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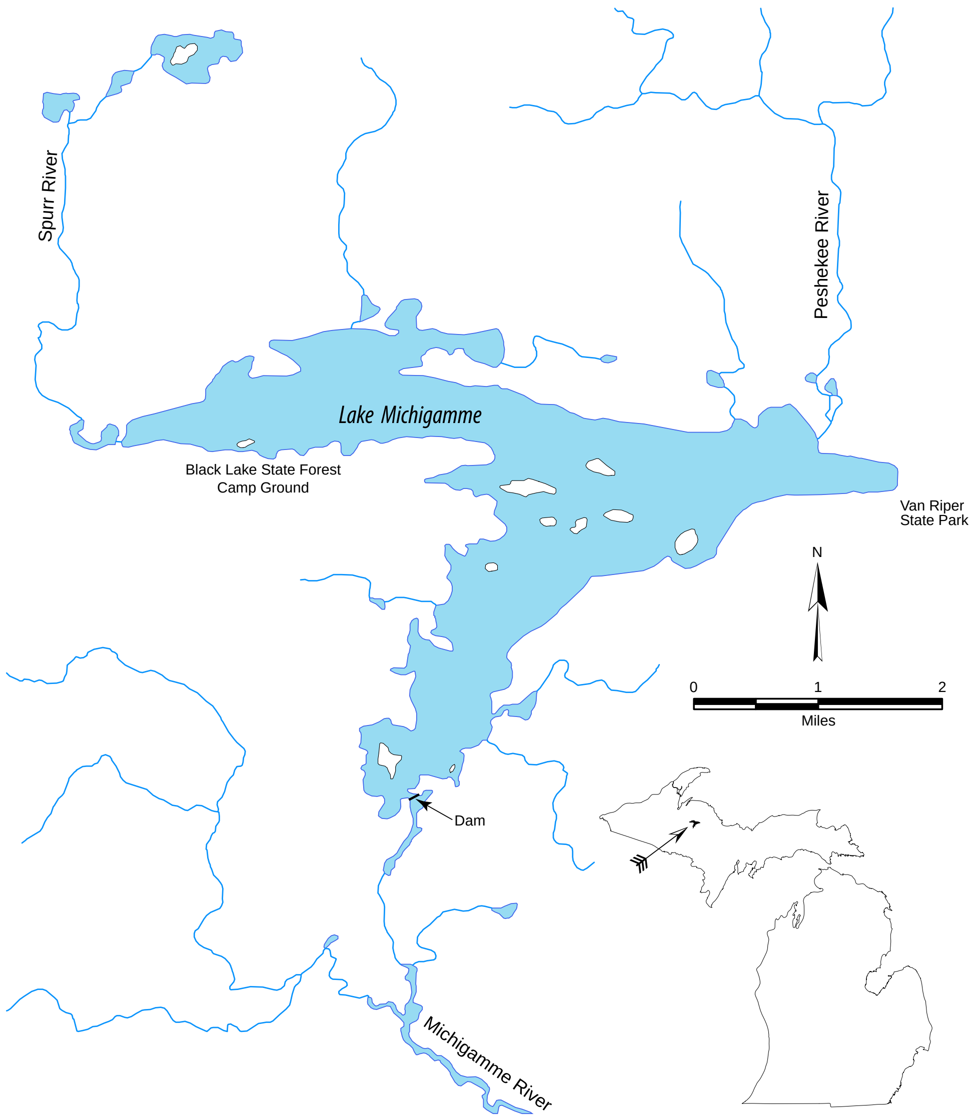
David C. Caroffino
and
Patrick A. Hanchin



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The Fish Community and Fishery of Lake Michigamme, Baraga and Marquette Counties, Michigan in 2006 with Emphasis on Walleye and Northern Pike

David C. Caroffino and Patrick A. Hanchin

Michigan Department of Natural Resources, Charlevoix Fisheries Research Station
96 Grant Street, Charlevoix, Michigan 49720

Introduction

The Michigan Department of Natural Resources (DNR), Fisheries Division surveyed fish populations and angler catch and effort in Lake Michigamme, Baraga and Marquette counties, Michigan from April through September 2006 (Figure 1). This survey was the seventeenth conducted as part of the Large Lakes Program, which is designed to assess and monitor the fish communities and fisheries in Michigan's largest inland lakes (Clark et al. 2004). The Large Lakes Program has three primary objectives that are focused on fish species supporting valuable fisheries (walleye *Sander vitreus*, northern pike *Esox lucius*, smallmouth bass *Micropterus dolomieui*, and muskellunge *Esox masquinongy*). The first objective is to produce indices of abundance and estimates of annual harvest and fishing effort. The second objective is to produce growth and mortality statistics to evaluate the effects of recreational fishing on these species. This usually involves targeted sampling to collect, sample, and mark sufficient numbers of fish. We initially selected walleye, northern pike, smallmouth bass, and muskellunge as target species in the Lake Michigamme survey; however, due to limited catches of smallmouth bass and muskellunge, this report focuses on walleye and northern pike, with only limited mention of smallmouth bass. The final objective is to evaluate the suitability of various statistical estimators for use in large lakes. For example, comparisons were made among four types of abundance and three types of exploitation rate estimators in this survey of Lake Michigamme. The Large Lakes Program maintains consistent sampling methods over lakes and time, which allows comparisons within and among lakes.

Study Area

Located 30 miles west of Marquette, with the town of Michigamme resting on its northwest shore, Lake Michigamme is within the Western Upper Peninsula ecoregion of Michigan (Eagle et al. 2005). This ecoregion is primarily forested (81%) and wetlands (11%), with some agricultural (2%) and urban (2%) land, and a mix (4%) of grassland, shrubland, and alvar (limestone plain with thin soil and sparse vegetation). Forest types include northern hardwoods, aspen, pines, and lowland conifers. The geology of the region consists of igneous and metamorphic bedrock with numerous exposures. Several extensive outwash plains are found within the ecoregion, which contain acidic sand and gravel soils that have little organic material. The relatively nutrient-poor, rocky, acidic soils result in waterbodies with low productivity, of which Lake Michigamme is one. This region also experiences the coldest temperatures, most snowfall, and shortest growing season of any area in Michigan.

Lake Michigamme is 4,360 acres with approximately 36 miles of irregular shoreline and numerous islands are found throughout the lake. The lake reaches a maximum depth of 72 feet, and shallow areas (<15 feet) are limited to less than 20% of the lake's surface area (Figure 2). Lake

Michigamme annually stratifies, with the thermocline ranging from 20 to 35 feet below the surface and adequate oxygen for fish in the upper 50 feet of water (Bullen 1984). The water is generally clear (Secchi depths between 5.5 and 8 ft.), but has been described as slightly brown in color. Although the number of residences on the lake has more than quadrupled since 1940, the shoreline remains heavily wooded and beach areas largely consist of gravel, cobble, boulders, and bedrock. Sandy beaches are limited but exist in the south and east arms. Van Riper State Park, located on the far eastern shore, has a sand swimming beach and public boat launch ramp. Spur Township Park is located on the extreme western end of the lake and also has a public boat launch ramp. There is also public boat launch ramp on the north shore of Lake Michigamme near Maple Ridge Resort, off Brown Road.

The Lake Michigamme watershed drains an area of 193 square miles. The Peshekee River is the main tributary to Lake Michigamme and empties into the northeast corner of the lake. This river drains approximately 134 square miles, and at its mouth is approximately 20 feet deep and 150 feet wide. The second largest tributary to Lake Michigamme is the Spur River, which drains approximately 20 square miles and is only 3 feet deep and 50 feet wide where it enters the western end of the lake. Lake Michigamme is drained by the Michigamme River from the southern end of the lake. The river flows generally south and eventually empties into the Menominee River and Green Bay. There is a dam on the lake outlet that affects the water level of the lake, though there is currently no control of the outflow. The dam was originally constructed in 1878 as a rock-filled timber-framed structure. It was 500 ft in length, with two 10-ft gates, and was designed to allow flow over most of its length with a fixed crest of 1,552.0 ft above sea level. Improvements were made to the dam using concrete; however, the year of repair is unknown. By 1984 deterioration had again caused it to no longer restrict fish movement nor maintain a particular lake level. Currently the dam only functions to maintain some minimum summer volume, and there is no active control of gates or boards. Spring runoff results in a 3- to 5-ft increase in the lake level, which lasts for approximately 30 days. During the time of our spring survey, most of the dam was approximately one foot underwater. An independent engineering study in 1964 suggested a lake level of 1,551.5 ft in the summer and 1,550.0 ft in the winter, though no legal lake level was ever established.

The historic fish community of Lake Michigamme was dominated by northern pike and smallmouth bass. Walleyes were introduced into the lake in the late 1930s and are now the most popular sport fish. Other species introductions, including tiger muskellunge, lake trout, and splake were unsuccessful. The survey history on this lake is limited as compared to some other large lakes in Michigan. The first recorded survey occurred in the late 1930s soon after walleye introduction (Brown 1940). The next comprehensive survey did not occur until 1972 (Peterson 1977). Additional surveys were completed during the 1980s (Bullen 1984) and 1990s (Madison 1994), leading up to the present study in 2006.

Methods

Fish populations in Lake Michigamme were sampled with fyke nets and by electrofishing from April 13–27, 2006. Fyke nets were 6 ft x 4 ft with 3/4-in stretch mesh and 70- to 100-ft leads. Nets were located to target walleye and northern pike (nonrandomly), though efforts were made to cover the entire lake. Duration of net sets ranged from 1–3 nights, but most were 1 night. Electrofishing occurred during both day and night, and boats used DC current to sample fish along the shoreline and in connecting rivers to increase the sample size of captured fish. Latitude and longitude were recorded for all net locations and electrofishing runs using handheld global positioning systems (GPS).

Fish Community

We described the status of the fish community by the species present, catch per unit effort, percent by number, and length frequencies. Mean catch per unit effort (CPUE) in fyke nets was calculated as an indicator of relative abundance, utilizing the number of fish per net night (including recaptures) for all net lifts that were determined to have fished effectively (i.e., without wave-induced rolling or human disturbance). We calculated the percentages by number of fish collected in each of three feeding guilds: 1) species that are primarily piscivores; 2) species that are primarily pelagic planktivores and/or insectivores; and 3) species that are primarily benthivores. These indices will be used to compare fish communities among lakes or within the same lake over time, especially in the future when more large lake surveys using similar methods are available for comparison. Of the species collected, we classified walleye, northern pike, smallmouth bass, largemouth bass, burbot, muskellunge, and tiger muskellunge as piscivores; rock bass, pumpkinseed, yellow perch, black crappie, and brook trout as pelagic planktivores-insectivores; and white sucker, black bullhead, and lake whitefish as benthivores.

Walleye, Northern Pike, and Smallmouth Bass

Size structure and sex ratio.–Total length (TL) of all walleyes, northern pike, smallmouth bass, and muskellunge was measured to the nearest 0.1 in. For other fish species, TL was measured to the nearest 0.1 in for subsamples of up to 200 fish per work crew. Crews ensured that TL was measured over the course of the survey to account for any temporal trends in the size structure of fish collected. Size-structure data for target species (walleye, northern pike, smallmouth bass, and muskellunge) only included fish on their initial capture occasion.

Walleyes, northern pike, and muskellunge with flowing gametes were identified as male or female; fish with no flowing gametes were identified as unknown sex. We were unable to accurately determine the sex of smallmouth bass due to the timing of the survey.

Abundance.–We estimated the abundance of adult and legal-size walleyes and northern pike using mark-recapture methods. Adult fish were defined as those greater than legal size, or less than legal size, but of identifiable sex by the extrusion of gametes. Legal-size walleyes (≥15 in) and northern pike (≥24 in) were fitted with monel-metal jaw tags (National Band and Tag© size 10 and 12). Tagged fish were also marked by clipping the anterior four dorsal spines or dorsal fin rays in order to assess tag loss. Reward ($10) and nonreward tags were applied in an approximate 1:1 ratio. Large tags (size 16) that were used on large esocids (≥36 in) were all nonreward. All marked fish were released away from the nets, toward the center of the lake.

Initial tag loss was assessed during the marking period as the proportion of recaptured fish of legal size without tags. This tag loss was largely caused by entanglement with nets, and thus was not used to adjust estimates of abundance or exploitation. Newman and Hoff (1998) reported similar netting-induced tag loss. All fish that lost tags during netting recapture were retagged, and were accounted for in the total number of marked fish at large.

We used two different methods for estimating abundance from mark-and-recapture data, one derived from marked-unmarked ratios during the spring survey (multiple census) and the other derived from marked-unmarked ratios from the angler survey (single census). For the multiple-census estimate, we used the Schumacher-Eschmeyer formula for daily recaptures during the tagging operation. We used the following formula adapted from Ricker (1975):

$$N_1 = \frac{\sum_{d=1}^{n} C_d M_d^{\;2}}{\sum_{d=1}^{n} R_d M_d}$$

N_1 = multiple-census population estimate (number of legal-size fish);

C_d = total number of fish caught during day d;

R_d = number of recaptures during day d;

M_d = number of marked fish available for recapture at start of day d;

d = day (ranging from d_1 to d_n).

The variance formula was,

$$Var(N_1) = \frac{\sum_{d=1}^{n}\left(\frac{R_d^{\;2}}{C_d}\right) - \left[\frac{\left(\sum_{d=1}^{n} R_d M_d\right)^2}{\sum_{d=1}^{n} C_d M_d^{\;2}}\right]}{m-1},$$

where m = number of days in which fish were actually caught.

Variance of $1/N_1$ is:

$$\frac{Var(N_1)}{\sum_{d=1}^{n} C_d M_d^{\;2}}.$$

The minimum number of recaptures necessary for an unbiased estimate was set a priori at four. Asymmetrical 95% confidence intervals were computed as:

$$\frac{1}{\frac{1}{N_1} \pm t(\sigma)},$$

where t = Student's T value for m -1 degrees of freedom; σ = standard error of $1/N_1$ (calculated as the square root of the variance of $1/N_1$).

The multiple-census method was used to estimate the abundance of both legal-size and adult walleyes and northern pike. Adult fish were defined as those greater than legal size, or less than legal size, but of identifiable sex by the discharge of gametes.

For the single-census estimate, the recapture sample was comprised of the number of marked and unmarked fish observed by creel clerks in the companion angler survey. The minimum number of recaptures necessary for an unbiased estimate was set a priori at three, and we used the Chapman modification of the Petersen method to generate population estimates using the following formula from Ricker (1975):

$$N_2 = \frac{(M+1)(C+1)}{R+1},$$

where N_2 = single-census population estimate (numbers of legal-size fish); M = number of fish caught, marked and released in first sample; C = total number of fish caught in second sample (unmarked + recaptures); and R = number of recaptures in second sample. We calculated the variance as:

$$Var(N_2) = \frac{{N_2}^2(C-R)}{(C+1)(R+2)},$$

Asymmetrical 95% confidence limits were calculated using values from the Poisson distribution for the 95% confidence limits on the number of recaptured fish (R), which were substituted into the equation for N above (Ricker 1975). We estimated numbers of adult walleyes and northern pike from the single-census estimates by dividing the estimates for legal-size fish by the proportion of legal-size fish on the spawning grounds, using the formula:

$$N_a = \frac{N_{leg} + N_{sub}}{N_{leg}} \times N_2,$$

N_a = estimated number of adult walleyes or northern pike;

N_{sub} = number of sublegal and mature fish (<15 in for walleye, or <24 in for northern pike) caught;

N_{leg} = number of legal-size fish caught;

N_2 = single-census estimate of legal-size walleye or northern pike.

