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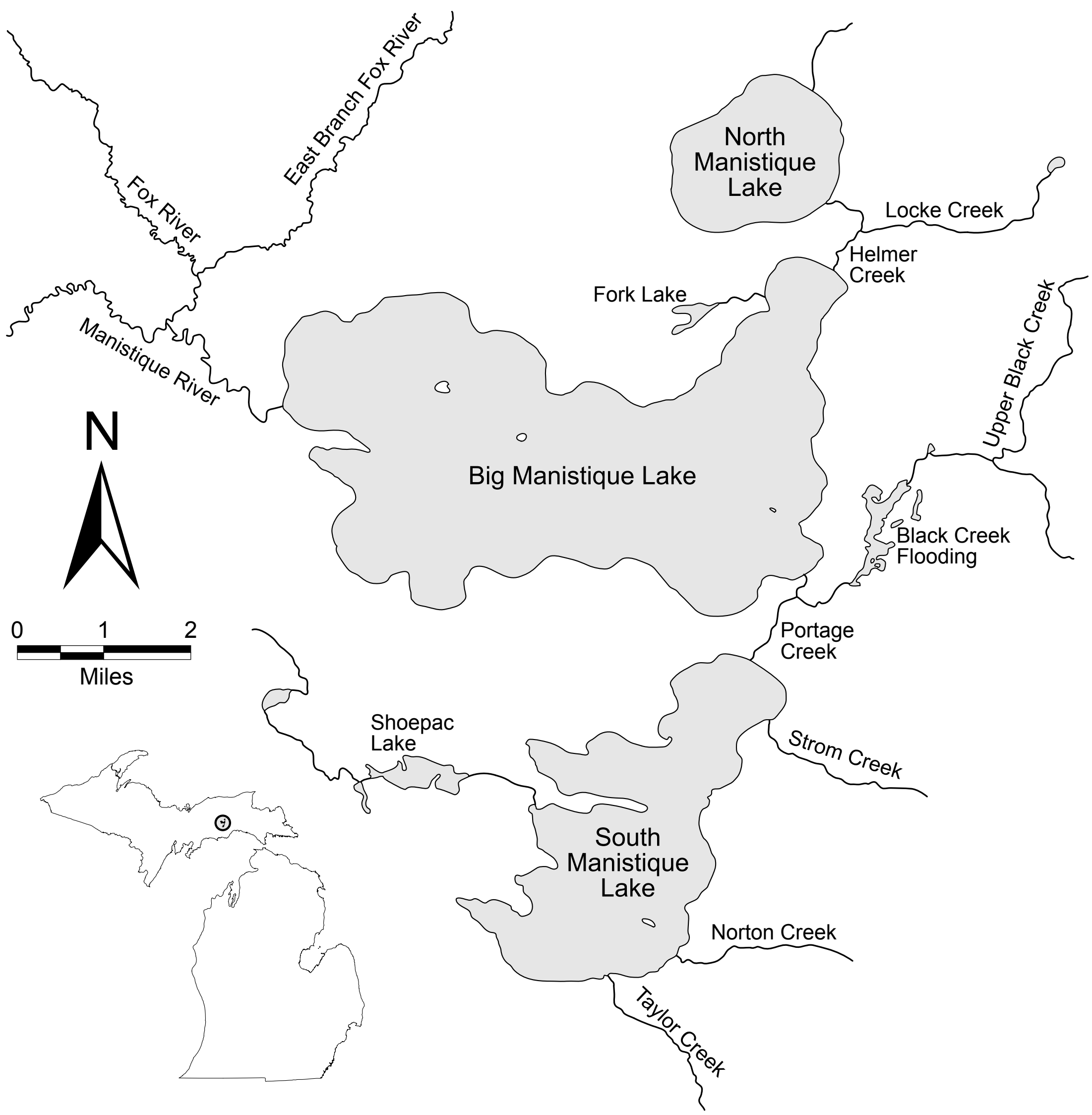
The Fish Community and Fishery of Big Manistique Lake, Luce and Mackinac Counties, Michigan in 2003–04 with Emphasis on Walleyes, Northern Pike, and Smallmouth Bass

Patrick A. Hanchin and Darren R. Kramer



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Michigan Department of Natural Resources
Fisheries Special Report 43, 2007

The Fish Community and Fishery of Big Manistique Lake, Luce and Mackinac Counties, Michigan in 2003–04 with Emphasis on Walleyes, Northern Pike, and Smallmouth Bass

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Introduction

Michigan Department of Natural Resources (MDNR), Fisheries Division surveyed fish populations and angler catch and effort at Big Manistique Lake, Luce and Mackinac County, Michigan from April 2003 through March 2004. This work was part of the Large Lakes Program, which is designed to improve assessment and monitoring of fish communities and fisheries in Michigan's largest inland lakes (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 were defined as species susceptible to trap or fyke nets and/or those readily harvested by anglers. Our goal is to produce statistics for important fishes to help detect major changes in their populations over time. Second, we want to produce growth and mortality statistics to evaluate effects of fishing on species which support valuable fisheries. This usually involves targeted sampling to collect, sample, and mark sufficient numbers of fish. We selected walleyes *Sander vitreus*, northern pike *Esox lucius*, and smallmouth bass *Micropterus dolomieu* as special-interest species in this survey of Big Manistique Lake. 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 three types of exploitation rate estimators in this survey of Big Manistique Lake.

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 among lakes or changes within a lake over time. Big Manistique Lake is only the ninth lake to be sampled under the protocols of the program; thus, we were limited in our ability to make valid comparisons among lakes. As the program progresses, we will eventually have a large body of netting data collected under the same conditions that will facilitate comprehensive analyses.

Study Area

The surface area of Big Manistique Lake is approximately 10,000 acres, with sources disagreeing only slightly on size. Humphrys and Green (1962) estimated 10,130 surface acres for Big Manistique Lake by taking measurements from United States Geological Survey (USGS) maps using handheld drafting tools. Breck (2004) estimated 10,346 acres as the surface area for Big Manistique Lake by using computerized digitizing equipment and USGS topographical maps. Boundaries of the lake polygon from the Michigan Digital Water Atlas Geographical Information System and aerial photos of the lake showed good agreement using ArcView© (ESRI, Inc., Redlands, California, http://www.esri.com/software/arcgis/index.html). In the Large Lakes Program, we 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, we will use the more modern estimate of 10,346 acres as the size of Big Manistique Lake in our analyses.

Big Manistique Lake is fed by Helmer Creek on the north and Portage Creek on the south (Figure 1). Portage Creek flows from South Manistique Lake into Big Manistique Lake and contains a small control structure designed to elevate the South Manistique Lake water level for summer recreation (Madison and Lockwood 2004). The Portage Creek Dam allows fish passage in both directions during most flows. Helmer Creek, a designated trout stream, is the outlet of North Manistique Lake, and also has a lake-level control structure (Tressler Dam). Tressler Dam allows downstream fish passage, but upstream fish passage is likely difficult for many species due to the shallow depth below the dam. A dam on Black Creek is owned by MDNR Wildlife Division and creates the Black Creek Flooding. The Manistique River is an outlet on the west side of Big Manistique Lake and drains to Lake Michigan. The Manistique Lake Dam is approximately four miles downstream of the lake, and immediately downstream of the confluence with the Fox River. The dam blocks upstream fish passage to Big Manistique Lake through the Manistique River, though fish can move between the Fox River and Big Manistique Lake (Madison and Lockwood 2004).

The shoreline of Big Manistique Lake is largely developed with private and commercial residences; the only public frontage can be found at the four boat access sites. The maximum depth of Big Manistique Lake is approximately 20 feet. The bathymetry is relatively uniform, and most of the lake (85% by area) is less than 15 feet deep (Figures 2 and 3). The substrate in shallow areas consists of sand, gravel, and rock, and substrate in deeper areas is sand and organic matter. Aquatic vegetation is sparse, and located in shallow areas and as submerged beds.

Water chemistry analyses were completed on Big Manistique Lake in 1936 with 3 stations sampled during the middle of August (Laarman 1976). Summer dissolved oxygen concentrations ranged from 9.1–8.5 parts per million (ppm) from the bottom to the surface. Methyl orange alkalinity (ppm) was 87, and pH ranged from 7.8–8.1.

The fish community of Big Manistique Lake includes species typical of northern Michigan. We listed common and scientific names of all fish species captured during this study in the Appendix. Henceforth, we will refer to fishes only by common name in the text. Families of fish include, but are not limited to: Cyprinidae, Catostomidae, Centrarchidae, Esocidae, Ictaluridae, Percidae, and Salmonidae. Prey species include: minnows, white suckers, shorthead redhorse, silver redhorse, panfish, and lake herring. Panfish species such as yellow perch and rock bass are common in Big Manistique Lake; bluegill are present, but less common.

Fish stocking in Big Manistique Lake has involved a variety of species, ages, and sizes dating to 1935. Walleye fry were stocked in 1935, and stocking of this species did not resume until 1970, when either fry or fingerlings were annually stocked through 1980. Stocking ceased until recently, when both walleye fry and fall fingerlings were stocked in 2005. Lake sturgeon were stocked in Big Manistique Lake in 1983, 1984, 1988, 1990, and 1993, and smallmouth bass were stocked in 1998 (Table 1).

There have been three State of Michigan Master Angler award fish taken from Big Manistique Lake during 1994–2005, including northern pike, rock bass, and smallmouth bass.

Methods

We used the same methods on Big Manistique Lake described by Clark et al. (2004) for Houghton Lake. We give a complete overview of methods in this report, but refer the reader to Clark et al. (2004) for additional details. Concurrent with our survey of Big Manistique Lake, we surveyed South and North Manistique lakes using identical methods.

Fish Community

We evaluated the status of the fish community in terms of species present, catch per unit effort, percent by number, and size distribution. We also collected more detailed data for walleyes, northern pike, and smallmouth bass (as described below). We sampled fish populations in Big Manistique Lake with trap nets and fyke nets from April 23 to May 2, 2003. We used three boats daily to work nets, each with three-person crews. Each net-boat crew tended about 10 nets per day.

Fyke nets were 6 ft x 4 ft with 2-in stretch mesh and 70- to 100-ft leads. Trap nets were 8 ft by 6 ft by 3 ft with 2-in stretch mesh and 70- to 100-ft leads. Duration of net sets was 1–2 nights, but most were 1 night. Latitude and longitude were recorded for all net locations using handheld global positioning systems (GPS). Nets were set in a non-random manner, in order to target walleyes.

We identified species and counted all fish captured. For non-target species, we measured lengths to the nearest 0.1 in for sub-samples of up to 200 fish per work crew. Lengths were taken over the duration of the survey to account for any temporal trends in the size structure of fish collected. Size distribution data only included measurements from initial captures (i.e., not recaptures). We recorded mean catch per unit effort (CPUE) in fyke nets and trap nets as indicators 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).

Schneider et al. (2000b) cautioned that trap net and fyke net collections provide “imperfect snapshots” of fish community composition in lakes. Yet, with proper consideration of gear biases and sampling time frames, some indices of species composition might provide useful insight into fish community dynamics. We calculated the percents by number of fish we collected in each of three feeding guilds: 1) species that are primarily piscivores; 2) species that are primarily pelagic planktivores and/or insectivores; and 3) species that are primarily benthivores. These indices will be used to compare fish communities among lakes or within the same lake over time, especially in the future when more large lake surveys using similar methods are available for comparison. Of the species we collected, we classified walleyes, northern pike, smallmouth bass, and largemouth bass as piscivores; rock bass, bluegill, pumpkinseed, yellow perch, lake herring, central mudminnow, and brook trout as pelagic planktivores-insectivores; and suckers and bullheads as benthivores.

Walleyes, Northern Pike, and Smallmouth Bass

Size structure.–All walleyes, northern pike, and smallmouth bass were measured to the nearest 0.1 in. Size structures were characterized as length frequencies indicating numbers collected per inch group (e.g., numbers of 10.0–10.9-in, 11.0–11.9-in), and only included fish measured on their initial capture occasion.

Sex composition.–We recorded sex of walleyes and northern pike when flowing gametes were present. Fish with no flowing gametes were identified as unknown sex. For smallmouth bass, sex determination was usually not possible because we were collecting them several weeks prior to their spawning time.

Abundance.–We estimated abundance of legal-size walleyes using mark-and-recapture methods. Walleyes were fitted with monel-metal jaw tags. In order to assess tag loss, we double-marked each tagged fish by also clipping the left pelvic fin. Reward ($10) and non-reward tags were applied in an approximate 1:1 ratio. Initial tag loss was assessed during the marking period as the proportion of recaptured fish of legal size without tags. 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.

There was one prior abundance estimate for walleyes in Big Manistique Lake to help us gauge how many fish to mark. In 2000, the MDNR estimated 9,484 (8,320 – 10,648) spawning walleyes based on a multiple-census estimate from spring netting that was concentrated in the north end of the lake. The authors suggested that there was potentially 20,000 to 30,000 spawning walleyes based on the assumption that only one portion of the spawning habitat was surveyed.

We also used two regression equations developed for Michigan lakes (MDNR unpublished data) to provide additional estimates of abundance. These regressions predict legal and adult (≥15 in or <15 in, but of identifiable sex) walleye abundance based on lake size, and were derived from historic abundance estimates made in Michigan over the past 20 years. Abundance estimates were derived using multiple-census and single-census methods, and lakes included populations with both natural reproduction and stocking. The following equation for adult walleyes was based on 35 abundance estimates:

$$\ln(N) = 0.1087 + 1.0727 \times \ln(A),$$

$$R^2 = 0.84, \qquad P = 0.0001,$$

where N is the estimated number of adult walleyes and A is the surface area of the lake in acres. For Big Manistique Lake, the equation gives an estimate of 22,585 adult walleyes, with a 95% prediction interval (Zar 1999) of 5,199 to 98,118.

The equation for legal walleyes was based on 21 estimates:

$$\ln(N) = 0.3323 + 1.0118 \times \ln(A),$$

$$R^2 = 0.85, \qquad P = 0.0001.$$

The equation gives an estimate of 16,086 legal walleyes, with a 95% prediction interval (Zar 1999) of 3,289 to 78,673 for Big Manistique Lake. Based on these previous estimates, we targeted approximately 2,000 legal walleyes (approximately 10%) for marking in Big Manistique Lake.

We compared two different abundance estimates from mark-and-recapture data, one derived from marked-unmarked ratios during the spring survey (multiple-census), and one derived from marked-unmarked ratios from the angler survey (single-census). Sample size was increased for the single-census estimates by using recapture data from a standard summer netting survey of the lake.

For the multiple-census estimate, we used the Schumacher-Eschmeyer formula (± 95% symmetrical confidence limits) from daily recaptures during the tagging operation. The minimum number of recaptures necessary for an unbiased estimate was set a priori at four (Ricker 1975). For the single-census estimate, we used numbers of marked and unmarked fish observed during the companion angler survey and those observed during a summer netting survey as the “recapture-run” sample. The Chapman modification of the Petersen method (Ricker 1975) was used to generate population estimates (± 95% symmetrical confidence limits). Probability of tag loss was calculated as the number of fish in a recapture sample with fin clips and no tag, divided by all fish in the recapture sample that had been tagged, including fish that had lost their tag. Standard errors were calculated assuming a binomial distribution (Zar 1999). For more details on methods for abundance estimates, see Clark et al. (2004).

We accounted for fish that recruited to legal size between the spring marking period and the creel survey sample by removing a portion of the unmarked fish observed by the angler survey clerk (i.e., reduced C in the Petersen formula for abundance estimate). Removal of unmarked fish 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 methods see Clark et al. (2004) and Ricker (1975). This adjusted ratio was used to make the primary (single census) population estimates.

Due to statewide size regulations for recreational fishing, single-census estimates were only for walleyes 15 in or greater. Because we clipped fins and recorded recaptures of all walleyes, we were also able to make a direct multiple-census estimate of adult walleyes 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 estimates by dividing our estimate of walleyes 15 in or greater by the proportion of adult walleyes on the spawning grounds that were 15 in or greater, using the equation in Clark et al. (2004).

The reliability of all abundance estimates was assessed using the coefficient of variation (CV; standard deviation/mean). Following the methods of Hansen et al. (2000), we considered abundance estimates with a CV of 0.40 or less to have adequate precision.

Mean lengths at age.–We used dorsal fin spines to age walleyes and smallmouth bass, and dorsal fin rays to age northern pike. We used these structures because 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 length-at-age data from Big Manistique Lake and methods given in Lockwood and Hayes (2000). For walleye and northern pike our goal was to collect aging structures from 20 male and 20 female fish per inch group. For smallmouth bass, we had a target of 20 total fish 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, leaving extra samples (5 per inch group) in case some samples were difficult to read. Two technicians independently aged samples. 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 either of the first two. For cases in which all three technicians disagreed on age, samples were either discarded if assigned ages were greater than 10% from each other, or an average age was used when assigned ages were within ±10% of each other (i.e., assigned ages = 12, 13, and 14).

After a final age was assigned for all samples, weighted mean lengths-at-age and age-length keys (Devries and Frie 1996) were computed for males, females, and all fish (males, females, and fish of unknown sex combined) for walleyes and northern pike. Where sample sizes were sufficient, weighted mean lengths-at-age and age-length keys were computed for smallmouth bass, without partitioning for sex.

We compared our mean lengths at age to those from previous surveys of Big Manistique Lake 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. (2000a). The mean growth index is the average of deviations between the observed mean length and the quarterly statewide average length. In addition, we fit mean length-at-age data to a von Bertalanffy growth equation using nonlinear regression, and calculated the total length at infinity (L_{∞}) for use as an index of growth potential. All growth curves were forced through the origin. The total length at infinity is a mathematically-derived number representing the length that an average fish approaches if it lives to age infinity, and grows according to the von Bertalanffy curve (Ricker 1975).

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.

