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

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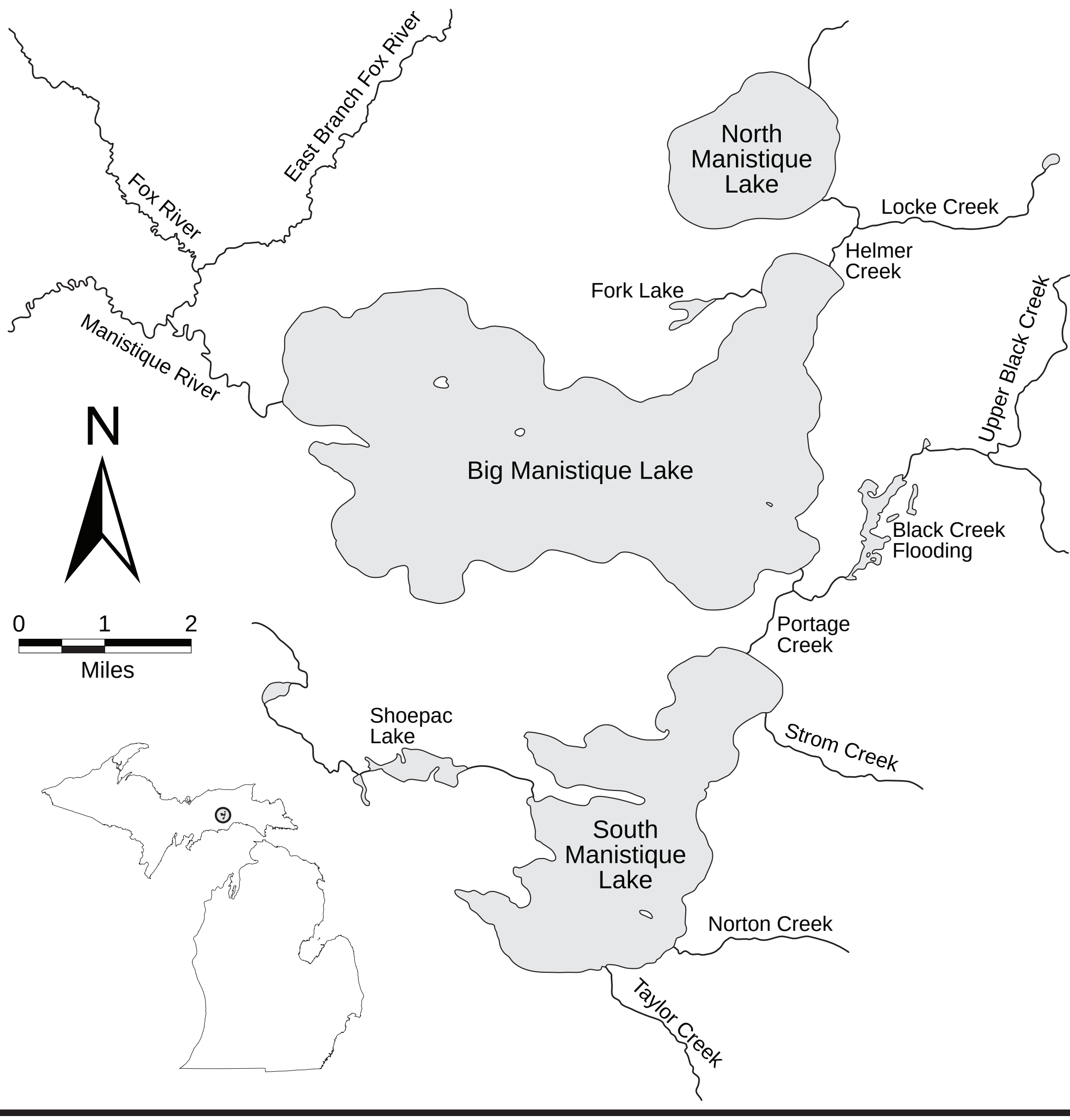

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Michigan Department of Natural Resources
Fisheries Special Report 48, 2008

The Fish Community and Fishery of South Manistique Lake, Mackinac County, 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 South Manistique Lake, Mackinac County, Michigan from April 2003 through March 2004. This work was part of a statewide program designed to improve assessment and monitoring of fish communities and fisheries in Michigan's largest inland lakes. Known as the Large Lakes Program, it is currently scheduled to survey about four lakes per year over the next ten years (Clark et al. 2004).

The Large Lakes Program has three primary objectives. First, we want to produce consistent indices of abundance and estimates of annual harvest and fishing effort for important fishes. Initially, important fishes are defined as species susceptible to trap or fyke nets and/or those readily harvested by anglers. Our hope is to produce statistics for important fishes to help detect major changes in their populations over time. Second, we want to produce sufficient growth and mortality statistics to evaluate effects of fishing on special-interest species which support valuable fisheries. This usually involves targeting special-interest species with nets or other gears to collect, sample, and mark sufficient numbers. We selected walleyes *Sander vitreus*, northern pike *Esox lucius*, and smallmouth bass *Micropterus dolomieui* as special-interest species in this survey of South 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 South 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 between lakes or changes within a lake over time. South Manistique Lake is the eighth lake to be sampled under the protocols of the program, thus, we were sometimes limited in our ability to make valid comparisons. Of course, as our program progresses we will eventually have a large body of netting data collected under the same conditions in the future.

Study Area

The surface area of South Manistique Lake, also known as Whitefish Lake, is approximately 4,000 acres, with sources disagreeing only slightly on size. Humphrys and Green (1962) estimated 4,001 surface acres for South Manistique Lake by taking measurements from United States Geological Survey (USGS) maps using hand-held drafting tools. Breck (2004) reported 4,133 acres for South 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 will compare various measures of productivity among lakes, such as number of fish per acre or harvest per acre, so an accurate measure of lake size is important. Therefore, we will use the more modern estimate of 4,133 acres as the size of South Manistique Lake in our analyses.

South Manistique is fed by Norton Creek and Taylor Creek (Figure 1); both of which are designated trout streams. Other tributaries that enter the lake include Strom Creek and the Shoepac River. The only outlet, Portage Creek, is located on the north end of the lake in Curtis and empties into Big Manistique Lake.

The shoreline is largely developed with private and commercial residences, but some public riparian land exists in the form of a state forest park. There are four public boat launches; one in the Village of Curtis on the northern end of the lake, and three owned by the Michigan Department of Natural Resources (MDNR) on the west, northwest, and southeast shores. Maximum water depth is approximately 29 feet with about 10% of the lake depth greater than 20 feet (Figures 2 and 3). Substrate on the immediate shoreline of South Manistique Lake is sand, with bays composed of sand, muck, and fiberous peat. Extensive and productive littoral zones can be found around the periphery of the lake. Aquatic vegetation consists of Chara, Potamogeton, bladderwort, flatstem pondweed, northern milfoil, lily pads, cattails, bulrushes, and common naiad.

The fish community of South Manistique Lake includes species typical of northern Michigan. We list 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, Percidae,* and *Salmonidae.*

Fish stocking in South Manistique Lake has involved a variety of species, ages, and sizes dating back to 1934. Yellow perch were stocked in 1936 and 1939. Northern pike were stocked in 1941, 1949, and 1950. Northern muskellunge and tiger muskellunge were introduced in 1972, and tiger muskellunge alone were stocked in 1979, 1981, and 1983. Northern muskellunge were stocked again in 1987, 1991, 1998, and 2002 (Table 1). Walleye fry and fingerlings have been the most frequently stocked fish in South Manistique Lake. Walleyes were stocked annually from 1934–41, and stocking again occurred on 17 occasions from 1971 to 1994 (Table 1).

There have been 13 State of Michigan Master Angler awards taken from South Manistique Lake from 1994–2005, including bluegill, brook trout, muskellunge, northern pike, rock bass, and yellow perch.

Methods

We used the same methods on South Manistique Lake as 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 South Manistique Lake, we surveyed North and Big Manistique lakes using identical methods.

Fish Community

We described the status of the overall 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 South Manistique Lake with trap nets, fyke nets, and electrofishing gear from April 22 to May 1, 2003. We used two boats daily to work nets, each with three-person crews, for two weeks. Each net-boat crew tended about 10 nets per day. Night electrofishing runs were also made occasionally.

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 ranged from 1–2 nights, but most were 1 night. We used a Smith-Root® boat equipped with boom-mounted electrodes (DC) for electrofishing. Latitude and longitude were recorded for all net locations and electrofishing runs using a GPS.

We identified species and counted all fish captured. For nontarget species, we measured lengths to the nearest 0.1 in for subsamples of up to 200 fish per work crew. Crews ensured that lengths were taken over the course of the survey to account for any temporal trends in the size structure of fish collected. We used Microsoft Access© to store and retrieve data collected during the tagging operation. Size distribution data only included fish on their initial capture occasion. 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 (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. As one possible index, 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, muskellunge, smallmouth bass, and largemouth bass as piscivores; rock bass, bluegill, pumpkinseed sunfish, yellow perch, and rainbow trout as pelagic planktivores-insectivores; and mottled sculpin, 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, northern pike, and smallmouth bass using mark-and-recapture methods. Walleyes (≥15 in), northern pike (≥24 in), and smallmouth bass (≥14 in) 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 nonreward 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 retagged, and so were accounted for in the total number of marked fish at large.

We compared two different abundance estimates from mark-and-recapture data, one derived from marked-unmarked ratios during the spring survey (multiple census) and the other derived from marked-unmarked ratios from the angler survey (single census). Sample size was increased for the single-census estimates by using recapture data from a standard summer netting survey of the lake. We calculated the coefficient of variation (CV) for each abundance estimate and considered estimates with a CV less than or equal to 0.40 reliable (Hansen et al. 2000).

For the multiple-census estimate, we used the Schumacher-Eschmeyer formula from daily recaptures during the tagging operation (Ricker 1975). The minimum number of recaptures necessary for an unbiased estimate was set a priori at four. For the single-census estimate, we used numbers of marked and unmarked fish seen by creel clerks in the companion angler survey as the "recapture-run" sample. The Chapman modification of the Petersen method (Ricker 1975) was used to generate population estimates. 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).

No prior abundance estimates existed for walleyes, northern pike or smallmouth bass in South Manistique Lake to help us gauge how many fish to mark. For walleyes, we used a regression equation developed for Wisconsin lakes (Hansen 1989) to provide an a priori estimate of abundance. This regression predicts adult walleye abundance in lakes with natural recruitment based on lake size. Parameters for this equation are re-calculated every year by Wisconsin Department of Natural Resources (WDNR). We used the same parameters used by WDNR in 2003 (Joe Hennessy, WDNR, personal communication):

$$\ln(N) = 1.6251 + 0.9441 \times \ln(A),$$

where N is the estimated number of walleyes and A is the surface area of the lake in acres. This equation was derived from abundance estimates on 185 lakes in northern Wisconsin. The equation gives an estimate of 13,183 walleyes, with a 95% prediction interval (Zar 1999) of 4,327 to 40,160, for South Manistique Lake. Based on this estimate, we targeted approximately 1,300 legal walleyes for marking in South Manistique Lake.

We also used two regression equations developed for Michigan lakes to provide additional estimates of abundance. These regressions predict legal and adult walleye abundance based on lake size. These equations were derived from historic abundance estimates made in Michigan over the past 20 years. The following equation for adult walleyes was based on 35 abundance estimates:

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

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

where N is the estimated number of adult walleyes and A is the surface area of the lake in acres. For South Manistique, the equation gives an estimate of 8,440 adult walleyes, with a 95% prediction interval (Zar 1999) of 1,997 to 35,669.

The equation for legal walleyes was based on 21 estimates:

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

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

where N is the estimated number of legal walleyes and A is the surface area of the lake in acres. The equation gives an estimate of 6,357 legal walleyes, with a 95% prediction interval (Zar 1999) of 1,348 to 29,981 for South Manistique Lake.

Our primary, single-census estimates were only for walleyes 15 in or larger. 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 sublegal 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 larger by the proportion of adult walleyes on the spawning grounds that were 15 in or larger, using the equation in Clark et al. (2004).

We accounted for fish that recruited to legal size over the course of the year between mark and recapture by removing a portion of the unmarked fish observed by the angler survey clerk or survey personnel (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 sublegal 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.

Similar to walleyes, we defined adult northern pike as those 24 in or larger, or less than 24 in but of identifiable sex. We estimated adult northern pike using the multiple-census and adjusted single-census methods as was done for walleyes. For smallmouth bass, we could not identify the sex, or sexual maturity of enough fish to make separate estimates for adult fish.

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

Sample sizes for age analysis were based on historical length-at-age data from South Manistique Lake and methods given in Lockwood and Hayes (2000). Our goal was to collect 20 male and 20 female fish per inch group for walleyes and northern pike. For species where sex was not determined (smallmouth bass, muskellunge), we had a target of 20 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. 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 one of the first two. Samples were discarded if three technicians disagreed on age, but occasionally an average age was used when ages assigned to older fish (≥ age 10) were within ±10% of each other.

After a final age was identified for all samples, 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) for walleyes and northern pike. Where sample sizes were sufficient, weighted mean lengths at age and age-length keys were computed for smallmouth bass and muskellunge, without partitioning for sex.

We compared our mean lengths at age to those from previous surveys of South 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, females, and all fish (males, females, and fish of unknown sex) 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 returned by anglers adjusted for tag loss. We did not assess tagging mortality, and made the assumption that mortality was negligible. Although we did not make a rigorous estimate of the reporting rate, we made a rough estimate from the proportion of reward tags observed by the creel clerk that were subsequently reported by the anglers. This was not a true estimate of nonreporting 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.

Additionally, we compared 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.

