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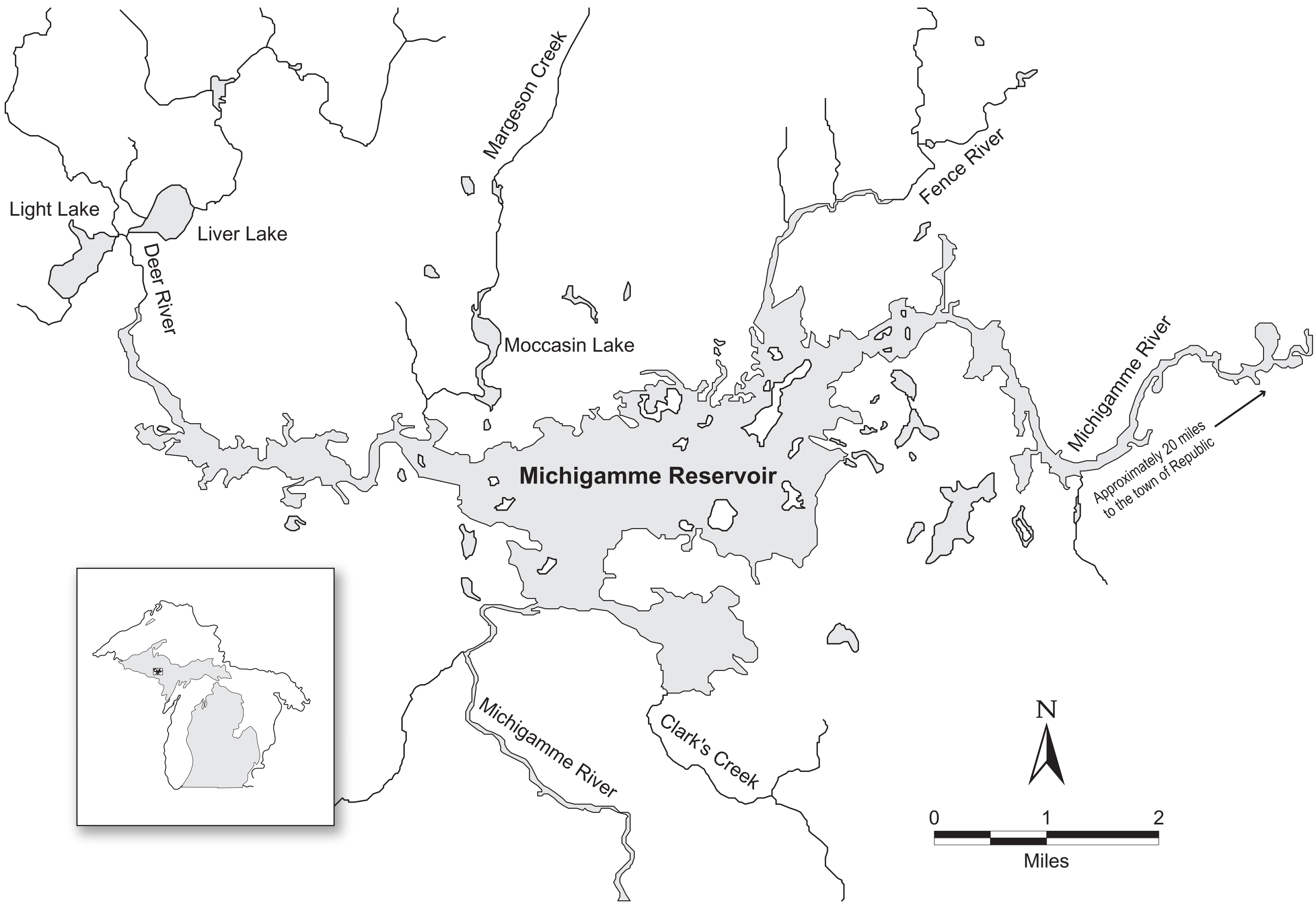

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The Fish Community and Fishery of Michigamme Reservoir, Iron County, Michigan with Emphasis on Walleyes and Northern Pike

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Introduction

Michigan Department of Natural Resources (MDNR), Fisheries Division surveyed fish populations and angler catch and effort at Michigamme Reservoir, Iron County, Michigan from April 2001 through February 2002. This work was part of a new, statewide program designed to improve assessment and monitoring of fish communities and fisheries in Michigan's largest inland lakes. Known as the Large Lakes Program, it is currently scheduled to survey about four lakes per year over the next ten years (Clark et al. 2004).

The Large Lakes Program has three primary objectives. First, we want to produce consistent indices of abundance and estimates of annual harvest and fishing effort for important fishes. Initially, important fishes are defined as species susceptible to trap or fyke nets and/or those readily harvested by anglers. Our hope is to produce statistics for important fishes to help detect major changes in their populations over time. Second, we want to produce abundance estimates and sufficient growth and mortality statistics to be able to evaluate effects of fishing on special-interest species which support valuable fisheries. This usually involves targeting special-interest species with nets or other gears to collect, sample, and mark sufficient numbers. We selected walleye *Sander vitreus* and northern pike *Esox lucius* as special-interest species in this survey of Michigamme Reservoir. Finally, we want to evaluate the suitability of various statistical estimators for use in large lakes. For example, we applied and compared three types of abundance and two types of exploitation rate estimators for walleyes and northern pike in this survey of Michigamme Reservoir.

The Large Lakes Program will maintain consistent sampling methods over lakes and time. This will allow us to build a body of fish population and harvest statistics to directly evaluate differences between lakes or changes within a lake over time. Because Michigamme Reservoir was one of the first lakes to be sampled under the protocols of the program, we were sometimes limited in our ability to make valid comparisons in this report. For example, most types of quantitative comparisons between catch per effort in our netting operations and those of most other surveys would not be valid. Our netting targeted walleyes, northern pike, and other spring spawners during spawning. Most past netting surveys occurred later in the year. Of course, as our program progresses we will eventually have a large body of netting data collected under the same conditions in the future. The first report in this series was on Houghton Lake (Clark et al. 2004), and was written as a model for future reports in the program.

Study Area

Michigamme Reservoir is located in Iron County, Michigan. It was created in 1941 when Wisconsin-Michigan Light and Power Company (Wisconsin Electric Power Company) built Way Dam. The reservoir watershed is 645 square miles. The reservoir was created to store spring runoff, to supplement low flows, and for power generation. Reports of the reservoir surface area vary from source to source. Hazzard (1943) reported 8,000 acres, Humphries and Green (1962) estimated 5,220 acres, Laarman (1976) reported 7,000 acres, Michigan Digital Water Atlas[1] (2003) reported 4,892 acres, and Wisconsin Electric Power Company (1999) reported 6,400 acres at full pool. Wisconsin Electric funded a study to examine storage as it related to probable maximum flood that involved determining the surface area of Michigamme Reservoir with remote sensing and photogrammetry (Joe Kick, Wisconsin Electric Power Company, personal communication). Their methods provided contours accurate to 2 ft, which likely resulted in the most accurate estimate of total surface area. In our Large Lakes Program, we want to compare various measures of productivity among lakes, such as number of fish per acre or harvest per acre, so a measure of lake size is fairly important. Therefore, in our analyses we will use the Wisconsin Electric Power Company estimate of 6,400 acres as the size of Michigamme Reservoir.

The Reservoir is fed by the Deer, Fence, and Michigamme rivers, and Margeson and Clark's

[1]A statewide program conducted by MDNR, Fisheries Division, Lansing to develop computerized maps and reference data for aquatic systems in Michigan.

creeks (Figure 1). Michigamme Reservoir is connected to several small lakes via its tributary systems.

The water level of Michigamme Reservoir is controlled by operation of Way Dam and is highly variable. Typically, the water level has been managed on an annual cycle with maximum pool at 6,400 acres in summer and minimum pool at 1,100 acres in winter; though a new dam-relicensing agreement (January 1, 2002) reduced the winter drawdown, so that minimum pool is around 3,700 acres. At maximum pool, average depth is 16 ft and maximum depth is 70 ft, occurring in the area of a natural lake (Deerskin Lake) that was inundated by the reservoir. Estimated normal total volume is 100,600 acre-feet (Wisconsin Electric 1999). Normal operating head on the dam is approximately 39 ft. Winter drawdown has typically been 25 ft (14 ft head), though the recent environmental assessment (Wisconsin Electric 1999) suggested a drawdown reduction to 15 ft (24 ft head). The 25 ft drawdown reduces volume by 90%, while the proposed drawdown would only reduce volume by 70%. The surface area and volume of the reservoir are depicted with varying elevations in Figures 2 and 3, respectively.

The reservoir has approximately 125 miles of undeveloped shoreline including islands. Habitat is diverse, including many shallow bays, wetlands, sandy shores, and large areas of open water. The shoreline development index, a comparative index relating the shoreline length to the circumference of a circle with the same area of the lake, is 6.6 (Laarman 1976). Substrates vary from sandy littoral areas to mucky deep zones. Cobble, rock, and tree stumps are common in shore areas. There are limited amounts of aquatic macrophytes in the reservoir likely limited by the winter drawdown (Wisconsin Electric 1999). The reservoir thermally stratifies in the summer, usually beginning in May and continuing through September. Laarman (1976) reported some water chemistry results from a 1959 survey. August bottom and surface temperatures were 69° and 75°F, respectively. Dissolved oxygen concentration ranged from 3.1 ppm at the bottom to 6.9 ppm at the surface. Surface alkalinity was 52 ppm, and pH was 7.2. Wisconsin Electric (1999) reported some water quality monitoring results and found that dissolved oxygen concentrations at times fell below 5 mg/L in the deeper areas. The Michigan Department of Environmental Quality (DEQ) calculated average alkalinity at 42 mg/L from surveys through 2002. Additional water quality information was reported by Wisconsin Electric (1999), and more recent data are available in files of MDNR and Michigan Department of Environmental Quality.

The fish community of Michigamme Reservoir includes species typical of this northern, forested region. We listed common and scientific names of all fish species captured during this and previous studies of Michigamme Reservoir in the Appendix. Henceforth, we will use only common names in the text. Families of fish include, but are not limited to, *Esocidae, Cyprinidae, Catostomidae, Centrarchidae, Percidae, Gadidae, and Salmonidae (including sub-family Coregoninae)*. Few stockings have taken place over the years, but attempts were made to augment prey fish populations by transferring small bluegills and yellow perch in 1980s (Table 1). Additionally, there have been occasional removals of undesirable fish (white sucker and longnose sucker.

Fisheries managers have long suspected water level fluctuations in Michigamme Reservoir have adversely affected fish populations. Fisheries managers do not think walleye and northern pike populations in Michigamme Reservoir are producing to their potentials. Populations are generally characterized as having average recruitment, slow growth, and a size structure dominated by smaller fish. Indices of age-0 walleye abundance in the fall are often high, but managers have argued that poor carryover to age-1 results in below average to average recruitment. Inadequate forage has been suggested as a cause of both the poor growth of predators and poor survival of juvenile walleyes from age 0 to age 1. Cannibalism has also been suggested as a possible factor influencing walleye year-class strength.

State of Michigan Master Angler entries from Michigamme Reservoir (1990-2003) have included 1 white sucker, 2 black crappies, 1 yellow perch, 6 northern pike, 4 bluegills, and 1 rock bass.

Methods

We used the same methods on Michigamme Reservoir as described by Clark et al. (2004) for Houghton Lake. We will give an overview of methods in this report, but will refer the reader to Clark et al. (2004) for details.

Briefly, we used nets and electrofishing gear to collect fish in April-May to coincide with spawning of primary targets – walleyes and northern pike. All fish captured were identified to species and counted. Fishing effort was recorded by individual net, but not for electrofishing. Electrofishing was only used to increase the sample size of walleyes and northern pike tagged. Standard total lengths were measured for subsamples of each non-target species. All walleyes and northern pike were measured and legal-sized fish were tagged with individually numbered jaw tags. Tagged fish were also fin clipped to evaluate tag loss. Angler catch and harvest surveys were conducted the year after tagging; one covered the summer fishery from May 15 through October 14, 2001 and one covered the winter fishery from December 29 through February 28, 2002. Tags on walleyes and northern pike observed during angler surveys were tallied and the ratios of marked to unmarked fish were used to calculate abundance estimates for walleyes and northern pike. In addition, voluntary tag recoveries were requested. All tags contained a unique number and a mailing address for an MDNR field station. To encourage voluntary tag returns, about 50% of tags were identified as reward tags, and we paid $10 rewards to anglers returning them.

Fish Community

We described the status of the overall fish community in terms of species present, catches per unit effort, percents by number, and length frequencies. We also collected more detailed data for walleyes and northern pike as described below. We sampled fish populations in Michigamme Reservoir with fyke nets and electrofishing gear from April 19 to May 4, 2001. We did not use trap nets as described in Clark et al. (2004). We used two boats daily to work nets, each with three-person crews, for 2 weeks. Each net-boat crew tended 10-15 nets. Another electrofishing boat collected walleyes and northern pike during the day.

Fyke nets were 6 ft long x 4 ft in diameter with ¾-in stretch mesh (some with ½-in mesh) and 75-ft leads. Duration of net sets ranged from 1-4 nights, but most were 1 night. We used a Smith-Root® boat equipped with boom-mounted electrodes (DC) for electrofishing. Latitude and longitude were recorded for all net locations and electrofishing runs using GPS.

We identified species and counted all fish captured. Total lengths of all walleyes and northern pike were measured to the nearest 0.1 in. For other fish, we measured lengths to the nearest 0.1 in for sub-samples of up to 200 fish per work crew. Crews ensured that lengths were taken over the course of the survey to account for any temporal trends in the size structure of fish collected. Size structure was characterized for purposes of comparison using percent over legal size.

We used Microsoft Access© to store and retrieve data collected during the tagging operation. Size-structure data only included fish on their initial capture occasion. We recorded mean catch per unit effort (CPUE) in fyke nets 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).

Walleyes and Northern pike

<u>*Sex Composition*</u>

We recorded sex of walleyes and northern pike. Fish with flowing gametes were categorized as male or female, respectively. Fish with no flowing gametes were categorized as unknown sex.

<u>*Abundance*</u>

We estimated abundance of legal-sized walleyes and northern pike using mark-and-recapture methods. Walleyes (≥ 15 in) and northern pike (≥ 24 in) were fitted with monel-metal jaw tags. In order to assess tag loss, we double-marked each tagged fish by clipping the left pelvic fin. We attempted to maintain approximately a 1:1 ratio of $10-reward:non-reward tags on fish tagged, but did not attempt to make the ratio exact. We did not think that an exact ratio was important, and maintaining an exact ratio would have been more difficult, given the multiple crews working simultaneously and numbers of fish we tagged. 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 concern for netting-induced tag loss. All fish that lost tags during netting recapture were re-tagged, and so were accounted for in the total number of marked fish at large.

We compared two different abundance estimates 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 (± 95% asymmetrical confidence limits) from daily recaptures during the tagging operation (Ricker 1975). The minimum number of recaptures necessary for an unbiased estimate was set a priori at four. For the single-census estimate, we used numbers of marked and unmarked fish seen by creel clerks in the companion angler survey as the "recapture-run" sample. The Chapman modification of the Petersen method (Ricker 1975) was used to generate population estimates (± 95% asymmetrical confidence limits). For more details on methods for abundance estimates, see Clark et al. (2004).

MDNR has made three prior multiple-census estimates of adult walleye abundance in Michigamme Reservoir, for which adult walleyes were defined as legal sized, or sub-legal sized of identifiable sex. They ranged from 9,100 to 13,300, with an average of 11,200 (William Ziegler, MDNR, personal communication). Additionally, we used a regression equation developed for Wisconsin lakes (Hansen 1989) to provide another a priori estimate of walleye abundance. This regression predicts adult walleye abundance based on lake size. Parameters for this equation are re-calculated every year by Wisconsin Department of Natural Resources (WDNR). We used the same parameters used by WDNR in 2001 (Doug Beard, WDNR, personal communication):

$$\ln(N) = 1.6106 + 0.9472 \times \ln(A),$$

where N is the estimated number of walleyes and A is the surface area of the lake in acres. This equation was derived from abundance estimates on 179 lakes in northern Wisconsin. For Michigamme Reservoir, the equation gives an estimate of 20,174 walleyes, with a 95% confidence interval of 6,628 to 61,402. The 'confidence interval' here is, more precisely, a prediction interval with 95% confidence (Zar 1999).

We determined our tagging goal by evaluating the effect of increasing the proportion tagged on the precision of the estimate (Clark et al. 2004). Based on this analysis, it was our judgment that marking 10% of the population achieved a good compromise between marking effort and precision, assuming the fraction marked was a function of marking effort (Figure 4). Thus, we set our tagging goal at 10% of the population or approximately 1,500 walleyes. This goal also corresponds with previous abundance estimates. Because those estimates were made for adult walleyes, the goal was optimistic for walleyes of legal size. We set no specific tagging goal for northern pike. We simply tagged as many northern pike as possible until the walleye goal was achieved.

It is important to recognize the difference between walleye abundance estimates from the Wisconsin regression equation and walleye abundance estimates we made. The Wisconsin equation predicts abundance of adult walleyes on the spawning grounds, while our primary, single-census estimate was only for walleyes ≥ 15 in. WDNR defined adult walleyes as legal sized, or sub-legal sized of identifiable sex, many of which would be smaller than 15 in. Because we clipped fins and recorded recaptures of all walleyes, we were also able to make a direct multiple-census estimate of adult walleyes for comparison using the Schumacher-Eschmeyer formula and including the sub-legal and mature fish that were marked and recaptured.

We estimated numbers of adult walleyes from our single-census estimate by dividing our estimate of walleyes ≥ 15 by the proportion of adult walleyes on the spawning grounds that were ≥ 15 in, using the equation in Clark et al. (2004).

Similar to walleyes, we defined adult northern pike as those ≥ 24 in or <24 in, but of identifiable sex. We estimated adult northern pike using the multiple-census and adjusted single-census methods as was done for walleyes.