We estimated angler exploitation rates using three methods: 1) the percent of reward tags returned by anglers; 2) the estimated harvest divided by the multiple-census estimate of abundance; and 3) the estimated harvest divided by the single-census estimate of abundance. We compared these three 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 (adjusted for tag loss) returned by anglers. We did not estimate tagging mortality or account for incomplete reporting of reward tags. We made the assumption that mortality was negligible and that 100% of reward tags on fish caught by anglers would be returned. Although we did not truly account for non-reporting, we did compare the actual number of tag returns to the number we expected (X) based on the ratio:

$$\frac{N_t}{N_C} = \frac{X}{H}$$

where,

N_t = Number of tags observed in creel,
N_c = Number of fish observed in creel,
H = Total expanded harvest of species.

Additionally, we compared the number of individual tags observed by the creel clerk to that subsequently reported by the anglers. However, this was also not a true estimate of non-reporting, because there is the possibility that some anglers believed the necessary information was obtained by the creel clerk during the interview, and further reporting to the MDNR was unnecessary.

Voluntary tag returns were encouraged with a monetary reward ($10) denoted on approximately ½ of the tags deployed. 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 (http://www.michigan.gov/dnr/0,1607,7-153-10364-44584--,00.html). All tag return data were entered into the database so that they could be efficiently linked to, and verified against, data collected during the tagging operation. Return rates were calculated separately for reward and non-reward tags.

In the second and third methods, we calculated exploitation as the estimated annual harvest from the angler survey divided by the multiple- and single-census abundance estimates for legal-size fish. For proper comparison with the single-census abundance of legal fish as existed in the spring, the estimated annual harvest was adjusted for non-surveyed months (using tag returns), and 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, 1987; Madenjian et al. 1996; 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, walleye stocking can affect year-class strength. However, stocking success is 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 Big Manistique Lake for only one year, and so could not rigorously evaluate year-class strength. However, valuable insight about the relative variability of recruitment can be gained by examining the 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.

Following Maceina (2003), we assumed the residuals of our catch-curve regressions were an index of year-class strength, and related this index to various environmental variables by using correlation, simple linear, and multiple regression analyses. Historic weather data were obtained from the National Weather Service observation station in Newberry, MI (station 205816). We did not have any associated water temperature data specific to the lake itself. Annual variables that we evaluated included: average monthly air temperature, average monthly minimum air temperature, minimum monthly air temperature, average monthly maximum air temperature, maximum monthly air temperature, and average monthly precipitation.

Movement.–Fish movements were assessed in a descriptive manner, by comparing 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, northern pike, and muskellunge during this survey were May 15, 2003–February 28, 2004. Fishing harvest seasons for smallmouth bass and largemouth bass were May 24 through December 31, 2003. Minimum size limits were 15 in for walleyes, 24 in for northern pike, 42 in for muskellunge, and 14 in for both smallmouth bass and largemouth bass. Daily bag limit was 5 fish, in any combination of walleyes, northern pike, smallmouth bass, or largemouth bass; with no more than two northern pike permitted in the daily bag.

Harvest was permitted all year for all other species present. No minimum size limits were imposed for other species. 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. Bag limit for lake herring was 12 fish.

Direct contact angler creel surveys were conducted during one spring–summer period – May 8 to October 15, 2003 – and one winter period – December 27, 2003 through March 28, 2004. Different methods were employed for summer and winter surveys.

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. 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 the period were Memorial Day (May 26, 2003), Independence Day (July 4, 2003), and Labor Day (September 1, 2003). 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. All count and interview data were collected and recorded by section, and effort and catch estimates were made by section.

Two different directions of aerial counting paths were used (Figure 4), selection of which was randomized. Counting began at Marker 1 and proceeded along the flight path ending at Marker 23; or counting began at Marker 23 and proceeded along the flight path ending at Marker 1. 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 20 min to complete with an air speed of about 100 mph. Counting was done by the contracted pilot, and only fishing boats were counted (i.e., watercrafts 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 included: date, count time, and number of fishing boats in each section.

This survey was designed to collect roving (incomplete-trip) interviews. Minimum fishing time prior to interview (incomplete-trip interview) was 1 h (Lockwood 2004). Historically, minimum fishing time prior to interviewing has been 0.5 h (Pollock et al. 1997). However, recent evaluations have shown that roving interview catch rates from anglers fishing a minimum of 1 h are more representative of access interview (completed-trip interview) catch rates (Lockwood 2004). Access interviews include information from complete trips and are appropriate standards for comparison. All roving interview data were collected by individual angler, to avoid party-size bias (Lockwood 1997).

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 of a completed trip.

Interview information collected included: date, section, fishing mode, start time of fishing trip, interview time, species targeted, bait used, number of fish harvested by species, number of fish caught and released by species, length of harvested walleyes, northern pike, smallmouth bass, and muskellunge, and tag number (where applicable). Number of anglers in each party was recorded on one interview form for each party.

The creel clerk also recorded presence or absence of jaw tags and fin clips, tag numbers, and lengths of walleyes, northern pike, smallmouth bass, and muskellunge. These data were used to estimate tag loss and to determine the ratio of marked-unmarked fish for single-census abundance estimates.

One of two shifts was selected each sample day for interviewing (Table 2). Interview starting location (Table 3, Figure 4) and direction were randomized daily. Scanner-ready interview forms, information, and techniques used during the summer survey period were the same as those used during the winter survey period.

Winter.–We used a progressive-roving design for winter surveys (Lockwood 2000b). One clerk working from a snowmobile collected count and interview data. Both weekend days and three randomly selected weekdays were selected for sampling during each week of the survey season. No holidays were sampled. Holidays during the winter sampling period were: New Year’s Day (January 1, 2004), Martin Luther King Day (January 19, 2004), and President’s Day (February 16, 2004). The clerk followed a randomized count and interview schedule. One of two shifts was selected each sample day (Table 2). Starting location (Figure 5) and direction of travel were randomized for both counting and interviewing.

Progressive (instantaneous) counts of open-ice anglers and occupied shanties were made once per day. Count information collected included: date, section, fishing mode (open ice or shanty), count time, and number of units (anglers or occupied shanties) counted.

Similar to summer interview methods, minimum fishing time prior to interviewing was 1 h. No anglers were interviewed while counting (Wade et al. 1991). Additional interviewing instructions and interview information collected followed methods for the summer survey period.

Estimation methods.–Catch and effort estimates were made by section, using a multiple-day method (Lockwood et al. 1999). Expansion values (number of hours within sample days, or "F" in Lockwood et al. 1999) are given in Table 2. Effort is the product of mean counts by section 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; i.e., no expansions were made to include periods not sampled (e.g., 2200 to 2400 or 0000 to 0600 hours).

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

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

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

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

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

From the angler 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). Angler trips differ from angler days because multiple trips can be made within a day. Historically, Michigan anglers have made on average 1.2 trips per day (MDNR Fisheries Division – unpublished data).

All creel estimates are reported as $\overline{X}$ ± 2 SE. Error bounds indicate statistical significance, assuming a normal distribution shape and $N \geq 10$ (per month), of 75% to 95% (Dixon and Massey 1957). All boat counts 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 of catch rates from normality.

Results[1]

Fish Community

We collected a total of 11,507 fish of 15 species (Table 4). Total sampling effort was 93 trap-net lifts and 98 fyke-net lifts. We captured 4,689 walleyes and 214 northern pike. Other game species collected in order of abundance of total catch were: yellow perch, rock bass, smallmouth bass, brook trout, lake herring, bluegill, pumpkinseed, and largemouth bass. Yellow perch comprised 8.5% of the catch by number. Mean length of this species was 7.3 in. Twenty percent of the rock bass collected were 8 in or larger (Table 5) and mean length was 6.8 in. Smallmouth bass captured during the survey represented 1.9% of the total catch by number. Sixty-five percent of those collected were legal size. Largemouth bass are present in Big Manistique Lake, yet rather uncommon based on survey catches. White suckers are common in Big Manistique Lake (Table 4); other common non-game fish included shorthead and silver redhorse, brown bullhead, and central mudminnow. The overall fish community composition in Big Manistique Lake was 45% piscivores, 11% pelagic planktivores-insectivores, and 44% benthivores (Table 4).

Walleyes, Northern Pike, and Smallmouth Bass

Size structure.–The percentage of walleyes, northern pike, and smallmouth bass that were legal size was 92, 50, and 66, respectively (Table 5). The population of spawning walleyes was dominated by 15- to 24-in walleyes, with none greater than 26 in. Northern pike were widely distributed among 12- to 49-in groups, with the majority from 18 to 27 in. Large pike (≥ 30 in) were relatively common, making up 17% of the total catch. Smallmouth bass, though few, were predominately 13- to 17-in fish; no fish over 19 in were collected.

Sex composition.–Male walleyes outnumbered females in our spring survey, which is typical for walleyes (Carlander 1997). Of all walleyes captured, 64% were male, 32% were female, and 4% were of unknown sex. Of legal-size walleyes captured, 64% were male, 35% were female, and 1% were of unknown sex. The sex ratio for northern pike appeared more balanced than walleyes; however, many fish were of unknown sex. Of all northern pike captured, 44% were male, 35% were female, and 21% were of unknown sex. Of legal-size northern pike captured, 45% were male, 45% were female, and 10% were of unknown sex. We did not identify the sex of enough smallmouth bass to accurately report the ratio of males to females.

Abundance.–We placed a total of 3,381 tags on legal-size walleyes (1,507 reward and 1,874 non-reward tags) and clipped fins of 280 sub-legal walleyes. Twenty-five recaptured walleye were observed to have died, or lost their tag during the spring netting/electrofishing survey; thus, the effective number tagged was 3,356. This initial 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.

The angler survey clerk observed a total of 73 walleyes on Big Manistique Lake, of which 21 were marked (had a fin clip or a tag). In a standard summer netting survey, we observed an additional 70 walleyes, of which 20 were marked. We reduced the number of unmarked walleyes in the single-census calculation by two fish to adjust for sub-legal fish that grew over the minimum size limit during the fishing season. We observed four fish that had a fin clip, no tag, and were determined to have been legal size at the time of tagging. Based on the sample of 41 recaptured fish, the estimate of tag loss is 9.8%, with a standard error of 0.2%.

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[1] We provide confidence limits for estimates in relevant tables, but not in the text.

The estimated number of legal-size walleyes was 7,384 using the multiple-census method and 11,350 using the single-census method (Table 6). The estimated number of adult walleyes was 8,070 using the multiple-census method, and 11,856 using the single-census method. The coefficient of variation (CV = standard deviation/estimate) was 0.04 for the two multiple-census estimates, and 0.13 for the single-census estimates.

We tagged 99 legal-size northern pike in Big Manistique Lake (47 reward and 52 non-reward tags). Two fish were observed to have died or lost tags during the spring netting survey so the effective number tagged was 97. We also clipped fins of 104 sub-legal northern pike. The creel clerk observed 31 northern pike, of which one was marked. In the summer netting survey we observed an additional thirteen northern pike, of which none were marked. We did not reduce the number of unmarked northern pike in the single-census calculation to adjust for sub-legal fish that grew over the minimum size limit during the fishing season. The only recaptured fish that was legal size at the time of tagging had apparently lost its tag. Although this undoubtedly indicates tag loss to some degree, the sample size was not sufficient to estimate a tag loss rate.

The estimated number of legal-size northern pike was 6,195 (CV = 1.21) using the multiple-census method, though the minimum number of recaptures (four) was not reached for this estimate. The estimated number of legal-size northern pike was 2,156 (CV = 0.56) using the single-census method. The estimated number of adult northern pike was 2,901 (CV = 0.39) using the multiple-census method and 3,642 (CV = 0.56) using the single-census method (Table 6).

We tagged 140 legal-size smallmouth bass in Big Manistique Lake (57 reward and 83 non-reward tags). No recaptured fish were observed to have died or lost tags during the spring netting. We also clipped fins of 76 sub-legal smallmouth bass. The creel clerk observed 17 smallmouth bass, of which one was tagged. In the summer netting survey we observed an additional twelve smallmouth bass, of which two were marked. We reduced the number of unmarked smallmouth bass by one in the single-census calculation to adjust for sub-legal fish that grew over the minimum size limit during the fishing season. There was no tag loss for smallmouth bass observed by the creel clerk. The estimated number of legal-size smallmouth bass was 5,510 (CV = 0.86) using the multiple-census method and 1,022 (CV = 0.42) using the single-census method (Table 6). The minimum number of recaptures was not obtained for the multiple-census estimate.

Mean lengths at age.–For walleyes, there was 50% agreement between the first two spine readers. For fish that were aged by a third reader, agreement was with first reader 77% of the time and with second reader 23% of the time; thus, there appeared to be some bias among readers. Eight percent of samples were discarded due to poor agreement, and an average age was used 2% of the time. At least two out of three readers agreed 89% of the time.

Female walleyes had higher mean lengths at age than males in Big Manistique Lake (Table 7). Females were 3 in longer than males at age 9 (Table 7). This sexually dimorphic growth is typical for walleye (Colby et al. 1979; Carlander 1997; Kocovsky and Carline 2000).

We calculated a mean growth index for walleyes of +0.4; indicating walleye mean lengths at age for Big Manistique Lake were higher than the state average. Mean length at age data for male, female, and all walleyes were fit to a von Bertalanffy growth curve. Male, female, and all walleyes had L_∞ values of 20.7, 24.0, and 23.3 in, respectively.

For northern pike, there was 68% agreement between the first two fin ray readers. For fish that were aged by a third reader, agreement was with the first reader 77% of the time and with the second reader 23% of the time; thus, there appeared to be some bias among readers. Less than 1% of samples were discarded due to poor agreement, and an average age was used for 1% of the samples. At least two out of three readers agreed 98% of the time.

Female northern pike generally had higher mean lengths-at-age than males (Table 8). Females were 5.7 in longer than males at age 5. As with walleyes, this is a typical pattern for northern pike (Carlander 1969; Craig 1996).

We calculated a mean growth index for northern pike of +3.4. Mean length-at-age data for male, female, and all northern pike were fit to a von Bertalanffy growth curve. Male, female, and all northern pike had L_∞ values of 28.1, 48.9, and 49.0 in, respectively.

For smallmouth bass, there was 64% agreement between the first two spine readers. For fish that were aged by a third reader, agreement was with the first reader 80% of the time and with the second reader 20% of the time; thus, there appeared to be some bias among readers. No samples were discarded due to poor agreement, and no average ages were used. At least two out of three readers agreed 100% of the time.

We calculated a mean growth index for smallmouth bass of +1.3. Mean length at age data for smallmouth bass (Table 9) were fit to a von Bertalanffy growth curve, and the resulting L_∞ value was 19.1 in.

Mortality.–For walleyes, we estimated catch-at-age using data from 2,347 males, 1,195 females, and 3,680 total walleyes, including those fish of unknown-sex (Table 10). We used ages 7 and older in the catch-curve analysis to represent the legal-size male population (Figure 6). We chose age 7 as the youngest age because: 1) average length of male walleyes at age 7 was 19.2 in, so likely all age-7 fish were legal size at the beginning of fishing season; and 2) relative abundance of fish younger than age 7 do not appear to be represented in proportion to their expected abundance (Figure 6; Table 10). We used ages 7 through 14 in the catch-curve analyses representing the legal-size female, and all walleye population based on the fact that a high proportion of age-7 fish were legal size at the beginning of fishing season, and fish younger than age 7 do not appear to be represented in proportion to their expected abundance. We did not use ages 15 and 16 because the influence of these three aged fish was not consistent with the proportion at age for majority of the adult walleye.

The catch-curve regressions for walleyes were all significant ($P < 0.05$), and produced total instantaneous mortality rates for legal-size fish of 0.7176 for males, 0.2352 for females, and 0.3709 for all fish combined (Figure 6). These instantaneous rates corresponded to annual mortality rates of 51% for males, 21% for females, and 31% for all walleyes combined.

Anglers returned a total of 245 tags (126 reward and 119 non-reward) from harvested walleyes, and one tag (reward) from released walleyes, in Big Manistique Lake in the year following tagging. The creel clerk also observed 5 tagged fish in the possession of anglers that were not subsequently reported to the central office by the anglers. The reward tag return estimate of annual exploitation of walleyes was 9.4% after adjusting for 9.8% tag loss (Table 6). Anglers reported reward tags at a higher rate than non-reward tags (8.4% versus 6.4%), and they likely did not fully report either type. The reporting rate of non-reward tags relative to reward tags (λ *in* Pollock et al. 1991) was 76%. Based on all tagged walleyes known to be caught, the reported release rate was 0.4%.

The estimated exploitation rate for walleyes was 22.8% based on dividing harvest by the multiple-census abundance estimate, and 14.8% based on dividing harvest by the single-census creel survey abundance estimate (Table 6).

For northern pike, we estimated catch at age for 95 males, 73 females, and 210 total northern pike, including those fish of unknown-sex (Table 10). We used ages 3 and older in the catch-curve analyses to represent the northern pike population (Figure 7). We chose age 3 as the youngest age because the average length of male, female, and all northern pike at age 3 was greater than legal size, and the relative abundance of age-3 fish appear to be represented in proportion to their expected abundance (Figure 7; Table 10).

The catch-curve regressions for female and all northern pike were significant ($P < 0.05$), and that for males was nearly significant (Figure 7). Total instantaneous mortality rates were 0.351 for males, 0.244 for females, and 0.376 for all fish combined. These instantaneous rates corresponded to annual mortality rates of 30% for males, 22% for females, and 31% for all northern pike combined.

Anglers returned a total of 21 tags (10 reward and 11 non-reward) from harvested northern pike, and no tags from released northern pike in Big Manistique Lake 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 reward tag return estimate of annual exploitation of northern pike was 22.4%. Anglers reported reward tags at a similar rate to non-reward tags (21.3% versus 22.0%), and they likely did not fully report either type. The reporting rate of non-reward tags relative to reward tags (λ *in* Pollock et al. 1991) was 103%. No tagged northern pike were reported as being released.

The estimated exploitation rate for northern pike was 14.8% based on dividing harvest by the multiple-census abundance estimate, and 42.6% based on dividing harvest by the single-census creel survey abundance estimate (Table 6).

