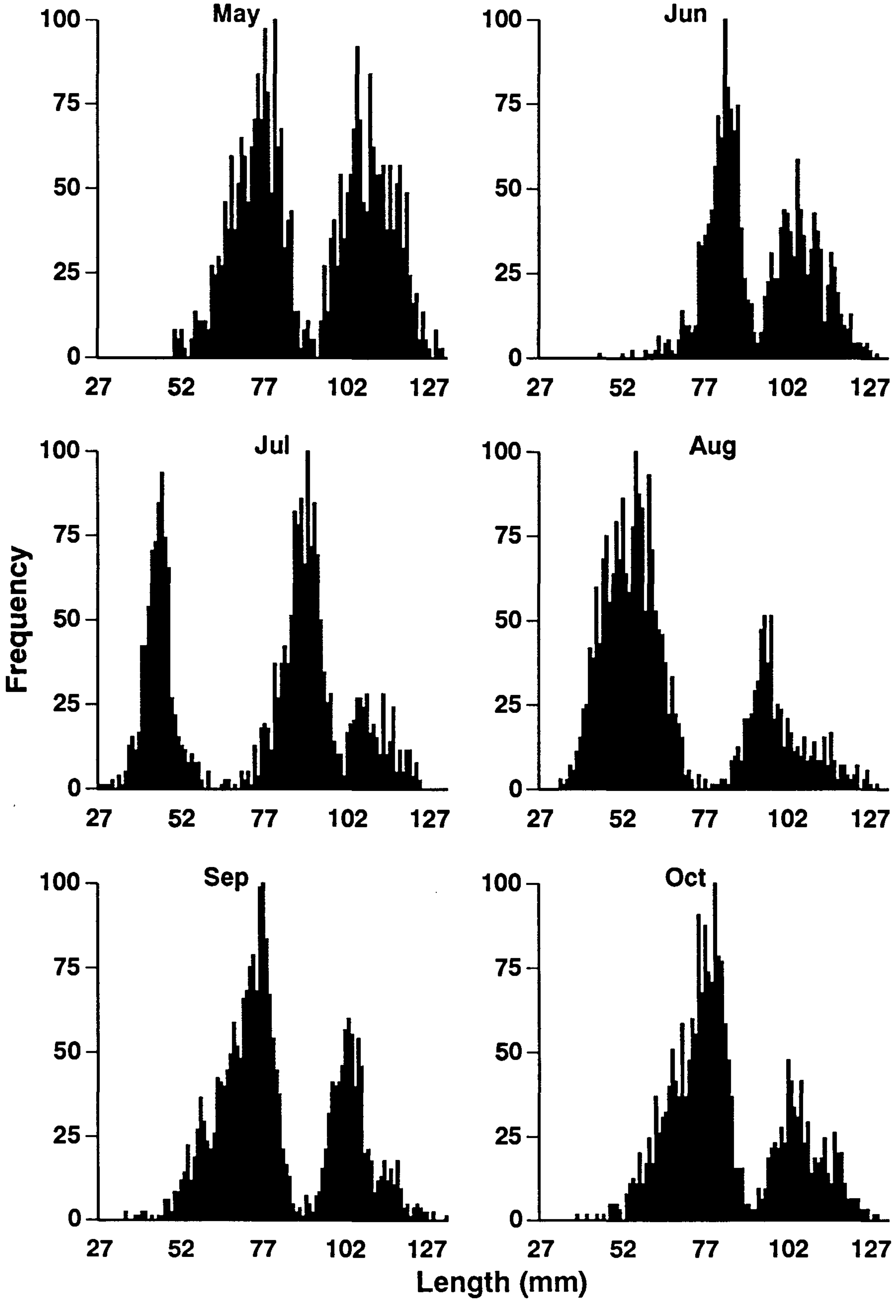


Figure 9.—Monthly length frequency (mm) of spottail shiners caught in bottom trawls in Saginaw Bay, Lake Huron during 1986-1988. Frequencies were standardized to peak at 100.

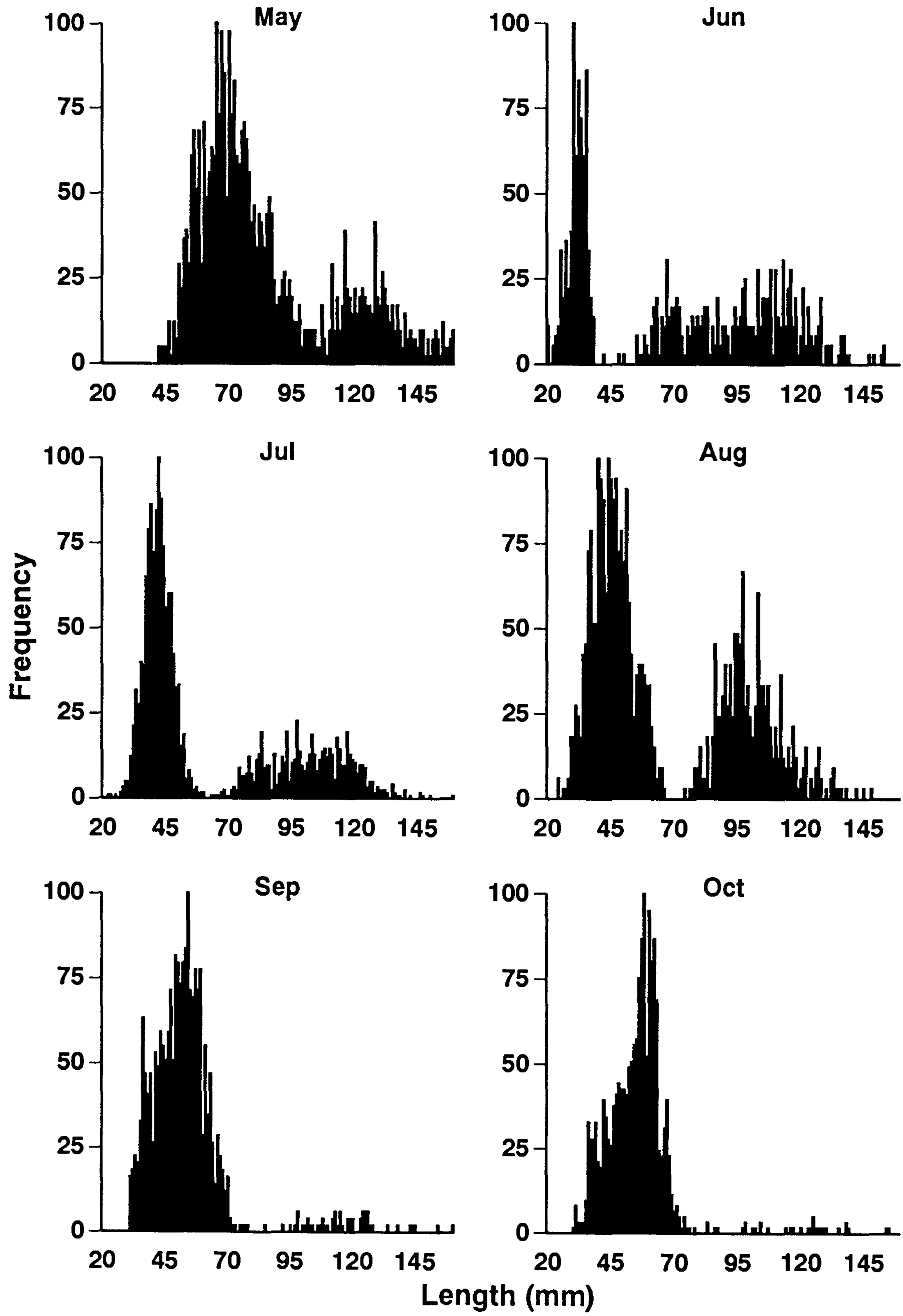


Figure 10.—Monthly length frequency (mm) of rainbow smelt caught in bottom trawls in Saginaw Bay, Lake Huron during 1986-1988. Frequencies were standardized to peak at 100.

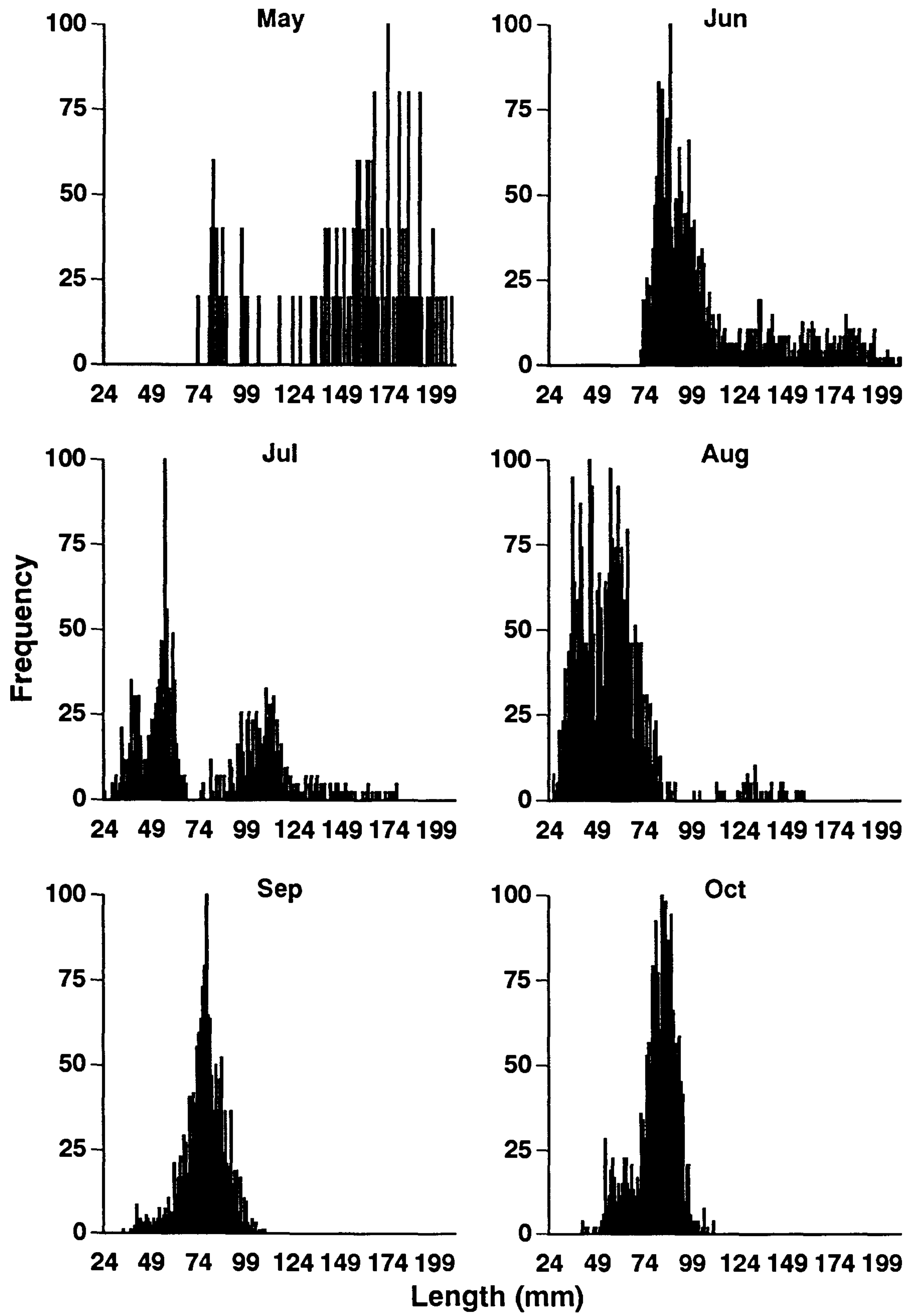


Figure 11.—Monthly length frequency (mm) of alewife caught in bottom trawls in Saginaw Bay, Lake Huron during 1986-1988. Frequencies were standardized to peak at 100.

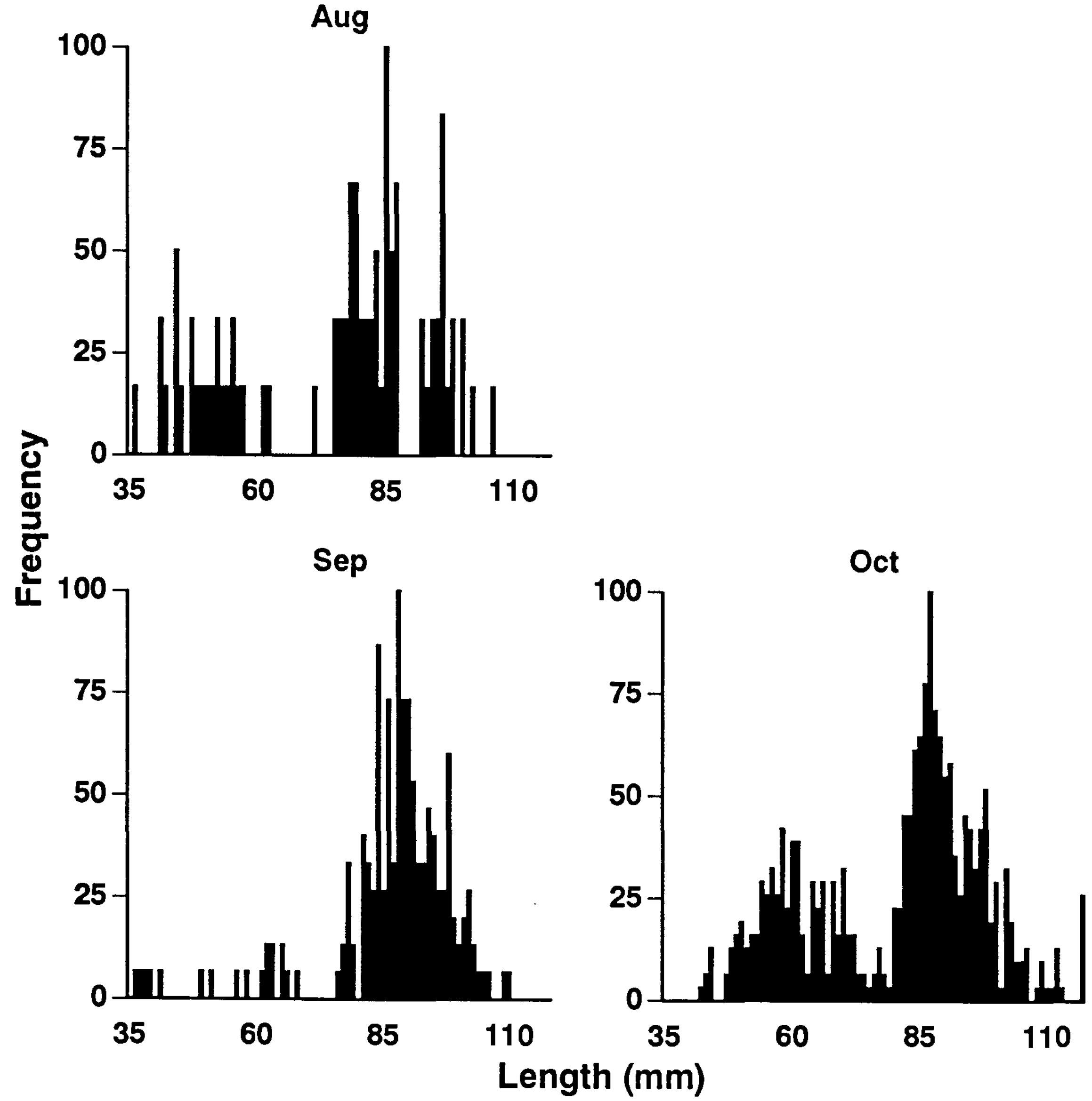


Figure 12.—Monthly length frequency (mm) of emerald shiner caught in bottom trawls in Saginaw Bay, Lake Huron during 1986-1988. Frequencies were standardized to peak at 100.

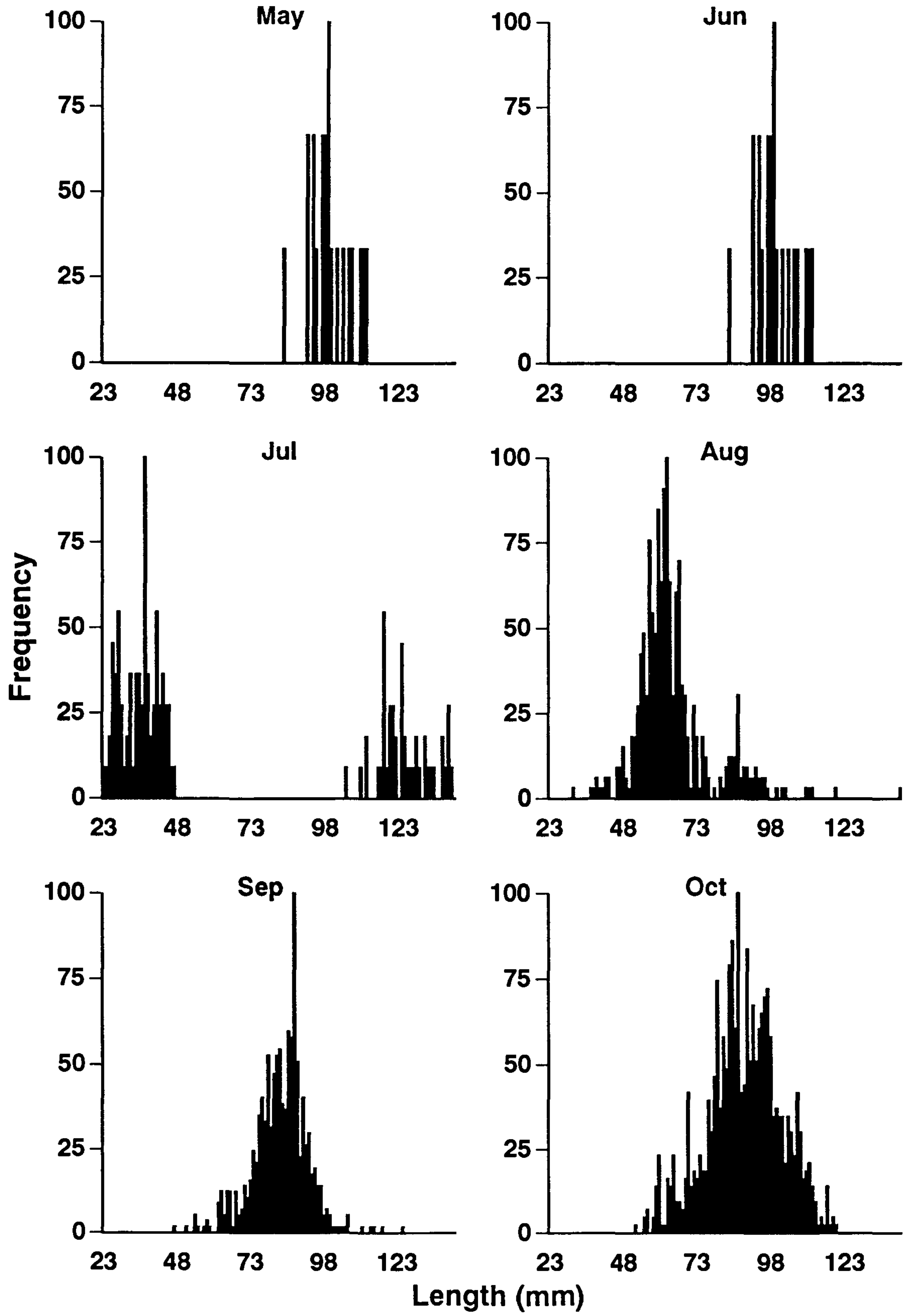


Figure 13.—Monthly length frequency (mm) of white perch caught in bottom trawls in Saginaw Bay, Lake Huron during 1986-1988. Frequencies were standardized to peak at 100.

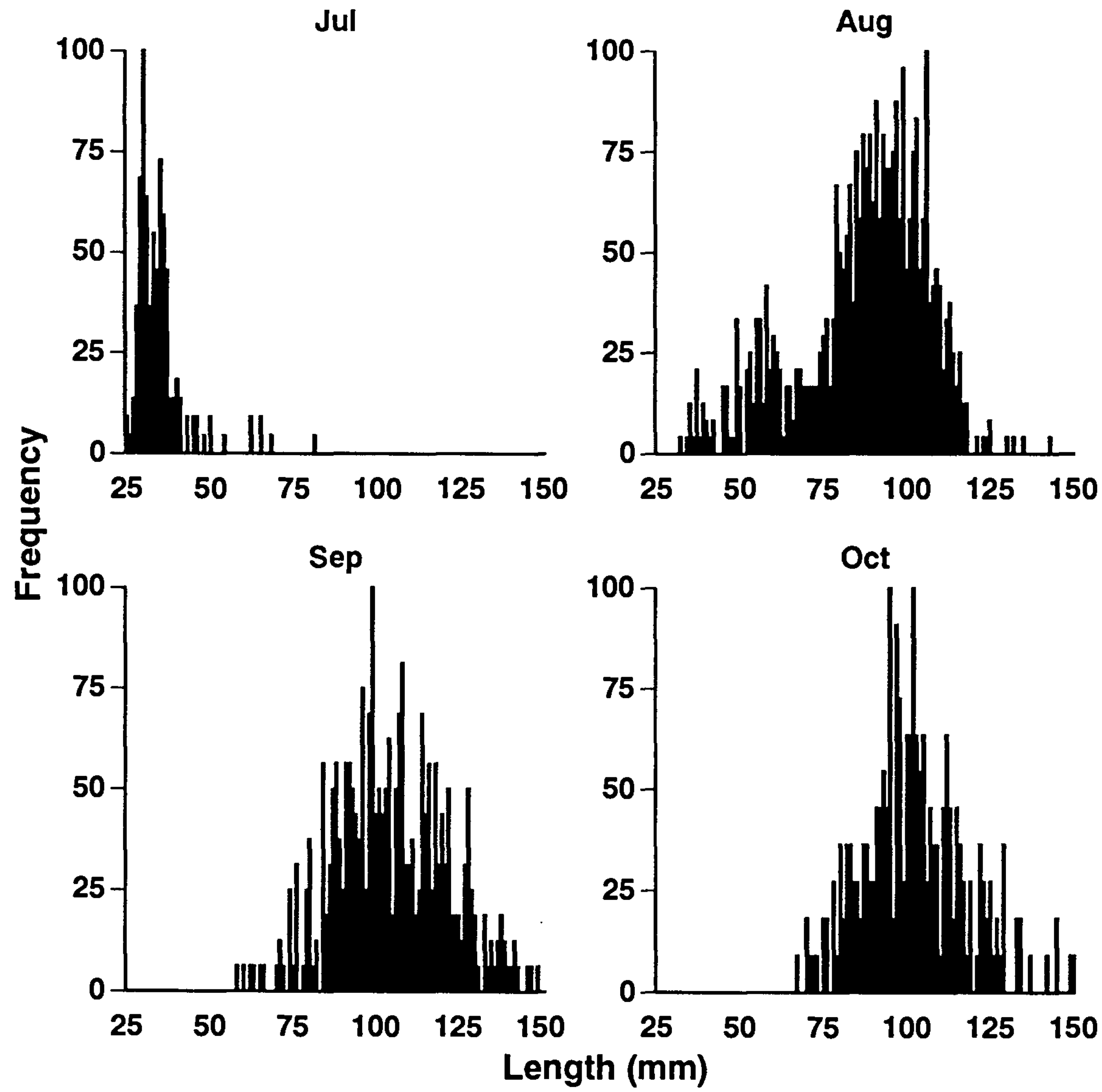


Figure 14.—Monthly length frequency (mm) of gizzard shad caught in bottom trawls in Saginaw Bay, Lake Huron during 1986-1988. Frequencies were standardized to peak at 100.

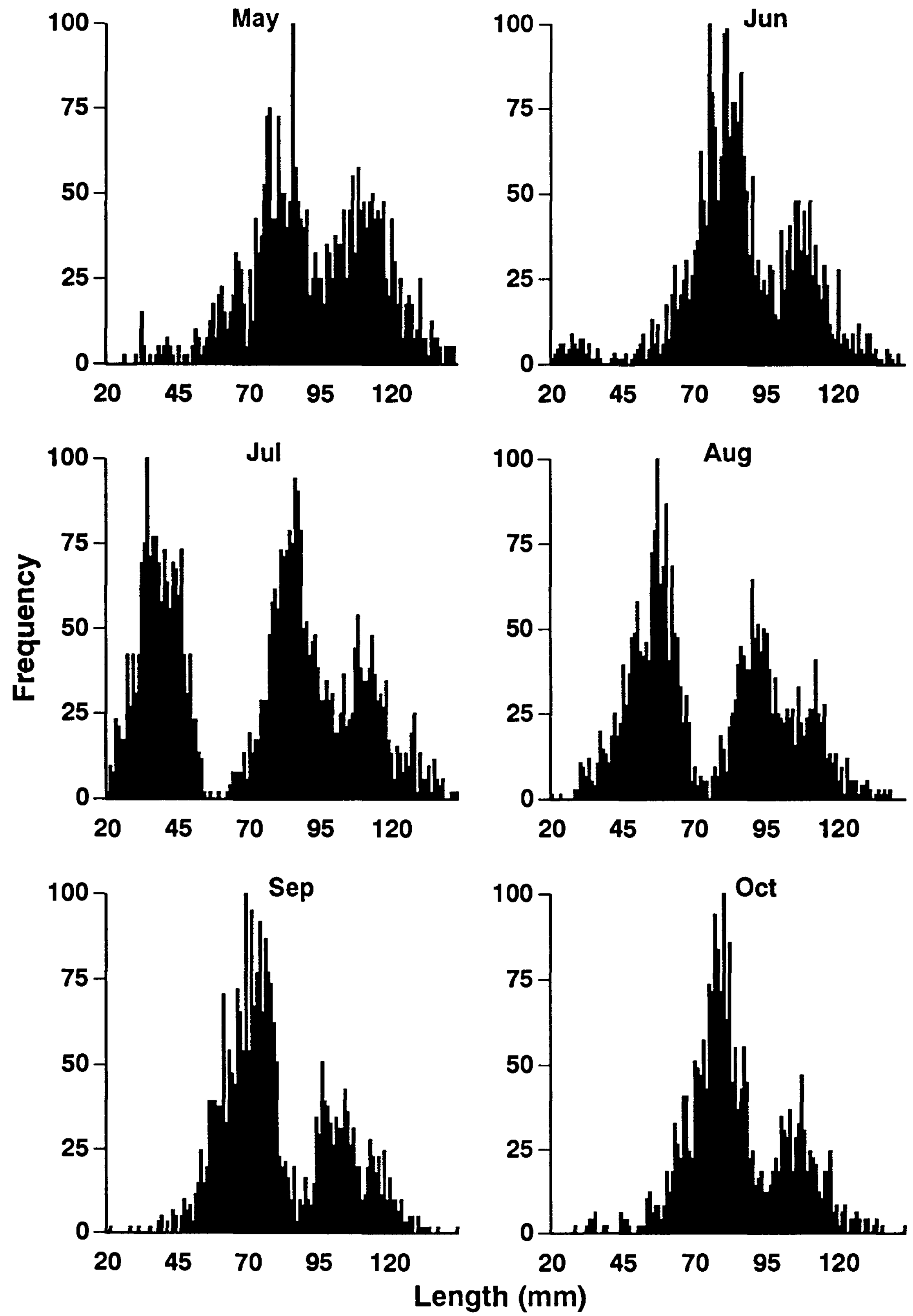


Figure 15.—Monthly length frequency (mm) of trout-perch caught in bottom trawls in Saginaw Bay, Lake Huron during 1986-1988. Frequencies were standardized to peak at 100.

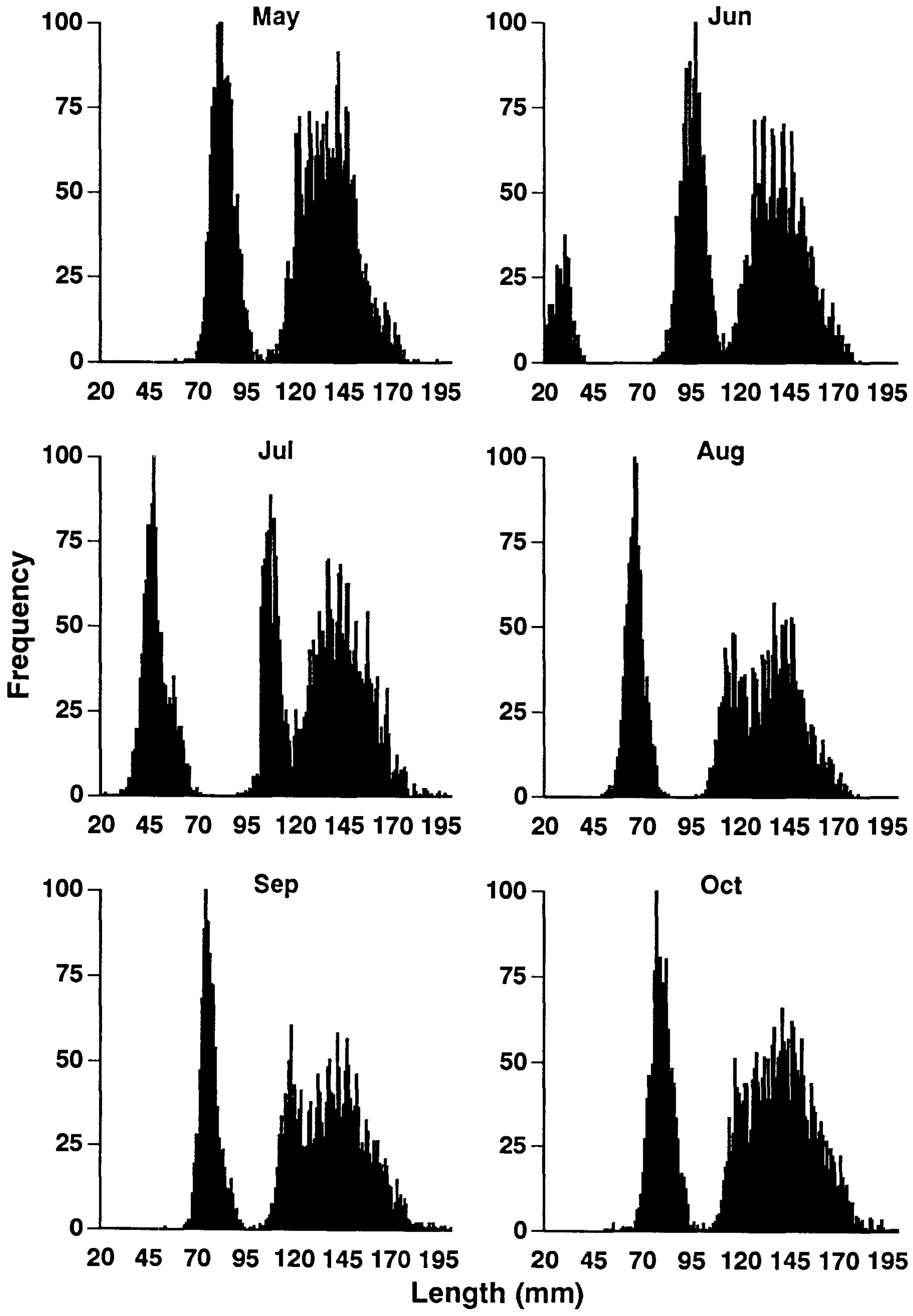


Figure 16.—Monthly length frequency (mm) of yellow perch caught in bottom trawls in Saginaw Bay, Lake Huron during 1986-1988. Frequencies were standardized to peak at 100.