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

In addition to data on harvested fish, we estimated the release rate of legal fish. We did this by adding a question to the tag return form asking if the fish was released.

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, but 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, 1996b; Nate, et al. 2000).

We obtained population data in South Manistique Lake for only one year, and so could not rigorously evaluate year-class strength. However, we suggest that valuable insight about the relative variability of recruitment can be gained by examining the properties of our catch-curve regressions for walleyes and northern pike. For example, Maceina (2003) used catch-curve residuals as a quantitative index of the relative year-class strength of black crappie and white crappie in Alabama reservoirs. He showed that residuals were related to various hydrological variables in the reservoirs. As Maceina (2003), we assumed the residuals of our catch-curve regressions were indices of year-class strength. We related year-class strength 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 historic water quality data specific to the lake. So analyses were limited to correlation with weather data. Variables that we tested 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 examining the location of angling capture versus the location of initial capture at tagging. Capture locations provided by anglers were often vague; thus, statistical analysis of distance moved would be questionable. Instead, we identified conspicuous movement such as to another lake or connected river.

Angler Survey

Fishing harvest seasons for walleyes, northern pike, and muskellunge during this survey were May 15, 2003–February 28, 2004. Minimum size limits were 15 in for walleyes, 24 in for northern pike, and 42 in for muskellunge. Fishing harvest seasons for smallmouth bass and largemouth bass were May 24 through December 31, 2003. Minimum size limit was 14 in for both smallmouth bass and largemouth bass. Daily bag limit was 5 fish in any combination of walleyes, northern pike, smallmouth bass, largemouth bass, or flathead catfish, with no more than two northern pike.

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 in combination with lake whitefish.

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. Ice cover in the winter requires different methods from the summer 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 summer 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. For sampling purposes, all three Manistique lakes were surveyed with a single air flight, with each lake as a separate section (Figure 4). All count and interview data were collected and recorded by section, and effort and catch estimates were made by section.

Two different 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 at 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 for each count was recorded on a lake map similar to Figure 4. This information included: date, count time, and number of fishing boats in each section.

Minimum fishing time prior to interview (incomplete-trip interview) was one hour (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 one hour are more representative of catch rates based on access interviews (completed-trip interviews) (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).

While this survey was designed to collect roving (incomplete trip) interviews, the clerk occasionally encountered anglers as they completed their fishing trips. The clerk was instructed to interview these anglers and record the same information as for roving interviews – noting that the interview was 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 applicable tag number(s). Number of anglers in each party was recorded on one interview form for each party. One of two sample shifts was selected each sample day for interviewing (Table 2). Interview starting location (Table 3) and direction were randomized daily.

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, 2002). The clerk followed a randomized count and interview schedule. One of two shifts was selected each sample day (Table 2). Starting location (Table 3; 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. Scanner-ready interview and count forms were used.

Similar to summer interview methods, minimum fishing time prior to interviewing was one hour. No anglers were interviewed while counting (Wade et al. 1991). Interview forms, information, and techniques used during the winter survey period were the same as those used during 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 (“F” in Lockwood et al. 1999) are given in Table 2. These values are the number of hours within sample days. Effort is the product of mean counts by section for a given period day type, days within the period, and the expansion value for that period. The angling effort and catch reported here are for those periods sampled; no expansions were made to include periods not sampled (e.g., 2200 to 2400 and 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:

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

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:

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

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

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

As a routine part of interviewing, the creel clerk recorded presence or absence of jaw tags and fin clips, tag numbers, and lengths of walleyes, 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.

Results[1]

Fish Community

We collected a total of 7,292 fish of 18 species (Table 4). Total sampling effort was 84 trap-net lifts, 58 fyke-net lifts, and 2 electrofishing runs. We captured 4,848 walleyes and 276 northern pike, not including recaptures. Other species collected, in order of abundance: yellow perch, white sucker, rock bass, bluegill, smallmouth bass, largemouth bass, rainbow trout, pumpkinseed sunfish, muskellunge, brown bullhead, redhorse suckers, black bullhead, mottled sculpin, and common shiner. Yellow perch comprised 14% of the total survey catch by number. Mean length of this species was 5.7 inches. Approximately 14% of the yellow perch captured were 7-inches or larger. Rock bass comprised 2.3% of the catch by number. Mean length of this species was 7.5 inches. Approximately 85% of the rock bass collected were 7-inches or larger. Other panfish, including bluegills and pumpkinseed sunfish, were captured in low numbers during the survey. Suckers (white and redhorse) are common in South Manistique Lake (Table 4) and comprise approximately 8% of the catch by number. The overall fish community composition in South Manistique Lake was 72% piscivores, 18% pelagic planktivores-insectivores, and 10% benthivores (Table 4).

Walleyes, Northern Pike, and Smallmouth Bass

Size structure.–Size structure of walleyes, northern pike, and smallmouth bass measured in our spring netting and electrofishing catches are presented in Table 5. The percentage of walleyes, northern pike, and smallmouth bass that were legal size was 74, 13, and 87, respectively. The population of spawning walleyes was dominated by 13- to 22-inch walleyes, with few (4%) larger than 22 inches. Most northern pike were 15 to 23 inches, and large pike (≥30 in) are almost nonexistent. Smallmouth bass, though few, were dominated by 15- to 18-inch fish, with no fish over 20 inches.

Sex composition.–Male walleyes outnumbered females in our spring survey, which is typical for walleyes (Carlander 1997). Of all walleyes captured, 64% were male, 25% were female, and 11% were unknown sex. Of legal-size walleyes captured, 64% were male, 34% were female, and 2% were 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, 17% were male, 21% were female, and 62% were unknown sex. Of 37 legal-size northern pike captured, 14% were male, 24% were female, and 62% were unknown sex. We did not identify the sex of enough smallmouth bass or muskellunge to accurately report the ratio of males to females.

Abundance.–In South Manistique Lake we placed a total of 2,812 tags on legal-sized walleyes (978 reward and 1,834 nonreward tags) and clipped fins of 984 sublegal walleyes. Six recaptured walleyes were observed to have died, or lost their tag during the spring netting/electrofishing survey, thus the effective number tagged was 2,806. 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.

Creel clerks observed a total of 203 walleyes on South Manistique Lake, of which 62 were marked (had a fin clip or a tag). In a standard summer netting survey we observed 51 legal size walleyes, of which 26 were marked. We reduced the number of unmarked walleyes in the single-census calculation by 55 fish to adjust for sublegal fish that grew over the minimum size limit during the fishing season. We observed three fish that had a fin clip, no tag, and were determined to have

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

been legal size at the time of tagging. Based on the sample of 62 re-captured fish, the estimate of tag loss is 4.8%, with a standard error of 0.1%.

The estimated number of legal-sized walleyes was 5,505 using the multiple-census method and 6,473 using the single-census method (Table 6). The estimated number of adult walleyes was 7,558 using the multiple-census method, and 7,898 using the single-census method. The coefficient of variation (CV = standard deviation/estimate) was 0.05 for the two multiple-census estimates, and was 0.08 for the single-census estimates.

We tagged 35 legal-sized northern pike in South Manistique Lake (12 reward and 23 nonreward tags). No fish were observed to have died, or lost tags during the spring netting/electrofishing survey. We also clipped fins of 233 sublegal northern pike. The creel clerk observed 49 northern pike, of which none were tagged. During the summer netting survey we observed 14 legal size northern pike, of which one was marked. We reduce the overall number of unmarked northern pike in the single-census calculation by 17 fish to adjust for sublegal fish that grew over the minimum size limit during the fishing season. There was no tag loss for northern pike observed by the creel clerk.

The estimated number of legal-sized northern pike was 164 (CV = 0.52) using the multiple-census method and 846 (CV = 0.57) using the single-census method. The estimated number of adult northern pike was 1,907 (CV = 0.59) using the multiple-census method and 2,881 (CV = 0.57) using the single-census method (Table 6).

We tagged 46 legal-sized smallmouth bass in South Manistique Lake (12 reward and 34 nonreward tags). No recaptured fish were observed to have died, or lost tags during the spring netting/electrofishing survey. We also clipped fins of 9 sublegal smallmouth bass. The creel clerk observed 2 smallmouth bass, of which none were tagged. During a standard summer survey we observed 17 legal-size smallmouth bass, of which two were marked. We reduced the overall number of unmarked smallmouth bass in the single-census calculation by two fish to adjust for sublegal 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-sized smallmouth bass was 229 (CV = 0.22) using the multiple-census method and 282 (CV = 0.46) using the single-census method (Table 6).

We tagged six legal-sized muskellunge in South Manistique Lake (all nonreward tags). One recaptured fish was observed to have lost its tag during the spring netting/electrofishing survey. We also clipped fins of 8 sublegal muskellunge. The creel clerk did not observe any muskellunge; thus no single-census abundance estimate was possible. Since we tagged so few legal-size muskellunge, we made our multiple-census estimate for muskellunge of all sizes. The estimated number of muskellunge was 13 (CV = 0.55) – one fish less than the number we had marked at large.

Mean lengths at age.–For walleyes, there was 70% agreement between the first two spine readers. For fish that were aged by a third reader, agreement was 33% with the first reader and 67% with the second reader; 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 4% of the time when ages assigned to older fish (≥ age 10) were within ±10% of each other. At least two out of three readers agreed 88% of the time.

Female walleyes had higher mean lengths at age than males in South Manistique Lake when samples were sufficient for comparison (Table 7). This sexually dimorphic growth is typical for walleye populations (Colby et al. 1979; Carlander 1997; Kocovsky and Carline 2000). We obtained sufficient sample sizes for a simple comparison of means for ages 4 through 9. Females were three inches longer than males at age 9 (Table 7).

We calculated a mean growth index for walleyes of -0.8. Thus, walleye mean lengths at age for South Manistique Lake appeared to be only slightly lower 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 20.6, 24.7, and 23.1 inches, respectively.

For northern pike, there was 80% agreement between the first two fin ray readers. For fish that were aged by a third reader, agreement was 50% with the first reader and 50% with the second reader; thus, there appeared to be no bias among readers. At least two out of three readers agreed 97% of the time (only 3% of samples were discarded due to poor agreement).

Female northern pike generally had higher mean lengths at age than males (Table 8), though sample sizes were low. As with walleyes, this is typical for northern pike populations in general (Carlander 1969; Craig 1996). Females were 2.6 inches longer than males at age 2 and 0.8 in longer at age 3 (Table 8).

We calculated a mean growth index for northern pike of -1.6. 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 27.1, 28.2, and 27.3 in, respectively.

For smallmouth bass, there was 58% agreement between the first two spine readers. For fish that were aged by a third reader, agreement was 25% with the first reader and 75% with the second reader; thus, there appeared to be some bias among readers. Five percent of samples were discarded due to poor agreement, and an average age was used 3% of the time when ages assigned to older fish (≥ age 10) were within ±10% of each other. At least two out of three readers agreed 92% of the time.

We calculated a mean growth index for smallmouth bass of +1.5. Mean length at age data for smallmouth bass (Table 9) were fit to a von Bertalanffy growth curve, and the resulting L_{∞} value was 18.9 in.

We only aged twelve muskellunge. The first two readers agreed 75% of the time, and of the remaining three samples, agreement was with one reader 100% of the time. At least two out of three readers agreed 100% of the time. We calculated a mean growth index for muskellunge of -1.8. Mean length at age data for muskellunge (Table 9) were fit to a von Bertalanffy growth curve, and the resulting L_{∞} value was 45.6 in.

Mortality.–For walleyes, we estimated catch at age for 2,446 males, 970 females, and 3,671 total walleyes, including those fish of unknown-sex (Table 10). We used ages 4 and older in the catch-curve analysis to represent the sexually mature, legal-size male population (Figure 6). We chose age 4 as the youngest age because: 1) average length of male walleyes at age 4 was 15.6 in, so a high proportion of age-4 fish were legal-size at the beginning of fishing season; and 2) relative abundance of fish younger than age 4 do not appear to be represented in proportion to their true abundance (Figure 6; Table 10), suggesting that male walleyes are not fully mature at age 3. We used ages 5 and older in the catch-curve analysis to represent the sexually mature, legal-size female population (Figure 6). We chose age 5 as the youngest age because: 1) average length of female walleyes at age 5 was 18.5 in, so a high proportion of age-5 fish were legal-size at the beginning of fishing season; and 2) relative abundance of fish younger than age 5 do not appear to be represented in proportion to their true abundance (Figure 6; Table 10), suggesting that female walleyes are not fully mature at age 4.

The catch-curve regressions for walleyes were all significant ($P < 0.05$), and produced total instantaneous mortality rates for legal-size fish of 0.411 for males, 0.253 for females, and 0.343 for all fish combined (Figure 6). These instantaneous rates corresponded to annual mortality rates of 34% for males, 22% for females, and 29% for all walleyes combined.

Anglers returned a total of 591 tags (252 reward and 339 nonreward) from harvested walleyes, and five tags (one reward and four nonreward) from released walleyes in South Manistique Lake in the year following tagging. The creel clerk also observed 15 tagged fish in the possession of anglers that were not subsequently reported to the central office by the anglers. The estimate of annual exploitation of walleyes was 28% after adjusting for tag loss (4.8%). Anglers reported reward tags at a higher rate than nonreward tags (26% versus 19%), and they likely did not fully report either type. The reporting rate of nonreward tags relative to reward tags (λ *in* Pollock et al. 1991) was 72%. Based on all tagged walleyes (legal fish) known to be caught, the reported release rate was 0.8%.