For smallmouth bass, we estimated catch-at-age for 217 fish of all sexes (Table 10). We used ages 4 and older in the catch-curve analyses to represent the legal-size smallmouth bass population (Figure 8). We chose age 4 as the youngest age because the average length-at-age 4 was equal to legal size, and age-4 fish appear to be represented in proportion to their true abundance (Figure 8; Table 10).

The catch-curve regression for smallmouth bass was significant ($P < 0.05$; Figure 8). The total instantaneous mortality rate was 0.599, which corresponds to an annual mortality rate of 45%.

Anglers returned a total of 22 tags (12 reward and 10 non-reward) from harvested smallmouth bass, and four tags (2 reward and 2 non-reward) from released smallmouth bass in Big Manistique Lake in the year following tagging. The creel clerk observed one tagged fish in the possession of an angler that was not subsequently reported to the central office. The reward tag return estimate of annual exploitation of smallmouth bass was 21.1%. Anglers reported reward tags at a higher rate than non-reward tags (21.1% versus 12.0%), and they likely did not fully report either one. The reporting rate of non-reward tags relative to reward tags (λ *in* Pollock et al. 1991) was 57.2%. Based on all tagged smallmouth bass known to be caught, the reported release rate was 14.8%.

The estimated exploitation rate for smallmouth bass was 8.6% based on dividing harvest by the multiple-census abundance estimate, and 46.6% based on dividing harvest by the single-census creel survey abundance estimate (Table 6).

Recruitment.–For walleyes in Big Manistique Lake, variability in year-class strength (based on catch at age of adult walleyes) was relatively high. Residual values from the catch curve regression were large (e.g., see scatter of observed values around the regression line for all walleyes, Figure 6) and the amount of variation explained by the age variable was relatively low ($R^2 = 0.82$). We did not find any relationships between climatological variables and walleye year-class strength in Big Manistique Lake, but water temperature and water quality data specific to the lake and weather data specific to the region are lacking. For northern pike and smallmouth bass, the amount of variation explained by the age variable (R^2) was 0.79 and 0.90, respectively, and there were similarly no relationships between climatological variables and year-class strength.

Movement.–Based on recaptures during the spring survey, there was movement of walleyes between Big and South Manistique lakes (Table 11). A total of 935 walleyes tagged in Big Manistique Lake were recaptured during the spring netting survey; of those, 99.6% were recaptured in Big Manistique Lake, and 0.4% were recaptured in South Manistique Lake. Movement of walleyes between Big and South Manistique lakes was also observed from voluntary tag returns (Table 12). Of walleyes recaptured by anglers, 96.3% were recaptured in Big Manistique Lake and 3.7% were recaptured in South Manistique Lake. There was no between-lake movement of northern pike or smallmouth bass detected during our spring survey, or from angler tag returns throughout the year following tagging.

Angler Survey

The clerk interviewed 1,248 boating anglers during the summer 2003 survey on Big Manistique Lake. Most interviews (91%) were roving (incomplete-fishing trip). Anglers fished an estimated 82,607 hours and made 28,888 trips (Table 13). The total harvest of 64,465 fish consisted of five different species (Table 13). Yellow perch were most numerous, with an estimated harvest of 61,563 fish. Anglers harvested 1,655 walleyes and reported releasing 1,538 walleyes (48% of total catch). Anglers harvested 717 northern pike, and reported releasing 1,318 (65% of total catch). Anglers harvested 493 smallmouth bass and released 1,320 smallmouth bass (73% of total catch). Size composition of the released fish was not evaluated.

The clerk interviewed 58 open ice anglers and 121 shanty anglers during the winter portion of the angler survey. Most open ice (81%) and shanty (75%) interviews were roving type. Open ice and shanty anglers fished 5,765 hours and made 2,498 trips on Big Manistique Lake (Table 14). A total of 7,188 fish were harvested (Table 14). Yellow perch were most numerous, with an estimated harvest of 6,924 fish. Anglers also harvested 42 walleyes and 222 northern pike, and reported releasing 86 walleyes (67% of total catch).

In the annual period from May 8 through October 15, 2003 and December 27, 2003 through March 28, 2004, anglers fished 88,373 hours and made 31,386 trips to Big Manistique Lake (Table 15). Of the total annual fishing effort, 93% occurred in the open-water summer period and 7% occurred during ice-cover winter period.

The estimated total annual harvest was 71,652 fish. The estimated total annual harvest of yellow perch was 68,487, making up 96% of the total harvest. The estimated total annual harvest of walleyes was 1,697, making up 2% of the total harvest. Estimated annual harvests for northern pike, smallmouth bass, and white sucker were 939, 493, and 35, respectively.

Yellow perch were the predominant species caught (harvested + released) at 93,142, with a resulting catch rate (catch per h) of 1.05. The total catch of walleye was 3,322, with a catch rate of 0.038. Walleye catch peaked in June and September; however, the 100% release rate in September suggests that catch was likely comprised of sub-legal walleyes. Anglers released 48.9% of all walleyes caught. Estimated total annual catch of northern pike was 2,257, with a resulting catch rate of 0.026. Anglers released 58% of northern pike caught. Estimated total annual catch of smallmouth bass was 1,813, with a resulting catch rate of 0.021. Smallmouth bass catch peaked in August, and was consistent throughout the summer. It should be noted that catch rates are calculated with general effort, not targeted effort, and are therefore not necessarily indicative of the rate that an angler targeting one species may experience. Although we did not differentiate between sub-legal and legal released fish, we assume that a large proportion of the released walleye and northern pike were sub-legal.

We did not survey from mid October through December, because we thought that relatively little fishing occurred during that time of year. In fact, only one walleye tag return was reported from mid October through December, prior to the start of the winter creel survey. Thus, the total annual walleye harvest was actually about 0.4% higher than our direct survey estimate, or 1,704 walleyes. No northern pike or smallmouth bass tag returns were reported as caught during the non-surveyed months (Table 16). April was not surveyed because walleye, northern pike, muskellunge, and smallmouth bass seasons are closed at that time.

Nine species that we captured during spring netting operations did not appear in the angler harvest – bluegill, brook trout, brown bullhead, central mudminnow, lake herring, largemouth bass, pumpkinseed, rock bass, and redhorse suckers. However, four of these species – bluegill, largemouth bass, pumpkinseed, and rock bass were caught and released. One species (common carp) caught by anglers was not present in our spring survey.

Discussion

Fish Community

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 includes spring spawners such as walleyes, northern pike, white sucker, and smallmouth bass.

The seasonal and gear biases associated with our survey preclude comparisons of population and community indices to most other surveys of Michigan lakes. Because of the mesh-size bias, smaller fish were not represented in our sample in proportion to their true abundance in the lake. This includes juveniles of all species as well as entire populations of smaller fishes known to exist in Big Manistique Lake (i.e., various species of minnows). For example, eight species of fish have been collected or observed in Big Manistique Lake in previous surveys that were not collected in 2003 (see Appendix).

As indicated previously, panfish were present in the survey, but were not found in great numbers (with the exceptions of yellow perch and rock bass). While the low numbers of these fish in our survey may be due to the survey gear and timing, the creel survey results also suggest that panfish densities are low, with the exception of yellow perch.

As part of the Large Lakes Program, the MDNR also surveyed South Manistique Lake (2003) and Michigamme Reservoir (Hanchin et al. 2005a) using methods and gear similar to those employed Big Manistique Lake. Thus, it should be reasonable to compare fish community composition indices for Big Manistique Lake to South Manistique Lake and Michigamme Reservoir.

The fish community of Big Manistique Lake was vastly different from South Manistique Lake, which had 72% piscivores, 18% planktivores-insectivores, and 9% benthivores. The differences in fish community composition are in part a result of differences in lake morphologies and habitats. For example, aquatic vegetation is often very abundant in South Manistique Lake, whereas vegetation is limited in Big Manistique Lake.

The proportion of piscivores in Big Manistique Lake was similar to Michigamme Reservoir, but the proportions of other feeding guilds were different. We observed 45% piscivores, 11% planktivores/insectivores, and 44% benthivores in Big Manistique Lake, versus 46% piscivores, 29% planktivores/insectivores, and 25% benthivores in Michigamme Reservoir.

Walleyes, Northern Pike, and Smallmouth Bass

Size structure.–The size structure of walleyes in our spring survey was above the average percentage (68%) of legal-size walleye in spring surveys for ten populations surveyed under the Large Lakes program. In spring surveys of Big Manistique Lake completed from 1983 to 1986, the percentage of legal-size walleyes averaged 79%. Based on length-frequency distributions alone, it does not appear that angler harvest is having any negative effect on the size structure of the walleye population. Walleyes in Big Manistique Lake are unlikely to attain lengths much greater than 25 in.

The size structure of northern pike in our spring survey was above the average percentage (20%) of legal-size northern pike in spring surveys for nine populations surveyed under the Large Lakes program. Based on length-frequency distributions alone, it does not appear that angler harvest is having any negative effect on the size structure of the northern pike population. While we did not collect a large number of northern pike, the number of very large (≥36 in) fish was impressive, and northern pike in Big Manistique Lake have the potential to reach large size (L_{∞} = 49.0 in).

The size structure of smallmouth bass in our spring survey was similar to the average percentage (70%) of legal-size smallmouth bass in spring surveys for nine populations surveyed under the Large Lakes program. Smallmouth bass in Big Manistique Lake are likely to attain lengths of 17 in, and have the potential to reach 20 in.

Sex composition.–Male walleyes outnumbered females in our survey when all sizes, or when legal-size fish were considered. This was consistent with past spring surveys of walleyes in Big Manistique Lake and for walleyes from other lakes in Michigan and elsewhere. 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). During egg-take operations from 1982 to 1987, the male:female ratio ranged from 2.4 to 7.8, with an average of 4.9. The 2003 male:female ratio (2.0) was below the average (4.1) that we have observed in ten large lakes surveyed to date.

Male northern pike outnumbered females in Big Manistique Lake, both when all sizes were considered (male:female = 1.3:1), and when legal fish were considered (1:1). In most other spring samples from large lakes, males make up the largest proportion of adult northern pike, but females make up the largest proportion of legal-size northern pike. In fact, this was the first northern pike population that we have observed in the Large Lakes program that had a male:female ratio for legal northern pike that was not less than 1:1. This may be due, in part, to the favorable growth that we observed for northern pike. The male:female sex ratio for adult northern pike (1.3) was similar to the average (1.2) that we have observed in nine large lakes surveyed to date. For northern pike from other lakes, males dominate sex composition in spawning-season samples, but not at other times of the year (Priegel and Krohn 1975; Bregazzi and Kennedy 1980).

Abundance.–We were successful in obtaining both multiple-census and single-census estimates of walleye abundance (Table 6). For the multiple-census estimate, the minimum number of recaptures was obtained; however, some conditions for an unbiased estimate may have been violated (see later discussion). For the single-census estimate, we had sufficient numbers of fish marked and observed for marks. Assuming that the legal walleye population was approximately 10,000 fish, and based on tagging 3,381 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 135 fish (Robson and Regier 1964). Our corrected recapture sample of 141 fish exceeded this recommendation. The CV’s were 0.04 and 0.13 for the multiple-census and single-census estimates, respectively. Thus, based on this measure of precision alone, we considered both our multiple-census and single-census estimates to be reliable.

The multiple-census estimate for walleyes was lower than the single-census estimate for both legal-size fish and adult fish (Table 6); however, in other large lakes, the multiple-census estimates have been much lower than the single-census estimates (Clark et al. 2004; Hanchin et al. 2005c). In the present study, 95% confidence limits of the two estimates did not overlap. Precision was higher for the multiple-census estimates (Table 6). Confidence limits were within 10% of the multiple-census estimates and within 25% of the single-census estimates.

Our estimates of walleye abundance were not comparable (up to 64% lower) to the *a priori* Michigan model estimates; however, both our multiple-census and single-census estimates of adult walleye abundance were similar to the 2000 estimate of 9,350 spawning walleyes in Big Manistique Lake.

Population density of walleyes in Big Manistique Lake was below average compared to other lakes in Michigan. Using the modern acreage of 10,346, our single-census estimate for 15-in-and-larger walleyes in Big Manistique Lake was 1.1 per acre. Density of legal-size walleyes estimated recently for ten large lakes in Michigan has averaged 2.3, and has ranged from 0.4 to 4.6 per acre (MDNR unpublished data). Density in nearby South Manistique Lake was 1.6 per acre in 2003 (Hanchin and Kramer 2007). Population density of adult walleyes from our single-census estimate was also 1.1 per acre. Adult walleye abundance has averaged 3.8 per acre in ten large lakes surveyed thus far as part of the Large Lakes program. Nate et al. (2000) reported an average density of 2.2 adult walleyes per acre for 131 Wisconsin lakes having natural reproduction.

We had less success in obtaining abundance estimates for northern pike (Table 6). The multiple-census estimate of legal northern pike was invalid because the minimum number of recaptures was not obtained. For adult fish, the minimum number of recaptures (N = 4) was reached, but not exceeded. In fact, this was the only estimate for northern pike that could be considered reliable based on the coefficient of variation.

For the single-census estimate of legal-size northern pike, we did not tag enough fish, or examine enough fish for marks, in the creel survey sample. Although we observed the minimum number of recaptures (N =1) during the creel survey, the coefficient of variation indicates that the estimate is not reliable. Using our estimate of the legal northern pike population of approximately 2,000 fish, and knowing that we tagged 99 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 803 fish. The recommended recapture sample to observe for marks in preliminary studies and management surveys (α = 0.05, P = 0.50; where: P denotes the level of accuracy, and 1-α the level of precision) is 380 fish (Robson and Regier 1964). Our corrected recapture sample of 43 fish was well short of both recommendations.

It is not prudent to make comparisons between the methods used to estimate northern pike abundance because we only had a single estimate that met our standards for reliability. Despite the lack of reliable estimates, the population density of legal-size northern pike in Big Manistique Lake is low relative to other lakes in Michigan and elsewhere. Our estimate of adult northern pike converts to a density of 0.3 per acre for the multiple-census method. The density of adult northern pike estimated recently for nine large lakes in Michigan has averaged 1.1, and has ranged from 0.1 to 2.9 per acre.

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 Big Manistique Lake also would essentially be for fish age 2 and older, and should be comparable. Perhaps the lower density we observed in Big Manistique Lake is due to the larger size of the lake, relative to the small Minnesota lakes that Pierce et al. (1995) surveyed.

We also had little success in obtaining abundance estimates for smallmouth bass, primarily due to the small number of fish marked (Table 6). For the multiple-census estimate, the estimate is not valid because the minimum number of recaptures was not obtained. For the single-census estimate of legal smallmouth bass, the coefficient of variation indicated that the estimate was not reliable. Also, we did not examine enough fish for marks in the creel survey. Using an estimate of the legal smallmouth bass population of approximately 1,000 fish, and knowing that we tagged 140 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 301 fish (Robson and Regier 1964). Our corrected recapture sample of 28 fish was well short of this recommendation, and the recommended recapture sample (130) to observe for marks in preliminary studies and management surveys (α = 0.05, P = 0.50). While we potentially could have marked more smallmouth bass if we continued our survey into late spring, it appears that our recapture sample in the creel survey would still have been a limiting factor.

The single-census estimate appeared low when judged in relation to the independently-derived harvest estimate. Our adjusted (for non-surveyed months, and fish that were sub-legal at tagging) harvest estimate of 476 legal-size smallmouth bass produced an exploitation rate of 46.6% when divided by the single-census abundance. This estimate is over two times greater than the exploitation estimate based on tag returns (21.1%). Although we consider the estimate based on tag returns to be a minimum, this ratio at least suggests that there are more than 1,000 legal smallmouth bass in Big Manistique Lake.

Our estimate converts to a density of 0.1 smallmouth bass per acre. Bryant and Smith (1988) reported an abundance estimate for adult smallmouth bass in the Lake St.Clair - Detroit River system that corresponds with a lake-wide density of about 3.5 per acre. Marinac-Sanders and Coble (1981) reported a density of 3.5 per acre for smallmouth bass greater than 225 mm (≈9 in) in an 845-acre northern Wisconsin lake. Engel et al. (1999) reported even higher densities, with an average density of 16.2 per acre for smallmouth bass ages 3–8 (approximately ≥8–9 in) in a Wisconsin lake. Closer to Big Manistique Lake, adult smallmouth bass density was estimated at 3.6, 13.4, and 25.1 per acre in three small (25–75 acre) western Upper Peninsula lakes (Clady 1975). Finally, Newman and Hoff (2000) reported a density (0.3 smallmouth bass > 16.0 in per acre) in Palette Lake, Wisconsin similar to that calculated for Big Manistique Lake. In South Manistique Lake (Hanchin et al. 2007) and South Lake Leelanau (Hanchin et al. 2006), the densities of legal smallmouth bass were 0.7 and 1.0 per acre, respectively.

One assumption of the multiple-census method for estimating abundance that we may have violated for all three species is the random mixing of marked fish 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 lake. 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. In contrast to the multiple-census method, the single-census estimate from the creel survey is more likely to be accurate because it allows sufficient time for marked fish to fully mix with unmarked fish. Additionally, for the single-census estimate it is not assumed that all spawning congregations are sampled in the initial tagging operation.

Pierce (1997) found that their multiple-census methods severely underestimated abundance of northern pike. 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 32–35% lower for walleyes. Pierce (1997) concluded that size selectivity and unequal vulnerability of fish to nearshore 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.

Based on our experience in this study, we believe it would be possible, but costly, to improve precision of walleye abundance estimates for Big Manistique Lake. Obtaining more precise estimates would require: 1) marking more fish, 2) observing more fish for the marked:unmarked ratio, or 3) both. Confidence limits on our single-census estimate of 11,350 legal-size walleyes were ±25% of the estimate (Table 6). We collected and marked 3,381 walleyes with three 10- to15-net, 3-person work crews. Therefore, the average number of fish marked per 3-person crew was about 1,100 over the course of the 2-week survey. In order to achieve precision of ±10%, it would be necessary to mark about 6,810 walleyes (60% of the population). Assuming that the number of fish marked per crew did not diminish with increasing number of crews, this would have taken three additional netting crews.