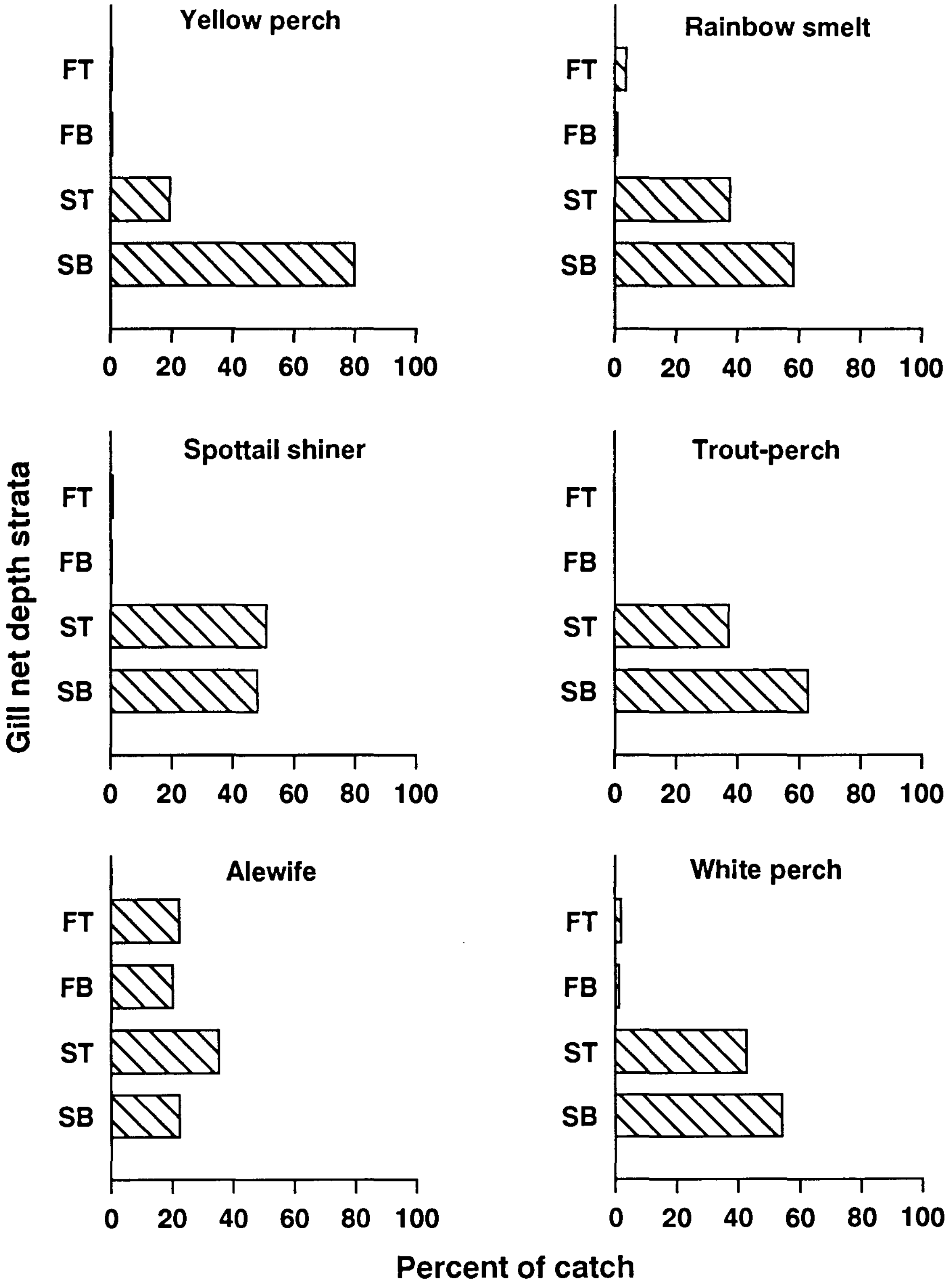
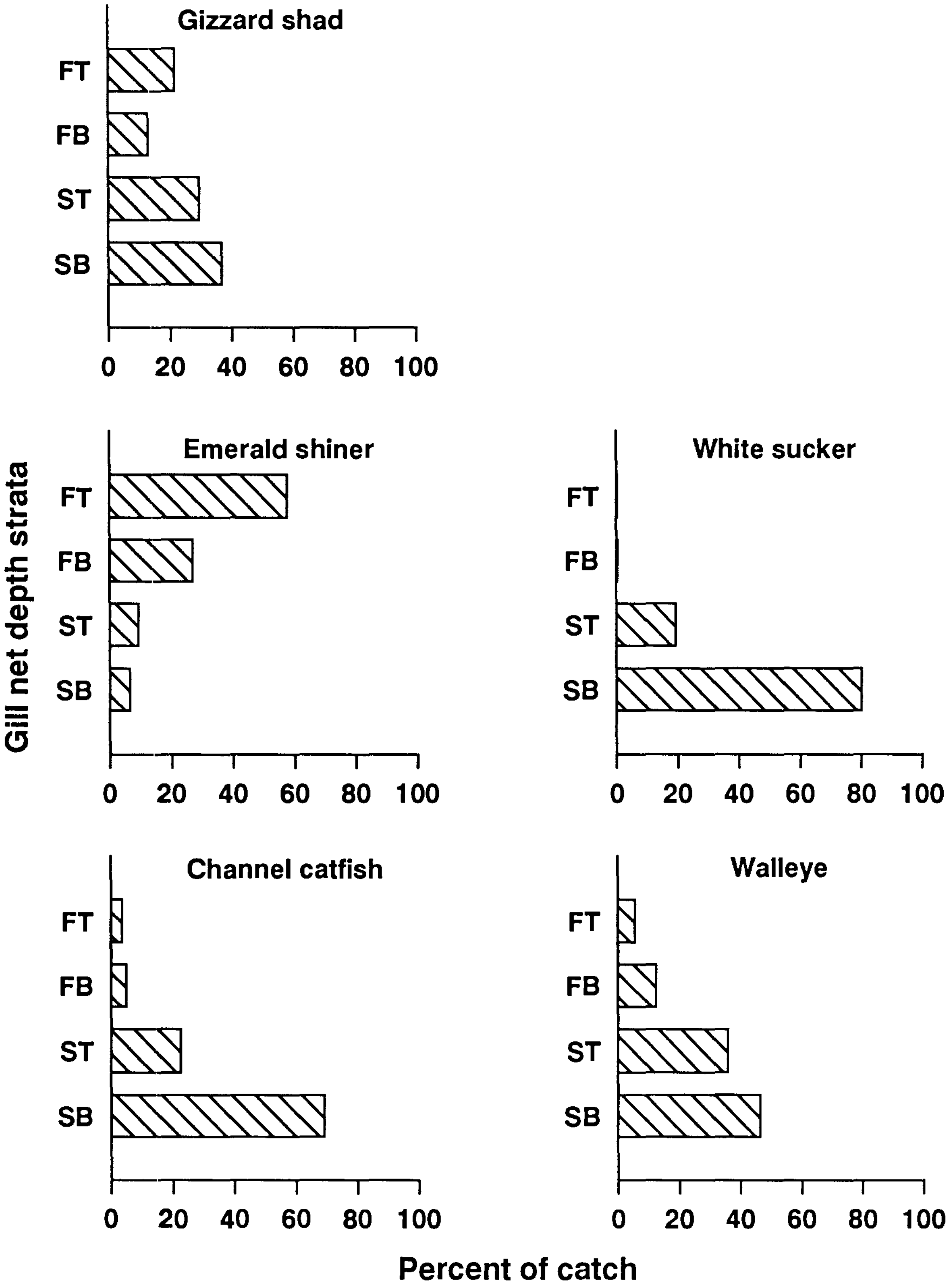


Figure 17.—Depth distribution of 11 major fish species caught in 1-m panels of vertically stratified gill nets in Saginaw Bay, Lake Huron during 1986-1988. (FT and FB denote top and bottom halves of floating gill nets, ST and SB denote top and bottom halves of sinking gill nets.)



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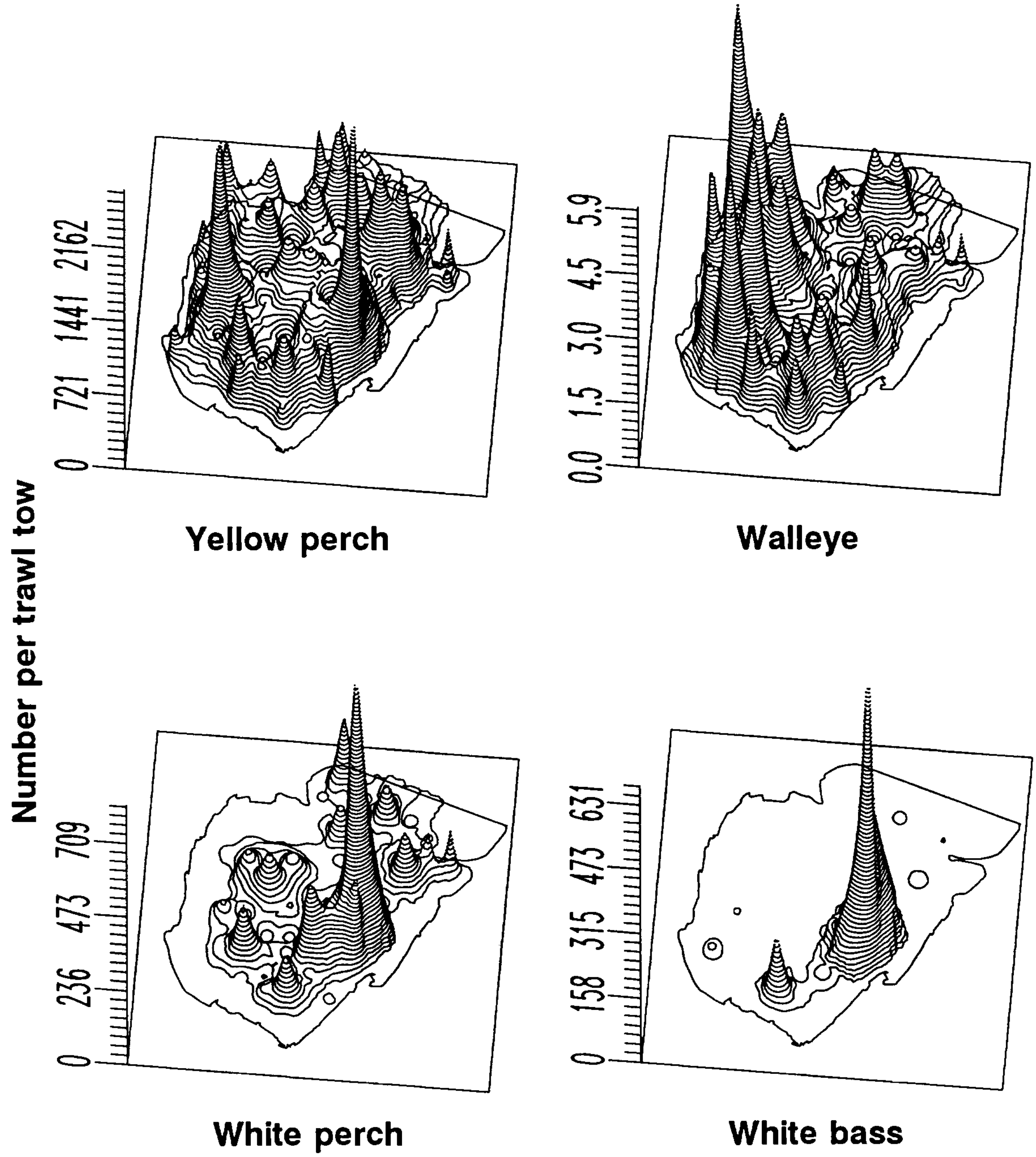


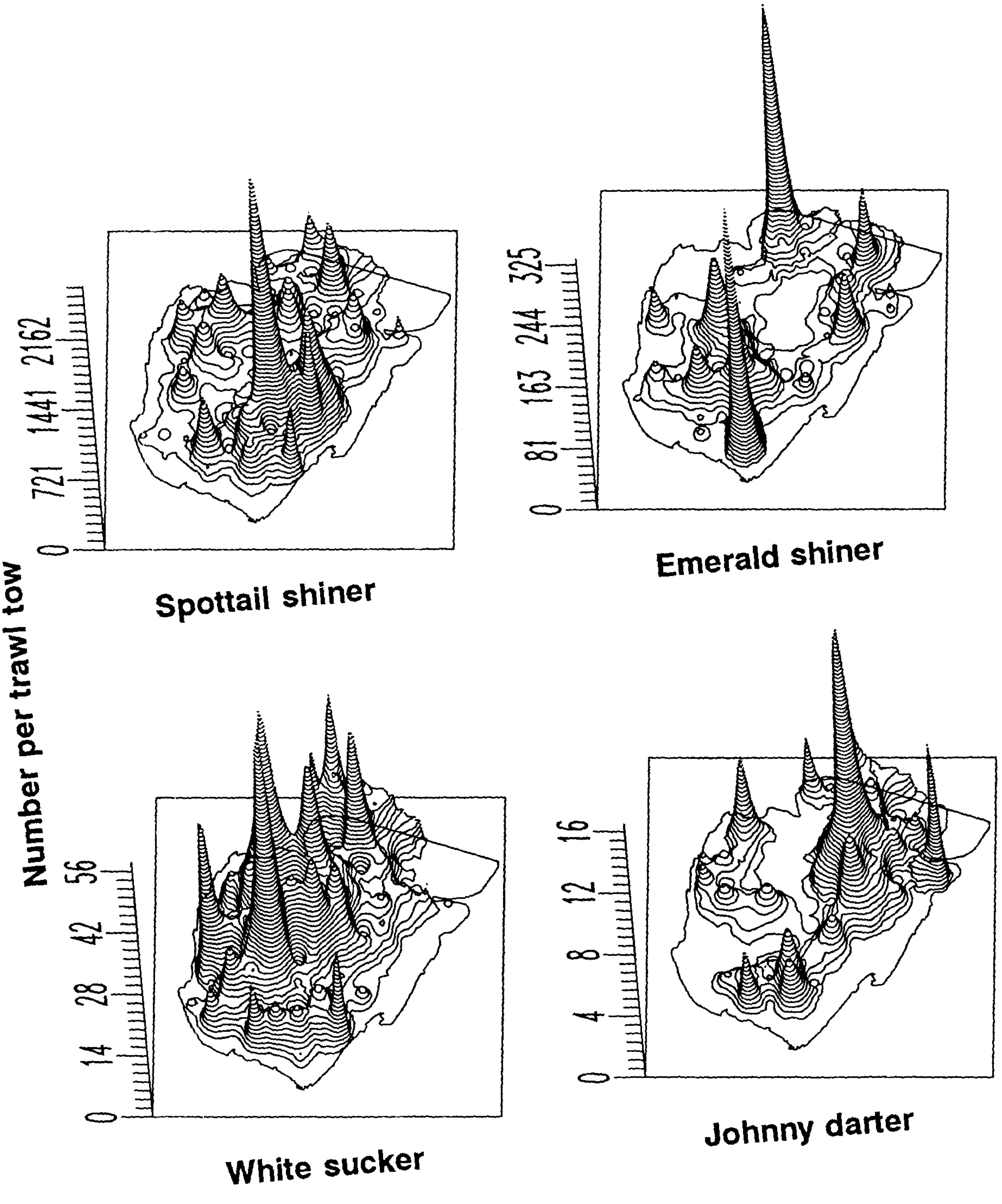
Yellow perch

Walleye

White perch

White bass

Figure 18.—Three dimensional graphs of the areal distribution of 15 fish species superimposed on a map of Saginaw Bay, Lake Huron. Distributions were estimated from bottom trawl CPUE data taken during 1986-1988, and were gridded using an inverse distance algorithm.



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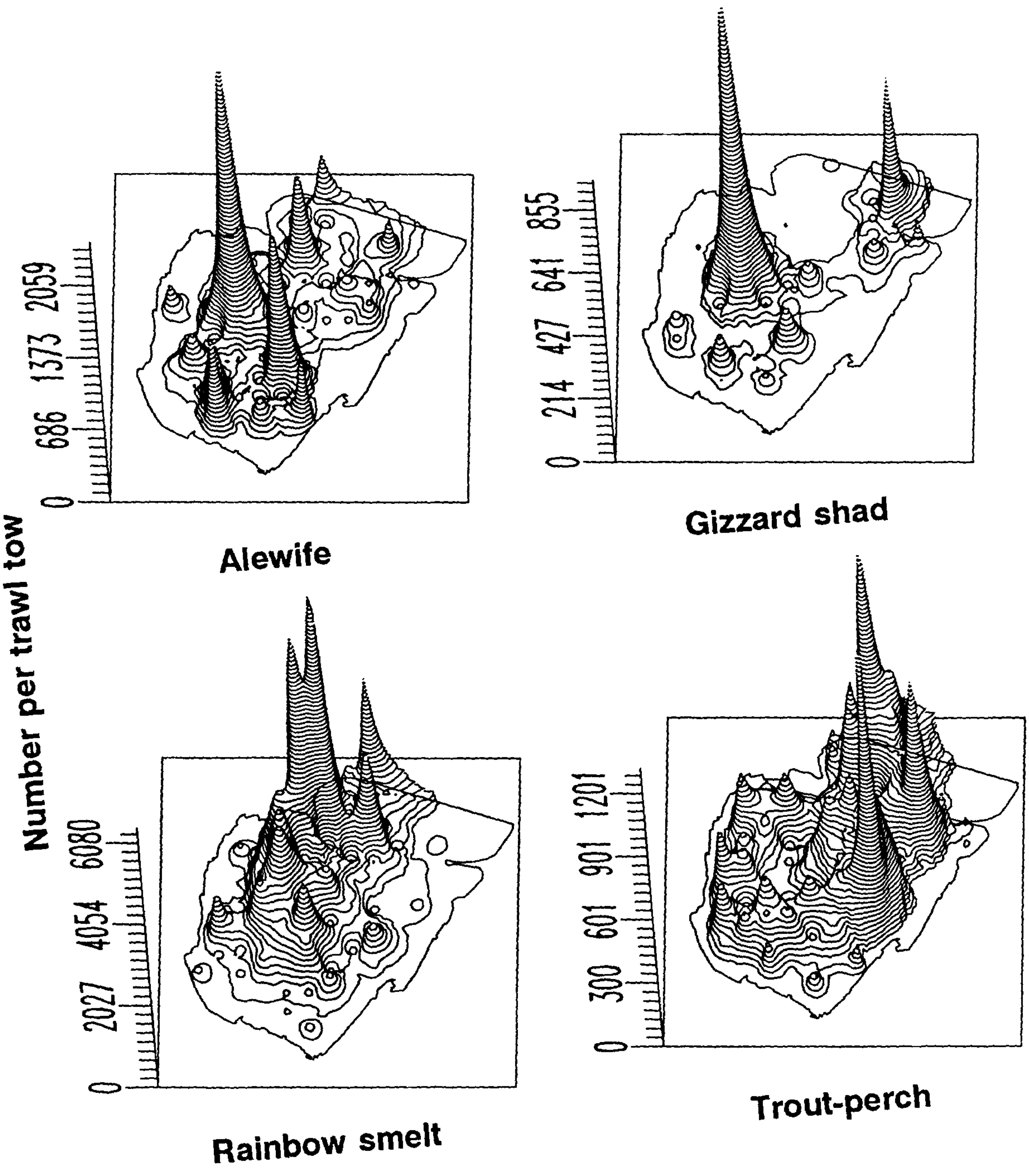

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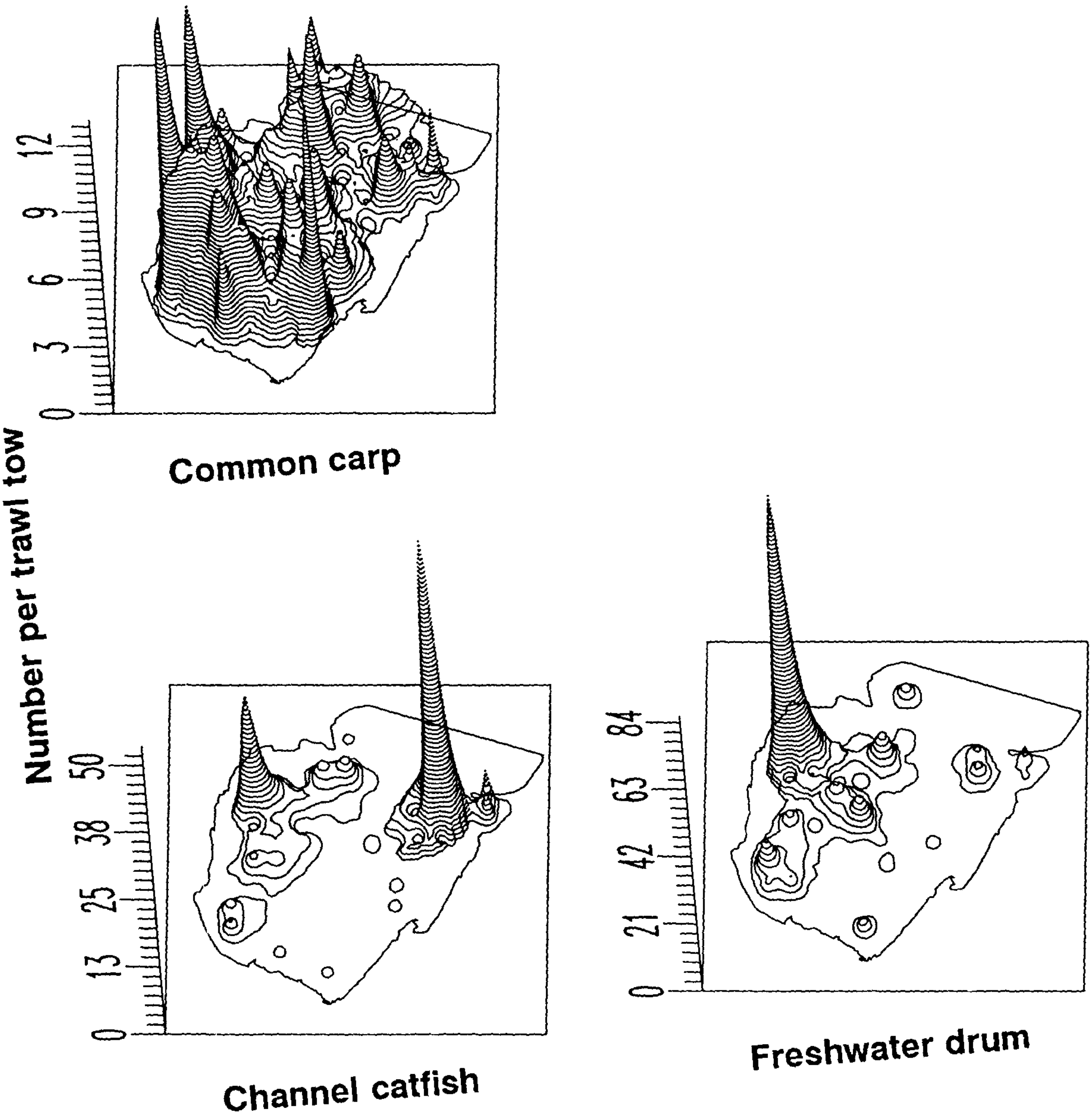

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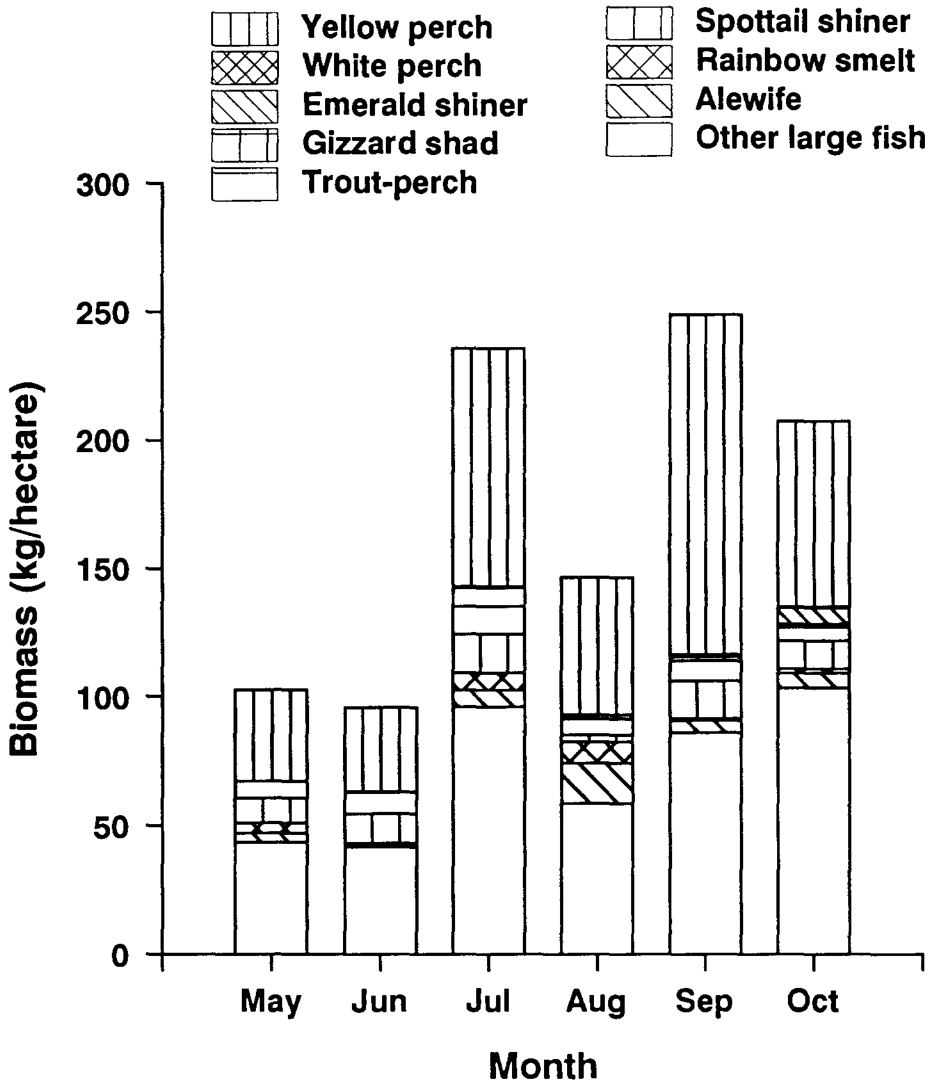


Figure 19.—Monthly biomass of all species caught in bottom trawls in the inner portion of Saginaw Bay, Lake Huron during 1986.

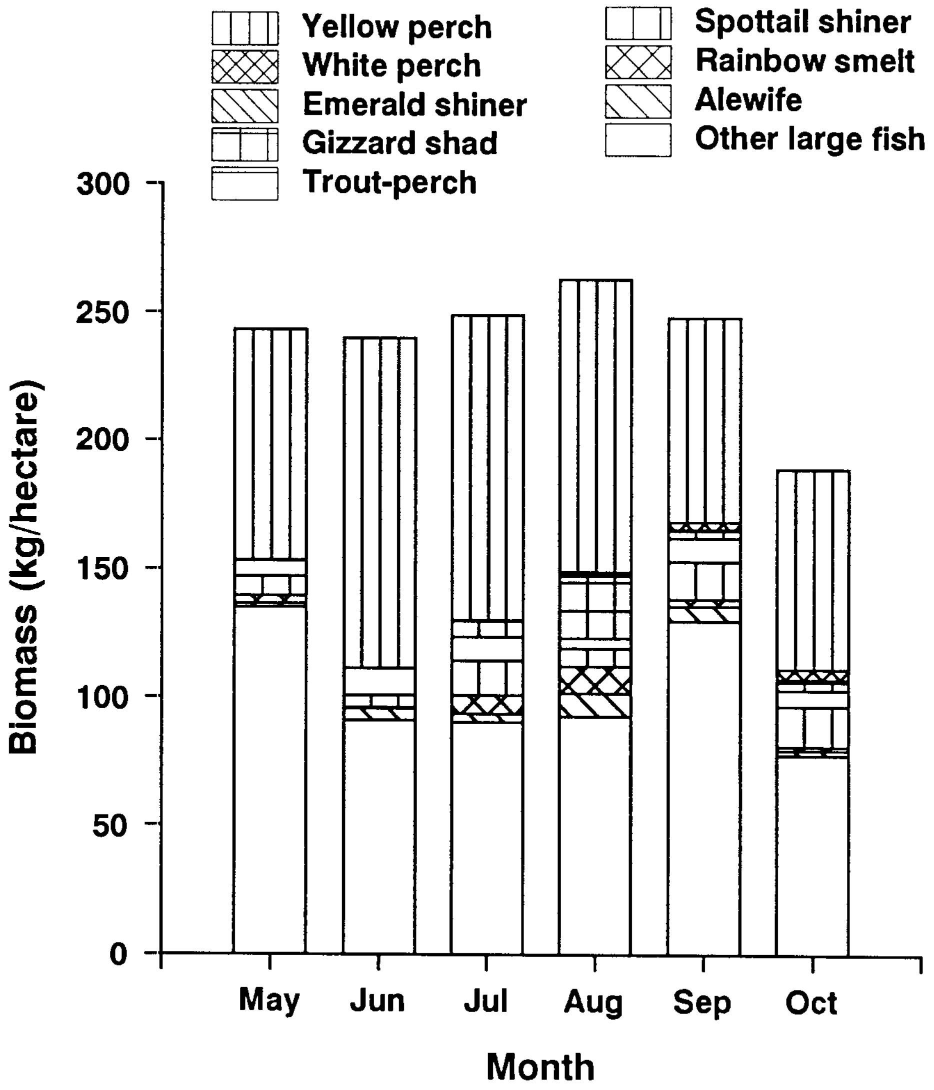


Figure 20.—Monthly biomass of all species caught in bottom trawls in the inner portion of Saginaw Bay, Lake Huron during 1987.

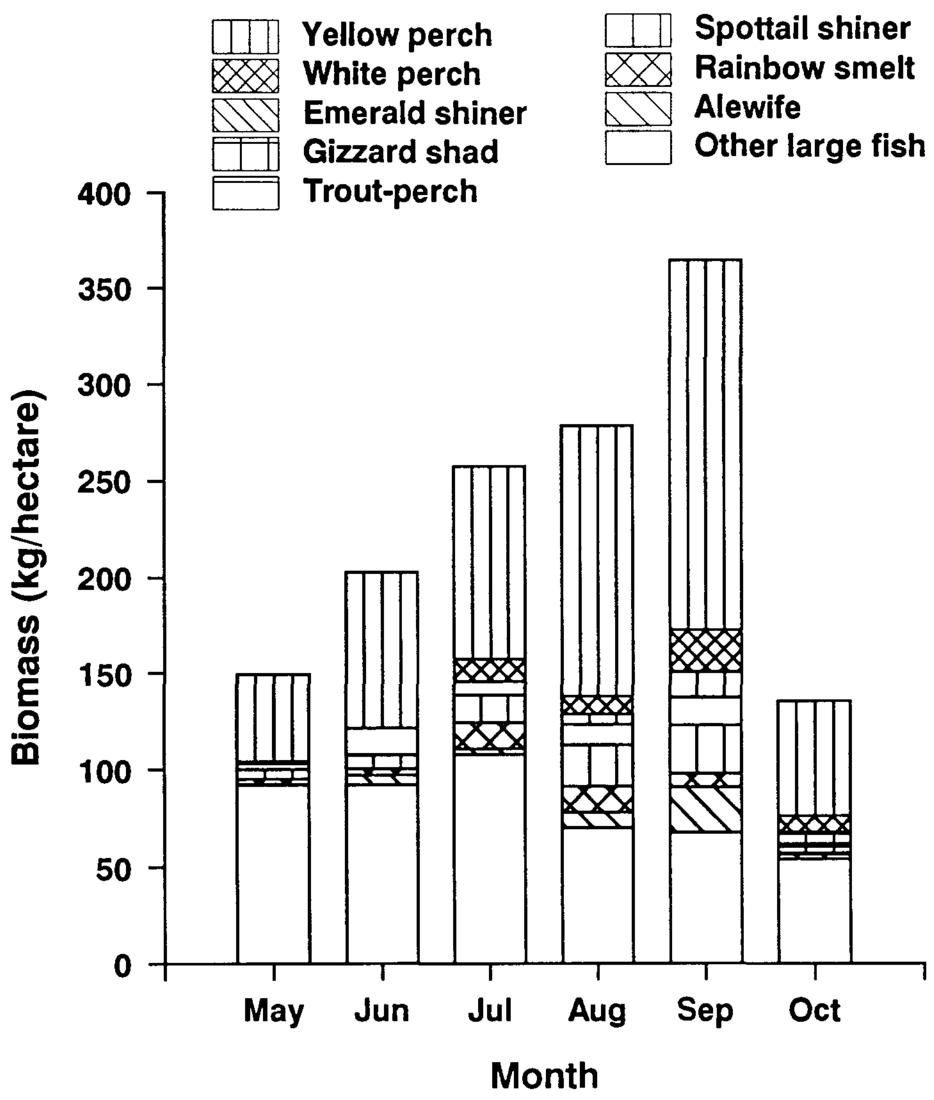


Figure 21.—Monthly biomass of all species caught in bottom trawls in the inner portion of Saginaw Bay, Lake Huron during 1988.

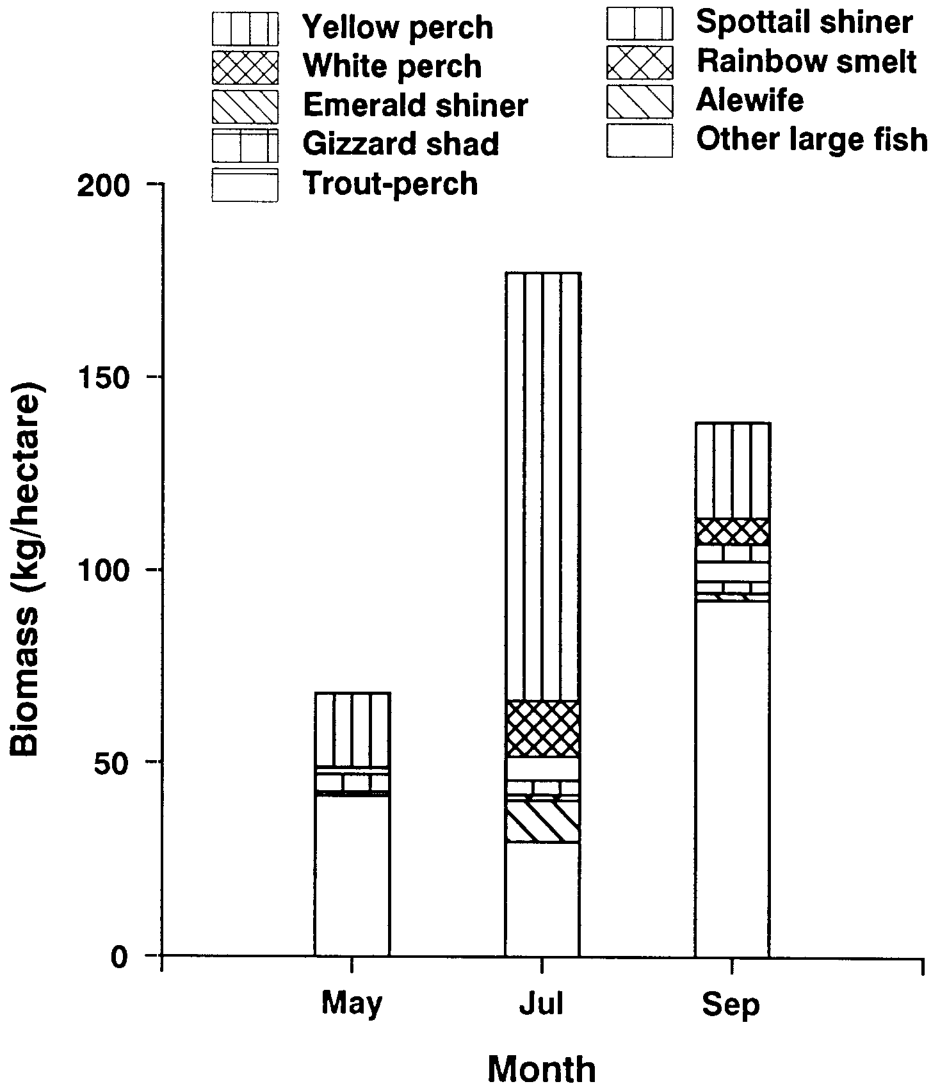


Figure 22.—Monthly biomass of all species caught in bottom trawls in the inner portion of Saginaw Bay, Lake Huron during 1991.