We accounted for fish that recruited to legal size over the course of the angler survey by removing a portion of the unmarked fish observed by the creel clerk. The number of unmarked fish removed was based on a weighted average monthly growth for fish of slightly sub-legal size (i.e., 14.0 - 14.9-in walleyes). For a detailed explanation of our methods to adjust for in-season recruitment, see Clark et al. (2004) and Ricker (1975). This adjusted ratio was used to make the primary (single census) population estimate.

Mean Lengths at Age

We used dorsal spines to age walleyes and dorsal fin rays to age northern pike. We used these structures because we thought they provided the best combination of ease of collection in the field and accuracy and precision of age estimates. Clark et al. (2004) described advantages and disadvantages of various body structures for aging walleyes and northern pike.

Sample sizes for age analysis were based on historical Michigamme Reservoir length at age data and methods given in Lockwood and Hayes (2000). Our goal was to collect 50 male and 50 female walleyes per inch group and 30 male and 30 female northern pike per inch group.

Samples were sectioned using a table-mounted Dremel® rotary cutting tool. Sections approximately 0.5-mm thick were cut as close to the proximal end of the spine or ray as possible. Sections were examined at 40x-80x with transmitted light and were photographed with a digital camera. The digital image was archived for multiple reads. We aged approximately 15 fish per sex per inch group. Two technicians independently aged walleyes. Ages were considered correct when results of both technicians agreed. Samples in dispute were aged by a third technician. Disputed ages were considered correct when the third technician agreed with one of the first two. Samples were discarded if three technicians disagreed on age.

After a final age was identified for all samples, weighted mean lengths at age and age-length keys were computed for males, females, and all fish (males, females, and fish of unknown sex) for both walleyes and northern pike (Devries and Frie 1996).

We compared our mean lengths at age to those from previous surveys of Michigamme Reservoir and other large lakes. Also, we computed a mean growth index to compare our data to Michigan state averages as described by Schneider et al. (2000). The mean growth index is the average of deviations between the observed mean lengths and statewide seasonal average lengths.

Mortality

We estimated instantaneous total mortality rates using a catch-curve regression (Ricker 1975). We used age groups where the majority of fish in each age group were sexually mature, recruited to the fishery (≥ minimum size limit), and represented on the spawning grounds in proportion to their true abundance in the population. For a more detailed explanation of age group selection criteria see Clark et al. (2004). When sufficient data were available, we computed separate catch curves for males and females to determine if total mortality differed by sex. A catch curve was also computed for all fish that included males, females, and fish of unknown sex.

We estimated angler exploitation rates using two methods: 1) the percent of reward tags returned by anglers; and 2) the estimated harvest divided by estimated abundance. We compared these two estimates of exploitation and converted them to instantaneous fishing mortality rates.

In the first method, exploitation rate was estimated as the fraction of reward tags returned by anglers adjusted for tag loss. We did not assess tagging mortality or incomplete reporting of reward tags. We made the assumption that mortality was negligible and that near 100% of reward tags would be returned.

Voluntary tag returns were encouraged with a monetary reward ($10) denoted on approximately ½ of the tags. Tag return forms were made available at boater access sites, at MDNR offices, and from creel clerks. Additionally, tag return information could be submitted on-line at the MDNR website. All tag return data were entered into the database so that it could be efficiently linked to and verified against data collected during the tagging operation. Return rates were calculated separately for reward and non-reward tags.

In the second method, we calculated exploitation as the estimated annual harvest from the angler survey divided by the estimated abundance of legal-sized fish from the single-census abundance estimate. For proper comparison with the abundance of legal fish as existed in the spring, the estimated annual harvest was adjusted for fish that would have recruited to legal size over the course of the creel survey (Clark et al. 2004).

Recruitment

We considered relative year-class strength as an index of recruitment. Year-class strength of walleyes is often highly variable, and factors influencing year-class strength have been studied extensively (Chevalier 1973; Busch et al. 1975; Forney 1976; Serns 1982a, 1982b, 1986, and 1987; Madenjian et al. 1996; and Hansen et al. 1998). Density-dependent factors, such as size of parent stock, and density-independent factors, such as variability of spring water temperatures, have been shown to correlate with success of walleye reproduction. In addition, stocking walleyes can affect year-class strength, but stocking success has also been highly variable, depending on the size and number of fish stocked, level of natural reproduction occurring, and other factors (Laarman 1978; Fielder 1992; Li et al. 1996a; Li et al. 1996b; and Nate et al. 2000).

We obtained population data in Michigamme Reservoir for only one year, and so could not rigorously evaluate year-class strength as did the investigators cited in the previous paragraph. However, we suggest that valuable insight about the relative variability of recruitment can be gained by examining the properties of our catch-curve regressions for walleyes and northern pike. 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. He showed that residuals were related to various hydrological variables in the reservoirs.

As Maceina (2003), we assumed the residuals of our catch-curve regressions were indices of year-class strength. For walleyes and northern pike, we related year-class strength to various hydrologic and environmental variables by using correlation, simple linear, and multiple regression analyses. Hydrologic data were provided by Wisconsin Electric, and historic weather data were taken from the National Oceanic and Atmospheric Administration (NOAA) weather station in Wausau, Wisconsin. We could not acquire weather data (with adequate history) closer to the reservoir, or historic water quality data specific to the reservoir itself.

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.

Angler Survey

Fishing harvest seasons for walleyes and northern pike during this survey were May 15, 2001 - February 28, 2002. Minimum size limits were 15 in for walleyes and 24 in for northern pike. Daily bag limit was five fish of any combination of walleyes, northern pike, smallmouth bass, or largemouth bass.

Fishing harvest seasons for smallmouth bass and largemouth bass were May 26, 2001 through Dec 31. Minimum size limit was 14 in for both smallmouth bass and largemouth bass.

Harvest was permitted all year for all other species present. Minimum size limit was 8 in for brook trout, with a daily limit of 5, no more than 3 of which could be 15 in or greater. No minimum size limits were imposed for other species. Bag limit for lake whitefish was 12. Bag limit for yellow perch was 50 per day. Bag limit for “sunfishes”, including black crappie, bluegill, pumpkinseed, and rock bass was 25 per day in any combination.

Direct contact angler creel surveys were conducted during one spring-summer period – May 15 to October 14, 2001, and one winter period – December 19, 2001 through February 28, 2002. General descriptions of summer and winter surveys are presented here with necessary specific information presented within the appropriate sections.

For sampling purposes, Michigamme Reservoir was divided into 5 sections (Figure 5). All count and interview data were collected and recorded by section. Similarly, effort and catch estimates were made by section and summed for lake-wide estimates. Scanner-ready interview and count forms were used.

Both summer and winter surveys were designed to collect roving interviews. Minimum fishing time prior to interview (incomplete-trip interview) was 1 h (Lockwood 2004). When anglers reported fishing in more than one section, the clerk recorded the section number where they spent most of that trip fishing. Global positioning system (GPS) coordinates were used to determine grid boundaries (Figure 5). All roving interview data were collected by individual angler to avoid party size bias (Lockwood 1997).

While both summer and winter surveys were designed to collect roving interviews, the clerk occasionally encountered anglers as they completed their fishing trips. The clerk was instructed to interview these anglers and record the same information as for roving interviews – noting that the interview was from a completed trip. Similar to roving interviews, all access interview data were collected by individual angler.

Count information collected included: date, grid, fishing mode (fishing boat, open ice, or occupied shanty), count time, and number of fishing boats counted. Interview information collected included: date, section, fishing mode (fishing boat open ice, or shanty), 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 and northern pike, and applicable tag number. Catch and release of smallmouth bass, largemouth bass, walleyes, northern pike, and muskellunge were recorded. Number of anglers in each party was recorded on one interview form for each party.

Summer

We used an aerial-roving design for the summer survey (Lockwood 2000b). Fishing boats were counted by aircraft and one clerk working from a boat collected angler interview data. Survey period was from May 15 through October 14, 2001. Both weekend days and three randomly selected weekdays were selected for counting and interviewing during each week of the survey season. No interview data were collected on holidays; however, aerial counts were made on holidays. Holidays during period were Memorial Day (May 28, 2001), Fourth of July, and Labor Day (September 3, 2001). Counting and interviewing were done on the same days (with exception to previously discussed holidays), and one instantaneous count of fishing boats was made per day.

One of two shifts was selected each sample day for interviewing (Table 2). Interview starting location (a section within the reservoir) and order were randomized daily. On days when the clerk interviewed in all sections prior to completion to the shift, they continued interviewing at the beginning of the specified order and proceeded to the appropriate scheduled sections. In this situation, interview forms were updated for any anglers encountered for a second time (i.e., anglers that had been interviewed earlier during the day). If the clerk knew that a party had been interviewed earlier that day but could not identify their interview form, the party was not re-interviewed. That is, no angling party had a second set of interview forms filled out for them on the same day.

Aerial counts progressed from marker A to marker H or from marker H to marker A (Figure 6). This sequence was randomized. The pilot flew one of the two randomly selected predetermined routes using GPS coordinates. Each flight was made at 500-700 ft elevation and took approximately 16 min to complete with air speed of about 90 mph. Counting was done by the contracted pilot and only fishing boats were counted (i.e., watercraft involved in alternate activities, such as water skiing, were not counted). Time of count was randomized to cover daylight times within the sample period. Count information for each count was recorded on a lake map similar to Figure 5.

Winter

We used a progressive-roving design for winter surveys (Lockwood 2000b). One clerk working from a snowmobile collected count and interview data. Survey period was from December 19, 2001 through February 28, 2002. No interview or count data were collected on holidays. Holidays during the period were New Years Eve (December 31, 2001), New Years Day (January 1, 2002), Martin Luther King Day (January 15, 2002), and President's Day (February 19, 2002). Both weekend days and three randomly selected weekdays were selected for sampling during each week of the survey season. The clerk followed a randomized count and interview schedule. One of two shifts was selected each sample day (Table 2). Starting location (section) and direction of travel were randomized for both counting and interviewing (Figure 5).

Progressive (instantaneous) counts of open-ice anglers and occupied shanties were made once per day. No anglers were interviewed while counting (Wade et al. 1991).

Estimation Methods

Catch and effort estimates were made by section using a multiple-day method (Lockwood et al. 1999). Expansion values ("F" in Lockwood et al. 1999) are given in Table 2. These values are the number of hours within sample days. Effort is the product of mean counts by grid for a given period day type, days within the period, and the expansion value for that period. Thus, the angling effort and catch reported here are for those periods sampled, no expansions were made to include periods not sampled (e.g., 0100 to 0400 hours). Lake-wide estimates were the sum of section estimates for each given time period and day type. While both summer and winter surveys were designed to collect roving interviews, the clerk was instructed to also collect access interviews from any angling parties observed completing their trip. Similar to roving interviews, all anglers within a party were interviewed. When 80% or more of interviews (80:20 ratio) within a time period (weekday or weekend day within a multiple-day period) were of an interview type, the appropriate catch-rate estimator for that interview type was used on all interviews. When less than 80% were of a single interview type, a weighted average R_w was used:

$$R_w = \frac{\left(\hat{R} \cdot n_1\right) \cdot \left(\overline{R} \cdot n_2\right)}{\left(n_1 + n_2\right)}, \qquad (1)$$

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

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

where $s_{\hat{R}}^2$ is the estimated variance of $\hat{R}$ and $s_{\overline{R}}^2$ is the estimated variance of $\overline{R}$. (See Lockwood et al. 1999 for appropriate catch rate and variance equations)

From the angler creel 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: Chapter 6). 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 (MDNR Fisheries Division – unpublished data).

All estimates are given with 2 SE. Error bounds (2 SE), provided statistical significance, assuming normal distribution shape and $N \geq 10$, of 75% to 95% (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.

As a routine part of interviewing, the creel clerk recorded presence or absence of jaw tags and fin clips, tag numbers, and lengths of walleyes and northern pike. These data were used to estimate tag loss and to determine the ratio of marked-unmarked fish for Petersen population estimates.

Results

We will provide confidence limits for various estimates in relevant tables, but not in the text.

Fish Community

We collected 15 species of fish with fyke nets and electrofishing gear (Table 3). Total sampling effort was 207 fyke-net lifts and 10 electrofishing runs. We captured 2,471 walleyes and 1,861 northern pike. Other species collected in order of abundance in total catch were: white sucker, rock bass, yellow perch, black crappie, bluegill, smallmouth bass, pumpkinseed sunfish, longnose sucker, burbot, largemouth bass, brook trout, common shiner, and lake whitefish. We caught a higher percentage of large, spring-spawning fish than a general management survey conducted in 1984 (Table 4).

A general survey of Michigamme Reservoir in 1984 collected 10 species in 21 fyke-net lifts. Walleyes, white sucker, and northern pike accounted for almost 70% of the total catch in our survey compared to 30% in the 1984 survey. The 1984 survey was conducted in late May and early June, thus catch was more dominated by rock bass and yellow perch.

Size structures of fish measured in our spring netting and electrofishing catches are presented in Table 4. The percents of walleyes and northern pike that were legal size were 53 and 6, respectively. The population of spawning walleyes was dominated by 15- to 20-in walleyes, and there were proportionally few walleyes over 20 in. Similarly, most northern pike were under 25 in and few fish were larger than 30 in.

The size structure of smallmouth bass had a relatively high proportion of larger fish, with 58% of those collected in our spring survey being of legal size. In general, the size of panfish species was impressive (Table 4); mean lengths for yellow perch, black crappie, and bluegills were 9.9, 9.6, and 7.8 in, respectively. The size score (Schneider 1990) for bluegills was 7.2, putting it in the 95th percentile of the 303 lakes that were used to develop that index. We discuss the potential biases that our gear may impose on interpreting size structure in the **Discussion** section.

Walleyes and Northern Pike

Sex Composition

Males outnumbered females for both walleyes and northern pike in our survey. This is typical for both walleyes (Carlander 1997) and northern pike (Preigel and Krohn 1975; Bregazzi and Kennedy 1980). Of all walleyes captured, 83.5% were male, 9.3% were female, and 7.2% were unknown sex. This corresponds to a sex ratio (M:F) of 9:1. Of legal-sized walleyes captured, 83.9% were male, 14.9% were female, and 1.2% were unknown sex. Of all northern pike captured, 57.2% were male, 37.8% were female, and 5.0% were unknown sex. The corresponding sex ratio is 1.5:1. Of legal-sized northern pike captured, 19.2% were male, 75.5% were female, and 5.3% were unknown sex.

Abundance

We tagged a total of 1,062 legal-sized walleyes (702 reward and 360 non-reward tags) and clipped fins of 948 sub-legal walleyes. Three recaptured walleyes were observed to have lost their tags during the spring netting/electrofishing survey, so the effective number tagged was 1,059. Creel clerks observed a total of 591 walleyes, of which 44 were tagged. We reduced the number of unmarked walleyes in the single-census calculation by 187 fish to adjust for sub-legal fish that grew over the minimum size limit during the fishing season. There was no tag loss for walleyes observed by the creel clerk.

The estimated number of legal-sized walleyes was 2,371 using the multiple-census method and 9,540 using the single-census method (Table 5). The estimated number of adult walleyes was 5,384 using the multiple-census method, 16,859 using the single-census method, and 20,174 using the Wisconsin regression. The coefficients of variation (CV = standard deviation/estimate) for all estimates were less than 0.40 which Hansen et al. (2000) considered indicative of reliable estimates.

We tagged a total of 94 legal-sized northern pike (2 reward and 92 non-reward tags) and clipped fins of 1,409 sub-legal northern pike. Four recaptured northern pike were observed to have lost their tags during the spring netting/electrofishing survey, so the effective number tagged was 90. The creel clerk observed 57 northern pike, of which 3 were tagged. We reduced the number of unmarked northern pike in the single-census calculation by 21 fish to adjust for sub-legal fish that grew over the minimum size limit during the fishing season. There was no tag loss for northern pike observed by the creel clerk.

The estimated number of legal-sized northern pike was 234 using the multiple-census method and 842 using the single-census method. The estimated number of adult northern pike was 4,299 using the multiple-census method and 13,052 using the single-census method (Table 5). All estimates had a CV < 0.40 (Hansen 2000) and were considered reliable, except for the single-census estimates of legal and adult northern pike (CV = 0.42) which had identical variance.

Mean Lengths at Age

For walleyes, there was 67.6% agreement between the first two aging technicians. For fish that were aged by a third reader, agreement was with first reader 75.3% of the time and with second reader 24.7% of the time; thus, there appeared to be some bias among readers. This bias was apparently due to identification of the first annulus. Only 1.8% of samples were discarded due to poor agreement; thus, at least two readers agreed 98.2% of the time. Our reader agreement (first two reads) for walleye spines was somewhat higher than other studies. Isermann et al. (2003) achieved 55% reader agreement and Kocovsky and Carline (2000) achieved 62%. Similar to us, Miller (2001) found that at least two of three readers agreed 94.2% of the time.

For northern pike, there was 80.5% agreement between the first two aging technicians. For fish that were aged by a third reader, agreement was with first reader 69.4% of the time and with second reader 30.6% of the time; thus, there appeared to be some bias among readers. Again, this bias was apparently due to identification of the first annulus. Only 1.3% of samples were discarded due to poor agreement; thus, at least two of three readers agreed 98.7% of the time. Clark et al. (2004) also found relatively good agreement (72.4%) for northern pike aged with fin rays from Houghton Lake.

Female walleyes had higher mean lengths at age than males (Table 6). This is typical for walleye populations in general (Colby et al. 1979; Carlander 1997; Kocovsky and Carline 2000). We obtained sufficient sample sizes for a simple comparison of means through age 11, and females were almost 4 in longer than males at age 11 (Table 6).

We calculated a mean growth index for walleyes of -3.2, which means walleyes in our sample from Michigamme Reservoir appeared to grow substantially slower than the state average. However, this difference was likely due, at least in part, to biases between aging methods. State average mean lengths were estimated by scale aging, and Kocovsky and Carline (2000) found that ages estimated from scales were younger than ages estimated from spines for the same fish. If so, this would cause estimated mean lengths at age of scale-aged fish to be larger than spine-aged fish. Eventually, the Large Lakes Program will obtain enough data to recalculate new state averages based on spines, if we continue to use them, which will improve future comparisons.