Improving precision by increasing the number of fish in the recapture sample would probably be better, though it 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 greater than a fivefold increase in the number of recaptures to improve precision to about ±10%. Again, the gain in precision by addition of a creel clerk would probably not be worthwhile, but supplemental recaptures with summer, or fall netting might be reasonable.

Mean lengths at age.–Our reader agreement for aging walleye spines was low (50%) when compared to previous studies. Reader agreement from other studies (Clark et al. 2004; Hanchin et al. 2005a; Isermann et al. 2003; Kocovsky and Carline 2000) has ranged from 53% to 82% between the initial two readers of northern pike fin rays.

Mean lengths at age for walleyes from our survey were similar to those from previous surveys of Big Manistique Lake (Table 17). In the past, the mean growth index for walleyes in Big Manistique Lake has been within the bounds of ±1.0 in (Table 17). Schneider et al. (2000a) suggests that growth indices in the range of ±1.0 in are satisfactory for game fish, so recent walleye growth in Big Manistique Lake has been satisfactory.

Walleye mean lengths at age in 2003 were comparable to the State of Michigan average for ages 2 through 7, while mean lengths of fish older than 8 years old were slightly lower than the state average (Table 17). However, this difference at older ages may be attributable to differences in aging techniques, and thus should be interpreted with caution. Walleyes appeared to grow significantly better in Big Manistique Lake than in Michigamme Reservoir, Iron County (Hanchin et al. 2005a). The typical walleye in Big Manistique Lake reaches legal size by age 3 (Table 17) compared to age 5 or 6 in Michigamme Reservoir.

The values calculated for L_∞ provide some insight into the growth potential of individual fish in a population. The L_∞ values for male, female, and all walleyes were 20.7, 24.0, and 23.3 in, respectively, which are lower than those for Muskegon Lake (24.9, 29.9, and 27.0, respectively; Hanchin et al. 2007), but higher than those for Crooked and Pickerel lakes (18.1, 20.7, and 18.6 in, respectively; Hanchin et al. 2005b). The L_∞ for walleyes in South Manistique Lake were very similar (20.6, 24.7, and 23.1 in, respectively).

Mean lengths at age for northern pike from our survey were much greater than those from a previous survey of Big Manistique Lake completed in 1997 (Table 18). In 1997 and 2003, the mean growth indices were -2.6 in and +3.4 in, respectively (Table 18). Mean lengths at age in these years were above (2003) and below (1997) the statewide average. Schneider et al. (2000a) suggests that growth indices in the range of ±1.0 in are satisfactory for game fish; based on this index, northern pike growth in Big Manistique Lake is more than satisfactory. As with walleyes, state averages for northern pike were based entirely on scale aging, which probably overestimates mean lengths for older ages.

Length at infinity (L_∞) values for male (28.1 in) and female (48.9 in) northern pike also suggest that growth potential is above average for this species. Female pike typically attain legal size (24 in) at age 3, while males attain this size at either age 3 or 4. Northern pike through age 12 were observed in the 2003 survey, indicating that these fish survive and reproduce for a number of years after recruiting to legal size in Big Manistique Lake.

Mortality.–Total mortality of walleyes in Big Manistique Lake was below average. For male walleyes the catch curve used (ages 7–14) was representative of older adult fish, not the total adult population. For female walleye, the catch curve regression was based on age groups 7 through 14. Age groups 15 and 16 were considered outliers due to their low sample size (based on only three aged fish), and their apparent departure from the trend of the previous eight age groups. Overall, sixteen year classes were represented and the age structure showed no indications of severe mortality associated with attainment of legal size (Table 10).

Compared to total mortality estimates for walleyes from other lakes in Michigan and elsewhere, our estimate of 31% is similar to the average (36.5%) from ten populations surveyed as part of the Large Lakes program in Michigan, which have ranged from 24% to 51%. Schneider (1978) summarized available estimates of total annual mortality for adult walleyes in Michigan and from lakes throughout Midwestern North America, other than Michigan. Michigan estimates ranged from 20% in Lake Gogebic to 65% in the bays de Noc, Lake Michigan. North American estimates 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. These estimates ranged from 13% to 84% for fish age 2 and older, with the majority of lakes between 35% and 65%. In 2003, the annual mortality rate for all walleyes in nearby South Manistique Lake was 29%.

Our three estimates of annual exploitation rate of walleyes were rather different; 9.4% from tag returns, 22.8% using harvest divided by the multiple-census abundance estimate, and 14.8% using harvest divided by the single-census abundance estimate. We consider the tag return estimate to be a minimum because we did not adjust for tagging mortality, or non-reporting. If these problems occurred to any degree, we would have underestimated exploitation (Miranda et al. 2002). We did not estimate tagging mortality, and we used an estimated tag loss rate of 9.8%.

We did not make a true estimate of non-reporting, but we attempted to get some measure of non-reporting of tags by offering a $10 reward on half of the tags and comparing return rates of reward to non-reward tags. We found that reporting rate for reward tags (8.5%) was slightly higher than for non-reward tags (6.4%). 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, in Michigamme Reservoir, there was a large difference in reporting rates, and the authors believed that anglers returned nearly 100% of reward tags (Hanchin et al. 2005a). The reporting rate of non-reward tags relative to reward tags (λ) of 76% was just below the average (80%) that we have observed in nine walleye populations from large lakes to date. We found additional evidence of non-reporting in that the number of tags voluntarily returned by anglers was 59% of the expected number of returns based on the ratio described previously in the **Methods** section. There was obviously non-reporting of non-reward tags, but we do not have a good estimate of the non-reporting rate for either reward or non-reward tags. We found that one of the ten reward tags (10%) observed by the creel clerk was not subsequently reported by the angler. This indicates that non-reporting of reward tags also occurred to some degree, but the small number of tagged fish observed by the creel clerk was not a large enough sample from which to draw convincing conclusions. If we adjust the exploitation estimate for both tag loss and this estimate of non-reporting, it increases to 10.3%.

Because we believe the exploitation estimate from tag returns is a minimum, the estimates derived by dividing harvest by abundance were both possible, and are assumed to represent an upper limit on the exploitation estimate. The major problem with estimating exploitation as harvest divided by abundance is that the error associated with two individual estimates is compounded. If our harvest estimate was biased high, and our abundance estimate was biased low, the exploitation estimate would include the error from both individual estimates in a single direction, resulting in a gross inaccuracy. We believe this error occurs to some degree when the multiple-census abundance estimate, which is likely biased low, is used. Because we believe the single-census abundance estimate is more reliable, the true annual exploitation rate of walleye in Big Manistique Lake is likely in the 15–20% range.

Compared to exploitation rates for walleyes from other lakes in Michigan and elsewhere, our estimate for Big Manistique Lake is comparable to the average (15.5%) exploitation rate for walleye from ten large lakes surveyed to date, which ranged from 3.5% to 29.3%. Also comparable to our estimate, Serns and Kempinger (1981) reported average exploitation rates of 24.6% and 27.3% for male and female walleyes respectively in Escanaba Lake, Wisconsin during 1958–79. In general, the range of exploitation for walleye across its range is large. For example, 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. Additionally, exploitation can vary over time for a single water body; in western Lake Erie, estimates ranged from 7.5% to 38.8% from 1989 through 1998 (Thomas and Haas 2000).

In 2003, we added a question to the tag return form asking anglers if they released walleyes. The low reported release rate (0.4%) for walleye of legal size is about what we would expect. We believe this estimate is a minimum, given that anglers releasing fish are less likely to remove tags, or record the tag number information. The reported release rate for walleyes of legal size in South Manistique Lake was 0.8% in 2003.

Total mortality of northern pike in Big Manistique Lake was lower than average, with twelve year classes represented. Age-12 northern pike represent the oldest pike we have observed thus far in the Large Lakes program. The age structure does not indicate any severe mortality associated with attainment of legal size. Compared to total mortality estimates for northern pike from other lakes in Michigan and elsewhere, our estimate of 31% is below average. Total mortality rates from nine populations surveyed as part of the Large Lakes program in Michigan have ranged from 31% to 69%, with an average of 52%. Thus, northern pike in Big Manistique Lake represent the lowest mortality rate observed thus far. Diana (1983) estimated total annual mortality for two other lakes in Michigan, Murray Lake (24.4%) and Lac Vieux Desert (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; estimates ranged from a low of 19% (Mosindy et al. 1987) to a high of 91% (Kempinger and Carline 1978), with the majority of lakes between 35% and 65%.

Our three estimates of annual exploitation rate of northern pike were rather different; 22.4% from tag returns, 14.8% using harvest divided by the multiple-census abundance estimate, and 42.6% using harvest divided by the single-census abundance estimate. Again, we consider the tag return estimate to be a minimum. We found that reporting rate for reward tags (21.3%) was essentially equal to that for non-reward tags (22.0%). There was obviously non-reporting of non-reward tags, but because no tagged northern pike were observed by the creel clerk we were not able to estimate non-reporting of reward tags.

Because we believe the exploitation estimate from tag returns is a minimum, only one of the estimates derived from harvest divided by abundance resulted in a valid estimate of exploitation. The estimate derived using the multiple-census abundance estimate is lower than the tag return estimate, which is further evidence that the multiple-census abundance estimate is biased high. However, the exploitation estimate based on the single-census abundance exceeded the estimate of total mortality by 37%. Potential biases of the exploitation method derived from dividing harvest by abundance have been previously discussed. We believe the true annual exploitation rate of northern pike in Big Manistique Lake is likely in the 22–25% range. Based on this value, and our estimate of total mortality (31%), it appears that fishing mortality contributes more to total mortality than natural sources in Big Manistique Lake.

Compared to exploitation rates for northern pike from other lakes in Michigan and elsewhere, our tag return estimate of 22% for Big Manistique Lake is about average. The average exploitation rate for northern pike from eight large lakes surveyed to date was 20.1%, with a range of 7.8% to 31.4%. Latta (1972) reported northern pike exploitation in two Michigan lakes, Grebe Lake (12–23%) and Fletcher Pond (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.

This was the first attempt to estimate total mortality of smallmouth bass in Big Manistique Lake. Our estimate of 45% for legal-size fish appears to be within the range for Midwestern waters reported in the literature. Forney (1961) reported estimates of 52%, 58%, and 18% total mortality for smallmouth bass in Oneida Lake, New York, while Paragamian and Coble (1975) reported 55% mortality for smallmouth bass in the Red Cedar River, Wisconsin. Clady (1975) reported total mortality estimates of 32.5% for smallmouth bass in a Michigan lake with no fishing, and 40.5–65.0% in a lake subject to simulated exploitation of 13.2–15.8%. Bryant and Smith (1988) reported 58% total mortality of adult smallmouth bass from Anchor Bay of Lake St. Clair. Total mortality of smallmouth bass in Big Manistique Lake was higher than the few other populations we have observed thus far in the Large Lakes program. Total mortalities in Lake Leelanau (Hanchin et al. 2006) and South Manistique Lake (Hanchin and Kramer 2007) were 39% and 25%, respectively.

Our three estimates of the annual exploitation rate of smallmouth bass were rather different; 21.1% from tag returns, 8.6% using harvest divided by the multiple-census abundance estimate, and 46.6% using harvest divided by the single-census abundance estimate. As for walleye, we consider the tag return estimate to be a minimum. We did not make a true estimate of non-reporting, but the number of tags voluntarily returned by anglers was within 10% of the predicted number of returns based on the ratio described previously in the **Methods** section. Because we believe the exploitation estimate from tag returns is a minimum, only the estimate derived from harvest divided by the single-census abundance resulted in a valid estimate of exploitation.

The discrepancy between the three estimates is most likely due to an overestimate of abundance from the multiple-census abundance method, and an underestimate from the single-census method. If we conservatively assume that a minimum of 25% of the total mortality estimate should be attributed to the expectation of natural death (v), the highest exploitation rate we should expect given a total mortality of 45% is 34%. Thus, the true exploitation rate is likely between 21% and 34%.

Compared to exploitation rates for smallmouth bass from other lakes in Michigan and elsewhere, our estimate for Big Manistique Lake appears to be average. Latta (1975) reported a range of 9% to 33% exploitation, with an average of 19.2%, for a sample of smallmouth bass populations throughout the Great Lakes region and the northeastern United States. In Oneida Lake, Forney (1972) reported 20% exploitation of adult smallmouth bass, while Paragamian and Coble (1975) reported 29% exploitation in the Red Cedar River of Wisconsin. In Michigan, Latta (1963) reported 22% exploitation of smallmouth bass near Waugoshance Point in Lake Michigan, and Bryant and Smith (1988) reported a rate of 13% for smallmouth bass in Lake St. Clair.

In 2003, we added a question to the tag return form asking anglers if they released smallmouth bass. The reported release rate (14.8%) for smallmouth bass of legal size was much higher than that for walleye in Big Manistique Lake. We believe this estimate is a minimum, given that anglers releasing fish are less likely to remove tags, or record the tag number information. The reported release rate for smallmouth bass of legal size in South Manistique Lake was 50% in 2003, but this estimate was based on only four tags returned.

Recruitment.–Walleyes in Big Manistique Lake were represented by 16 year classes (ages 1 through 16) in our samples. Variability in year-class strength was low (R^2 = 0.90; Figure 6), though the R^2 value was improved by not including some older age classes in the catch curve regression. In ten other Michigan walleye populations surveyed as part of the Large Lakes program to date, the R^2 has ranged from 0.67 to 0.98, with an average of 0.85. Given that no walleye were stocked in years corresponding with year classes we collected, it appears that substantial natural reproduction occurs regularly. Thus, we conclude that natural reproduction of walleyes is sufficient to maintain the current population.

Northern pike were represented by 12 year classes (ages 1 through 12) in our samples. Variability in year-class strength was relatively high (R^2 = 0.79; Figure 7). In eight other Michigan northern pike populations surveyed as part of the Large Lakes program to date the R^2 has ranged from 0.67 to 1.00, with an average of 0.89.

Smallmouth bass were represented by 10 year classes (ages 2 through 11) in our samples. Variability in year-class strength appeared relatively low (R^2 = 0.90), though we have few lakes for comparison. In Lake Leelanau and South Manistique Lake, which were surveyed as part of the Large Lakes program, the R^2 values were 0.91 and 0.61, respectively.

Movement.–The movement patterns that we observed show that walleyes can move freely between Big Manistique Lake and South Manistique Lake. Most movement probably occurs during the three weeks following ice-out, though there is movement throughout the year. Hanchin and Kramer (2007) reported 17 walleyes tagged in South Manistique Lake were recaptured during spring netting in Big Manistique Lake. In contrast, four walleyes that we tagged in Big Manistique Lake were recaptured in South Manistique Lake during spring netting. This suggests that a greater number of walleyes are moving downstream into Big Manistique Lake during the spawning period. However, the timing of this apparent movement is not known.

The downstream movement of spawning walleyes from South Manistique Lake to Big Manistique Lake was also noted by Reynolds (1948). He installed a weir in Portage Creek to mark walleye migrating out of South Manistique Lake into Big Manistique Lake. The intention was to maintain the weir throughout the open water period to answer the question of whether walleye and northern pike migrated back into South Manistique Lake following the spawning period. They proved that walleye do migrate from South Manistique Lake downstream to Big Manistique Lake during the spring in large numbers; however, due to vandalism they were unable to continue the project into the autumn months. Despite the early termination of the project, it was Reynolds' (1948) opinion that if the project was continued through the autumn months, it would have shown that walleye migrate back upstream to South Manistique Lake. This contention was supported by the return of a few marked fish in late May, and by observations of numerous walleye in a pool below South Manistique Lake; without however having seen any fish migrating out of South Manistique Lake during that time.

When we apportion the percent movement as depicted from tag returns by abundance, we estimated that around 400 walleyes moved from Big Manistique Lake to South Manistique Lake between marking and angler capture. Hanchin and Kramer (2007) reported that around 100 walleyes moved from South Manistique Lake to Big Manistique Lake; thus, the net movement is apparently upstream to South Manistique Lake. Again, the direction and timing of this apparent movement is not totally clear; walleye may have moved upstream to South Manistique Lake as part of a spawning migration, or they may have moved following spawning in Big Manistique Lake. Our results from tag returns offer support for the contention of Reynolds (1948) that walleye migrate upstream from Big Manistique Lake to South Manistique Lake throughout the summer and fall months.

We did not detect any movement of walleye downstream from Big Manistique Lake. The Manistique Lake Dam is located approximately four miles downstream from the lake, with the purpose of maintaining lake levels to accommodate boating (Madison and Lockwood 2004). Although the dam blocks the upstream movement of walleyes from the Manistique River, it is possible that fish could move downstream over the dam. Historic angler surveys on the Manistique River (Madison and Lockwood 2004) have shown that walleye and northern pike are regularly caught in lower portions of the river. Thus, if upstream fish passage was allowed it would likely benefit the walleye population in Big Manistique Lake. Although the Fox River and its tributaries are freely connected to Big Manistique Lake, the fish community is dominated by coldwater species such as brook trout.

Although we do not necessarily know the timing of walleye movements, a large portion of the fish likely move from early spring through early summer. It would be interesting to know the seasonal movement patterns of fish between Big and South Manistique lakes, but movements associated with spawning are the most important. Currently, we assume that most walleyes in Big Manistique Lake demonstrate site fidelity in spawning, but we do not truly know. Knowledge of site fidelity would have potential implications in the allocation of walleye harvest, and thus should be considered in future research. This could be accomplished by surveying spawning walleyes in successive years after marking.