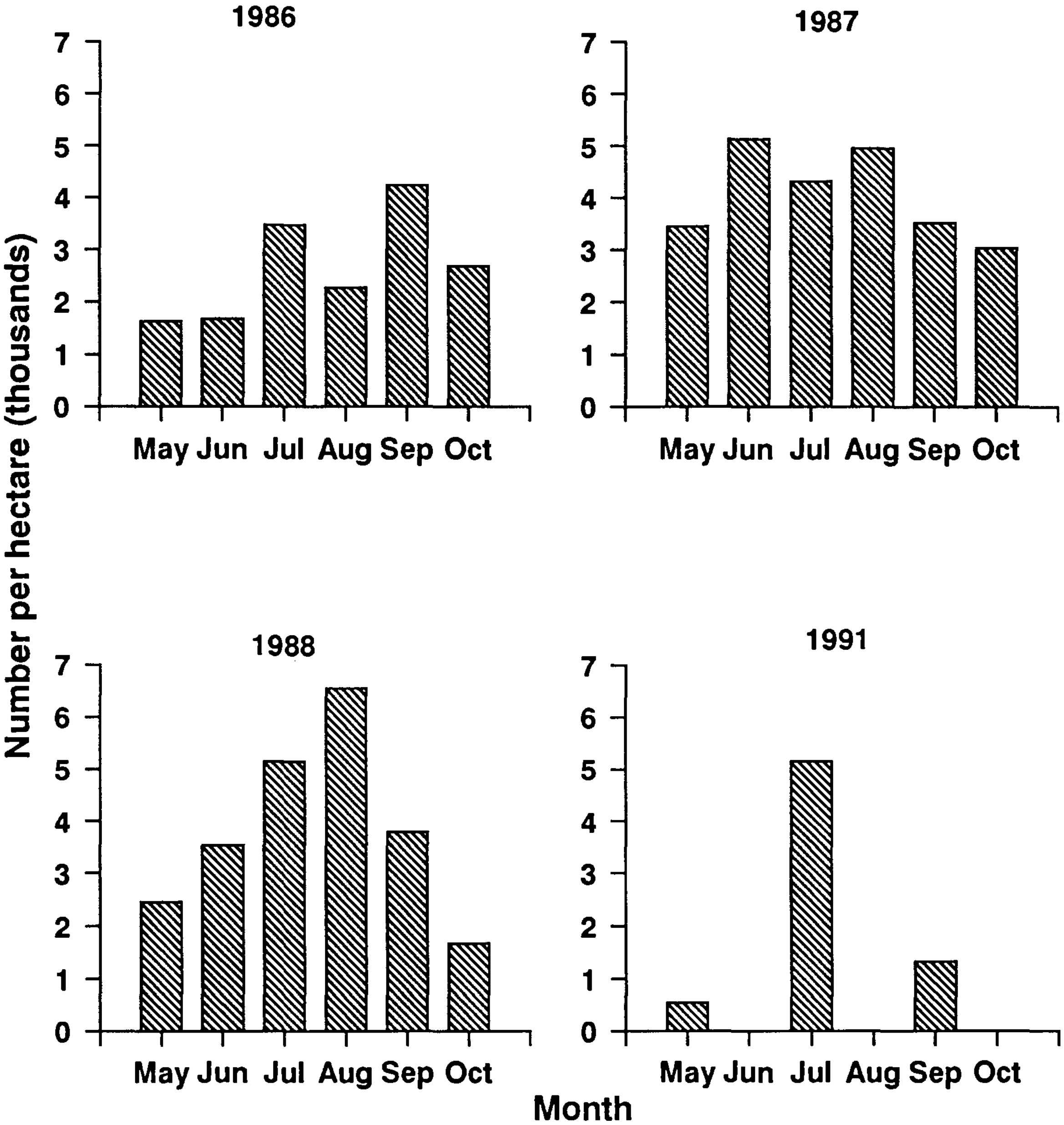


Figure 23.—Monthly abundance of yearling and older yellow perch in the inner portion of Saginaw Bay, Lake Huron estimated from bottom trawl CPUE.

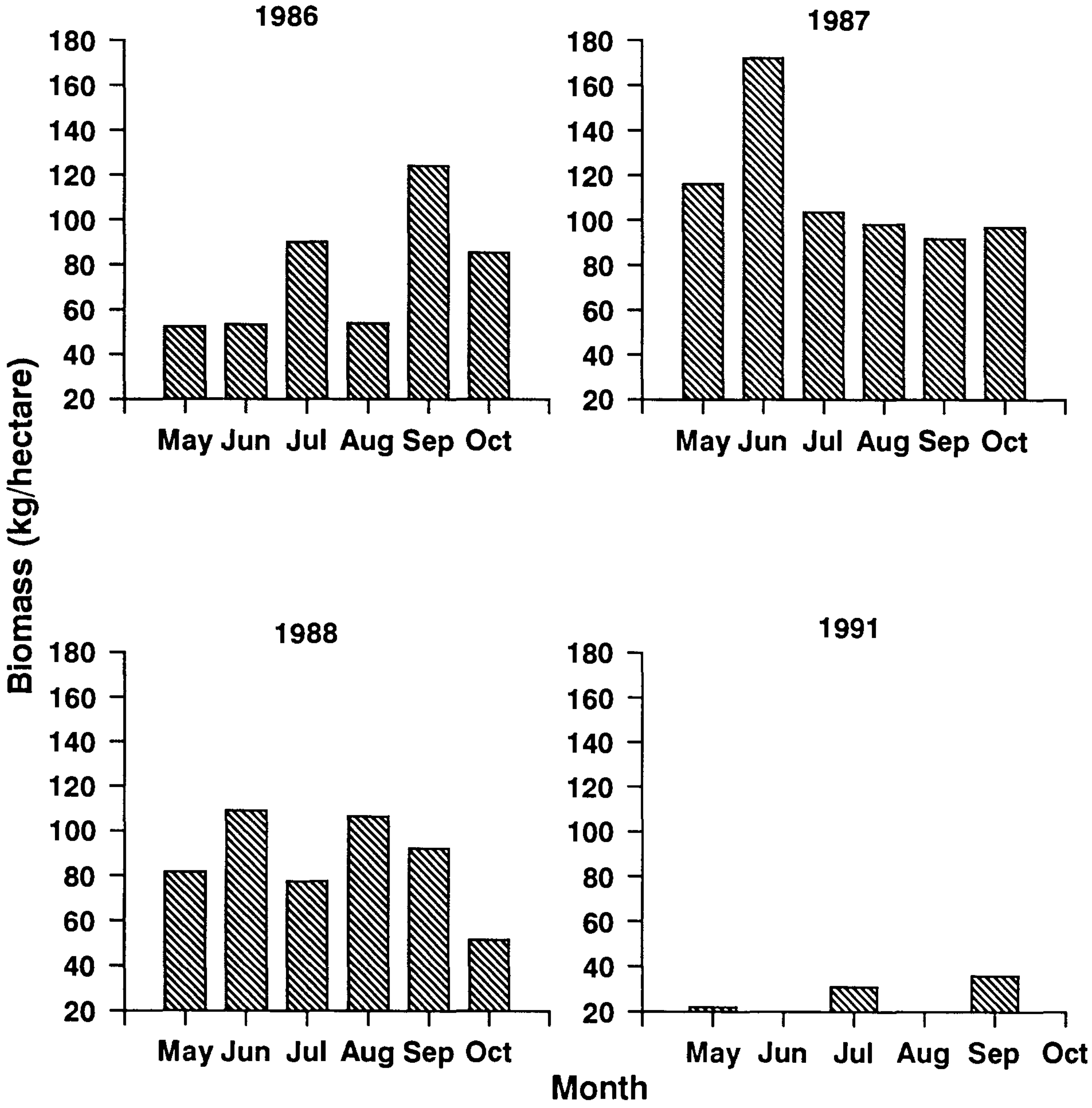


Figure 24.—Monthly biomass of yearling and older yellow perch in the inner portion of Saginaw Bay, Lake Huron estimated from bottom trawl CPUE.

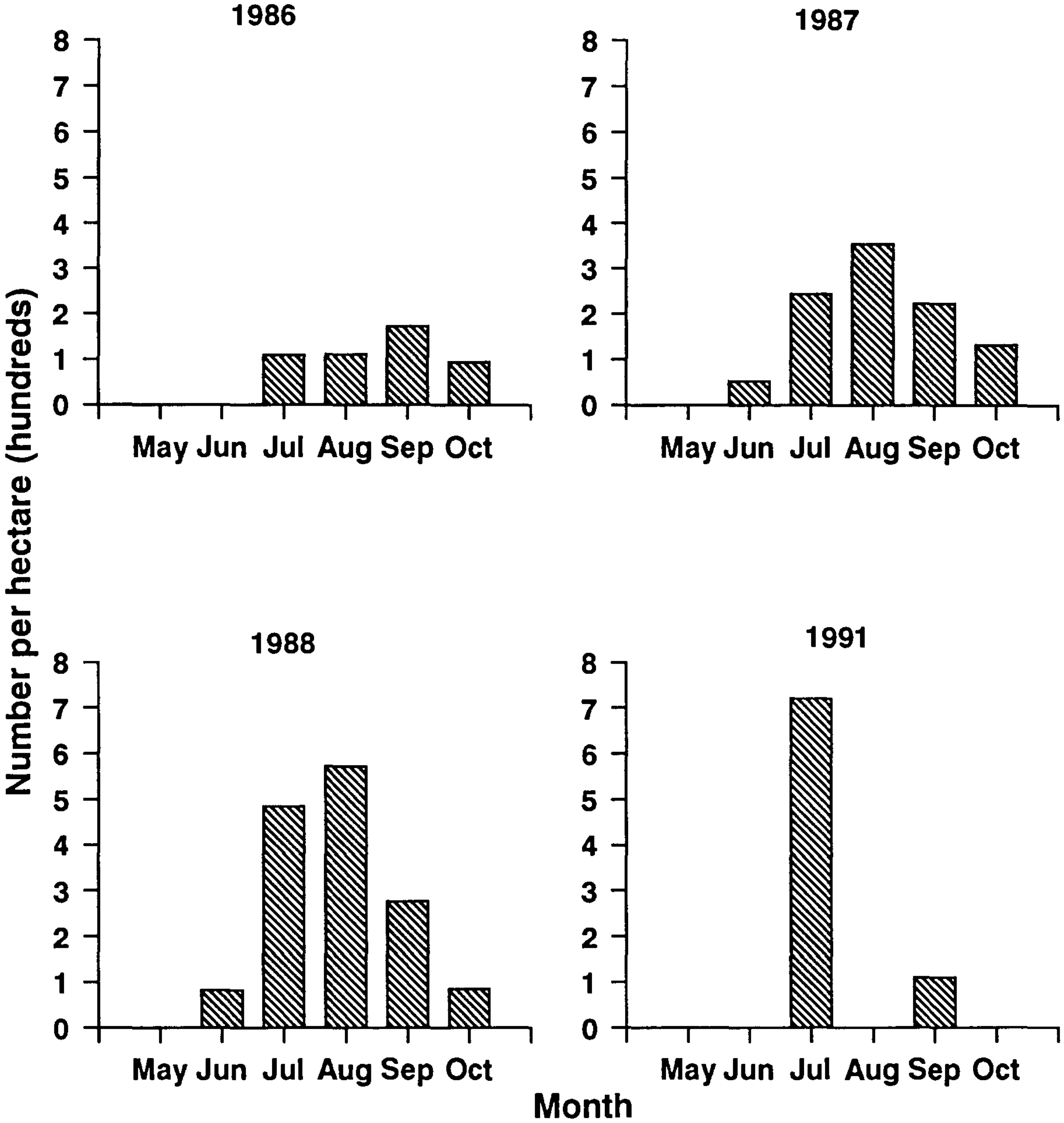


Figure 25.—Monthly abundance of young-of-the-year yellow perch in the inner portion of Saginaw Bay, Lake Huron estimated from bottom trawl CPUE.

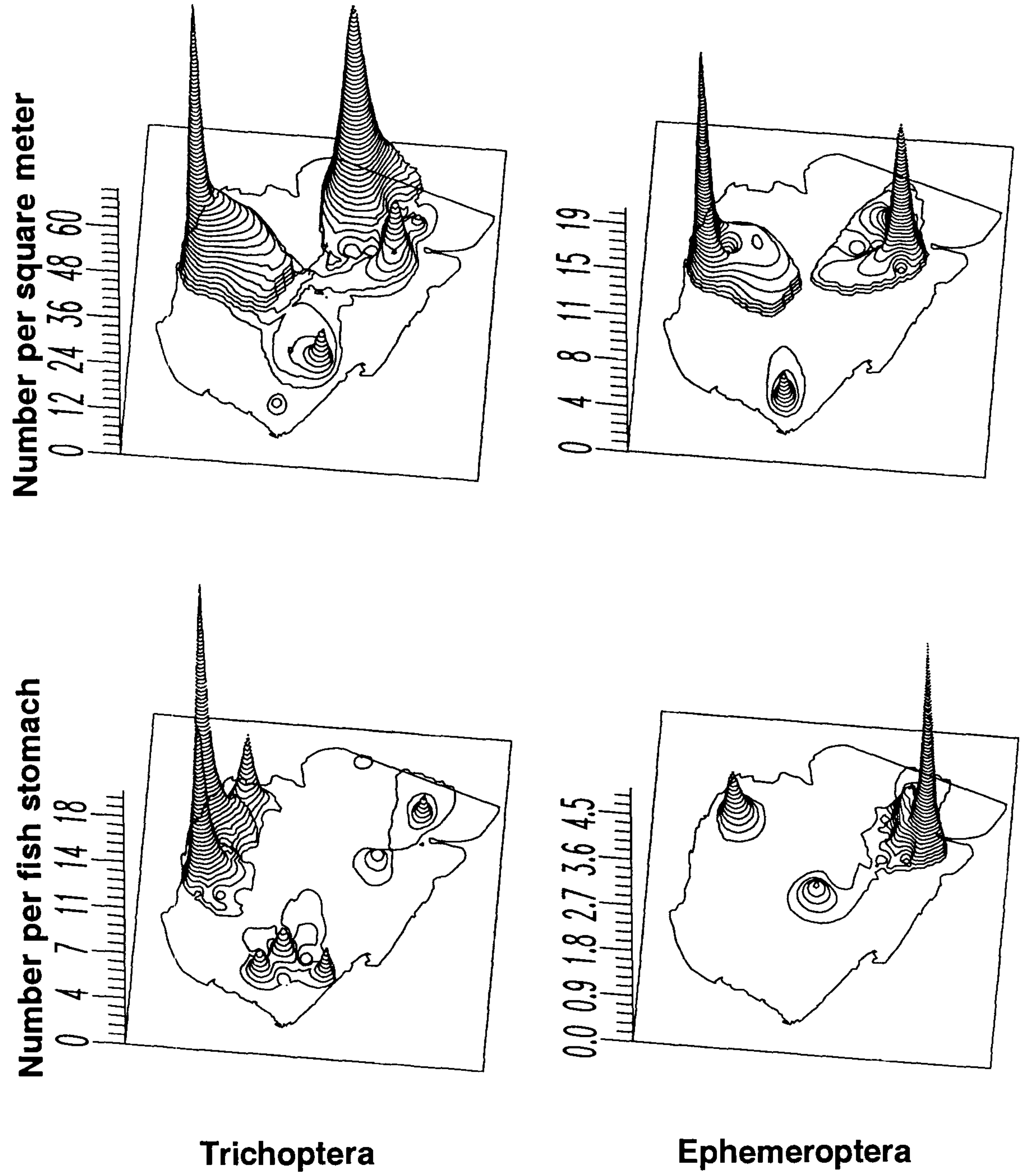
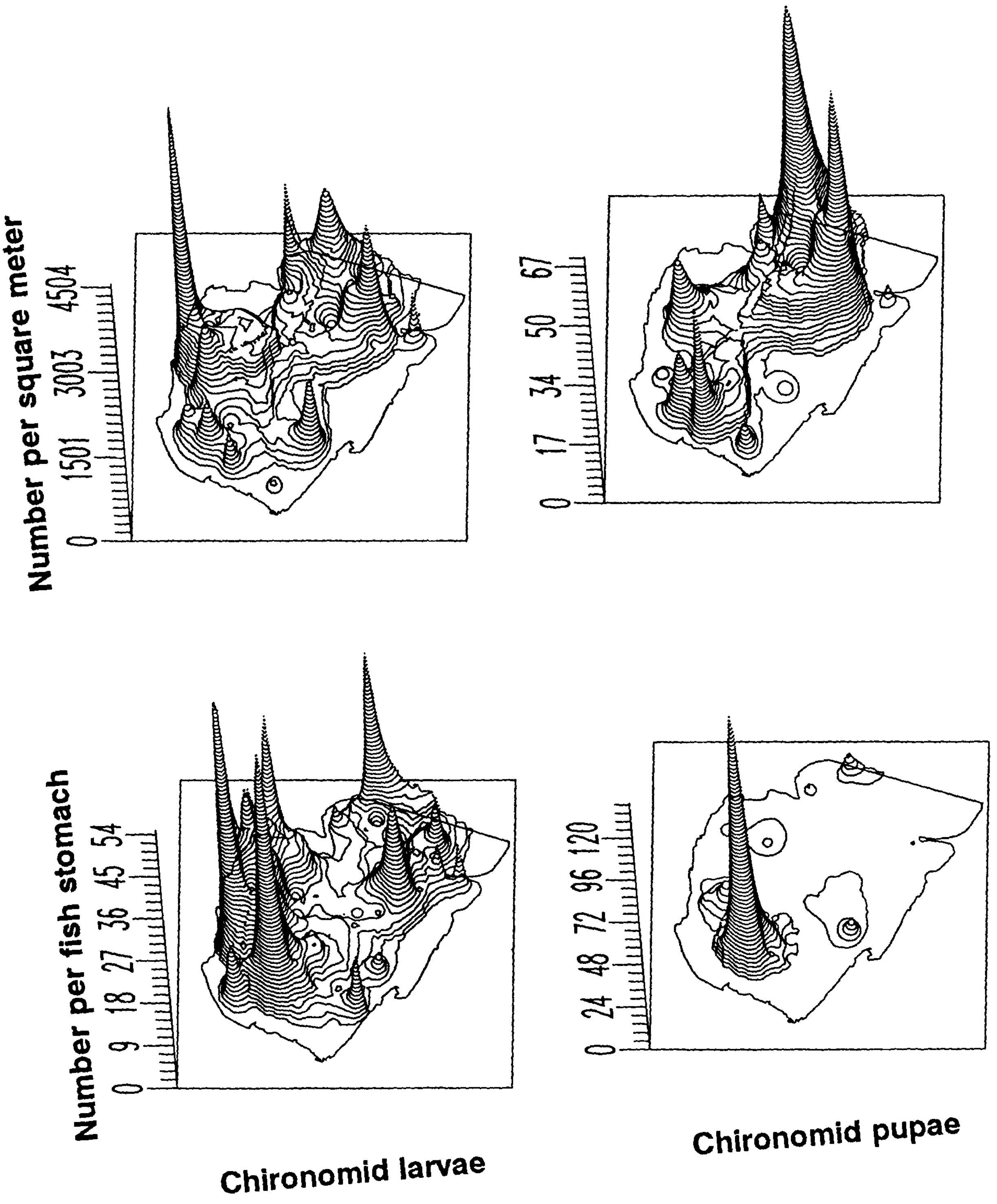


Figure 26.—Three dimensional graphs of the areal distribution of 10 benthic diet items and their numerical occurrence in yellow perch stomachs superimposed on a map of Saginaw Bay, Lake Huron. Distributions were estimated from stomach contents of yellow perch caught in bottom trawls and concurrent Ponar samples taken during 1986-1988, and were gridded using an inverse distance algorithm.



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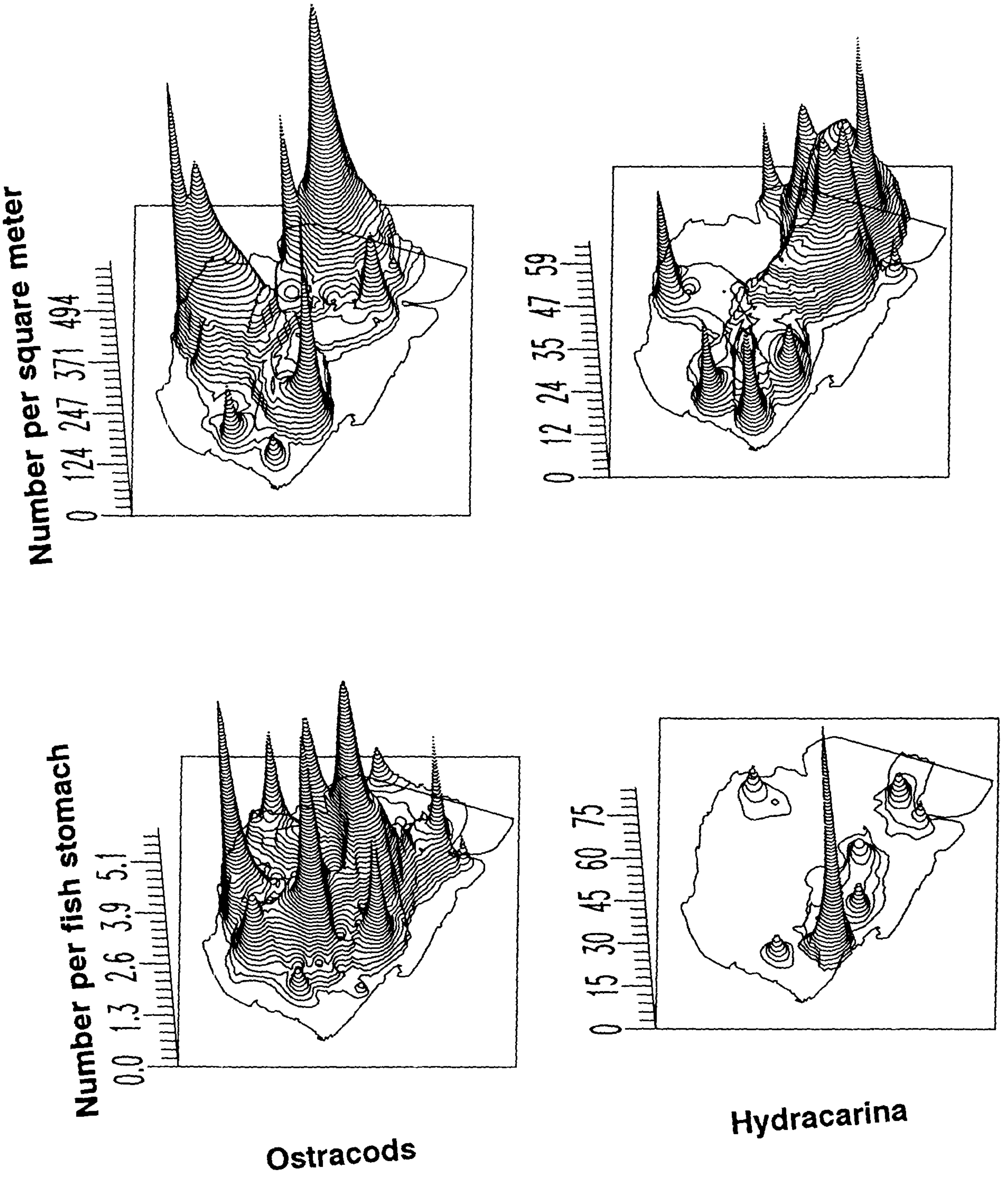

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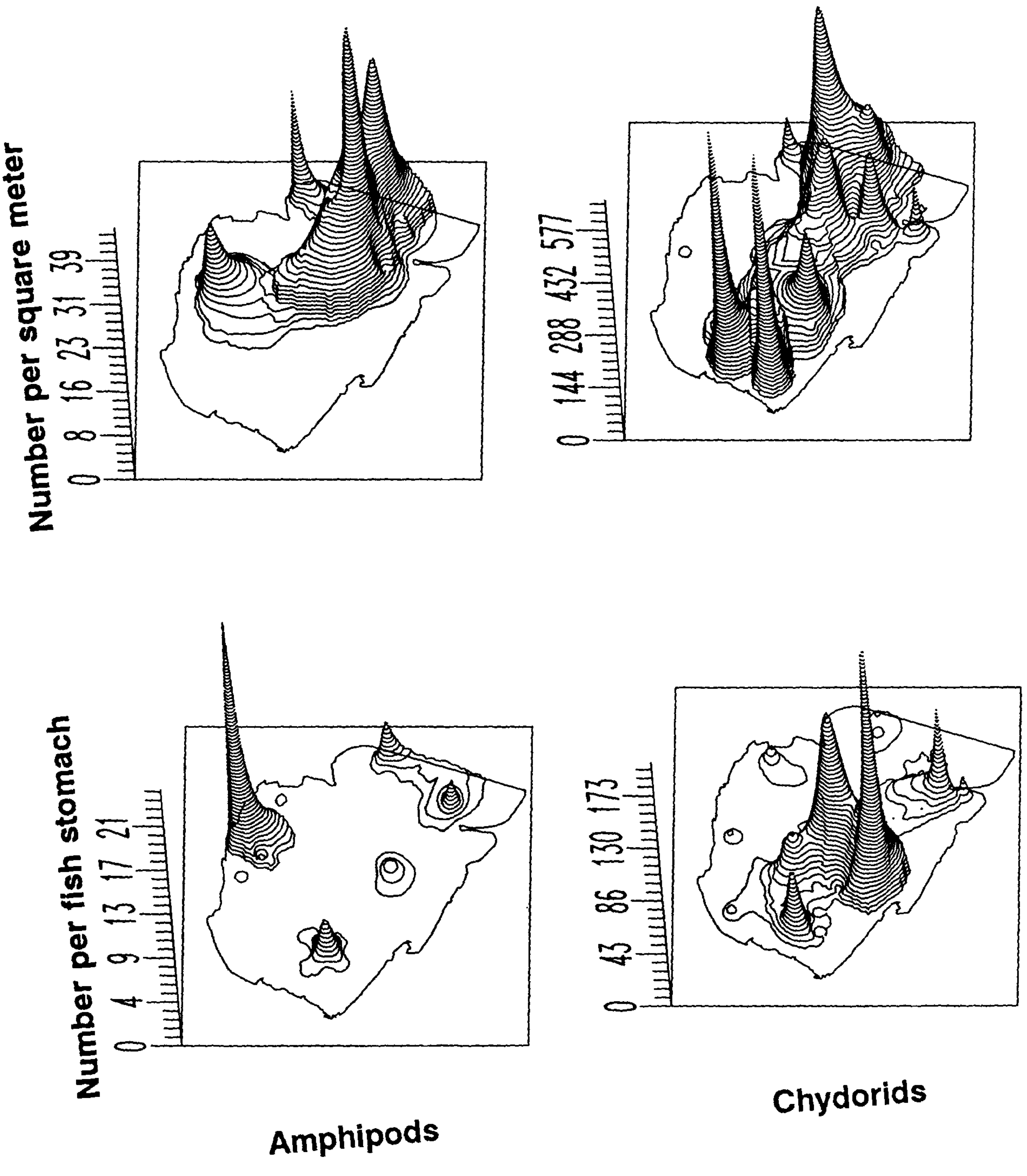

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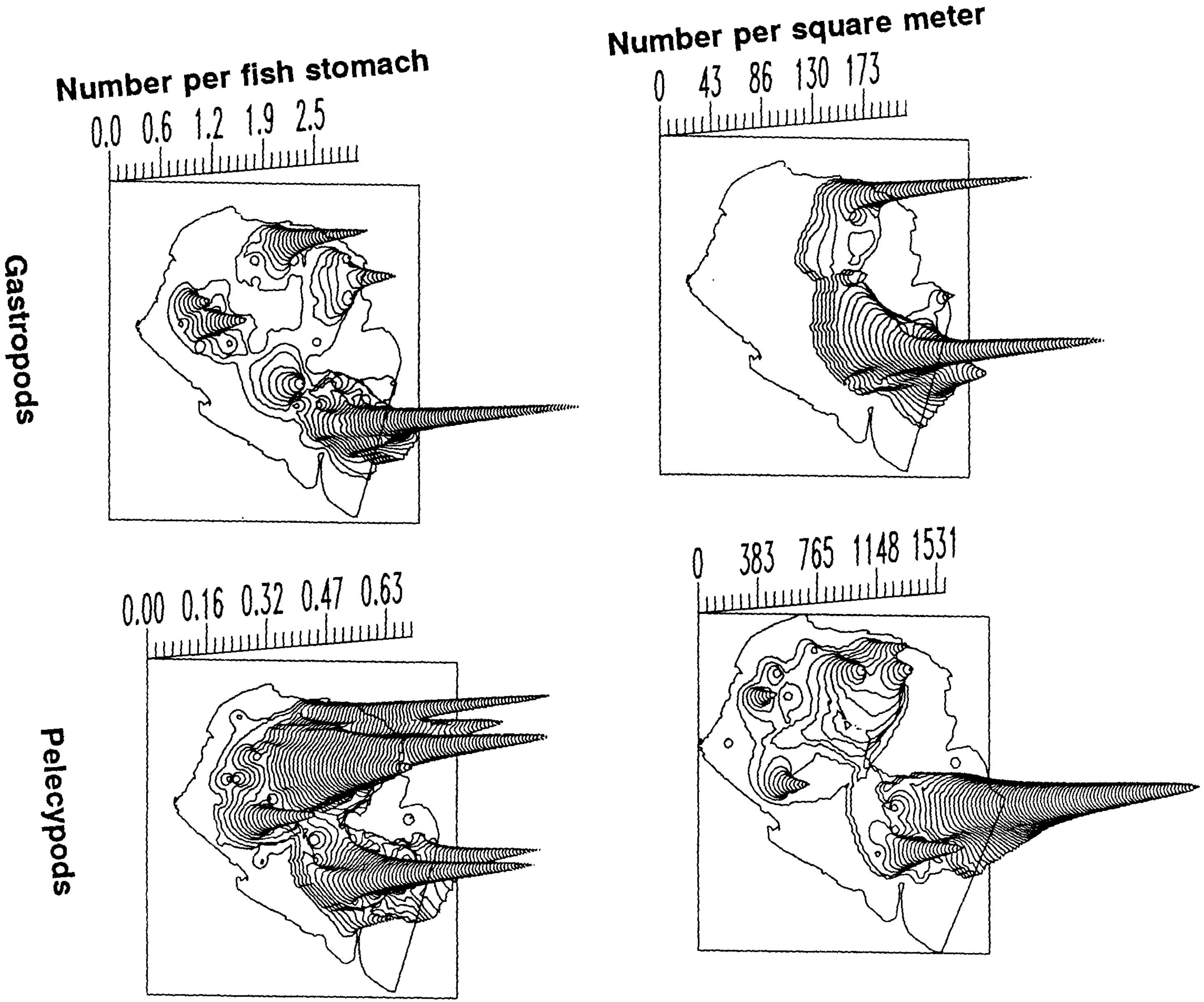

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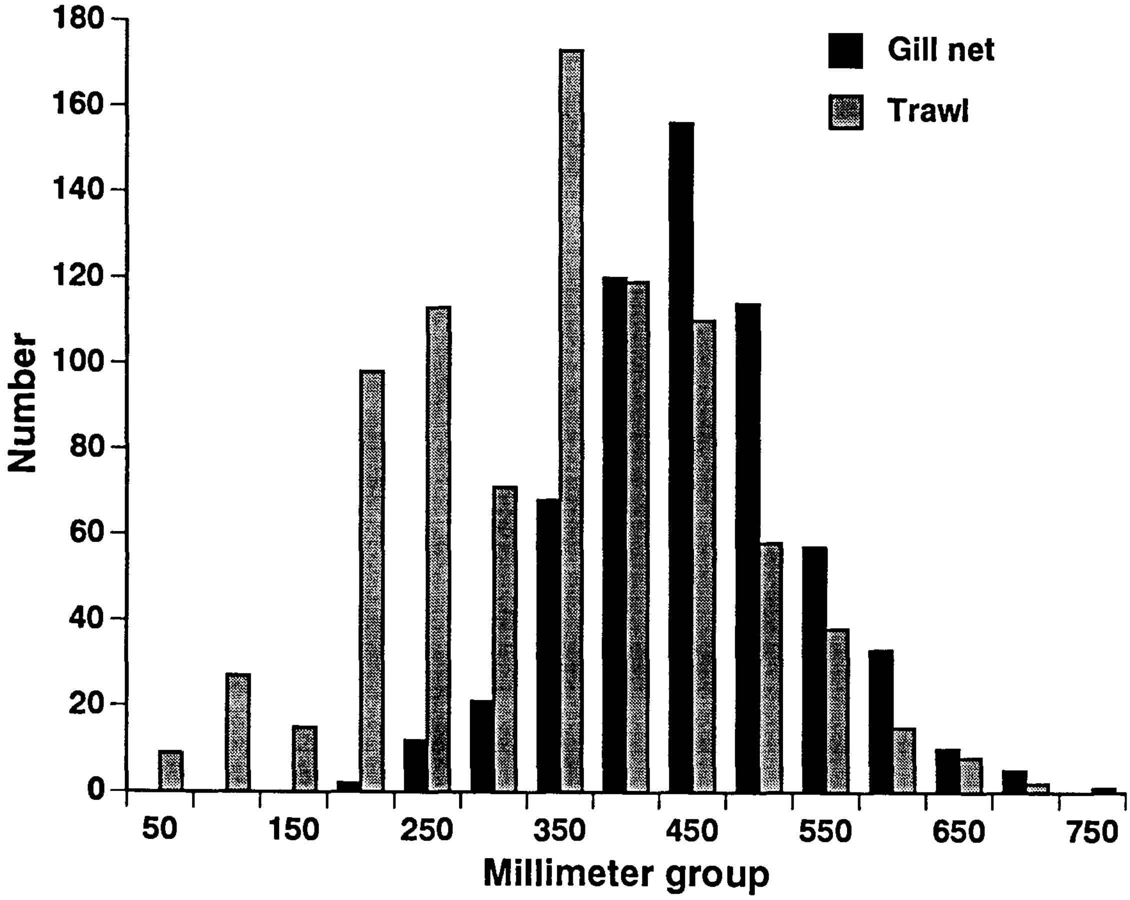

Figure 27.—Length frequencies of walleye collected in trawls and gill nets from the inner portion of Saginaw Bay, Lake Huron during 1986-1988. The 50 mm group includes fish from 50 mm to 99 mm, the 100 mm group includes fish from 100 mm to 149 mm, and so on.