Female northern pike generally had higher mean lengths at age than males (Table 7). As with walleyes, this is typical for northern pike populations in general (Carlander 1969; Craig 1996). We obtained sufficient sample sizes for comparison through age 6, and females were 2 in longer than males at age 6 (Table 7).

We calculated a mean growth index for northern pike of -2.7, which means northern pike in our sample from Michigamme Reservoir appeared to grow substantially slower than the state average. However, unknown biases associated with use of fin rays for aging makes this result dubious. As with walleyes, the Large Lakes Program will eventually age enough northern pike with fin rays to recalculate state averages for future comparisons.

Mortality

For walleyes, we estimated catch at age for 1,704 males, 188 females, and 152 unknown-sex fish (Table 8). We used ages 6 and older in the catch-curve analysis to represent the legal-sized population (Figure 7). We chose age 6 as the youngest age because: 1) average lengths of walleyes at age 6 was 15.1 in for males and 16.7 in for females (Table 6), so a high proportion of age-6 fish were of legal size at the beginning of fishing season; and 2) relative abundance of fish younger than age 6 do not appear to be represented in proportion to their true abundance (Figure 7), suggesting that fish (males and females) are not fully mature at age 5. Although we only aged one fish to 17 years, we believe the age to be accurate, and removing this age group did little to change the total mortality estimate.

The catch-curve regressions for walleyes were all significant ($P < 0.0500$), and produced total instantaneous mortality rates for legal-sized fish of 0.4205 for males, 0.4137 for females, and 0.4630 for all fish combined (Figure 7). These instantaneous rates corresponded to annual percent mortality rates of 34% for males, 34% for females, and 37% for all fish combined. Thus, for walleyes total mortality was equal for males and females.

For northern pike, we estimated catch at age for 887 males, 583 females, and 32 unknown-sex fish (Table 8). The mean length of males was greater than legal size (> 24 in) by age 7, but not enough age groups were present to calculate a catch curve (Table 8). Thus, we used ages 3 through 5 in a catch-curve regression to represent the sub-legal male northern pike population (Figure 8). For female northern pike and all northern pike, we used ages 6-9 in the catch curve analysis. We chose age 6 as the youngest age because mean length at age 6 was 25.8 in for females and 25.3 in for all northern pike (Table 7), so a high proportion of age-6 fish were legal-sized at the beginning of fishing season. Additionally, the relative abundance of fish appeared to be represented in proportion to their true abundance at ages younger than age 6 (Table 8, Figure 8), suggesting that they are fully mature by age 6, or perhaps as young as age 3. We did not include catch of age 11 fish in the regression for female, or all northern pike both because it was based on a single fish, and there was no catch of age-10 fish (Table 8).

The catch-curve regression of sub-legal male northern pike was not significant ($P > 0.0500$), but it resulted in a total instantaneous mortality rate of 0.5811 (Figure 8). The regressions for legal female and all northern pike were also insignificant ($P > 0.0500$), with total instantaneous mortality rates of 1.0275 and 0.9949, respectively. These instantaneous rates corresponded to total annual mortality rates of 44% for sub-legal males, 64% for legal-sized females, and 63% for legal-sized fish of all sexes combined.

For northern pike, a comparison of mortality between males and females is not appropriate due to the fact that the estimate for males did not include fishing mortality. Additionally, none of the catch curve regressions was significant at the 95% level.

Anglers returned a total of 273 walleye tags (205 reward and 68 non-reward tags) in the year following tagging. The creel clerk did not observe any tagged fish in the possession of anglers that were not subsequently reported to the central office by the anglers. The estimated exploitation rate for walleyes was 29.3% based on return of reward tags and 22.3% based on dividing harvest by abundance (Table 5). Anglers reported reward tags at a much higher rate than non-reward tags (29.3% versus 18.9%), but they likely did not fully report either one. Thus, the true exploitation rate for walleyes is likely 30% or greater.

For northern pike, we failed to tag enough fish with reward tags, so the tag-return estimate was based on angler returns of 10 tags (0 reward and 10 non-reward) from an initial 90 tagged fish at large (2 reward and 88 non-reward). In this case, we used both reward and non-reward tag returns to make an estimate of exploitation. All tags observed by the creel clerk were reported to the central office. The estimated exploitation rates for northern pike were 11.1% based on tag returns and 28.3% based on dividing harvest by abundance (Table 5). We think the true exploitation rate for northern pike is likely between those made by the two different methods and is probably closer to the higher rate. We will address possible violations to assumptions for exploitation estimates later in the **Discussion** section.

Recruitment

For walleyes, variability in year-class strength was relatively high in Michigamme Reservoir, which can be seen in the statistics of the catch-curve regression. Residual values were large (see scatter of observed values around the regression line for all walleyes in Figure 7) and the amount of variation explained by the age variable was low (R^2 = 0.87). Clark et al. (2004) similarly found an R^2 value of 0.86 for a catch curve regression of walleyes in Houghton Lake, Michigan.

We did not find any environmental or climatological variables that were significantly related to walleye year-class strength. Variables that we tested included: the average, minimum, and maximum monthly water elevations, reservoir acreage, reservoir volume, regional air temperature, and regional precipitation. In addition to using variables from the year matching year-class formation, we also used variables from the following year. We hypothesized that winter drawdown may affect year-class formation and thus used the water elevations, acreages, and volumes for the months of January, February, and March in the year following each year class. We found only one weak relationship that corresponded with our hypothesis. The residuals from the walleye catch curve were positively correlated with the average acreage of the reservoir in the March following year-class formation (r = 0.63, P = 0.1320, df = 6). Although this relationship suggests possible "biological" significance, it was weak statistically and only evident when using consecutive age groups (6-12) where more than 10 fish were aged. The relationship was not apparent when all age groups used in the catch curve regression were used.

For northern pike, variability in year-class strength was also high in Michigamme Reservoir, which can be seen in the statistics of the catch-curve regression. The catch curve regression was insignificant, the residual values were relatively large (see scatter of observed values around the regression line for all northern pike in Figure 8), and the amount of variation explained by the age variable was low (R^2 = 0.85). Clark et al. (2004) reported low recruitment variability for northern pike in Houghton Lake, Michigan (R^2 = 0.99).

As for walleyes, we did not find any environmental or climatological variables that were related to northern pike year-class strength. We tested the same environmental variables for northern pike as we did for walleyes.

Movement

Based on voluntary tag returns, there was little movement of walleyes or northern pike out of Michigamme Reservoir, but they moved extensively within the lake. One walleye tag return came from a significant distance up the Michigamme River: a 20.0 in male caught south of Leif Ericson Park, on M-95 south of the town of Republic (Figure 1). Additionally, a 22.0 in male was caught in Light Lake, which is connected to Michigamme Reservoir by the Deer River (Figure 1). Based on these returns, approximately 99.3 % of the walleyes were harvested within the reservoir. However, walleye movement could potentially be greater than what is depicted by tag return data. Specifically, if angling pressure is low on the Michigamme River above the reservoir few tag returns would come from that area. Within the reservoir, most walleyes were recovered considerable distances from their tagging sites. All northern pike tag returns came from within Michigamme Reservoir.

Angler Survey

Summer

Our clerk interviewed 2,622 boating anglers during the summer 2001 survey. Approximately equal numbers of roving and access interviews were collected. The clerk collected 1,294 roving interviews and 1,328 access interviews. Anglers fished an estimated 34,383 angler hours and made 22,052 angler trips (Table 9).

The total harvest was 8,860 fish and consisted of ten different species (Table 9). Yellow perch were most numerous with an estimated harvest of 3,127. Anglers harvested 2,102 walleyes and 225 northern pike, and reported releasing 9,131 walleyes (81% of total catch) and 5,584 (96% of total catch) northern pike. Anglers harvested 371 smallmouth bass and released 1,672 (82% of total catch). We do not know what proportion of the released fish was legal size. In future surveys, we recommend distinguishing between sub-legal- and legal-size fish released.

Winter

Our clerk interviewed 967 open ice anglers and 57 shanty anglers. Most open ice (99%) and shanty (93%) interviews were roving type. Open ice and shanty anglers fished 18,303 angler hours and made 5,074 trips on Michigamme Reservoir (Table 10).

A total of 2,039 fish were harvested. Anglers harvested 1,013 walleyes and reported releasing 822 (45% of total catch). Anglers harvested 152 northern pike and released 2,373 (94% of total catch). Anglers harvested 482 black crappie, 317 yellow perch, and 75 bluegills. Anglers released 1 smallmouth bass and 61 largemouth bass. A total of 3,257 fish were caught and released.

Annual Totals for Summer and Winter

In the annual period from May 2001 through February 2002, anglers fished 52,686 hours and made 27,126 trips to Michigamme Reservoir (Table 11). Of the total annual fishing effort, 65% occurred in the open-water summer period and 35% occurred during ice-cover winter period.

The total annual harvest was 10,899 fish. Yellow perch were the most commonly harvested species at 3,444. Combined panfish (black crappie, bluegill, rock bass, and yellow perch) made up 64% of the total harvest. Panfish were harvested in the highest numbers during July through September/October, although winter harvest was also significant.

Walleyes and northern pike were the most numerous species caught (harvested + released) at 13,068 and 8,334, respectively. Resulting catch rates (catch per h) for walleyes and northern pike were 0.2480 and 0.1582, respectively. Estimated total annual harvests of walleyes and northern pike were 3,115 and 377, respectively. Harvests of both walleyes and northern pike were rather evenly distributed among months. Anglers released 76% of all walleyes caught and 95% of northern pike caught. Although we did not differentiate between sub-legal and legal released fish, we assume that a large proportion was sub-legal. This assumption that the high release rate was due to catching mostly sub-legal walleyes and northern pike is corroborated by the low size structures of both species, which contained high proportions of sub-legal-sized fish (Table 11). In the spring survey, the proportions of all walleyes and northern pike that were sub-legal were 47% and 94%, respectively.

We did not survey from October 15 through December 28, because we thought that relatively little fishing occurred during that time of year. However, three walleye tag returns (1.1% of total annual returns) were reported as caught in December, prior to the start of the winter creel survey (Table 12). Thus, it appears that we may have missed some of angler effort taking place on early ice, and consequently have underestimated the total annual walleye harvest from Michigamme Reservoir. Total annual walleye harvest from Michigamme Reservoir was actually about 1.1% higher than our direct survey estimate, or 3,149 walleyes. No northern pike tag returns were reported as caught during the portions of October and December that were not surveyed (Table 13). March and April were not surveyed because both walleye and northern pike seasons are closed at that time.

Six species that we captured during spring netting operations did not appear in the angler harvest – pumpkinseed, longnose sucker, burbot, brook trout, common shiner, and lake whitefish.

Discussion

Fish Community

The seasonal and gear biases associated with our survey preclude comparisons of population and community indices to other Michigan lakes. Because of the mesh-size bias, smaller fish would not be represented in our sample in proportion to their true abundance in the lake. This would include juveniles of all species as well as entire populations of smaller fishes known to exist in Michigamme Reservoir such as various species of shiners, darters, and minnows. For example, Michaud (1985) reported catching logperch, Johnny darters, and other darters in Michigamme Reservoir using seines. Other species collected by the MDNR in past electrofishing surveys of Michigamme Reservoir include sculpins, golden shiners, and bluntnose minnows. A complete list is given in the Appendix.

MDNR collected and tagged 889 walleyes and 129 northern pike with fyke nets from April 16 through May 9, 1986. They found 74% of walleyes were ≥ 15 in, compared to only 53% in our survey. Fish were not aged in the 1986 survey, so we cannot determine if this difference was due to a reduction in growth or a fluctuation in year-class strength.

Because of the seasonal bias, we likely caught more large, mature fish of several species than would normally be caught in surveys that have historically been conducted later in spring or summer. This would include spring spawners such as walleyes, northern pike, white sucker, rock bass, smallmouth bass, and yellow perch. Quantitative comparisons of species and size compositions between our survey and others would not be prudent until more sampling has been done using similar methods under the Large Lakes Program.

Walleyes and Northern Pike

Sex Composition

Male walleyes outnumbered females in our survey both when all sizes and fish of legal size were considered. We were unable to find any previous information concerning sex composition from Michigamme Reservoir for comparison. Sex of walleyes is readily determined during the spawning season by extruding gametes, but at other times of the year, sex determination would require dissection of the fish, which is not part of past sampling protocols.

For walleyes from other lakes in Michigan and elsewhere, males consistently dominate sex composition in samples taken during spawning (Clark et al. 2004). This is likely due to males maturing at earlier sizes and ages than females and to males having a longer presence on spawning grounds than females (Carlander 1997). The sex ratio we observed for walleyes was high (9:1), but not nearly as high as is normally observed in nearby Lake Gogebic. The sex ratio (M:F) of spawning walleyes in Lake Gogebic ranged from 2:1 to 114:1 from 1971 to 1996, and the average was 26:1 (Miller 2001).

Male northern pike outnumbered females in Michigamme Reservoir when all sizes were considered. However, females greatly outnumbered males when only legal size fish were considered. This disparity between sex composition of all sizes and fish of legal size is likely due to faster growth in females. Higher mortality of males as reported by Craig (1996) would also contribute to this disparity, though our estimates of mortality for northern pike were uncertain. Clark et al. (2004) found the same disparity in sex ratio of all northern pike versus northern pike of legal size in Houghton Lake, Michigan.

For northern pike from other lakes, males dominate sex composition in spawning-season samples, but not at other times of the year (Preigel and Krohn 1975; Bregazzi and Kennedy 1980). Bregazzi and Kennedy (1980) sampled northern pike with gill nets set throughout the year in Slapton Ley, a eutrophic lake in southern England. Sex ratios during the February and March spawning period ranged from 6:1 to 8:1 (male to female), but the overall sex ratio for an entire year of sampling was not significantly different from 1:1.

Abundance

MDNR made previous mark-and-recapture estimates of adult walleye abundance for Michigamme Reservoir in the late 1980s. In 1986, 1987, and 1988 they tagged 889, 425, and 1,198 walleyes, respectively. Multiple-census estimates of adult walleye abundance ranged from 9,000 to 13,000 per year for the 3-year period (William Ziegler, MDNR, Fisheries Division, personal communication). Although they potentially missed some spawning congregations of fish within the reservoir system due to using nets only, their estimates were fairly consistent among years.

We used more extensive methods than previous abundance estimates and were successful in obtaining both multiple- and single-census estimates (Table 5). For the multiple-census estimate, the minimum number of recaptures was obtained; however, we may have violated some conditions for an unbiased estimate that are discussed later. For the single-census estimate, we had sufficient numbers of both marked fish and number of fish observed for marks. Assuming that the legal walleye population was approximately 10,000 fish, and based on tagging around 1,000 fish, the recommended recapture sample to observe for marks in management studies (α = 0.05, P = 0.25; where P denotes the level of accuracy, and 1-α the level of precision) is approximately 600 fish (Robson and Regier 1964). Our corrected recapture sample of 404 fish was short of this recommendation, but exceeded the requirement for preliminary studies and management surveys (α = 0.05, P = 0.50).

We think our single-census estimates were more reliable than our multiple-census estimates. Single-census estimates compared more favorably to other independently-derived estimates and had less serious methodological biases. The multiple-census estimate for walleyes was considerably lower than the single-census estimate for both legal size fish and adult fish (Table 5), similar to estimates made in Houghton Lake (Clark et al. 2004). The 95% confidence limits between the two types of estimates did not overlap. Thus, estimates between methods are likely significantly different at the 95% confidence level. Precision was better for single-census than multiple-census estimates (Table 5). Confidence limits were within 27.3% of the single-census estimate, and within 50.1% of the multiple-census estimate.

Our single-census estimate appeared more accurate than the multiple-census estimate when judged in relation to the independently-derived harvest estimate. For example, our harvest estimate of 3,115 legal-sized walleyes would be nearly impossible to achieve if our multiple-census population estimate of 2,371 legal-sized walleyes was accurate (Table 5), but it fits well with the single-census population estimate of 9,540.

Our single-census estimate of adult walleyes was also reasonably close to the Wisconsin regression estimate of 20,174, but the multiple-census estimate was not (Table 5). Our multiple-census estimate was 73% lower at 5,384, and our single-census estimate was 16% lower at 16,859. Clark et al. (2004) also found estimates from the Wisconsin regression for walleyes in Houghton Lake, Michigan were reasonably close to a single-census estimate. More comparisons will be made on a variety of Michigan walleye lakes in the future. Ultimately, Michigan will develop their own predictive equation for walleye abundance, or along with Wisconsin might be able to develop a joint, regional walleye regression with a much greater sample size and variety of lake types.

Population density of walleyes in Michigamme Reservoir was below average to average compared to other lakes in Michigan and elsewhere. Our single-census estimate for 15-in-and-larger walleyes in Michigamme Reservoir was 9,540 or 1.5 per acre (Table 5). Lockwood (1998, unpublished data) used the single-census method to estimate abundance of 15-in-and-larger walleyes on 16,630-acre Mullett Lake. He estimated walleye abundance to be 14,350 or 0.82 per acre. Clark et al. (2004) estimated the abundance of legal walleyes in Houghton Lake to be 58,854 or 2.93 per acre.

Miller (2001) estimated 62,497 male spawning walleyes (approximately 13 in and greater) in Lake Gogebic, or 4.8 adult males per acre. Norcross (1986) similarly estimated 63,000 male walleyes in Lake Gogebic, though after adjusting for under-sampled females he arrived at an estimate of around 125,000 legal (≥13 in) walleyes, or 9.5 per acre. Nate et al. (2000) reported an average density of 2.24 adult walleyes per acre for 131 Wisconsin lakes having natural reproduction. A different version of the single-census method has been used for walleyes since the mid-1980s on smaller lakes in Wisconsin, Michigan, and Minnesota (Hansen 1989; Rose et al. 2002). These authors recaptured marked fish with electrofishing gear several days after the fish were marked. Results of these estimates were used to create the Wisconsin regression equation, which predicts Michigamme Reservoir should have 20,174 spawning walleyes or 3.2 adult walleyes per acre. Population densities from our multiple-census estimate and single-census estimates for adult walleyes were 0.8 and 2.6 per acre, respectively.