Angler Survey

The fishery of Big Manistique Lake is dominated by yellow perch and walleyes. These two species comprised 98% of the total annual harvest and were caught throughout the year. Harvest of yellow perch increased monthly from spring to fall and was relatively lower in the winter. Walleye were harvested most readily from May through July, though they were caught throughout the year. Catch rate for walleye was highest in September (0.120/hour), followed by May (0.077/hour), and June (0.058/hour). The high September catch rate may have been a result of young walleye caught while fishing for yellow perch, a hypothesis based on the fact that no walleye were reported as being harvested in September. Yellow perch catch peaked in August, though the harvest was highest in September. Northern pike catch peaked in June and harvest occurred mainly in the spring and winter. Smallmouth bass were harvested to a small degree in July and August, though they were often caught and released in the spring and summer months. The catch rate for smallmouth bass over the entire survey was 0.02 per hour. Few other species provide angling opportunities throughout the year.

Historical comparisons.–The oldest harvest and effort estimates for Big Manistique Lake were reported by Laarman (1976). A general creel census from 1928–64 included Big Manistique Lake, 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, yellow perch, walleye, and northern pike were the predominant species in the fishery from 1928–39, 1940–50, and from 1951–64. The catch per hour of all species during these periods was 1.48, 1.14, and 1.04, respectively, for an average of 1.22. These values are similar to our 2003 overall catch rate of 1.14 fish per hour. A notable absence from the 2003 angler catch was lake herring, which comprised 0.3, 0.8, and 1.8 percent of the total catch in the three historic angler survey periods.

In 1970 and 1973, annual fishing effort on Big Manistique Lake was estimated as 55,780 and 48,780 angler days, respectively, from mail surveys. Using current knowledge of the average number of trips per day (1.2 trip/day), and the average length of a trip (2.34 h/trip) from the 2003 angler survey, the 1970 and 1973 estimates equate to 156,630 and 136,974 hours of fishing effort, respectively. These estimates are much higher than our 2003–04 estimate of 88,373 total angler hours; thus, it appears that effort may have decreased from what it was in 1970 and 1973.

The most complete historic creel surveys of Big Manistique Lake took place from May 1978 to February 1979, and from May 1979 to February 1980 (Ryckman and Lockwood 1985). These on-site creel surveys used methods that were similar to those used in the current survey and should be useful for comparison. Total angler effort was 64,691 angler hours in 1978–79 and was 46,068 in 1979–80. Both of these surveys represent lower angler effort than was estimated in 2003, but a multitude of factors affecting angler effort (i.e., weather conditions, fishing success, etc.) makes interpretation difficult. In both historic angler surveys, the total catch was dominated by yellow perch (18,271 fish, 67% of total catch for 1978; 16,975 fish, 65% of total catch for 1979). These estimates are much lower than the 93,142 (92% of total catch) yellow perch caught in 2003. In contrast, the number of walleye caught in the past surveys was higher than our current estimate. In 1978–79 and 1979–80 the total catches of walleye were 6,637 (23% of total catch) and 5,335 (21% of total catch), respectively, compared to 3,322 (3% of total catch) in 2003. In fact, during the summer and fall of 1979, 95.9% of anglers sought walleye, 3.3% sought northern pike, and only 0.8% sought yellow perch. Although three angler surveys does not constitute a lengthy data series, it appears that there could be a trend of alternating walleye and yellow perch abundance in Big Manistique Lake as seen by the catch per hour (Figure 9). If walleyes are a significant predator on yellow perch, we may expect to see low yellow perch abundance when walleye abundance is high. The proportions of other species caught were rather similar among years, with the exception of lake herring which were only detected in the 1979–1980 angler survey. For example, the total catch of northern pike was 2,176, 1,974, and 2,257 in 1978–79, 1979–80, and 2003, respectively.

Comparison to other large lakes.–In addition to the historic creel survey data for Big Manistique Lake, comparisons with creel surveys from other large lakes can be useful. In general, surveys conducted in Michigan in the past 10 years used the same methods we used on Big Manistique Lake, but some of them differ from our survey in seasonality. For example, some other surveys were not done in consecutive summer and winter periods. 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). In addition, we compared results to eight other lakes that have been surveyed as part of the Large Lakes Program to date.

We estimated 88,373 angler hours occurred on Big Manistique Lake during the year from May 8 through October 15, 2003 and December 27, 2003 through March 28, 2004. The harvest per acre and hours fished per acre were below average relative to other large lakes (Table 19), but the harvest per hour was above average.

For walleyes, our estimated annual harvest from Big Manistique Lake was 0.16 fish per acre. This harvest was well below the average of other waters in Michigan. In fact, it was the lowest we have observed thus far in the Large Lakes program. The average harvest of ten large Michigan lakes was 0.77 walleyes per acre. These Michigan lakes all were subject to similar gears and fishing regulations, including a 15-in minimum size limit. In contrast to Big Manistique Lake, nearby South Manistique Lake had the highest walleye harvest per acre that we have observed thus far in the Large Lakes program. The catch per hour (harvest and release combined) of all walleye in Big Manistique Lake (0.038) was also below the average (0.127) for the Large Lakes surveyed thus far.

For northern pike, our estimated annual harvest from Big Manistique Lake was 0.09 fish per acre. This harvest was below average compared to other large lakes surveyed in Michigan. 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 less than 0.1 per acre in Bond Falls Flowage, Gogebic County to 0.7 per acre in Fletcher Pond, Alpena County. The average harvest from nine lakes surveyed as part of the Large Lakes program thus far was 0.18 per acre. 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. The catch per hour of all northern pike (0.026) in Big Manistique Lake was also below the average (0.06) for the Large Lakes surveyed thus far.

The total catch (harvest + release) of smallmouth bass in Big Manistique Lake was 1,813. This exceeded the total annual catch of smallmouth bass in Crooked and Pickerel lakes (1,300; Hanchin et al. 2005b), and Burt Lake (796; Hanchin et al. 2005c), but was less than the total annual catch in South Manistique Lake (2,051; Hanchin et al. 2007), Lake Leelanau (5,792; Hanchin et al. 2006), and Houghton Lake (3,049; Clark et al. 2004), which all had year-long creel surveys.

The total catch and harvest of yellow perch in Big Manistique Lake was impressive, with an estimated 6.6 yellow perch harvested per acre. In comparison, the harvest per acre of yellow perch in Burt Lake, Crooked and Pickerel lakes, and Muskegon Lake were 3.4, 1.8, and 10.7, respectively. The catch rate of yellow perch in Big Manistique Lake (1.05 per hour) was greater than that of

Muskegon Lake (0.69), Burt Lake (0.80), and Crooked and Pickerel lakes (0.22), indicating that much of the total angler effort in Big Manistique Lake is directed at yellow perch.

Management Implications

The walleye fishery in Big Manistique Lake in 2002–03 was of good quality, though the population was likely at a low point in terms of density. The lake contained an estimated 1.1 legal walleyes per acre and anglers harvested 0.16 per acre at a rate of 0.02 per hour fished. These are low values relative to other large lakes in Michigan. However, growth and size structure were favorable, with 92% of the spring spawning stock above the 15-in minimum size limit.

Stocking does not appear to be necessary to maintain the walleye population or fishery in Big Manistique Lake. However, if walleye stocking were considered as a management option, it should be kept at a level that will prevent potential harmful effects from density-dependent interactions such as increased competition for food or cannibalism. One possible management option to augment walleye recruitment would be to allow upstream fish passage via the Manistique Lake Dam. Madison and Lockwood (2004) presented removal or fixed-crest operation of control structures as management options in their Manistique River Assessment.

Our estimates of legal and adult walleye abundance were lower than the estimates made a priori with the Michigan regression equation, but this would be expected if we believe the population is at a low point. In the short term, it would be reasonable to apply the regression to estimate legal walleye abundance in Michigan lakes when abundance estimates are needed for management purposes. In the long term, the MDNR should continue to work towards developing an improved regression by conducting abundance estimates in other Michigan lakes.

The northern pike fishery in Big Manistique Lake was typical for large lakes. The harvest per acre was average, though the catch rate was below average. Big Manistique Lake had a higher than average density of legal northern pike but a lower than average density of adult northern pike. The total number of recruits produced was consistently low, which was perhaps a result of the low abundance of reproductive habitat. However, conditions are favorable for northern pike growth, and the mean growth index was the highest that we have observed in the Large Lakes Program. Size structure of northern pike was high, with 50% of the spring spawning stock above the 24-in minimum size limit. Total mortality of northern pike was low, as we found fish up to age 12, the oldest we have seen thus far in the Large Lakes program.

The northern pike population in Big Manistique Lake was consistent with the criteria for the MDNR's Type III classification for northern pike waters — that is, low density, fast growth, and low mortality. Thus, the potential exists for having a higher size limit. Big Manistique Lake has the potential to produce 50-in northern pike, substantiated by the fact that we collected a 49.4-in northern pike in our spring survey. However, Big Manistique Lake is producing large northern pike with the current regulations; thus, perhaps nothing should be changed. If increasing exploitation of northern pike is observed, or if size structure decreases, the concept of a higher size limit should be revisited.

The smallmouth bass fishery in Big Manistique Lake is typical of large lakes in northern Michigan. Anglers harvested 0.048 smallmouth bass per acre and caught 0.021 per hour. We were unable to obtain a reliable estimate of smallmouth bass abundance, though there are probably between 0.1 and 0.2 legal smallmouth bass per acre in Big Manistique Lake. Although we have few other populations for comparison, the population density of legal-size smallmouth bass in Big Manistique Lake is low relative to walleye. Smallmouth bass are growing well, and overall mortality is reasonable. Size structure of smallmouth bass was similar to other Michigan lakes, with 66% of the spring net catch above the 14-in minimum size limit. Our best estimate of smallmouth bass exploitation is 20 to 25%, which is likely not high enough to have a negative effect on the population.

Overall, the fishery in Big Manistique Lake is of high quality. The number of fish harvested per hour was above average, considering large lakes surveyed under similar methods. The number of fish harvested per acre was below average, but was greater than 50% of the large lakes surveyed under similar methods. Big Manistique Lake is primarily a yellow perch and walleye fishery, with decent northern pike and smallmouth bass fisheries as well. The harvest per acre of yellow perch (6.6) exceeded that for Burt Lake (3.4) which is considered a quality perch fishery.

Methods used for harvest, abundance, age and growth, and mortality estimates for walleyes performed well. Estimates for northern pike and smallmouth bass were hindered by the small number of legal-size fish collected, but the information we gained is still the best we have for Big Manistique Lake.

Acknowledgements

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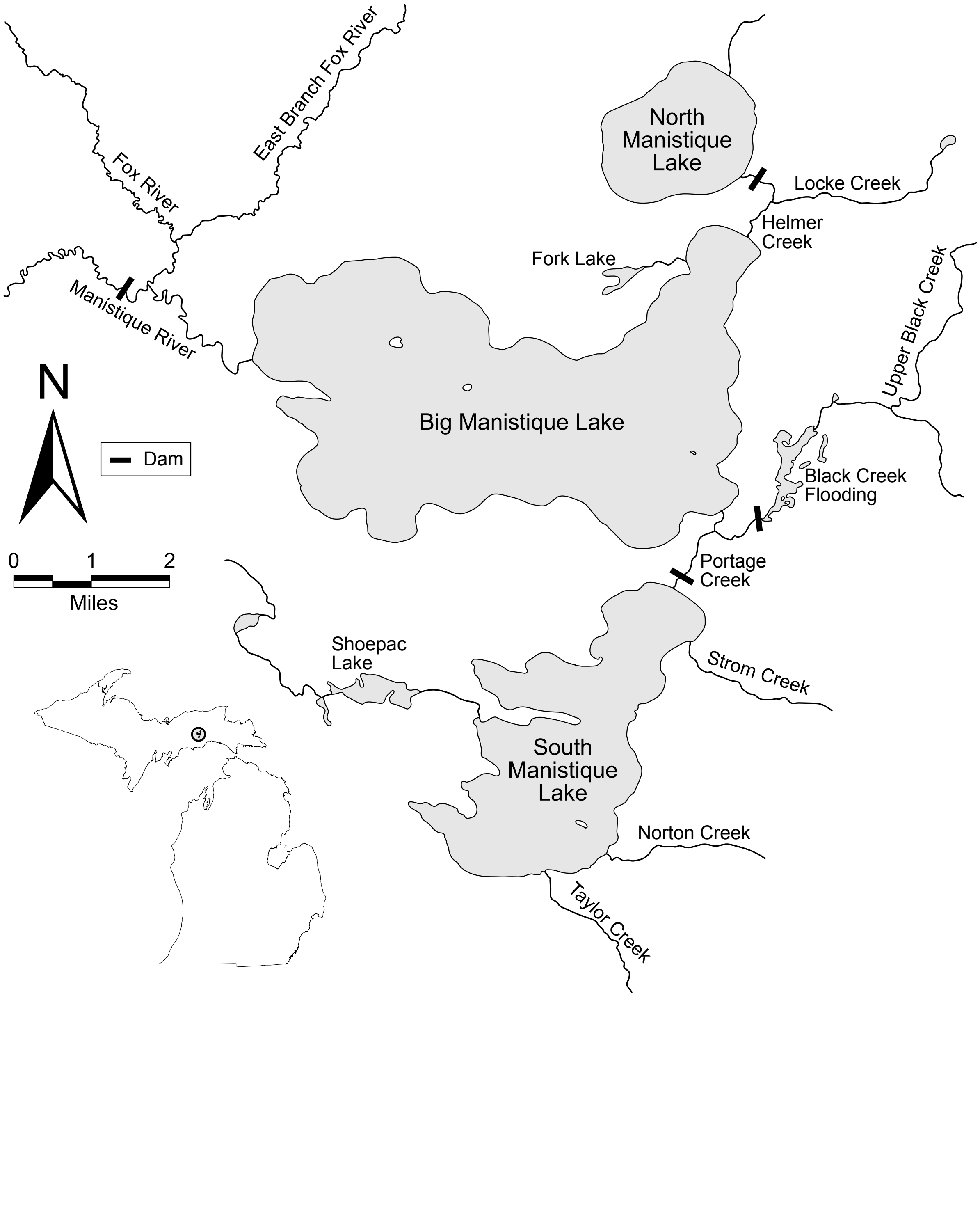

Figure 1.–Map of Manistique Lake system, Luce and Mackinac Counties, Michigan.

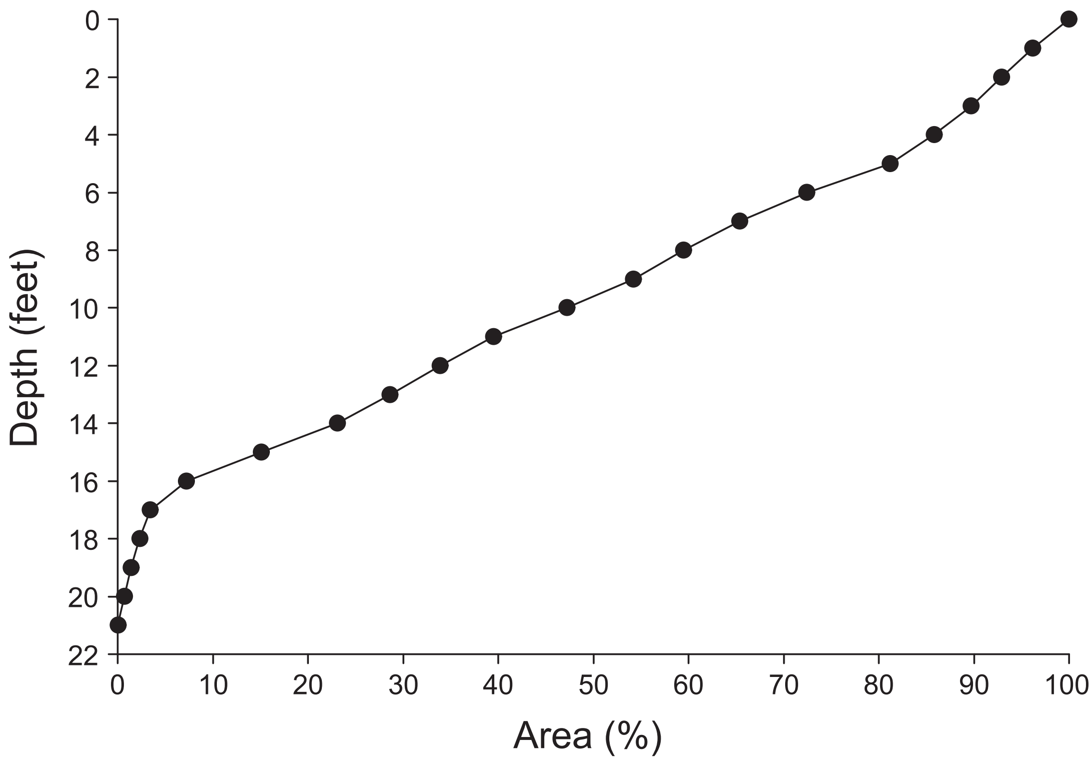

Figure 2.–Percent of area equal to or greater than a given depth for Big Manistique Lake. Data taken from MDNR Digital Water Atlas.