We calculated the variance as:

$$Var(N_a) = \left(\frac{N_{leg} + N_{sub}}{N_{leg}}\right)^2 \times Var(N_2).$$

There were no prior abundance estimates for walleyes in Lake Michigamme to help determine how many fish to mark so we used three regression equations, one developed from Wisconsin lakes, and two from Michigan lakes, to provide estimates of walleye abundance. These regressions predict adult or legal-size walleye abundance based on lake size and were derived from historic abundance estimates made in each State over the past 20–25 years. The following equation for adult walleyes in Michigan was based on 31 abundance estimates:

$$\log_e(N) = 0.3710 + 1.0461 \times \log_e(A),$$

$$R^2 = 0.80, \quad P < 0.0001,$$

where N is the estimated number of adult walleyes and A is the surface area of the lake in acres. For Lake Michigamme, the equation gives an estimate of 9,148 adult walleyes, with a 95% prediction interval (Zar 1999) of 1,731 to 48,335. The equation for adult walleyes in the Treaty-ceded territory of Wisconsin (used to set 2004 harvest quotas) was based on 185 estimates:

$$\log_e(N) = 1.5923 + 0.9489 \times \log_e(A),$$

$$R^2 = 0.56, \quad P < 0.0001,$$

where *N* is the estimated number of adult walleyes and *A* is the surface area of the lake in acres. The equation gives an estimate of 13,761 walleyes, with a 95% prediction interval of 4,504 to 42,042 for Lake Michigamme. The equation for legal-size walleyes in Michigan was based on 32 estimates:

$$\log_e(N) = 0.5423 + 0.9794 \times \log_e(A),$$

$$R^2 = 0.74, \quad P < 0.0001,$$

where *N* is the estimated number of legal-size walleyes and *A* is the surface area of the lake in acres. The equation gives an estimate of 6,216 legal-size walleyes, with a 95% prediction interval of 1,339 to 28,864 for Lake Michigamme. Based on all of the existing abundance estimates, we set a goal of tagging a minimum of 1,000 legal-size walleyes. We did not set tagging goals for northern pike, but simply tagged all legal-size fish encountered during the survey.

For the single-census estimate, we accounted for fish that recruited to legal-size during the angler survey based on the estimated weighted average monthly growth for fish of slightly sublegal size. Because we were estimating the abundance of legal-size fish at the time of marking and growth of fish occurred during the recapture period, it was necessary to reduce the number of unmarked fish by the estimated number that recruited to legal size during the recapture period. For example, to make this adjustment for walleye we determined the annual growth of slightly sublegal fish (i.e., 14.0–14.9-in fish) from mean length-at-age data. We then divided by the length of the growing season in months (6; Schneider et al. 2000) and rounded to the nearest 0.1 in. This average monthly growth was used as the criteria to remove unmarked fish that were observed in the angler survey. The largest sublegal walleye during the marking period was 14.9 in; thus, an average monthly growth of 0.2 in would result in all unmarked fish ≤ 15.1 in caught during the first full month (June) after tagging to be removed from the dataset. Adjustments were made for each month of the angler survey resulting in a final ratio of marked to unmarked fish. This final ratio was used to make the single-census abundance estimate. We also calculated the coefficient of variation (CV = standard deviation/mean) for each abundance estimate (single- and multiple-census) and considered estimates with a CV less than or equal to 0.40 to be reliable (Hansen et al. 2000).

Age and growth.–We used dorsal spines to age walleyes and dorsal fin rays to age northern pike because they do not require sacrificing fish, are easy to collect, and are more accurate than scales for aging older fish. Other structures (e.g. otoliths) have been shown to be the most accurate and precise aging structure for older walleyes (Heidinger and Clodfelter 1987; Koscovsky and Carline 2000; Isermann et al. 2003) and northern pike (Casselman 1974; Harrison and Hadley 1979), but collecting these structures requires killing fish and would have greatly reduced the number of marked fish at large. Results from several studies comparing aging structures for walleye agreed that spines were quicker to remove than scales, but they did not agree that spines were more accurate than scales (Campbell and Babaluk 1979; Kocovsky and Carline 2000; Isermann et al. 2003). Errors in ages from spines were often related to misidentifying the first annulus in older fish (Ambrose 1983; Isermann et al. 2003). There was also considerable disagreement as to whether spines or scales were more precise for walleye age estimation. Erickson (1983) and Campbell and Babaluk (1979) found that spines were more precise, Belanger and Hogler (1982) found spines and scales were equally precise, and Kocovsky and Carline (2000) found scales were more precise. Because northern pike older than 6 years are notoriously difficult to age with scales (Carlander 1969), we used dorsal fin rays. Studies have demonstrated that fin rays are a valid aging structure for a number of species (Skidmore and Glass 1953; Ambrose 1983), including northern pike (Casselman 1996), but no statistical comparisons have been made to compare accuracy and precision of fin rays to other aging structures for northern pike. Sample size goals were 20 male and 20 female fish per inch group.

Samples were sectioned using a table-mounted high-speed rotary cutting tool. Sections approximately 0.02-in thick were cut as close to the proximal end of the spine or ray as possible. Sections were examined at 40x–80x magnification with transmitted light and were photographed with a digital camera. Two technicians independently aged samples, and ages were considered final when independent estimates were in agreement. Samples in dispute were aged by a third technician. Disputed ages were considered final when the third technician agreed with one of the first two. Samples were discarded if three technicians disagreed on age, though occasionally an average age was used when ages assigned to older fish (≥ age 10) were within ±10% of each other. After a final age was identified for all samples, age-length keys (Devries and Frie 1996) were constructed and weighted mean lengths-at-age were calculated. Mean lengths-at-age were compared to those from previous samples from Lake Michigamme and to other large lakes. We also computed a mean growth index to compare the data to Michigan state averages, as described by Schneider et al. (2000). The mean growth index is the average of deviations (by age group) between the observed mean lengths and statewide seasonal average lengths.

Mortality.–We calculated catch-at-age for males, females, and all fish (including males, females, and those of unknown sex), and estimated instantaneous total mortality rates using catch-curve analyses with assumptions described by Ricker (1975). Our goal was to estimate total mortality for fish of legal size for comparison with mortality attributable to fishing. When choosing age groups to be included in the analyses, we considered several potential problems. First, an assumption of catch-curve analysis is that the mortality rate is uniform over all age groups considered to be fully recruited to the collection gear. In our analysis tagged fish were collected with types of gear (e.g., nets and electrofishing boats) different from those used in the recreational fishery. For fish smaller than the minimum size limit, mortality was M+H; for larger fish, mortality was M+H+F, where M, H, and F are natural, hooking (from catch and release), and fishing mortality, respectively. Second, walleyes and northern pike exhibit sexual dimorphism in growth (Carlander 1969, 1997), which could lead to differences in mortality between sexes. Thus, when sufficient data were available, we computed separate catch curves for males and females to determine if instantaneous total mortality differed by sex. A catch curve was also computed for all fish that included males, females, and fish of unknown sex. Third, walleyes and northern pike were collected during the spawning season, so we needed to be sure that fish in each age group were sexually mature and represented on the spawning grounds in proportion to their true abundance in the population. Thus, we included in the analyses only age groups of fish that we judged to be mostly mature. We based this judgment on a combination of information, including relative abundance, mean size at age, and percent maturity by size.

We estimated angler exploitation rates using three methods: 1) the percent of reward tags returned by anglers; 2) the estimated harvest divided by the multiple-census estimate of abundance; and 3) the estimated harvest divided by the single-census estimate of abundance. Probability of tag loss was calculated as the number of fish in the recapture sample that had lost tags (fin clip and no tag) divided by all fish in the recapture sample that had been tagged, including fish that had lost their tag. Standard errors were calculated assuming a binomial distribution (Zar 1999).

Using the first method, exploitation rate was estimated as the fraction of available reward tags returned by anglers, adjusted for tag loss. The tag loss adjustment was made by reducing the number of available reward tags by the percentage of tags lost over the course of the creel survey. We made the assumption that tagging mortality was negligible and that near 100% of reward tags on fish caught by anglers would be returned. Although we did not truly assess nonreporting (for all tags, reward and nonreward), we did compare the actual number of tag returns to the expected number (X) based on the ratio:

$$\frac{R}{C} = \frac{X}{H_a}$$

where R = the number of tags observed in creel, C = the number of fish observed in creel (adjusted for those that recruited to legal size over the course of the fishing season, and H_a = the total expanded harvest adjusted first for nonsurveyed period (based on fraction of tag returns from nonsurveyed period) and second for fish that recruited to legal size over the course of the fishing season.

Additionally, we checked individual tags observed by the creel clerk to see if they were subsequently reported by anglers. This last step is not a true estimate of nonreporting because there is the possibility that anglers believed the necessary information was obtained by the creel clerk, and further reporting to the DNR was unnecessary. Tags observed by the creel clerk that were not voluntarily reported by the angler were added to the voluntary tag returns for exploitation estimates.

Voluntary tag returns were encouraged with a monetary reward ($10) denoted on approximately 50% of the tags. Tag return forms were made available at boater access sites, at DNR offices, and from creel clerks. Additionally, tag return information could be submitted online at the DNR website (http://www.michigandnr.com/taggedfish/). All tag return data were entered into the database so that they could be efficiently linked to and verified against data collected during the tagging operation. We developed linked documents in Microsoft Word® computer software so that payment vouchers for anglers who submitted reward tag data and letters to all anglers who contributed tag returns were automatically produced. Letters sent to anglers contained information on the length and sex of the tagged fish, and the location and date of tagging. Return rates were calculated separately for reward and nonreward tags, unadjusted for tag loss. The reporting rate of nonreward tags relative to reward tags (λ *in* Pollock et al. 1991) was calculated as the fraction of nonreward tags harvested and reported divided by the fraction of reward tags harvested and reported (with available tags adjusted for short-term tag loss and mortality during tagging. In addition to data on harvested fish, we estimated the release rate of legal fish from responses to a question on the tag return form asking if the fish was released. The release rate was calculated as the total number of tag returns reported as released divided by all of the tagged fish known to have been caught (voluntary returns and unreported tags observed in the creel survey).

In the second and third methods, we calculated exploitation as the adjusted harvest estimate from the angler survey (H_a from above) divided by the multiple- and single-census abundance estimates for legal-size fish. The estimated annual harvest was adjusted for the nonsurveyed period based on the fraction of tag returns from the nonsurveyed period. Also, for proper comparison with the abundance estimates of legal fish as existed in the spring, the harvest estimate was reduced to account for fish that grew to legal size over the course of the creel survey. The reduction of harvest was based on the percentage of fish observed in the creel survey that were determined to have been sublegal at the time of the spring survey (See *Abundance* subsection of the *Methods* section). We calculated 95% confidence limits for these exploitation estimates assuming a normal distribution, and summing the variances of the abundance and harvest estimates.

Recruitment.–We obtained population data for fish in Lake Michigamme during only one year, and so could not rigorously evaluate year-class strength. However, we suggest that some insight about the relative variability of recruitment can be gained by examining the amount of variation explained by the age variable (R^2) in the catch curve regressions. For example, Isermann et al. (2002) used the coefficient of determination from catch curve regressions as a quantitative index of the recruitment variability in crappie populations.

Movement.–Fish movements were assessed in a descriptive manner by examining the location of angling capture versus the location of initial capture at tagging. Capture locations provided by anglers were often vague; thus, statistical analysis of distance moved would be questionable. Instead, we identified conspicuous movement, such as to another lake or connected river. Recapture data could not be adjusted for effort since the creel survey for Lake Michigamme did not include its tributaries or connected lakes.

Angler Survey

Fishing harvest seasons during this survey were May 15, 2006 through February 28, 2007 for walleye and northern pike, and May 27 through December 31, 2006 for smallmouth and largemouth bass. Minimum size limits were 15 in for walleye, 24 in for northern pike, 14 in for smallmouth and largemouth bass, and 42 in for muskellunge. Daily bag limit was five fish in any combination of walleye, northern pike (no more than two northern pike), smallmouth bass, or largemouth bass, and one for muskellunge. Harvest was permitted all year for other species present and no minimum size limits were imposed. The daily bag limit for yellow perch was 50. The daily bag limit for “sunfish”, including black crappie, bluegill, pumpkinseed, and rock bass was 25 in any combination. The daily bag limit for lake whitefish and lake herring was 12 in combination. Direct contact angler surveys were conducted during the open-water period from May 15 to September 30, 2006. The winter ice-cover period was not surveyed because Lake Michigamme receives very little fishing effort during that time.

An aerial-roving design was used to sample anglers during the open-water periods (Lockwood 2000b). Complete counts of fishing boats were made from an airplane, and a single clerk conducted angler interviews from a boat. Both weekend days and three randomly-determined weekdays were selected for counting and interviewing, but no holidays were sampled. One of two possible count orders was randomly selected each scheduled day. Counting began at Marker 1 and proceeded along the path ending at Marker 12, or counting began at Marker 12 and proceeded along the path ending at Marker 1 (Figure 1; Table 1). Time of count was randomized to cover daylight times within the sample period.

One of two shifts was selected each sample day for interviewing, and starting location and direction of travel were randomized daily. The clerk sampled for eight hours including either the sunrise or sunset periods. Interviews began at a different site (1–5) each day (Figure 1), and the direction of travel varied. Clerks were to complete one path during each shift, and devote some time to sampling both shore anglers and anglers at public boat launch ramps, who had completed their fishing trips. Contacted anglers must have completed at least 1 h of fishing before an interview would be conducted (Lockwood 2004; Clark et al. 2004). All roving interview data were collected by individual angler to avoid party size bias (Lockwood 1997), though the number of anglers in each party was recorded on one interview form for each party. While this survey was designed to collect roving interviews, completed-trip interviews were noted. Interview information collected included: date, fishing mode, start time of fishing trip, interview time, species targeted, bait used, number of fish harvested by species, number of fish caught and released by species, length of harvested walleyes, northern pike, and smallmouth bass, and applicable tag numbers.

Catch and effort estimates were made using a multiple-day method (Lockwood et al. 1999). Expansion values (“F” in Lockwood et al. 1999) are the number of hours within sample days (Table 2). Effort is the product of mean counts for a given day, days within the period, and the expansion value for that period. Thus, the angling effort and catch reported are for those periods sampled, no expansions were made to include periods not sampled (e.g., 0100 to 0400 hours or the month of October).