Although we consider the walleye density in Michigamme Reservoir to be about average, it actually varies seasonally with water level fluctuations. For example, the density of adult walleyes in May 2001 (2.6 per acre at 6,400 acres) is relatively low, while the density in March 2001 (6.6 per acre at 2,600 acres) would be considered high (Figure 9). At times during the late 1980s, the winter drawdown resulted in a surface area around 1,300 acres. If the abundance of walleyes then was similar to that of 2001, this would have resulted in a density of 13 adults per acre, which ranks among the highest densities reported in the literature. The seasonal variation in walleye density has potential impacts on recruitment and angler harvest which are discussed later.

We were less successful in obtaining abundance estimates for northern pike (Table 5), largely due to the small number of legal size northern pike that were marked. For the multiple-census estimate, the minimum number of recaptures was obtained; however, we may have violated conditions for an unbiased estimate that are discussed later. For the single-census estimate of legal northern pike, we did not examine enough fish for marks in the creel survey sample. Using our estimate of the legal northern pike population of approximately 1,000 fish, and knowing that we tagged around 100 fish, the recommended recapture sample to observe for marks in preliminary studies and management surveys ($\alpha = 0.05$, $P = 0.50$; where: P denotes the level of accuracy, and $1-\alpha$ the level of precision) is approximately 200 fish (Robson and Regier 1964). Our corrected recapture sample of 36 fish was short of this recommendation.

Confidence intervals of abundance estimates were broad (Table 5). For example, while multiple-census estimates were considerably lower than single-census estimates, 95% confidence limits for the two estimates overlapped. Precision was better for the multiple-census estimate than for the single-census estimate, though both estimates had low precision. Confidence limits were within 76.5% of the multiple-census estimate and within 85.7% of the single-census estimate.

Despite the lack of precision, our single-census estimate appeared more accurate than the multiple-census estimate when judged in relation to the independently-derived harvest estimate. Our harvest estimate of 377 legal-sized northern pike would be impossible if our multiple-census population estimate of 234 legal-sized northern pike was accurate (Table 5), and it fits better with the single-census population estimate of 842.

Population density of northern pike in Michigamme Reservoir was low compared to other lakes in Michigan and elsewhere. Craig (1996) gives 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 (<300 ha) Minnesota lakes. Their estimates of density ranged from 4.5 to 22.3 per acre for fish age 2 and older. Our estimates of numbers of adult northern pike in Michigamme Reservoir also would essentially be for fish age 2 and older, and should be comparable, but our estimates converted to densities are only 0.7 per acre for the multiple-census method and 2.0 per acre for the single-census method.

However, similar to walleyes, the density of northern pike in Michigamme Reservoir actually varies seasonally with water level fluctuations. For example, the density of northern pike in May 2001 (2.0 adults per acre at 6,400 acres) is relatively low, while the density in March 2001 (5.0 adults per acre at 2,600 acres) would be considered average (Figure 10). If the abundance of northern pike was similar to that of 2001, the severe winter drawdowns that occurred in the past could have resulted in densities around 10 adults per acre, which as for walleyes, ranks among the highest densities reported in the literature.

There are several potential sources of error in our multiple-census estimates of walleye and northern pike abundances. One assumption of the method is that marked fish become randomly mixed with unmarked fish. Over the course of our netting operation, marked fish were probably not mixing completely with the total population at large, and we possibly did not sample all spawning congregations in this large reservoir. An alternative description of this condition is that fishing effort is randomly distributed over the population being sampled (Ricker 1975). As fish moved off the spawning grounds and were excluded from our sampling gear, we violated this assumption. Additionally, because we used different gears during the collection (i.e., electrofishing in tributaries, and netting in the Reservoir proper) we likely exerted unequal effort in different parts of the system. In contrast to the problems associated with the multiple-census method, the single-census estimate from the creel survey is likely to be more accurate because it allows sufficient time for the marked fish to fully mix with unmarked fish. Additionally, it does not matter if all spawning congregations are sampled in the initial tagging operation.

Pierce (1997) also found that multiple-census methods severely underestimated abundance. He compared multiple-census estimates of northern pike abundance made with a single gear type (trap nets) to single-census estimates made with two gear types (marking with trap nets and recapturing several weeks later with experimental gill nets). He found that multiple-census estimates averaged 39% lower than single-census estimates. Our multiple-census estimates were 75% lower for walleyes and 72% lower for northern pike. Pierce concluded that gear size selectivity and unequal vulnerability of fish to near shore netting make multiple-census estimates consistently low. He also concluded that recapturing fish at a later time with a second gear type resulted in estimates that were more valid. Clark et al. (2004) also found similar patterns between abundance estimation methods for walleyes and northern pike in Houghton Lake, Michigan.

While single-census estimates using two gear types are probably better than multiple-census estimates, they are not without problems. Mark-and-recapture estimates assume tags are not lost, so if tag loss increased with time, it would have affected the single-census method more than the multiple-census method. Higher tag loss would lead to an overestimate of abundance, and our single-census estimates were higher than our multiple-census estimates. However, we think tag loss, even after a year, was probably minimal. We did not detect any tag loss during the angler survey, that is, no fin-clipped fish > 15 in without tags were observed by survey clerks. Also, jaw tags of the type we used generally have had a good record of retention in previous studies. For example, Schneeberger and Scott (1997) used the same type of jaw tags on yellow perch and found 100% tag retention in experimental ponds.

Clark et al. (2004) described how to improve accuracy and precision of abundance estimates on Houghton Lake by increasing either the number of fish tagged or recaptured, but noted that even marginal improvements would be very costly. Michigamme Reservoir is only about one-third the size of Houghton Lake.

Based on our experience in this study, we believe it would be possible, but costly, to improve precision of walleye abundance estimates for Michigamme Reservoir or other lakes of comparable size. Obtaining more precise estimates would require: 1) marking more fish, 2) recapturing more marked fish, or 3) both. Confidence limits on our single-census estimate of 9,540 legal-sized walleyes were ±27% of the estimate (Table 5), which is about what would be predicted from Figure 4 given 1,059 fish or 11% of the population was marked. We collected and marked 426 walleyes with two 10-to-15 net, 3-person work crews, and collected 633 walleyes with electrofishing. However, the netting crews occasionally assisted the electrofishing crew by tagging their fish that were placed in a net pen. Therefore, the average number of fish marked per 3-person crew was about 350 over the course of the 2-week survey. In order to achieve precision of ±20%, it would be necessary to mark about 2,862 walleyes (30% of the population – Figure 4). Assuming that the number of fish marked per crew did not diminish with increasing number of crews, this would have taken 5 netting crews with 15 people and 50-75 nets, and 3 electrofishing crews with 9 people and 3 electrofishing boats working together on the lake during the two weeks after ice-out. This amount of necessary effort would more than double the effort used on the survey, however it pales in comparison to the 6-fold increase in effort needed on Houghton Lake (Clark et al. 2004) in order to achieve precision of about ±20%.

Improving precision by increasing the number of fish recaptured would also be costly. Based on the formula for confidence limits, a supplemental recapture effort using nets, electrofishing gear, or additional angler survey clerks would have to obtain slightly less than a 2-fold increase in the number of recaptures to improve precision to about ±20%. This would require a minimum of one additional angler survey clerk or a substantial netting and/or electrofishing effort.

Mean Lengths at Age

Mean lengths at age for walleyes from our survey were lower for ages 2-8 than those from a 1987 survey of Michigamme Reservoir, but about equal above age 8 (Table 14). We used the same aging structures and collected samples at a similar time of the year.

Walleye mean lengths at age were lower than the state average for all ages (Table 14). While slow growth is consistent with past surveys of Michigamme Reservoir, it should be noted that all state averages to this point have been calculated using scales; thus, comparisons to mean lengths at age from spine aging are not necessarily informative. Past studies comparing spine aging to scale aging suggest that biases of these techniques generally lead to scale-aged fish having greater mean lengths (Miller 2001; Clark et al. 2004). The mean lengths at age and growth index for Michigamme walleyes appear to be similar to those of other waters in the region, such as Cisco, Thousand Island, and Gogebic lakes, Peavy Pond, and Bond Falls Flowage (Table 14). The latter two are also reservoirs with fluctuating water levels. Peavy Pond historically experiences a 15-ft winter drawdown, but does not fluctuate more than 1 ft during the summer.

The slow growth that we see for Michigamme Reservoir walleyes was not associated with high density on a number per acre basis. In fact, the number of walleye per acre was below average to average for most of the year. However, walleye density could be high relative to the low density of forage fish (Michaud 1985). Norcross (1986) attributed the slow growth of walleyes in Lake Gogebic, another lake in the region, to the low supply of forage fish, though walleye density in that lake was also high on a number per acre basis. Growth is also probably constrained by regional environmental factors, such as short growing season, cool temperatures, and/or low productivity of waters. Walleye mean lengths in other lakes of Michigan's Western Upper Peninsula were all below average (Table 14).

Mean lengths at age for northern pike from our survey were slightly lower than those from a previous survey in 1958, though numbers of fish aged in 1958 were relatively low (Table 15). Our estimated mean lengths at age for northern pike were also lower than state averages (Table 15). As with walleyes, state averages for northern pike were based entirely on scale aging, which probably overestimates mean lengths for older ages. Unfortunately, biases of finray aging are unknown. Additionally, the mean lengths at age and growth index for Michigamme northern pike appear to be on average smaller than those of other waters in the region, such as Lac Vieux Desert, Thousand Island, and Gogebic lakes, Peavy Pond, and Bond Falls Flowage (Table 15). The northern pike population in Michigamme Reservoir appears to be slow growing, and has historically had slow growth. Just as with walleyes, density is low most of the year, and growth is likely determined by regional environmental factors.

Mortality

To our knowledge, this was the first attempt to estimate total mortality of walleyes from Michigamme Reservoir. Total mortality of walleyes in Michigamme Reservoir was generally low, with 16 year classes (age 2-17) represented. Regarding longevity, the maximum age that we observed in samples was 3 years older for males than females, suggesting males might be somewhat longer lived, even though slopes of catch curves for both sexes was the same.

Compared to total mortality estimates for walleyes from other lakes in Michigan and elsewhere, our estimate of 37% was relatively low. Clark et al. (2004) estimated total mortality of walleyes in Houghton Lake to be 46%. Schneider (1978) summarized available estimates of total annual mortality for adult walleyes in Michigan. They ranged from 20% in Lake Gogebic to 65% in the bays de Noc, Lake Michigan. Schneider 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%. Finally, Miller (2001) reported a total annual mortality rate of 37% for male walleyes in Lake Gogebic, which was identical to our estimate.

Our two different estimates of annual exploitation rate of walleyes were relatively close, 29.3% from tag returns and 22.3% based on estimated harvest/abundance. Both estimates were in a reasonable range, and lower than the estimates of total mortality. We consider the tag return estimate to be a minimum because we did not adjust for tagging mortality, tag loss, or non-reporting, and if these problems occurred to any degree, we would have underestimated exploitation (Miranda et al. 2002). We did not estimate tagging mortality, and we did not observe any tag loss on double-marked fish. We did not make a true estimate of non-reporting, but all tags observed by the creel clerk were subsequently reported by anglers.

We attempted to measure non-reporting of tags by offering a $10 reward on about half of the tags and comparing return rates of reward to non-reward tags. We found that reporting rate for reward tags (29.3%) was much better than for non-reward tags (18.9%), in spite of the fact that our reward amount was relatively low compared to those used by other authors (Miranda et al. 2002). Clark et al. (2004) used the same tags and reward amount in Houghton Lake and did not observe much difference in return rates of reward and non-reward tags. However, for Michigamme Reservoir, we think this big difference in reporting rates combined with the relatively low total mortality estimate of 37% and the presence of older fish in the population (Table 8; Figure 7) suggests that anglers must have returned nearly 100% of reward tags. Thus, the true exploitation rate of walleyes in Michigamme Reservoir must be in the 30% to 35% range.

Our return rates for both reward and non-reward tags were higher than similar rates observed in the 1980s. The MDNR previously estimated walleye exploitation in Michigamme Reservoir from tag returns in three consecutive years. They had 12%, 10%, and 20% return rates of 889, 425, and 1,198 tagged walleyes in 1986, 1987, and 1988 respectively. Reward tags were only used in 1988, when 100 $10-tags were used. The disparity between the return rates could possibly be due to the higher visibility of our study in 2001 or the greater proportion of reward tags we used. Our exploitation estimate was higher than the 21% that Miller (2001) reported for nearby Lake Gogebic, but they did not use reward tags. Our return rate for non-reward tags is much closer to their estimate, which suggests that they underestimated exploitation of walleyes in their study.

Compared to exploitation rates for walleyes from other lakes in Michigan and elsewhere, our estimate of 29.3% for Michigamme Reservoir is average to above average. For example, Thomas and Haas (2000) estimated angler exploitation rates from western Lake Erie at 7.5% to 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, WI during 1958-1979. 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.

This was the first attempt to estimate total mortality of northern pike from Michigamme Reservoir. Although the catch curve regression was not significant, our estimate of total annual mortality for northern pike (63%) was above average compared to other lakes in Michigan and elsewhere. Clark et al. (2004) estimated total annual mortality for northern pike in Houghton Lake, Michigan to be 51%. Diana (1983) estimated total annual mortality for two other lakes in Michigan, Murray Lake at 24.4% and Lac Vieux Desert at 36.2%. Pierce et al. (1995) estimated total mortality for northern pike in seven small (< 300 acres) lakes in Minnesota to be 36% to 65%. They also summarized total mortality for adult northern pike from a number of lakes across North America and they 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%.

Our estimate of the annual exploitation rate of northern pike was 11.1% from tag returns and 28.3% based on estimated harvest/abundance. The large discrepancy between the two estimates has several possible causes: (1) we underestimated exploitation based on tag returns due to underreporting; (2) harvest may have been overestimated in the creel survey; or (3) we may have underestimated abundance. As with walleyes, we considered the exploitation estimate from tag returns to be a minimum because we did not adjust for tagging mortality, tag loss, or non-reporting. Additionally, our estimate from tag returns was based on only 90 tagged fish, 98% of which were non-reward; thus, we are not satisfied with its accuracy. Because we tagged so few pike and observed so few in the creel, it is also likely that both harvest and abundance estimates have significant uncertainty. While both estimates of exploitation were at least lower than the estimates of total mortality, the true rate of exploitation is likely closer to the estimate derived from the harvest/abundance.

The MDNR previously estimated exploitation of northern pike in Michigamme Reservoir from tag returns in two consecutive years. They had 7% and 4% return rates of 129 and 167 tagged northern pike in 1986 and 1987, respectively. Our estimate of exploitation was higher than those estimates made in the 1980s, likely due to the high visibility of our study in 2001.

Compared to exploitation rates for northern pike from other lakes in Michigan and elsewhere, our estimate of 11.1% to 28.3% for Michigamme Reservoir appears to be average. 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. Carlander (1969) gave a range of 14% to 41% for a sample of lakes throughout North America. Finally, Clark et al. (2004) reported rates of exploitation from 18.2% to 44.7% for northern pike in Houghton Lake, Michigan.

Recruitment

Walleyes in Michigamme Reservoir were represented by 16 year classes (ages 2 through 17) in our samples (Table 8). So while variability in year-class strength was relatively high (R^2 = 0.87 in Figure 7), substantial natural reproduction did occur every year from 1984 through 1999. Thus, we conclude that natural reproduction of walleyes is sufficient to maintain the current population, although the current population density is below average to average compared to other lakes.

For northern pike, 9 year classes (ages 2 through 9, and 11) were represented in our samples (Table 8). So, as with walleyes, natural reproduction of northern pike was variable (R^2 = 0.85 in Figure 8) but probably consistent enough to maintain the current population. However, the current population density is low compared to populations in other lakes. As mentioned previously in the text, the water level of the reservoir is drawn down during the months of January through April. This elevates the predator density in the reservoir, which poses several potential threats. The winter drawdown may concentrate both predators and prey enough so that foraging efficiency is greatly increased, resulting in greater mortality of forage fish. Undoubtedly, small walleyes are one component of the forage base. Accordingly, managers have repeatedly reported an apparent low survival of walleyes from age-0 to age-1. Therefore, it is possible that walleye year-class strength is affected, in part by the winter drawdown. This concern over high mortality of age-0 walleyes was the impetus behind the reduced drawdown that was part of the recent re-licensing agreement. As part of the Wilderness Shores Settlement Agreement (WSSA) with Wisconsin Electric, winter drawdown of Michigamme Reservoir was reduced from 25 ft to 15 ft, resulting in a minimum pool of about 3,700 acres. Compliance with this new licensing agreement took effect January 1, 2002.

Movement

Although we documented some movement of walleyes outside of Michigamme Reservoir, we do not know the extent and duration of movement. While it would be interesting to know the seasonal movement patterns of walleyes within the system, movements associated with spawning are the most important. Walleyes in Michigamme Reservoir spawn both in the reservoir and in tributaries, but we do not know if they demonstrate site fidelity in spawning. Knowledge of site fidelity would have potential implications in the allocation of walleye harvest, and thus should be considered in future research. Future efforts should involve extensive collection of spawning walleyes in the years after marking.

Angler Survey

Historical Comparisons

Previous harvest and effort estimates for Michigamme Reservoir were reported by

Laarman (1976). A general creel census from 1943-64 included Michigamme Reservoir, but this "census" was designed only to measure success of anglers who were actually interviewed and was not expanded to estimate total catch of all anglers. These general census estimates would not be directly comparable to our estimates. However, considering the general census alone, walleyes and northern pike were the predominant species in the fishery from 1943-49 and from 1951-64, with black crappie and yellow perch also making up much of the total catch. Laarman (1976) also reported the walleye fishery as being characterized by large numbers of sub-legal fish, but few large fish. The size limit was 13 in at that time. Thus, it appears that the fishery of Michigamme Reservoir has remained relatively unchanged.

In 1970, annual fishing effort on Michigamme Reservoir was estimated as 8,120 angler days from a mail survey. Using current knowledge of the average number of trips per day, and the average length of a trip from the 2001 creel survey, the 1970 estimate equates to 18,903 hours of fishing effort. Though not directly comparable to our results, this is considerably less than the 2001 estimate of 52,686 total angler hours. It appears that effort has increased from what it was in 1970.