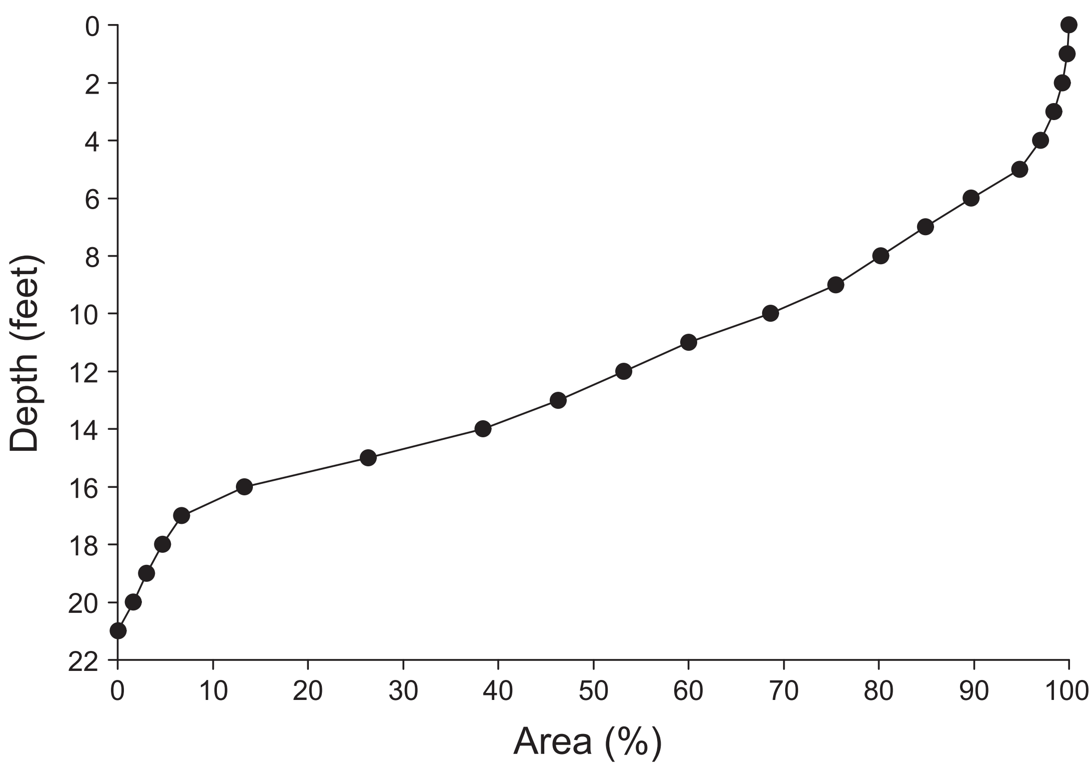

Figure 3.–Percent of volume equal to or greater than a given depth for Big Manistique Lake. Data taken from MDNR Digital Water Atlas.

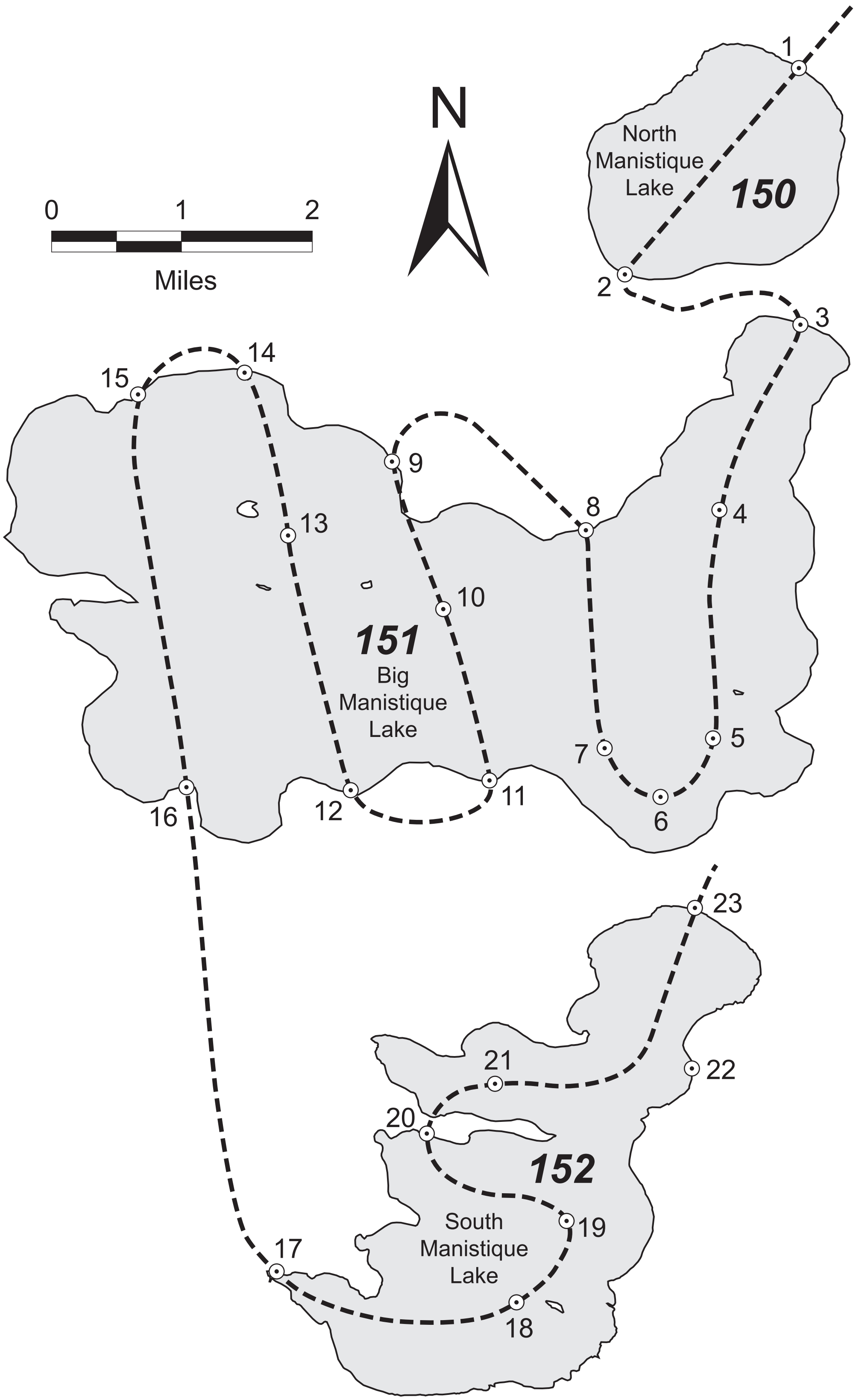

Figure 4.–Counting path, associated count path way points, and interview starting locations (points 1, 2, 3, 8, 11, 15, 17, and 23) for the Manistique Lakes, summer 2003 survey. Latitude and longitude for points 1-23 are given in Table 3.

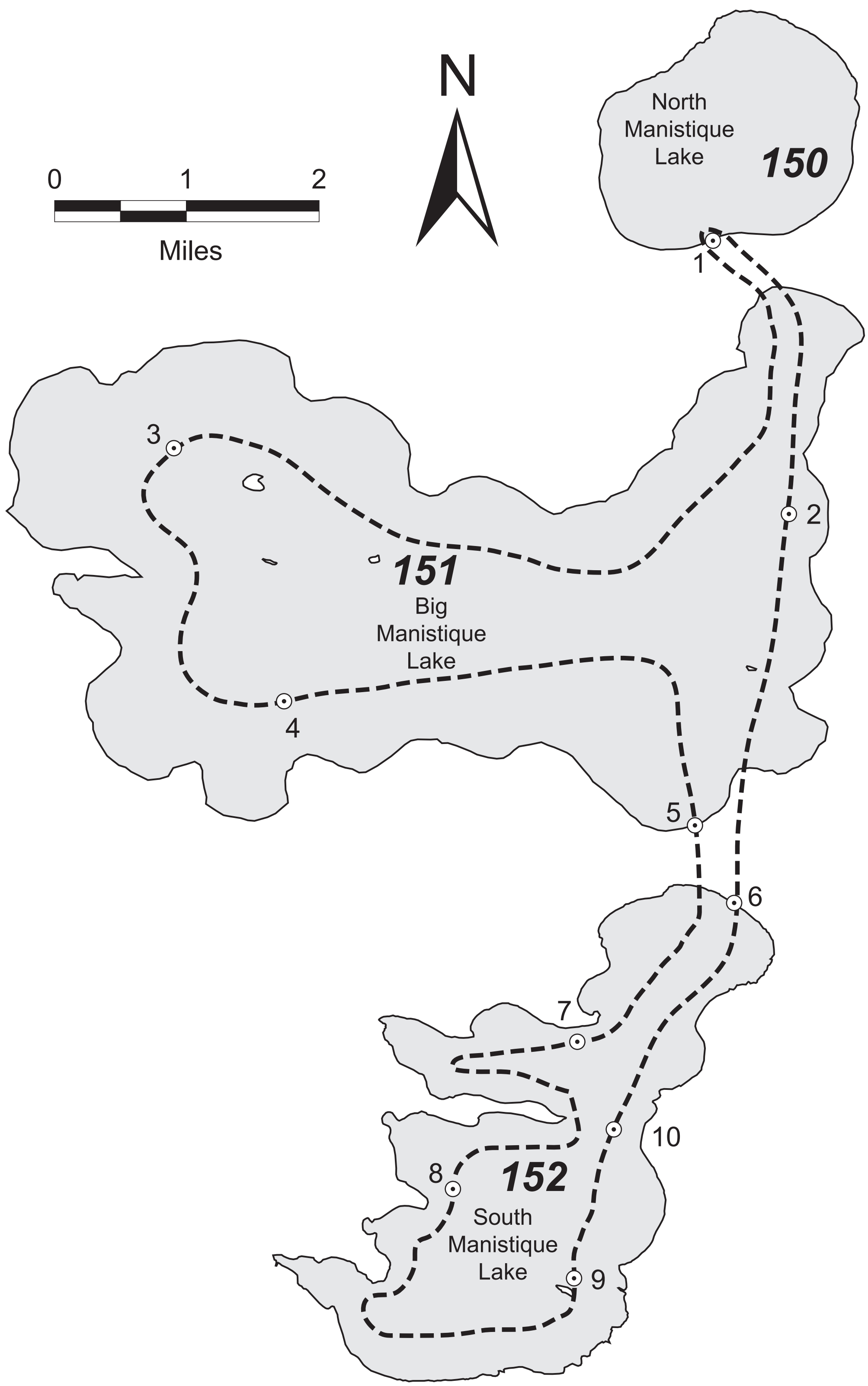

Figure 5.–Counting path, and approximate interview starting locations (points 1–10) for the Manistique Lakes, winter 2003-04 survey.

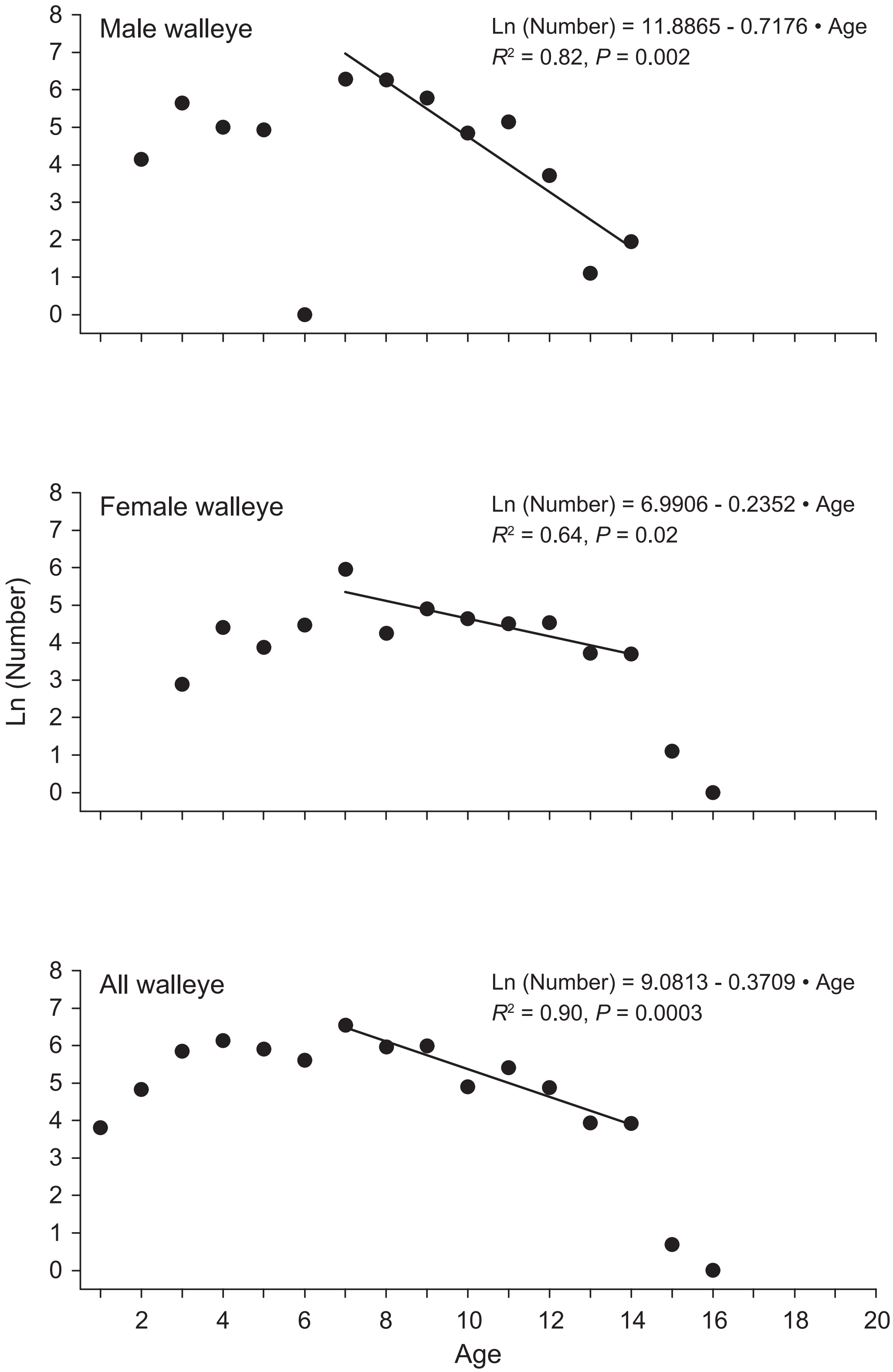

Figure 6.–Plots of observed ln(number) versus age for male, female, and all (including males, females, and unknown sex) walleyes in Big Manistique Lake. Lines are plots of the regression equations shown.

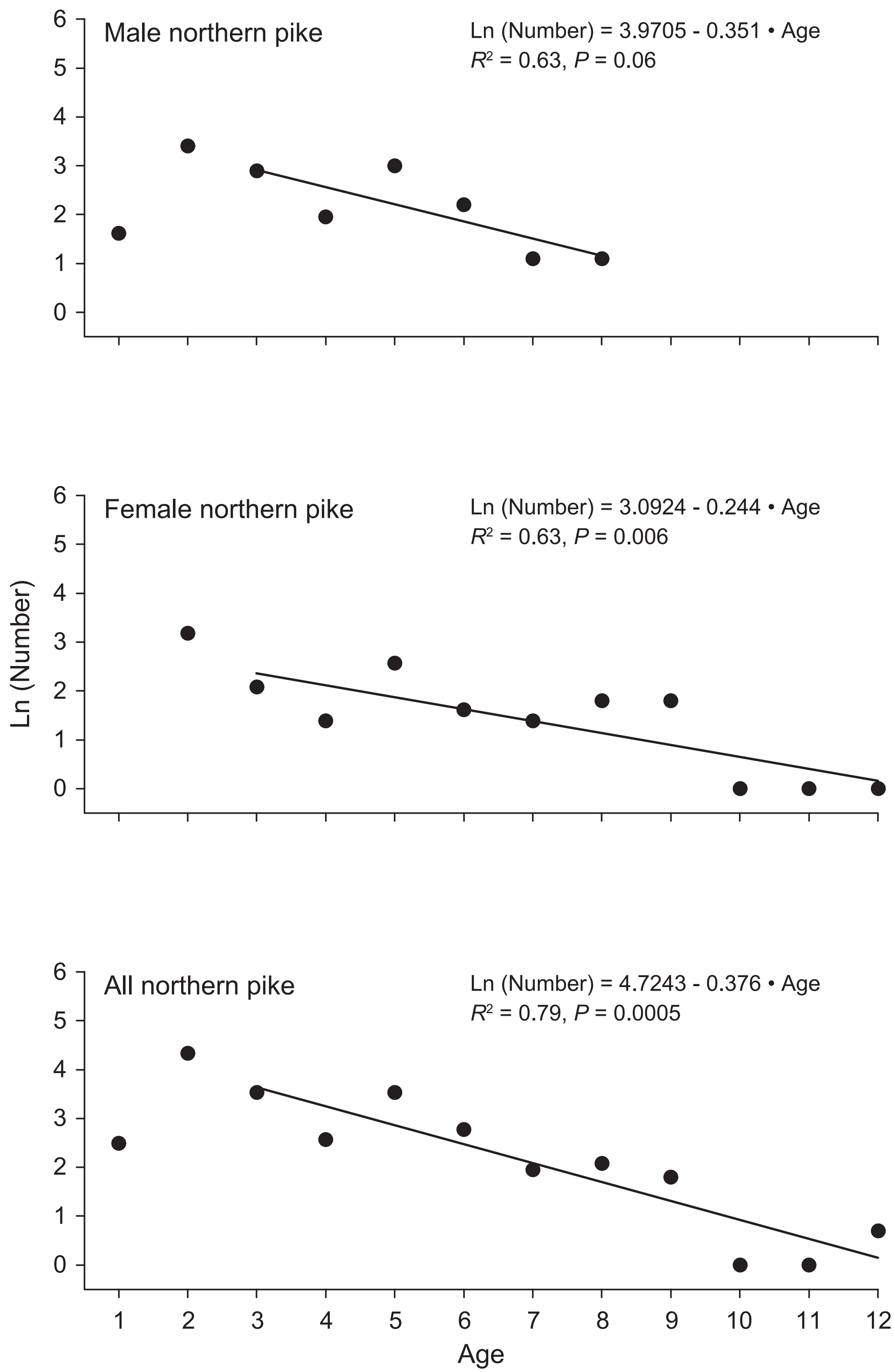

Figure 7.–Plots of observed ln(number) versus age for male, female, and all (including males, females, and unknown sex) northern pike in Big Manistique Lake. Lines are plots of the regression equations shown.