The estimated exploitation rate for walleyes was 95% (CV = 0.14) based on dividing harvest by the multiple-census abundance estimate, and 80% (CV = 0.16) based on dividing harvest by the single-census creel survey abundance estimate (Table 6). The harvest estimate used here was first adjusted for nonsurveyed months (using tag returns), and second for the proportion of harvested fish that were not of legal size at the time of tagging.

For northern pike, we estimated catch at age for 42 males, 55 females, and 264 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). Due to the paucity of legal-size northern pike, we used the first age group where the relative abundance of fish was highest, and likely represented in proportion to their true abundance (Figure 7; Table 10). Most northern pike in South Manistique Lake are not fully mature at age 2, but probably many are mature by age 3.

The catch-curve regressions for male and all northern pike were significant ($P < 0.05$), and that for females was nearly significant (Figure 7). Total instantaneous mortality rates were 0.470 for males, 0.826 for females, and 0.650 for all fish combined. These instantaneous rates corresponded to annual mortality rates of 38% for males, 56% for females, and 48% for all northern pike combined.

Anglers returned a total of 11 tags (5 reward and 6 nonreward) from harvested northern pike, and no tags from released northern pike in South 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. The estimate of annual exploitation of northern pike was 32%. Anglers reported reward tags at a higher rate than nonreward tags (42% versus 26%), and they likely did not fully report either one. The reporting rate of nonreward tags relative to reward tags (λ *in* Pollock et al. 1991) was 63%. No tagged northern pike were reported as being released.

The estimated exploitation rate for northern pike was 605% (CV = 0.57) based on dividing harvest by the multiple-census abundance estimate, and 117% (CV = 0.61) based on dividing harvest by the single-census creel survey abundance estimate (Table 6). The harvest estimate used here was first adjusted for nonsurveyed months (using tag returns), and second for the proportion of harvested fish that were not of legal size at the time of tagging. The potential biases of the estimates used to derive these exploitation rates are stated in the Discussion section.

For smallmouth bass, we estimated catch at age for 56 fish, including those fish of unknown-sex (Table 10). We used ages 5 and older in the catch-curve analyses to represent the legal smallmouth bass population (Figure 8). We chose age 5 as the youngest age because: 1) average length of smallmouth bass at age 5 was 16.1 in, so a high proportion of age-5 fish were legal-size at the beginning of fishing season; and 2) relative abundance of fish younger than age 5 do not appear to be represented in proportion to their true abundance (Figure 8; Table 10).

The catch-curve regression for smallmouth bass was significant ($P < 0.05$), and resulted in a total instantaneous mortality rate of 0.288, or annual mortality rate of 25%.

Anglers returned a total of two tags (0 reward and 2 nonreward) from harvested smallmouth bass, and two tags from released smallmouth bass in South Manistique Lake in the year following tagging. Thus, based on this small sample of all tagged smallmouth bass (legal fish) known to be caught, the reported release rate was 50%. The creel clerk did not observe any tagged fish in the possession of anglers that were not subsequently reported to the central office. The estimate of annual exploitation of smallmouth bass was 4% based on tag returns.

The estimated exploitation rate for smallmouth bass was 42% (CV = 0.94) based on dividing harvest by the multiple-census abundance estimate, and 34% (CV = 1.02) based on dividing harvest by the single-census creel survey abundance estimate (Table 6). The harvest estimate used here was first adjusted for nonsurveyed months (using tag returns), and second for the proportion of harvested fish that were not of legal size at the time of tagging.

Recruitment.–For walleyes in South Manistique, variability in year-class strength was relatively high, which can be seen in the statistics of the catch-curve regression. Residual values were large (see scatter of observed values around the regression line for all walleyes in Figure 6) and the amount of variation explained by the age variable (R^2) was 0.78.

We did not find any relationships between climatological variables and walleye year-class strength in South Manistique Lake, but water temperature and water quality data specific to the lake are lacking. Additionally, there was no relationship (F = 1.449, P = 0.256) between the residuals from the catch curve regression and the number of walleyes stocked in South Manistique Lake, but walleyes were stocked in only four of the twelve years used in the regression.

For the northern pike catch curve, the amount of variation explained by the age variable (R^2) was 0.86 (Figure 7, All northern pike). We found one weak relationship between climatological variables and northern pike year-class strength in South Manistique Lake. The residuals from the catch curve were positively correlated with April maximum temperature (r = 0.708, P = 0.049, df = 8), though this relationship was highly influenced by a single value. Although this relationship is weak, and does not imply causation, it is at least in agreement with the findings of other studies on recruitment relationships (Casselman and Lewis 1996; Craig 1996).

For smallmouth bass in South Manistique, variability in year-class strength was relatively high, which can be seen in the statistics of the catch-curve regression. Residual values were large (see scatter of observed values around the regression line in Figure 8) and the amount of variation explained by the age variable (R^2) was 0.61). We did not find any relationships between climatological variables and smallmouth bass year-class strength in South Manistique Lake.

We did not age enough muskellunge to evaluate recruitment. However, we compared the years that muskellunge were stocked to see if they corresponded with the ages of those muskellunge that we collected. The only stocked year classes of muskellunge that were adults when we surveyed South Manistique Lake were those from 1998, 1991, and 1987. These year classes correspond with ages 5, 12, and 16. Of the twelve muskellunge aged, we found fish aged 4, 5, 9, 10, and 11. Our observation of three age-5 muskellunge suggests that the 1998 stocking event was successful.

Movement.–Based on re-captures during the spring survey, there was movement of walleyes between South and Big Manistique lakes (Table 11). A total of 915 walleyes tagged in South Manistique Lake were recaptured during the spring netting survey. Of those recaptured walleyes, 98% were recaptured in South Manistique Lake, and 2% were recaptured in Big Manistique Lake. Similar movement was estimated from voluntary tag returns (Table 12). Of walleyes recaptured by anglers, 98% were recaptured in South Manistique Lake, and 2% were recaptured in Big Manistique Lake. There was no movement of northern pike, smallmouth bass, or muskellunge detected during our spring survey, or from angler tag returns throughout the year following tagging.

Angler Survey

Summer.–The creel clerk interviewed 1,560 boating anglers during the summer 2003 survey on South Manistique Lake. Most interviews (97%) were roving (incomplete-fishing trip). Anglers fished an estimated 123,953 angler hours and made 52,987 angler trips (Table 13).

The total harvest was 36,584 fish, of eight species (Table 13). Bluegills were most numerous with an estimated harvest of 16,497 fish, followed by yellow perch (10,635 fish). Anglers harvested 5,729 walleyes and reported releasing 7,331 walleyes (56% of total catch). Anglers harvested 1,117 northern pike, and reported releasing 20,736 (95% of total catch). Anglers harvested 108 smallmouth bass and 276 largemouth bass, and released 1,917 smallmouth bass (95% of total catch) and 4,809 largemouth bass (95% of total catch). We do not know how many of the released fish were of legal size.

Winter.–The creel clerk interviewed 212 open ice anglers and 426 shanty anglers. Most open ice (85%) and shanty (76%) interviews were roving type. Open ice and shanty anglers fished 18,733 angler hours and made 5,918 trips on South Manistique Lake (Table 14).

A total of 7,070 fish were harvested. Yellow perch were most numerous with an estimated harvest of 5,490 fish, followed by walleyes (908 fish). Anglers also harvested 336 bluegill, 241 northern pike, 40 rainbow trout, 37 lake herring, and 18 pumpkinseed sunfish. No smallmouth bass or largemouth bass were harvested during winter months. Anglers reported releasing 2,302 walleyes (72% of total catch) and 1,432 northern pike (86% of total catch).

Annual totals for summer and winter.–The annual period from May 8 through October 15, 2003 and December 27, 2003 through March 28, 2004, anglers fished 142,686 hours and made 58,815 trips to South Manistique Lake (Table 15). Of the total annual fishing effort, 87% occurred in the open-water summer period and 13% occurred during the ice-cover winter period.

The total annual harvest was 43,654 fish. The estimated total annual harvest of bluegill and yellow perch was 16,833 and 16,124 fish, respectively. Panfish species (bluegill, yellow perch, pumpkinseed, and rock bass) made up 81% of the total harvest. The estimated total annual harvest of walleyes was 6,637, making up 15% of the total harvest. Harvests of northern pike and smallmouth bass were rather low, with an estimated 1,359 and 108 fish, respectively. There was no harvest of muskellunge detected in our angler survey, though an estimated 44 were caught and released.

Bluegill were the predominant species caught (harvested + released = 75,174 fish), with a resulting catch rate (catch per h) of 0.53. Yellow perch similarly had a high total catch (51,985) and catch rate (0.36 fish/h). The total catch of walleyes was 16,270 fish, with a catch rate of 0.11 fish/h. The walleye catch peaked in June, but walleyes were readily caught throughout the year. Anglers released 59% of all walleyes caught. Estimated total annual catch of northern pike was 23,527, with a resulting catch rate of 0.16 fish/h. Anglers released 94% of northern pike caught. Estimated total annual catch of smallmouth bass was 2,051, with a resulting catch rate of 0.01 fish/h. Smallmouth bass catch peaked in August, but was fairly consistent throughout the summer. It should be noted that catch rates are calculated with total 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 sublegal and legal released fish, we assume that a large proportion of the released walleyes and northern pike were sublegal. At least for northern pike, the assumption that the high release rate was due to catching many sublegal fish is corroborated by the skewed size structure of this population, which contained a high proportion of sublegal-sized fish (Table 5).

We did not survey from mid October through mid December, because we thought that relatively little fishing occurred during that time of year. In fact, only three walleye tag returns were reported during the portions of October through December that were not surveyed as part of the winter creel (Table 16). Thus, the total annual walleye harvest was actually about 0.5% higher than our direct survey estimate, or 6,671 walleyes. No northern pike or smallmouth bass tag returns were reported as caught during the nonsurveyed months (Table 16). April was not surveyed because walleye, northern pike, muskellunge, and smallmouth bass seasons are closed at that time.

Seven species that we captured during spring netting operations did not appear in the angler harvest – black bullhead, brown bullhead, central mudminnow, common shiner, white sucker, redhorse sucker, and mottled sculpin.

Discussion

Fish Community

Because of bias introduced into the survey due to the cold-water temperatures during the early spring survey period, we likely captured more large, mature fish of several species than would normally be caught in lake surveys that have historically been conducted later in the spring or summer. This includes spring-spawning fish species 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 types of surveys in Michigan lakes. Because of the mesh-size bias, small fish are 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 South Manistique Lake such as various species of shiners and minnows. However, only one species was observed in South Manistique Lake in previous surveys that was not collected in 2003 (See Appendix).

Overall, the current fish community in South Manistique Lake has not changed drastically since it was surveyed in the 1930s. Redhorse suckers and mottled sculpin were captured in 2003, but there is no record of them being present in 1937. Two species currently present in the 2003 fish community but absent in 1937 are rainbow trout and muskellunge. Public groups have stocked rainbow trout for winter fishing derbies and the MDNR has stocked muskellunge to create additional trophy angling opportunity.

South Manistique Lake has always supported natural reproduction of walleyes, although a good year-class of fish is not produced every year. This is to be expected given the widely varying environmental conditions that can be experienced during the early spring spawn event and egg incubation period. During the 1970s and 1980s, apparent declines in walleye abundance instigated a private fishing club from Curtis to stock walleye fry under the supervision of the MDNR. However, contribution of the fry stocked in South Manistique Lake to the overall population of walleyes (which included naturally-reproduced fish) is not known, as stocked fish could not be differentiated from natural fish. In the early 1990s, the club vastly improved their walleye fry rearing techniques, and nearly doubled the numbers of fry stocked into South Manistique Lake. Growth rates of walleyes from the 1998 survey, as compared to walleyes from the mid-1990s survey (Table 17), indicated a severe decline in average growth (over 3 inches below the Statewide average for some age classes). This was a clear indication of over-stocking. Growth rates of most other species also declined significantly, possibly indicating an overall lack of forage. Walleye stocking was discontinued after 1994 to allow the fish community to recover and to promote improved growth rates of walleyes and other species. After several years, growth rates of walleyes and most other species recovered to acceptable levels, as evidenced by the data from the 2000 and 2003 surveys (Table 17).

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

The fish community of South Manistique Lake was vastly different from Michigamme Reservoir, which had 46% piscivores, 29% planktivores-insectivores, and 25% benthivores (South Manistique Lake had 72, 18, and 10%, respectively). The differences in fish community composition are in part a result of differences in lake morphology and habitat. For example, aquatic vegetation is often very abundant in South Manistique Lake while vegetation is limited in Michigamme Reservoir. The abundant vegetation in South Manistique Lake likely contributes to successful northern pike reproduction, which results in a higher proportion of piscivores. On the other hand, Michigamme Reservoir has several large tributaries (Deer, Fence, and Michigamme Rivers) which likely favor reproduction of sucker species, and result in a higher proportion of benthivores. South Manistique Lake is fed by three creeks and the Shoepac River.

Walleyes, Northern Pike, and Smallmouth Bass

Size structure.–The size structure of walleyes in our spring survey was about average relative to other large lakes in Michigan. Seventy-four percent of walleyes were of legal size compared to an average of 70% for the Large Lakes Program to date (MDNR files). Based on the length-frequency distributions, it does not appear that angler harvest is having any negative effect on the size structure of the population. Additionally, the size structure of walleyes appears normal for a mesotrophic large lake. Based on the fish we observed in the spring survey, walleyes in South Manistique Lake are unlikely to attain lengths much greater than 25 in, though there is the potential to reach 30 in.