Most interviews (>80%) collected during the summer survey period were of a single type (roving). However, during some shorter periods (i.e., day within a month for a section) fewer than 80% of interviews were of a single type. When 80% or more of interviews within a time period (weekday or weekend day within a month and section) were of an interview type, the appropriate catch-rate estimator for that interview type (Lockwood et al. 1999) was used on all interviews. When less than 80% were of a single interview type, a weighted average R_w was used:

$$R_w = \frac{\left(\hat{R} \cdot n_1\right) + \left(\overline{R} \cdot n_2\right)}{\left(n_1 + n_2\right)},$$

where $\hat{R}$ is the ratio-of-means estimator for n_1 complete-trip interviews and $\overline{R}$ the mean-of-ratios estimator for n_2 incomplete-trip interviews. Estimated variance s_w^2 was calculated as:

$$s_w^2 = \frac{\left(s_{\hat{R}}^2 \cdot n_1^2\right) + \left(s_{\overline{R}}^2 \cdot n_2^2\right)}{\left(n_1 + n_2\right)^2},$$

where $s_{\hat{R}}^2$ is the estimated variance of $\hat{R}$ and $s_{\overline{R}}^2$ is the estimated variance of $\overline{R}$.

From the angler interview data collected, catch and harvest by species were estimated and angling effort expressed as both angler hours and angler trips. An angler trip is defined as the period an angler is at a lake (fishing site) and actively fishing. When an angler leaves the lake or stops fishing for a significant period of time (e.g., an angler leaving the lake to eat lunch), the trip has ended. Movement between fishing spots, for example, was considered part of the fishing trip. Mail or telephone surveys typically report angling effort as angler days (Pollock et al. 1994). Angler trips differ from angler days because multiple trips can be made within a day. Historically, Michigan angler creel data average 1.2 trips per angler day (DNR Fisheries Division, unpublished data).

All estimates are given with ± 2 SE, which provided statistical significance of 75 to 95% assuming a normal distribution and $N \geq 10$ (Dixon and Massey 1957). All count samples exceeded minimum sample size (10) and effort estimates approximated 95% confidence limits. Most error bounds for catch and release, and harvest estimates also approximated 95% confidence limits. However, coverage for rarely caught species is more appropriately described as 75% confidence limits due to severe departure from normality of catch rates.

Results[1]

Fish Community

A total of 3,935 fish representing 15 species were collected during the 2006 sampling effort in Lake Michigamme (Table 3). Total effort was 224 fyke-net lifts and 23 electrofishing runs. The total catch included 2,326 walleyes, 653 northern pike, and 117 smallmouth bass which made up approximately 59%, 17%, and 3% of the total catch, respectively. Other fish species captured, in order of their sampled abundance included: rock bass, yellow perch, white sucker, black crappie, burbot, lake whitefish, black bullhead, pumpkinseed, largemouth bass, brook trout, muskellunge, and tiger muskellunge. Walleye was the most abundant species in the catch, and the sampled fish community composition was 80% piscivores, 17% pelagic planktivores-insectivores, and 3% benthivores (Table 4).

Walleye, Northern Pike, and Smallmouth Bass

Size structure and sex ratio.–The percentages of legal-size walleyes, northern pike, and smallmouth bass were 77, 31, and 42%, respectively (Table 4). The population of spawning walleyes was dominated by 14- to 18-inch fish, which made up 83% of the catch. The mean length of a captured walleye was 16.4 inches. Northern pike between 17 and 25 inches made up 70% of the

[1] Confidence limits for estimates are provided in relevant tables, but not in the text.

sampled population, although the length distribution extended to 43 inches. Large pike (≥ 30 in) made up 9% of the total catch for this species. Male walleyes outnumbered females in the spring survey by a ratio of 9:1, and 6% of all walleyes were of unknown sex (Table 5). Male northern pike outnumbered females by a ratio of 1.5:1 when all sizes were considered, but the sexes were found in nearly equal proportions (slightly more females, 1.1:1) when only fish of legal size were considered. Fifteen percent of all northern pike were of unknown sex.

Abundance.–Crews tagged a total of 1,519 legal-size walleyes (800 reward and 719 nonreward tags) and marked (with jaw tag or fin clip) 1,942 adult walleyes. Four walleyes were recaptured in the fyke nets and were observed to have lost tags during the spring netting/electrofishing survey; thus, the effective number tagged (*M*) was 1,515. In the entire recapture sample, we observed a total of 240 walleyes, of which 38 were marked (*R*; had a fin clip, or a tag). We reduced the initial *C* by 29 (12.1%) to adjust for sublegal fish that grew over the minimum size limit during the fishing season (final *C* = 211). No recaptured walleyes were observed with lost tags; however, we used a long-term tag loss rate of 5%, based on previous lakes surveyed in the Large Lake Program. The estimated number of legal-size walleyes was 4,615 (CV = 0.10) using the multiple-census method and 8,241 (CV = 0.14) using the single-census method (Table 6). The estimated number of adult walleyes was 5,965 (CV = 0.09) using the multiple-census method, and 10,392 (CV = 0.14) using the single-census method.

Crews tagged a total of 157 legal-size northern pike (84 reward and 73 nonreward tags) and marked (with jaw tag or fin clip) a total of 468 fish. Two recaptured northern pike were observed to have lost tags during the spring netting/electrofishing survey; thus, the effective number tagged (*M*) was 155. In the entire recapture sample, we observed a total of 13 northern pike, of which one was marked (*R*; had a fin clip, or a tag). We reduced the initial *C* by 3 (23.1%) to adjust for sublegal fish that grew over the minimum size limit during the fishing season (final *C* = 10). The single northern pike recaptured in the creel survey had not lost its tag; however, we used a long-term tag loss rate of 5%, based on previous lakes surveyed in the Large Lake Program. The estimated number of legal-size northern pike was 272 (CV = 0.19) using the multiple-census method, and was 858 (CV = 0.52) using the single-census method. The estimated number of adult northern pike was 671 (CV = 0.15) using the multiple-census method and 2,448 (CV = 0.52) using the single-census method (Table 6).

Crews tagged a total of 39 (*M*) legal-size smallmouth bass (27 reward and 12 nonreward tags). No recaptured smallmouth bass were observed to have lost tags. In the entire recapture sample, we observed a total of 7 smallmouth bass, of which one was marked (*R*; had a fin clip, or a tag). We reduced the initial *C* by 2 (28.6%) to adjust for sublegal fish that grew over the minimum size limit during the fishing season (final *C* = 5); however, because of the low number captured, estimates of smallmouth bass abundance were not made.

Age and growth.–We aged 301 walleyes (Table 7), 356 northern pike (Table 8), and 83 smallmouth bass (Table 9). The overall mean growth index for walleye was -3.5. Walleye mean lengths-at-age were less than all statewide average values, and deviations generally increased with age (Table 10). Females had higher mean lengths-at-age than males, with the largest differences occurring at the older ages when males were reaching their maximum age. For northern pike, the overall mean growth index was 0.3. Mean lengths-at-age were generally within 1.2 in of the statewide average at all ages (Table 11). Like walleye, female northern pike had higher mean lengths-at-age than males. Smallmouth bass had lower mean lengths-at-age than the statewide average, with a mean growth index of -1.8.

Mortality.–For walleye, the aged subsample was apportioned to 2,019 fish (Table 7), which differs slightly from the number of unique walleyes measured (Table 4) as a result of rounding in the age-length key. Ages 7 and older were used in the catch-curve analyses to represent the male walleye population and overall legal-size walleye population because: 1) average length of walleyes at age 7 was greater than legal size, so most age-7 fish were legal-size at the beginning of fishing season; and 2) relative abundance of fish younger than age 7 did not appear to be represented in proportion to their expected abundance (Figure 3; Table 7). Only age 8 and greater walleyes were used to represent the female population. All catch-curve regressions were significant ($P < 0.05$) and the instantaneous mortality rate of male walleye (0.603) was higher than that of female walleye (0.352). The estimate of instantaneous mortality for legal-size walleye of both sexes combined was 0.527 (Figure 3). This corresponds to an annual mortality rate of 41%.

Anglers returned a total of 256 tags (146 reward and 110 nonreward) from harvested walleyes and 3 tags (1 reward and 2 nonreward) from caught and released walleyes in 2006–07. The creel clerk observed 38 tagged fish during the creel survey period, 11 of which (5 reward and 6 nonreward) were not voluntarily reported caught by the anglers. The reward tag return estimate of annual exploitation of walleye was 20.0% after adjusting for 5% tag loss (Table 6). Anglers reported reward tags at a higher rate than nonreward tags (18.4% versus 15.6%). The reporting rate of nonreward tags relative to reward tags (λ *in* Pollock et al. 1991) was 83.9%. The expected number of returns (376) was higher than the number voluntarily returned from harvested fish (256), providing some evidence of nonreporting of walleye tags. Based on all tagged walleyes known to be caught, the reported release rate of legal-size fish was 1.1%. The estimated exploitation rate for walleye was 45.2% based on dividing harvest by the multiple-census abundance estimate, and 25.3% based on dividing harvest by the single-census angler survey abundance estimate (Table 6). Angler exploitation of walleye peaked at the 16 in size class, and was lower for larger fish (Figure 4). The exploitation rate decreased from 20% on 16-in walleyes to 14% on walleyes greater than or equal to 20 in.

For northern pike, the aged subsample was apportioned to 531 fish (Table 8). We used ages 4 and older in the catch-curve analyses to represent the adult male northern pike population, and used ages 5 and older for the legal-size female and overall legal-size population (Figure 5). The catch-curve regressions were all significant ($P < 0.05$) and resulted in total annual mortality rates for males, females, and all northern pike of 56%, 47%, and 48%, respectively (Figure 5). Anglers returned a total of 20 tags (12 reward and 8 nonreward) from harvested northern pike and 5 tags (2 reward and 3 nonreward) from released northern pike in 2006–07. The creel clerk observed one tagged northern pike (reward) during the creel survey period. The reward tag return estimate of annual exploitation of northern pike was 15.2% after adjusting for 5% tag loss (Table 6). Anglers reported reward tags at a slightly higher rate than nonreward tags (16.9% versus 15.3%). The reporting rate of nonreward tags relative to reward tags (λ *in* Pollock et al. 1991) was 76.9%. The expected number of returns (11) was lower than the number voluntarily returned from harvested fish (20), providing some evidence of adequate reporting of northern pike tags; however, sample sizes were low for this analysis. The estimated exploitation rate for northern pike was 41.0% based on dividing harvest by the multiple-census abundance estimate, and 13.0% based on dividing harvest by the single-census abundance estimate (Table 6). Exploitation varied with length and no clear pattern was observed (Figure 6); however, sample sizes were small for each inch group.

We did not survey at the best time of year to target and collect smallmouth bass, and not enough were tagged to make reliable estimates. However, anglers returned 5 (4 reward and 1 nonreward) of 39 tags for an estimated exploitation rate of 15.6% (adjusted for an average tag loss rate of 5%). Based on 4 tag returns (3 reward and 1 nonreward) from released smallmouth bass, 44.4% of legal-size smallmouth bass caught were subsequently released.

Recruitment.–Walleyes in Lake Michigamme were represented by 17 year classes (ages 2 through 18) in our samples, and the coefficient of determination from the catch curve regression (R^2) was 0.96 (Figure 3). Northern pike were represented by 11 (ages 1 through 11) year classes and the R^2 was 0.95.

Movement.–Because our spring survey was conducted primarily in Lake Michigamme, our ability to detect movement of walleyes, northern pike, or smallmouth bass to other connected waters such as downstream to the Michigamme River or upstream into the tributaries was limited. However, we did collect a considerable portion of the walleyes in the Spur (5% of total) and Peshekee (44% of total) rivers, suggesting that walleyes likely move from Lake Michigamme into these tributaries to spawn. In fact, all of the first-year tag returns from walleyes tagged in the Peshekee and Spur rivers were reported as being caught in Lake Michigamme. Based on all first-year angler tag returns, 99.6% of tagged walleyes were recaptured in Lake Michigamme and 0.4% (1/270) were caught in the Michigamme River, less than ¼ mile downstream of the lake outlet. For northern pike, all tag returns were reported as caught in Lake Michigamme. Smallmouth bass were largely caught in Lake Michigamme (88.9%), though one tag return (of 9 total) came from the Peshekee River, less than ¼ mile upstream from Lake Michigamme.

Angler Survey

The clerk interviewed 968 anglers during the open-water season on Lake Michigamme. Most interviews (94%) were roving (incomplete-fishing trip). Anglers fished an estimated 26,574 hours and made 8,719 trips, with a peak during the month of August (Table 12). The total harvest of 4,307 fish consisted of five different species. Walleyes and rock bass made up the largest proportion of the harvest at 54 and 31%, respectively. We estimated that anglers harvested 2,338 walleyes and released 3,086 walleyes (57% of total walleye catch). We estimated that anglers harvested 145 northern pike, and released 1,118 northern pike (89% of total catch). Overall catch rates on Lake Michigamme were 0.68 fish per hour (0.16 harvested fish per hour and 0.52 released fish per hour). The harvest rate was highest for walleye (0.09 fish per hour) and the release rate was highest for rock bass (0.18 fish per hour). Walleye catch rates were consistent in May and June (0.06 to 0.07 fish per hour), peaked in July (0.14 fish per hour) and then declined through August and September (0.09 to 0.05 fish per hour). It should be noted that catch rates are calculated with general effort, not targeted effort, and are therefore not necessarily indicative of the rate that an angler targeting one species may have experienced. Although no differentiation was made between sublegal and legal-size released fish, we assume that a large proportion of the released walleyes were sublegal. Size composition of the released fish was not evaluated. The angler survey was not conducted from October through the ice fishing season because it was thought that relatively little fishing occurred during that time of year. However, 4 of the 267 tag returns reported for harvested walleyes were caught during these nonsurveyed periods (Table 13). Thus, the total walleye harvest may have actually been about 1.5% higher than our direct survey estimate, or 2,373 walleyes. No northern pike or smallmouth bass tag returns were reported during this nonsurveyed period. The estimated harvest of fish that were considered legal size during spring netting was 2,086, 112, and 63, for walleye, northern pike, and smallmouth bass, respectively. The actual numbers harvested were adjusted for sublegal fish that recruited to legal size over the course of the angling season.

Discussion

Fish Community

Active management of the fishery resources in Lake Michigamme began in the 1930s. At the time, the lake was designated a northern pike lake, and the predator community was composed mainly of northern pike and smallmouth bass. From 1936 to 1940, 6 million walleye fry were stocked into the lake (Table 14). By 1940, very few walleyes from the stocking efforts had been caught and Brown (1940) wrote that, "The futility of planting walleyes has already been proven." That evaluation turned out to be premature as the walleyes from those stocking efforts survived and produced a strong fishery during the mid- to late-1940s (Peterson 1977). Natural reproduction was variable and did not sustain the population at a high abundance. The fishery declined during the early 1950s, became strong in the late 1950s, declined in the 1960s, and around 1970 consecutive strong year classes of walleye produced the best sport fishery since the 1940s (Peterson 1977; Madison 1994). After angler reports of poor fishing, walleye stocking resumed in 1983 and continued every two to four years through 2002. Fishing reports during that time were both positive and negative, perhaps indicating that periodic strong year classes and/or high survival of stocked fish were followed by years of poor recruitment and/or survival; however, year-class failures were never documented.

Northern pike have never been stocked into Lake Michigamme. The past and current population is a result of fluctuating levels of natural reproduction over the past 80 years. Abundance was high during the 1930s then declined in the 1940s and remained at low levels until increasing in the mid-1970s (Peterson 1977). Populations remained at a higher level through the 1980s (Bullen 1984). Northern muskellunge have never been stocked into Lake Michigamme, but the first reported harvest of this species occurred in 1957. Muskellunge likely migrated to Lake Michigamme from lakes near the headwaters of the Peshekee River system. In 1976, a new state record muskellunge was caught, which measured 51 inches in length and weighed 40 lb 15 oz. Introductions of tiger muskellunge in the late 1970s were unsuccessful, likely due to steady and increasing populations of northern muskellunge and northern pike (Bullen 1984).