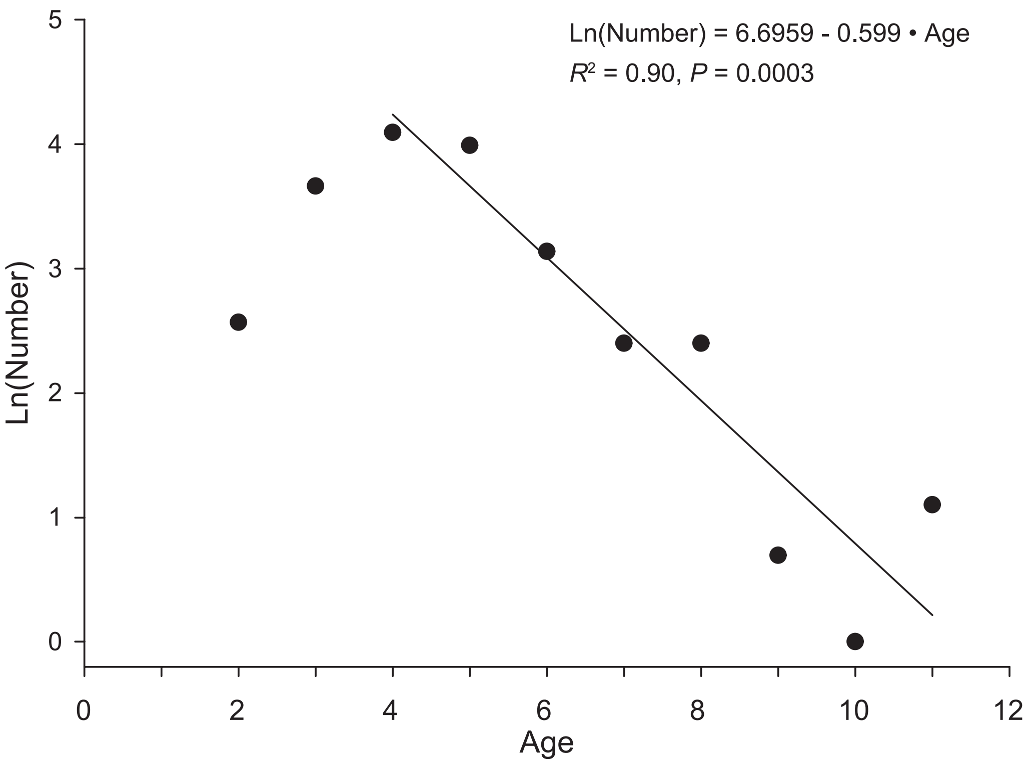

Figure 8.–Plots of observed ln(number) versus age for smallmouth bass in Big Manistique Lake. Line is plot of regression shown.

Figure 9.–Estimated catch per hour for yellow perch and walleye on Big Manistique Lake. Surveys in 1978 through 1980 are reported in Ryckman and Lockwood (1985). Error bars represent two standard errors.

Table 1.–Number and size of fish stocked in Big Manistique Lake 1983 through 2005.

Species	Year	Number	Weight (lbs)	Average size (in)
Lake sturgeon	1983	2,900	22.2	–
	1984	10,000	57.4	3.4
	1988	3,742	33.7	4.6
	1990	6,898	36.1	3.4
	1993	7,636	73.7	4.2
Smallmouth bass	1998	10,000	41.6	2.3
Walleye	2005	1,000,000	13.2	0.3
	2005	4,700	–	8.2

Table 2.–Survey periods, sampling shifts, and expansion value “F” (number of fishing hours within a sample day) for the Manistique lakes angler survey, spring 2003 through winter 2004.

Survey period	Sample shifts (h)		F
May 8–31	0600–1430	1330–2200	17
June	0600–1430	1330–2200	17
July	0600–1430	1300–2130	17
August	0630–1500	1230–2100	16
September	0630–1500	1200–2030	15
October 1–15	0630–1500	1030–1900	14
December 27–January 31	0700–1530	1100–1930	13
February	0700–1530	1100–1930	13
March 1–28	0700–1530	1100–1930	13

Table 3.–Coordinates (decimal degrees) for the Manistique lakes summer 2003 angler survey. See Figure 4 for general flight path and numbered locations.

Marker	Latitude	Longitude
1	46.29826ºN	85.72318ºW
2	46.27573ºN	85.75184ºW
3	46.26972ºN	85.72218ºW
4	46.24910ºN	85.73583ºW
5	46.22357ºN	85.73731ºW
6	46.22964ºN	85.76630ºW
7	46.22364ºN	85.75542ºW
8	46.24733ºN	85.75889ºW
9	46.25511ºN	85.78970ºW
10	46.23839ºN	85.78221ºW
11	46.21930ºN	85.77548ºW
12	46.21846ºN	85.79896ºW
13	46.24675ºN	85.81025ºW
14	46.26507ºN	85.81756ºW
15	46.26044ºN	85.83568ºW
16	46.21878ºN	85.82295ºW
17	46.16479ºN	85.80901ºW
18	46.16196ºN	85.77076ºW
19	46.17020ºN	85.76226ºW
20	46.18036ºN	85.78676ºW
21	46.18611ºN	85.77577ºW
22	46.18764ºN	85.75160ºW
23	46.20462ºN	85.74061ºW

Table 4.–Fish collected from Big Manistique Lake using a total sampling effort of 93 trap-net lifts and 98 fyke-net lifts from April 23 to May 2, 2003.

Species	Total catch[a]	Percent by number	Mean CPUE[a,b] trap-net	Mean CPUE[a,b] fyke-net	Length (in) range	Length (in) average[c]	Number measured[c]
Walleye	4,689	40.7	39.9	9.2	7.0–26.5	19.2	3,693
White sucker	4,608	40.0	26.1	20.4	6.6–20.5	14.9	726
Yellow perch	982	8.5	0.5	9.5	5.0–13.4	7.3	502
Rock bass	262	2.3	0.4	1.9	3.4–9.9	6.8	183
Smallmouth bass	221	1.9	1.3	1.0	7.9–19.9	14.5	217
Redhorse spp.	215	1.9	1.5	0.6	10.2–24.5	14.2	215
Northern pike	214	1.9	1.1	1.1	12.2–49.4	24.7	207
Shorthead redhorse	131	1.1	0.6	0.7	9.4–23.2	15.1	130
Silver redhorse	78	0.7	0.3	0.5	10.2–23.5	19.0	78
Brown bullhead	53	0.5	0.2	0.3	6.6–11.1	9.0	53
Brook trout	17	0.1	0.1	0.1	5.5–20.9	10.1	17
Lake herring	14	0.1	0.1	<0.1	5.8–12.9	7.1	14
Bluegill	9	0.1	<0.1	0.1	4.7–8.4	6.1	9
Central mudminnow	7	0.1	<0.1	<0.1	–	–	0
Pumpkinseed	5	<0.1	<0.1	<0.1	3.9–7.8	5.8	5
Largemouth bass	2	<0.1	0	<0.1	16.8–17.0	16.9	2

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

Table 5.–Number of fish per inch group caught and measured in spring netting on Big Manistique Lake, April 23 to May 2, 2003.

Inch group	Species														
	Walleye	White sucker	Yellow perch	Rock bass	Smallmouth bass	Redhorse spp.	Northern pike	Shorthead redhorse	Silver redhorse	Brown bullhead	Brook trout	Lake herring	Bluegill	Pumpkinseed	Largemouth bass
3	–	–	–	2	–	–	–	–	–	–	–	–	–	1	–
4	–	–	–	5	–	–	–	–	–	–	–	–	1	1	–
5	–	–	18	32	–	–	–	–	–	–	1	2	5	1	–
6	–	2	188	61	–	–	1	–	–	1	–	10	–	–	–
7	24	8	206	47	1	–	2	–	–	1	–	–	1	2	–
8	37	54	63	29	3	–	–	–	–	22	4	–	2	–	–
9	1	95	15	7	2	–	–	2	–	21	6	–	–	–	–
10	–	31	6	–	12	10	–	3	1	7	3	–	–	–	–
11	2	25	1	–	18	21	2	8	3	1	1	–	–	–	–
12	26	30	3	–	12	57	1	22	3	–	1	2	–	–	–
13	115	24	2	–	28	45	1	13	5	–	–	–	–	–	–
14	75	9	–	–	44	21	8	18	3	–	–	–	–	–	–
15	181	21	–	–	33	10	4	19	2	–	–	–	–	–	–
16	127	78	–	–	33	15	14	15	2	–	–	–	–	–	1
17	188	147	–	–	22	10	1	4	2	–	–	–	–	–	1
18	552	148	–	–	7	11	18	14	7	–	–	–	–	–	–
19	973	50	–	–	2	3	8	6	10	–	–	–	–	–	–
20	527	4	–	–	–	7	15	3	12	–	1	–	–	–	–
21	359	–	–	–	–	1	9	1	13	–	–	–	–	–	–
22	260	–	–	–	–	2	11	1	7	–	–	–	–	–	–
23	154	–	–	–	–	1	14	1	8	–	–	–	–	–	–
24	72	–	–	–	–	1	16	–	–	–	–	–	–	–	–
25	14	–	–	–	–	–	17	–	–	–	–	–	–	–	–
26	6	–	–	–	–	–	13	–	–	–	–	–	–	–	–
27	–	–	–	–	–	–	13	–	–	–	–	–	–	–	–
28	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–
29	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–
30	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–
31	–	–	–	–	–	–	4	–	–	–	–	–	–	–	–
32	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–
33	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–
34	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–
35	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–
36	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
37	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
38	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
39	–	–	–	–	–	–	6	–	–	–	–	–	–	–	–
40	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–
41	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–
42	–	–	–	–	–	–	4	–	–	–	–	–	–	–	–
43	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
44	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–
45	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
46	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
47	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
48	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
49	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
Total	3,693	726	502	183	217	215	207	130	78	53	17	14	9	5	2

Table 6.–Estimates of abundance, angler exploitation rates, and instantaneous fishing mortality rates for Big Manistique Lake walleyes, northern pike, and smallmouth bass. Symmetrical 95% confidence intervals for estimates are given in parentheses, where applicable.

Parameter	Walleyes	Northern pike	Smallmouth bass
Number tagged	3,381	99	140
Total tag returns	246	21	26
Number of legal-size[a] fish			
Multiple-census estimate	7,384 (6,685–8,083)	6,195 (99–23,089)	5,510[b] (140–16,437)
Single-census estimate	11,350 (8,478–14,222)	2,156 (99–4,610)	1,022 (151–1,893)
Michigan model prediction[c]	16,086 (3,289–78,673)	NA	NA
Number of adult[d] fish			
Multiple-census method	8,070 (7,270–8,869)	2,901 (350–5,453)	–
Single-census estimate	11,856 (8,882–14,830)	3,642 (174–7,788)	–
Michigan model prediction[e]	22,585 (5,199–98,118)	NA	NA
Annual exploitation rates			
Based on reward tag returns	9.4%	22.4%	21.1%
Based on harvest/abundance[f]	22.8% (14.0–31.5%)	14.8% (0–51.2%)	8.6% (0–24.5%)
Based on harvest/abundance[g]	14.8% (8.1–21.5%)	42.6% (0–94.5%)	46.6% (0–95.3%)
Annual mortality rates	31%	31%	45%

[a] Walleyes ≥15 in, northern pike ≥24 in, smallmouth bass ≥14 in.
[b] Minimum number of recaptures not obtained.
[c] Michigan model prediction of legal walleye abundance based on lake area (N = 21 lakes).
[d] Fish of legal-size and sexually mature fish of sub-legal size on spawning grounds.
[e] Michigan model prediction of adult walleye abundance based on lake area (N = 35 lakes).
[f] Multiple-census estimate of legal-size fish abundance.
[g] Single-census estimate of legal-size fish abundance.

Table 7.–Weighted mean lengths and sample sizes by age and sex for walleyes collected from Big Manistique Lake, April 23 to May 2, 2003. Standard deviation is in parentheses.

	Mean length						Number aged		
Age	Males		Females		All fish[a]		Males	Females	All fish[a]
1	–		–		8.0	(0.5)			9
2	13.2	(0.3)	–		12.6	(1.6)	15	–	36
3	15.2	(0.8)	16.3	(0.9)	15.3	(0.9)	24	10	40
4	16.6	(0.9)	18.4	(0.7)	18.2	(1.1)	11	14	25
5	18.5	(1.2)	19.3	(0.6)	19.2	(0.8)	5	6	11
6	–		20.2	(0.7)	19.7	(0.4)	0	6	6
7	19.2	(0.6)	21.1	(0.7)	20.1	(1.1)	10	16	26
8	19.3	(0.9)	21.8	(0.9)	19.8	(1.3)	11	3	14
9	19.5	(0.8)	22.5	(1.2)	20.9	(1.7)	10	7	18
10	19.9	(–)	22.6	(1.0)	21.5	(1.6)	1	5	6
11	19.7	(0.7)	23.1	(0.9)	21.5	(1.7)	5	6	12
12	20.8	(0.6)	23.1	(0.8)	22.3	(1.2)	3	7	10
13	22.6	(–)	23.3	(1.4)	23.2	(1.2)	1	6	8
14	21.7	(–)	23.1	(1.3)	22.8	(1.4)	1	5	7
15	–		26.0	(0.3)	26.0	(0.4)	–	2	2
16	–		16.3	(–)	25.2	(–)	–	1	1

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

Table 8.–Weighted mean lengths and sample sizes by age and sex for northern pike collected from Big Manistique Lake, April 23 to May 2, 2003. Standard deviation is in parentheses.

Age	Mean length						Number aged		
	Males		Females		All fish[a]		Males	Females	All fish[a]
1	14.8	(1.8)	–		15.5	(1.3)	4	–	9
2	18.8	(2.1)	20.5	(2.5)	19.6	(2.7)	23	21	61
3	24.1	(2.7)	24.4	(2.6)	24.1	(2.7)	12	5	27
4	24.8	(1.8)	29.5	(1.9)	26.1	(3.1)	6	4	12
5	25.6	(1.4)	31.3	(2.5)	27.8	(3.5)	15	11	28
6	26.1	(1.5)	36.4	(4.0)	30.1	(5.5)	7	4	13
7	26.0	(1.6)	37.8	(2.5)	32.7	(6.6)	2	4	6
8	32.0	(1.8)	41.0	(1.5)	38.6	(4.7)	2	5	7
9	–		41.4	(1.7)	41.4	(1.7)	–	5	5
10	–		49.4	(–)	49.4	(–)	–	1	1
11	–		44.3	(–)	44.3	(–)		1	1
12	–		43.7	(–)	38.4	(7.6)		1	2

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

Table 9.–Weighted mean lengths and sample sizes for smallmouth bass collected from Big Manistique Lake, April 23 to May 2, 2003. Standard deviation is in parentheses.

Age	Mean length		N
2	10.2	(1.0)	8
3	12.1	(1.6)	21
4	14.0	(1.0)	27
5	15.3	(1.0)	29
6	16.6	(0.6)	15
7	17.6	(0.6)	8
8	17.6	(0.6)	9
9	18.1	(0.6)	2
10	19.9	(–)	1
11	17.9	(0)	2

Table 10.–Catch-at-age estimates (apportioned by age-length key) by sex for walleyes, northern pike, and smallmouth bass from Big Manistique Lake, April 23 to May 2, 2003.

Age	Year class	Walleyes			Northern pike			Smallmouth bass
		Males	Females	All fish[a]	Males	Females	All fish[a]	All fish[a]
1	2002	–	–	45	5	–	12	–
2	2001	62	–	125	30	24	76	13
3	2000	281	18	347	18	8	34	39
4	1999	147	82	461	7	4	13	60
5	1998	137	48	367	20	13	34	54
6	1997	0	87	272	9	5	16	23
7	1996	533	385	688	3	4	7	11
8	1995	520	70	387	3	6	8	11
9	1994	322	134	396	–	6	6	2
10	1993	126	103	133	–	1	1	1
11	1992	171	90	224	–	1	1	3
12	1991	40	93	131	–	1	2	–
13	1990	2	41	51	–	–	–	–
14	1989	6	40	50	–	–	–	–
15	1988	–	3	2	–	–	–	–
16	1987	–	1	1	–	–	–	–
Total		2,347	1,195	3,680	95	73	210	217

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

Table 11.–Movement of fish tagged in Big Manistique Lake and recaptured during the spring survey (April 23 to May 2, 2003). Percent of total recaptured fish is in parentheses.

	Recapture location		
Species	South Manistique	Big Manistique	North Manistique
Walleye	4 (0.4)	931 (99.6)	0 (0)
Northern pike	0 (0)	1 (100)	0 (0)
Smallmouth bass	0 (0)	2 (100)	0 (0)

Table 12.–Movement of walleyes, northern pike, and smallmouth bass tagged in Big Manistique Lake, based on angler tag returns (reward and non-reward) during the year following tagging. Percent of total first-year tag returns is in parentheses.

	Recapture location		
Species	South Manistique	Big Manistique	North Manistique
Walleye	9 (3.7)	232 (96.3)	0 (0)
Northern pike	0 (0)	21 (100)	0 (0)
Smallmouth bass	0 (0)	26 (100)	0 (0)

Table 13.–Angler survey estimates for summer 2003 from Big Manistique Lake. Survey period was from May 8 through October 15, 2003. Two standard errors are given in parentheses.