The size structure of northern pike in South Manistique Lake is below average. Thirteen percent of northern pike were of legal size compared to an average of 28% for the Large Lakes Program to date (MDNR files). Based on the length-frequency distributions, it appears that slow growth, or high mortality is having a negative effect on the size structure of the population. Very few northern pike of legal size are available for harvest by anglers. While we did collect a few large northern pike, the population is dominated by fish of sublegal size. Based on the fish we observed in the spring survey, northern pike in South Manistique Lake are unlikely to attain lengths much greater than 26 in, though there is the potential to reach 30 in.

The size structure of smallmouth bass in South Manistique Lake was high (87% legal), which is above average for populations in large lakes of northern Michigan. On average, 65% of the smallmouth bass caught in Large Lakes Program surveys are legal size (MDNR files). Based on the length-frequency distributions, it does not appear that angler harvest is having a negative effect on the size structure of the population. Also based on the length-frequencies, smallmouth bass in South Manistique Lake are likely to attain lengths of 18 in, and have good potential to reach 20 in.

Sex composition.–Male walleyes outnumbered females in our survey, both when all sizes, and when only legal-size fish were considered. We were unable to find any previous information concerning sex composition from South Manistique Lake for comparison. The male : female sex ratio for legal walleyes (1.9) was below the average (3.0) that we have observed in eight large lakes surveyed to date.

For walleyes from other lakes in Michigan and elsewhere, males consistently dominate sex composition in samples taken during spawning (Clark et al. 2004). This is likely due to males maturing at earlier sizes and ages than females and to males having a longer presence on spawning grounds than females (Carlander 1997).

Female northern pike outnumbered males in South Manistique, both when all sizes, and when only legal-size fish were considered. In most other spring samples from large lakes surveys, males make up the largest proportion of adult northern pike, but females make up the largest proportion of legal-size northern pike. Higher mortality of males as reported by Craig (1996) could contribute to this disparity. Our estimated annual mortality was greater for female northern pike (56% for females versus 38% for males); however, our catch curve regression for male northern pike was highly influenced by a single fish, and annual mortality for male northern pike is likely higher than we estimated. 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).

The male : female sex ratio for adult northern pike (0.8) was slightly below the average (1.1) that we have observed in eight large lakes surveyed to date. The male : female sex ratio for legal size northern pike (0.6) was higher than the average (0.2) that we have observed in eight large lakes surveyed to date, but this estimate was based on a total sample of only 14 fish.

*Abundance.–*To our knowledge, this was the first estimate of walleye abundance for South Manistique Lake. We were successful in obtaining both multiple-census and single-census estimates of abundance. For the multiple-census estimate, the minimum number of recaptures was obtained; however, some conditions for an unbiased estimate may have been violated. For the single-census estimate, we had sufficient numbers of fish marked and observed for marks for the desired level of precision. Assuming that the legal walleye population was approximately 7,000 fish, and based on tagging approximately 3,000 fish, the recommended recapture sample to observe for marks in management studies (α = 0.05, *P* = 0.25; where P denotes the level of accuracy, and 1-α the level of precision) is approximately 100 fish (Robson and Regier 1964). Our corrected recapture sample of 195 fish was greater than this recommendation, but short of Robson and Regier's (1964) requirement for research studies (α = 0.05, *P* = 0.10). Precision was similar between the multiple-census and single-census estimates; the CV's were 0.05 and 0.08 for the multiple-census and single-census estimates, respectively. 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. In other large lakes, the multiple-census estimates have also been much lower than the single-census estimates (Clark et al 2004; Hanchin et al. 2005a, 2005c). Our estimates of adult walleye abundance were not similar (39% lower) to the a priori Wisconsin regression estimate of 13,183, using natural reproduction as the primary recruitment source. In contrast, our Michigan model prediction of 8,440 adult walleyes was only 7% higher than our single-census estimate.

Population density of walleyes in South Manistique Lake was slightly below average compared to other lakes in Michigan. Using the modern acreage of 4,133, our single-census estimate for legal-size walleyes in South Manistique Lake was 1.6 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.

Population density of adult walleyes from our single-census estimate was 1.9 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. Miller (2001) estimated 4.8 adult male walleyes per acre in Lake Gogebic, which would have made the density of all adult walleyes much higher. 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. For the multiple-census estimates, the minimum number of recaptures was not obtained for legal fish, and was reached (*N* = 4), but not exceeded for adult fish. For the single-census estimate of legal northern pike, we did not tag enough fish, or examine enough fish for marks in the creel survey and summer netting survey to achieve our desired level of precision. Using our single-census estimate of the legal northern pike population of approximately 1,000 fish, and knowing that we tagged 35 fish, the recommended recapture sample to observe for marks in preliminary studies and management surveys (α = 0.05, *P* = 0.50) is approximately 700 fish (Robson and Regier 1964). Sample size requirements are even higher for management studies and research studies, as defined by Robson and Regier (1964). Our corrected recapture sample of 46 fish was well short of all recommendations. Confidence intervals of the single- and multiple-census abundance estimates were broad, and 95% confidence limits for the two estimates overlapped. Precision was similar between the multiple-census and single-census estimates; CVs ranged from 0.52 to 0.59 for the multiple-census estimates and were 0.57 fro the single-census estimates.

Despite the lack of precision of both estimates, the single-census estimate appeared more reasonable when judged in relation to the independently-derived harvest estimate. Our adjusted (for nonsurveyed months, and fish that were sublegal at tagging) harvest estimate of 992 legal-sized northern pike produced an exploitation rate of 605% when divided by the multiple-census abundance, and 117% when divided by the single-census abundance. Although both exploitation estimates are impossible (>100%), the exploitation estimate derived using the single-census abundance is the closest to reality. Considering potential methodological biases and measures of precision, we consider the single-census estimate to be the most reliable, though it could be biased low.

Regardless of which estimate is more accurate, population density of legal-size northern pike in South Manistique Lake is about average relative to other large lakes in Michigan. Our estimates converted to densities for the entire lake are only 0.04 fish per acre for the multiple-census method and 0.2 fish per acre for the single-census method. Density of 24-in northern pike estimated recently for seven large lakes in Michigan has averaged 0.2, and has ranged from 0.1 to 0.5 fish per acre (P. Hanchin, personal communication).

Our estimates of adult northern pike abundance were higher than those for legal-size fish. The estimates for South Manistique Lake convert to densities of 0.5 and 0.7 adult pike per acre from multiple-census and single-census estimates, respectively. Adult northern pike abundance has averaged 1.2 per acre (range 0.1–2.9) in eight lakes surveyed as part of the Large Lakes Program thus far in Michigan (P. Hanchin, personal communication), so density of adult pike in South Manistique Lake is below average for large lakes in Michigan.

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

We had mixed success in obtaining abundance estimates for smallmouth bass, primarily due to the small number of fish marked. For the multiple-census estimate, the minimum number of recaptures was not obtained, and for the single-census estimate of legal smallmouth bass, we did not examine enough fish for marks in the creel and summer netting samples to achieve a satisfactory level of precision. Using our single-census estimate of the legal smallmouth bass population of approximately 282 fish, and knowing that we tagged 46 fish, the recommended recapture sample to observe for marks in management studies ($\alpha = 0.05$, $P = 0.25$) is approximately 158 fish (Robson and Regier 1964). Our corrected recapture sample of 17 fish was well short of this recommendation. While we potentially could have marked more smallmouth bass if we continued our survey into late spring, it appears that our recapture sample would still have been a limiting factor.

Though our estimates had low precision, they converted to densities for the entire lake of only 0.06 – 0.07 per acre for the two methods. A thorough comparison of smallmouth bass density to other lakes in Michigan and elsewhere is difficult due to the paucity of abundance estimates for smallmouth bass in lakes. Bryant and Smith (1988) reported an abundance estimate for adult smallmouth bass in the Lake St. Clair - Detroit River system that corresponds with a system-wide density of about 3.5 per acre. Marinac-Sanders and Coble (1981) reported a density of 3.5 per acre for smallmouth bass larger than 225 mm ($\approx$ 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 $\geq$8-9 in) in a Wisconsin 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). Newmann and Hoff (2000) reported a density in Palette Lake, WI more similar to ours of 0.3 smallmouth bass (>16.0 in) per acre. In South Lake Leelanau, another large lake in Michigan, the density of legal smallmouth bass was 1.0 per acre (Hanchin et al. 2007).

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 assumption is that fishing effort is randomly distributed over the population being sampled (Ricker 1975). As fish move off the spawning grounds and away from near-shore areas and are excluded from our sampling gear, we violated this assumption. In contrast to the problems associated with the multiple-census method, the single-census estimate from the creel survey is more likely to be accurate because it allows sufficient time for the marked fish to fully mix with unmarked fish. Additionally, for the single-census estimate it is not critical that all spawning congregations are sampled in the initial tagging operation.

Pierce (1997) found that multiple-census methods severely underestimated abundance. He compared multiple-census estimates of northern pike abundance made with a single gear type (trap nets) to single-census estimates made with two gear types (marking with trap nets and recapturing several weeks later with experimental gill nets). He found that multiple-census estimates averaged 39% lower than single-census estimates. Our multiple-census estimates were 4–15% lower for walleyes, 34–81% lower for northern pike, and 19% lower for smallmouth bass. Pierce (1997) concluded that gear size selectivity and unequal vulnerability of fish to near-shore netting make multiple-census estimates consistently low. He also concluded that recapturing fish at a later time with a second gear type resulted in estimates that were more valid.

While single-census estimates using two gear types are probably better than multiple-census estimates, they are not without problems. Mark-and-recapture estimates assume tags are not lost, so if tag loss increased with time, it would have affected the single-census method more than the multiple-census method. Higher tag loss would lead to an overestimate of abundance, and our single-census estimates were generally higher than our multiple-census estimates. However, since we double-marked fish, we were able to identify marked fish even if they had lost their tag. We only detected tag loss for walleyes (5%) during the angler survey.

Based on our experience in this study, we believe it would be possible, but costly, to improve precision of walleye abundance estimates for South 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 6,473 legal-sized walleyes were ±16% of the estimate. We collected and marked 2,812 walleyes with two 10-to-15 net, 3-person work crews. Therefore, the average number of fish marked per 3-person crew was about 1,400 over the course of the 2-week survey. In order to achieve precision of ±10%, it would be necessary to mark about 3,930 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 one additional netting crew. While this additional effort is not tremendous, the gain in precision is probably not justified. We consider confidence limits that are within 20% of the estimate to be sufficient.

Improving precision by increasing the number of fish recaptured would also be costly. Based on the formula for confidence limits, a supplemental recapture effort using nets, electrofishing gear, or additional angler survey clerks would have to obtain greater than a 3-fold increase in the number of recaptures to improve precision to about ±10%. 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 (70%) was comparable to that observed in previous studies. Clark et al. (2004) achieved 53% reader agreement, Hanchin et al. (2005a) found 68%, Isermann et al. (2003) achieved 55%, and Kocovsky and Carline (2000) achieved 62% reader agreement. Mean lengths at age for walleyes from our survey were different from previous surveys of South Manistique Lake (Table 17). Mean lengths were higher for ages 2 through 7, but were lower for ages 8 and above. Perhaps the younger age classes (ages 2 through 7) are benefiting from the termination of stocking in 1994, while the older age classes (ages 8+) are still experienced density-dependent slowing of growth.

In the past, the mean growth index for walleyes in South Manistique Lake has been outside the bounds of ±1.0 in (MDNR Fisheries Division, unpublished data; Table 17) suggested by Schneider (2000a) as satisfactory for game fish; for example, in 1995 the mean growth index was -1.8 in. Recent walleye growth in South Manistique Lake (mean growth index = -0.8 and -0.2 for 2003 and 2000, respectively) has been satisfactory.

Walleye mean lengths at each age in 2003 were near the statewide average for ages 2 through 6, whereas mean lengths of fish older than 6 years old were lower than the state average (Tables 7 and 17). However, this may be attributable to differences in aging techniques as explained earlier, and thus the results should be interpreted with caution. Walleyes appeared to have slower growth in South Manistique Lake than in Big Manistique Lake (Hanchin and Kramer 2007; Table 17).

The values calculated for L_∞ (theoretical maximum length that an average fish attains in its lifetime) provide some insight into the growth potential of individual fish in a population. The L_∞ for male and female walleyes in South Manistique Lake was 20.6 and 24.7 in, respectively, which indicates normal to good growth potential. For comparison, values of L_∞ for walleyes in Crooked and Pickerel lakes were considerably lower at 18.1 in for males, 20.7 in for females, and 18.6 in for all walleyes (Hanchin et al. 2005b).

For northern pike, our reader agreement for aging fin rays (80%) was comparable to that observed in previous studies. Clark et al. (2004) found 72% agreement, and Hanchin et al. (2005a) reported 82% agreement between the initial two readers of northern pike fin rays. Mean lengths at age for northern pike from our survey were similar to those from previous surveys of South Manistique Lake, when sample sizes from older surveys were adequate (Table 18). In 1995 and 2003, the mean growth indices were -2.0 in. and -1.6 in, respectively (Table 18). Mean lengths at age in both 1995 and 2003 were below the statewide average. Schneider et al. (2000a) suggests that growth indices in the range of ±1.0 in are satisfactory for game fish, so northern pike growth in South Manistique Lake has typically been slow. As with walleyes, state averages for northern pike were based entirely on scale aging, which probably overestimates mean lengths for older ages. Although biases of finray aging are unknown, we consider the most recent estimates to be the most accurate.

Values of L_∞ for male (27.1 in) and female (28.2 in) northern pike suggest that growth is average for this species. Female pike typically attain legal size (24 in) at around age 4, whereas males attain this size later. Northern pike through age 10 were observed in the 2003 survey, indicating that these fish can survive and reproduce for a number of years after recruiting to legal size.