Smallmouth bass have not been an abundant species in Lake Michigamme, but have always been present at low levels. Periodic stocking of this species has occurred since 1984, but a large increase in the population abundance has not been observed or documented through fish surveys. Yellow perch have also been present at low abundance. The transfer of 43,000 adult yellow perch from nearby lakes in 1983 and 1984 failed to noticeably increase their population (Madison 1994).

Lake trout, rainbow smelt, and splake were stocked into Lake Michigamme between 1938 and 1963 to enhance the coldwater fisheries of the lake. However, these stocking efforts never produced any fish either in a creel survey or general lake survey (Peterson 1977) and were not stocked again until the year 2000. From 2000 to 2005 another attempt was made to enhance the coldwater fish community of Lake Michigamme as lake trout, splake, brook trout, and rainbow trout all were stocked. Although this survey was not designed to catch these species, and not all of the stocked fish were of catchable size in 2006, none were captured during the large lake survey. A single lake trout was observed in the angler survey, but it was not recorded during a formal interview, so harvest estimates were not made for this species.

All fisheries reports written about Lake Michigamme have mentioned its low productivity (Brown 1940; Peterson 1977; Bullen 1984; Madison 1994). Lake Michigamme cannot support a large fish community because it lacks the necessary nutrient base. Throughout the past 30 years, the sucker and lake whitefish populations have been strong, providing forage for game fish that reach a size large enough to utilize this resource, but forage for smaller predator fish may be more limiting. The proportion of piscivorous fish captured in Lake Michigamme was high (80%) compared to other area lakes surveyed by the DNR Large Lakes Program (Peavy Pond 46%, Hanchin 2011a; Michigamme Reservoir 46%, Hanchin et al. 2005a), but was similar to the proportion of piscivores captured in Lake Gogebic (79%, Hanchin 2011b), another Upper Peninsula lake that lacks an abundant forage base.

Walleye, Northern Pike, and Smallmouth Bass

Size structure and sex ratio.–It is difficult to compare the size structure of fish in Lake Michigamme over the time series of available survey data. Fish were collected at different times of year, using different gear, and due to low sample sizes, average sizes are easily skewed. In some cases in historical records, large fish were recorded only as a plus group; so for example, all fish over 22 in were lumped together. Despite these limitations, the average size of a captured walleye has typically been near 15 in. Few survey data are available on the size structure of the walleye population before the 1970s. In 1976, the average size of a captured walleye was 15.3 in. In 1982, the average size was 14.5 in, and by 1983 captured walleyes averaged 15.1 in. In 1992, the sampled population averaged 14.2 in, and in the present survey the walleye population averaged 16.4 in. The increase in average length between 1992 and 2006 is likely a function of the target population. Our sampling protocol in 2006 targeted the largest individuals in the population and occurred during the spawning period. The survey in 1992 and most previous surveys were conducted in either the summer or fall, and did not target the spawning populations of walleye or northern pike. Comparisons of the proportion of legal-size walleyes are subject to the same limitations as the average size. However, in 1976, 41% of the walleyes exceeded 16 in total length and 61% exceeded 14 in total length, so it is likely nearly half of the population was of legal size. In 1984, it was reported that 45% of the walleye population exceeded the legal size of 15 in (Bullen 1984), and in 1993, 43% exceeded 15 in (Madison 1994). The proportion of legal-size walleyes in this survey (77%) is likely biased high, when compared to previous surveys, because spawning fish were targeted; whereas, past surveys were conducted in the summer or fall. However, the percent of legal-size fish in Lake Michigamme is only slightly higher than the average (70%) for other large lakes sampled in the spring as part of the Large Lakes Program.

Comparisons of the historic size structure of northern pike to the one observed in the current study have the same problems as walleyes, with different gear types, seasons, sample sizes, and recording abnormalities that confound historical comparisons. In 1938, the average size of the sampled northern pike was 18.5 in. Although the sample was dominated by small fish, pike up to 36 in were captured (Brown 1940). In 1976, the average size was 23.8 in, with a 42 in fish recorded. In 1982, northern pike averaged 22.7 in, in 1985 they averaged 18.2 in, and in 1993 they averaged 19.8 in. In this survey, pike averaged 22 in, but the largest pike ever recorded in a Lake Michigamme survey was captured (43 in), indicating that this lake has the potential to produce large pike. In the late 1990s the size limit for northern pike increased from 20 in to 24 in, so the proportion of legal size fish is relative to these two values. In 1976, 69% of northern pike were of legal size in Lake Michigamme. That number decreased to 32% in 1983, 14% in 1993, and was 31% in the current survey. These changes likely reflect changes in gear types and time of year of sampling, rather than drastic changes in the population. The proportion of legal-size northern pike in the spring survey of 2006 was above the average (28%) of the lakes sampled under the Large Lakes Program.

The 2006 survey was the first to examine the sex ratio of fish in Lake Michigamme. Sex ratios of spawning fish will change with the timing of both spawning and sampling, but for walleye, males generally outnumber females during spawning surveys as they mature earlier and spend more time on the spawning grounds (Carlander 1997). During spring surveys of walleye in Lake Gogebic, the sex ratio has been as high as 306 males for every female (Hanchin 2011b). Sex ratios obtained during the spawning season are rarely indicative of the true sex ratio in the population. Netting efforts early in the spawning season are dominated by males, while netting during the peak and end of spawning have a relatively higher proportion of females. The sex ratio observed in Lake Michigamme (9:1) was above the average (4.4:1) observed in other lakes sampled as part of the Large Lakes Program. Sex ratios of northern pike are also dependent upon the timing of sampling during the spawning period. Males dominate sex composition in spawning-season samples, but not at other times of the year (Priegel and Krohn 1975; Bregazzi and Kennedy 1980). Compared to other lakes sampled under the Large Lakes Program, the sex ratio patterns observed in Lake Michigamme (more males when all sizes were considered and more females when only legal-size fish were considered) was similar, but the sex ratio (1.5 males for every female) was more balanced than the average (2.3 males for every female).

Abundance.–Estimates of absolute walleye abundance in Lake Michigamme have not been made prior to the present study. Relative abundance has been recorded for many of the surveys conducted throughout the years. Walleyes have been absent from some gill-net surveys in the lake, but when collected the number per 100’ of gill net has ranged from 0.02 (August 1938) to 0.59 (July 1972;

Peterson 1977). Impoundment gear catch rates have ranged from 0.08 (July 1972) to 4.3 (August 1958; Peterson 1977) per net night. The catch per fyke net night observed in this study (1.3) was the second highest on record for Lake Michigamme.

Our multiple-census estimates for walleye abundance were much lower than the single-census estimates for both legal-size fish and adult fish, which is consistent with results from most other large lakes surveyed (Clark et al. 2004, Hanchin et al 2005a, b, c, Hanchin and Kramer 2007). The single-census estimates also compared better to other independently-derived estimates. For example, the exploitation estimate derived using the single-census estimate was only 26% higher than the tag-return estimate, while the exploitation estimate derived using the multiple-census estimate was 126% higher (Table 6). Multiple-census estimates made during the onshore spawning migration of species such as walleye and northern pike are likely biased low due to size selectivity and unequal vulnerability of fish to nearshore netting (Pierce 1997). Additionally, they have the potential problem of incomplete mixing, which is not a problem with the single-census method because it allows sufficient time for marked fish to fully mix with unmarked fish. In comparing surveys conducted similarly to ours, Pierce (1997) concluded that recapturing fish at a later time with a second gear type resulted in estimates that were more valid. Thus, based on comparisons with the independently-derived creel estimates and the more rigorous evaluation by Pierce (1997), we consider the single-census estimate to be more accurate than the multiple-census estimate for Lake Michigamme.

The single-census estimate of walleye abundance was higher than the Michigan model estimate but lower than the Wisconsin model estimate. Our single-census estimate for legal-size walleyes was only about 14% higher than the Michigan model and 25% lower than the Wisconsin model. Accordingly, the population density of walleye in Lake Michigamme was within the expected range compared to other walleye lakes in Michigan and Wisconsin. Our single-census estimate for 15-in-and-larger walleyes in Lake Michigamme was 1.9 per acre. Recent estimates of legal-size walleye density for nineteen large lakes in Michigan has averaged 2.0 fish per acre (range = 0.4 to 4.6 fish per acre), though the median (1.6 fish per acre) is a better measure of central tendency for these data (DNR unpublished data). Population density of adult walleyes from our single-census estimate was 2.4 fish per acre, which is just below the average (3.2 fish per acre) and equal to the median (2.4 fish per acre) in nineteen large lakes surveyed thus far as part of the Large Lakes Program. Adult walleye density in Lake Michigamme is about equal to the average density (2.2 adult walleyes per acre) for 131 northern Wisconsin lakes having natural reproduction (Nate et al. 2000).

We did not consider the single-census abundance estimate for northern pike to be valid, due to its high (0.52) CV. The multiple-census estimate had an acceptable CV and produced a lower estimate of abundance. Despite the methodological biases known about multiple-census estimates (Pierce 1997) we considered it our best estimate. Pierce (1997) considered his multiple-census estimates of northern pike abundance as minimums, with the true abundances likely higher. The multiple-census estimate for legal-size northern pike converts to a density of 0.06 per acre, which is below the average (0.16) and median (0.09) estimated recently in the Large Lakes Program. Nearby, Michigamme Reservoir and Bond Falls Flowage had only slightly higher densities of 0.13 and 0.08 per acre, respectively (Hanchin et al. 2005a; Hanchin 2009). The density of adult northern pike (0.15 per acre) is below the average (0.90) and median (0.46) estimated recently in the Large Lakes Program; however, the Lake Michigamme estimates are likely minimums. Nearby, populations in the Cisco Chain, Peavy Pond, and Bond Falls Flowage had much higher densities of 2.9, 2.3, and 2.6 per acre, respectively (Hanchin et al. 2009; Hanchin 2011a; Hanchin 2009). Craig (1996) gave a table of abundance estimates (converted to density) for northern pike from various investigators across North America and Europe, including one from Michigan (Beyerle 1971). The sizes and ages of fish included in these estimates vary, but considering only estimates done for age 1 and older fish, the range in density was 1 to 29 fish per acre. Also, Pierce et al. (1995) estimated abundance and density of northern pike in seven small (<740 acres) Minnesota lakes. Their estimates of density ranged from 4.5 to 22.3 fish per acre for fish age 2 and older. Our estimates for adult northern pike in Lake Michigamme are essentially for fish age 4 and older, so they should be lower. Additionally, the lower density observed in Lake Michigamme is likely due to the larger size of the lake, and the lower relative proportion of spawning habitat as compared to the small Minnesota lakes that Pierce et al. (1995) surveyed.

Age and growth.–Lake Michigamme is a deep lake, located at high latitude, and it has cold water and limited nutrient inputs. That combination results in a lake that will take longer to produce large fish. Growth is not slow because the density of fish is high, as compared to other lakes, but density can at times be high for the amount of forage available in Lake Michigamme. Every survey report for this lake since 1940 mentions its low productivity and its inability to support a large fish biomass. In years of higher relative abundance, competition for the limited forage base can retard growth.

Diet studies of Lake Michigamme walleyes are limited. There have been some historic reports of fish consuming yellow perch and mayfly nymphs. Whitefish and both white and longnose suckers are abundant in the lake, but they are of a size more easily utilized by northern pike and muskellunge than by walleyes. Cannibalism by walleyes has not been documented in Lake Michigamme, although it likely occurs. Other possible prey sources for juvenile and subadult walleyes include red-belly dace, common and golden shiners, Iowa darters, and bluntnose minnows, all of which are present but in low abundance.

Mean lengths-at-age for walleyes from our survey of Lake Michigamme were well below the statewide averages. Historic surveys did not catch the number of fish that we did, and low sample sizes prevented comparison to statewide averages for many surveys. Despite these limitations, growth of walleyes was slightly below the statewide average in the 1970s, but was at or slightly above average, during the 1980s, before declining in the 2000s (Table 10). Mean total lengths-at-age for northern pike were slightly above the state averages, and higher than other waters in the Upper Peninsula (Table 11). Northern pike, which are present in lower abundance than walleyes, were likely better able to make use of the sucker and whitefish populations as a forage base. Only in a 2002 survey were catches of northern pike great enough to compare growth to statewide averages. In that survey pike also demonstrated growth rates slightly above the statewide average.

Mortality.–This study represents the first known attempt to estimate mortality of the Lake Michigamme walleye population. Total mortality of walleyes (53%) was higher than the average (41%) for 19 populations surveyed in the Large Lakes Program, which have ranged from 24% to 57%. Schneider (1978) summarized available estimates of total annual mortality for adult walleyes in Michigan, which ranged from 20% in Lake Gogebic to 65% in the bays de Noc, Lake Michigan. He also presented estimates from lakes throughout Midwestern North America, other than Michigan. They ranged from 31% in Escanaba Lake, Wisconsin to 70% in Red Lakes, Minnesota. Colby et al. (1979) summarized total mortality rates for walleyes from a number of lakes across North America. They ranged from 13% to 84% for fish age 2 and older, with the majority of lakes between 35% and 65%. Despite the above average mortality rate of walleyes in Lake Michigamme, longevity of this species was strong with 18 year classes represented in the catch. Annual mortality for males (60%) was higher than that of females (35%), similar to the pattern observed in Big Manistique Lake (Hanchin and Kramer 2007), Burt Lake (Hanchin et al. 2005b), and Michigamme Reservoir (Hanchin et al. 2005a).

Our three estimates of walleye exploitation varied considerably; 20% from tag returns, 45% using harvest divided by the multiple-census abundance estimate, and 25% using harvest divided by the single-census abundance estimate. The much higher estimate derived using the multiple-census abundance estimate is further evidence that abundance is underestimated using multiple-census methods, and this pattern has been observed in other lakes sampled as part of the Large Lakes Program. Because the tag return estimate is likely a minimum, and the harvest divided by the single census abundance estimate is slightly higher, we assume that 25% is our best estimate of exploitation for this population. Compared to exploitation rates for walleyes from other lakes in Michigan and elsewhere, exploitation in Lake Michigamme is approximately average or slightly above. In 17 other lakes sampled as part of the Large Lakes Program, walleye exploitation averaged 15%. However, in other waters, estimates have been higher. For example, Thomas and Haas (2005) estimated angler exploitation rates from western Lake Erie to vary between 7.5% and 38.8% from 1989 through 1998. Serns and Kempinger (1981) reported average exploitation rates of 24.6% and 27.3% for male and female walleyes respectively in Escanaba Lake, Wisconsin during 1958–79. Schneider (1978) gave a range of 5% to 50% for lakes in Midwestern North America, and Carlander (1997) gave a range of 5% to 59% for a sample of lakes throughout North America.