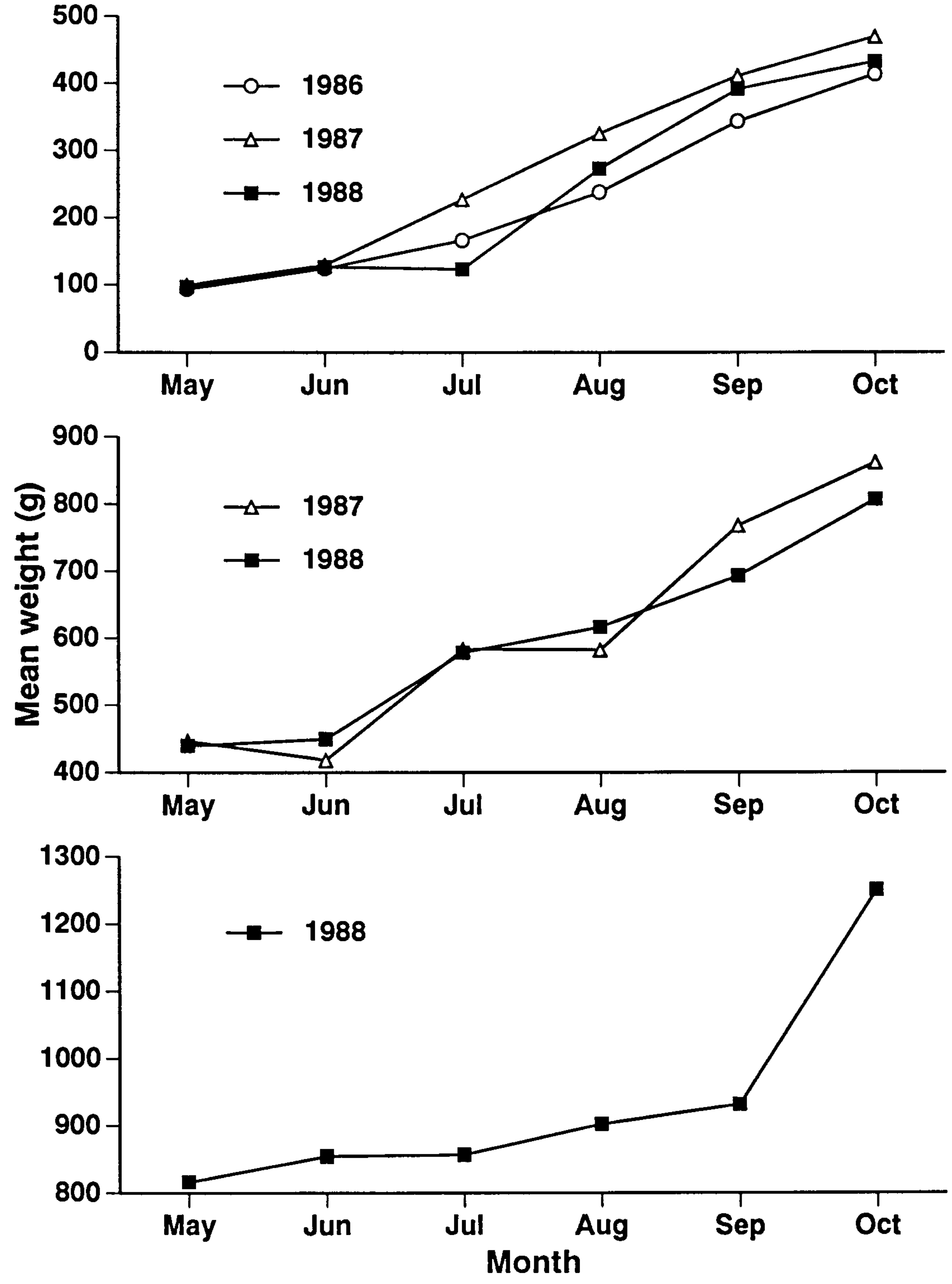

Figure 28.—Seasonal changes in mean weight (g) of age-1 (1986-1988), age-2 (1987-1988), and age-3 (1988) walleye collected using bottom trawls and experimental gill nets in the inner portion of Saginaw Bay, Lake Huron.

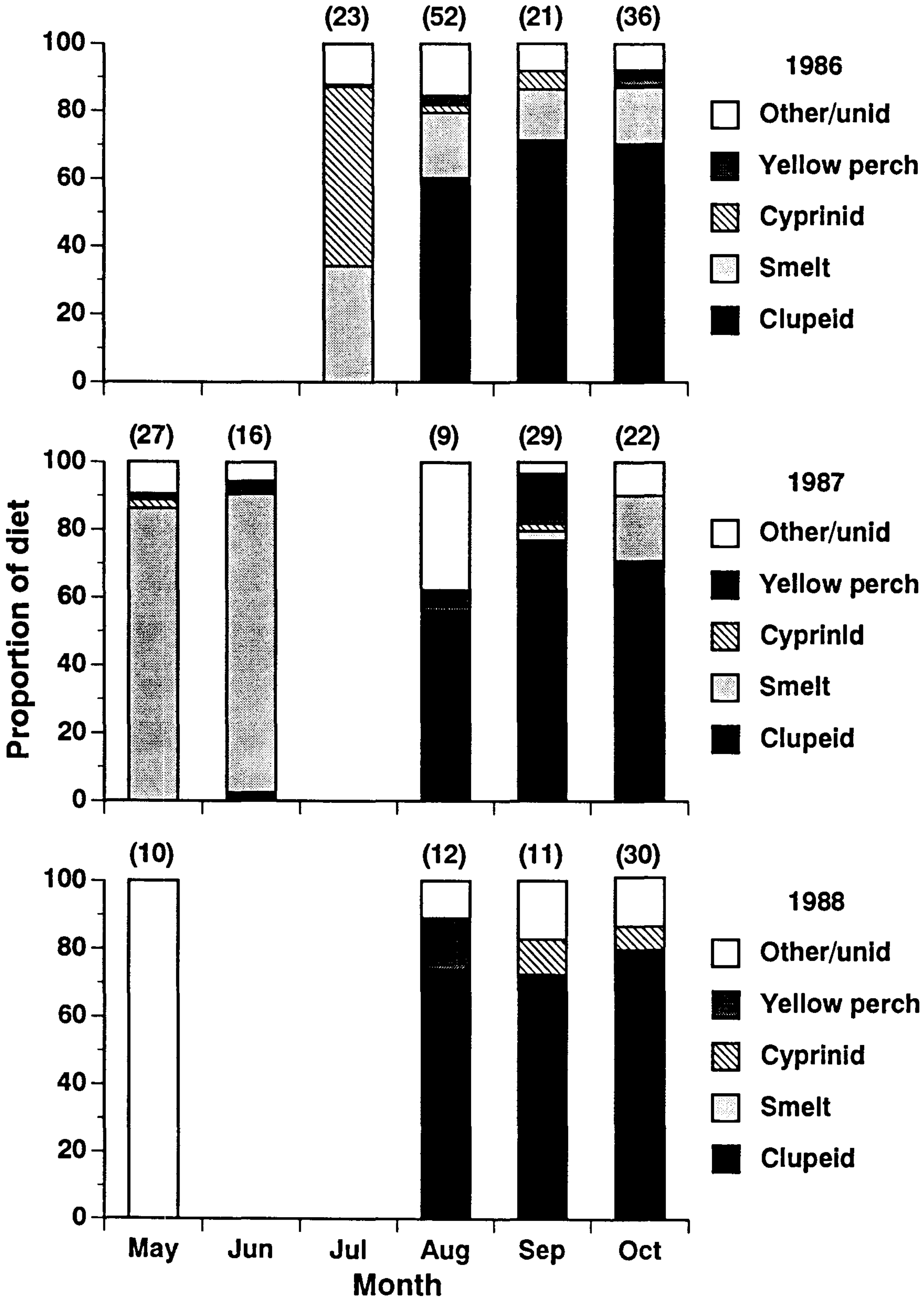

Figure 29.—Percent contribution of individual prey types to the diet of age-1 walleye from the inner portion of Saginaw Bay, Lake Huron, based on back-calculated prey weight at capture.

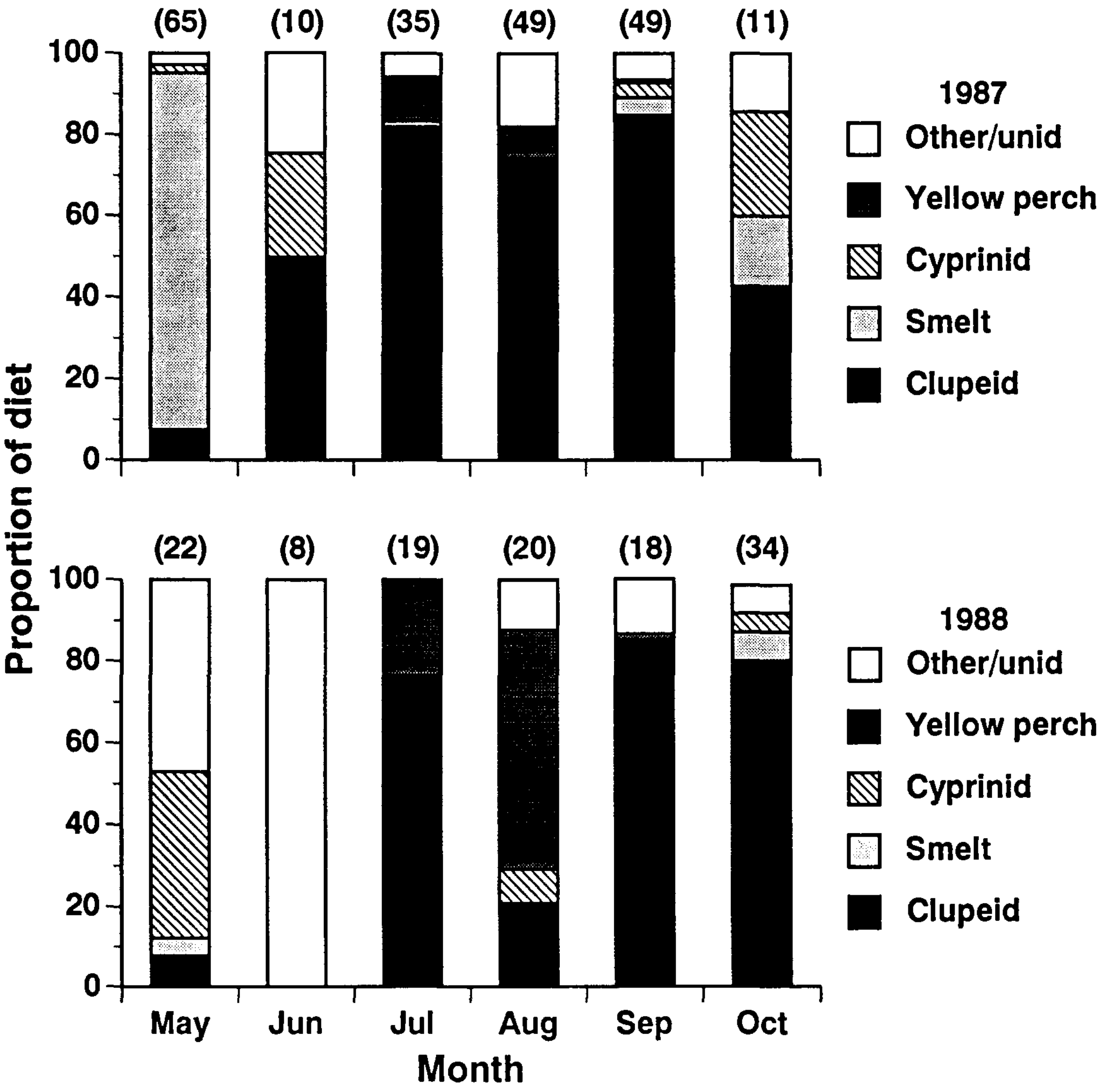

Figure 30.—Percent contribution of individual prey types to the diet of age-2 walleye from the inner portion of Saginaw Bay, Lake Huron, based on back-calculated prey weight at capture.

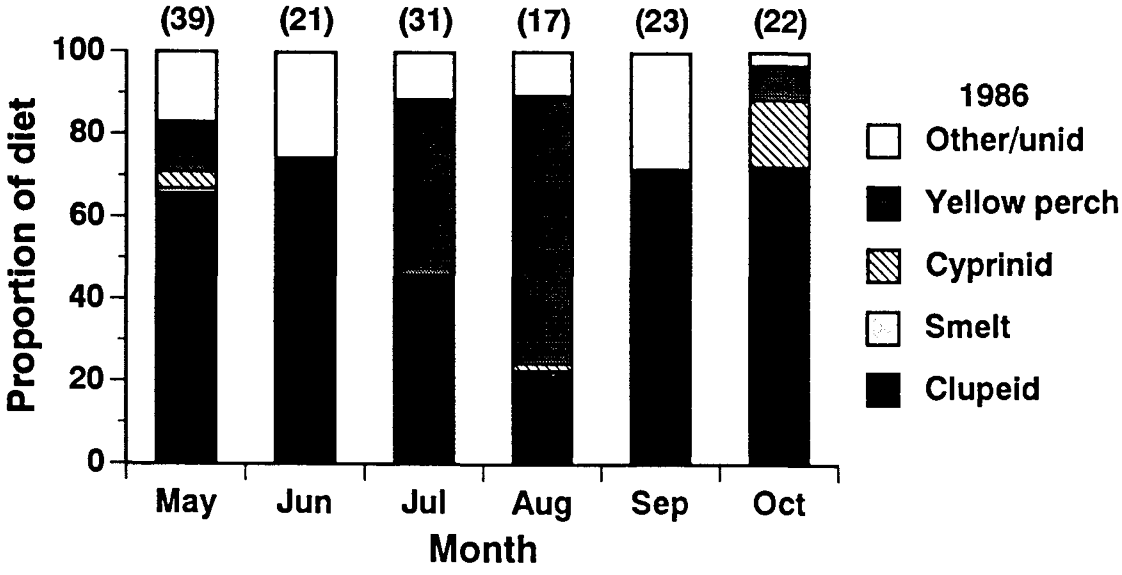

Figure 31.—Percent contribution of individual prey types to the diet of age-3 walleye from the inner portion of Saginaw Bay, Lake Huron, based on back-calculated prey weight at capture.

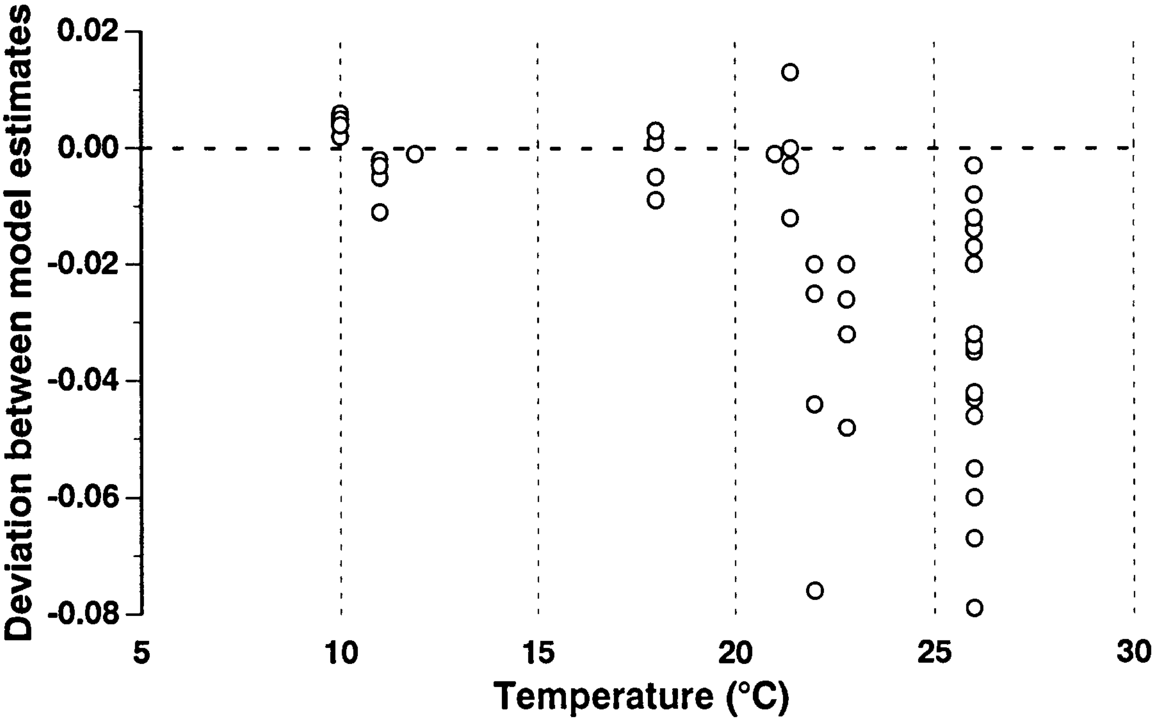

Figure 32.—Deviation between model estimates (energetics model minus Elliot and Persson) showing lack of fit between the two consumption models versus temperature (°C). All points should fall on zero line.

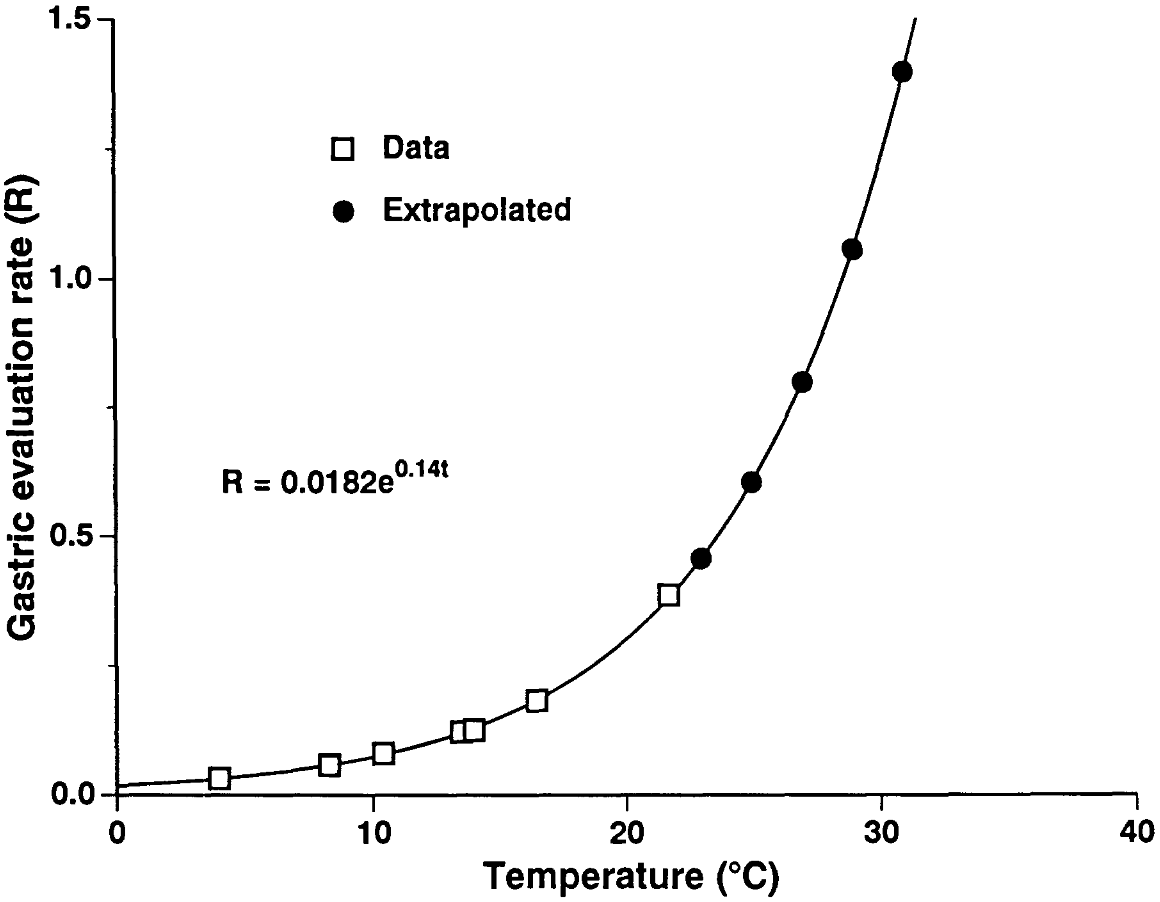

Figure 33.—Empirical and extrapolated estimates of the instantaneous gastric evacuation rate (R) of European perch versus temperature (°C).

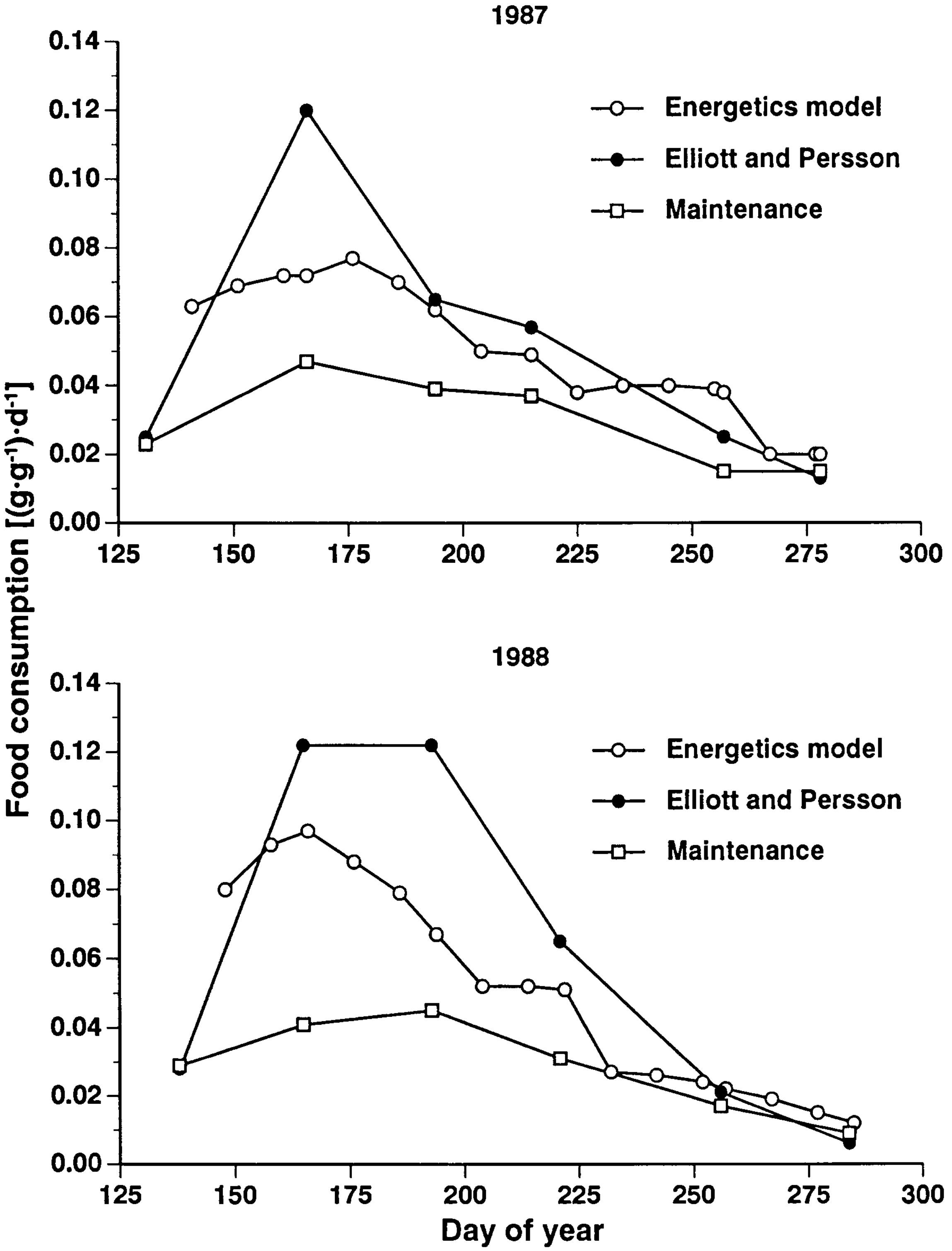

Figure 34.—Estimated food consumption [$(g \cdot g^{-1}) \cdot d^{-1}$] on a wet weight basis of age-1 yellow perch collected from the Wildfowl Bay Station, Saginaw Bay, Lake Huron during 1987-1988 using the Elliot and Persson (1978) direct method, and a bioenergetics model (Hewett and Johnson 1989). Maintenance ration was estimated with the bioenergetics model (Hewett and Johnson 1989).

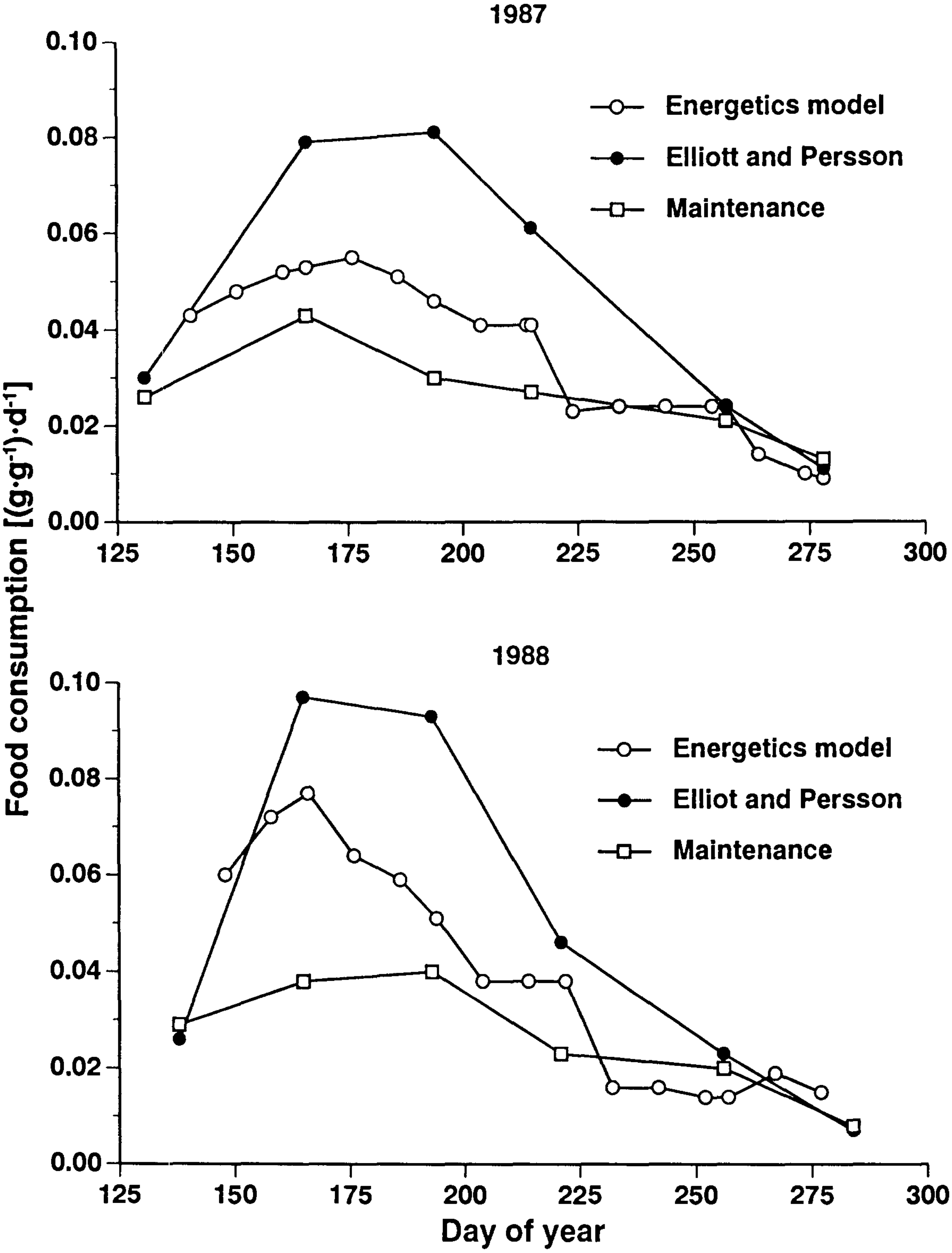

Figure 35.—Estimated food consumption $[(g \cdot g^{-1}) \cdot d^{-1}]$ on a wet weight basis of age-2 yellow perch collected from the Wildfowl Bay Station, Saginaw Bay, Lake Huron during 1987-1988 using the Elliot and Persson (1978) direct method, and a bioenergetics model (Hewett and Johnson 1989). Maintenance ration was estimated with the bioenergetics model (Hewett and Johnson 1989).