For smallmouth bass, mean lengths at age were higher than the statewide average for age classes 2 through 9 (where data was available), even accounting for the potential biases of scale aging methods. Statewide mean lengths were estimated by scale aging, and though we did not find literature comparing smallmouth bass aging structures, it is likely that biases exist similar to those mentioned for walleyes and northern pike. Statewide mean lengths have not been established for smallmouth bass 11 years and older. Thus, 11- and 13-year-old smallmouth bass captured in the 2003 survey could not be compared to statewide mean lengths.

Mortality.–Total mortality of walleyes in South Manistique Lake was lower than average, with at least 14 year classes represented. The age structure does not indicate any severe mortality associated with attainment of legal size. Instead, the decline in catch at age is gradual, suggesting that mortality is rather constant. One previous estimate of walleye mortality was made in 2000 using MDNR's traditional low-intensity sampling for age and growth assessment. This method (Schneider et al. 2000b) employs simple inferences from the age frequency of a random sample, rather than regression analysis. In the 2000 summer survey of South Manistique Lake, the estimated mortality of 15-inch and larger walleyes was 23%. While we have more confidence in our estimate of total mortality, this past estimate of relatively low overall mortality is consistent with our more recent estimate (29% total annual mortality).

Compared to total mortality estimates for walleyes from other lakes in Michigan and elsewhere, our estimate of 29% is below average. Total mortality rates from ten lakes surveyed as part of the Large Lakes Program in Michigan have ranged from 24% to 51%, with an average of 36.5%. Schneider (1978) summarized available estimates of total annual mortality for adult walleyes in Michigan. They ranged from 20% in Lake Gogebic to 65% in the bays de Noc, Lake Michigan. Schneider (1978) also presented estimates from lakes throughout midwestern North America, other than Michigan. They ranged from 31% in Escanaba Lake, Wisconsin to 70% in Red Lakes, Minnesota. Colby et al. (1979) summarized total mortality rates for walleyes from a number of lakes across North America. They ranged from 13 to 84% for fish age 2 and older, with the majority of lakes between 35 and 65%.

Our three estimates of the annual exploitation rate of walleyes were quite different; 27.5% from tag returns, 94.5% using harvest divided by the multiple-census abundance estimate, and 80.4% using harvest divided by the single-census abundance estimate. We consider the tag return estimate to be a minimum because we did not estimate and adjust for tagging mortality, or nonreporting; if these problems occurred to any degree, we would have underestimated exploitation (Miranda et al. 2002).

We did not make a true estimate of nonreporting, but we attempted to get some measure of nonreporting of tags by offering a $10 reward on approximately half of the tags and comparing return rates of reward to nonreward tags. We found that reporting rate for reward tags (26%) was slightly higher than for nonreward tags (19%), which might be expected given that our reward amount was relatively low compared to those used by other authors (Miranda et al. 2002). There was obviously nonreporting of nonreward tags, and the true question is what level of nonreporting there was for reward tags. We found that three of twenty reward tags (15%) observed by the creel clerk were not subsequently reported by anglers. We do not believe this is a true estimate of nonreporting, since anglers may have believed that the tag was already “reported” when the creel clerk observed it and recorded the number. However, if we adjust the exploitation estimate for both tag loss and nonreporting, it increases to 32%. We found additional evidence of nonreporting, in that the number of tags voluntarily returned by anglers was 50% of the expected number of returns based on the ratio described previously in the **Methods** section. 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 nonreward tags. However, in Michigamme Reservoir, there was a large difference in reporting rates, and the authors believed that anglers must have returned nearly 100% of reward tags (Hanchin et al. 2005a).

Both of the exploitation estimates derived from harvest divided by abundance resulted in possible, but not probable, estimates of exploitation; both of these estimates considerably exceeded the estimate of total mortality. 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 of bias, resulting in a gross inaccuracy. We believe this occurred to some degree; thus, the true annual exploitation rate of walleyes in South Manistique Lake was likely in the 30–35% range.

Compared to exploitation rates for walleyes from other lakes in Michigan and elsewhere, our estimate for South Manistique Lake is above average. The average exploitation rate for walleyes from ten large lakes surveyed to date was 16% with a range of 4 to 29%. Comparable to our estimate, Serns and Kempinger (1981) reported average exploitation rates of 25 and 27% for male and female walleyes respectively in Escanaba Lake, WI during 1958–79. In general, the range of exploitation for walleyes 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 8 to 39% from 1989 through 1998 (Thomas and Haas 2000).

In 2003, we added a question to the tag return form asking anglers if they released the fish. The low reported release rate (0.8%) for walleyes of legal size is consistent with our expectations. We believe this estimate is a minimum, given that anglers releasing fish are less likely to remove tags, or record the tag number information.

Total mortality of northern pike in South Manistique Lake was slightly lower than average, with nine year classes represented. The age structure does not indicate any severe mortality associated with attainment of legal size; however, due to growth limitations, proportionally few fish reach legal size. The decline in catch at age is gradual, suggesting that both recruitment and mortality are rather consistent. We believe that our estimate of mortality for male northern pike (38%) is probably biased low as it was highly influenced by a single fish; the true mortality rate is likely higher. We included this outlier because a significant catch curve regression was not possible without it, and we felt that the estimate with its potential bias is better than no estimate.

Compared to total mortality estimates for northern pike from other lakes in Michigan and elsewhere, our estimate of 48% is below average. Total mortality rates from ten lakes surveyed as part of the Large Lakes Program in Michigan have ranged from 36 to 69%, with an average of 55%. Diana (1983) estimated total annual mortality for three lakes in Michigan, Murray Lake at 24%, Lac Vieux Desert at 36%, and Houghton Lake at 57%. 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; these estimates ranged from a low of 19% (Mosindy et al. 1987) to a high of 91% (Kempinger and Carline 1978), with the majority of lakes between 35 and 65%.

The only reasonable estimate of the annual exploitation rate of northern pike was that from tag returns (31%). Both of the estimates derived from dividing harvest by abundance were greater than 100%. As occurred with walleyes, we believe that the estimates were biased high, likely due to an overestimated harvest, an underestimated abundance, or a combination of both. Again, we consider the tag return estimate to be a minimum. We found that reporting rate for reward tags (42%) was much higher than for nonreward tags (26%). We used both reward and nonreward tags to estimate exploitation due to the small number of reward tags at large. There was obviously nonreporting of nonreward tags, but since no tagged northern pike were observed by the creel clerk we were not able to estimate nonreporting of reward tags. Based on the exploitation estimate from tag returns and our estimate of total mortality, it appears that fishing mortality constitutes a much larger portion of northern pike total mortality than natural sources in South Manistique Lake.

Compared to exploitation rates for northern pike from other lakes in Michigan and elsewhere, our estimate of 31% for South Manistique Lake is within the range of observed values. The average exploitation rate for northern pike from seven large lakes surveyed to date was 20%, with a range of 8 to 31%. Latta (1972) reported northern pike exploitation in two Michigan lakes, Grebe Lake at 12–23% and Fletcher Pond at 38%. Pierce et al. (1995) reported rates of 8 to 46% for fish over 20 in for seven lakes in Minnesota. Carlander (1969) gave a range of 14 to 41% for a sample of lakes throughout North America.

Recruitment.–Walleyes in South Manistique Lake were represented by 14 year classes (ages 2 through 15) in our samples. Variability in year-class strength was about average (R^2 = 0.78 in Figure 6) in South Manistique Lake. 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 0.83. Given that walleyes were stocked in only four of the years (1991–94) corresponding with year classes we collected, it appears that frequent substantial natural reproduction occurs. Thus, we conclude that natural reproduction of walleyes is sufficient to maintain the current population.

Northern pike were represented by 9 year classes (ages 1 through 8, 9 and 10) in our samples. Variability in year-class strength was about average (R^2 = 0.86, 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 9, 11 and 13) in our samples. Variability in year-class strength appeared relatively high (R^2 = 0.61, Figure 8), though we have few lakes for comparison. In Lake Leelanau, which was surveyed as part of the Large Lakes Program in 2002, the R^2 was 0.91.

Movement.–The movement patterns that we observed show that walleyes move freely between South and Big Manistique lakes. Most movement probably occurs during the three weeks following ice-out, though there is movement throughout the year. During the spring survey of the Manistique lakes, we recaptured 17 walleyes in Big Manistique that had been tagged in South Manistique Lake. This represented approximately 2% of the fish tagged in South Manistique Lake that were recaptured during the spring survey. In contrast, Hanchin and Kramer (2007) reported only four walleyes that were tagged in Big Manistique to have been recaptured in South Manistique during the 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 totally clear, even over this brief period. It is possible that the walleyes may have been moving downstream to Big Manistique after spawning.

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 walleyes 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 walleyes and northern pike migrated back into South Manistique Lake following the spawning period. They proved that walleyes 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 the author's opinion that if the project was continued through the autumn months, it would have shown that walleyes 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 walleyes in a pool below South Manistique Lake, without 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 100 walleyes moved from South Manistique Lake to Big Manistique Lake between marking and angler capture. Hanchin and Kramer (2007) reported that around 400 walleyes moved from Big Manistique Lake to South Manistique Lake over the same time period; thus, the net movement is apparently upstream to South Manistique Lake. Again, the direction and timing of this apparent movement is not totally clear; walleyes 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 walleyes migrate upstream from Big Manistique Lake to South Manistique Lake throughout the summer and fall months. Apparently, the low-head Portage Creek Dam does not impede passage of upstream migrants.

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 South Manistique demonstrate site fidelity in spawning. Improved knowledge of site fidelity would have implications for 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 South Manistique Lake is not very diverse, but there are significant angling opportunities for the species present. The fishery is dominated by bluegill, yellow perch, walleyes, and northern pike. Walleyes are harvested readily throughout the year, though most were caught in the spring. Catch rate for walleyes was highest in March (0.25/hour), followed by December–January (0.18/hour), and June (0.17/hour). Yellow perch catch peaked in July, though the harvest was highest in May and December–January. Bluegill catch and harvest peaked in July. Northern pike catch peaked in May, and harvest was rather steady from May through August. Black bass were not frequently harvested throughout the year, though they are often caught and released from the spring through the fall. The catch rate for black bass over the entire survey was 0.05 fish per hour.

A few other species provide angling opportunity throughout the year. Lake herring are occasionally caught during the winter, and rainbow trout were caught following a winter stocking event for a fishing derby.

*Historical comparisons.–*The only historic creel survey of South Manistique Lake took place from May to September 1978 (Ryckman and Lockwood 1985). This on-site creel survey used methods that were similar to those used in the current survey, but the reduced time frame makes the estimates less viable for comparison. Total angler effort in 1978 was 61,472 angler hours, which is less than half of what was estimated in 2003. In 1978 the total catch was dominated by walleyes at 14,137 fish (44% of total catch) which is a similar to the 16,270 walleyes that we estimated in 2003. There were also a considerable number of yellow perch (9,293) and northern pike (4,440) caught in 1978. These estimates are much lower than the 51,985 yellow perch and 23,527 northern pike caught in 2003. The proportions of other species caught were rather similar between years, with the exception of muskellunge which were likely not present in South Manistique Lake in 1978.

*Comparison to other large lakes.–*In addition to historic creel survey data for South Manistique Lake, comparisons with other Llarge lakes can be useful. In general, surveys conducted in Michigan in the past 10 years used the same methods we used on South Manistique Lake, but some of them differ from our survey in seasonality. 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 from seven other large lake surveys that have been summarized to date.

We estimated 142,686 angler hours occurred on South Manistique Lake during the year from May 8 through October 15, 2003 and December 27, 2003 through March 28, 2004. The harvest per acre was about average relative to other large lakes (Table 19), but the hours fished per acre was above average. We should note that the release rate of several species was high on South Manistique Lake.

For walleyes, our estimated annual harvest from South Manistique Lake was 1.61 fish per acre. This harvest is above average relative to other waters in Michigan. In fact, it is the highest we have observed thus far in the Large Lakes Program. The average harvest for nine large Michigan lakes was 0.8 walleyes per acre. These Michigan lakes all were subject to similar gears and fishing regulations, including a 15-in minimum size limit.

For northern pike, our estimated annual harvest from South Manistique Lake was 0.33 fish per acre. This harvest was above 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 fewer 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 eight lakes surveyed as part of the Large Lakes Program thus far was 0.19 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 total catch (harvest + release) of black bass in South Manistique Lake was 7,179. This exceeded the total annual catch of black bass in Lake Leelanau (5,928; Hanchin et al. 2007), Houghton Lake (4,314; Clark et al. 2004), Crooked and Pickerel lakes (1,463; Hanchin et al 2005b), and Burt Lake (1,405; Hanchin et al. 2005c), which all had year-long creel surveys.

Management Implications

The current walleye density in South Manistique Lake is slightly below average when compared to other large lakes in Michigan. There does not appear to be any severe density-dependent effect on growth, and size structure is favorable, with 74% of the spring spawning stock above the 15-in minimum size limit. This is similar to the highly productive Houghton Lake, in which 73% of the spring spawning stock was above 15 in.

Our estimate of exploitation for South Manistique Lake walleyes was above average for Michigan lakes. The annual harvest of 1.6 walleyes per acre is the highest we have seen so far in the Large Lakes Program, and is about twice the average. Obviously, much of the angler effort is directed towards walleyes. Catch per hour for walleyes of all sizes was 0.11, which is only slightly below average for large lakes in Michigan. While this catch rate indicates a good walleye fishery, it is not always indicative of walleye density since we do not measure targeted effort. The current harvest, or at least the harvest in 2003, is cause for some concern. Current Michigan sportfishing regulations for walleyes will adequately protect the walleye population; however, sustained harvest at this level could cause reductions in size structure.