In March of 1988, the MDNR monitored an extended season fishery on Michigamme Reservoir to assess angler pressure and success. Though the methods were not as comprehensive as current angler surveys, some comparisons can be made. Creel clerks interviewed 351 anglers over 9 days from March 2-15, 1988 who fished for a total of 1,882 hours. The average number of angler hours per day was 208, which is less than half of the 425 angler hours per day that we calculated for February of 2001. The mean catch rates for walleyes and northern pike were 0.07 and 0.05 respectively in the 1988 survey compared with February catch rates of 0.08 and 0.15 for walleyes and pike in the 2001 survey. Disregarding the differences in methods between the two surveys the walleye catch rate appears to be similar, though the catch rate of northern pike appears higher. Biologists did not believe that the extended season in March of 1988 was detrimental, though they acknowledged the potential for harm if the water level was drawn down to a low level for a long period.

Comparison to Other Large Lakes

In general, surveys conducted in Michigan in the past 10 years used the same methods we used on Michigamme Reservoir, but most of them still differ from our survey in seasonal time frame. For example, few other surveys were done in consecutive summer and winter periods. Regardless, for comparison, we used recent angler survey results for Michigan's large inland lakes from 1993 through 1999 as compiled by Lockwood (2000a) and results for Michigan's Great Lakes waters in 2001 compiled by Rakoczy and Wesander-Russell (2002).

We estimated 52,686 angler hours occurred on Michigamme Reservoir during the year from May 2001 through February 2002. This total effort is low compared to other large lakes (Table 16), but is not surprising due to the low human population density in the area, and lack of development on the Reservoir. Michigamme Reservoir had similar effort per acre, harvest per acre, and harvest per h to nearby Lake Gogebic which was sampled recently on a similar annual time frame (Table 16).

For walleyes, our estimated annual harvest from Michigamme Reservoir was 0.5 fish per acre. This harvest is below average relative to other waters in Michigan. The average harvest of six other large Michigan lakes (> 1,000 acres) reported by Lockwood (2000a) was 0.9 walleyes per acre, ranging from 0.1 per acre in Brevoort Lake, Mackinac County to 2.4 per acre in Chicagon Lake, Iron County. These Michigan lakes all were subject to similar gears and fishing regulations, including a 15-in minimum size limit.

A comparison of walleye catch rate in Michigamme Reservoir to that of Houghton Lake offered some possible insight into the two fisheries. Although direct estimates of walleye density and CPUE were higher in Houghton Lake, the catch rate of walleyes was higher in Michigamme Reservoir. Legal walleye harvest per h was 0.037 for Houghton Lake and 0.059 for Michigamme Reservoir, and catch and release rate was 0.003 for Houghton Lake and 0.189 for Michigamme Reservoir. Total catch rate (combined harvest and release) was 0.04 for Houghton Lake and 0.25 for Michigamme Reservoir. We thought of several hypotheses for this relationship. One possibility is that anglers target walleyes more often in Michigamme

Reservoir than in Houghton Lake. While Houghton Lake is known for pike and walleye fishing, it also attracts many anglers for panfish. This, coupled with our deficiency in measuring targeted effort, would result in underestimated catch rates for walleyes in Houghton Lake. It is also possible that walleyes are more vulnerable to angling where aquatic vegetation is less abundant, and there is significantly more aquatic vegetation in Houghton Lake than in Michigamme Reservoir.

For northern pike, our estimated annual harvest from Michigamme Reservoir was 0.06 fish per acre. This harvest was below average compared to other waters in Michigan and elsewhere. The average harvest of seven other large Michigan lakes (> 1,000 acres) reported by Lockwood (2000a) was 0.2 northern pike per acre, ranging from < 0.1 per acre in Bond Falls Flowage, Gogebic County to 0.7 per acre in Fletcher Pond, Alpena County. These Michigan lakes all were 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. These lakes ranged from 136 to 628 acres in size and had no minimum size limits for northern pike.

Management Implications

Michigamme Reservoir has slow-growing walleye and northern pike populations when compared to state averages, but they are not much below average for Michigan's Western Upper Peninsula. The current walleye density is below average to average when compared to other lakes in Michigan and elsewhere. Michigamme Reservoir has limited prey for walleyes (Michaud 1985), which results in slow growth and a size structure with 47% of the spring spawning stock below the 15-in minimum size limit (Table 4). By comparison, in Houghton Lake, Michigan, only 27% of the spring spawning stock was below 15 in. Most walleyes do not reach legal size (15 in) until age 6 in Michigamme Reservoir, compared to age 5 in Houghton Lake. But, on average, walleyes appeared to live somewhat longer in Michigamme Reservoir (up to age 17) than in Houghton Lake (up to age 15). Our estimate of exploitation for Michigamme walleyes was near the maximum sustainable rate of 35% that the Wisconsin Department of Natural Resources and tribal biologists currently use to set harvest quotas in the 1837 and 1842 ceded territories of Wisconsin (Hansen 1989; Staggs et al. 1990). However, that 35% exploitation rate was designed to protect walleye stocks in absence of minimum size limit regulations. Michigamme Reservoir has a fairly restrictive 15-in minimum size limit, and walleye populations can probably sustain exploitation rates somewhat higher than 35% in combination with a 15-in minimum size limit.

We considered the possibility that the relatively high walleye exploitation rate in Michigamme Reservoir was due in part to the 90% reduction in water volume concentrating fish for anglers to target in winter. If the winter drawdown caused above average exploitation of walleye, we would expect monthly catch rates to be positively correlated with walleye density. In fact, the opposite was true. The monthly catch rate of walleyes (number per h) was negatively correlated with average monthly adult walleye density (number per acre; Figure 11). This is surprising, however our creel survey methods do not allow for a simple interpretation. The low water level obviously attracts anglers, as the highest angler effort was estimated for February, the month with the lowest surface area (of surveyed months). However, since we do not estimate targeted effort by anglers, we do not know what species anglers were targeting. For example, if there was significant effort towards panfish during February, our walleye catch rate would not be indicative of the true rate, and the significance of our negative correlation between walleye catch rate and density would be questionable. Other possibilities for our negative correlation are that walleyes are not feeding as extensively in the late winter, or that angler's lures must compete with concentrated prey at low water levels.

In the future, it will be beneficial to compare the walleye populations of Michigamme Reservoir with nearby Bond Falls Flowage and Peavy Pond; these additional two reservoirs were surveyed as part of the Large Lakes study in 2003 and 2004, respectively. Peavy Pond is similar to Michigamme Reservoir in that it experiences a 15-ft winter drawdown, while

Bond Falls Flowage only experiences an 8-ft drawdown.

Despite relatively high angler exploitation of walleyes, estimates indicated that overall mortality was low. Additionally, recruitment appeared to be high enough to sustain the population. The age structure of the population contained cohorts up to age 17. This supports previous information derived from recruitment surveys (Sern's indices) which have shown relatively good recruitment of age-0 fish in fall surveys (MDNR, Fish Collection System).

Our high-pool estimate of adult northern pike density in Michigamme Reservoir was similar to that of Clark et al. (2004), who estimated the density of adult northern pike in Houghton Lake to be around 1.6 per acre. However, Houghton's population was classified as a low-density, fast-growing population. The major difference between the northern pike populations in Michigamme Reservoir and Houghton Lake is that Michigamme's population also has relatively small mean lengths at age, and thus should be classified as a low-density, slow-growing population.

In 2003, Michigamme Reservoir was included in a set of lakes with no size limit for northern pike. This regulation is consistent with the results of this study in that recruitment was sufficient, and the population had a large proportion of sub-legal size fish. This regulation change may result in increased growth if harvest of smaller pike is substantial. Regardless of whether an improvement in growth is observed, it appears to be a safe regulation that will allow additional harvest.

Methods used for harvest, abundance, age and growth, and mortality estimates for walleyes and northern pike performed fairly well, considering the large size of Michigamme Reservoir. Most estimates seemed reasonable when compared to those from other lakes. We are not yet able to determine which of the different methods for estimating abundance (multiple- or single-census) and fishing mortality (tag returns or harvest/abundance) are best for long-term use. Comparisons must be repeated on more lakes before conclusions can be made. Thus, the overall approach used in this study should be continued on a variety of other large lakes for at least several years before significant changes are made.

Our estimates of adult walleye abundance were fairly close to the estimate made a priori with the Wisconsin regression equation. Thus, in the short term, it seems reasonable to apply the Wisconsin regression to estimate walleye abundance in other Michigan lakes when abundance estimates are needed for management purposes. In the long term, MDNR should continue to work towards developing an improved regression by conducting abundance estimates in other Michigan lakes.

Acknowledgements

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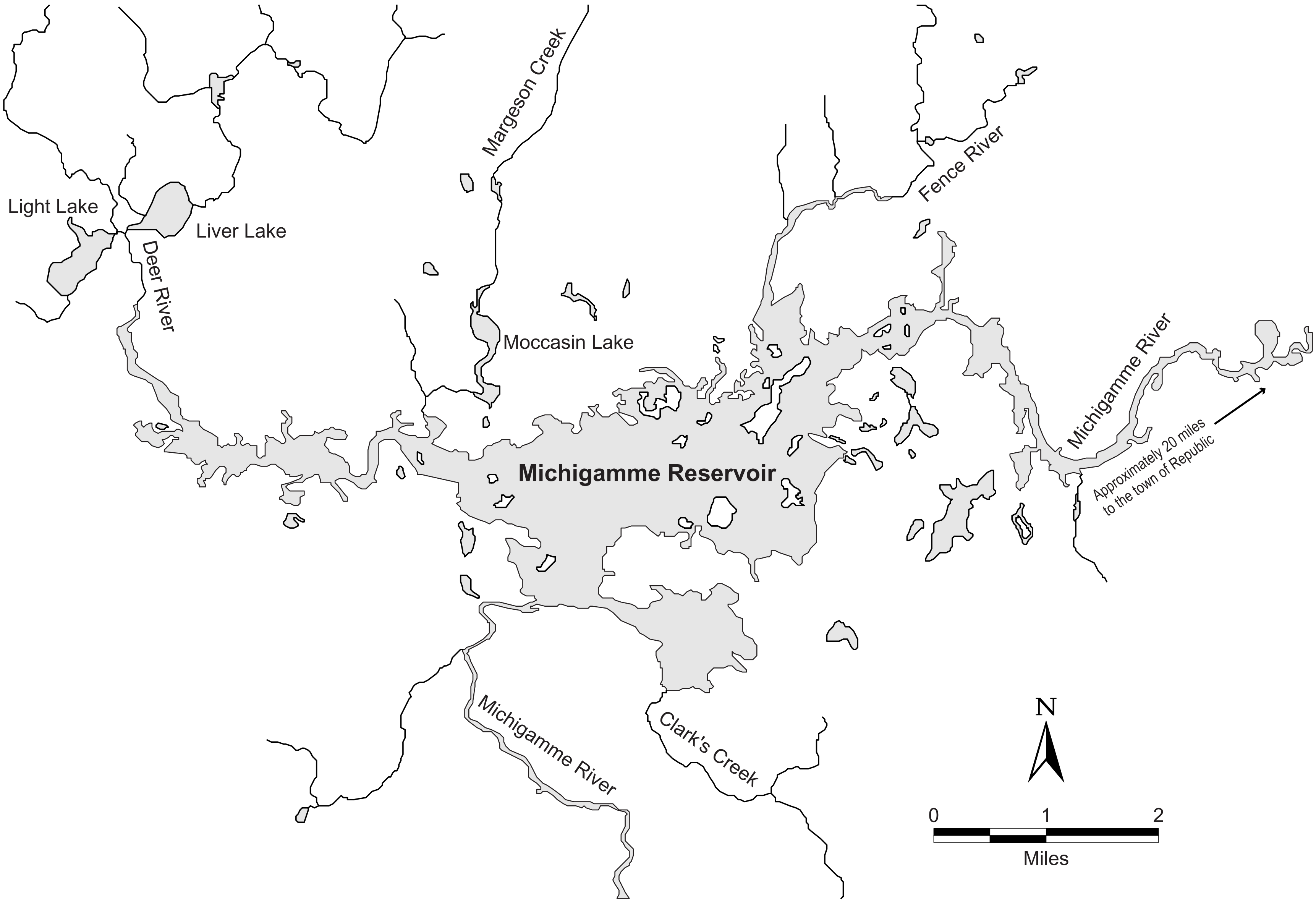


Figure 1.–Map of Michigamme Reservoir, Iron County, Michigan.

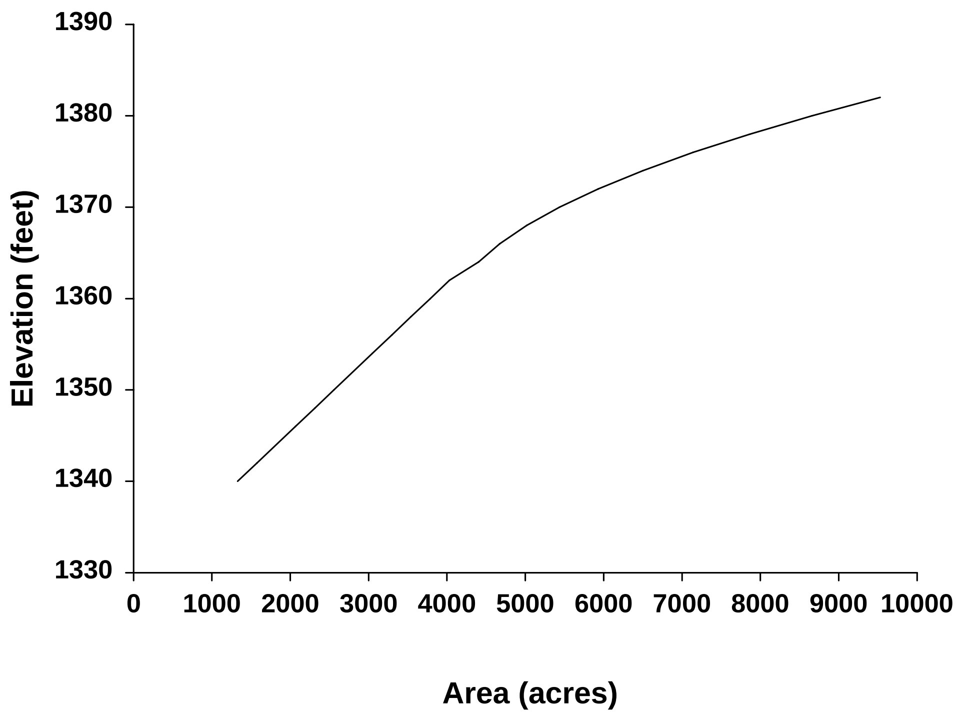


Figure 2.–Surface area (acres) of Michigamme Reservoir by water level (elevation in feet). Data provided by Wisconsin Electric Power Company, Milwaukee.

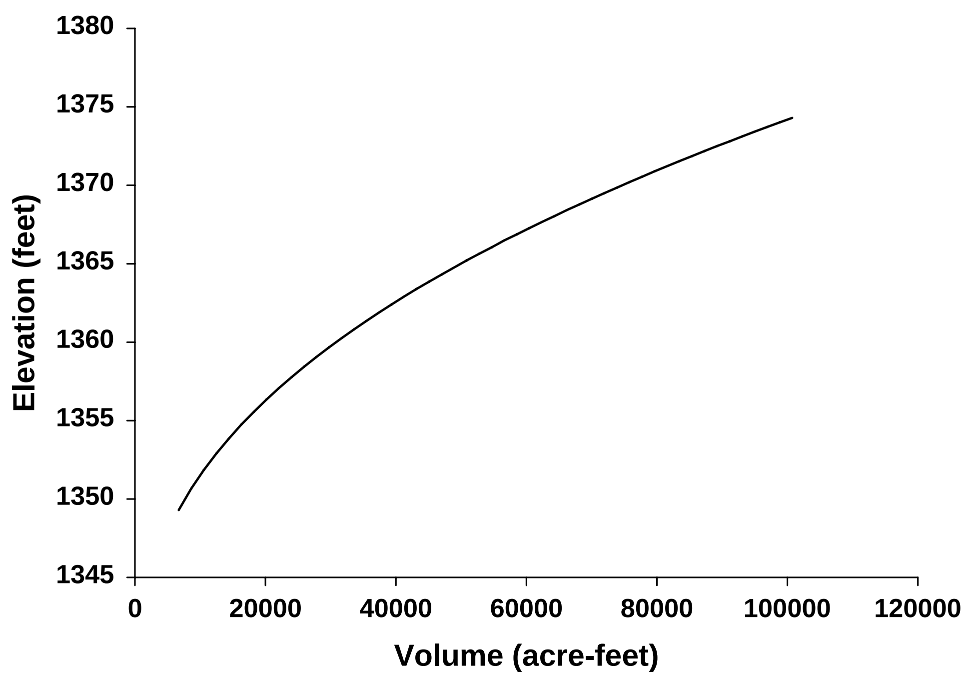


Figure 3.–Volume (acre-feet) of Michigamme Reservoir by water level (elevation in feet). Data provided by Wisconsin Electric Power Company, Milwaukee.