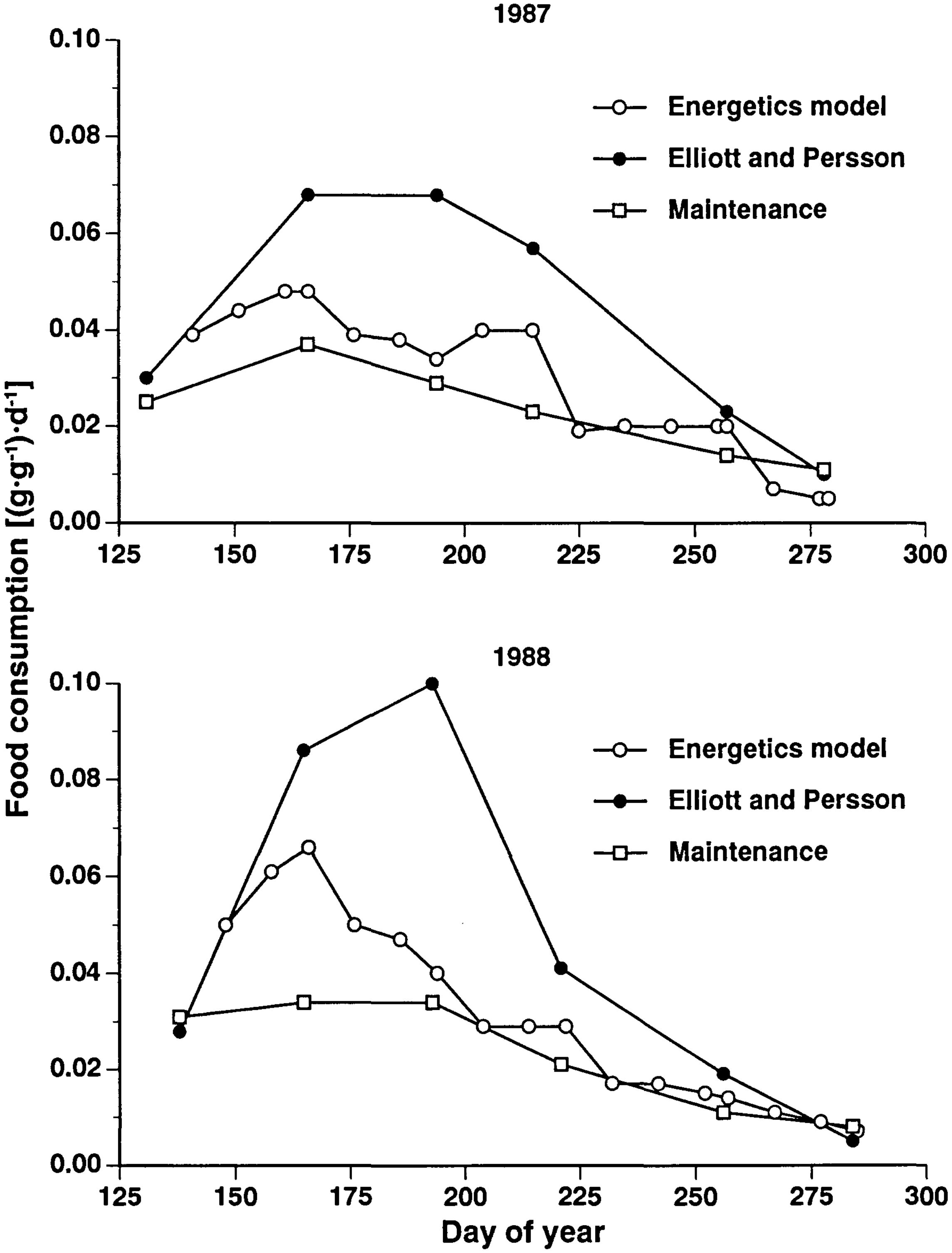

Figure 36.—Estimated food consumption $[(g{\cdot}g^{-1}){\cdot}d^{-1}]$ on a wet weight basis of age-3 yellow perch collected from the Wildfowl Bay Station, Saginaw Bay, Lake Huron during 1987-1988 using the Elliot and Persson (1978) direct method, and a bioenergetics model (Hewett and Johnson 1989). Maintenance ration was estimated with the bioenergetics model (Hewett and Johnson 1989).

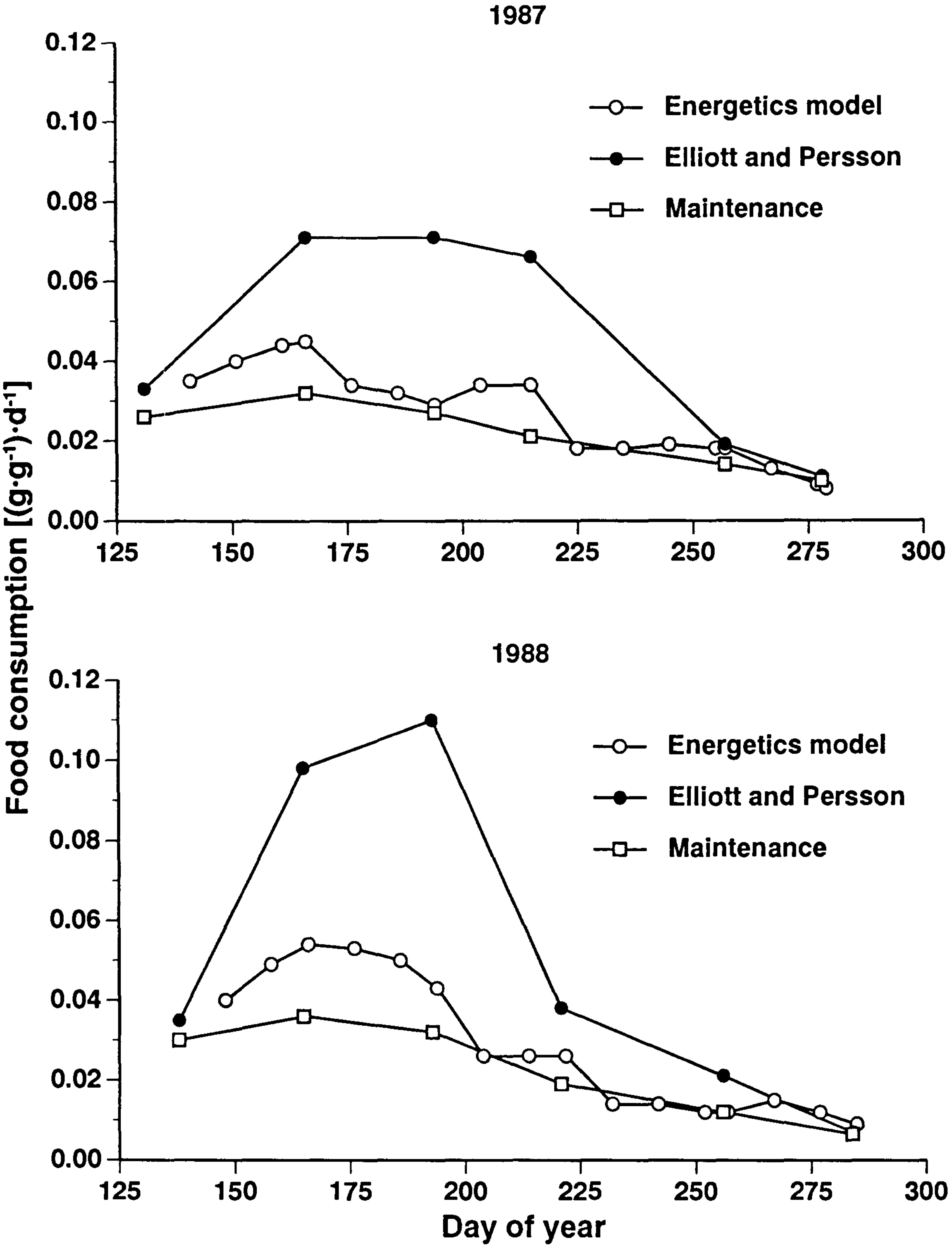

Figure 37.—Estimated food consumption $[(g{\cdot}g^{-1}){\cdot}d^{-1}]$ on a wet weight basis of age-4 yellow perch collected from the Wildfowl Bay Station, Saginaw Bay, Lake Huron during 1987-1988 using the Elliot and Persson (1978) direct method, and a bioenergetics model (Hewett and Johnson 1989). Maintenance ration was estimated with the bioenergetics model (Hewett and Johnson 1989).

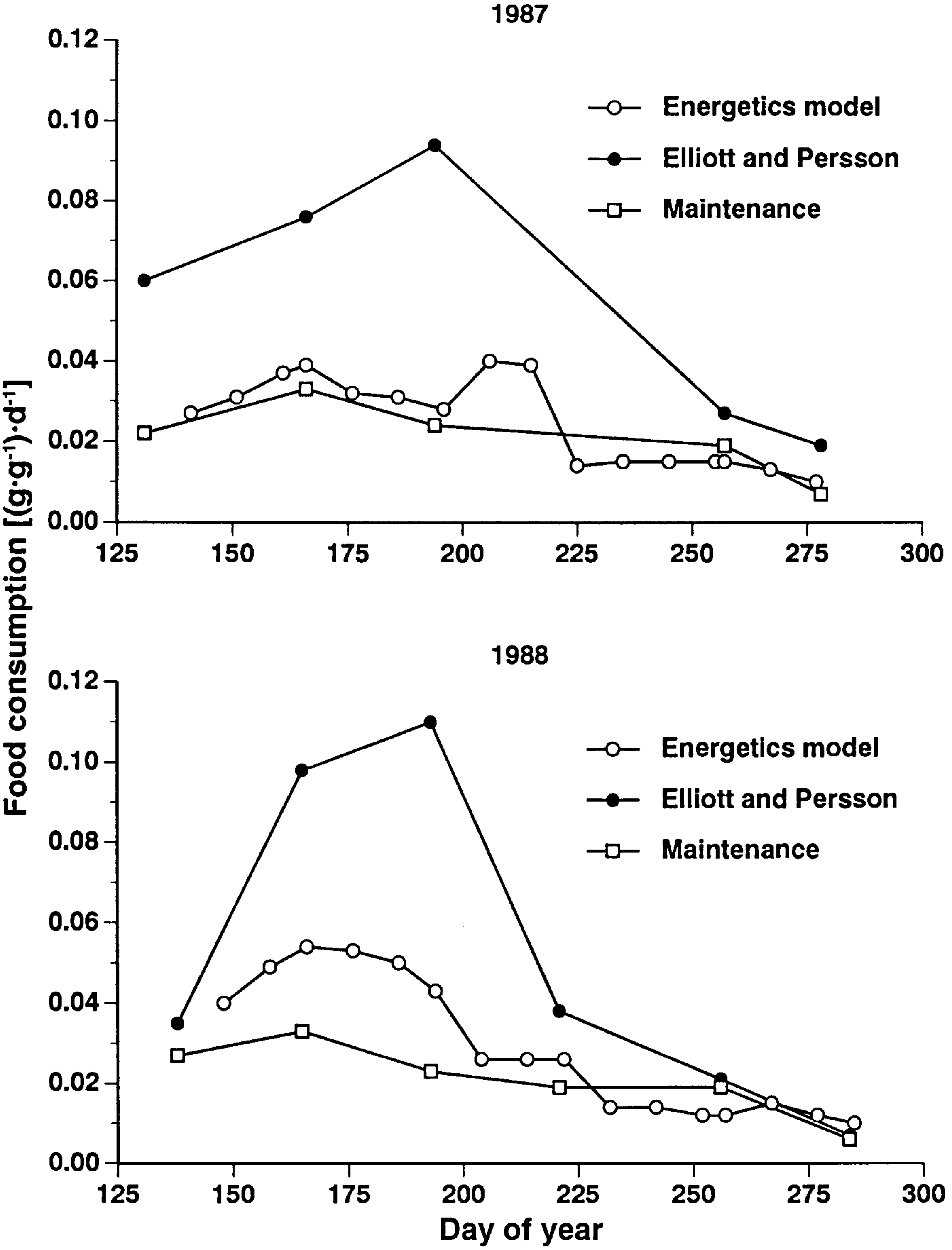

Figure 38.—Estimated food consumption [(g·g^{-1})·d^{-1}] on a wet weight basis of age-5 yellow perch collected from the Wildfowl Bay Station, Saginaw Bay, Lake Huron during 1987-1988 using the Elliot and Persson (1978) direct method, and a bioenergetics model (Hewett and Johnson 1989). Maintenance ration was estimated with the bioenergetics model (Hewett and Johnson 1989).

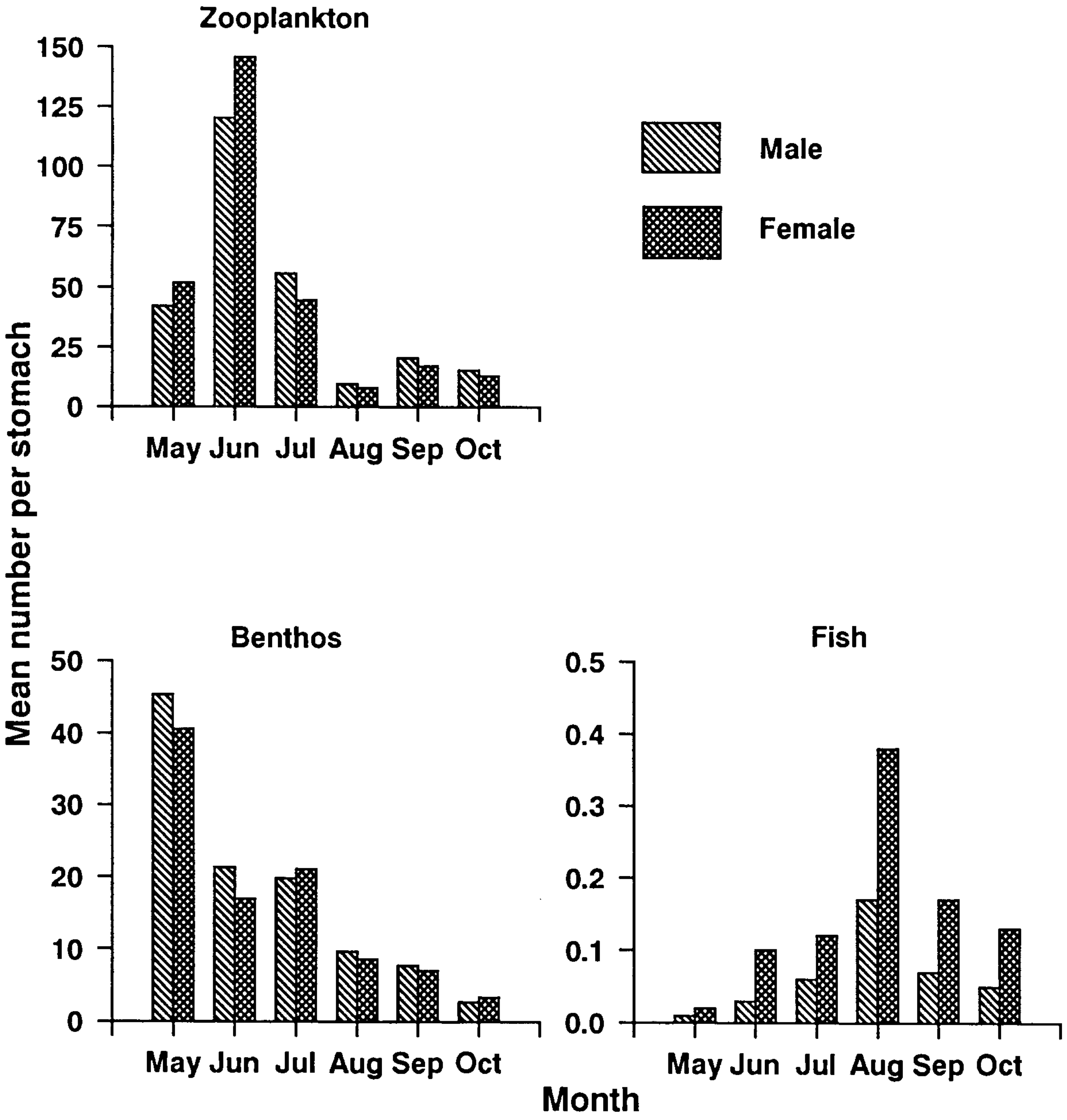

Figure 39.—Monthly frequency of occurrence for the three major diet groups in male and female yellow perch.

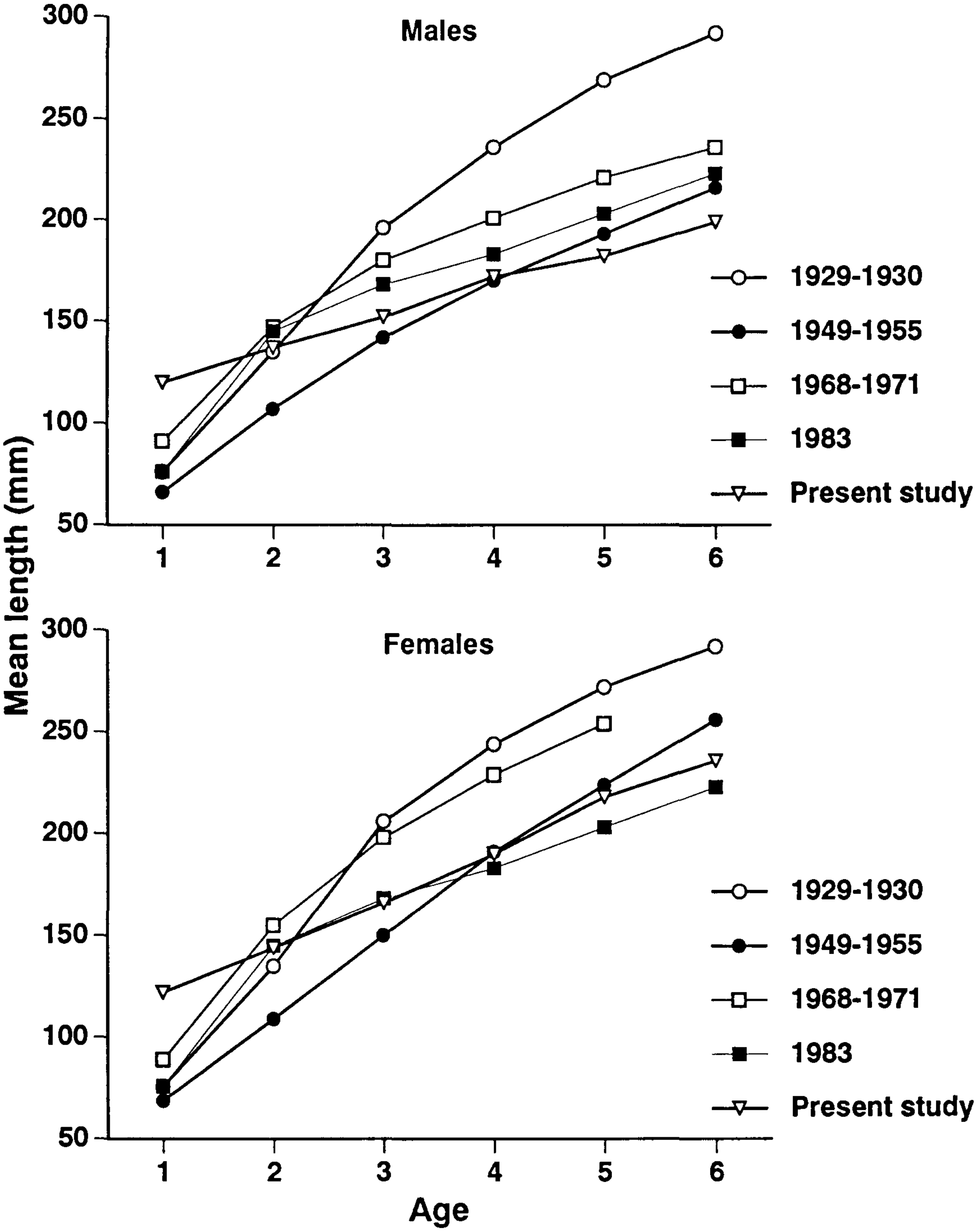

Figure 40.—Historical records of mean length at age of yellow perch from Saginaw Bay, Lake Huron.

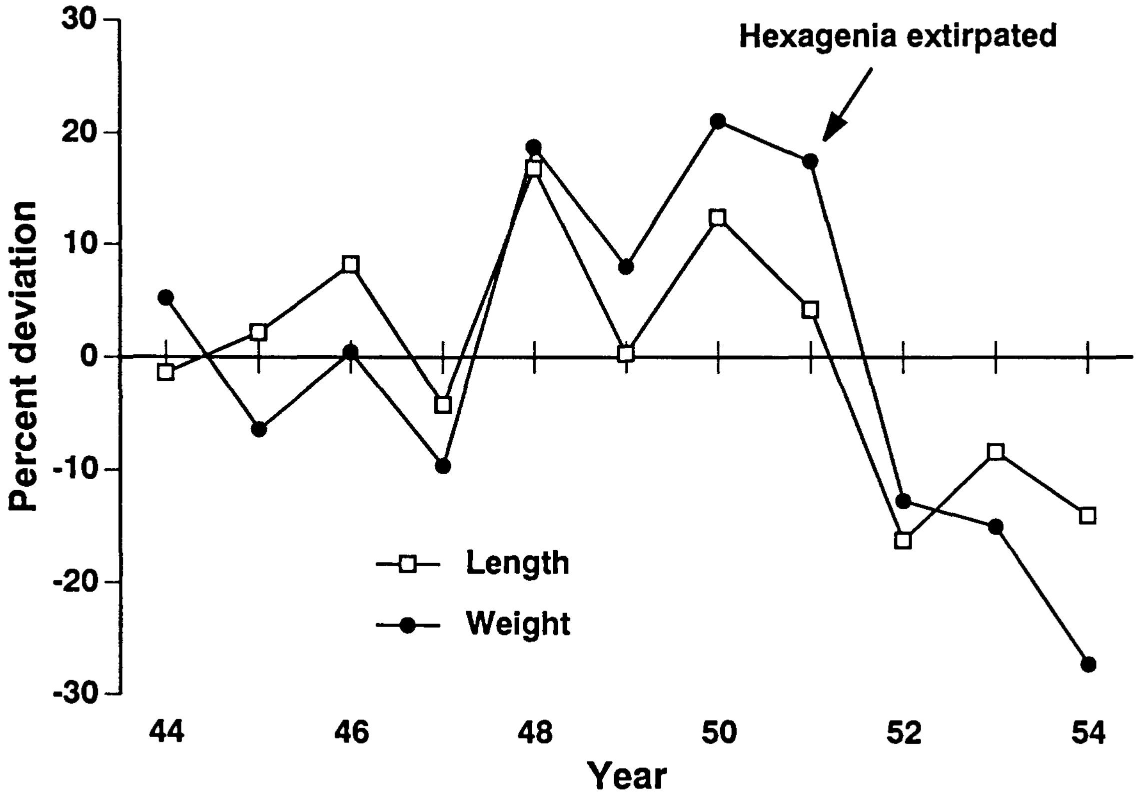

Figure 41.—Percentage deviation of growth in length and weight from the 1944-1954 mean for adult yellow perch. Data from El-Zarka (1959).

Table 1.—List of common and scientific names of fishes collected in Saginaw Bay, Lake Huron during 1986-1988.

Common name	Scientific name
Yellow perch	*Perca flavescens*
Rainbow smelt	*Osmerus mordax*
Spottail shiner	*Notropis hudsonius*
Trout-perch	*Percopsis omiscomaycus*
Alewife	*Alosa pseudoharengus*
White perch	*Morone americana*
Gizzard shad	*Dorosoma cepedianum*
Emerald shiner	*Notropis atherinoides*
White bass	*Morone chrysops*
White sucker	*Catostomus commersoni*
Channel catfish	*Ictalurus punctatus*
Freshwater drum	*Aplodinotus grunniens*
Common carp	*Cyprinus carpio*
Johnny darter	*Etheostoma nigrum*
Quillback	*Carpiodes cyprinus*
Walleye	*Stizostedion vitreum*
Lake whitefish	*Coregonus clupeaformis*
Pumpkinseed	*Lepomis gibbosus*
Black crappie	*Pomoxis nigromaculatus*
Brown bullhead	*Ictalurus nebulosus*
Unidentified fish	
Longnose gar	*Lepisosteus osseus*
Stonecat	*Noturus flavus*
Bluegill	*Lepomis macrochirus*
Largemouth bass	*Micropterus salmoides*
Logperch	*Percina caprodes*
Brown trout	*Salmo trutta*
Golden shiner	*Notemigonus crysoleucas*
Shorthead redhorse	*Moxostoma macrolepidotum*
Rock bass	*Ambloplites rupestris*

Table 2.—Features used to identify partially digested forage fishes consumed by walleyes in Saginaw Bay, Lake Huron, 1986-1988.

Species	Characteristics
Alewife	Long and numerous pyloric caeca. Long process on neural and hemalspines overlaps centrum of vertebra.
Gizzard shad	Gizzard resists digestion. Process on neural and hemal spines present, and more robust than alewife.
Rainbow smelt	Large canine teeth resist digestion. Body extremely thin for length.
Notropis spp.	Few distinguishing characteristics. Have cycloid scales, weberian apparatus, and pharyngeal teeth. During early summer, eggs of gravid females resist digestion.
Trout-perch	Rounded thick skull resists digestion.
White perch	Anal spines distinct, resist digestion.
Yellow perch	Vertical bars surprisingly persistent, redworms also diagnostic.

Table 3.—Water temperatures (°C) recorded from fixed, diel, and random stations in inner Saginaw Bay, Lake Huron, 1986-1988.

Year, mean, range	Month									
			Jun			Jul				
	May	Jun	Early	Late	Jul	Early	Late	Aug	Sep	Oct
1986										
Mean	—	—	15.0	19.7	—	22.0	23.3	21.9	15.5	16.7
Range	—	—	15-16	19-21	—	20-23	19-25	21-23	14-17	16-17
N	—	—	43	10	—	13	12	42	23	24
1987										
Mean	14.8	22.2	—	—	25.2	—	—	25.0	19.3	11.3
Range	14-16	20-23	—	—	21-28	—	—	23-26	18-21	10-12
N	39	40	—	—	49	—	—	38	40	45
1988										
Mean	13.4	20.9	—	—	25.0	—	—	25.3	17.6	10.2
Range	12-17	19-23	—	—	22-28	—	—	20-27	17-18	8-11
N	42	43	—	—	42	—	—	41	39	43

Table 4.—Caloric densities of predators and prey used as inputs to the energetics model. We assumed caloric density did not vary seasonally for alewife and gizzard shad.

Species	Caloric density ($\mathrm{cal}\bullet\mathrm{g}^{-1}$ wet weight)	Source
Alewife	1,227-2,362	Flath and Diana (1985).
Gizzard shad	1,200-1,320	Pierce et al. (1980).
Rainbow smelt	1,367	Foltz and Norden (1977). Assumes 75% water.
Trout-perch	1,000	Assumed.
White perch	1,065	Wissing (1974). Data for white bass.
Emerald shiner	1,191	Kelso (1972).
Spottail shiner	1,191	Assumed to be same as emerald shiner.
Yellow perch	1,362	Hurley (1986).
Other species	1,000	Assumed.
Unidentified	1,191	Assumed to be cyprinid.

Table 5.—Mean catch per 10 minute tow (CPUE) for all species caught in 694 trawl drags in Saginaw Bay, Lake Huron during 1986-1988.

	CPUE				
Species	Mean	Standard deviation	Maximum	Coefficient of variation	Percent
Yellow perch	588.4	651.6	8,624	1.1	27.1
Rainbow smelt	452.8	1,238.7	11,896	2.7	20.9
Spottail shiner	388.0	743.7	7,020	1.9	17.9
Trout-perch	277.5	524.0	6,337	1.9	12.8
Alewife	245.4	834.3	12,832	3.4	11.3
White perch	86.1	260.7	2,284	3.0	4.0
Gizzard shad	65.3	254.0	3,768	3.9	3.0
Emerald shiner	26.6	88.8	980	3.3	1.2
White bass	12.1	68.0	1,145	5.6	0.6
White sucker	10.5	17.9	148	1.7	0.5
Channel catfish	4.1	25.6	646	6.3	0.2
Freshwater drum	3.9	14.2	297	3.6	0.2
Common carp	3.4	5.7	60	1.7	0.2
Johnny darter	1.8	4.5	48	2.5	0.1
Quillback	1.5	6.4	91	4.2	0.1
Walleye	1.5	2.5	18	1.7	0.1
Lake whitefish	1.0	6.1	99	5.9	0.0
Pumpkinseed	0.6	3.0	37	4.7	0.0
Black crappie	0.1	0.7	10	5.1	0.0
Brown bullhead	0.1	0.5	6	6.4	0.0
Unidentified fish	0.1	1.1	21	18.3	0.0
Longnose gar	0.0	0.4	8	10.3	0.0
Stonecat	0.0	0.3	4	8.7	0.0
Bluegill	0.0	0.2	4	7.3	0.0
Largemouth bass	0.0	0.3	4	12.5	0.0
Logperch	0.0	0.2	3	10.5	0.0
Brown trout	0.0	0.0	1	—	0.0
Golden shiner	0.0	0.1	1	—	0.0
Shorthead redhorse	0.0	0.1	2	—	0.0
Rock bass	0.0	0.0	1	—	0.0
Total	2170.8				

Table 6.—Statistical results from comparisons of mean trawl catch per 10 minute tow (CPUE) between fixed and random stations. The tests used were the parametric, One-way Analysis of Variance (ANOVA) and the nonparametric, Kruskal-Wallis (K-W).

Species	Fixed CPUE	Random CPUE	*F* significance	K-W significance
Yellow perch				
YOY	212.46	179.03	0.4093	0.4781
Adult	539.21	377.76	0.0026	0.0000
Rainbow smelt	605.21	598.57	0.9618	0.3556
Spottail shiner	549.63	348.82	0.0109	0.0072
Trout-perch	327.94	275.09	0.3377	0.1988
Alewife	176.19	326.95	0.1004	0.8704
White perch	56.83	74.33	0.3729	0.7968
Gizzard shad	16.17	56.99	0.0775	0.3257
Emerald shiner	12.74	29.09	0.0645	0.0391
Total catch	2,535.48	2,309.80	0.5598	0.0824
Total catch minus yellow perch	1,783.81	1,753.02	0.9050	0.6908

Table 7.—Length frequency (mm) of major species from combined gill net catches in Saginaw Bay, Lake Huron, during 1986-88. Data are percent by number of the total sample.

Length interval	Emerald shiner	Spottail shiner	Trout-perch	Smelt	Yellow perch	White perch	Alewife	Gizzard shad	White sucker	Channel catfish	Walleye
26-49	—	0.1	—	—	0.1	—	—	—	—	—	—
50-75	0.3	0.3	0.5	0.8	1.3	2.3	6.2	21.0	—	—	—
76-100	65.4	61.9	68.4	15.7	8.0	9.1	14.6	8.3	—	—	—
101-125	33.9	36.8	26.5	33.1	20.0	14.0	6.9	3.9	0.2	0.1	—
126-151	0.3	0.9	4.6	19.3	27.5	24.7	7.9	10.9	0.1	0.1	—
152-175	—	—	—	13.8	28.3	31.4	32.7	12.0	—	0.2	0.7
176-201	—	—	—	13.4	11.3	13.7	29.0	9.9	0.1	0.3	—
202-226	—	—	—	2.8	2.7	3.9	2.4	2.8	0.4	1.2	—
227-252	—	—	—	0.8	0.6	0.9	0.3	0.8	1.9	7.8	0.5
253-277	—	—	—	0.4	0.2	0.2	—	0.5	1.4	27.0	1.7
278-303	—	—	—	—	—	—	—	2.8	2.0	15.8	1.0
304-328	—	—	—	—	—	—	—	2.0	3.9	13.0	2.5
329-353	—	—	—	—	—	—	—	2.4	9.8	14.6	2.8
354-379	—	—	—	—	—	—	—	2.3	27.3	8.5	6.8
380-404	—	—	—	—	—	—	—	6.5	32.8	4.1	7.0
405-428	—	—	—	—	—	—	—	6.0	14.7	3.0	12.7
429-454	—	—	—	—	—	—	—	4.9	4.2	1.0	11.5
455-481	—	—	—	—	—	—	—	2.3	0.9	1.2	13.0
482-506	—	—	—	—	—	—	—	0.5	0.3	0.7	11.7
507-532	—	—	—	—	—	—	—	0.1	—	0.4	9.3
533-557	—	—	—	—	—	—	—	0.1	—	0.5	6.5
558-582	—	—	—	—	—	—	—	—	—	0.1	3.8
583-608	—	—	—	—	—	—	—	—	—	0.2	3.8
609-633	—	—	—	—	—	—	—	—	—	0.1	1.8
634-658	—	—	—	—	—	—	—	—	—	—	1.0
659-684	—	—	—	—	—	—	—	—	—	—	0.8
685-709	—	—	—	—	—	—	—	—	—	—	0.8
710-734	—	—	—	—	—	—	—	—	—	—	0.2
Sample	573	1,484	196	254	5,713	1,904	4,340	751	1,234	1,350	600

Table 8.—October[1] trawl CPUE of major forage and predator species by survey year from Saginaw Bay, Lake Huron.

Survey year	Rainbow smelt	Spottail shiner	Trout-perch	Alewife	Gizzard shad	Emerald shiner
1971	392.4	94.4	44.6	126.1	3.3	3.7
1972	375.4	419.4	99.9	109.3	1.0	2.5
1973	286.7	16.0	10.5	2.6	2.3	0.2
1974	139.2	191.7	119.9	7.7	21.5	0.9
1975	220.1	435.1	47.4	21.9	17.2	1.3
1976	779.9	93.9	9.2	40.7	370.0	0.2
1977	64.6	448.8	28.2	13.1	3.5	18.7
1978	498.6	562.6	24.6	71.6	146.5	0.3
1979	336.9	711.9	177.2	352.5	4.5	0.9
1980	801.6	441.8	45.4	83.7	48.1	0.2
1981	98.3	849.0	55.7	288.7	3.0	0.0
1982	265.5	211.5	30.3	127.1	1.9	3.1
1983	57.7	1,236.5	255.4	1,029.5	38.5	53.7
1984	249.7	787.1	148.0	58.3	7.2	2.8
1985	202.1	164.7	314.6	18.1	10.8	11.4
1986	366.0	284.9	156.7	303.5	10.5	242.0
1987	210.5	470.3	167.1	56.6	29.2	41.9
1988	176.0	106.8	53.6	85.7	41.3	54.9
1989	220.5	340.1	232.2	226.1	168.9	57.3
1990	47.5	203.3	137.9	16.1	45.1	44.9
1991	46.6	132.3	176.5	86.2	52.7	15.8
All years	277.9	390.6	111.2	148.8	48.9	26.5

[1] September 1991 trawl CPUE substituted for October 1991.

Table 8.—Continued.