Stocking does not appear to be necessary for the walleye population or fishery in South Manistique Lake, though it has likely contributed to the population size in the past. If the walleye population appears to decline in the future, stocking rates or frequency should be kept at levels that will prevent potential harmful effects from density-dependent interactions such as increased competition for food or cannibalism. Li et al. (1996a) found that in places where walleye year-class strength was increased from stocking, the mean weight of individual fish decreased. Current walleye growth in South Manistique Lake is satisfactory, and growth should not be compromised by introducing more fish into the system.

Our estimates of legal and adult walleye abundance were similar to the estimates made a priori with the Michigan regression equation. Thus, 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.

Although our estimates were questionable, the density of legal-size northern pike in South Manistique appears to be average relative to other large lakes in Michigan. The density of adult northern pike is below average. The mean growth index (-1.6) for northern pike is below the tolerances of acceptable growth for Michigan pike populations; however, it is only slightly below the average (-1.3) that we have observed thus far in eight Michigan large lakes. Most male northern pike in South Manistique Lake never reach legal size (24 inches), and female pike reach legal size between the ages of 4 and age 6. Northern pike up to age 10 were represented in our samples. Size structure of northern pike is low, with only 14% of the spring spawning stock above the 24-in minimum size limit; however, this is similar to other large Michigan lakes that have an abundance of northern pike spawning habitat. The South Manistique Lake northern pike population has consistent natural reproduction and below average mortality.

Our estimate of northern pike exploitation was above average relative to other large lakes in Michigan. In fact, the exploitation was the highest we have seen in eight large lakes surveyed to date.

The annual harvest was 0.3 northern pike per acre, and catch per hour for northern pike of all sizes was 0.165 – the highest we have seen in the large lakes program thus far. These estimates are above average for northern pike populations in Michigan's large lakes, though the variation among populations is high.

The northern pike population in South Manistique Lake is consistent with the general criteria for having no size limit (i.e., consistent recruitment, slow growth, and low size structure with a large proportion of sublegal size fish). However, the density of adult pike was actually below average, and growth would likely not appear as slow if compared to a statewide average derived from fin-ray aging. The removal of a size limit usually is appropriate for populations that display slow growth due to relatively high density. In such cases, the presence of high density suggests that natural reproduction is adequate to support increased exploitation. At this time, it is wise to maintain the current regulations for northern pike on South Manistique Lake.

The density of legal smallmouth bass of 0.07 per acre was lower than the estimate for South Lake Leelanau (0.4), but was about the same as for North Lake Leelanau (0.06). Although we have few other populations for comparison, the population density of legal-size smallmouth bass in South Manistique Lake is low relative to walleyes and northern pike.

Smallmouth bass in South Manistique Lake are growing well, with a mean growth index of +1.5. Most smallmouth bass reach legal size (14 in) in their fourth year of life. Smallmouth bass up to age 13 were present in our samples, and overall mortality is low.

Size structure of smallmouth bass was similar to other Michigan lakes, with 87% of the fish in the spring survey above the 14-in minimum size limit. This is similar to North Lake Leelanau, South Lake Leelanau, and Burt Lake, in which 83, 81, and 80% of the spring spawning stock were above 14 in, respectively.

Our estimates of smallmouth bass exploitation were inconclusive. The estimate from tag returns (4.3%) was low, but it was based on a small sample size. The estimates made from dividing harvest by abundance were higher (34–42%), but the reliability of these estimates is low. Exploitation is likely not high enough to have a negative effect on the population. The annual harvest per acre (0.026) was low, though this harvest estimate has low precision. The catch per hour of all smallmouth bass (0.014) is low, especially when compared to walleyes and northern pike. One thing that is obvious from the creel survey is that most smallmouth bass that are caught end up being released.

Overall, the fishery in South Manistique Lake is of high quality. The number of fish harvested per hour was about average, considering large lakes surveyed under similar methods. Fish harvested per acre was in the 67th percentile of large lakes surveyed under similar methods. South Manistique Lake is primarily a walleye and panfish fishery, with a moderate pike fishery as well. The harvest per acre of yellow perch (3.9) exceeded that for Burt Lake (3.4) which is considered a quality yellow 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 South Manistique Lake. Our estimate of adult walleye abundance was similar to the estimate made a priori with the Michigan regression equation. Although this regression does not have the sample size of the Wisconsin regression, it appears reasonable to apply the Michigan regression to estimate walleye abundance in Michigan lakes when abundance estimates are needed for management purposes. This is especially true for Michigan lakes whose characteristics differ strongly from those in northern Wisconsin. In the long term, the MDNR should continue to work towards developing an improved regression by conducting abundance estimates in other Michigan lakes.

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We thank the many Michigan Department of Natural Resources employees who collected the data for this study. We especially thank Chuck Payment, MDNR, Newberry, and other employees from Newberry who made the tagging operation and angler survey a success. We thank Carl Christiansen, MDNR, Newberry, and Bryce Kucharek for many hours on the water surveying anglers; Chris Schelb, MDNR, Bay City for data entry, tag return processing, and preparation of figures; Deborah MacConnell, MDNR, Alpena, and Cathy Sullivan, MDNR, Charlevoix for tag return processing; Alan Sutton, MDNR, Ann Arbor for assisting in preparation of angler survey estimates; and Roger Lockwood, University of Michigan for designing the angler survey. Also, we thank anglers that provided assistance by returning tags and responding to creel clerks.

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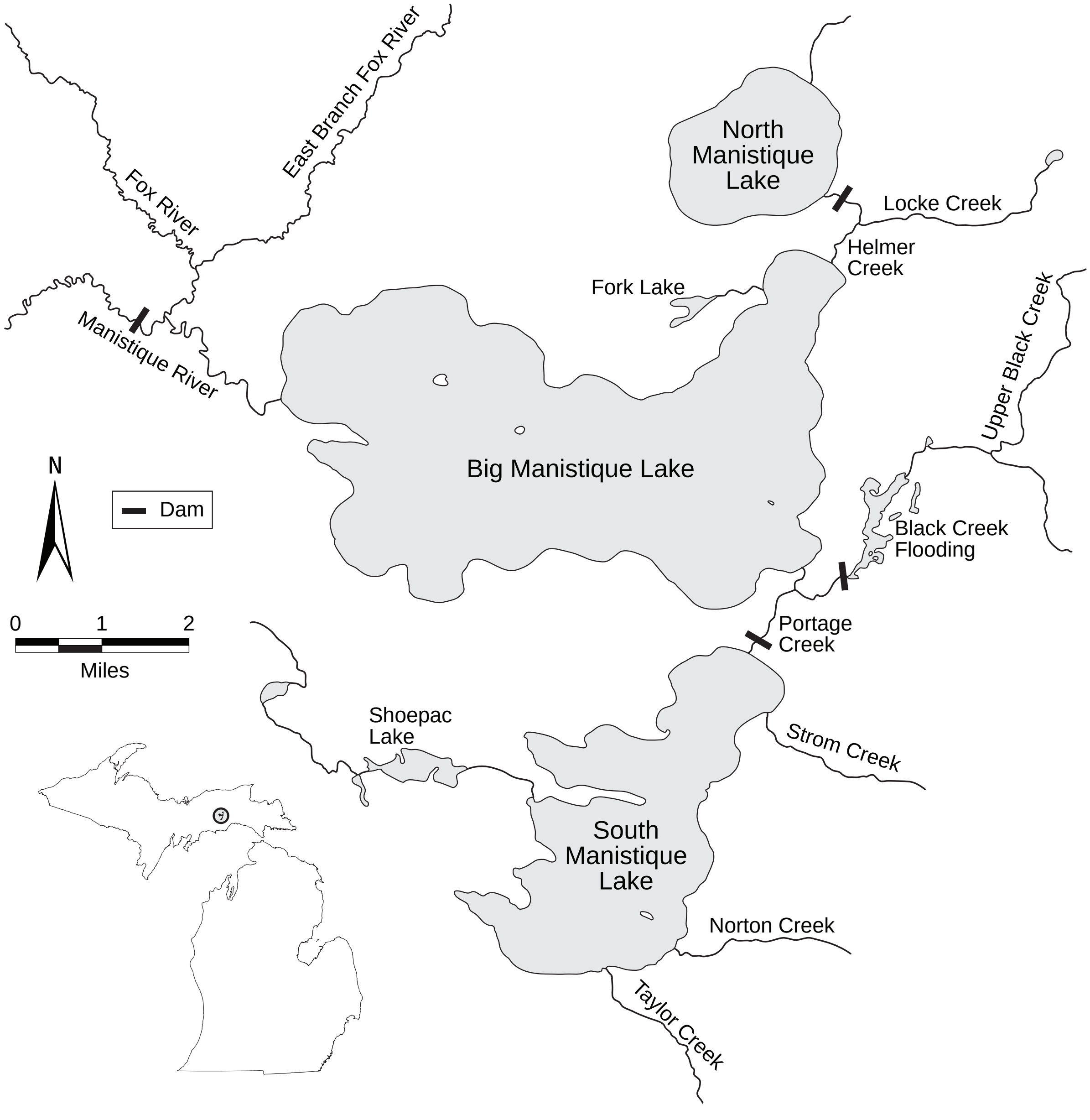

Figure 1.–Map of South Manistique Lake, Mackinac County, Michigan along with the connected waters of Big Manistique Lake and North Manistique Lake.

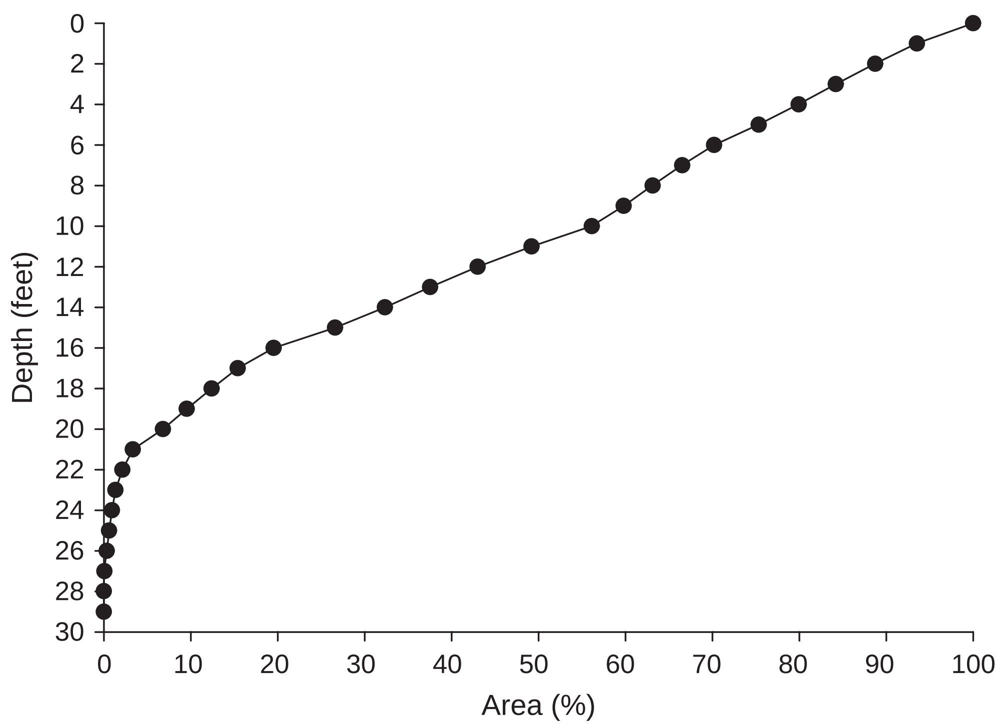

Figure 2.–Percent of area equal to or greater than a given depth for South Manistique Lake. Data taken from MDNR Digital Water Atlas.

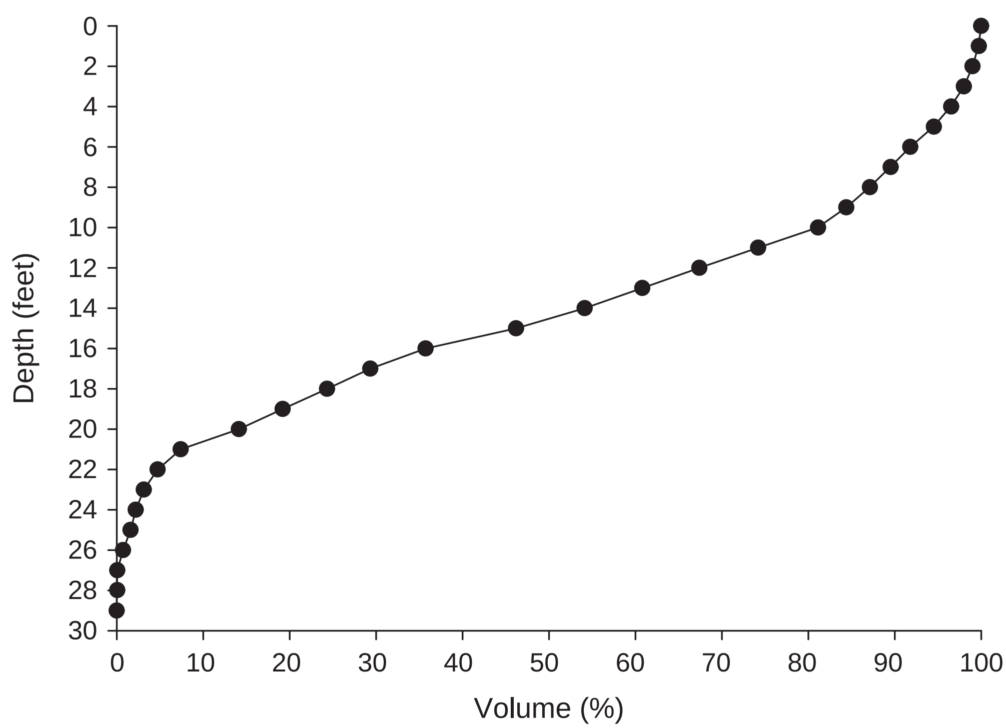

Figure 3.–Percent of volume equal to or greater than a given depth for South Manistique Lake. Data taken from MDNR Digital Water Atlas.