Total mortality of northern pike in Lake Michigamme (64%) was above average (50%) relative to nineteen northern pike populations surveyed as part of the Large Lakes Program in Michigan. It is also higher than Diana's (1983) estimated total annual mortality from two other Michigan lakes, Murray Lake (24.4%) and Lac Vieux Desert (36.2%). Other western Upper Peninsula lakes—Bond Falls Flowage, Cisco Lake Chain, Michigamme Reservoir, and Peavy Pond—had mortality rates of 48%, 64%, 63%, and 56%, respectively. In Minnesota, Pierce et al. (1995) reported a range of total mortality for northern pike in seven small (< 300 acres) lakes from 36% to 65%. They also summarized total mortality for adult northern pike from a number of lakes across North America; estimates ranged from a low of 19% (Mosindy et al. 1987) to a high of 91% (Kempinger and Carline 1978), with the majority of lakes between 35% and 65%.

The three exploitation rate estimates for northern pike in Lake Michigamme varied greatly (15% from tag returns, 41% using harvest divided by the multiple-census abundance estimate, and 13% using harvest divided by the single-census abundance estimate). As with walleye, the exploitation rate using harvest divided by the multiple-census abundance estimate is likely biased high, and the other estimates of exploitation are likely better. Given the total mortality estimate, natural mortality appears to contribute significantly more than fishing mortality for northern pike. However, hooking mortality from released fish is unknown and could be significant given the high percentage (89%) of released northern pike. Clark (1983) warned that voluntary release rates higher than 10% change the interpretation of conventional angler survey estimates of catch and fishing mortality. If hooking mortality were 15%, approximately half of the highest reported in the literature for esocids (DuBois et al. 1994, Tomcko 1997), estimated mortality due to fishing would double.

Compared to exploitation rates for northern pike from other lakes in Michigan and elsewhere, our estimates for Lake Michigamme (13–15%) are average or slightly below. The mean exploitation rate for northern pike from Large Lake surveys to date is 16.8% with a range of 3% to 31%. Nearby Bond Falls Flowage had a much higher exploitation rate of 26.8% (Hanchin 2009), while Michigamme Reservoir (Hanchin et al. 2005a) had a slightly lower rate of 11.1%. Latta (1972) reported northern pike exploitation in two Michigan lakes, Grebe Lake at 12–23% and Fletcher Pond at 38%. Pierce et al. (1995) reported rates of 8% to 46% for fish over 20 in for seven lakes in Minnesota, and Carlander (1969) gave a range of 14% to 41% for a sample of lakes throughout North America.

Recruitment.–Although we obtained population data in Lake Michigamme for only one year and could not rigorously evaluate year-class strength, insight about the relative variability of recruitment can be gained by examining the properties of the catch-curve regressions. For example, Maceina (2003) used catch-curve residuals as a quantitative index of the relative year-class strength of black crappie and white crappie in Alabama reservoirs, and showed that residuals were related to various hydrological variables in the reservoirs. Similarly, Isermann et al. (2002) used the coefficient of determination from catch curve regressions as an index of crappie recruitment variability.

Natural reproduction of walleye occurs in Lake Michigamme. After the initial introduction of stocked fish in the late 1930s and 1940, stocking did not occur again until 1983. Walleyes persisted without stocking during this 40-year time period and supported a recreational fishery. Similar to other populations in the region, walleye abundance in Lake Michigamme has cycled up and down with periodic strong year classes occurring in the late-1950s and late-1960s, and poor fishing being reported in the mid-1950s, late 1970s, and prior to recruitment of stocked fish in the 1980s (Peterson 1977; Bullen 1984). Although stocking in lakes that support natural reproduction is often unsuccessful, managers suggested stocking periodically to supplement poor year classes and sustain a fishery. Fall recruitment surveys conducted by DNR in 2002, 2004, and 2005 provide evidence that natural reproduction occurs, as all three surveys captured age-0 walleyes. Walleyes were stocked in 2002, and captured fish may have represented fish of either a hatchery or natural origin. However, in both 2004 and 2005 no walleyes were stocked, and all fish captured from those year classes would have been the product of natural reproduction. The presence of 17 consecutive year classes of walleye represented in the catch curve analysis provides further evidence of natural reproduction in Lake Michigamme, as a complete year-class failure had not occurred since at least 1988. Walleyes were only stocked every two years in the late 1980s and every four years in the 1990s, ending in 2002. If natural reproduction did not fill in the nonstocked years, missing year classes would result, causing more variability in the regression coefficient of the catch curve. The high R^2 value from the catch curve (0.96) also suggests that recruitment has been consistent over the time series. Recruitment in Lake Michigamme was above both the average (0.79) and median (0.87) from other Michigan walleye populations surveyed as part of the Large Lakes Program to date (N = 17).

The R^2 value for northern pike (0.95) was above the average (0.87) and median (0.88) from other Michigan northern pike populations surveyed as part of the Large Lakes Program, indicating less variation in recruitment than the average population. Northern pike have never been stocked in Lake Michigamme so all recruitment is from natural reproduction. There were 11 year classes present in the sample with no gaps, suggesting that a year-class failure has not occurred since at least 1995.

Movement.–Movement of fish during spring netting is difficult to assess, as fish are not released at their site of capture. Movement is better analyzed by examining where tagged fish are recaptured by anglers. This shows whether or not fish leave the lake system and use connecting rivers during different periods of the year. In Lake Michigamme only a single tagged walleye was captured outside of the main lake. That individual was captured in the Michigamme River, but less than ¼ mile from the lake. This indicates that fish remain in Lake Michigamme throughout the season, and population changes do not occur due to emigration from the system. Movement of fish into Lake Michigamme could not be assessed with the current data set, but has historically occurred. It is thought that the northern muskellunge population in the lake is a result of immigration from other systems. Muskellunge were stocked into lakes near the headwaters of the Peshekee River, which drains into Lake Michigamme, in the early 1950s. The first reported catch of a muskellunge in Lake Michigamme occurred in the 1950s, and no records of angler catches or muskellunge stockings exist for earlier years.

Angler Survey

Summary.–The fishery of Lake Michigamme is typical of other large lakes located in the western Upper Peninsula. The angler catch was dominated by walleye and rock bass, which comprised 63% of the total catch. The majority of walleyes and northern pike caught were released (57 and 89%, respectively). If the assumption is made that nearly all legal-size walleyes caught would be harvested (supported by the estimated 1% release of legal-size fish), the overall release rate provides another estimate of the percent of the population that is legal size. This estimate (43%) is closer to the other estimates obtained during summer surveys in past years (Bullen 1984; Madison 1994). For northern pike, the percent of fish released was higher than the estimated proportion of sublegal fish in the population, suggesting that anglers release legal-size fish. Overall, the fishery of Lake Michigamme is not very diverse, though this is similar to most other waters in the western Upper Peninsula, as only five species were reported harvested during the creel survey period. In addition to walleyes, northern pike, and rock bass, it was estimated that 88 smallmouth bass were harvested along with 418 yellow perch (Table 12). The creel clerk also observed one lake trout and one muskellunge; however, these were not observed as part of an angler interview, so they were not recorded in the survey data.

Historical comparisons.–The creel survey conducted on Lake Michigamme in 2006 was the first using modern sampling protocols, thus it cannot be compared to other historical creel surveys. Informal creel work was performed by Conservation Officers in the late 1930s and late 1940s. They reported catches of walleye, northern pike, and smallmouth bass. Periodic reports of muskellunge being caught in the 1950s and 1970s have been recorded, but the only other creel information on record is the periodic complaints by anglers of low catch rates of walleye and yellow perch. On an informal basis, one angler corresponded with DNR biologists annually for 15 years. This individual intensely fished the lake and voluntarily reported his catch and effort and collected biological data and scale samples from all fish caught. The angler always had better success on Lake Michigamme than most other individuals, causing DNR fisheries personnel to question some of the reports of poor fishing on the lake.

Comparison to other large lakes.–Although historical creel surveys that would allow comparison of past and present trends in the fishery do not exist, the most recent angler survey can be compared to 17 other lakes that have had similar surveys as part of the Large Lakes Program (Table 15). An estimated 26,574 angler hours occurred on Lake Michigamme during the angler survey, which corresponds to 6.2 hours per acre. This is below the median and less than half the mean value for other lakes surveyed under the Large Lakes Program (Table 15). The harvest for Lake Michigamme was 1.0 fish per acre, which is the lowest to date of all lakes with complete survey information (although Lake Michigamme lacked the winter creel survey that was completed on most other lakes). This value is half the median and only 13% of the mean harvest per acre for other large lakes surveyed. Michigan lakes with a high harvest per acre generally have popular bluegill/sunfish fisheries that bolster the total harvest, but these species are not present in Lake Michigamme.

For walleye, the estimated annual harvest from Lake Michigamme was 0.54 fish per acre, which is slightly above the average (0.51 per acre) and median (0.45 per acre) for 17 lakes surveyed as part of the Large Lakes Program. The average harvest of six other large Michigan Lakes (> 1,000 acres) reported by Lockwood (2000a) was 0.63 walleyes per acre, ranging from 0.01 for Brevoort Lake to 1.68 for Chicagon Lake. These Michigan lakes were subject to similar gears and fishing regulations, including a 15-in-minimum size limit. The walleye harvest is above average despite the lowest overall harvest of fish per acre on record (Table 15), because the percentage of walleye in the total harvest of fish is high. The harvest per hour (0.09) for walleyes on Lake Michigamme was more than double the average (0.04) and median (0.04) values from the Large Lakes Program. Given that these harvest rates are calculated with general effort, the higher rate for Lake Michigamme is likely a reflection of the fact that anglers mainly target walleyes in this lake.

For northern pike, the estimated annual harvest was 0.03 fish per acre, which was below average compared to other waters in Michigan. The average harvest in 17 other lakes (having a 24-in minimum size limit) sampled in the Large Lakes Program was 0.08 northern pike per acre, ranging from 0.003 in North Manistique Lake (Hanchin and Kramer 2008) to 0.464 in Houghton Lake (Clark et al. 2004). The average harvest of seven other large Michigan lakes (> 1,000 acres) reported by Lockwood (2000a) was 0.151 northern pike per acre, ranging from 0.002 per acre in Bond Falls Flowage to 0.654 per acre in Fletcher Pond. The lakes reported by Lockwood (2000a) were all subject to similar gears and fishing regulations, including a 24-in minimum size limit. Elsewhere, Pierce et al. (1995) estimated harvests from 0.7 to 3.6 per acre in seven smaller Minnesota lakes, which ranged from 136 to 628 acres in size and had no minimum size limit for northern pike.

The estimated annual harvest of smallmouth bass was 0.02 fish per acre, which was well below the average (0.10) from seventeen other lakes sampled in the Large Lakes Program. The average harvest of seven other large (>1,000 acres) Michigan lakes reported by Lockwood (2000a) was 0.08 smallmouth bass per acre, ranging from 0.03 in Brevoort Lake to 0.15 in Elk Lake. The lakes reported by Lockwood (2000a) were all subject to similar gears and fishing regulations, however, the surveys did not always include the entire open-water period. Yellow perch had an estimated annual harvest of

0.10 per acre in Lake Michigamme. In comparison, harvest per acre of yellow perch has averaged 2.6 per acre (median 1.4) in 19 populations surveyed in the Large Lakes Program. This indicates the paucity of yellow perch in Lake Michigamme.

Summary

There is a paucity of information on Lake Michigamme compared to some other large lakes in Michigan. Because of its location and surrounding landscape, Lake Michigamme is an unproductive system. It cannot support the fish biomass of other large lakes its size in other areas of the State. Perhaps due to its low productivity and smaller biomass of fish, it does not receive the angling pressure of other comparable lakes. Available information indicates that after a successful introduction in the late 1930s, the walleye population persisted at fluctuating levels until stocking occurred again in the 1980s. Present data suggests that natural reproduction is successful, consistent, and likely sufficient to maintain the population. Walleye growth is slow in Lake Michigamme, likely due to the low forage density and low system productivity. Mortality rates of walleyes are average, but fish do attain an advanced age. Overall fish harvested per acre was much lower than other lakes surveyed as part of the Large Lakes Program. In 2006, there were an estimated 1.9 legal-size walleyes per acre and anglers harvested 0.5 per acre at a rate of 0.09 per hour fished. Although walleye density was near the average of other large lakes surveyed recently in Michigan, the harvest rate was above average, which is a result of the high percentage of anglers targeting walleyes. The estimate of adult walleye abundance from the Michigan regression equation was 12% lower than the empirical estimate, while the prediction from the Wisconsin regression equation was 32% higher.

Northern pike are much less abundant than walleyes in Lake Michigamme. The density of both adult and legal-size northern pike was much lower than in most large, Michigan lakes, and the percentage of legal-size northern pike was average. Accordingly, measures of angler harvest and catch rates were less than half of the average for other large lakes. Growth of northern pike exceeded state averages, which is noteworthy given the lakes geographic location. Most lakes in this region contain slow growing northern pike populations. Mortality of northern pike is within acceptable limits, although slightly higher than the average for Michigan's large lakes. Recruitment is consistent, and no missing year classes were observed.

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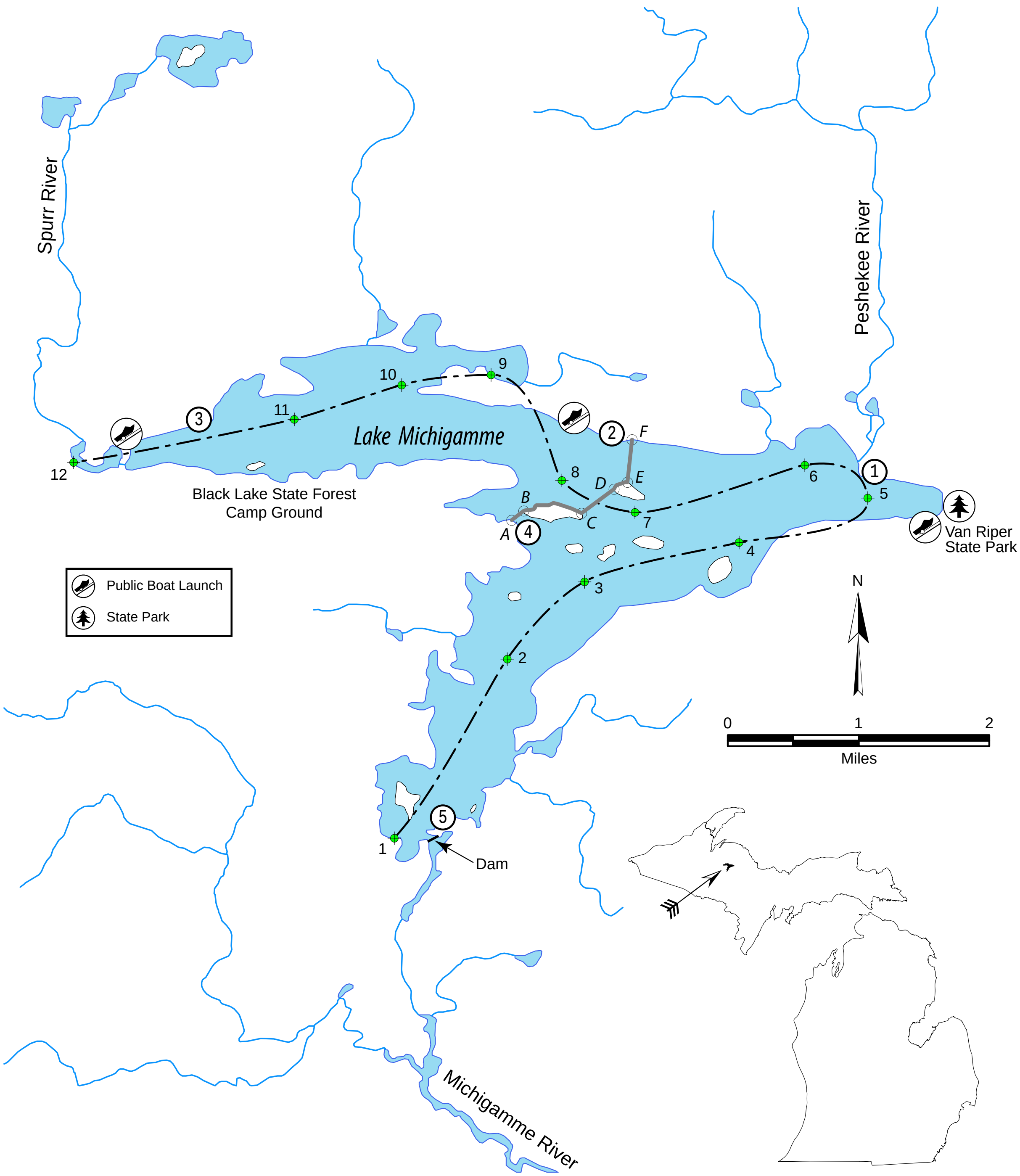

Figure 1.–Map of Lake Michigamme, Marquette and Baraga counties, Michigan. Numbers connected with dashed line represent aerial flight path used to count anglers, and circled numbers represent starting sites for creel interviews.