Survey year	Yellow perch	White perch	White bass	White sucker	Channel catfish	Common carp	Walleye	Freshwater drum
1971	109.7	0.0	0.0	1.3	0.8	1.7	0.2	0.0
1972	191.4	0.0	0.0	1.3	1.3	3.5	0.0	0.0
1973	112.9	0.0	0.0	0.7	3.2	1.7	0.0	0.0
1974	460.0	0.0	0.0	0.6	14.2	9.0	0.0	0.3
1975	547.3	0.0	0.0	0.5	16.8	1.6	0.0	0.6
1976	673.3	0.0	0.1	0.4	0.8	0.6	0.0	0.0
1977	391.3	0.0	0.0	8.7	1.4	2.2	0.0	1.4
1978	286.0	0.0	0.0	4.5	0.8	0.5	0.0	0.4
1979	670.2	0.0	0.0	9.2	4.1	3.1	0.0	0.9
1980	679.1	0.0	0.0	1.3	11.2	1.0	0.1	1.4
1981	415.7	0.0	0.0	5.0	4.6	3.3	0.3	0.3
1982	332.7	0.0	2.5	14.5	0.7	0.1	0.5	3.6
1983	302.1	0.0	0.2	7.4	0.8	1.3	0.2	11.0
1984	414.9	0.1	9.8	14.3	3.2	1.3	0.3	7.7
1985	340.0	0.7	4.1	6.4	2.5	1.0	1.6	15.1
1986	396.6	10.8	13.4	5.5	2.9	5.7	1.4	16.8
1987	492.0	57.7	1.1	6.2	4.4	2.6	1.0	3.5
1988	276.6	168.3	10.4	4.4	3.9	5.4	2.6	0.9
1989	799.1	2,321.3	3.2	3.3	1.9	5.7	2.6	9.4
1990	152.3	685.6	3.6	11.4	4.8	5.3	1.6	23.9
1991	188.3	430.9	6.4	13.1	0.5	3.3	5.9	26.3
All years	392.0	175.0	2.6	5.7	4.0	2.9	0.9	5.9

[1]September 1991 trawl CPUE substituted for October 1991.

Table 9.—Trawl CPUE for major fish species during October[1] from Saginaw Bay, Lake Huron, during 1986-1991.

	Year						
Species	1986	1987	1988	1989	1990	1991	Mean
Rainbow smelt	366.0	210.5	176.0	220.5	47.5	46.6	193.7
Spottail shiner	284.9	470.3	106.8	340.1	203.3	132.3	272.6
Trout-perch	156.7	167.1	53.6	232.2	137.9	176.5	139.7
Alewife	303.5	56.6	85.7	226.1	16.1	86.2	117.6
Gizzard shad	10.5	29.2	41.3	168.9	45.1	52.7	47.0
Emerald shiner	242.0	41.9	54.9	57.3	44.9	15.8	75.6
Yellow perch	396.6	492.0	276.6	799.1	152.3	188.3	385.5
White perch	10.8	57.7	168.3	2,321.3	685.6	430.9	399.7
White bass	13.4	1.1	10.4	3.2	3.6	6.4	6.4
White sucker	5.5	6.2	4.4	3.3	11.4	13.1	6.5
Channel catfish	2.9	4.4	3.9	1.9	4.8	0.5	3.4
Common carp	5.7	2.6	5.4	5.7	5.3	3.3	4.5
Walleye	1.4	1.0	2.6	2.6	1.6	5.9	2.2
Freshwater drum	16.8	3.5	0.9	9.4	23.9	26.3	9.7

[1] September 1991 trawl CPUE substituted for October 1991.

Table 10.—Trawl CPUE by month for major fish species from Saginaw Bay, Lake Huron, during 1986-1988 and 1991.

	Month						
Species	May	Jun	Jul	Aug	Sep	Oct	Mean
1986-1988 average							
Rainbow smelt	123.3	207.8	624.1	758.7	799.7	231.7	452.8
Spottail shiner	157.4	164.6	477.4	625.3	638.5	292.8	388.0
Trout-perch	113.8	291.7	414.4	364.0	350.7	122.1	277.5
Alewife	11.5	70.4	98.1	688.1	540.3	121.9	245.4
Gizzard shad	0.0	6.7	54.6	220.7	82.6	29.7	65.3
Emerald shiner	1.2	12.5	19.5	15.2	26.7	90.8	26.6
Yellow perch	393.6	553.1	677.9	735.1	795.8	390.0	588.4
White perch	3.6	0.4	49.7	186.1	213.6	89.0	86.1
White bass	0.1	0.1	37.8	12.4	12.4	7.3	12.1
White sucker	18.4	15.1	10.2	5.2	7.4	5.4	10.4
Channel catfish	4.1	1.7	2.9	7.5	4.6	3.9	4.1
Common carp	1.2	1.6	3.7	4.9	4.8	4.3	3.4
Walleye	1.3	0.8	1.5	1.4	2.1	1.7	1.5
Freshwater drum	1.6	0.8	3.9	3.9	8.8	5.4	3.9
1991							
Rainbow smelt	36.1	—	162.8	—	46.6	—	78.0
Spottail shiner	91.2	—	145.9	—	132.3	—	122.1
Trout-perch	40.8	—	255.8	—	176.5	—	153.2
Alewife	0.1	—	1,320.8	—	86.2	—	429.4
Gizzard shad	0.0	—	2.9	—	52.7	—	19.3
Emerald shiner	0.1	—	1.2	—	15.8	—	5.9
Yellow perch	86.9	—	807.2	—	188.3	—	340.0
White perch	4.3	—	356.7	—	430.9	—	259.7
White bass	0.0	—	1.6	—	6.4	—	2.7
White sucker	11.7	—	3.5	—	13.1	—	9.7
Channel catfish	1.5	—	0.2	—	0.5	—	0.7
Common carp	0.0	—	1.8	—	3.3	—	1.7
Walleye	0.4	—	0.6	—	5.9	—	2.4
Freshwater drum	0.2	—	0.9	—	26.3	—	9.5

Table 11.—Cumulative trawl CPUE for yearling and older yellow perch in Saginaw Bay, Lake Huron by sex and CPUE and mean length of YOY yellow perch in fall.

Year class	CPUE yearling and older			YOY	
	Males	Females	Total	CPUE	Mean length
1970	47.1	22.7	156.2	29.5	96.5
1971	175.3	74.9	191.2	20.2	91.4
1972	85.3	29.5	114.8	13.9	83.8
1973	212.2	94.7	306.9	30.6	91.4
1974	124.9	66.8	191.7	27.9	88.9
1975	263.2	169.2	432.4	247.9	88.9
1976	186.1	49.9	236.0	11.1	91.4
1977	164.0	67.0	231.0	52.9	91.4
1978	334.7	211.7	546.4	99.8	86.4
1979	545.5	230.9	776.4	166.7	78.7
1980	159.6	42.8	202.4	39.0	86.4
1981	228.9	128.8	357.7	71.3	83.8
1982	96.6	45.7	142.3	686.7	76.2
1983	281.8	169.6	451.4	251.9	76.2
1984	216.7	105.8	322.5	171.0	78.7
1985	197.1	129.6	326.6	147.8	78.7
1986	128.0	76.0	203.9	93.3	75.0
1987	103.4	63.3	166.7	132.2	79.7
1988	—	—	—	84.2	75.1
1989	—	—	—	502.2	70.3
1990	—	—	—	36.1	79.4
1991	—	—	—	110.8	70.2

Table 12.—Mean length (mm) ± approximate 95% confidence interval of yellow perch by age group from October trawl catches in Saginaw Bay, Lake Huron.

Sex	Sample year					
and age	1986	1987	1988	1989	1990	1991
Males						
1	118 ± 0.8	120 ± 1.5	119 ± 1.0	120 ± 1.0	124 ± 1.3	125 ± 2.6
2	137 ± 1.5	137 ± 2.0	137 ± 1.5	141 ± 2.0	146 ± 2.2	147 ± 2.1
3	154 ± 1.7	152 ± 2.2	150 ± 1.7	157 ± 2.1	165 ± 2.8	169 ± 2.8
4	184 ± 2.6	168 ± 2.5	164 ± 2.6	170 ± 3.3	175 ± 3.6	185 ± 2.9
5	199 ± 8.5	190 ±11.9	177 ± 5.4	185 ± 3.5	186 ± 4.1	203 ± 4.9
6	209 ±28.3	189 ±22.5	201 ± 5.4	194 ± 4.5	195 ± 6.1	215 ±14.1
7	249	223	211	210	270	—
8	236	217	—	—	—	—
Females						
1	121 ± 1.2	122 ± 1.5	123 ± 1.5	123 ± 1.1	126 ± 1.1	128 ± 1.9
2	145 ± 1.5	143 ± 1.5	143 ± 2.2	149 ± 2.0	157 ± 2.5	155 ± 2.4
3	173 ± 2.2	166 ± 2.7	160 ± 2.1	169 ± 3.4	176 ± 2.7	180 ± 3.1
4	197 ± 5.0	190 ± 4.3	183 ± 3.7	184 ± 3.2	199 ± 5.2	205 ± 4.4
5	233 ± 7.1	214 ± 8.4	207 ± 8.0	208 ± 5.7	215 ± 6.4	225 ± 4.0
6	265 ±19.3	226 ±12.9	217 ±29.9	222 ±16.0	235 ±14.5	250 ± 3.9
7	222	256	245	246	283	—
8	236	248	—	—	—	—
9	286	271	—	—	—	—

Table 13.—Mean observed length at age by year class for male yellow perch from Saginaw Bay, Lake Huron, from fall trawl samples collected in 1986-1990.

Year	Age								
class	0	1	2	3	4	5	6	7	8
1980	—	—	—	—	—	—	208.5	249.0	—
1981	—	—	—	—	—	198.9	188.7	222.5	236.0
1982	—	—	—	—	181.4	189.8	201.4	211.3	216.7
1983	—	—	—	153.9	167.8	176.6	194.4	210.4	
1984	—	—	136.9	152.4	164.2	184.9	195.3		
1985	—	118.0	137.1	149.5	169.6	186.1			
1986	76.1	120.2	137.1	157.2	175.1				
1987	80.5	118.9	140.9	165.3					
1988	76.9	119.8	145.6						
1989	70.2	125.2							
1990	79.5								

Table 14.—Incremental change in fall mean observed length (mm) between sample years for male yellow perch.

Age	1986-87	1987-88	1988-89	1989-90
1	2.3	-1.3	0.8	5.4
2	0.1	0.0	3.8	4.7
3	-1.6	-2.8	7.7	8.1
4	-13.6	-3.6	5.4	5.5
5	-9.0	-13.3	8.3	1.3
6	-19.8	12.7	-6.9	0.9
Sum	-41.7	-8.2	19.0	26.0

Table 15.—Mean observed length at age by year class for female yellow perch from Saginaw Bay, Lake Huron, from fall trawl samples collected in 1986-1990.

Year	Age										
class	0	1	2	3	4	5	6	7	8	9	10
1980	—	—	—	—	—	—	265.0	256.0	235.5	286.0	274.0
1981	—	—	—	—	—	233.0	226.2	—	—	271.0	
1982	—	—	—	—	196.8	214.1	216.7	245.4	248.0		
1983	—	—	—	172.3	189.8	207.2	228.9	245.8			
1984	—	—	144.9	165.7	182.5	208.1	234.5				
1985	—	120.8	142.8	160.0	184.4	214.9					
1986	76.3	122.3	143.5	168.5	198.7						
1987	78.3	122.8	148.7	176.0							
1988	73.9	122.7	156.9								
1989	70.2	127.5									
1990	79.5										

Table 16.—Incremental change in fall mean observed length (mm) between sample years for female yellow perch.

Age	1986-87	1987-88	1988-89	1989-90
1	1.5	0.5	-0.0	4.8
2	-2.2	0.7	5.3	8.2
3	-6.6	-5.7	8.5	7.5
4	-7.0	-7.2	1.8	14.4
5	-18.9	-6.9	0.9	6.8
6	-38.8	-9.5	12.3	5.6
Sum	-72.0	-28.3	28.8	47.1

Table 17.—Length frequency (mm) of yellow perch caught in gill nets in Saginaw Bay, Lake Huron, during 1986-1988 by month.

Length interval	May	Jun	Jul	Aug	Sep	Oct	Total	Percent	Accumulated percent
0-25	7	0	0	0	0	0	7	0.1	0.1
26-50	1	0	0	10	61	3	75	1.3	1.4
51-75	76	183	1	4	140	54	458	8.0	9.5
76-100	108	338	273	155	218	52	1,144	20.0	29.5
101-125	238	484	267	192	297	92	1,570	27.5	57.0
126-150	264	457	252	223	239	183	1,618	28.3	85.3
151-175	105	175	102	57	108	101	648	11.3	96.6
176-200	33	44	24	7	32	12	152	2.7	99.3
201-225	4	11	3	1	10	3	32	0.6	99.8
226-250	2	4	1	1	0	1	9	0.2	100.0
Total	838	1,696	923	650	1,105	501	5,713		

Table 18.—Average monthly trawl CPUE and 95% confidence interval for age 1-6 yellow perch caught at fixed stations in Saginaw Bay, Lake Huron.

		CPUE					
Survey period	Month	Males	95% Confidence interval	Females	95% Confidence interval	Total	95% Confidence interval
1986-1988	May	272.5	204.4 - 340.5	159.2	119.5 - 199.0	431.7	324.0 - 539.4
1986-1988	Jun	559.7	324.6 - 794.9	272.5	158.1 - 387.0	832.3	482.6 - 1,181.9
1986-1988	Jul	294.3	250.1 - 338.6	188.4	160.1 - 216.7	482.7	410.2 - 555.3
1986-1988	Aug	268.5	190.3 - 346.7	145.5	103.0 - 187.9	414.0	293.3 - 534.6
1986-1988	Sep	433.3	222.7 - 643.9	261.4	134.4 - 388.5	694.7	357.1 - 1,032.4
1986-1988	Oct	297.2	205.5 - 388.9	168.9	116.6 - 221.1	466.1	322.2 - 610.0
1989	Oct	188.7	109.5 - 267.8	108.3	62.7 - 153.8	296.9	172.2 - 421.6
1990	Oct	73.8	53.1 - 94.4	43.1	31.2 - 55.1	116.9	84.3 - 149.5
1991	May	45.8	28.0 - 63.6	41.1	25.1 - 57.0	86.9	53.1 - 120.6
1991	Jul	52.5	34.9 - 98.3	22.2	11.6 - 32.8	88.8	46.5 - 131.2
1991	Oct	48.9	29.6 - 68.2	32.3	19.6 - 45.0	81.2	49.2 - 113.2

Table 19.—Trawl CPUE of yellow perch by age group in Saginaw Bay, Lake Huron.

Sex and age	Sample year 1986	1987	1988	1989	1990	1991
Males						
1	68.0	47.5	24.9	46.0	25.8	11.6
2	65.5	69.1	22.0	54.9	13.4	20.7
3	66.1	60.1	28.4	45.5	16.1	11.4
4	11.5	36.0	23.1	25.6	8.1	7.5
5	1.0	6.1	8.0	11.1	6.0	4.9
6	0.2	1.6	1.7	3.8	3.2	1.2
7	0.0	0.3	0.3	1.0	0.9	0.1
8	0.0	0.0	0.0	0.2	0.2	0.0
Females						
1	37.4	26.9	18.9	32.5	16.6	5.4
2	34.4	51.4	18.2	30.3	7.2	12.1
3	35.7	26.1	22.4	19.8	7.5	9.0
4	5.3	14.9	7.5	16.4	7.1	6.6
5	1.4	2.6	2.3	6.1	2.1	4.1
6	0.3	0.7	0.7	2.4	0.4	1.5
7	0.4	0.3	0.0	1.2	0.3	0.3
8	0.0	0.0	0.1	0.0	0.1	0.0
9	0.0	0.0	0.0	0.2	0.1	0.0

Table 20.—Male:female sex ratio (M:F) from fall trawl samples taken during years 1971-1991.

Age	M:F sex ratio	95% Confidence interval	Number sample years
1	1.64	1.38 - 1.91	20
2	2.09	1.77 - 2.40	20
3	3.44	2.53 - 4.34	20
4	3.46	2.62 - 4.30	20
5	2.07	1.48 - 2.66	14
6	1.81	0.26 - 3.36	10
Overall	2.50	2.19 - 2.81	20

Table 21.—Average density (number/L) and length (mm) ± approximate 95% confidence interval of zooplankton species collected from Saginaw Bay, Lake Huron, during 1988.

Species	Density	Mean length
Bosmina longirostris	3.97 ± 3.09	0.42 ± 0.01
Gastropus sp.	0.01 ± 0.04	0.75 ± 0.35
Ceriodaphnia quadrilangula	1.45 ± 1.40	0.52 ± 0.03
Chydorus sphaericus	0.74 ± 0.97	0.33 ± 0.03
Diacyclops thomasi	0.97 ± 0.99	1.10 ± 0.09
Holopedium sp.	0.02 ± 0.02	0.61 ± 0.13
Eubosmina coregoni	2.44 ± 1.39	0.45 ± 0.01
Daphnia longi'is	1.65 ± 1.06	0.78 ± 0.03
Daphnia galeata mendotae	0.16 ± 0.17	0.94 ± 0.18
Daphnia pulex	0.09 ± 0.08	1.14 ± 0.24
Daphnia pulicaria	0.04 ± 0.08	0.38 ± 0.08
Daphnia retrocurva	4.03 ± 3.04	0.85 ± 0.02
Daphnia schodleri	0.02 ± 0.04	0.88 ± 0.03
Diaptomus oregonensis	0.01 ± 0.01	1.00 ± 0.47
Diaptomus sicilis	0.02 ± 0.03	1.06 ± 0.31
Epischura lacustris	0.01 ± 0.01	0.20 ± 0.09
Leptodera kindtii	0.05 ± 0.05	1.94 ± 0.56
Mesocyclops edax	0.37 ± 0.32	1.17 ± 0.14
Sida crystallina	0.04 ± 0.03	0.66 ± 0.14
Diaphanasoma sp.	0.01 ± 0.01	0.70 ± 0.32
Polyphemus sp.	0.01 ± 0.01	0.90 ± 0.30
Unid. Cyclopoids	0.58 ± 0.57	0.86 ± 0.06
Unid. Calanoids	0.82 ± 0.41	0.93 ± 0.03
Unid. Copepods	0.02 ± 0.05	0.93 ± 0.25
Nauplii	0.09 ± 0.05	0.29 ± 0.04
Rotifers	1.49 ± 0.84	0.47 ± 0.01
Ostracods	0.01 ± 0.02	0.82 ± 0.19
Chydorids	0.01 ± 0.01	0.80 ± 0.27

Table 22.—Monthly mean length (mm) ± approximate 95% confidence interval of zooplankton species collected from Saginaw Bay, Lake Huron, during 1988.

	Month					
Species	May	Jun	Jul	Aug	Sep	Oct
Bosmina longirostris	0.48±0.01	0.47±0.01	0.94±0.04	0.44±0.02	0.31±0.02	0.35±0.01
Gastropus sp.	0.50±0.00	1.00±0.00	0.00	0.00	0.00	0.00
Ceriodaphnia quadrilangula	0.00	0.58±0.04	0.52±0.01	0.48±0.03	0.45±0.05	0.45±0.06
Chydorus sphaericus	0.39±0.01	0.34±0.04	0.43±0.13	0.26±0.01	0.20±0.00	0.39±0.08
Diacyclops thomasi	1.16±0.05	1.02±0.09	0.96±0.06	0.93±0.10	0.95±0.01	0.93±0.14
Holopedium sp.	0.00	0.00	0.00	0.90±0.20	0.50±0.00	0.58±0.07
Eubosmina coregoni	0.51±0.02	0.50±0.01	0.39±0.02	0.42±0.03	0.41±0.02	0.41±0.01
Daphnia longi'is	0.87±0.04	0.80±0.05	0.74±0.05	0.64±0.07	0.59±0.07	0.70±0.16
Daphnia galeata mendotae	1.23±0.24	0.92±0.07	0.91±0.08	0.00	0.60±0.00	0.00
Daphnia pulex	1.52±0.15	0.66±0.06	0.00	0.00	0.00	0.00
Daphnia pulicaria	0.00	0.38±0.12	0.00	0.00	0.00	0.00
Daphnia retrocurva	0.94±0.08	0.91±0.02	0.81±0.02	0.81±0.03	0.82±0.07	0.96±0.12
Daphnia schodleri	1.40±0.20	0.00	0.00	0.00	0.00	0.68±0.12
Diaptomus oregonensis	1.00±0.00	0.00	0.00	0.00	0.00	0.00
Diaptomus sicilis	1.10±0.20	1.03±0.07	0.00	0.00	0.00	0.00
Epischura lacustris	0.00	0.00	0.00	0.00	0.00	0.20±0.00
Leptodera kindtii	0.00	1.90±0.40	2.13±0.74	2.80±0.00	1.00±0.00	0.00
Mesocyclops edax	1.23±0.07	1.09±0.08	1.07±0.09	1.07±0.01	0.90±0.00	0.00
Sida crystallina	0.30±0.00	0.00	0.65±0.14	0.74±0.04	0.50±0.20	0.00
Diaphanasoma sp.	0.00	0.00	0.00	0.80±0.00	0.60±0.00	0.00
Polyphemus sp.	0.00	0.00	0.00	0.90±0.20	0.00	0.00
Unid. Cyclopoids	1.05±0.06	0.85±0.05	0.73±0.05	0.72±0.06	0.66±0.10	0.65±0.07
Unid.Calanoids	1.04±0.05	0.98±0.04	0.94±0.04	0.92±0.03	0.90±0.05	0.87±0.08
Unid. Copepods	0.00	0.00	0.93±0.35	0.00	0.00	0.00
Nauplii	0.27±0.00	0.30±0.00	0.40±0.20	0.34±0.08	0.27±0.03	0.24±0.00
Rotifers	0.54±0.04	0.45±0.08	0.50±0.02	0.48±0.01	0.45±0.01	0.46±0.02
Ostracods	0.00	0.83±0.10	0.00	0.00	0.00	0.00
Chydorids	0.00	0.00	0.00	0.00	0.00	0.80±0.00

Table 23.—Monthly mean biomass (μg/L) of zooplankton species collected from Saginaw Bay, Lake Huron, during 1988.

Species	Month						
	May	Jun	Jul	Aug	Sep	Oct	Mean
Bosmina longirostris	50.06	9.98	1.52	2.07	0.47	1.30	10.90
Gastropus sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ceriodaphnia quadrilangula	0.00	2.66	17.28	0.18	0.07	0.05	3.37
Chydorus sphaericus	7.38	0.14	0.29	0.25	0.00	0.07	1.28
Diacyclops thomasi	36.59	3.11	1.69	0.37	0.05	0.07	6.62
Holopedium sp.	0.00	0.00	0.00	0.24	0.00	0.19	0.07
Eubosmina coregoni	19.79	16.23	7.28	0.35	0.36	1.06	7.51
Daphnia longi'is	53.46	10.07	7.52	1.34	0.64	0.21	12.20
Daphnia galeata mendotae	1.33	4.47	3.46	0.00	0.03	0.00	1.55
Daphnia pulex	4.22	0.73	0.00	0.00	0.00	0.00	0.83
Daphnia pulicaria	0.00	0.33	0.00	0.00	0.00	0.00	0.05
Daphnia retrocurva	15.48	46.86	50.01	2.66	0.16	0.19	19.23
Daphnia schodleri	2.50	0.00	0.00	0.00	0.00	0.11	0.43
Diaptomus oregonensis	0.12	0.00	0.00	0.00	0.00	0.00	0.02
Diaptomus sicilis	1.22	0.81	0.00	0.00	0.00	0.00	0.34
Epischura lacustris	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Leptodera kindtii	0.00	12.60	23.63	0.44	1.24	0.00	6.32
Mesocyclops edax	22.15	3.21	4.92	0.19	0.03	0.00	5.08
Sida crystallina	0.02	0.00	0.67	0.19	0.02	0.00	0.15
Diaphanasoma sp.	0.00	0.00	0.00	0.02	0.01	0.00	0.01
Polyphemus sp.	0.00	0.00	0.00	0.24	0.00	0.00	0.04
Unid. Calanoids	20.44	14.07	7.05	12.66	2.62	1.06	9.65
Unid. Copepods	0.00	0.00	1.60	0.00	0.00	0.00	0.27
Nauplii	0.42	0.14	0.36	0.34	0.21	0.06	0.26
Rotifers	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chydorids	0.00	0.00	0.00	0.00	0.00	0.07	0.01

Table 24.—Benthos density estimated from Ponar samples collected in Saginaw Bay, Lake Huron, during 1986.

Taxon	Number per m^2	Percent of number present	Percent of potential perch food
Turbellaria	29.7	0.28	
Nemertea	3.6	0.03	
Nematoda	1,1219.4	11.53	
Mollusca			
Gastropoda	21.2	0.20	0.49
Pelecypoda	216.6	2.05	5.03
Annelida			
Oligochaeta	5,020.1	47.46	
Hirudinea	1.1	0.01	0.03
Arthropoda; Arachnida			
Acari	21.8	0.21	0.51
Arthropoda; Crustacea			
Ostrocoda	200.2	1.89	4.65
Cladocera	199.3	1.88	4.63
Copepoda	2,311.6	21.85	53.70
Amphipoda	7.7	0.07	0.18
Arthropoda; Insecta			
Ephemeroptera; Caenidae	2.9	0.03	0.07
Trichoptera; Leptoceridae	8.5	0.08	0.20
Diptera; Ceratopogonidae	0.4	0.00	0.01
Diptera; Chironomidae	1,313.7	12.42	30.52
Total	10,577.7	100.00	100.00

Table 25.—Mean lengths of walleyes collected from inner Saginaw Bay, Lake Huron, during 1986-1988 using bottom trawls and experimental gill nets. Sample sizes in parentheses.

Year, and age	Month								
			Jun			Jul			
	May	Jun	Early	Late	Jul	Early	Late	Aug	Sep	Oct
1986										
1	—	—	229	246	—	262	276	306	334	352
	—	—	(19)	(14)	—	(6)	(23)	(52)	(21)	(36)
2	—	—	375	376	—	366	379	358	—	433
	—	—	(6)	(4)	—	(3)	(4)	(7)	—	(2)
3	—	—	435	438	—	—	475	492	545	—
	—	—	(7)	(3)	—	—	(1)	(2)	(2)	—
4	—	—	474	465	—	432	469	519	502	462
	—	—	(18)	(7)	—	(4)	(15)	(3)	(4)	(6)
5	—	—	518	501	—	497	574	—	540	567
	—	—	(1)	(4)	—	(1)	(1)	—	(1)	(1)
6	—	—	534	—	—	522	503	—	—	503
	—	—	(3)	—	—	(1)	(1)	—	—	(1)
7	—	—	—	—	—	—	636	—	—	—
	—	—	—	—	—	—	(1)	—	—	—
8	—	—	528	685	—	—	—	660	—	662
	—	—	(1)	(1)	—	—	—	(1)	—	(2)
1987										
1	233	256	—	—	—	—	—	333	360	369
	(25)	(16)	—	—	—	—	—	(9)	(28)	(22)
2	365	360	—	—	406	—	—	408	438	445
	(64)	(10)	—	—	(35)	—	—	(49)	(48)	(11)
3	431	434	—	—	466	—	—	452	488	473
	(16)	(2)	—	—	(17)	—	—	(16)	(7)	(2)
4	539	497	—	—	506	—	—	503	543	533
	(13)	(3)	—	—	(9)	—	—	(3)	(7)	(4)
5	541	—	—	—	509	—	—	558	580	552
	(6)	—	—	—	(2)	—	—	(7)	(5)	(8)
6	565	663	—	—	507	—	—	—	579	646
	(4)	(1)	—	—	(1)	—	—	—	(4)	(1)
7	638	—	—	—	564	—	—	576	—	—
	(4)	—	—	—	(1)	—	—	(2)	—	—
8	681	725	—	—	—	—	—	—	—	—
	(1)	(1)	—	—	—	—	—	—	—	—
9	692	—	—	—	—	—	—	720	—	—
	(1)	—	—	—	—	—	—	(1)	—	—

Table 25.—Continued:

	Month									
			Jun			Jul				
Year, and age	May	Jun	Early	Late	Jul	Early	Late	Aug	Sep	Oct
1988										
1	230	254	—	—	254	—	—	318	358	363
	(10)	(10)	—	—	(3)	—	—	(9)	(10)	(30)
2	363	372	—	—	404	—	—	417	427	438
	(22)	(8)	—	—	(19)	—	—	(20)	(18)	(34)
3	442	449	—	—	450	—	—	473	471	506
	(39)	(21)	—	—	(31)	—	—	(17)	(23)	(22)
4	461	479	—	—	484	—	—	508	536	526
	(7)	(8)	—	—	(14)	—	—	(11)	(10)	(7)
5	528	533	—	—	511	—	—	496	524	617
	(11)	(12)	—	—	(7)	—	—	(2)	(4)	(1)
6	573	564	—	—	547	—	—	545	619	446
	(8)	(5)	—	—	(7)	—	—	(4)	(2)	(3)
7	611	598	—	—	601	—	—	—	—	546
	(5)	(6)	—	—	(2)	—	—	—	—	(1)
8	—	664	—	—	—	—	—	—	—	—
	—	(2)	—	—	—	—	—	—	—	—
9	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—
10	—	581	—	—	—	—	—	—	—	—
	—	(1)	—	—	—	—	—	—	—	—

Table 26.—Mean weights of walleyes collected from Saginaw Bay, Lake Huron, 1986-1988 using bottom trawls and experimental gill nets.

Year, and age	Month									
			Jun			Jul				
	May	Jun	Early	Late	Jul	Early	Late	Aug	Sep	Oct
1986										
1	—	—	93	124	—	143	166	238	343	414
2	—	—	469	474	—	477	479	397	—	800
3	—	—	777	786	—	—	1,100	1,091	1,560	—
4	—	—	1,019	967	—	785	968	1,344	1,160	1,023
5	—	—	1,357	1,218	—	1,215	1,907	—	1,700	1,890
6	—	—	1,505	—	—	1,340	1,231	—	—	1,220
7	—	—	—	—	—	—	2,770	—	—	—
8	—	—	—	1,446	—	3,050	—	2,610	—	2,890
9	—	—	—	—	—	3,020	—	—	—	—
1987										
1	99	129	—	—	—	—	—	325	411	470
2	446	418	—	—	583	—	—	582	768	862
3	728	790	—	—	959	—	—	799	1,096	1,090
4	1,581	1,263	—	—	1,331	—	—	1,133	1,580	1,598
5	1,543	—	—	—	1,370	—	—	1,494	2,060	1,793
6	1,695	2,580	—	—	1,310	—	—	—	2,003	3,170
7	2,498	—	—	—	1,860	—	—	1,836	—	—
8	2,890	3,930	—	—	—	—	—	—	—	—
9	3,050	—	—	—	—	—	—	—	4,230	—
1988										
1	96	126	—	—	123	—	—	273	391	433
2	439	449	—	—	578	—	—	616	693	807
3	816	855	—	—	857	—	—	902	931	1,250
4	961	1,046	—	—	1,097	—	—	1,175	1,384	1,646
5	1,381	1,433	—	—	1,097	—	—	1,174	1,384	1,646
6	1,679	1,746	—	—	1,571	—	—	1,467	1,975	1,247
7	2,064	2,083	—	—	2,150	—	—	—	—	1,570
8	—	2,580	—	—	—	—	—	—	—	—
9	—	—	—	—	—	—	—	—	—	—
10	—	1,841	—	—	—	—	—	—	—	—

Table 27.—Seasonal patterns of consumption by age-2 and age-3 walleyes, 1987-1988.

Year and cohort	Time	Clupeids Alewife	Clupeids Gizzard shad	Rainbow smelt	White perch	*Notropis* spp.	Yellow perch	Other
1987								
Age 2								
1	May-Jun	239.3	9.9	111.0	0.0	81.4	13.6	68.5
2	Jul	78.5	33.0	0.7	3.6	13.6	13.6	0.0
3	Aug	198.5	200.7	10.4	12.0	57.2	21.8	0.0
4	Sep	82.4	43.8	19.0	0.0	40.1	1.0	5.2
Totals		598.7	287.4	141.1	15.6	192.3	50.0	73.5
1988								
Age 2								
1	May	7.7	3.3	3.7	0.0	70.6	10.4	13.8
2	Jun	18.9	33.4	7.7	0.0	175.7	103.7	28.8
3	Jul	7.7	39.1	1.8	0.0	73.9	121.5	6.7
4	Aug	48.1	122.4	0.0	11.2	44.0	98.3	0.0
5	Sep	79.3	171.2	9.5	14.4	25.2	1.7	1.3
Totals		161.7	369.4	22.7	25.6	389.4	335.6	50.6
1988								
Age 3								
1	May	153.4	0.0	0.0	0.0	35.8	12.2	15.6
2	Jun	143.8	7.0	1.0	0.0	31.2	50.4	15.7
3	Jul	72.3	41.5	0.0	0.0	37.4	174.7	0.0
4	Aug	37.2	117.5	0.0	9.7	55.7	109.5	0.0
5	Sep	101.5	302.3	0.0	18.3	115	20.1	0.0
Totals		508.2	468.3	1.0	28.0	275.1	366.9	31.3

Table 28.—Diet of age-1 yellow perch collected from Saginaw Bay, Lake Huron, 1986-1988. Numbers represent percent contribution of individual prey types to total wet weight of the diet. All fish pooled.