Species	Catch/hour	May	June	July	August	September	October	Season
		Number harvested						
Smallmouth bass	0.0060 (0.0039)	0 (0)	92 (151)	160 (153)	183 (216)	30 (61)	27 (40)	493 (313)
Walleye	0.0200 (0.0082)	615 (455)	802 (379)	175 (217)	64 (77)	0 (0)	0 (0)	1,655 (635)
Yellow perch	0.7453 (0.2380)	0 (0)	312 (246)	2,450 (1,256)	22,036 (7,741)	23,288 (13,386)	13,477 (8,087)	61,563 (17,497)
Northern pike	0.0087 (0.0051)	134 (149)	267 (253)	279 (278)	37 (53)	0 (0)	0 (0)	717 (407)
White Sucker	0.0004 (0.0009)	0 (0)	0 (0)	35 (71)	0 (0)	0 (0)	0 (0)	35 (71)
Total harvested	0.7804 (0.2406)	749 (478)	1,472 (539)	3,099 (1,315)	22,321 (7,744)	23,318 (13,386)	13,504 (8,807)	64,465 (17,516)
		Number caught and released						
Smallmouth bass	0.0160 (0.0092)	583 (88)	485 (440)	334 (408)	443 (418)	0 (0)	0 (0)	1,320 (736)
Largemouth bass	0.0004 (0.0008)	0 (0)	0 (0)	32 (64)	0 (0)	0 (0)	0 (0)	32 (64)
Walleye	0.0186 (0.0122)	60 (119)	199 (222)	29 (59)	0 (0)	1,189 (944)	61 (101)	1,538 (984)
Northern pike	0.0160 (0.0077)	411 (326)	441 (292)	325 (391)	98 (153)	43 (61)	0 (0)	1,318 (609)
White Sucker	0.0004 (0.0008)	0 (0)	0 (0)	0 (0)	35 (70)	0 (0)	0 (0)	35 (70)
Rock bass	0.0017 (0.0034)	0 (0)	0 (0)	0 (0)	140 (280)	0 (0)	0 (0)	140 (280)
Carp	0.0004 (0.0007)	0 (0)	0 (0)	29 (59)	0 (0)	0 (0)	0 (0)	29 (59)
Bluegill	0.0020 (0.0026)	0 (0)	0 (0)	0 (0)	168 (212)	0 (0)	0 (0)	168 (212)
Pumpkinseed	0.0002 (0.0003)	0 (0)	0 (0)	0 (0)	0 (0)	13 (26)	0 (0)	13 (26)
Yellow perch	0.2957 (0.938)	0 (0)	486 (364)	4,227 (1,889)	13,214 (5,004)	4,333 (2,915)	2,168 (3,179)	24,427 (6,881)
Total released	0.3513 (0.0993)	529 (358)	1,611 (679)	4,977 (1,975)	14,098 (5,036)	5,578 (3,065)	2,229 (3,181)	29,021 (7,026)
Total (harvested + released)	1.1317 (0.2817)	1,278 (597)	3,083 (867)	8,076 (2,373)	36,419 (9,238)	28,896 (13,732)	15,734 (8,691)	93,486 (18,872)
		Fishing effort						
Angler hours		8,795 (4,126)	17,362 (3,746)	21,372 (6,789)	21,393 (5,973)	9,948 (5,324)	3,737 (1,898)	82,607 (12,032)
Angler trips		2,812 (1,729)	4,852 (1,289)	8,307 (3,183)	8,437 (2,452)	3,311 (1,941)	1,170 (658)	28,888 (5,000)

Table 14.–Angler survey estimates for winter 2004 from Big Manistique Lake. Survey period was from December 27, 2003 through March 28, 2004. Two standard errors are given in parentheses.

Species	Catch/hour	Dec–Jan	February	March	Season
		Number harvested			
Walleye	0.0073 (0.0073)	13 (18)	29 (35)	0 (0)	42 (39)
Yellow perch	1.2010 (0.7814)	653 (434)	4,737 (3,494)	1,534 (1,525)	6,924 (3,837)
Northern pike	0.0385 (0.0287)	62 (74)	159 (127)	0 (0)	222 (147)
Total harvested	1.2467 (0.7901)	728 (440)	4,925 (3,496)	1,534 (1,525)	7,188 (3,840)
		Number caught and released			
Walleye	0.0149 (0.0201)	82 (112)	4 (07	0 (0)	86 (112)
Yellow perch	0.0395 (0.0486)	14 (27)	166 (255)	48 (80)	228 (269)
Total released	0.0544 (0.0539)	96 (115)	170 (255)	48 (80)	314 (291)
Total (harvested + released)	1.3011 (0.8010)	824 (455)	5,096 (3,506)	1.582 (1,527)	7,501 (3,851)
		Fishing effort			
Angler hours		1,675 (666)	3,128 (1,697)	962 (737)	5,765 (1,966)
Angler trips		497 (254)	1,440 (896)	562 (467)	2,498 (1,042)

Table 15.–Angler survey estimates for summer and winter 2003–04 from Big Manistique Lake. Survey period was May 8 through October 15, 2003 and December 27, 2003 through March 28, 2004. Two standard errors are given in parentheses.

Species	Catch/hour	May	June	July	August	September
		Number harvested				
Smallmouth bass	0.0056 (0.0036)	0 (0)	92 (151)	160 (153)	183 (216)	30 (61)
Walleye	0.0192 (0.0077)	615 (455)	802 (379)	175 (217)	64 (77)	0 (0)
Yellow perch	0.7750 (0.2292)	0 (0)	312 (246)	2,450 (1,256)	22,036 (7,741)	23,288 (13,386)
Northern pike	0.0106 (0.0051)	134 (149)	267 (253)	279 (278)	37 (53)	0 (0)
White Sucker	0.0004 (0.0008)	0 (0)	0 (0)	35 (71)	0 (0)	0 (0)
Total harvested	0.8108 (0.2317)	749 (478)	1,472 (539)	3,099 (1,315)	22,321 (7,744)	23,318 (13,386)
		Number caught and released				
Smallmouth bass	0.0149 (0.0086)	583 (88)	485 (440)	334 (408)	443 (418)	0 (0)
Largemouth bass	0.0004 (0.0007)	0 (0)	0 (0)	32 (64)	0 (0)	0 (0)
Walleye	0.0184 (0.0115)	60 (119)	199 (222)	29 (59)	0 (0)	1,189 (944)
Northern pike	0.0149 (0.0072)	411 (326)	441 (292)	325 (391)	98 (153)	43 (61)
White Sucker	0.0004 (0.0008)	0 (0)	0 (0)	0 (0)	35 (70)	0 (0)
Rock bass	0.0016 (0.0032)	0 (0)	0 (0)	0 (0)	140 (280)	0 (0)
Carp	0.0003 (0.0007)	0 (0)	0 (0)	29 (59)	0 (0)	0 (0)
Bluegill	0.0019 (0.0024)	0 (0)	0 (0)	0 (0)	168 (212)	0 (0)
Pumpkinseed	0.0001 (0.0003)	0 (0)	0 (0)	0 (0)	0 (0)	13 (26)
Yellow perch	0.2790 (0.0869)	0 (0)	486 (364)	4,227 (1,889)	13,214 (5,004)	4,333 (2,915)
Total released	0.3319 (0.0918)	529 (358)	1,611 (679)	4,977 (1,975)	14,098 (5,036)	5,578 (3,065)
Total (harvested + released)	1.1427 (0.2690)	1,278 (597)	3,083 (867)	8,076 (2,373)	36,419 (9,238)	28,896 (13,732)
		Fishing effort				
Angler hours		8,795 (4,126)	17,362 (3,746)	21,372 (6,789)	21,393 (5,973)	9,948 (5,324)
Angler trips		2,812 (1,729)	4,852 (1,289)	8,307 (3,183)	8,437 (2,452)	3,311 (1,941)

Table 15.–Extended.

Species	Catch/hour	October	Dec–Jan	February	March	Season
		Number Harvested				
Smallmouth bass	0.0056 (0.0036)	27 (40)	0 (0)	0 (0)	0 (0)	493 (313)
Walleye	0.0192 (0.0077)	0 (0)	13 (18)	29 (35)	0 (0)	1,697 (636)
Yellow perch	0.7750 (0.2292)	13,477 (8,087)	653 (434)	4,737 (3,494)	1,534 (1,525)	68,487 (17,912)
Northern pike	0.0106 (0.0051)	0 (0)	62 (74)	159 (127)	0 (0)	939 (433)
White Sucker	0.0004 (0.0008)	0 (0)	0 (0)	0 (0)	0 (0)	35 (71)
Total harvested	0.8108 (0.2317)	13,504 (8,807)	728 (440)	4,925 (3,496)	1,534 (1,525)	71,652 (17,932)
		Number Released				
Smallmouth bass	0.0149 (0.0086)	0 (0)	0 (0)	0 (0)	0 (0)	1,320 (736)
Largemouth bass	0.0004 (0.0007)	0 (0)	0 (0)	0 (0)	0 (0)	32 (64)
Walleye	0.0184 (0.0115)	61 (101)	82 (112)	4 (7)	0 (0)	1,625 (991)
Northern pike	0.0149 (0.0072)	0 (0)	0 (0)	0 (0)	0 (0)	1,318 (609)
White Sucker	0.0004 (0.0008)	0 (0)	0 (0)	0 (0)	0 (0)	34 (70)
Rock bass	0.0016 (0.0032)	0 (0)	0 (0)	0 (0)	0 (0)	140 (280)
Carp	0.0003 (0.0007)	0 (0)	0 (0)	0 (0)	0 (0)	29 (59)
Bluegill	0.0019 (0.0024)	0 (0)	0 (0)	0 (0)	0 (0)	168 (212)
Pumpkinseed	0.0001 (0.0003)	0 (0)	0 (0)	0 (0)	0 (0)	13 (26)
Yellow perch	0.2790 (0.0869)	2,168 (3,179)	14 (27)	166 (255)	48 (80)	24,655 (6,886)
Total released	0.3319 (0.0918)	2,229 (3,181)	96 (115)	170 (255)	48 (80)	29,335 (7,032)
Total (harvested + released)	1.1427 (0.2690)	15,734 (8,691)	824 (455)	5,096 (3,506)	1,582 (1,527)	100,987 (19,261)
		Fishing effort				
Angler hours		3,737 (1,898)	1,675 (666)	3,128 (1,697)	962 (737)	88,373 (12,191)
Angler trips		1,170 (658)	497 (254)	1,440 (896)	562 (467)	31,386 (5,107)

Table 16.–Voluntary angler tag returns from walleyes (reward and non-reward, harvested and released) by month for the year following tagging in Big Manistique Lake. Percentage of total is in parentheses.

Month	Species					
	Walleye		Northern pike		Smallmouth bass	
4	0	(0)	0	(0)	0	(0)
5	55	(22.8)	5	(25.0)	8	(30.8)
6	150	(62.2)	8	(40.0)	9	(34.6)
7	7	(2.9)	4	(20.0)	5	(19.2)
8	20	(8.3)	1	(5.0)	4	(15.4)
9	1	(0.4)	0	(0)	0	(0)
10	4	(1.7)	0	(0)	0	(0)
11	0	(0)	0	(0)	0	(0)
12	1	(0.4)	0	(0)	0	(0)
1	2	(0.8)	0	(0)	0	(0)
2	1	(0.4)	2	(10.0)	0	(0)
3	0	(0)	0	(0)	0	(0)
Total	241		20		26	

Table 17.–Mean lengths of walleyes from the 2003 survey of Big Manistique Lake, compared to other surveys. Number aged in parentheses.

		Lake							
	State	Big Manistique			South Manistique	Michigamme Reservoir	Gogebic	Bond Falls	Lake Michigamme
Age	average[a]	2003[b]	2000[c]	1997[d]	2003[b]	2001[b]	1999[b]	1999[d]	2002[d]
2	10.4	12.6 (36)	15.2 (2)		11.4 (2)	8.3 (9)		8.5 (1)	8.3 (2)
3	13.9	15.3 (40)	14.7 (1)	13.6 (2)	13.5 (21)	12.5 (76)	11.4 (1)		10.4 (4)
4	15.8	18.2 (25)	17.5 (7)	15.8 (4)	15.9 (51)	14.0 (90)	13.0 (1)	14.5 (3)	11.9 (1)
5	17.6	19.2 (11)	18.3 (5)	17.8 (2)	17.1 (33)	14.8 (41)	13.8 (34)	15.7 (11)	12.7 (5)
6	19.2	19.7 (6)	19.7 (10)	17.6 (7)	19.7 (10)	15.5 (91)	16.4 (2)		15.1 (2)
7	20.6	20.1 (26)	21.1 (3)	20.0 (8)	19.4 (8)	16.2 (64)	16.7 (1)	18.7 (1)	14.5 (1)
8	21.6	19.8 (14)	20.8 (2)	21.1 (11)	19.8 (17)	16.8 (20)	17.1 (10)		16.7 (1)
9	22.4	20.9 (18)	23.2 (1)	22.5 (5)	19.9 (17)	18.7 (15)	17.0 (3)	22.0 (1)	
10	23.1	21.5 (6)	23.8 (1)	23.9 (2)	18.8 (2)	19.4 (15)	17.8 (7)		21.4 (1)
11		21.5 (12)	23.4 (2)	23.2 (1)	21.0 (19)	20.3 (12)	17.3 (2)		
12		22.3 (10)	26.0 (1)	22.9 (1)	22.1 (16)	18.7 (19)			18.4 (1)
13		23.2 (8)			23.6 (8)	19.9 (9)	20.1 (3)		
14		22.8 (7)			22.6 (4)	19.3 (11)			
15		26.0 (2)			26.0 (5)	20.2 (3)			
16		25.2 (1)				19.5 (3)			22.3 (1)
17						20.5 (1)			
Mean growth index[e]		+0.4	+0.6	-1.0	-0.8	-3.2	-3.3	-2.3	-5.3

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

Table 18.–Mean lengths of northern pike from the 2003 survey of Big Manistique Lake, compared to other surveys. Number aged in parentheses.

		Lake						
	State	Big Manistique			South Manistique	Michigamme Reservoir	Bond Falls	Lake Michigamme
Age	average[a]	2003[b]	2000[c]	1997[d]	2003[b]	2001[b]	1999[d]	2002[d]
2	17.7	19.6 (61)	18.9 (2)	14.9 (3)	16.7 (41)	16.0 (94)	17.5 (5)	17.1 (8)
3	20.8	24.1 (27)	24.7 (3)	21.3 (3)	20.2 (46)	18.8 (118)	19.6 (7)	19.4 (17)
4	23.4	26.1 (12)	25.4 (2)	22.4 (11)	23.6 (26)	20.6 (64)	21.5 (9)	23.6 (6)
5	25.5	27.8 (28)		23.5 (14)	22.5 (5)	21.3 (51)	23.7 (4)	22.8 (5)
6	27.3	30.1 (13)	29.3 (1)	25.6 (4)	23.9 (6)	25.3 (35)	31.7 (1)	28.5 (10)
7	29.3	32.7 (6)		27.9 (3)	24.8 (4)	25.6 (21)		34.8 (8)
8	31.2	38.6 (7)		29.9 (1)		27.5 (3)		31.5 (1)
9		41.4 (5)			28.6 (1)	36.3 (4)		32.1 (1)
10		49.4 (1)			29.1 (1)			
11		44.3 (1)				34.0 (1)		
12		38.4 (2)						
Mean growth index[e]		+3.4	–	-2.6	-1.6	-2.7	-2.1	-0.5

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

Table 19.–Comparison of recreational fishing effort and total harvest on Big Manistique Lake 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	Fishing effort (h) total	Fishing effort (h) per acre	Fish harvested total	Fish harvested per h	Fish harvested per acre
Michigan[a] multiple	–	Jan–Nov, 2001	2,684,359	–	677,360	0.25	–
Huron[a] multiple	–	Jan–Oct, 2001	1,807,519	–	1,057,819	0.59	–
Houghton Roscommon	20,075	Apr 2001–Mar 2002	499,048	24.9	386,287	0.77	19.2
Erie[a] Wayne/Monroe	–	Apr–Oct, 2001	490,807	–	378,700	0.77	–
Superior[a] multiple	–	Apr–Oct, 2001	180,428	–	60,947	0.34	–
Cisco Chain Gogebic/Vilas	3,987	May 2002–Feb 2003	180,262	45.2	120,412	0.67	30.2
Muskegon Muskegon	4,232	April 2002–Mar 2003	180,064	42.5	184,161	1.02	43.5
Fletcher Pond Alpena/Montmorency	8,970	May–Sep, 1997	171,521	19.1	118,101	0.69	13.2
Burt Cheboygan	17,120	April 2001–Mar 2002	134,205	7.8	68,473	0.51	4.0
South Manistique Mackinac	4,133	May 2003–March 2004	142,686	34.5	43,654	0.31	10.6
Gogebic Ontonagon/Gogebic	13,380	May 1998–Apr 1999	121,525	9.1	26,622	0.22	2.0
Leelanau Leelanau	8,607	April 2002–March 2003	112,112	13.0	15,464	0.14	1.8
Big Manistique[b] Luce and Mackinac	10,346	May 2003–March 2004	88,373	8.5	71,652	0.81	6.9
Mullett Cheboygan	16,630	May–Aug, 1998	87,520	5.3	18,727	0.21	1.1
Crooked and Pickerel Emmet	3,434	April 2001–Mar 2002	55,894	16.3	13,665	0.24	4.0
Michigamme Reservoir Iron	6,400	May 2001–Feb 2002	52,686	8.2	10,899	0.21	1.7

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

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Appendix.–Fish species captured in Big Manistique Lake from 1987 through 2003 using various gear types.

Common name	Scientific name
Species collected in 2003 with fyke nets and electrofishing gear	
Bluegill	*Lepomis macrochirus*
Brook Trout	*Salvelinus fontinalis*
Brown bullhead	*Ameiurus nebulosus*
Central mudminnow	*Umbra limi*
Lake Herring	*Coregonus artedi*
Largemouth bass	*Micropterus salmoides*
Northern pike	*Esox lucius*
Pumpkinseed	*Lepomis gibbosus*
Rock bass	*Ambloplites rupestris*
Shorthead Redhorse	*Moxostoma macrolepidotum*
Silver Redhorse	*Moxostoma anisurum*
Smallmouth bass	*Micropterus dolomieu*
Walleye	*Sander vitreus*
White sucker	*Catostomus commersonii*
Yellow perch	*Perca flavescens*
Additional species collected with fyke nets and gill nets (1987–2000)	
Bluntnose minnow	*Pimephales notatus*
Common shiner	*Luxilus cornutus*
Fathead minnow	*Pimephales promelas*
Golden shiner	*Notemigonus crysoleucas*
Lake chub	*Couesius plumbeus*
Logperch	*Percina caprodes*
Mottled sculpin	*Cottus bairdii*
Spottail shiner	*Notropis hudsonius*