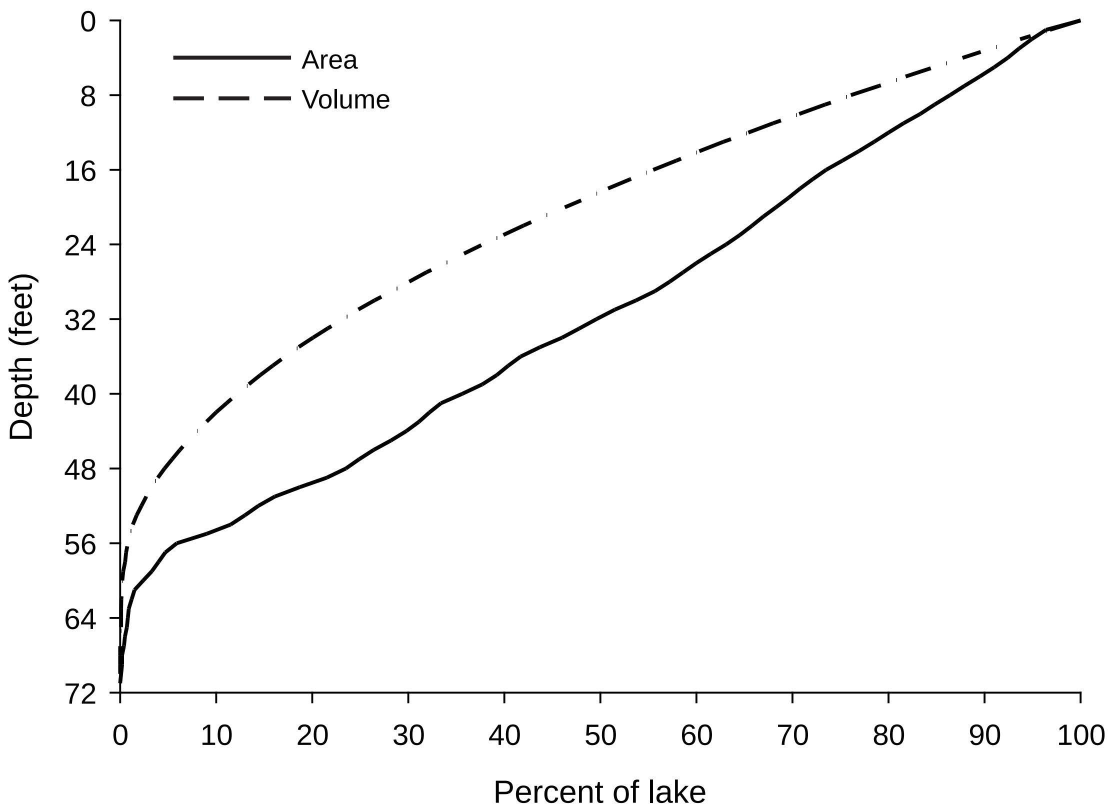

Figure 2.–Percent of lake surface area and volume equal to or greater than a given depth for Lake Michigamme. Data from DNR Digital Water Atlas (Breck 2004).

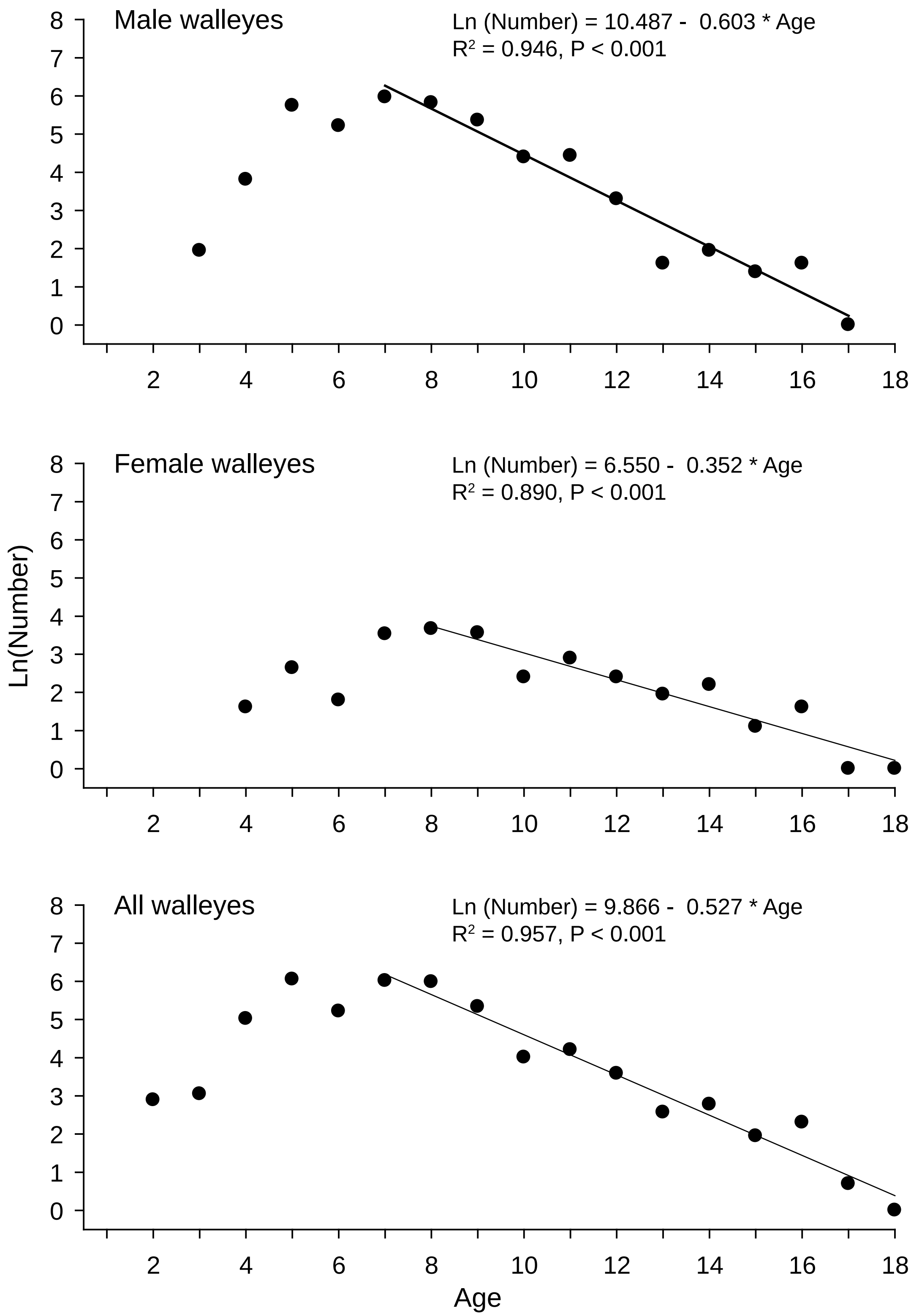

Figure 3.–Plot of observed catch [ln(number)] versus age for legal-size (≥15 in; male, female, and combined) walleyes in Lake Michigamme. Lines are plots of the regression equations given.

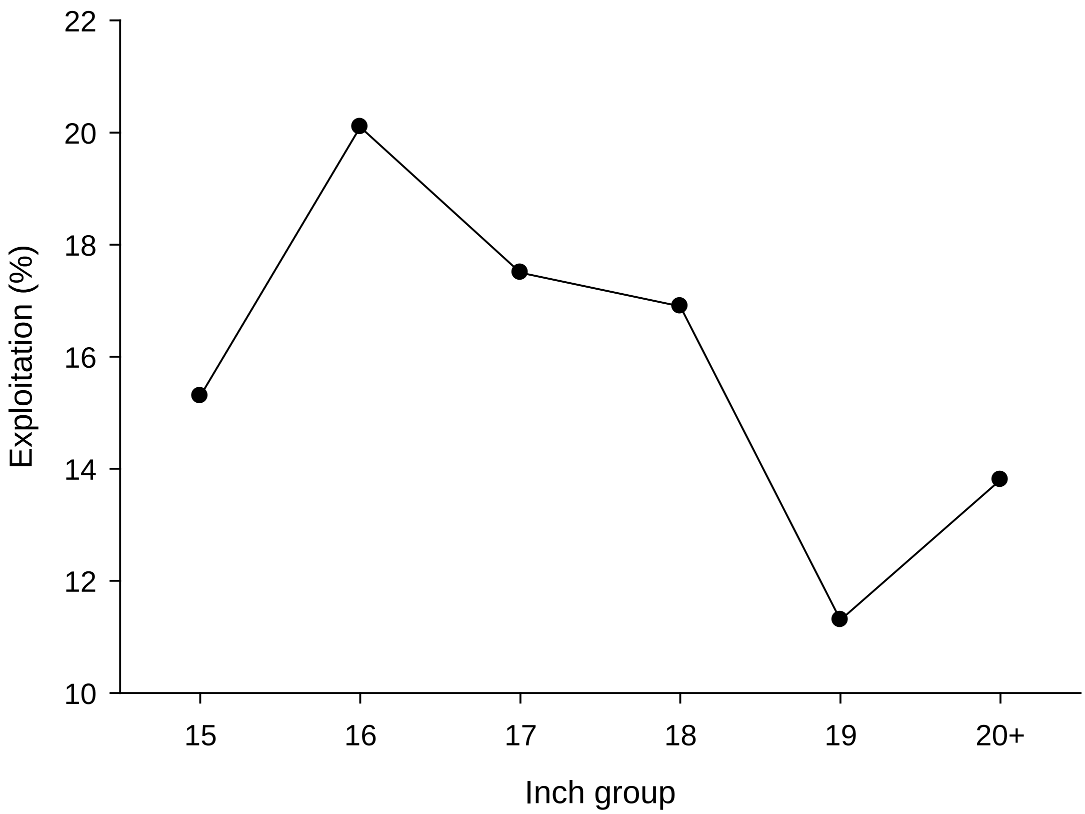

Figure 4.–Walleye exploitation (%) by inch group. A minimum of 50 walleye were tagged in each inch group.

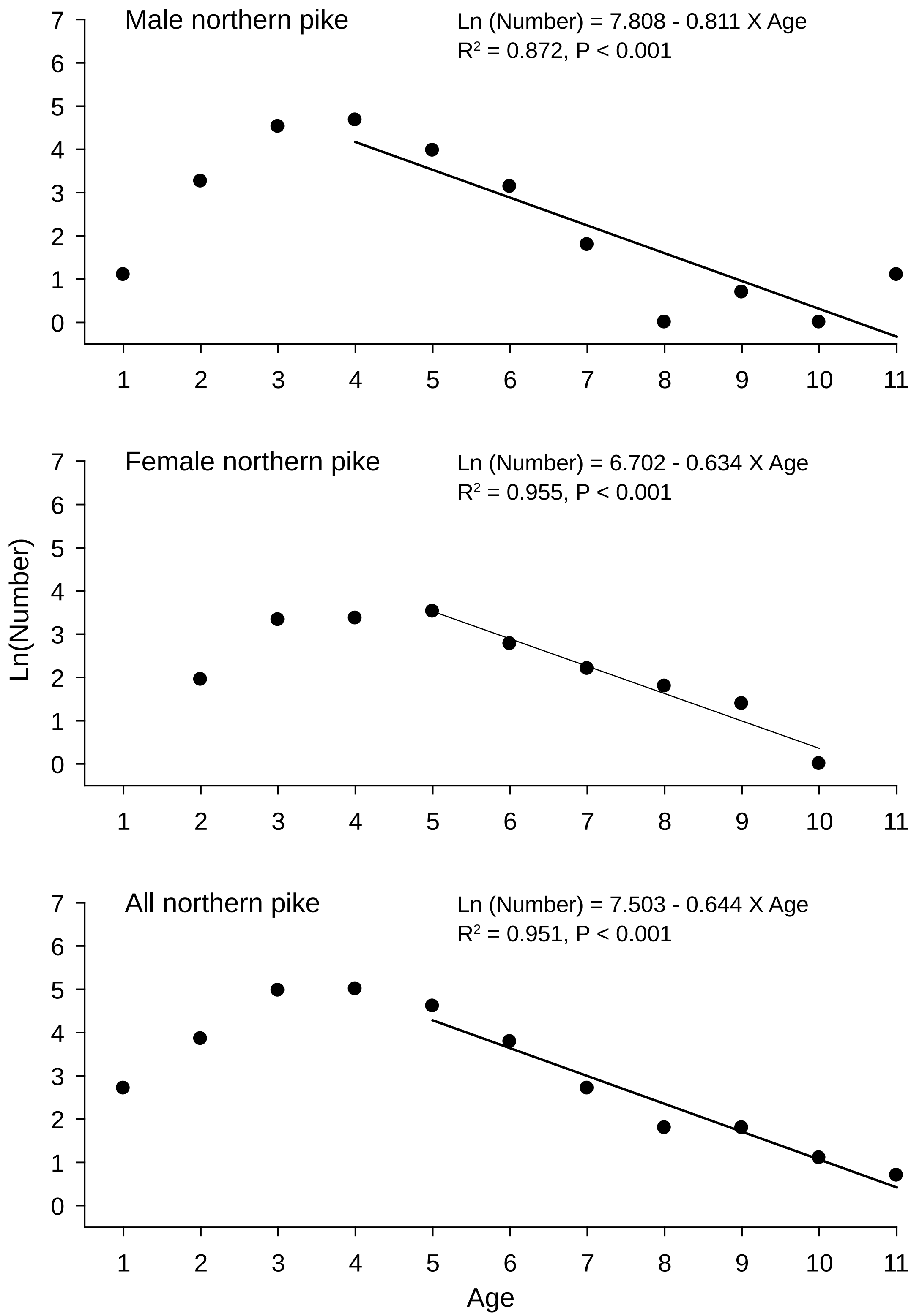

Figure 5.–Plot of observed catch [ln(number)] versus age for adult male, legal-size (≥24 in) female, and all legal-size (males, females, and unknown sex) northern pike in Lake Michigamme. Lines are plots of the regression equations given.