	Month					
	May	Jun	Jul	Aug	Sep	Oct
1986						
Chironomidae	—	20.3	47.2	84.6	92.2	55.0
Zooplankton	—	52.1	14.0	0.5	1.0	6.0
Insecta	—	2.8	18.5	1.4	1.6	0.2
Mollusca	—	0.0	0.0	0.0	0.0	0.1
Gizzard shad	—	0.0	0.0	0.0	0.0	0.0
Alewife	—	0.0	0.0	2.7	0.0	0.0
Yellow perch	—	0.0	0.0	0.0	0.0	0.0
Cyprinid	—	0.0	0.0	0.0	0.0	0.0
Trout-perch	—	2.7	5.0	0.0	0.0	0.0
Rainbow smelt	—	0.0	2.5	0.0	0.0	0.0
Unidentified fish	—	22.1	12.8	10.8	5.2	38.7
Number examined	0	262	397	249	140	70
1987						
Chironomidae	92.6	87.0	81.6	87.0	93.6	84.6
Zooplankton	7.4	8.4	0.9	0.4	0.7	3.9
Insecta	0.0	0.6	6.8	3.7	0.4	1.0
Mollusca	0.0	0.0	0.0	0.3	0.0	0.0
Gizzard shad	0.0	0.0	0.0	0.0	0.0	0.0
Alewife	0.0	0.0	0.0	0.0	0.0	0.0
Yellow perch	0.0	0.0	0.0	0.0	0.0	0.0
Cyprinid	0.0	0.0	0.0	0.0	0.0	0.0
Trout-perch	0.0	0.0	0.0	0.0	0.0	0.0
Rainbow smelt	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified fish	0.0	4.0	10.7	8.6	5.3	10.5
Number examined	100	121	145	85	117	108
1988						
Chironomidae	95.4	82.0	87.7	68.7	92.5	81.8
Zooplankton	4.0	10.4	4.9	0.6	2.5	10.6
Insecta	0.6	1.9	7.4	5.8	2.0	2.0
Mollusca	0.0	0.0	0.0	0.1	0.0	0.0
Gizzard shad	0.0	0.0	0.0	0.0	0.0	0.0
Alewife	0.0	0.0	0.0	0.0	0.0	0.0
Yellow perch	0.0	0.0	0.0	0.0	0.0	0.0
Cyprinid	0.0	0.0	0.0	0.0	0.0	0.0
Trout-perch	0.0	0.0	0.0	0.0	0.0	0.0
Rainbow smelt	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified fish	0.0	5.7	0.0	24.8	3.0	5.6
Number examined	152	155	157	218	203	206

Table 29.—Diet of age-2 yellow perch collected from Saginaw Bay, Lake Huron, 1986-1988. Numbers represent percent contribution of individual prey types to total wet weight of the diet. All fish pooled.

	Month					
	May	Jun	Jul	Aug	Sep	Oct
1986						
Chironomidae	—	80.2	56.1	41.9	69.6	42.3
Zooplankton	—	5.6	7.6	0.1	0.4	4.2
Insecta	—	7.5	21.6	0.5	2.0	0.4
Mollusca	—	1.0	1.0	0.0	0.1	0.1
Gizzard shad	—	0.0	1.0	0.0	0.0	0.0
Alewife	—	0.0	0.0	24.8	2.3	0.0
Yellow perch	—	0.0	2.0	0.0	1.6	0.0
Cyprinid	—	0.0	0.0	0.0	0.0	8.8
Trout-perch	—	1.9	4.8	0.8	0.0	0.0
Rainbow smelt	—	0.0	1.9	1.2	3.8	0.0
Unidentified fish	—	3.8	4.0	30.7	20.2	44.2
Number examined	0	171	346	256	231	91
1987						
Chironomidae	94.6	91.6	80.9	79.2	94.0	88.4
Zooplankton	2.2	3.3	0.5	0.2	0.4	1.2
Insecta	0.3	3.9	5.4	3.7	0.4	0.1
Mollusca	0.0	0.0	0.2	0.0	0.0	0.0
Gizzard shad	0.0	0.0	0.0	0.0	0.0	0.0
Alewife	1.0	0.0	0.0	1.7	0.0	0.0
Yellow perch	0.0	0.0	0.0	1.7	0.0	0.0
Cyprinid	0.0	0.0	0.0	0.9	0.0	0.0
Trout-perch	0.0	0.0	0.0	0.0	0.0	0.0
Rainbow smelt	0.0	0.0	0.0	0.8	0.0	0.0
Unidentified fish	1.9	1.2	13.0	11.8	5.2	10.3
Number examined	211	238	274	303	379	275
1988						
Chironomidae	97.7	87.3	85.1	62.3	95.3	58.8
Zooplankton	1.2	3.7	0.3	0.4	1.0	5.3
Insecta	1.1	4.2	9.1	7.4	0.8	2.6
Mollusca	0.0	0.0	0.0	0.1	0.1	0.0
Gizzard shad	0.0	0.0	0.0	0.0	0.0	0.0
Alewife	0.0	0.0	0.0	0.0	0.0	0.0
Yellow perch	0.0	0.0	2.8	0.0	0.0	0.0
Cyprinid	0.0	0.0	0.0	6.0	0.0	0.0
Trout-perch	0.0	0.0	0.0	0.0	0.0	0.0
Rainbow smelt	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified fish	0.0	4.8	2.7	23.8	2.8	33.3
Number examined	148	116	145	152	150	180

Table 30.—Diet of age-3 yellow perch collected from Saginaw Bay, Lake Huron, 1986-1988. Numbers represent percent contribution of individual prey types to total wet weight of the diet. All fish pooled.

	Month					
	May	Jun	Jul	Aug	Sep	Oct
1986						
Chironomidae	—	72.3	68.0	25.8	36.9	30.9
Zooplankton	—	1.1	2.1	0.0	0.2	2.3
Insecta	—	5.3	9.6	0.6	1.4	1.5
Mollusca	—	0.5	0.1	0.0	0.0	0.1
Gizzard shad	—	1.3	0.7	0.0	0.9	0.0
Alewife	—	5.3	0.3	40.6	18.4	5.4
Yellow perch	—	0.0	1.4	0.0	1.8	0.0
Cyprinid	—	0.0	0.0	0.0	2.6	0.0
Trout—perch	—	2.0	3.7	0.5	1.7	0.0
Rainbow smelt	—	4.6	6.0	0.8	1.7	10.8
Unidentified fish	—	7.6	8.1	31.7	34.4	49.0
Number examined	0	292	561	334	251	122
1987						
Chironomidae	96.1	92.5	77.3	68.4	85.8	70.4
Zooplankton	0.9	2.0	0.2	0.3	0.4	0.3
Insecta	2.9	4.4	7.4	5.3	0.3	0.1
Mollusca	0.1	0.1	0.2	0.2	0.0	0.0
Gizzard shad	0.0	0.0	1.0	0.0	0.0	0.0
Alewife	0.0	0.0	0.0	0.0	0.0	0.0
Yellow perch	0.0	0.0	4.5	0.0	0.0	8.0
Cyprinid	0.0	0.0	0.5	0.0	0.0	0.0
Trout-perch	0.0	0.5	0.0	0.0	2.2	0.0
Rainbow smelt	0.0	0.0	0.5	4.0	2.2	0.0
Unidentified fish	0.0	0.5	8.4	21.8	9.1	21.2
Number examined	201	228	255	206	189	185
1988						
Chironomidae	95.4	89.9	82.0	42.5	79.0	48.6
Zooplankton	0.2	2.3	0.3	0.1	0.5	1.6
Insecta	4.4	4.8	11.4	3.1	1.6	1.6
Mollusca	0.0	0.0	0.0	0.0	0.0	0.1
Gizzard shad	0.0	0.0	0.0	0.0	0.0	0.0
Alewife	0.0	0.0	0.0	0.0	1.9	0.0
Yellow perch	0.0	0.0	1.7	6.6	0.0	0.0
Cyprinid	0.0	0.0	0.0	1.6	0.0	0.0
Trout-perch	0.0	1.0	0.0	0.0	0.0	0.0
Rainbow smelt	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified fish	0.0	2.0	4.6	46.1	17.0	48.1
Number examined	332	381	362	255	232	234

Table 31.—Diet of age-4 yellow perch collected from Saginaw Bay, Lake Huron, 1986-1988. Numbers represent percent contribution of individual prey types to total wet weight of the diet. All fish pooled.

	Month					
	May	Jun	Jul	Aug	Sep	Oct
1986						
Chironomidae	-	76.2	53.6	7.9	27.0	3.3
Zooplankton	-	0.2	0.6	0.0	0.0	0.1
Insecta	-	3.7	12.3	0.0	0.0	0.2
Mollusca	-	0.3	0.7	0.0	0.0	0.0
Gizzard shad	-	0.0	1.4	0.0	0.0	9.6
Alewife	-	0.0	0.0	47.7	4.3	0.0
Yellow perch	-	0.0	2.8	0.0	0.0	0.0
Cyprinid	-	3.9	1.4	0.0	12.9	0.0
Trout-perch	-	9.1	13.6	0.0	21.4	0.0
Rainbow smelt	-	2.6	1.4	13.6	0.0	0.0
Unidentified fish	-	4.0	12.2	30.8	34.4	86.8
Number examined	0	88	99	26	40	25
1987						
Chironomidae	94.1	91.7	70.3	48.6	65.5	55.9
Zooplankton	0.5	0.9	0.1	0.0	0.2	0.6
Insecta	1.0	4.0	12.1	2.2	0.7	0.0
Mollusca	0.4	0.2	0.0	0.1	0.0	0.0
Gizzard shad	0.0	0.0	1.0	0.0	0.0	0.0
Alewife	0.0	0.0	1.0	18.9	0.0	0.0
Yellow perch	0.0	0.0	0.0	0.0	11.5	0.0
Cyprinid	2.4	0.0	0.0	0.0	0.0	0.0
Trout-perch	0.0	0.0	0.0	0.0	0.0	2.9
Rainbow smelt	0.0	0.0	0.0	3.8	0.0	0.0
Unidentified fish	1.6	2.9	15.5	26.4	22.1	40.6
Number examined	195	208	130	96	111	110
1988						
Chironomidae	95.6	92.8	83.6	16.1	65.0	21.6
Zooplankton	0.1	0.8	0.1	0.1	0.4	0.2
Insecta	2.6	3.0	5.4	0.7	0.5	0.0
Mollusca	0.0	1.5	0.1	0.0	0.0	0.0
Gizzard shad	0.0	0.0	0.0	0.0	0.0	0.0
Alewife	0.0	1.0	0.0	5.8	3.8	0.0
Yellow perch	0.0	0.0	1.7	0.0	0.0	8.1
Cyprinid	0.0	0.0	0.0	3.4	0.0	3.9
Trout-perch	0.0	0.9	0.0	1.7	0.0	0.0
Rainbow smelt	0.3	0.0	0.0	1.7	0.0	0.0
Unidentified fish	1.4	0.0	9.1	70.5	30.3	66.2
Number examined	213	173	140	126	105	114

Table 32.—Diet of age-5 yellow perch collected from Saginaw Bay, Lake Huron, 1986-1988. Numbers represent percent contribution of individual prey types to total wet weight of the diet. All fish pooled.

	Month					
	May	Jun	Jul	Aug	Sep	Oct
1986						
Chironomidae	—	37.3	20.2	0.0	0.0	—
Zooplankton	—	1.3	0.3	0.0	0.0	—
Insecta	—	2.0	0.1	0.0	0.0	—
Mollusca	—	0.0	0.1	0.0	0.0	—
Gizzard shad	—	0.0	5.2	0.0	0.0	—
Alewife	—	0.0	0.0	78.6	30.0	—
Yellow perch	—	0.0	0.0	0.0	0.0	—
Cyprinid	—	0.0	10.4	0.0	10.0	—
Trout-perch	—	38.2	15.6	0.0	0.0	—
Rainbow smelt	—	21.2	31.2	7.1	10.0	—
Unidentified fish	—	0.0	16.9	14.3	50.0	—
Number examined	0	33	32	5	15	2
1987						
Chironomidae	90.2	95.1	79.9	59.5	2.3	31.8
Zooplankton	0.3	0.2	0.0	0.0	0.0	0.1
Insecta	0.1	2.4	0.3	3.3	0.0	0.2
Mollusca	0.1	0.1	0.0	0.1	0.0	0.0
Gizzard shad	0.0	0.0	0.0	0.0	0.0	0.0
Alewife	3.7	0.0	0.0	0.0	0.0	13.4
Yellow perch	0.0	0.0	0.0	0.0	0.0	27.8
Cyprinid	1.9	0.0	0.0	0.0	0.0	0.0
Trout-perch	0.0	0.0	0.0	0.0	9.7	0.0
Rainbow smelt	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified fish	3.7	2.2	19.8	37.1	88.0	26.7
Number examined	58	92	42	18	27	28
1988						
Chironomidae	97.5	88.0	83.0	13.7	29.6	18.7
Zooplankton	0.1	0.3	0.2	0.1	0.4	0.5
Insecta	2.0	1.8	6.7	0.1	0.8	0.0
Mollusca	0.0	0.0	0.1	0.0	0.0	0.0
Gizzard shad	0.0	0.0	0.0	0.0	0.0	0.0
Alewife	0.0	0.0	0.0	0.0	0.0	0.0
Yellow perch	0.0	0.0	0.0	0.0	0.0	0.0
Cyprinid	0.0	0.0	0.0	0.0	0.0	0.0
Trout-perch	0.0	1.4	0.0	0.0	0.0	0.0
Rainbow smelt	0.0	0.0	0.0	0.0	0.0	10.1
Unidentified fish	0.4	8.5	10.0	86.1	69.2	70.7
Number examined	117	91	59	60	51	50

Table 33.—Weighted average total food weight (g) by month of male yellow perch, 1986-1988.

Age	Month May	Jun	Jul	Aug	Sep	Oct	Mean
0	—	—	0.007	0.376	0.328	0.542	0.313
1	0.577	0.458	0.270	0.484	0.370	0.569	0.455
2	0.528	0.392	0.303	0.357	0.238	0.474	0.382
3	0.712	0.549	0.438	0.495	0.359	0.456	0.501
4	0.703	0.621	0.595	0.673	0.493	0.642	0.621
5	0.917	0.724	0.879	0.804	0.965	0.860	0.858
6	0.869	0.889	1.096	1.017	0.788	1.425	1.014
7	1.042	0.918	0.666	1.113	0.976	2.023	1.123
8	1.754	1.034	—	—	—	—	1.394
9	1.706	—	—	—	12.740	—	7.223
10	—	—	—	—	—	—	—
Mean	0.881	0.698	0.532	0.665	1.917	0.874	1.262
Sum 1-7	5.350	4.550	4.250	4.940	4.190	6.450	5.267

Table 34.—Weighted average total food weight (g) by month for female yellow perch, 1986-1988.

	Month						
Age	May	Jun	Jul	Aug	Sep	Oct	Mean
0	0.010	—	0.005	0.557	0.391	0.594	0.311
1	0.623	0.301	0.287	0.547	0.326	0.623	0.451
2	0.513	0.333	0.353	0.435	0.261	0.540	0.406
3	0.738	0.648	0.525	0.711	0.659	0.767	0.675
4	0.888	0.720	0.765	0.774	0.826	1.141	0.852
5	0.969	1.305	0.920	1.092	1.540	1.523	1.225
6	0.944	1.539	2.031	0.937	1.998	2.307	1.626
7	1.028	1.189	0.844	2.595	1.267	3.415	1.723
8	—	1.765	11.810	—	6.320	2.755	4.530
9	—	—	—	—	2.790	—	1.395
10	—	—	—	—	—	—	
Mean	0.519	0.975	1.949	0.956	1.638	1.518	1.319
Sum 1-7	5.703	6.035	5.724	7.089	6.878	10.316	6.958

Table 35.—Mean weight (g) of food per gram of male yellow perch, 1986-1988.

Age	Month May	Jun	Jul	Aug	Sep	Oct	Mean
0	—	—	0.004	0.105	0.067	0.109	0.071
1	0.097	0.052	0.020	0.030	0.020	0.032	0.042
2	0.029	0.019	0.012	0.013	0.008	0.017	0.016
3	0.026	0.018	0.013	0.014	0.009	0.012	0.015
4	0.019	0.015	0.013	0.014	0.010	0.012	0.014
5	0.019	0.014	0.014	0.013	0.014	0.013	0.014
6	0.012	0.013	0.013	0.012	0.009	0.016	0.013
7	0.012	0.011	0.008	0.010	0.009	0.013	0.011
8	0.015	0.013	—	—	—	—	0.014
9	0.015	—	—	—	—	—	0.015
10	—	—	—	—	—	—	—
Mean	0.025	0.019	0.012	0.026	0.018	0.028	0.021
Sum 1-7	0.220	0.140	0.090	0.110	0.080	0.120	0.196

Table 36.—Mean weight (g) of food per gram of female yellow perch, 1986-1988.

Age	Month May	Jun	Jul	Aug	Sep	Oct	Mean
0	0.005	—	0.007	0.274	0.112	0.222	0.124
1	0.111	0.040	0.026	0.045	0.021	0.055	0.049
2	0.027	0.024	0.018	0.024	0.011	0.033	0.023
3	0.024	0.024	0.018	0.026	0.026	0.033	0.025
4	0.019	0.019	0.016	0.035	0.024	0.050	0.027
5	0.015	0.042	0.017	0.047	0.039	0.041	0.033
6	0.011	0.025	0.029	0.007	0.026	0.017	0.019
7	—	0.021	0.004	—	0.009	0.037	0.018
8	—	—	—	—	0.023	—	—
9	—	—	—	—	—	—	—
10	—	—	—	—	—	—	—
Mean	0.021	0.028	0.017	0.065	0.033	0.061	0.040
Sum 1-7	0.208	0.193	0.127	0.184	0.157	0.265	0.318

Table 37.—Biomass (kg wet weight) of prey consumed by 1 million walleye (ages 1-3) in the inner portion of Saginaw Bay, 1988.

Age	Number of walleye	Alewife	Gizzard shad	Rainbow smelt	*Notropis* spp.	White perch	Yellow perch	Others
1	488,900	66,890	60,090	0	138,000	0	12,830	325
2	309,300	109,600	77,510	5,960	43,250	0	66,520	6,649
3	197,800	58,120	51,360	171	4,651	3,600	38,990	3,348
Total		234,610	188,960	6,131	185,901	3,600	118,340	10,322

Table 38.-Biomass (kg wet weight) of major prey consumed by yellow perch (ages 1-5) in the inner portion of Saginaw Bay, 1988.

Age	Chironomids	Alewife	*Notropis* spp.	Trout-perch	Yellow perch	Unidentified fish
1	6,324,000	0	0	0	0	688,000
2	9,757,000	0	176,400	0	0	492,700
3	12,600,000	38,070	60,080	0	224,300	1,523,000
4	8,915,000	62,890	46,850	112,000	97,730	1,192,000
5	3,371,000	0	0	0	0	889,700
Total	40,967,000	100,960	283,330	112,000	322,030	4,785,400

Table 39.—Mean annual abundance, size, biomass, and production of chironomids found in benthos samples and yellow perch stomachs in Saginaw Bay, 1986-1988.

	Benthos samples						Yellow perch stomachs		
Taxon	Density (number•m^{-2})	Mean length (mm)	Mean weight (g)	Biomass (g•m^{-2})	Total biomass (kg)	Total production (kg)	Sample	Percent	Mean length (mm)
Chironomus spp.	694.57	14.25	0.00489	3.398	5,338,897	78,214,844	1,554	42.5	8.2
Tanytarsus spp.	43.39	5.00	0.00172	0.074	117,020	1,714,347	491	13.4	3.6
Procladius spp.	99.02	5.78	0.00198	0.196	308,720	4,522,750	378	10.3	5.7
Cryptochironomous spp.	35.83	5.45	0.00187	0.067	105,323	1,542,985	33	0.9	5.4
Polypedilum spp.	61.21	5.51	0.00189	0.116	181,930	2,665,277	22	0.6	4.8
Cladotanytarsus spp.	332.34	5.00	0.00172	0.570	896,347	13,131,481	13	0.4	
Paracladopelma spp.	1.26	5.00	0.00172	0.002	3,399	49,793	6	0.2	
Pseudochironomous spp.	2.88	7.52	0.00258	0.007	11,684	171,176	2	0.1	
Cladopelma spp.	0.36	5.00	0.00172	0.001	971	14,228	1	0.0	
Paratendipes spp.	3.78	5.00	0.00172	0.006	10,197	149,382	1	0.0	
All pupae	22.68	15.00	0.00515	0.117	183,542	2,688,894	1,159	31.7	11.8
Other chironomids	16.38	5.00	0.00013	0.002	3,402	49,832			
Total	1,313.71			4.560	7,158,031	104,865,157	3,660		

Table 40.—Production (kg wet weight) of major prey taxa of walleye and yellow perch in the inner portion of Saginaw Bay, 1988.

Taxon	Production
Chironomids	104,865,157
Alewife	2,132,000
Gizzard shad	2,273,276
Rainbow smelt	906,000
Notropis spp.	2,004,000
Trout-perch	595,000
Yellow perch	14,977,334
Total	127,752,767

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Appendix 1.—Gill net CPUE[1] for Saginaw Bay, Lake Huron, during 1986.

	Month							Percent of total
Species	May	Jun	Jul	Aug	Sep	Oct	Total	
Yellow perch	12.4	63.4	21.0	20.5	44.7	24.7	186.8	34.0
Rainbow smelt	1.2	1.6	1.1	0.3	0.0	2.2	6.3	1.1
Spottail shiner	4.5	40.1	2.0	4.0	3.6	7.3	61.5	11.2
Trout-perch	1.5	2.0	0.2	0.3	4.1	0.2	8.2	1.5
Alewife	10.8	119.1	3.4	1.4	2.6	5.4	142.6	26.0
White perch	0.0	0.0	0.0	0.2	1.1	0.4	1.7	0.3
Gizzard shad	0.0	0.3	0.4	4.8	0.2	3.9	9.7	1.8
Emerald shiner	0.8	19.5	2.3	1.5	0.4	2.2	26.6	4.8
White sucker	3.5	17.4	10.1	8.4	17.0	8.6	64.9	11.8
White bass	0.0	0.4	0.3	0.5	0.0	0.0	1.3	0.2
Channel catfish	0.7	5.5	4.4	3.8	0.7	6.0	21.2	3.9
Freshwater drum	0.1	1.0	0.2	0.1	1.5	0.4	3.3	0.6
Common carp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Walleye	1.1	3.1	1.7	2.3	2.2	3.7	14.1	2.6
Johnny darter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quillback	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lake whitefish	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.0
Pumpkinseed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Longnose gar	0.0	0.1	0.1	0.0	0.1	0.2	0.5	0.1
Black crappie	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brown bullhead	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified fish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stonecat	0.0	0.2	0.0	0.0	0.1	0.0	0.3	0.1
Largemouth bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bluegill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Logperch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brown trout	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Golden shiner	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shorthead redhorse	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rock bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	36.6	273.6	47.3	48.0	78.3	65.4	549.1	

[1] Number caught per 1,000 feet of net lifted.

Appendix 2.—Gill net CPUE for Saginaw Bay, Lake Huron, during 1987.

Species	Month May	Jun	Jul	Aug	Sep	Oct	Total	Percent of total
Yellow perch	11.6	70.1	34.2	20.8	28.7	23.8	189.1	33.7
Rainbow smelt	0.1	0.0	0.1	0.1	0.5	0.5	1.2	0.2
Spottail shiner	9.4	5.1	1.8	1.7	4.1	2.7	24.8	4.4
Trout-perch	2.6	1.0	0.0	0.5	0.0	0.0	4.1	0.7
Alewife	20.4	82.2	9.2	6.0	21.7	1.8	141.3	25.2
White perch	0.2	0.1	3.3	4.3	2.9	1.0	11.8	2.1
Gizzard shad	0.0	0.0	19.3	1.9	5.4	6.5	33.2	5.9
Emerald shiner	5.2	1.4	0.7	0.5	2.3	1.0	11.1	2.0
White sucker	10.1	6.7	1.4	1.1	2.7	3.3	25.2	4.5
White bass	0.2	0.3	3.6	1.1	0.2	0.1	5.4	1.0
Channel catfish	40.0	3.3	8.7	8.5	2.8	3.0	66.3	11.8
Freshwater drum	0.6	1.9	3.0	3.3	0.2	0.1	9.1	1.6
Common carp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Walleye	4.7	0.5	4.4	5.3	2.0	1.1	18.0	3.2
Johnny darter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quillback	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lake whitefish	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Pumpkinseed	0.0	0.0	0.1	0.1	0.0	0.1	0.3	0.1
Longnose gar	0.1	0.1	3.9	0.1	1.8	11.2	17.2	3.1
Black crappie	0.0	0.1	0.5	0.1	0.5	0.3	1.4	0.3
Brown bullhead	0.0	0.1	0.0	0.1	0.1	0.0	0.3	0.1
Unidentified fish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stonecat	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Largemouth bass	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0
Bluegill	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0
Logperch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brown trout	0.1	0.0	0.0	0.0	0.1	0.0	0.2	0.0
Golden shiner	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shorthead redhorse	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rock bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	105.1	172.9	94.2	55.7	75.8	56.6	560.3	

Appendix 3.—Gill net CPUE for Saginaw Bay, Lake Huron, during 1988.

Species	Month						Total	Percent of total
	May	Jun	Jul	Aug	Sep	Oct		
Yellow perch	26.5	25.4	28.3	19.8	38.0	18.5	156.5	32.2
Rainbow smelt	0.0	0.0	0.1	0.7	0.3	0.7	1.7	0.4
Spottail shiner	10.6	10.1	14.1	2.2	2.1	3.3	42.4	8.7
Trout-perch	1.7	1.4	0.1	0.0	0.0	0.1	3.3	0.7
Alewife	1.7	56.2	2.8	0.0	30.8	2.4	93.9	19.3
White perch	0.8	0.3	1.8	9.4	17.2	9.3	38.8	8.0
Gizzard shad	0.6	0.3	4.4	7.5	14.8	1.2	28.7	5.9
Emerald shiner	2.3	3.3	0.7	1.0	3.1	2.6	13.1	2.7
White sucker	9.4	3.9	0.6	0.9	3.0	6.2	23.9	4.9
White bass	0.2	0.3	2.6	0.4	0.1	0.0	3.5	0.7
Channel catfish	4.7	2.2	15.8	3.9	1.8	8.0	36.4	7.5
Freshwater drum	0.5	0.9	8.9	3.2	0.1	0.1	13.7	2.8
Common carp	0.0	0.1	0.0	0.1	0.2	0.4	0.8	0.2
Walleye	4.7	4.1	4.8	2.4	3.7	4.9	24.5	5.1
Johnny darter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quillback	0.0	0.3	0.2	0.0	0.0	0.1	0.6	0.1
Lake whitefish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pumpkinseed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Longnose gar	0.0	0.0	1.6	0.7	0.0	0.0	2.2	0.5
Black crappie	0.0	0.1	0.0	0.3	0.2	0.1	0.7	0.1
Brown bullhead	0.0	0.2	0.2	0.4	0.0	0.0	0.7	0.1
Unidentified fish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stonecat	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0
Largemouth bass	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.1
Bluegill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Logperch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brown trout	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Golden shiner	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shorthead redhorse	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0
Rock bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	63.5	109.1	86.9	52.7	115.7	58.1	485.9	

Appendix 4.—Length frequency (mm) of yellow perch caught in gill nets in Saginaw Bay, Lake Huron, during 1986, 1987, and 1988 by month.

Length interval	May	Jun	Jul	Aug	Sep	Oct	Total	Percent	Accumulated percent
1986									
0-25	0	0	0	0	0	0	0	0.0	0.0
26-50	0	0	0	3	39	1	43	2.0	2.0
51-75	41	124	1	2	48	2	218	10.2	12.2
76-100	52	248	107	76	108	18	609	28.4	40.6
101-125	111	120	70	62	119	35	517	24.1	64.8
126-150	138	163	43	72	54	39	509	23.8	88.5
151-175	58	62	21	23	8	16	188	8.8	97.3
176-200	7	20	2	4	4	4	41	1.9	99.2
201-225	2	9	0	0	2	0	13	0.6	99.8
226-250	1	2	1	0	0	0	4	0.2	100.0
Total	410	748	245	242	382	115	2,142		
1987									
0-25	7	0	0	0	0	0	7	0.4	0.3
26-50	1	0	0	5	4	0	10	0.5	0.8
51-75	4	33	0	1	33	34	105	5.4	6.3
76-100	29	61	100	25	45	14	274	14.2	20.5
101-125	44	249	121	66	112	42	634	32.9	53.4
126-150	36	214	91	83	78	111	613	31.8	85.2
151-175	17	85	46	12	25	53	238	12.3	97.5
176-200	5	9	13	1	12	2	42	2.2	99.7
201-225	1	0	0	0	2	1	4	0.2	99.9
226-250	0	1	0	0	0	0	1	0.1	99.9
Total	144	652	371	193	311	257	1,928		
1988									
0-25	0	0	0	0	0	0	0	0.0	0.0
26-50	0	0	0	2	18	2	22	1.3	1.3
51-75	31	26	0	1	59	18	135	8.2	9.6
76-100	27	29	66	54	65	20	261	15.9	25.4
101-125	83	115	76	64	66	15	419	25.5	50.9
126-150	90	80	118	68	107	33	496	30.2	81.1
151-175	30	28	35	22	75	32	222	13.5	94.6
176-200	21	15	9	2	16	6	69	4.2	98.8
201-225	1	2	3	1	6	2	15	0.9	99.8
226-250	1	1	0	1	0	1	4	0.2	100.0
Total	284	296	307	215	412	129	1,643		

Appendix 5.—Depth distribution for fish caught in floating and sinking gill nets presented as the percent taken in 1-m vertical net panels. Data summarized by survey year and month.

	Year				Month					
	1986	1987	1988	1986-1988	May	Jun	Jul	Aug	Sep	Oct
					Yellow perch					
Float-upper	0.28	0.31	0.49	0.35	0.12	0.06	0.65	1.85	0.00	0.00
Float-lower	0.65	0.73	0.18	0.54	0.48	0.00	0.43	2.46	0.36	0.60
Sink-upper	22.50	21.57	12.60	19.34	9.55	26.30	13.22	17.54	25.88	11.35
Sink-lower	76.56	77.40	86.73	79.77	89.86	73.64	85.70	78.15	73.76	88.05
Sample	2,142	1,929	1,643	5,714	838	1,696	923	650	1,105	502
					Rainbow smelt					
Float-upper	2.41	0.00	12.50	3.57	5.13	0.00	0.00	18.18	0.00	0.00
Float-lower	1.20	0.00	0.00	0.89	2.56	0.00	0.00	0.00	0.00	0.00
Sink-upper	44.58	23.08	12.50	37.50	41.03	42.11	20.00	18.18	25.00	55.00
Sink-lower	51.81	76.92	75.00	58.04	51.28	57.89	80.00	63.64	75.00	45.00
Sample	83	13	16	112	39	19	15	11	8	20
					Spottail shiner					
Float-upper	0.40	0.73	1.32	0.74	0.79	0.47	1.02	3.45	0.00	0.00
Float-lower	0.13	0.00	0.88	0.34	0.26	0.00	2.04	0.00	0.00	0.00
Sink-upper	50.59	46.52	53.96	50.88	35.09	58.31	61.73	62.07	53.06	26.74
Sink-lower	48.88	52.75	43.83	48.05	63.85	41.22	35.20	34.48	46.94	73.26
Sample	757	273	454	1484	379	638	196	87	98	86
					Trout-perch					
Float-upper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Float-lower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sink-upper	35.96	43.48	32.35	37.11	32.00	39.13	66.67	0.00	57.14	0.00
Sink-lower	64.04	56.52	67.65	62.89	68.00	60.87	33.33	100.00	42.86	100.00
Sample	114	46	34	194	100	46	3	8	35	2
					Alewife					
Float-upper	17.33	27.56	24.19	22.34	21.88	22.41	18.24	16.05	25.21	16.13
Float-lower	20.21	19.71	20.49	20.11	19.01	19.33	13.53	13.58	28.09	17.74
Sink-upper	36.79	34.22	34.16	35.31	33.87	35.85	41.76	46.91	29.78	45.16
Sink-lower	25.67	18.51	21.16	22.23	25.24	22.41	26.47	23.46	16.92	20.97
Sample	1,870	1,426	1,054	4,350	626	2,820	170	81	591	62
					White perch					
Float-upper	0.00	1.65	2.08	1.93	10.00	0.00	3.57	2.78	0.88	1.28
Float-lower	0.00	1.65	1.04	1.16	0.00	0.00	3.57	0.69	0.88	1.28
Sink-upper	53.85	38.84	43.64	42.77	30.00	75.00	51.79	50.69	39.21	32.05
Sink-lower	46.15	57.85	53.25	54.14	60.00	25.00	41.07	45.83	59.03	65.38
Sample	13	121	385	519	10	4	56	144	227	78

Appendix 5.—Continued:

	Year				Month					
	1986	1987	1988	1986-1988	May	Jun	Jul	Aug	Sep	Oct
Gizzard shad										
Float-upper	26.44	24.86	15.86	21.35	14.29	0.00	34.22	33.54	7.69	0.00
Float-lower	9.20	15.36	10.68	12.73	0.00	12.50	25.48	7.59	5.43	4.12
Sink-upper	18.39	24.30	38.19	29.31	0.00	37.50	25.10	29.75	35.75	26.80
Sink-lower	45.98	35.47	35.28	36.60	85.71	50.00	15.21	29.11	51.13	69.07
Sample	87	358	309	754	7	8	263	158	221	97
Emerald shiner										
Float-upper	60.38	56.78	51.52	57.55	57.02	63.35	58.82	57.58	51.61	25.64
Float-lower	30.67	22.03	21.97	26.82	30.70	25.98	32.35	30.30	29.03	10.26
Sink-upper	4.79	15.25	14.39	9.24	4.39	5.69	8.82	9.09	16.13	38.46
Sink-lower	4.15	5.93	12.12	6.39	7.89	4.98	0.00	3.03	3.23	25.64
Sample	313	118	132	563	114	281	34	33	62	39
White sucker										
Float-upper	0.42	0.00	0.00	0.24	0.00	0.96	0.00	0.00	0.00	0.00
Float-lower	0.28	0.36	0.00	0.24	0.60	0.00	0.72	0.00	0.00	0.00
Sink-upper	21.64	11.55	21.55	19.35	15.87	26.60	15.83	21.85	20.29	10.08
Sink-lower	77.67	88.09	78.45	80.16	83.53	72.44	83.45	78.15	79.71	89.92
Sample	721	277	232	1,230	334	312	139	119	207	119
Channel catfish										
Float-upper	3.20	2.09	7.12	3.64	0.88	5.74	6.65	8.43	3.57	0.00
Float-lower	2.28	4.19	7.67	4.82	2.28	5.74	10.76	5.42	3.57	0.00
Sink-upper	21.46	19.11	29.86	22.40	18.91	18.03	26.58	28.31	14.29	28.21
Sink-lower	73.06	74.61	55.34	69.14	77.93	70.49	56.01	57.83	78.57	71.79
Sample	219	764	365	1,348	571	122	316	166	56	117
Walleye										
Float Top	1.92	10.36	4.00	5.51	1.39	3.37	5.83	11.76	9.88	1.59
Float Bot	15.38	14.51	8.80	12.35	10.42	11.24	18.33	9.80	19.75	1.59
Sink Top	33.97	30.57	40.80	35.73	31.94	48.31	33.33	36.27	28.40	39.68
Sink Bot	48.72	44.56	46.40	46.41	56.25	37.08	42.50	42.16	41.98	57.14
Sample	156	193	250	599	144	89	120	102	81	63

Appendix 6.—Trawl CPUE[1] by month for major fish species from Saginaw Bay during 1986-1988.