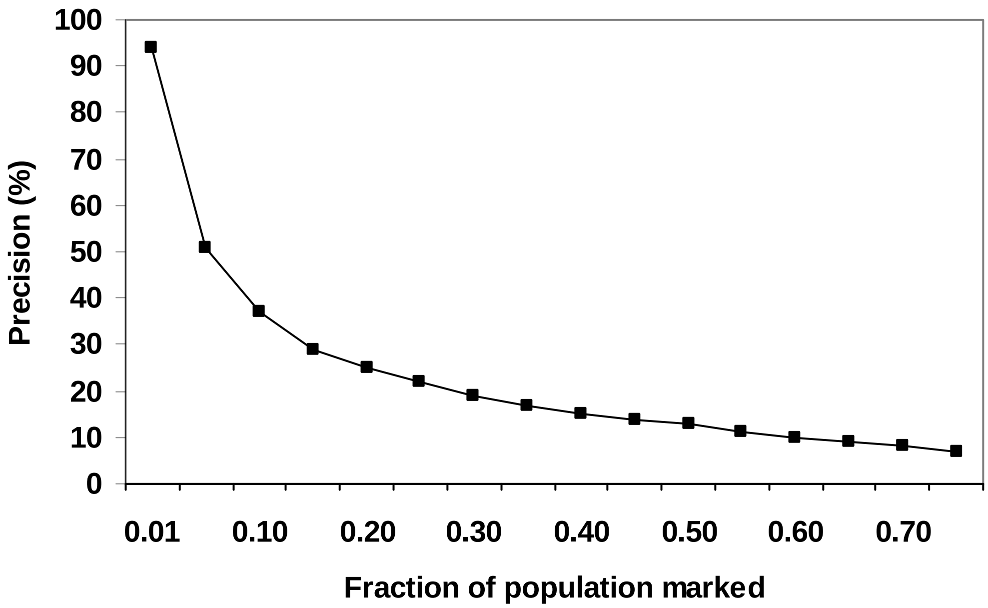
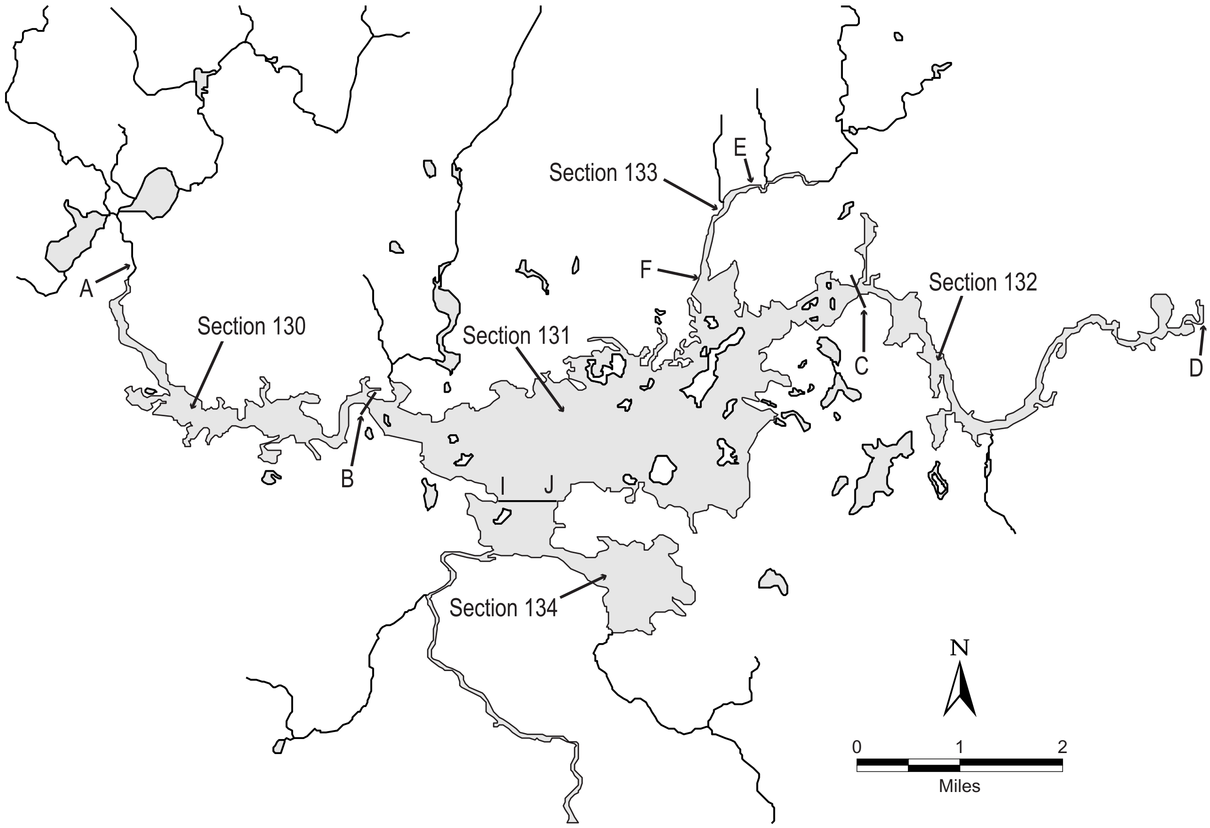
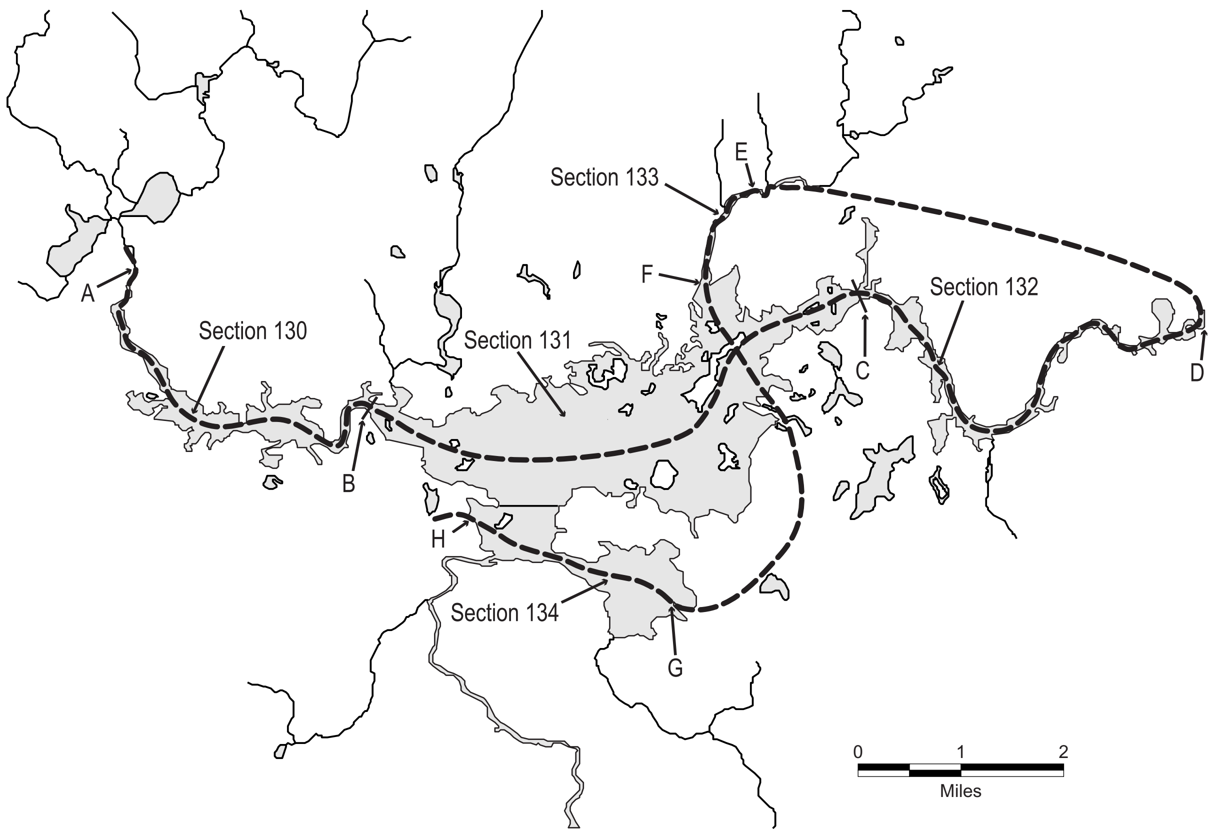


Figure 4.–Precision of walleye population estimate based on fraction of the population marked. Precision is expressed as a percentage and is the quotient of 2SE of the estimate with a given number marked and estimated population.



Map location code and description	Latitude	Longitude
A – WPA bridge	46°12.23′ N	88°19.11′ W
B – boundary between sections 130-131	46°10.93′ N	88°15.90′ W
C – boundary between sections 131-132	46°12.10′ N	88°09.42′ W
D – upper end of section 132	46°12.08′ N	88°04.83′ W
E – upper end of section 133	46°12.78′ N	88°11.31′ W
F – boundary between sections 131-133	46°12.15′ N	88°11.47′ W
I – west edge of section 131-134 boundary	46°10.04′ N	88°14.14′ W
J – east edge of section 131-134 boundary	46°10.04′ N	88°13.33′ W

Figure 5.–Michigamme Reservoir count and interview sections used during summer 2001 angler survey. Markers indicate section boundary line points.



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C – boundary between sections 131-132	46°12.10′ N	88°09.42′ W
D – upper end of section 132	46°12.08′ N	88°04.83′ W
E – upper end of section 133	46°12.78′ N	88°11.31′ W
F – boundary between sections 131-133	46°12.15′ N	88°11.47′ W
G – SE edge of section 134	46°09.18′ N	88°11.77′ W
H – west edge of section 134	46°09.92′ N	88°14.53′ W

Figure 6.–Aerial counting path, latitude and longitude coordinates for each of the 8 counting path markers, and count interview grids used during the Michigamme Reservoir angler creel survey, summer 2001.

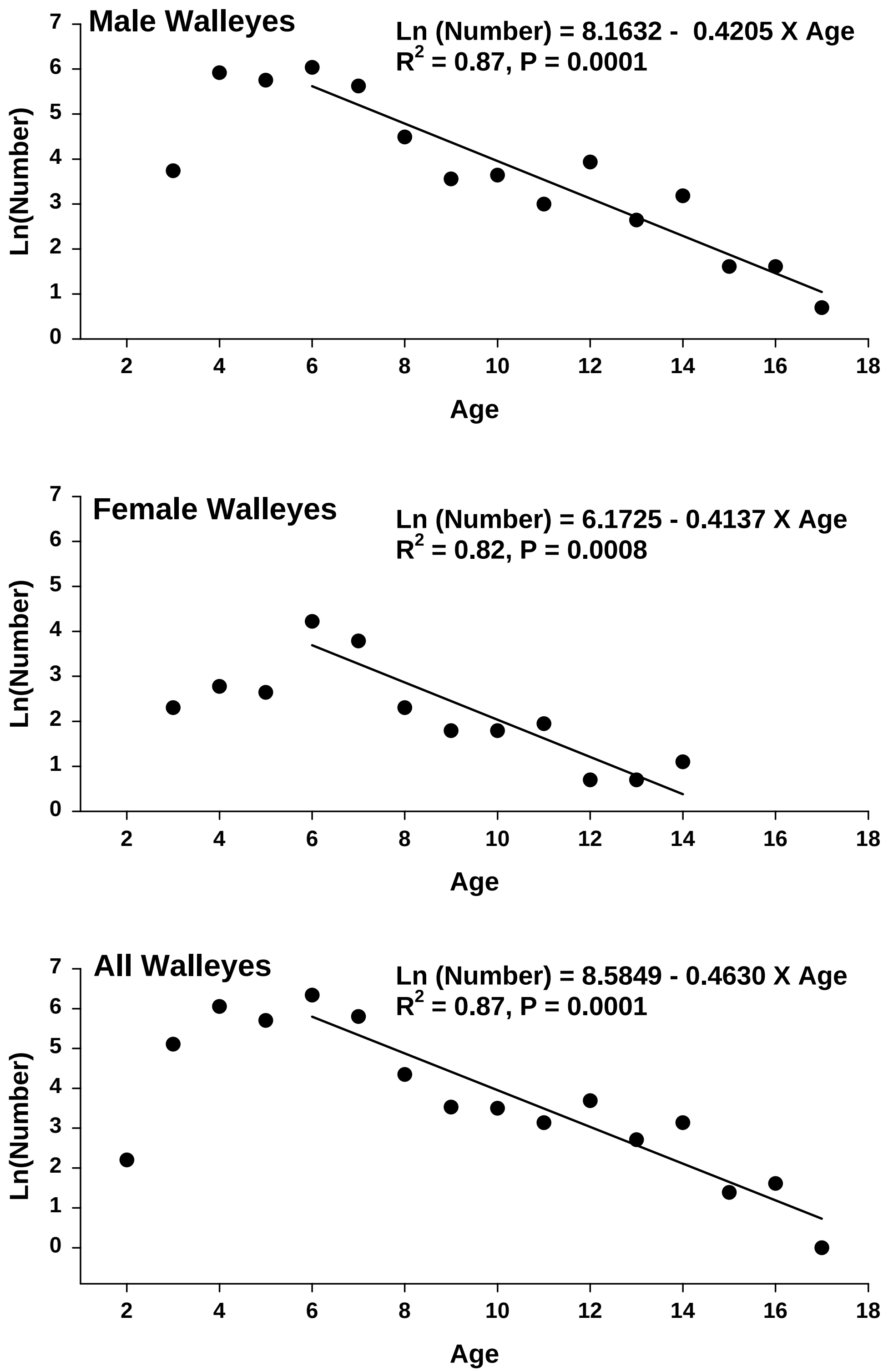

Figure 7.–Plots of observed ln(number) versus age for male, female, and all (including males, females, and unknown sex) walleyes in Michigamme Reservoir. Lines are plots of regression equations given beside each graph.

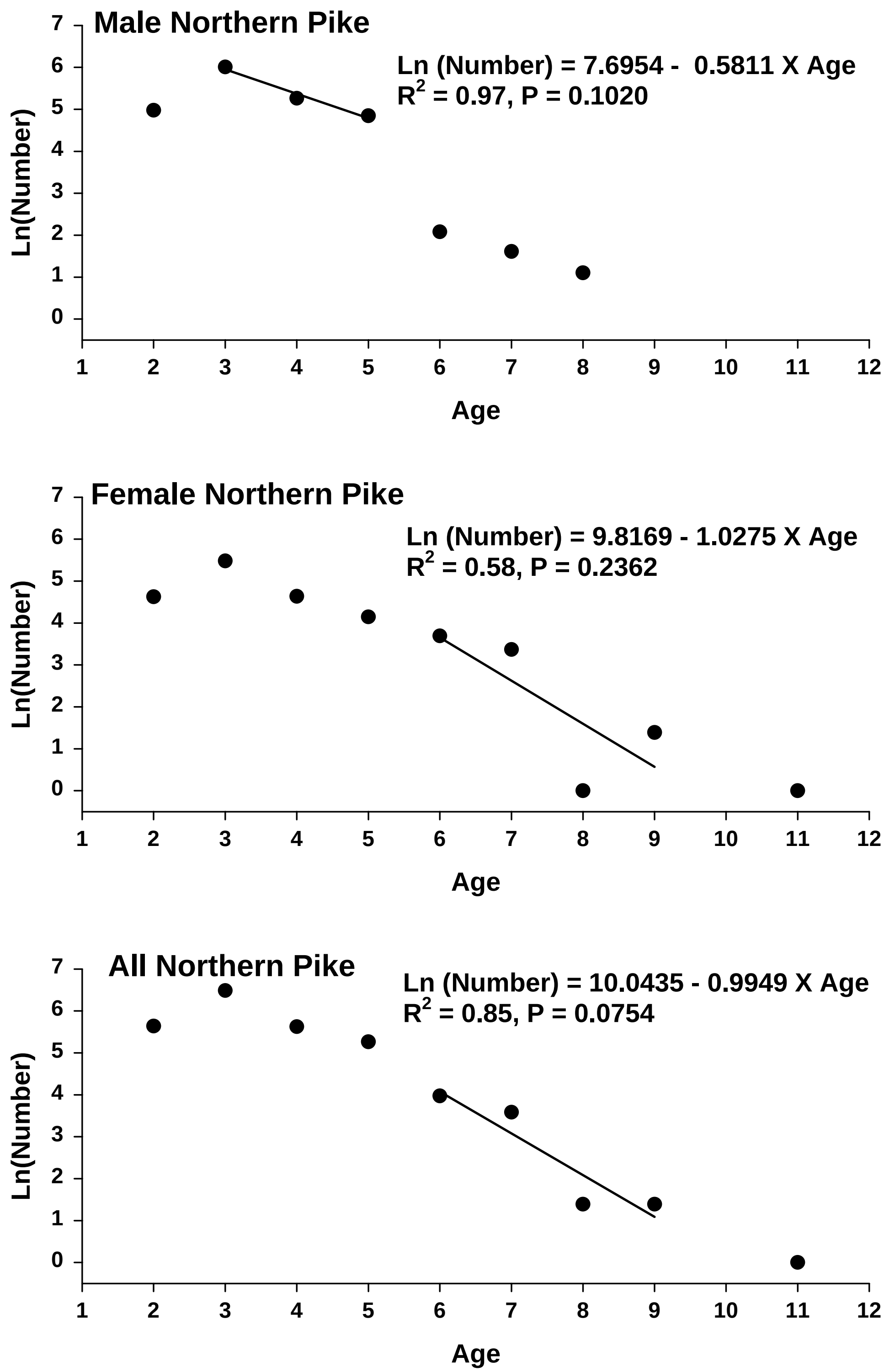

Figure 8.–Plots of observed ln(number) versus age for male, female, and all (including males, females, and unknown sex) northern pike in Michigamme Reservoir. Lines are plots of regression equations given beside each graph.