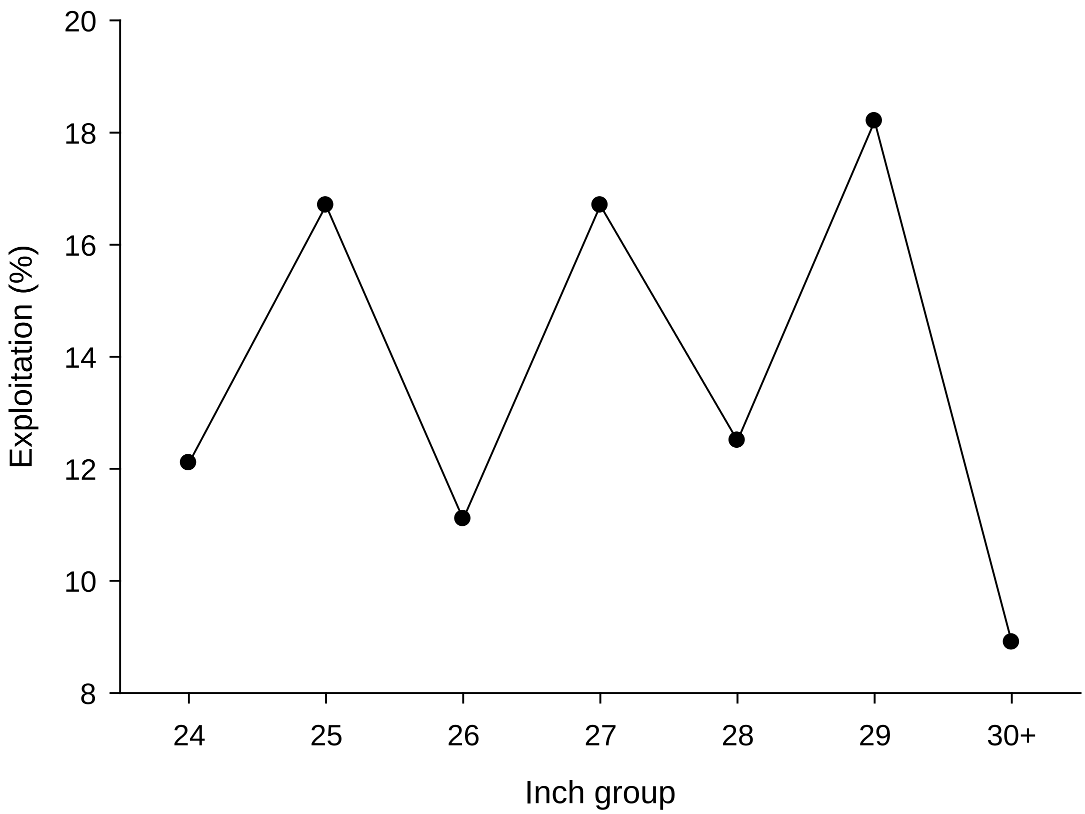

Figure 6.–Northern pike exploitation (%) by inch group. A minimum of eight northern pike were tagged in each inch group.

Table 1.–Coordinates for the flight path used for boat counts during the Lake Michigamme 2006 angler survey. See Figure 1 for general flight path and numbered locations.

Marker	Latitude	Longitude
1	46° 29.06' N	88° 04.69' W
2	46° 30.27' N	88° 03.65' W
3	46° 30.79' N	88° 02.92' W
4	46° 31.08' N	88° 01.44' W
5	46° 31.40' N	88° 00.21' W
6	46° 31.60' N	88° 00.83' W
7	46° 31.26' N	88° 02.45' W
8	46° 31.46' N	88° 03.16' W
9	46° 32.15' N	88° 03.87' W
10	46° 32.07' N	88° 04.73' W
11	46° 31.82' N	88° 05.76' W
12	46° 31.50' N	88° 07.87' W

Table 2.–Survey periods, sampling shifts, and expansion value "F" (number of fishing hours within a sample day) for the Lake Michigamme angler survey.

Survey period	Sample shift (h)		F
May	0600–1430	1300–2130	16
June	0600–1430	1330–2200	16
July	0600–1430	1330–2200	16
August	0600–1430	1300–2130	16
September	0700–1530	1230–2100	14

Table 3.–Fish collected from Lake Michigamme using a total sampling effort of 224 fyke-net lifts and 23 electrofishing runs from April 13–27, 2006.

Species	Total catch[a]	Percent by number	Mean fyke-net CPUE[a,b]	Length range (in)	Average length (in)[c]	Number measured[c]
Walleye	2,326	59.1	1.3	5.8–30.7	16.4	1,986
Northern pike	653	16.6	1.8	9.8–43.7	22.5	516
Rock bass	507	12.9	1.5	4.6–11.5	8.0	509
Yellow perch	144	3.7	1.5	2.7–12.3	7.0	144
Smallmouth bass	117	3.0	0.1	9.6–18.2	13.8	92
White sucker	100	2.5	0.3	7.4–22.4	17.7	100
Black crappie	30	0.8	<0.1	2.2–12.6	9.4	30
Burbot	28	0.7	0.1	8.3–24.7	17.3	28
Lake whitefish	10	0.3	0	11.6–16.2	14.6	10
Black bullhead	7	0.2	<0.1	5.1–9.2	6.5	7
Pumpkinseed	4	0.1	<0.1	3.2–7.6	5.2	4
Largemouth bass	3	0.1	<0.1	14.9–16.5	15.9	3
Brook trout	3	0.1	0	11.5–12.0	11.7	3
Muskellunge	2	<0.1	0	38.5–43.5	41.0	2
Tiger muskellunge	1	<0.1	0	27.7	27.7	1

[a] Includes recaptures
[b] Number per fyke-net night
[c] Does not include recaptures for walleyes, northern pike, or smallmouth bass.

Table 4.–Number of fish per inch group collected from Lake Michigamme, April 13–27, 2006.

	Species														
Inch group	Walleyes	Northern pike	Rock bass	Yellow perch	Smallmouth bass	White sucker	Black crappie	Burbot	Lake whitefish	Black bullhead	Pumpkinseed	Largemouth bass	Brook trout	Muskellunge	Tiger muskellunge
1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	2	–	–	1	–	–	–	–	–	–	–	–
3	–	–	–	20	–	–	–	–	–	–	2	–	–	–	–
4	–	–	6	12	–	–	–	–	–	–	–	–	–	–	–
5	1	–	26	19	–	–	1	–	–	3	–	–	–	–	–
6	2	–	68	15	–	–	2	–	–	2	1	–	–	–	–
7	1	–	136	21	–	1	3	–	–	1	1	–	–	–	–
8	1	–	168	21	–	–	3	2	–	–	–	–	–	–	–
9	1	1	78	16	1	–	8	–	–	1	–	–	–	–	–
10	1	1	24	9	2	1	2	1	–	–	–	–	–	–	–
11	9	4	3	5	11	4	7	1	1	–	–	–	2	–	–
12	26	2	–	4	18	3	3	1	–	–	–	–	1	–	–
13	105	4	–	–	21	4	–	–	2	–	–	–	–	–	–
14	304	7	–	–	12	4	–	2	2	–	–	1	–	–	–
15	495	17	–	–	15	8	–	1	4	–	–	–	–	–	–
16	443	16	–	–	9	6	–	3	1	–	–	2	–	–	–
17	276	30	–	–	2	16	–	3	–	–	–	–	–	–	–
18	131	40	–	–	1	17	–	2	–	–	–	–	–	–	–
19	71	41	–	–	–	12	–	6	–	–	–	–	–	–	–
20	41	55	–	–	–	10	–	1	–	–	–	–	–	–	–
21	24	59	–	–	–	9	–	1	–	–	–	–	–	–	–
22	15	38	–	–	–	5	–	3	–	–	–	–	–	–	–
23	6	40	–	–	–	–	–	–	–	–	–	–	–	–	–
24	10	34	–	–	–	–	–	1	–	–	–	–	–	–	–
25	5	25	–	–	–	–	–	–	–	–	–	–	–	–	–
26	7	19	–	–	–	–	–	–	–	–	–	–	–	–	–
27	3	18	–	–	–	–	–	–	–	–	–	–	–	–	1
28	5	8	–	–	–	–	–	–	–	–	–	–	–	–	–
29	1	11	–	–	–	–	–	–	–	–	–	–	–	–	–
30	2	11	–	–	–	–	–	–	–	–	–	–	–	–	–
31	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–
32	–	6	–	–	–	–	–	–	–	–	–	–	–	–	–
33	–	6	–	–	–	–	–	–	–	–	–	–	–	–	–
34	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–
35	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–
36	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–
37	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–
38	–	2	–	–	–	–	–	–	–	–	–	–	–	1	–
39	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–
40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
41	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
42	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–
43	–	1	–	–	–	–	–	–	–	–	–	–	–	1	–
44	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total	1,986	516	509	144	92	100	30	28	10	7	4	3	3	2	1

Table 5.–Catch-at-age estimates (apportioned by age-length key) by sex for walleyes and northern pike from Lake Michigamme, April 13–27, 2006.

	Year	Walleyes			Northern pike		
Age	class	Males	Females	All fish[a]	Males	Females	All fish[a]
1	2005	–	–	–	3	–	15
2	2004	–	–	18	26	7	47
3	2003	7	–	21	92	28	144
4	2002	45	5	151	107	29	149
5	2001	313	14	425	53	34	100
6	2000	184	6	184	23	16	44
7	1999	390	34	409	6	9	15
8	1998	336	39	397	1	6	6
9	1997	212	35	207	2	4	6
10	1996	81	11	55	1	1	3
11	1995	84	18	67	3	–	2
12	1994	27	11	36	–	–	–
13	1993	5	7	13	–	–	–
14	1992	7	9	16	–	–	–
15	1991	4	3	7	–	–	–
16	1990	5	5	10	–	–	–
17	1989	1	1	2	–	–	–
18	1988	–	1	1	–	–	–
19	1987	–	–	–	–	–	–
20	1986	–	–	–	–	–	–
Total		1,701	199	2,019	317	134	531

[a] Represents all fish captured, including male, female, and those of unknown sex.

Table 6.–Estimates of abundance, angler exploitation rates, and instantaneous fishing mortality rates for Lake Michigamme walleyes and northern pike using methods described in text. Asymmetrical 95% confidence intervals (prediction intervals for model estimates) for estimates are given in parentheses, where applicable.

Parameter	Walleyes	Northern pike
Number of legal-size[a] fish		
Multiple-census estimate	4,615	272
	(3,774–5,938)	(192–466)
Single-census estimate	8,241	858
	(6,046–11,523)	(261–1,674)
Michigan model prediction[b]	6,216	–
	(1,339–28,864)	
Number of adult[c] fish		
Multiple-census method	5,965	671
	(4,988–7,418)	(500–1,019)
Single-census estimate	10,392	2,448
	(7,483–13,301)	(745–4,776)
Michigan model prediction[d]	9,148	–
	(1,731–48,335)	
Wisconsin model prediction[e]	13,761	–
	(4,504–42,042)	
Annual exploitation rates		
Based on reward tag returns	20.0%	15.2%
Based on harvest/abundance[f]	45.2%	41.0%
	(29.3%–31.1%)	(7.7%–74.3%)
Based on harvest/abundance[g]	25.3%	13.0%
	(15.9%–34.8%)	(0%–29.5%)
Total annual mortality rates	41%	48%

[a] Walleyes ≥ 15 in, and northern pike ≥ 24 in.
[b] Michigan model prediction of legal-size walleye abundance based on lake area, N = 32.
[c] Fish of legal-size and sexually mature fish of sublegal size on spawning grounds.
[d] Michigan model prediction of adult walleye abundance based on lake area, N = 31
[e] Wisconsin model prediction of adult walleye abundance based on lake area, N = 185.
[f] Multiple-census estimate of legal-size walleye abundance.
[g] Single-census estimate of legal-size walleye abundance.

Table 7.–Weighted mean total lengths (in) and sample sizes by age for walleyes collected from Lake Michigamme, April 13–27, 2006. Standard deviation is in parentheses.

Age	Mean length			Number aged		
	Males	Females	All fish[a]	Males	Females	All fish[a]
2	–	–	7.9 (1.0)	–	–	5
3	13.0 (–)	–	11.5 (1.2)	1	–	10
4	13.3 (0.5)	15.0 (0.9)	14.3 (1.2)	14	6	32
5	15.0 (0.9)	15.9 (1.2)	15.2 (1.0)	19	12	36
6	15.6 (1.1)	17.5 (1.2)	15.7 (1.1)	8	4	13
7	16.1 (1.1)	18.3 (1.4)	16.5 (1.4)	15	21	38
8	15.9 (1.2)	18.3 (1.8)	16.3 (1.5)	16	24	40
9	16.9 (1.2)	20.4 (2.3)	17.6 (2.0)	14	25	39
10	17.3 (1.1)	21.7 (1.8)	18.4 (2.2)	6	9	15
11	16.9 (1.0)	22.2 (2.7)	18.6 (2.8)	6	14	20
12	19.3 (0.6)	21.8 (3.2)	20.1 (2.2)	8	8	16
13	20.2 (0.5)	25.1 (3.1)	22.9 (3.3)	4	6	10
14	20.1 (0.4)	25.3 (3.1)	23.7 (3.9)	3	8	11
15	20.5 (0.0)	22.8 (2.2)	21.4 (1.8)	3	3	6
16	21.8 (0.8)	25.8 (3.4)	23.6 (3.3)	3	4	7
17	21.4 (–)	28.8 (–)	25.1 (5.2)	1	1	2
18	–	24.5 (–)	24.5 (–)	–	1	1

[a] Mean length for ‘All fish’ includes males, females, and fish of unknown sex.

Table 8.–Weighted mean total lengths (in) and sample sizes by age for northern pike collected from Lake Michigamme, April 13–27, 2006. Standard deviation is in parentheses.

Age	Mean length			Number aged		
	Males	Females	All fish[a]	Males	Females	All fish[a]
1	13.3 (1.3)	–	12.2 (1.6)	4	–	12
2	17.0 (1.8)	18.6 (2.5)	16.9 (2.2)	19	8	35
3	19.2 (1.8)	20.5 (1.8)	19.6 (2.0)	45	23	84
4	21.8 (2.6)	24.2 (4.2)	22.5 (3.3)	51	28	92
5	23.5 (2.3)	26.7 (4.4)	24.8 (3.6)	29	28	69
6	25.6 (4.2)	28.5 (4.5)	26.9 (4.3)	13	14	33
7	27.7 (1.6)	32.2 (4.7)	31.4 (4.6)	4	8	14
8	26.3 (–)	38.0 (4.3)	35.3 (5.7)	1	5	6
9	30.1 (0.8)	37.3 (6.2)	34.9 (6.1)	2	4	6
10	29.1 (–)	39.6 (–)	37.0 (6.9)	1	1	3
11	33.8 (0.5)	–	34.0 (0.6)	2	–	2

[a] Mean length for ‘All fish’ includes males, females, and fish of unknown sex.