	Month						
Species	May	Jun	Jul	Aug	Sep	Oct	Mean
1986							
Rainbow smelt	96.8	421.2	483.5	1,035.3	288.6	366.0	469.1
Spottail shiner	194.2	228.9	391.6	196.5	378.5	284.9	269.5
Trout-perch	163.6	352.4	632.9	401.9	300.0	156.7	349.3
Alewife	19.5	14.4	100.6	1,014.7	210.4	303.5	287.6
Gizzard shad	0.0	0.0	0.0	54.7	47.1	10.5	17.2
Emerald shiner	1.6	38.7	37.7	15.7	30.8	242.0	49.8
Yellow perch	252.5	253.5	524.6	362.9	720.8	396.6	394.3
White perch	0.0	0.0	0.8	2.0	13.3	10.8	3.3
White bass	0.0	0.1	2.5	6.0	5.1	13.4	3.8
White sucker	8.8	9.0	16.4	7.6	8.7	5.5	9.7
Channel catfish	1.6	1.7	3.0	2.4	1.7	2.9	2.2
Common carp	1.1	0.5	2.9	3.2	3.1	5.7	2.5
Walleye	0.5	0.7	1.9	1.7	2.0	1.4	1.3
Freshwater drum	0.2	0.7	3.6	3.7	18.7	16.8	5.6
1987							
Rainbow smelt	209.8	142.1	486.2	670.5	417.2	210.5	358.2
Spottail shiner	129.3	90.6	551.1	565.3	586.7	470.3	407.8
Trout-perch	124.8	247.7	346.6	195.4	259.8	167.1	227.6
Alewife	13.0	149.8	162.4	627.4	181.0	56.6	192.5
Gizzard shad	0.0	0.0	101.6	394.8	24.7	29.2	89.7
Emerald shiner	0.8	0.8	16.5	16.4	27.9	41.9	17.9
Yellow perch	549.8	824.9	662.9	797.7	515.7	492.0	636.5
White perch	1.5	0.1	33.4	47.4	46.7	57.7	31.9
White bass	0.2	0.1	0.8	9.1	5.2	1.1	2.6
White sucker	34.1	19.0	8.8	2.6	9.6	6.2	13.1
Channel catfish	7.1	0.3	2.9	18.9	6.2	4.4	6.4
Common carp	0.6	2.3	3.9	8.0	5.0	2.6	3.7
Walleye	2.0	0.9	0.7	1.4	2.8	1.0	1.4
Freshwater drum	1.1	0.4	3.2	2.5	7.2	3.5	3.0
1988							
Rainbow smelt	68.8	92.2	915.5	565.9	1,484.8	176.0	534.9
Spottail shiner	147.6	177.7	471.0	1,111.2	836.7	106.8	464.4
Trout-perch	55.0	281.0	290.5	486.3	474.4	53.6	269.4
Alewife	2.4	46.0	20.7	419.2	1,101.0	85.7	264.5
Gizzard shad	0.0	18.0	50.5	221.2	163.2	41.3	79.8
Emerald shiner	1.1	1.7	6.0	13.6	23.2	54.9	16.4
Yellow perch	386.2	556.7	837.8	1,047.8	1,132.0	276.6	697.6
White perch	9.1	1.0	114.0	501.9	499.9	168.3	208.1
White bass	0.2	0.3	113.7	21.9	23.9	10.4	28.5
White sucker	13.0	16.6	6.1	5.2	4.5	4.4	8.4
Channel catfish	3.8	3.0	2.8	1.8	4.4	3.9	3.3
Common carp	1.7	2.0	4.2	3.8	5.6	5.4	3.7
Walleye	1.4	0.8	2.2	1.2	1.4	2.6	1.6
Freshwater drum	3.3	1.1	5.1	5.6	4.9	0.9	3.4

[1] Number caught per 10 minute trawl tow.

Appendix 7.—Mean length, weight, and biomass of fish caught in trawls in Saginaw Bay, Lake Huron, during 1986-1988 and 1991.

Species	Mean length (mm)	Mean weight (g)	Biomass (kg/hectare)
1986			
Alewife	96.6	9.4	6.1
Rainbow smelt	57.6	1.9	3.7
Spottail shiner	85.9	6.0	10.8
Trout-perch	77.4	4.4	8.8
Gizzard shad	85.0	9.4	0.7
Emerald shiner	87.7	2.5	1.2
White perch	82.6	6.4	0.2
Yellow perch	117.1	25.1	69.9
Other species			71.7
Total			173.0
1987			
Alewife	91.4	6.7	4.4
Rainbow smelt	64.0	1.6	4.2
Spottail shiner	80.9	5.3	10.5
Trout-perch	84.0	5.5	7.5
Gizzard shad	110.7	11.5	6.1
Emerald shiner	79.4	2.5	0.3
White perch	74.1	4.9	1.3
Yellow perch	117.0	24.9	101.4
Other species			102.7
Total			238.5
1988			
Alewife	106.5	12.4	6.9
Rainbow smelt	74.5	3.3	6.8
Spottail shiner	80.3	4.8	12.6
Trout-perch	83.5	5.4	8.5
Gizzard shad	75.6	9.0	4.0
Emerald shiner	73.5	1.9	0.2
White perch	84.3	9.8	8.6
Yellow perch	113.0	23.6	103.1
Other species			80.7
Total			231.5

Appendix 7.—Continued:

Species	Mean length (mm)	Mean weight (g)	Biomass (kg/hectare)
1991			
Alewife	71.6	2.3	4.1
Rainbow smelt	64.2	2.2	0.9
Spottail shiner	79.3	5.0	3.7
Trout-perch	79.5	5.0	4.4
Gizzard shad	87.8	8.1	1.5
Emerald shiner	68.3	1.3	0.0
White perch	65.3	5.9	7.1
Yellow perch	115.4	25.6	51.6
Other species			54.6
Total			128.0

Appendix 8.—Diet of age-1 walleyes collected from Saginaw Bay, Lake Huron, 1986-1988. Numbers represent percent contribution of individual prey types to total wet weight of the diet, based on prey weight at capture.

	Month									
			Jun			Jul				
Prey	May	Jun	Early	Late	Jul	Early	Late	Aug	Sep	Oct
1986										
Alewife	—	—	0.0	21.1	—	0.0	0.0	12.6	56.4	49.9
Gizzard shad	—	—	0.0	0.0	—	0.0	0.0	46.2	15.0	20.5
Unidentified clupeid	—	—	0.0	0.0	—	0.0	0.0	1.6	0.0	0.0
Rainbow smelt	—	—	83.9	78.9	—	0.0	34.2	19.1	15.0	16.6
Trout-perch	—	—	0.0	0.0	—	0.0	0.0	2.5	0.0	0.0
White perch	—	—	0.0	0.0	—	0.0	0.0	0.0	0.0	0.0
Emerald shiner	—	—	0.0	0.0	—	0.0	38.9	2.3	0.0	2.5
Spottail shiner	—	—	0.0	0.0	—	100.0	0.0	0.0	0.0	0.0
Notropis spp.	—	—	0.0	0.0	—	0.0	14.0	0.0	7.0	0.2
Yellow perch	—	—	0.0	0.0	—	0.0	0.8	2.7	0.0	4.4
Other spp.	—	—	0.0	0.0	—	0.0	12.1	1.0	0.0	0.0
Unidentified fish	—	—	16.1	0.0	—	0.0	0.0	12.0	8.1	7.8
Number examined	—	—	19	14	—	6	23	52	21	36
Number with food	—	—	6	3	—	1	15	27	19	27
1987										
Alewife	0.0	2.5	—	—	—	—	—	15.5	47.7	41.9
Gizzard shad	0.0	0.0	—	—	—	—	—	38.2	28.4	26.1
Unidentified clupeid	0.0	0.0	—	—	—	—	—	2.4	0.8	2.9
Rainbow smelt	86.2	88.0	—	—	—	—	—	0.0	2.8	19.2
Trout—perch	0.0	0.0	—	—	—	—	—	0.0	0.0	0.0
White perch	0.0	0.0	—	—	—	—	—	0.0	22.0	0.0
Emerald shiner	2.6	0.0	—	—	—	—	—	0.0	0.0	0.0
Spottail shiner	0.0	0.0	—	—	—	—	—	0.0	2.1	0.0
Notropis spp.	0.0	0.0	—	—	—	—	—	0.0	0.0	0.0
Yellow perch	1.7	3.8	—	—	—	—	—	6.1	14.8	0.0
Other spp.	0.0	4.6	—	—	—	—	—	8.2	0.0	6.6
Unidentified fish	9.5	1.0	—	—	—	—	—	7.5	3.4	3.3
Number examined	27	16	—	—	0	—	—	9	29	22
Number with food	14	8	—	—	0	—	—	8	20	17
1988										
Alewife	0.0	—	—	—	0.0	—	—	46.8	24.4	38.1
Gizzard shad	0.0	—	—	—	0.0	—	—	27.2	35.0	41.8
Unidentified clupeid	0.0	—	—	—	0.0	—	—	0.0	13.1	0.0
Rainbow smelt	0.0	—	—	—	0.0	—	—	0.0	0.0	0.0
Trout—perch	0.0	—	—	—	0.0	—	—	0.0	0.0	0.0
White perch	0.0	—	—	—	0.0	—	—	0.0	0.0	2.1
Emerald shiner	0.0	—	—	—	0.0	—	—	0.0	0.0	1.1
Spottail shiner	0.0	—	—	—	0.0	—	—	0.0	4.6	5.7
Notropis spp.	0.0	—	—	—	100.0	—	—	0.0	5.7	0.0
Yellow perch	0.0	—	—	—	0.0	—	—	15.0	0.0	0.0
Other spp.	0.0	—	—	—	0.0	—	—	5.9	0.0	1.9
Unidentified fish	100.0	—	—	—	0.0	—	—	5.1	17.2	7.9
Number examined	10	12	—	—	3	—	—	12	11	30
Number with food	4	0	—	—	1	—	—	7	7	21

Appendix 9.—Diet of age-2 walleyes collected from Saginaw Bay, Lake Huron, 1986-1988. Numbers represent percent contribution of individual prey types to total wet weight of the diet, based on prey weight at capture.

	Month									
			Jun			Jul				
Prey	May	Jun	Early	Late	Jul	Early	Late	Aug	Sep	Oct
1986										
Alewife	—	—	0.0	89.0	—	100.0	—	43.0	—	6.2
Gizzard shad	—	—	0.0	0.0	—	0.0	—	17.3	—	32.3
Unidentified clupeid	—	—	0.0	0.0	—	0.0	—	1.7	—	10.6
Rainbow smelt	—	—	100.0	11.0	—	0.0	—	18.8	—	0.0
Trout-perch	—	—	0.0	0.0	—	0.0	—	0.0	—	39.8
White perch	—	—	0.0	0.0	—	0.0	—	0.0	—	0.0
Emerald shiner	—	—	0.0	0.0	—	0.0	—	0.0	—	0.0
Spottail shiner	—	—	0.0	0.0	—	0.0	—	0.0	—	0.0
Notropis spp.	—	—	0.0	0.0	—	0.0	—	0.0	—	0.0
Yellow perch	—	—	0.0	0.0	—	0.0	—	0.0	—	0.0
Other spp.	—	—	0.0	0.0	—	0.0	—	0.0	—	0.0
Unidentified fish	—	—	0.0	0.0	—	0.0	—	19.2	—	10.1
Number examined	—	—	6	4	—	3	4	7	0	4
Number with food	—	—	3	3	—	1	0	5	0	3
1987										
Alewife	7.6	49.8	—	—	74.2	—	—	36.1	42.1	42.7
Gizzard shad	0.0	0.0	—	—	7.9	—	—	38.1	42.1	0.0
Unidentified clupeid	0.0	0.0	—	—	0.0	—	—	0.0	0.7	0.0
Rainbow smelt	87.6	0.0	—	—	1.3	—	—	0.2	4.3	17.2
Trout—perch	1.0	0.0	—	—	0.0	—	—	0.0	0.0	0.0
White perch	0.0	0.0	—	—	0.0	—	—	4.5	0.0	0.0
Emerald shiner	1.9	25.7	—	—	0.0	—	—	0.0	0.0	4.7
Spottail shiner	0.0	0.0	—	—	0.0	—	—	0.0	2.4	12.8
Notropis spp.	0.0	0.0	—	—	0.2	—	—	0.0	1.1	0.0
Yellow perch	0.0	0.0	—	—	10.6	—	—	7.7	0.8	0.0
Other spp.	1.3	24.7	—	—	0.0	—	—	0.3	0.0	5.7
Unidentified fish	0.6	0.0	—	—	5.8	—	—	13.1	6.5	8.6
Number examined	65	10	—	—	35	—	—	49	49	11
Number with food	33	5	—	—	11	—	—	25	29	10
1988										
Alewife	7.8	0.0	—	—	76.6	—	—	1.8	22.2	24.2
Gizzard shad	0.0	0.0	—	—	0.0	—	—	19.1	56.8	56.2
Unidentified clupeid	0.0	0.0	—	—	0.0	—	—	0.0	6.4	0.0
Rainbow smelt	4.4	0.0	—	—	0.0	—	—	0.0	0.0	7.0
Trout—perch	0.0	0.0	—	—	0.0	—	—	0.0	0.0	0.0
White perch	0.0	0.0	—	—	0.0	—	—	0.0	7.4	2.4
Emerald shiner	0.0	0.0	—	—	0.0	—	—	0.0	0.0	0.7
Spottail shiner	17.5	0.0	—	—	0.0	—	—	8.2	0.0	1.1
Notropis spp.	23.3	0.0	—	—	0.0	—	—	0.0	0.0	2.5
Yellow perch	0.0	0.0	—	—	23.4	—	—	58.6	1.4	0.0
Other spp.	15.3	69.7	—	—	0.0	—	—	0.0	0.0	1.0
Unidentified fish	31.7	30.3	—	—	0.0	—	—	12.3	6.1	3.4
Number examined	22	8	—	—	19	—	—	20	18	34
Number with food	9	2	—	—	4	—	—	11	15	27

Appendix 10.—Diet of age-3 walleyes collected from Saginaw Bay, Lake Huron, 1986-1988. Numbers represent percent contribution of individual prey types to total wet weight of the diet, based on prey weight at capture.

	Month									
			Jun			Jul				
Prey	May	Jun	Early	Late	Jul	Early	Late	Aug	Sep	Oct
1986										
Alewife	—	—	14.8	37.0	—	—	—	—	20.6	—
Gizzard shad	—	—	0.0	0.0	—	—	—	—	79.4	—
Unidentified clupeid	—	—	0.0	0.0	—	—	—	—	0.0	—
Rainbow smelt	—	—	85.2	55.7	—	—	—	—	0.0	—
Trout-perch	—	—	0.0	7.3	—	—	—	—	0.0	—
White perch	—	—	0.0	0.0	—	—	—	—	0.0	—
Emerald shiner	—	—	0.0	0.0	—	—	—	—	0.0	—
Spottail shiner	—	—	0.0	0.0	—	—	—	—	0.0	—
Notropis spp.	—	—	0.0	0.0	—	—	—	—	0.0	—
Yellow perch	—	—	0.0	0.0	—	—	—	—	0.0	—
Other spp.	—	—	0.0	0.0	—	—	—	—	0.0	—
Unidentified fish	—	—	0.0	0.0	—	—	—	—	0.0	—
Number examined	—	—	7	3	—	0	1	2	2	0
Number with food	—	—	3	1	—	0	0	0	2	0
1987										
Alewife	86.9	100.0	—	—	91.5	—	—	22.2	0.0	0.0
Gizzard shad	0.0	0.0	—	—	0.0	—	—	74.5	26.4	56.0
Unidentified clupeid	0.0	0.0	—	—	0.0	—	—	0.0	14.0	0.0
Rainbow smelt	13.1	0.0	—	—	0.0	—	—	1.2	0.0	0.0
Trout—perch	0.0	0.0	—	—	0.0	—	—	0.0	0.0	0.0
White perch	0.0	0.0	—	—	0.0	—	—	0.0	0.0	0.0
Emerald shiner	0.0	0.0	—	—	0.0	—	—	0.0	0.0	0.0
Spottail shiner	0.0	0.0	—	—	0.0	—	—	0.0	18.2	28.1
Notropis spp.	0.0	0.0	—	—	0.0	—	—	0.0	5.2	15.9
Yellow perch	0.0	0.0	—	—	0.0	—	—	0.0	34.4	0.0
Other spp.	0.0	0.0	—	—	0.0	—	—	0.0	1.8	0.0
Unidentified fish	0.0	0.0	—	—	8.5	—	—	2.1	0.0	0.0
Number examined	16	2	—	—	17	—	—	16	7	2
Number with food	9	1	—	—	6	—	—	6	4	1
1988										
Alewife	65.8	74.3	—	—	39.9	—	—	2.6	15.0	15.9
Gizzard shad	0.0	0.0	—	—	5.7	—	—	20.2	51.7	56.5
Unidentified clupeid	0.0	0.0	—	—	0.0	—	—	0.0	5.0	0.0
Rainbow smelt	1.2	0.0	—	—	0.0	—	—	0.0	0.0	0.0
Trout-perch	0.0	11.8	—	—	0.0	—	—	0.0	0.0	0.0
White perch	0.0	0.0	—	—	0.0	—	—	0.0	5.6	0.0
Emerald shiner	2.2	0.0	—	—	0.0	—	—	0.8	0.0	0.3
Spottail shiner	0.0	0.0	—	—	0.4	—	—	0.0	0.0	12.2
Notropis spp.	1.7	0.0	—	—	0.0	—	—	0.8	0.0	0.3
Yellow perch	12.1	0.0	—	—	42.5	—	—	65.1	0.0	8.5
Other spp.	2.4	0.0	—	—	0.0	—	—	0.0	0.0	0.0
Unidentified fish	14.6	13.8	—	—	11.4	—	—	10.6	22.6	3.0
Number examined	39	21	—	—	31	—	—	20	23	22
Number with food	14	9	—	—	8	—	—	1	10	17

Appendix 11.—Estimated consumption (g) of Saginaw Bay walleyes using an energetics model during May-October 1986-1988. Percent of total amount consumed is in parentheses.

	1986	1987		1988		
Prey type	Age 1	Age 1	Age 2	Age 1	Age 2	Age 3
Alewife	167.7 (21.7)	197.8 (22.1)	597.7 (44.0)	212.5 (24.4)	161.7 (11.9)	508.2 (30.3)
Gizzard shad	132.8 (17.2)	213.5 (23.9)	287.4 (21.2)	156.5 (18.0)	369.4 (27.3)	468.3 (27.9)
Rainbow smelt	228.6 (29.6)	242.9 (27.2)	141.1 (10.3)	0.0 (0.0)	22.7 (1.7)	1.0 (0.0)
White perch	14.5 (1.8)	80.9 (9.1)	15.6 (1.2)	0.7 (0.0)	25.6 (1.9)	28.0 (1.7)
Notropis spp.	149.7 (19.3)	50.0 (5.6)	192.2 (14.2)	442.1 (50.8)	389.4 (28.7)	275.1 (16.4)
Yellow perch	19.0 (2.5)	64.1 (7.2)	50.0 (3.7)	42.6 (4.9)	335.6 (24.8)	366.9 (21.9)
Other	61.3 (7.9)	43.4 (4.9)	73.5 (5.4)	16.9 (1.9)	50.6 (3.7)	31.0 (1.8)
Total	773.6	892.6	1,357.5	871.3	1,355.0	1,678.5

Appendix 12.—Seasonal patterns of consumption (g) for age-1 walleyes, 1986-1988.

Year and cohort	Time	Alewife	Gizzard shad	Rainbow smelt	White perch	*Notropis* spp.	Yellow perch	Other
1986								
1	Early Jun	7.2	0.0	51.4	0.0	4.6	0.0	0.0
2	Late Jun	8.1	0.0	34.5	0.0	6.7	0.1	1.5
3	Early Jul	4.0	0.0	32.5	0.0	27.1	0.5	6.1
4	Late Jul	12.0	36.9	51.1	0.0	66.4	3.5	13.5
5	Aug	61.1	70.4	37.1	0.0	29.3	3.9	5.6
6	Sep	75.3	25.5	22.0	14.5	15.6	11.0	34.6
Totals		167.7	132.8	228.6	14.5	149.7	19.0	61.3
1987								
1	May	1.3	0.0	71.5	0.0	4.7	2.5	2.2
2	Jun-Jul	58.6	109.8	155.7	61.7	25.7	25.6	31.3
3	Aug	83.5	72.4	4.2	19.2	14.8	26.3	7.0
4	Sep	54.4	31.3	11.5	0.0	4.8	9.7	3.5
Totals		197.8	213.5	242.9	80.9	50.0	64.1	44.0
1988								
1	May	0.0	0.0	0.0	0.0	77.5	0.0	0.0
2	Jun-Jul	49.2	28.3	0.0	0.0	298.2	15.7	6.3
3	Aug	122.6	87.7	0.0	0.0	43.2	24.3	9.7
4	Sep	40.7	40.5	0.0	0.7	23.2	2.6	0.9
Totals		212.5	156.5	0.0	0.7	442.1	42.6	16.9

Appendix 13.—Male yellow perch growth and food occurrence by month from combined samples taken during 1986-1988.

Age and month	Sample	Mean length (mm)	Mean wet weight (g)	Mean food weight (g)	Mean number per stomach		
					Zooplankton	Benthos	Fish
Age 0							
Jul	83	54.0	1.84	0.01	62.31	2.58	0.02
Aug	141	68.1	3.58	0.02	78.09	2.59	0.04
Sep	138	76.3	4.91	0.02	114.89	2.05	0.03
Oct	136	77.8	4.98	0.02	41.83	2.01	0.01
Weighted mean		70.7	4.04	0.02	75.76	2.28	0.03
Age 1							
May	142	81.9	5.92	0.09	152.29	10.36	0.00
Jun	275	89.1	8.78	0.12	453.34	7.44	0.01
Jul	518	104.0	13.63	0.09	123.16	7.48	0.03
Aug	432	111.6	16.35	0.07	7.27	9.99	0.05
Sep	276	115.9	18.11	0.07	28.17	10.00	0.03
Oct	238	116.3	17.68	0.06	21.65	3.03	0.02
Weighted mean		105.2	14.13	0.08	120.23	8.07	0.03
Age 2							
May	242	119.2	18.01	0.28	90.50	33.14	0.01
Jun	363	120.6	20.95	0.22	116.81	18.39	0.01
Jul	503	126.1	24.89	0.16	66.77	16.70	0.04
Aug	494	131.0	27.52	0.12	7.40	14.31	0.13
Sep	416	133.2	28.44	0.11	9.87	10.33	0.04
Oct	264	133.8	27.90	0.17	15.01	2.79	0.05
Weighted mean		127.7	25.10	0.17	48.03	15.42	0.05
Age 3							
May	348	135.4	27.07	0.47	19.27	41.14	0.00
Jun	593	136.8	30.68	0.29	76.75	22.58	0.02
Jul	897	139.8	33.54	0.21	37.27	25.72	0.05
Aug	693	142.8	36.28	0.18	2.83	10.19	0.22
Sep	450	146.2	38.43	0.26	7.32	7.60	0.10
Oct	321	145.6	37.31	0.11	10.44	2.52	0.03
Weighted mean		140.8	33.95	0.24	28.55	18.80	0.08
Age 4							
May	300	147.0	36.20	0.65	7.42	43.62	0.02
Jun	424	150.1	42.00	0.42	31.33	27.26	0.03
Jul	327	155.0	46.91	0.34	9.07	32.07	0.10
Aug	247	155.7	47.43	0.26	0.95	4.93	0.27
Sep	195	160.1	51.76	0.24	2.70	5.28	0.12
Oct	175	159.0	51.41	0.29	2.18	3.09	0.13
Weighted mean		153.4	44.85	0.39	11.76	22.73	0.10

Appendix 13.—Continued:

Age and month	Sample	Mean length (mm)	Mean wet weight (g)	Mean food weight (g)	Mean number per stomach		Fish
					Zooplankton	Benthos	
Age 5							
May	172	160.4	49.53	1.94	1.99	87.93	0.01
Jun	228	161.9	53.56	0.54	37.06	28.36	0.05
Jul	138	168.0	61.38	0.57	2.33	20.18	0.19
Aug	87	169.0	64.17	0.38	5.55	3.73	0.28
Sep	62	174.1	69.81	0.57	4.83	2.00	0.20
Oct	57	172.1	63.91	0.30	1.47	2.84	0.13
Weighted mean		165.3	57.47	0.83	13.41	33.58	0.11
Age 6							
May	32	177.7	69.98	2.42	0.28	77.50	0.09
Jun	60	176.2	70.04	0.76	23.50	15.13	0.13
Jul	36	185.1	83.08	0.72	0.53	17.36	0.34
Aug	25	183.8	82.40	0.78	0.00	1.00	0.92
Sep	13	184.0	84.41	0.23	0.23	0.84	0.00
Oct	17	188.9	90.28	2.04	0.29	1.29	0.23
Weighted mean		181.0	77.18	1.13	7.90	22.24	0.27
Age 7							
May	12	187.0	84.74	4.09	0.09	143.58	0.00
Jun	15	182.5	79.87	1.00	3.13	43.73	0.07
Jul	8	188.1	87.06	0.54	0.12	15.88	0.75
Aug	6	205.7	109.93	0.89	0.00	0.00	1.17
Sep	4	195.0	106.04	0.51	0.50	3.25	0.25
Oct	5	215.0	150.49	5.11	0.40	1.20	2.00
Weighted mean		191.5	94.95	2.03	1.06	50.50	0.50
All age groups							
May	1,252	134.1	30.14	0.75	42.18	45.32	0.01
Jun	1,963	134.9	32.62	0.33	120.11	21.26	0.03
Jul	2,510	131.3	30.81	0.21	55.49	19.75	0.06
Aug	2,125	131.8	31.21	0.16	9.64	9.59	0.17
Sep	1,555	134.6	32.78	0.18	20.49	7.68	0.07
Oct	1,213	134.1	32.28	0.19	15.35	2.70	0.05
Weighted mean		133.2	31.60	0.28	46.98	17.30	0.07

Appendix 14.—Female yellow perch growth and food occurrence by month from combined samples taken during 1986-1988.

Age and month	Sample	Mean length (mm)	Mean wet weight (g)	Mean food weight (g)	Mean number per stomach Zooplankton	Benthos	Fish
Age 0							
Jul	11	57.0	2.13	0.01	8.09	1.36	0.18
Aug	93	68.3	3.49	0.02	65.79	2.15	0.01
Sep	77	75.6	4.74	0.02	138.20	1.43	0.01
Oct	113	75.5	4.56	0.02	47.87	1.05	0.04
Weighted mean		72.6	4.18	0.02	75.71	1.51	0.03
Age 1							
May	113	81.0	5.53	0.08	258.66	10.61	0.00
Jun	243	89.0	8.59	0.10	595.10	5.74	0.03
Jul	422	105.3	13.98	0.10	109.95	8.41	0.03
Aug	359	112.9	16.83	0.08	7.30	12.52	0.04
Sep	199	115.7	17.56	0.08	21.63	10.51	0.03
Oct	160	118.6	17.91	0.16	15.27	2.82	0.03
Weighted mean		105.4	14.05	0.10	153.48	8.81	0.03
Age 2							
May	196	120.9	19.19	0.30	58.47	33.54	0.01
Jun	235	123.2	22.68	0.22	69.03	17.02	0.02
Jul	352	131.6	28.40	0.18	41.32	21.56	0.05
Aug	411	136.6	31.12	0.20	5.41	10.04	0.35
Sep	383	139.0	31.43	0.15	8.24	10.70	0.11
Oct	230	140.0	31.06	0.19	12.51	5.22	0.03
Weighted mean		133.1	28.26	0.20	27.94	15.27	0.12
Age 3							
May	266	140.3	30.03	0.50	15.02	36.47	0.00
Jun	503	144.9	36.30	0.42	41.29	21.43	0.02
Jul	620	147.7	39.06	0.30	22.01	27.38	0.05
Aug	460	151.4	42.35	0.36	1.27	6.73	0.22
Sep	302	155.7	45.32	0.45	3.36	5.02	0.10
Oct	236	156.2	44.61	0.39	1.64	2.96	0.03
Weighted mean		148.8	39.45	0.39	16.92	17.92	0.08
Age 4							
May	193	159.1	46.08	0.95	0.84	44.25	0.04
Jun	195	160.3	50.74	0.62	17.84	22.19	0.15
Jul	183	166.0	57.89	0.63	3.89	32.40	0.28
Aug	115	166.2	58.61	0.61	0.17	5.55	0.62
Sep	110	175.5	66.64	0.55	3.92	2.32	0.25
Oct	79	176.8	67.97	1.05	0.23	4.52	0.32
Weighted mean		165.4	55.80	0.72	0.35	22.91	0.24

Appendix 14.—Continued:

Age and month	Sample	Mean length (mm)	Mean wet weight (g)	Mean food weight (g)	Mean number per stomach Zooplankton	Benthos	Fish
Age 5							
May	70	175.0	66.17	1.88	0.68	84.78	0.06
Jun	74	180.6	77.65	1.23	41.66	14.58	0.38
Jul	78	187.9	86.45	0.78	0.63	18.00	0.33
Aug	25	182.4	77.72	0.68	0.00	3.32	1.24
Sep	56	197.1	97.16	1.59	0.12	0.21	0.50
Oct	28	200.3	105.44	2.22	0.11	1.82	0.43
Weighted mean		185.7	82.95	1.36	9.64	25.87	0.39
Age 6							
May	25	193.0	86.49	2.85	0.16	101.84	0.04
Jun	33	198.3	110.97	2.63	0.40	8.24	0.64
Jul	23	202.2	108.06	1.97	0.31	12.91	0.65
Aug	8	213.3	131.16	0.71	0.00	0.63	0.75
Sep	18	210.4	123.40	2.57	0.00	0.44	0.72
Oct	9	209.7	130.37	3.74	0.00	0.11	1.00
Weighted mean		201.7	109.94	2.49	0.21	26.97	0.56
Age 7							
May	3	223.0	137.78	7.28	0.67	226.33	0.00
Jun	7	204.4	118.90	1.43	0.00	0.57	0.57
Jul	8	214.6	131.92	0.47	0.00	0.00	0.38
Aug	2	240.0	176.12	2.10	0.00	0.00	2.00
Sep	7	226.0	155.36	1.05	0.00	0.00	0.29
Oct	2	243.5	216.57	2.92	0.00	0.00	0.50
Weighted mean		219.5	143.93	2.03	0.07	50.50	0.48
All age groups							
May	867	137.0	32.85	0.71	51.79	40.57	0.02
Jun	1,292	136.6	35.58	0.46	145.65	16.92	0.10
Jul	1,699	138.4	36.12	0.32	44.41	21.05	0.12
Aug	1,473	134.9	33.08	0.25	7.85	8.58	0.38
Sep	1,154	143.5	39.95	0.37	16.96	7.01	0.17
Oct	859	138.6	36.49	0.41	12.97	3.35	0.13
Weighted mean		138.0	35.67	0.40	47.77	15.85	0.17