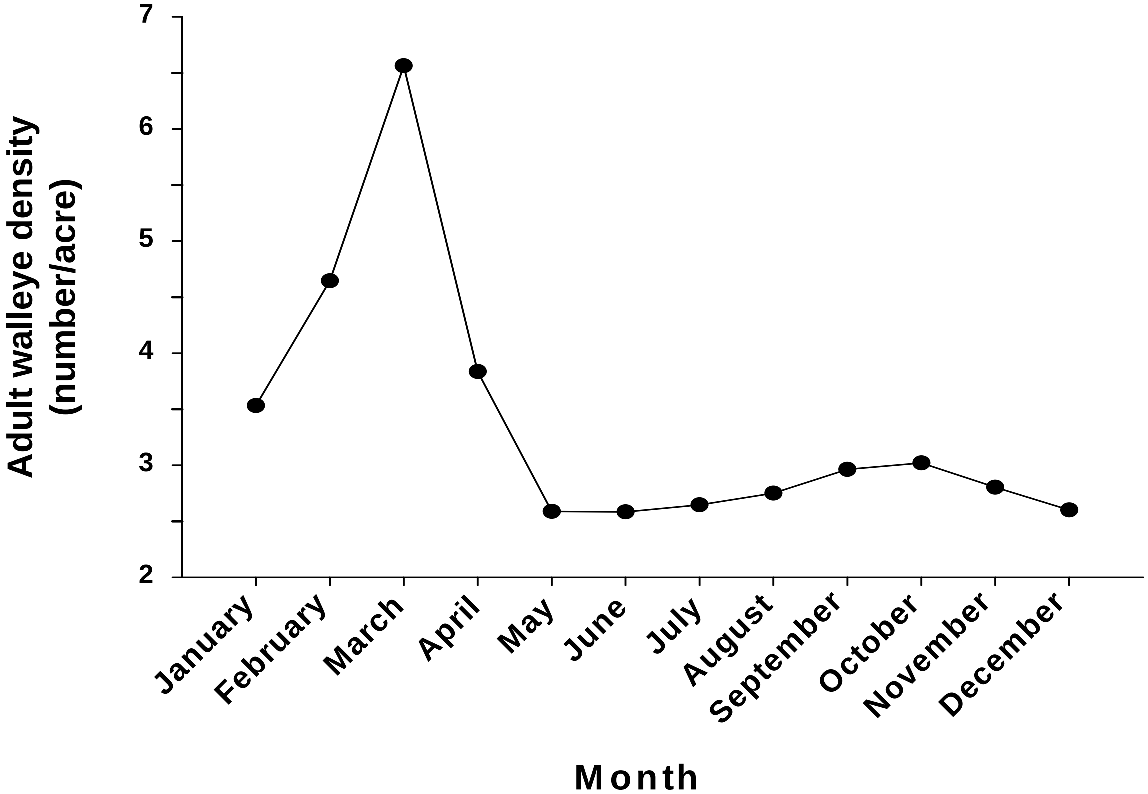

Figure 9–Density of adult (≥ 15 in, or < 15 in, but of identifiable sex) walleyes in relation to seasonal surface area (acres) in Michigamme Reservoir during the year 2001. We assumed mortality and recruitment were balanced throughout the year to maintain a constant abundance of 16,859 fish and that changes in density were due only to changes in surface area.

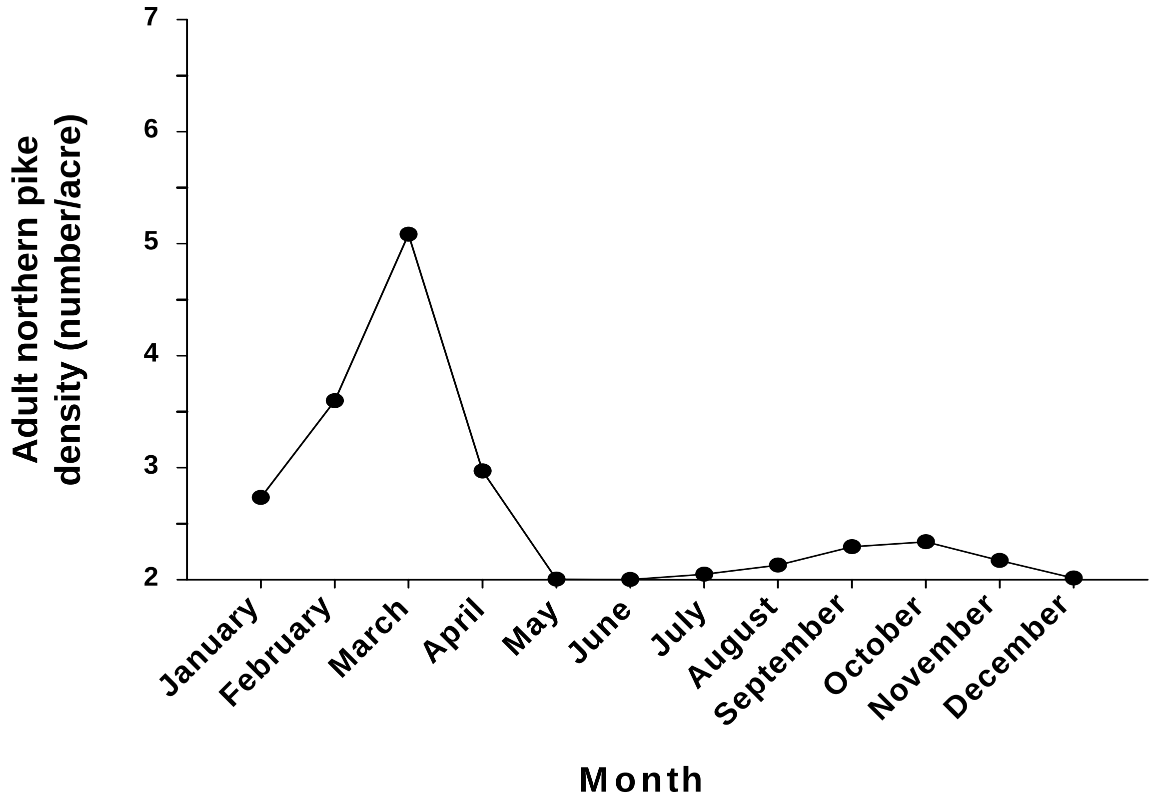

Figure 10.–Density of adult (≥ 15 in, or < 15 in, but of identifiable sex) northern pike in relation to seasonal surface area (acres) in Michigamme Reservoir during the year 2001. We assumed mortality and recruitment were balanced throughout the year to maintain a constant abundance of 13,052 fish and that changes in density were due only to changes in surface area.

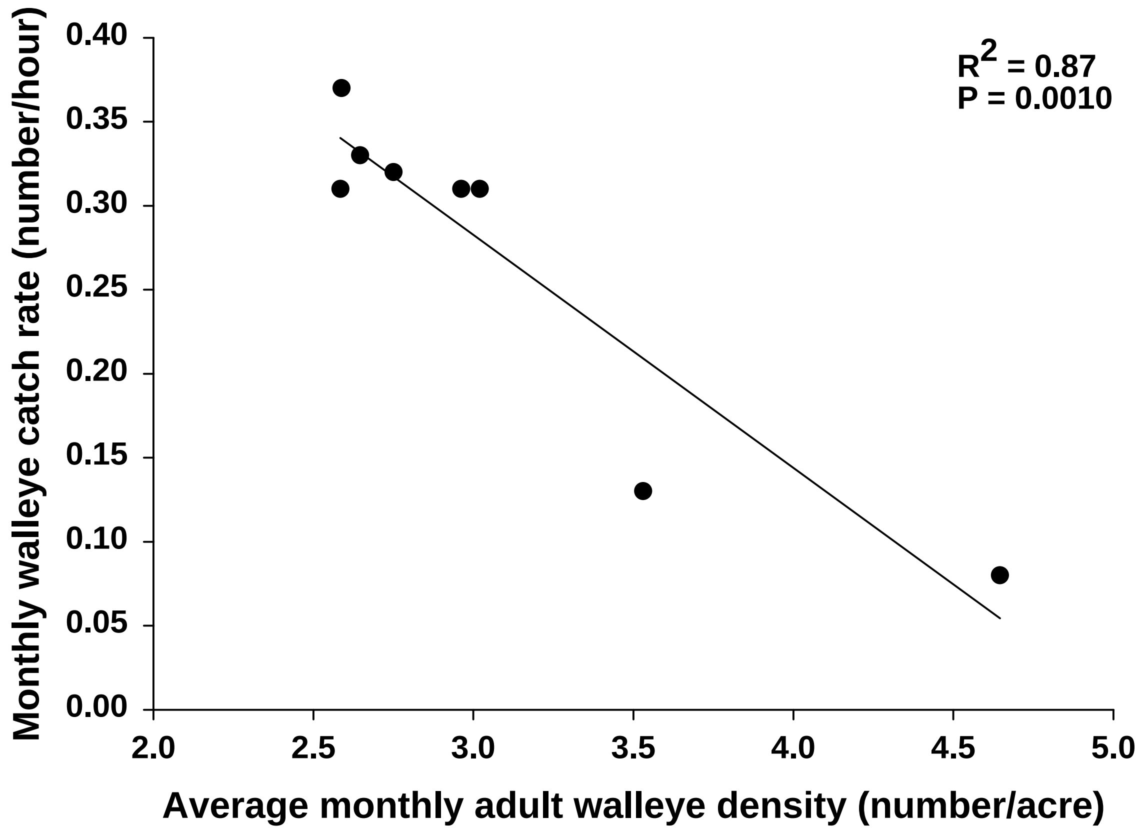

Figure 11.–Correlation between average monthly adult walleye density (number/acre based on acreage in 2001) and monthly walleye catch rate (number/hour) for Michigamme Reservoir.

Table 1.–Number and size of fish stocked in Michigamme Reservoir from 1985 through 2001.

Year	Source lake	Species	Number	Weight (lbs)	Average size (in)
1985	Mitchell	Yellow perch	–	640	5.2
1985	Chicagon	Yellow perch	–	15,823	–
1989	Little Smokey	Yellow perch	22,680	1,890	5.8
1989	Buck	Bluegill	6,400	–	–

Table 2.–Survey periods, sampling shifts, and expansion value "F" (number of fishing hours within a sample day) for Michigamme Reservoir angler creel survey, spring 2001 through winter 2002.

Survey period	Sample shifts (h)		F
May 15–31	0600–1430	1330–2200	16
June	0600–1430	1330–2200	18
July	0600–1430	1300–2130	18
August	0630–1500	1230–2100	17
September–October 14	0630–1500	1200–2030	16
December 28–December 31	0700–1530	0900–1730	13
January–February 28	0700–1530	1100–1930	13

Table 3.–Fish collected from Michigamme Reservoir using a total sampling effort of 207 fyke-net lifts and 10 electrofishing runs from April 19 to May 4, 2001.

Species	Total catch[a]	Percent by number	Mean fyke-net CPUE[b]	Length range (in)	Average length (in)	Number measured[c]
Walleyes	2,471	25.7	3.7	7.7–26.6	15.3	2,039
White sucker	2,364	24.6	8.4	5.7–25.0	19.3	326
Northern pike	1,861	19.3	6.0	9.6–39.9	19.4	1,504
Rock bass	1,442	15.0	4.2	4.0–11.2	7.9	460
Yellow perch	546	5.7	1.6	5.7–14.7	9.9	430
Black crappie	535	5.6	1.7	5.8–14.6	9.6	374
Bluegill	196	2.0	0.7	6.0–10.6	7.8	196
Smallmouth bass	127	1.3	0.3	10.6–20.8	14.7	127
Pumpkinseed	44	0.5	0.2	5.1–8.7	7.0	44
Longnose sucker	16	0.2	0.08	–	–	0
Burbot	10	0.1	0.03	11.9–21.0	17.6	10
Largemouth bass	8	<0.1	0.03	13.3–18.3	15.3	8
Brook trout	5	<0.1	0	9.5–13.6	11.0	5
Common shiner	1	<0.1	0	6.6	6.6	1
Lake whitefish	1	<0.1	0	18.8	18.8	1

[a] Includes recaptures
[b] Number per fyke-net night
[c] Does not include recaptures for northern pike and walleyes

Table 4.–Number of fish per inch group caught and measured in spring netting and electrofishing operations on Michigamme Reservoir, April 19 to May 4, 2001.

	Species													
Inch group	Walleyes	White sucker	Northern pike	Rock bass	Yellow perch	Black crappie	Bluegill	Smallmouth bass	Pumpkinseed	Burbot	Largemouth bass	Brook trout	Common shiner	Lake whitefish
2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4	–	–	–	4	–	–	–	–	–	–	–	–	–	–
5	–	1	–	27	2	1	–	–	1	–	–	–	–	–
6	–	–	–	105	12	4	18	–	22	–	–	–	1	–
7	2	–	–	103	60	5	98	–	19	–	–	–	–	–
8	8	–	–	109	76	73	65	–	2	–	–	–	–	–
9	9	1	1	74	77	211	9	–	–	–	–	2	–	–
10	25	1	–	35	74	33	6	1	–	–	–	–	–	–
11	45	3	1	3	63	6	–	11	–	1	–	2	–	–
12	76	1	5	–	47	29	–	26	–	–	–	–	–	–
13	296	3	24	–	15	11	–	15	–	–	4	1	–	–
14	500	4	51	–	4	1	–	20	–	–	–	–	–	–
15	480	13	89	–	–	–	–	11	–	2	–	–	–	–
16	237	13	127	–	–	–	–	22	–	1	2	–	–	–
17	146	21	188	–	–	–	–	11	–	2	1	–	–	–
18	124	45	237	–	–	–	–	5	–	1	1	–	–	1
19	45	91	227	–	–	–	–	3	–	–	–	–	–	–
20	19	48	180	–	–	–	–	2	–	2	–	–	–	–
21	9	44	137	–	–	–	–	–	–	1	–	–	–	–
22	9	25	102	–	–	–	–	–	–	–	–	–	–	–
23	2	7	40	–	–	–	–	–	–	–	–	–	–	–
24	1	4	38	–	–	–	–	–	–	–	–	–	–	–
25	3	1	15	–	–	–	–	–	–	–	–	–	–	–
26	3	–	12	–	–	–	–	–	–	–	–	–	–	–
27	–	–	3	–	–	–	–	–	–	–	–	–	–	–
28	–	–	2	–	–	–	–	–	–	–	–	–	–	–
29	–	–	4	–	–	–	–	–	–	–	–	–	–	–
30	–	–	2	–	–	–	–	–	–	–	–	–	–	–
31	–	–	2	–	–	–	–	–	–	–	–	–	–	–
32	–	–	4	–	–	–	–	–	–	–	–	–	–	–
33	–	–	1	–	–	–	–	–	–	–	–	–	–	–
34	–	–	4	–	–	–	–	–	–	–	–	–	–	–
35	–	–	–	–	–	–	–	–	–	–	–	–	–	–
36	–	–	2	–	–	–	–	–	–	–	–	–	–	–
37	–	–	–	–	–	–	–	–	–	–	–	–	–	–
38	–	–	4	–	–	–	–	–	–	–	–	–	–	–
39	–	–	2	–	–	–	–	–	–	–	–	–	–	–
40	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total	2,039	326	1,504	460	430	374	196	127	44	10	8	5	1	1

Table 5.–Estimates of abundance, angler exploitation rates, and instantaneous fishing mortality rates for Michigamme Reservoir walleyes and northern pike using the different methods described in text. Estimated 95% confidence intervals for estimates are given in parentheses.

	Walleyes	Northern pike
Number tagged	1,059	90
Total tag returns	273	10
Number of legal-sized[a] fish:		
Multiple-census method	2,371 (1,778–3,559)	234 (164–413)
Single-census method	9,540 (6,933–12,147)	842 (120–1,563)
Number of adult[b] fish:		
Multiple-census method	5,384 (3,905–8,662)	4,299 (3,315–6,114)
Single-census method	16,859 (12,265–21,452)	13,052 (2,247–23,856)
Wisconsin equation	20,174 (6,628–61,402)	na
Annual exploitation rates:		
Based on reward tag returns	29.3%	11.1%[c]
Based on harvest/abundance[d]	22.3% (14.7%–29.9%)	28.3% (0%–56.7%)
Instantaneous fishing rates (F):		
Based on reward tag returns	0.3655	0.1755
Based on harvest/abundance[d]	0.2784	0.4464

[a] Walleyes ≥ 15 in and northern pike ≥ 24 in.
[b] Estimated numbers of legal size fish, and sub-legal size fish of identifiable sex, on spawning grounds in April–May 2001.
[c] Annual exploitation for northern pike is based on reward and non-reward tag returns
[d] Single-census estimate of abundance.

Table 6.–Weighted mean lengths and sample sizes (number aged) by age and sex for walleyes collected from Michigamme Reservoir, April 19 to May 4, 2001. Standard error is in parentheses.

Age	Mean length (SE)						Number aged		
	Males		Females		All fish[a]		Males	Females	All fish[a]
2	–		–		8.3	(0.6)	–	–	9
3	13.2	(0.6)	13.2	(0.8)	12.5	(1.4)	10	14	76
4	14.1	(0.9)	14.8	(1.5)	14.0	(1.2)	45	16	90
5	14.7	(0.9)	16.1	(2.0)	14.8	(1.1)	25	13	41
6	15.1	(1.1)	16.7	(1.3)	15.5	(1.3)	35	55	91
7	16.0	(0.9)	17.3	(1.7)	16.2	(1.3)	28	36	64
8	16.4	(0.9)	19.0	(2.0)	16.8	(1.5)	12	8	20
9	18.2	(0.6)	20.3	(1.9)	18.7	(1.4)	9	6	15
10	18.4	(0.4)	23.8	(2.9)	19.4	(2.4)	10	5	15
11	18.9	(1.9)	22.8	(2.1)	20.3	(2.6)	6	6	12
12	18.3	(1.2)	22.5	(2.8)	18.7	(1.6)	17	2	19
13	19.4	(0.7)	22.0	(0.7)	19.9	(1.3)	7	2	9
14	18.8	(0.8)	23.2	(4.0)	19.3	(2.1)	9	2	11
15	20.3	(0.8)	–		20.2	(1.0)	3	–	3
16	19.5	(0)	–		19.5	(0)	3	–	3
17	20.5	(–)	–		20.5	(–)	1	–	1

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

Table 7.–Weighted mean lengths and sample sizes (number aged) by age and sex for northern pike collected from Michigamme Reservoir, April 19 to May 4, 2001. Standard error is in parentheses.

Age	Mean length (SE)						Number aged		
	Males		Females		All fish[a]		Males	Females	All fish[a]
2	15.9	(1.8)	16.4	(2.0)	16.0	(1.8)	49	45	94
3	18.3	(1.7)	19.3	(1.8)	18.8	(1.7)	58	60	118
4	20.0	(1.6)	21.6	(2.3)	20.6	(1.9)	33	31	64
5	20.8	(1.6)	21.9	(1.8)	21.3	(1.8)	29	21	51
6	23.8	(1.2)	25.8	(4.5)	25.3	(4.1)	5	29	35
7	28.5	(2.4)	25.2	(4.8)	25.6	(4.6)	5	16	21
8	24.5	(0)	36.5	(–)	27.5	(6.0)	2	1	3
9	–		36.3	(3.3)	36.3	(3.3)	–	4	4
10	–		–		–		–	–	–
11	–		34.0	(–)	34.0	(–)	–	1	1

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

Table 8.–Catch at age estimates (apportioned by age-length key) by sex for walleyes and northern pike collected from Michigamme Reservoir, April 19 to May 4, 2001.