Table 9.–Weighted mean total lengths (in) and sample sizes by age for smallmouth bass collected from Lake Michigamme, April 13–27, 2006. Standard deviation is in parentheses.

Age	Mean length	Number aged
3	9.6 (–)	1
4	12.0 (0.9)	24
5	11.7 (1.5)	13
6	14.4 (1.3)	14
7	14.0 (1.9)	20
8	14.5 (1.4)	8
9	17.4 (1.2)	2
10	–	0
11	17.2 (–)	1

[a] Mean length for 'All fish' includes males, females, and fish of unknown sex.

Table 10.–Mean total lengths (in) of walleyes (males and females combined) captured during the 2006 survey of Lake Michigamme compared to previous collections. Number of walleyes aged in parentheses.

Age	State average[a]	Year				
		2006[b]	2002/2004[c]	1986/1988[d]	1982/1983[e]	1972/1976[e]
2	10.4	7.9 (5)	9.6 (8)	11 (17)	12 (7)	11.7 (5)
3	13.9	11.5 (10)	11.7 (7)	14 (25)	14 (18)	13.3 (36)
4	15.8	14.3 (32)	13.1 (3)	15.5 (23)	16.7 (4)	15.4 (7)
5	17.6	15.2 (36)	12.7 (5)	17.2 (20)	16.8 (2)	17.8 (8)
6	19.2	15.7 (13)	15.1 (2)	19.4 (17)		17.1 (5)
7	20.6	16.5 (38)	14.5 (1)	20 (4)	20.2 (3)	20.1 (3)
8	21.6	16.3 (40)	16.7 (1)	21.5 (2)		
9	22.4	17.6 (39)		24.1 (1)		
10	23.1	18.4 (15)	19.3 (2)	31.8 (1)		24.2 (1)
11		18.6 (20)				
12		20.1 (16)	18.4 (1)		30.4 (1)	
13		22.9 (10)				
14		23.7 (11)				
15		21.4 (6)				
16		23.6 (7)	22.3 (1)			
17		25.1 (2)				
18		24.5 (1)				
Mean growth index[f]		-3.5	-2.6	0	+0.9	-0.3

[a] Jan–May averages from Schneider et al. (2000), aged using scales.
[b] Fish collected in the spring and aged using spines.
[c] Fish collected in the fall, ageing structures unknown.
[d] Fish collected in the summer and aged using scales.
[e] Fish collected in the summer and fall, ageing structures unknown.
[f] The mean deviation from the Statewide quarterly average. Only age groups with $N \geq 5$ were used.

Table 11.–Mean total lengths (in) of northern pike (males and females combined) from the 2006 survey of Lake Michigamme compared to surveys on nearby lakes. Number of northern pike aged in parentheses.

Age	State average[a]	Lake Michigamme 2006[b]		Lake Michigamme 2002[c]		Lake Gogebic 2005[b]		Peavy Pond 2004[b]		Bond Falls Flowage 2003[b]		Michigamme Reservoir 2001[b]	
1	11.7	12.2	(12)			9.7	(14)	10.2	(75)	12.2	(11)		
2	17.7	16.9	(35)	17.1	(8)	14.7	(14)	15.3	(132)	17.4	(52)	16.0	(94)
3	20.8	19.6	(84)	19.4	(17)	19.6	(144)	18.4	(92)	20.1	(73)	18.8	(118)
4	23.4	22.5	(92)	23.6	(6)	21.7	(114)	19.9	(65)	22.3	(79)	20.6	(64)
5	25.5	24.8	(69)	22.8	(5)	25.4	(98)	22.0	(60)	22.8	(20)	21.3	(51)
6	27.3	26.9	(33)	28.5	(10)	24.3	(12)	25.0	(41)	23.7	(3)	25.3	(35)
7	29.3	31.4	(14)	34.8	(8)	24.8	(4)	27.0	(15)	27.3	(5)	25.6	(21)
8	31.2	35.3	(6)	31.5	(1)	32.6	(6)	34.1	(8)	33.6	(6)	27.5	(3)
9		34.9	(6)	32.1	(1)	37.2	(4)	32.7	(4)	37.3	(3)	36.3	(4)
10		37.0	(3)			40.9	(3)	34.9	(4)	35.1	(1)		
11		34.0	(2)			39.1	(1)					34.0	(1)
Mean growth index[d]		+0.3		+0.4		-1.4		-1.9		-0.6		-2.7	

[a] Jan–May averages from Schneider et al. (2000), aged using scales.
[b] Fish collected in the spring and aged using fin rays.
[c] Fish collected in the summer and aged using fin rays.
[d]The mean deviation from the Statewide quarterly average. Only age groups with N ≥ 5 were used.

Table 12.–Angler survey estimates for Lake Michigamme. Survey period was May 15 through September 30, 2006. Catch per hour (C/H) is harvest and release rate, respectively (fish per hour). Two standard errors are given in parentheses.

Species	C/H	May	Jun	Jul	Aug	Sep	Season
		Month					
		Number harvested					
Walleye	0.0880	170	436	925	645	162	2,338
	(0.0243)	(133)	(217)	(389)	(297)	(98)	(560)
Northern pike	0.0054	0	13	58	69	5	145
	(0.0037)	(0)	(17)	(63)	(69)	(9)	(96)
Smallmouth bass	0.0033	0	0	43	45	0	88
	(0.0030)	(0)	(0)	(45)	(65)	(0)	(79)
Yellow Perch	0.0157	0	7	80	259	73	418
	(0.0083)	(0)	(13)	(83)	(176)	(87)	(213)
Rock bass	0.0496	68	226	406	559	59	1,318
	(0.0214)	(135)	(225)	(337)	(318)	(75)	(538)
Total harvested	0.1621	238	682	1,512	1,577	299	4,307
	(0.0378)	(190)	(313)	(528)	(479)	(151)	(815)
		Number released					
Walleye	0.1161	265	254	922	1,262	383	3,086
	(0.0332)	(185)	(154)	(375)	(587)	(236)	(774)
Northern pike	0.0421	18	512	169	361	57	1,118
	(0.0174)	(30)	(324)	(118)	(260)	(60)	(437)
Largemouth bass	0.0008	0	21	0	0	0	21
	(0.0016)	(0)	(43)	(0)	(0)	(0)	(43)
Smallmouth bass	0.1624	66	686	1,266	1,542	755	4,315
	(–)	(74)	(334)	(581)	(724)	(–)	(–)
Yellow Perch	0.0247	7	78	96	428	46	656
	(0.0137)	(15)	(69)	(92)	(321)	(93)	(354)
Rock bass	0.1812	0	1,334	1,846	905	729	4,815
	(0.0528)	(0)	(692)	(757)	(409)	(560)	(1,238)
Total released	0.5272	356	2,885	4,299	4,498	1,970	14,011
	(–)	(202)	(852)	(1,036)	(1,099)	(–)	(–)
Total (harvested + released)	0.6893	594	3,567	5,811	6,075	2,269	18,318
	(–)	(277)	(908)	(1,163)	(1,199)	(–)	(–)
Angler hours		2,852	6,321	6,687	7,220	3,495	26,574
		(910)	(1,596)	(1,953)	(2,092)	(1,278)	(3,633)
Angler trips		867	2,224	2,208	2,319	1,101	8,719
		(441)	(1,285)	(1,071)	(1,022)	(–)	(–)

Table 13.–Angler tag returns (reward and nonreward, harvested and released combined) from walleyes and northern pike by month for the year following tagging in Lake Michigamme. Tags observed by creel clerk, but not reported by angler are also included. Percentage of total is in parentheses.

Month	Species	
	Walleyes	Northern pike
4	0 (0)	0 (0)
5	63 (23.3)	8 (32.0)
6	54 (20.0)	9 (36.0)
7	52 (19.3)	3 (12.0)
8	71 (26.3)	3 (12.0)
9	26 (9.6)	2 (8.0)
10	0 (0)	0 (0)
11	0 (0)	0 (0)
12	0 (0)	0 (0)
1	4 (1.5)	0 (0)
2	0 (0)	0 (0)
3	0 (0)	0 (0)
Total	270	25

Table 14.–Number and life stage of fish stocked in Lake Michigamme 1936 through 2006.

Year (s)	Species	Number[a]	Life stage
1936	Yellow perch	9,000	Unknown
1936	Walleye	450,000	Fry
1937	Walleye	2,250,000	Fry
1938	Walleye	1,980,000	Fry
1938	Lake trout	2,500	Adult
1939	Walleye	1,050,000	Fry
1939	Smelt	6,000	Adult
1939	Yellow perch	6,000	Unknown
1940	Walleye	960,000	Fry
1941	Lake trout	4,550	Adult
1942	Smelt	4,000	Adult
1942	Lake trout	10,400	Adult
1943	Lake trout	4,200	Adult
1963	Lake trout	100,000	Fingerlings
1973	Splake	15,000	Yearling
1978	Tiger muskellunge	Unknown	Fingerling
1979	Tiger muskellunge	4,350	Fingerling
1983	Walleye	18,423	Fry
1983	Yellow perch	10,998	Adult
1984	Yellow perch	32,243	Adult
1984	Walleye	53,671	Fry
1984	Smallmouth bass	1,516	Fingerling
1985	Smallmouth bass	1,931	Yearling
1986	Walleye	52,706	Fingerling
1988	Walleye	22,715	Fingerling
1989	Smallmouth bass	52,146	Fry
1990	Walleye	40,055	Fingerling
1992	Walleye	28,128	Fingerling
1992	Smallmouth bass	10,487	Fingerling
1994	Walleye	1,950,000	Fry
1994	Walleye	204,240	Fingerling
1997	Smallmouth bass	40,610	Fry
1998	Walleye	2,000,000	Fry
1998	Smallmouth bass	33,530	Fry
2000	Brook trout	43,942	Fingerling
2000	Splake	13,662	Fingerling
2000	Lake trout	18,391	Fingerling
2001	Brook trout	150	Adult
2001	Lake trout	31,916	Yearling
2002	Splake	32,333	Fingerling
2002	Walleye	85,845	Fingerling
2002	Rainbow trout	56,490	Fingerling
2002	Lake trout	269	Adult
2003	Lake trout	38,662	Yearling
2003	Splake	15,000	Yearling
2003	Lake trout	900	Adult

Table 14.–Continued.

Year (s)	Species	Number[a]	Life stage
2003	Brook trout	200	Adult
2004	Lake trout	185,541	Fingerling
2004	Lake trout	59,669	Yearling
2004	Brook trout	17,843	Fingerling
2005	Brook trout	19,664	Yearling
2005	Splake	26,313	Yearling
2005	Splake	39,288	Fingerling
2005	Lake trout	22,795	Yearling

[a] Approximate number stocked for early years because discrepancies exist in records.

Table 15.–Comparison of recreational fishing effort and total harvest on Lake Michigamme to estimates from other selected Michigan lakes. Lakes are listed from highest to lowest total fishing effort.

Lake	County	Size (acres)	Survey period	Fishing effort (hours)	Fish harvested (number)	Fish harvested per hour	Hours fished per acre	Fish harvested per acre
Houghton	Roscommon	20,075	Apr 2001–Mar 2002	499,048	386,287	0.77	24.9	19.2
Cisco Chain	Gogebic, Vilas	3,987	May 2002–Feb 2003	180,262	120,412	0.67	45.2	30.2
Muskegon	Muskegon	4,232	Apr 2002–Mar 2003	180,064	184,161	1.02	42.5	43.5
Burt	Cheboygan	17,395	Apr 2001–Mar 2002	134,205	68,473	0.51	7.7	3.9
South Manistique	Mackinac	4,133	May 2003–Mar 2004	142,686	43,654	0.31	34.5	10.6
Lake Leelanau	Leelanau	8,607	Apr 2002–Mar 2003	112,112	15,464	0.14	13.0	1.8
Lake Gogebic	Gogebic, Ontonagon	13,127	May 2005–Mar 2006	101,372	15,689	0.15	7.7	1.2
Big Manistique	Luce, Mackinac	10,346	May 2003–Mar 2004	88,373	71,652	0.81	8.5	6.9
Black Lake	Cheboygan, Presque Isle	10,113	Apr 2005 Mar 2006	59,874	18,762	0.31	5.9	1.9
Charlevoix	Charlevoix	17,268	Apr 2006 Mar 2007	57,126	19,671	0.34	3.3	1.1
Crooked and Pickerel	Emmet	3,434	Apr 2001–Mar 2002	55,894	13,665	0.24	16.3	4.0
Michigamme Reservoir	Iron	6,400	May 2001–Feb 2002	52,686	10,899	0.21	8.2	1.7
Long	Presque Isle, Alpena	5,342	Apr 2004–Mar 2005	34,894	7,004	0.20	6.5	1.3
Grand	Presque Isle	5,822	Apr 2004–Mar 2005	33,037	10,623	0.32	5.7	1.8
Lake Michigamme	Baraga, Marquette	4,292	May–Sep 2006	26,574	4,307	0.16	6.2	1.0
Peavy Pond	Iron	2,794	May 2004–Feb 2005	26,447	6,299	0.24	9.5	2.3
Bond Falls Flowage	Ontonagon	2,127	May–Oct 2003	21,182	3,193	0.15	10.0	1.5
North Manistique	Luce	1,709	May 2003–Mar 2004	10,614	7,603	0.72	6.2	4.4
Average				100,914	55,990	0.40	14.6	7.7
Median				58,500	15,577	0.31	8.4	2.1

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Edward A. Baker, Reviewer
Darren Kramer, Reviewer
Robert C. Haas, Editor
Alan D. Sutton, Graphics
Ellen S. Grove, Desktop Publisher

Approved by Tammy J. Newcomb

Appendix.–Fish species collected in Lake Michigamme 1938 through 2006.

Common name	Scientific name
Species collected in spring 2006 with fyke nets and electrofishing	
Black bullhead	*Ameiurus melas*
Black crappie	*Pomoxis nigromaculatus*
Brook trout	*Salvelinus fontinalis*
Burbot	*Lota lota*
Lake whitefish	*Coregonus clupeaformis*
Largemouth bass	*Micropterus salmoides*
Muskellunge	*Esox masquinongy*
Northern pike	*Esox lucius*
Pumpkinseed	*Lepomis gibbosus*
Rock bass	*Ambloplites rupestris*
Smallmouth bass	*Micropterus dolomieu*
Tiger Muskellunge	*E. masquinongy x E. lucius*
Walleye	*Sander vitreus*
White sucker	*Catostomus commersoni*
Yellow perch	*Perca flavescens*
Additional species collected in previous surveys	
Bluegill	*Lepomis macrochirus*
Bluntnose minnow	*Pimephales notatus*
Cisco	*Coregonus artedi*
Common shiner	*Luxilus cornutus*
Golden shiner	*Notemigonus crysoleucas*
Iowa darter	*Etheostoma exile*
Longnose sucker	*Catostomus catostomus*
Mottled sculpin	*Cottus bairdi*
Rainbow smelt	*Osmerus mordax*
Red-belly dace	*Phoxinus eos*