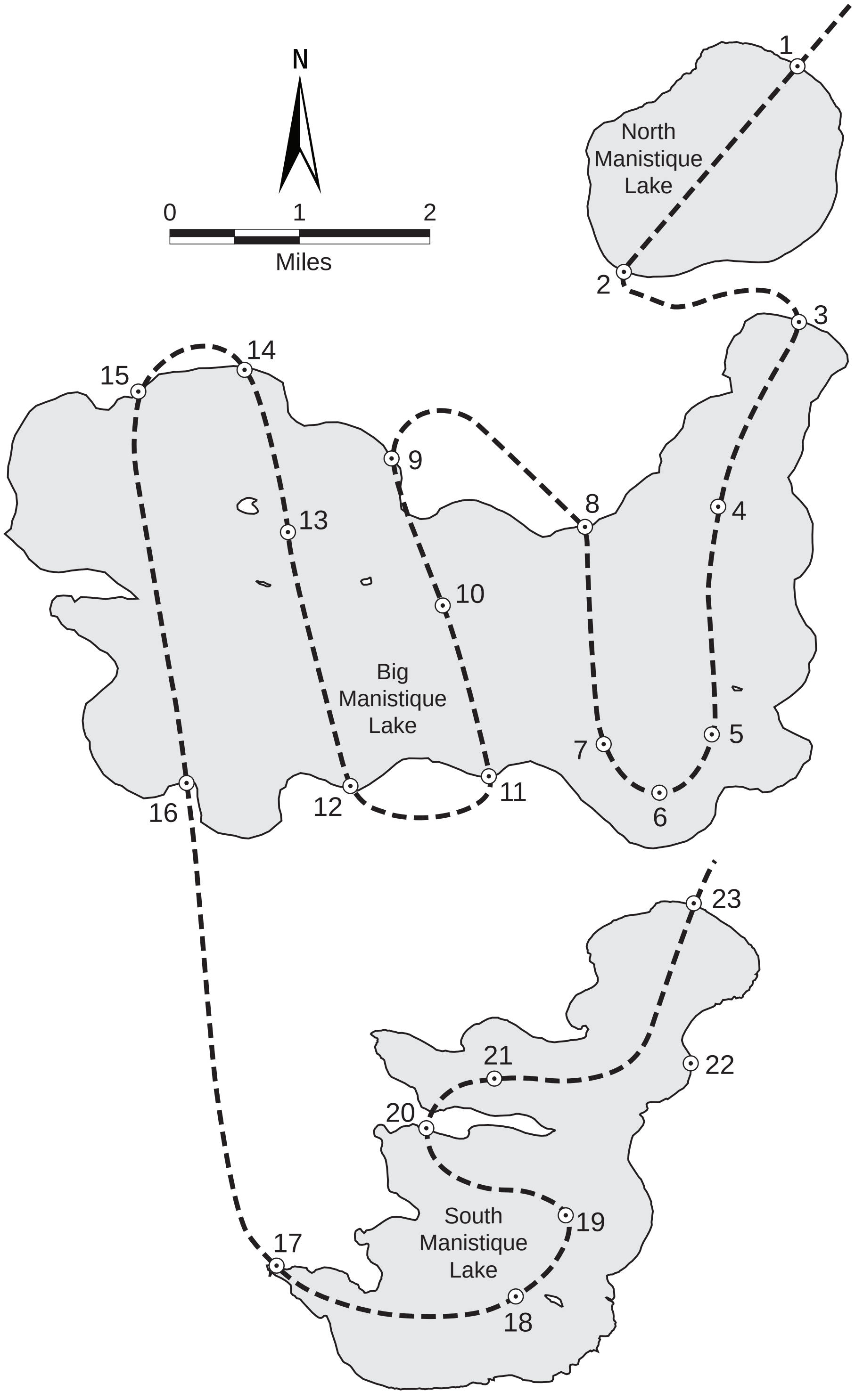

Figure 4.–Counting path, associated count path way points, and interview starting locations (points 1, 2, 3, 8, 11, 15, 17, and 23) for the Manistique lakes, summer 2003 survey. Latitude and longitude for points 1–23 are given in Table 3.

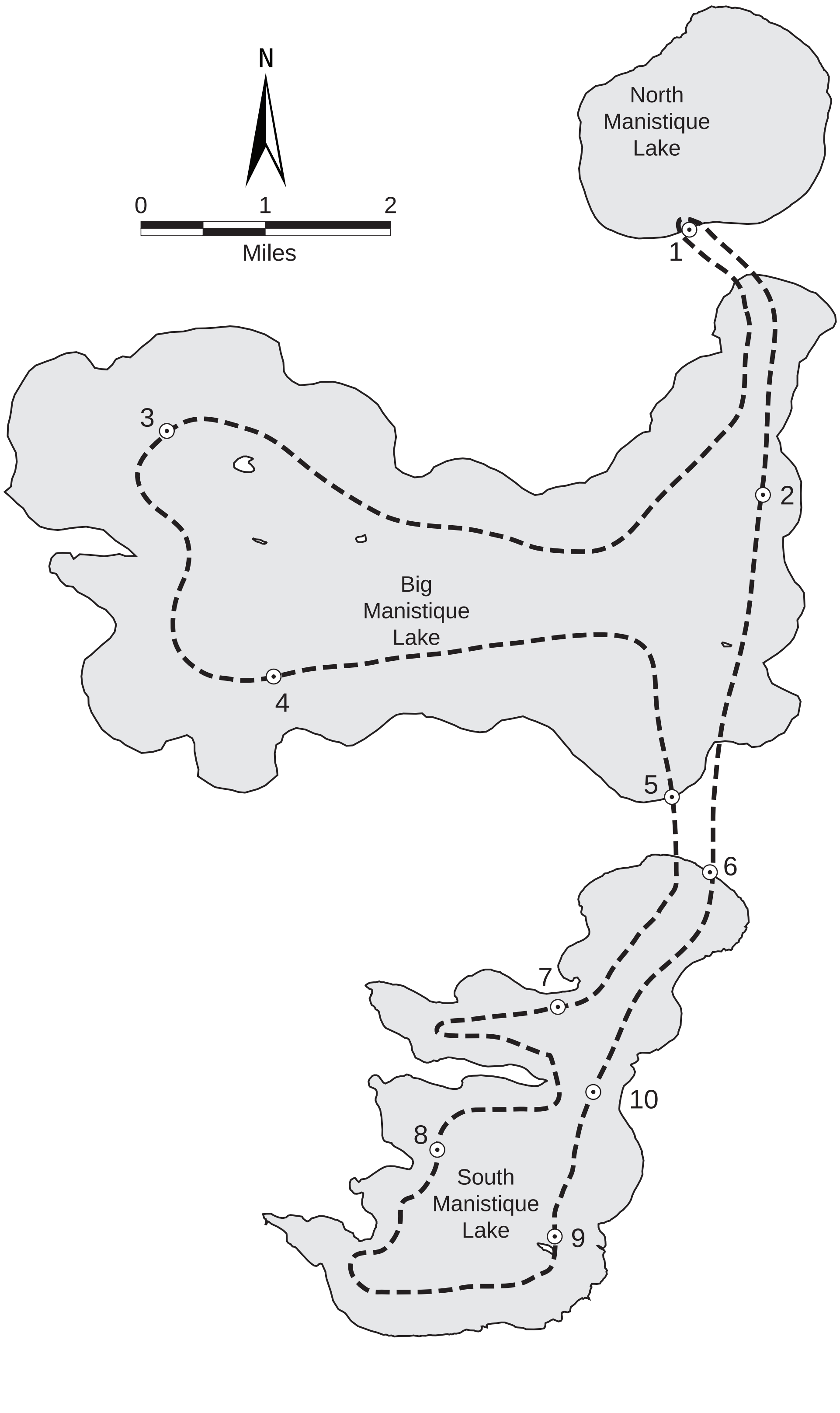

Figure 5.–Counting path, and approximate interview starting locations (points 1–10) for the Manistique lakes, winter 2003-04 survey.

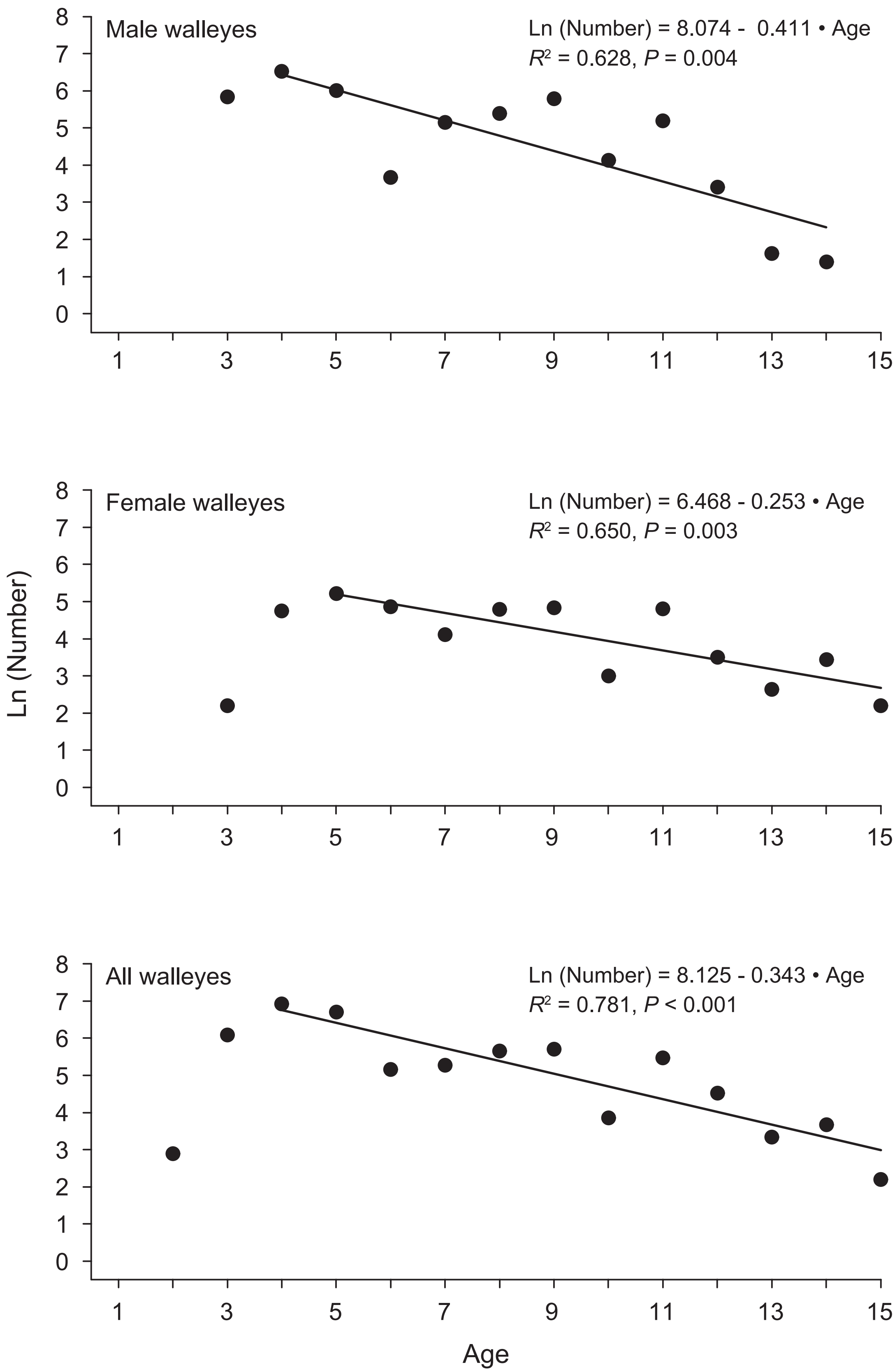

Figure 6.–Plots of observed ln(number) versus age for male, female, and all (including males, females, and unknown sex) walleyes in South Manistique Lake. Lines are plots of regression equations provided.