Age	Year class	Walleyes			Northern Pike		
		Males	Females	All fish[a]	Males	Females	All fish[a]
2	1999	–	–	9	145	102	281
3	1998	42	10	165	406	240	654
4	1997	371	16	424	193	103	276
5	1996	314	14	299	127	63	193
6	1995	418	68	563	8	40	53
7	1994	276	44	329	5	29	36
8	1993	89	10	77	3	1	4
9	1992	35	6	34	–	4	4
10	1991	38	6	33	–	–	–
11	1990	20	7	23	–	1	1
12	1989	51	2	40	–	–	–
13	1988	14	2	15	–	–	–
14	1987	24	3	23	–	–	–
15	1986	5	–	4	–	–	–
16	1985	5	–	5	–	–	–
17	1984	2	–	1	–	–	–
Total		1,704	188	2,044	887	583	1,502

[a] Catch at age for ‘All fish’ includes males, females, and fish of unknown sex.

Table 9.–Angler survey estimates for summer 2001 from Michigamme Reservoir. Survey period was from May 15 through October 14, 2001. Two standard errors are given in parentheses.

Species	Catch/h	May	June	July	August	Sept–Oct	Season
		Number harvested					
Smallmouth bass	0.0108 (0.0056)	33 (39)	49 (56)	79 (89)	145 (137)	65 (59)	371 (187)
Walleyes	0.0611 (0.0177)	423 (227)	502 (301)	602 (334)	289 (140)	286 (123)	2,102 (537)
Yellow perch	0.0909 (0.0383)	91 (80)	597 (477)	715 (419)	504 (298)	1,220 (1,028)	3,127 (1,247)
Northern pike	0.0065 (0.0054)	33 (38)	11 (5)	65 (57)	74 (168)	42 (34)	225 (184)
Black crappie	0.0281 (0.0107)	42 (89)	1 (1)	206 (131)	482 (274)	235 (135)	966 (344)
Bluegill	0.0441 (0.0183)	0 (0)	67 (49)	312 (371)	707 (355)	430 (294)	1,516 (594)
Largemouth bass	0.0001 (0.0000)	0 (0)	0 (0)	0 (0)	0 (0)	3 (1)	3 (1)
Rock bass	0.0154 (0.0095)	12 (25)	41 (54)	211 (246)	202 (180)	65 (74)	531 (320)
White sucker	0.0003 (0.0001)	0 (0)	0 (0)	4 (2)	8 (2)	0 (0)	12 (3)
Other	0.0002 (0.0008)	7 (26)	0 (0)	0 (0)	0 (0)	0 (0)	7 (26)
Total harvested	0.2577 (0.0575)	641 (263)	1,268 (570)	2,194 (715)	2,411 (622)	2,346 (1,089)	8,860 (1,574)
		Number caught and released					
Smallmouth bass	0.0486 (0.0142)	190 (166)	344 (178)	383 (218)	526 (257)	229 (124)	1,672 (434)
Largemouth bass	0.0001 (0.0002)	0 (0)	4 (6)	0 (0)	0 (0)	0 (0)	4 (6)
Walleyes	0.2656 (0.0634)	1,470 (763)	1,501 (582)	2,321 (982)	2,236 (784)	1,603 (856)	9,131 (1,798)
Northern pike	0.1624 (0.0507)	658 (353)	1,177 (1,009)	1,051 (500)	1,600 (733)	1,098 (735)	5,584 (1,571)
Muskellunge	0.0000 (0.0000)	0 (0)	0 (0)	0 (0)	1 (0)	0 (0)	1 (0)
Total catch and release	0.4767 (0.0955)	2,318 (855)	3,026 (1,177)	3,755 (1,123)	4,363 (1,103)	2,930 (1,135)	16,392 (2,425)
Total catch (harvest & release)	0.7344 (0.1299)	2,959 (895)	4,294 (1,307)	5,949 (1,331)	6,774 (1,267)	5,276 (1,572)	25,252 (2,891)
		Fishing effort					
Angler hours		5,115 (1,837)	6,411 (2,111)	8,865 (2,632)	7,908 (1,682)	6,084 (1,983)	34,383 (4,638)
Angler trips		2,936 (1,742)	4,391 (1,466)	5,292 (2,244)	5,567 (1,607)	3,866 (2,190)	22,052 (4,195)

Table 10.–Angler survey estimates for winter 2002 from Michigamme Reservoir. Survey period was from Dec 29, 2001 through February 28, 2002. Two standard errors are given in parentheses.

Species	Catch/h		December–January[a]		February		Season	
			Number harvested					
Walleyes	0.0553	(0.0178)	439	(208)	574	(163)	1,013	(264)
Yellow perch	0.0173	(0.0072)	157	(102)	160	(57)	317	(117)
Northern pike	0.0083	(0.0032)	32	(10)	120	(51)	152	(52)
Black crappie	0.0263	(0.0114)	154	(98)	328	(161)	482	(188)
Bluegill	0.0041	(0.0010)	71	(12)	4	(1)	75	(12)
Total harvest	0.1114	(0.0284)	853	(252)	1,186	(240)	2,039	(348)
			Number caught and Released					
Smallmouth bass	0.0001	(0.0000)	1	(0)	0	(0)	1	(0)
Largemouth bass	0.0033	(0.0009)	21	(7)	40	(10)	61	(12)
Walleyes	0.0449	(0.0146)	392	(166)	430	(140)	822	(217)
Northern pike	0.1297	(0.0401)	691	(260)	1,682	(519)	2,373	(580)
Total catch and release	0.1779	(0.0477)	1,105	(308)	2,152	(537)	3,257	(619)
Total catch (harvest & release)	0.2894	(0.0671)	1,958	(398)	3,338	(588)	5,296	(710)
			Fishing effort					
Angler hours			6,397	(1,996)	11,906	(2,831)	18,303	(3,464)
Angler trips			2,066	(651)	3,008	(707)	5,074	(961)

[a] All shanty counts during the December–January period were 0. However, 29 shanty anglers were interviewed and empirical data from these interviews are included in the December–January estimates. Inclusion of these data provide minimum December–January shanty estimates.

Table 11.–Angler survey estimates for summer and winter 2001–02 from Michigamme Reservoir. Survey period was May 15 through October 14, 2001 and Dec 29, 2001 through February 28, 2002. Two standard errors are given in parentheses.

Species	Catch/h	May 2001	June 2001	July 2001	August 2001	Sept–Oct 2001	Dec–Jan[a] 2001–02	February 2002	Season
		Number harvested							
Smallmouth bass	0.0070 (0.0036)	33 (39)	49 (56)	79 (89)	145 (137)	65 (59)	0 (0)	0 (0)	371 (187)
Walleyes	0.0591 (0.0131)	423 (227)	502 (301)	602 (334)	289 (140)	286 (123)	439 (208)	574 (163)	3,115 (599)
Yellow perch	0.0654 (0.0248)	91 (80)	597 (477)	715 (419)	504 (298)	1,220 (1,028)	157 (102)	160 (57)	3,444 (1,253)
Northern pike	0.0072 (0.0037)	33 (38)	11 (5)	65 (57)	74 (168)	42 (34)	32 (10)	120 (51)	377 (192)
Black crappie	0.0275 (0.0080)	42 (89)	1 (1)	206 (131)	482 (274)	235 (135)	154 (98)	328 (161)	1,448 (392)
Bluegill	0.0302 (0.0118)	0 (0)	67 (49)	312 (371)	707 (355)	430 (294)	71 (12)	4 (1)	1,591 (594)
Largemouth bass	0.0001 (0.0000)	0 (0)	0 (0)	0 (0)	0 (0)	3 (1)	0 (0)	0 (0)	3 (1)
Rock bass	0.0101 (0.0062)	12 (25)	41 (54)	211 (246)	202 (180)	65 (74)	0 (0)	0 (0)	531 (320)
White sucker	0.0002 (0.0001)	0 (0)	0 (0)	4 (2)	8 (2)	0 (0)	0 (0)	0 (0)	12 (3)
Other	0.0001 (0.0005)	7 (26)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	7 (26)
Total harvested	0.2069 (0.0381)	641 (263)	1,268 (570)	2,194 (715)	2,411 (622)	2,346 (1,089)	853 (252)	1,186 (240)	10,899 (1,612)
		Number caught and released							
Smallmouth bass	0.0318 (0.0089)	190 (166)	344 (178)	383 (218)	526 (257)	229 (124)	1 (0)	0 (0)	1,673 (434)
Largemouth bass	0.0012 (0.0003)	0 (0)	4 (6)	0 (0)	0 (0)	0 (0)	21 (7)	40 (10)	65 (14)
Walleyes	0.1889 (0.0402)	1,470 (763)	1,501 (582)	2,321 (982)	2,236 (784)	1,603 (856)	392 (166)	430 (140)	9,953 (1,811)
Northern pike	0.1510 (0.0359)	658 (353)	1,177 (1,009)	1,051 (500)	1,600 (733)	1,098 (735)	691 (260)	1,682 (519)	7,957 (1,675)
Musky	0.0000 (0.0000)	0 (0)	0 (0)	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)	1 (0)
Total released	0.3729 (0.0627)	2,318 (855)	3,026 (1,177)	3,755 (1,123)	4,363 (1,103)	2,930 (1,135)	1,105 (308)	2,152 (537)	19,649 (2,503)
Total (harvested & released)	0.5798 (0.0852)	2,959 (895)	4,294 (1,307)	5,949 (1,331)	6,774 (1,267)	5,276 (1,572)	1,958 (398)	3,338 (588)	30,548 (2,977)
		Fishing effort							
Angler hours		5,115 (1,837)	6,411 (2,111)	8,865 (2,632)	7,908 (1,682)	6,084 (1,983)	6,397 (1,996)	11,906 (2,831)	52,686 (5,789)
Angler trips		2,936 (1,742)	4,391 (1,466)	5,292 (2,244)	5,567 (1,607)	3,866 (2,190)	2,066 (651)	3,008 (707)	27,126 (4,304)

[a] All shanty counts during the December–January period were 0. However, 29 shanty anglers were interviewed and empirical data from these interviews are included in the December–January estimates. Inclusion of these data provide minimum December–January shanty estimates.

Table 12.–Angler tag returns from walleyes (reward and non-reward) by month for the year following tagging.

Month	Number of tag returns	Percentage of total
1	15	5.5
2	21	7.7
3	0	0.0
4	1	0.4
5	48	17.6
6	91	33.3
7	36	13.2
8	22	8.1
9	26	9.5
10	6	2.2
11	0	0.0
12	7	2.6
Total	273	100

Table 13.–Angler tag returns from northern pike (reward and non-reward) by month for the year following tagging.

Month	Number of tag returns	Percentage of total
1	3	30.0
2	0	0
3	0	0
4	0	0
5	2	20.0
6	3	30.0
7	1	10.0
8	0	0
9	1	10.0
10	0	0
11	0	0
12	0	0
Total	10	100

Table 14.–Mean lengths of walleyes from the 2001 survey of Michigamme Reservoir compared to other surveys. Number aged in parentheses.

Age	State average[a]	Mean lengths							
		Michigamme 2001[b]	Michi gamme 1987[c]	Cisco 1990[b,c]	Thousand Island 1990[b,d]	Gogebic 1999[b]	Peavy Pond 1999[e]	Bond Falls 1999[f]	Lake Michigamme 2002[f]
2	10.4	8.3 (9)	9.8 (5)	9.0 (7)	10.3 (4)		10.8 (9)	8.5 (1)	8.3 (2)
3	13.9	12.5 (76)	12.7 (29)	12.1 (8)	13.7 (5)	11.4 (1)	11.5 (2)		10.4 (4)
4	15.8	14.0 (90)	14.4 (34)	13.7 (8)	15.1 (8)	13.0 (1)	15.5 (3)	14.5 (3)	11.9 (1)
5	17.6	14.8 (41)	15.7 (73)	14.9 (9)	15.1 (1)	13.8 (34)	16.9 (1)	15.7 (11)	12.7 (5)
6	19.2	15.5 (91)	16.8 (59)	17.6 (2)	16.8 (4)	16.4 (2)			15.1 (2)
7	20.6	16.2 (64)	17.8 (50)	19.0 (5)	18.6 (7)	16.7 (1)		18.7 (1)	14.5 (1)
8	21.6	16.8 (20)	18.4 (31)	17.9 (4)	20.5 (1)	17.1 (10)			16.7 (1)
9	22.4	18.7 (15)	18.5 (15)	20.0 (1)	18.2 (1)	17.0 (3)		22.0 (1)	
10	23.1	19.4 (15)	18.9 (28)	24.0 (2)	22.5 (1)	17.8 (7)			21.4 (1)
11		20.3 (12)	19.2 (39)			17.3 (2)			
12		18.7 (19)	19.7 (22)						18.4 (1)
13		19.9 (9)	19.9 (9)			20.1 (3)			
14		19.3 (11)	21.7 (3)	26.5 (2)					
15		20.2 (3)	19.4 (2)						
16		19.5 (3)	22.0 (1)						22.3 (1)
17		20.5 (1)							
Mean growth index[g]		-3.2	-2.4	-1.9	-1.0	-3.3	-2.5	-2.3	-5.3

[a] Jan–May averages from Schneider et al (2000), aged using scales.
[b] Fish collected in the spring and aged using spines.
[c] From Deephouse (1993b).
[d] From Deephouse (1993a).
[e] Fish collected in the fall and aged using spines.
[f] Fish collected in June and aged using spines.
[g] The mean deviation from the statewide quarterly average. Only age groups where N ≥ 5 were used.

Table 15.–Mean lengths of northern pike from the 2001 survey of Michigamme Reservoir compared to other surveys. Number aged in parentheses.

		Mean lengths													
Age	State average[a]	Michigamme 2001[b]		Michigamme 1987[c]		Lac Vieux Desert 1998[b]		Thousand Island 1997[c]		Peavy Pond 1999[d]		Bond Falls 1999[c]		Lake Michigamme 2002[c]	
2	17.7	16.0	(94)	16.3	(21)	14.5	(3)	17.9	(2)	17.6	(4)	17.5	(5)	17.1	(8)
3	20.8	18.8	(118)	18.9	(79)	16.3	(17)	21.0	(5)			19.6	(7)	19.4	(17)
4	23.4	20.6	(64)	22.3	(25)	19.4	(10)	24.5	(1)	21.4	(1)	21.5	(9)	23.6	(6)
5	25.5	21.3	(51)	24.8	(27)	24.5	(1)					23.7	(4)	22.8	(5)
6	27.3	25.3	(35)	29.2	(9)	19.4	(2)					31.7	(1)	28.5	(10)
7	29.3	25.6	(21)											34.8	(8)
8	31.2	27.5	(3)											31.5	(1)
9		36.3	(4)											32.1	(1)
10															
11		34.0	(1)												
12															
Mean growth index[e]		-2.7		-0.6		-4.3		-0.8		–		-2.1		-0.5	

[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 summer and aged using spines.
[d] Fish collected in the fall and aged using spines.
[e] The mean deviation from the statewide quarterly average. Only age groups where N ≥ 5 were used.

Table 16.–Comparison of recreational fishing effort and total harvest on Michigamme Reservoir to those of other selected Michigan lakes. Lakes are listed from highest to lowest total fishing effort. Lake size was from Laarman (1976).

Lake, County	Size (acres)	Survey period	Total fishing effort (h)	Fish harvested (number)	Fish harvested per h	Hours fished per acre	Fish harvested per acre
Michigan[a], many	–	Jan–Nov 2001	2,684,359	677,360	0.25	–	–
Huron[a], many	–	Jan–Oct 2001	1,807,519	1,057,819	0.59	–	–
Houghton, Roscommon (All year)	20,075	Apr 2001–Mar 2002	499,048	386,287	0.77	24.9	19.2
Erie[a], Wayne and Monroe	–	Apr–Oct 2001	490,807	378,700	0.77	–	–
Houghton, Roscommon (Summer only)	20,075	Apr–Sep 2001	278,214	325,148	1.17	13.9	16.2
Superior[a], many	–	Apr–Oct 2001	180,428	60,947	0.34	–	–
Fletcher Pond, Alpena and Montmorency	8,970	May–Sep 1997	171,521	118,101	0.69	19.1	13.2
Burt, Cheboygan	17,120	Apr–Sep 1993	134,957	20,734	0.15	7.9	1.2
Gogebic, Ontonagon and Gogebic	13,380	May 1998–Apr 1999	121,525	26,622	0.22	9.1	2.0
Mullett, Cheboygan	16,630	May–Aug 1998	87,520	18,727	0.21	5.3	1.1
Michigamme Reservoir, Iron	6,400	May 2001–Feb 2002	52,686	10,899	0.21	8.2	1.7

[a] Does not include charter boat harvest or effort.

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Appendix–Fish species captured in Michigamme Reservoir from 1985 through 2001 using various gear types.

Common name	Scientific name
Species we collected in 2001 with fyke nets and electrofishing gear	
Black crappie	*Pomoxis nigromaculatus*
Bluegill	*Lepomis macrochirus*
Brook trout	*Salvelinus fontinalis*
Burbot	*Lota lota*
Common shiner	*Notropis cornutus*
Lake whitefish	*Coregonus clupeaformis*
Largemouth bass	*Micropterus salmoides*
Longnose sucker	*Catostomus catostomus*
Northern pike	*Esox lucius*
Pumpkinseed	*Lepomis gibbosus*
Rock bass	*Ambloplites rupestris*
Smallmouth bass	*Micropterus dolomieu*
Walleye	*Sander vitreus*
White sucker	*Catostomus commersonii*
Yellow perch	*Perca flavescens*
Additional species collected with electrofishing gear (1990–2001)	
Bluntnose minnow	*Pimephales notatus*
Golden shiner	*Notemigonus crysoleucas*
Johnny darter	*Etheostoma nigrum*
Logperch	*Percina caprodes*
Sculpin, unidentified	*Cottus* sp.
Additional species collected with seines (Michaud 1985)	
Darter, unidentified	*Etheostoma* sp.