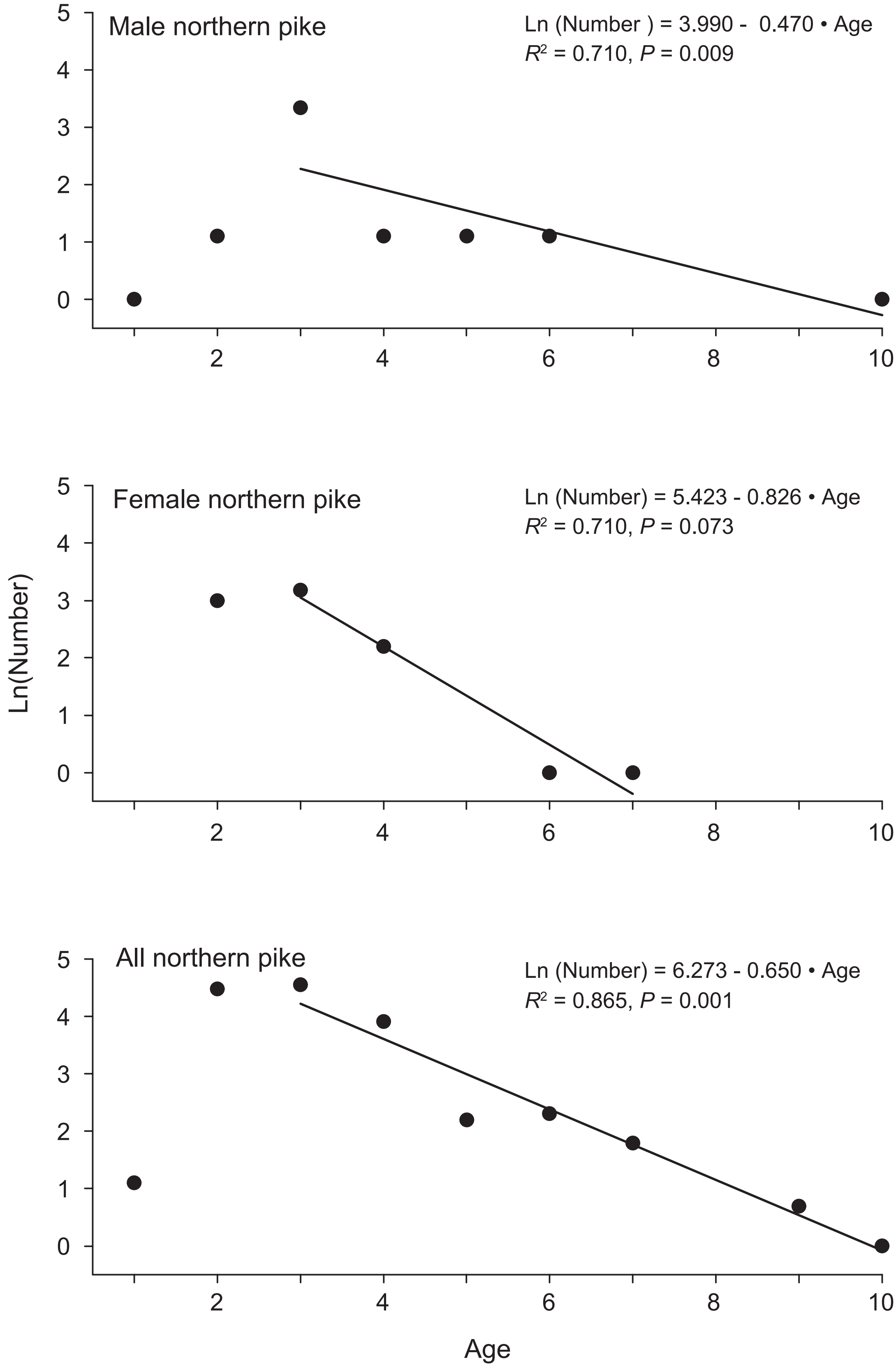

Figure 7.–Plots of observed ln(number) versus age for male, female, and all (including males, females, and unknown sex) northern pike in South Manistique Lake. Lines are plots of regression equations provided.

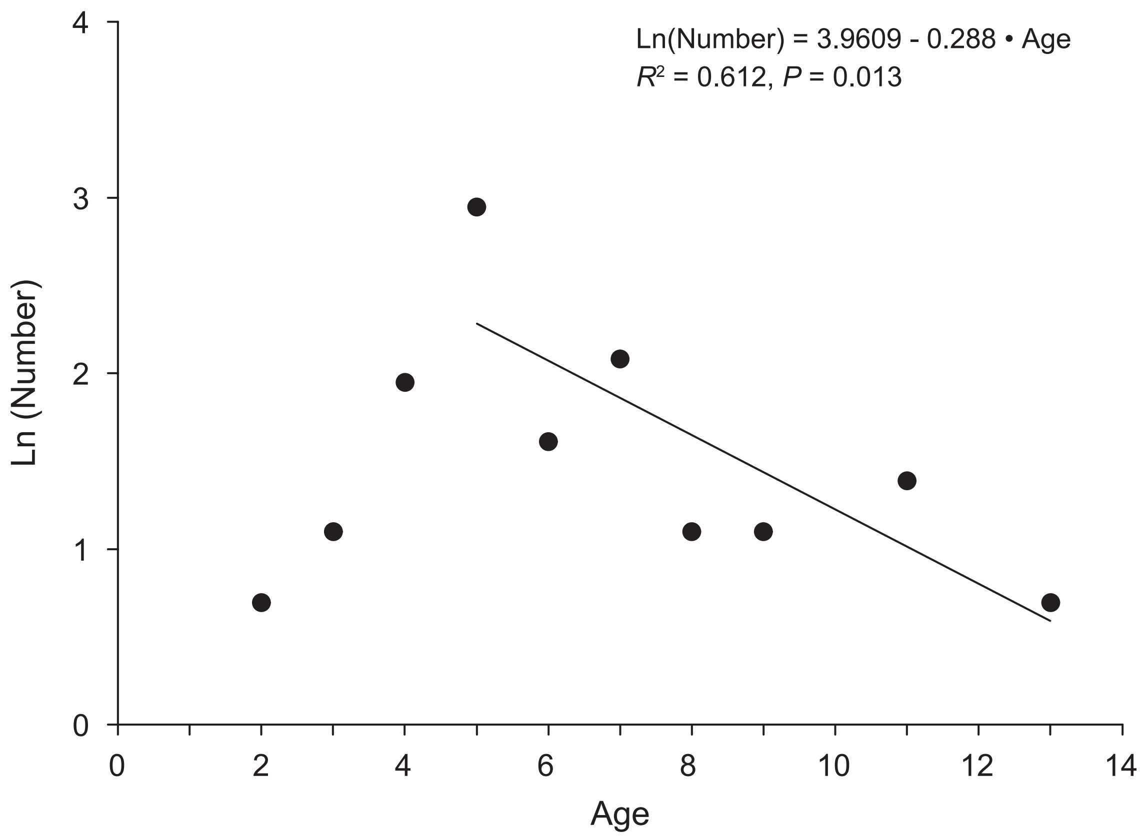

Figure 8.–Plots of observed ln(number) versus age for smallmouth bass in South Manistique Lake. Line is plot of regression equation provided.

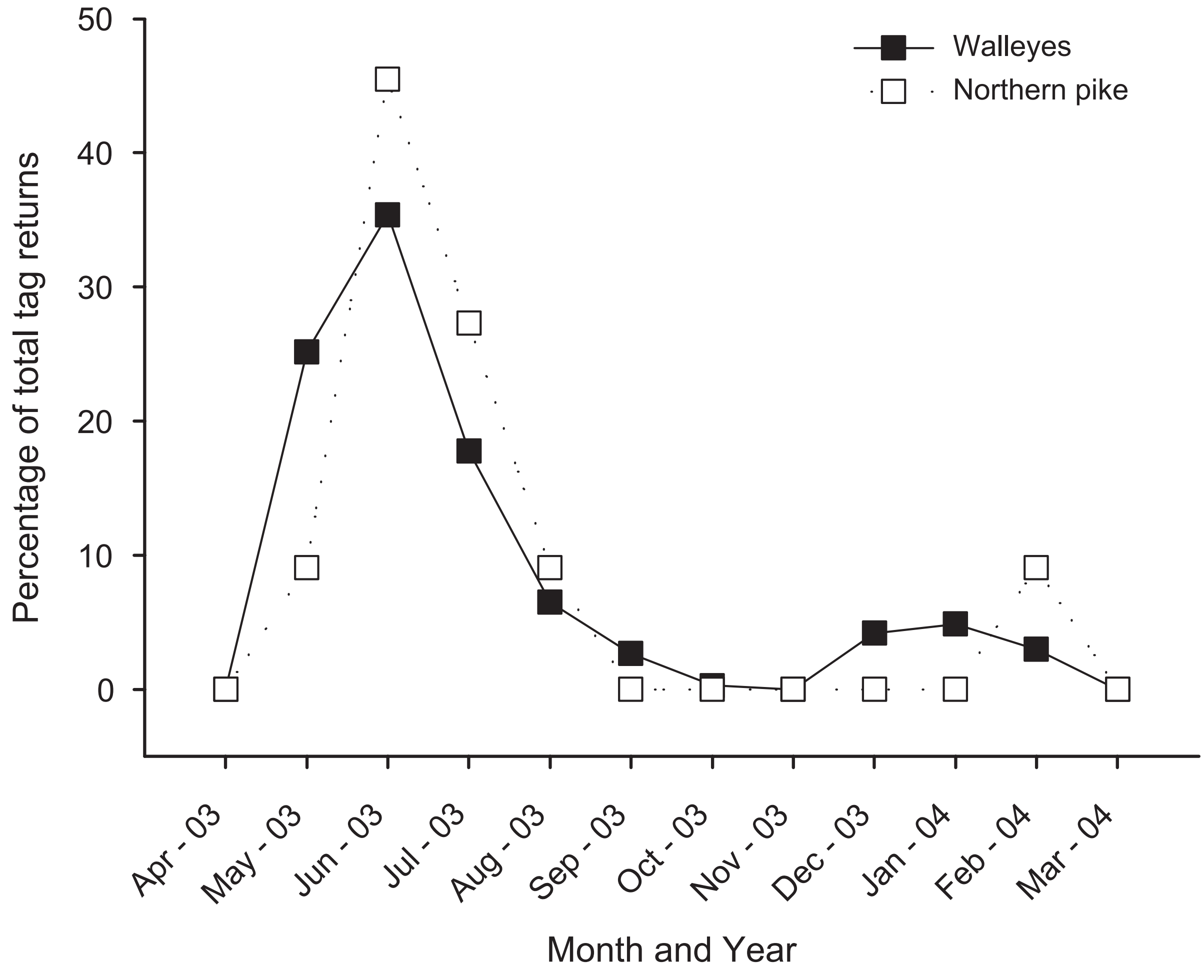

Figure 9.–Plots of observed ln(number) versus age for male, female, and all (including males, females, and unknown sex) walleyes and northern pike in the entire Cisco Lake Chain. Lines are plots of regression equations given beside each graph.

Table 1.–Number and size of fish stocked in South Manistique Lake from 1985 through 2002.

Year	Species	Number	Average size (in)
1985	Walleye	600,000	0.5
1986	Walleye	2,700,000	0.5
1987	Northern Muskellunge	4,000	7.4
1991	Walleye	1,461,000	0.2
	Northern Muskellunge	1,700	10.9
1992	Walleye	1,500,000	0.2
1993	Walleye	2,100,000	0.2
1994	Walleye	3,856,000	0.2
1998	Northern Muskellunge	2,000	11.3
2002	Northern Muskellunge	1,319	14.2

Table 2.–Survey periods, sample 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 creel survey. See Figure 4 for general flight path and numbered locations (marker).

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 South Manistique Lake using a total sampling effort of 84 trap-net lifts, 58 fyke-net lifts, and 2 electrofishing runs from April 22 to May 1, 2003.

Species	Total catch[a]	Percent by number	Mean trap-net CPUE[a,b]	Mean fyke-net CPUE[a,b]	Length range (in)	Average length (in)[c]	Number measured[c]
Walleye	4,855	66.6	44.5	11.5	6.7–29.1	17.1	3,836
Yellow perch	1,011	13.9	0.3	16.2	4.3–12.5	5.7	110
White sucker	592	8.1	5.2	2.0	7.3–22.0	17.7	304
Northern pike	277	3.8	2.3	1.0	7.8–31.1	19.9	270
Rock bass	170	2.3	1.1	1.1	3.0–11.0	7.5	67
Bluegill	145	2.0	1.2	0.8	3.7–8.0	5.8	85
Smallmouth bass	60	0.8	0.3	0.3	6.6–20.0	16.0	57
Largemouth bass	54	0.7	0.1	0.1	7.4–19.9	12.7	54
Rainbow trout	42	0.6	0.4	0.1	13.5–18.5	14.8	43
Pumpkinseed	25	0.3	0.3	0.1	3.9–8.2	6.8	23
Muskellunge	19	0.3	0.2	<0.1	12.1–48.4	36.9	14
Brown bullhead	15	0.2	0.1	0.1	7.0–13.7	11.1	14
Redhorse spp.	11	0.2	0.1	0.0	10.3–23.9	19.3	11
Black bullhead	10	0.1	<0.1	<0.1	5.3–14.1	9.8	8
Central mudminnow	3	<0.1	<0.1	<0.1	–	–	–
Silver redhorse	1	<0.1	0.0	<0.1	23.2	23.2	1
Common shiner	1	<0.1	0.0	<0.1	6.0	6.0	1
Mottled sculpin	1	<0.1	<0.1	0.0	–	–	–

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

Table 5.–Number of fish per inch group caught and measured in spring netting and electrofishing operations on South Manistique Lake, April 22 to May 1, 2003.

	Species															
Inch group	Walleye	Yellow perch	White sucker	Northern pike	Rock bass	Bluegill	Smallmouth bass	Largemouth bass	Rainbow trout	Pumpkinseed	Muskellunge	Brown bullhead	Redhorse spp.	Black bullhead	Silver redhorse	Common shiner
3	–	–	–	–	2	1	–	–	–	1	–	–	–	–	–	–
4	–	26	–	–	3	21	–	–	–	–	–	–	–	–	–	–
5	–	58	–	–	6	20	–	–	–	5	–	–	–	1	–	–
6	4	7	–	–	14	30	1	–	–	4	–	–	–	1	–	1
7	72	12	1	1	11	12	2	2	–	11	–	1	–	–	–	–
8	70	5	–	1	21	1	–	–	–	2	–	1	–	1	–	–
9	3	1	–	1	5	–	–	6	–	–	–	–	–	1	–	–
10	15	–	2	1	4	–	–	13	–	–	–	3	2	2	–	–
11	45	–	1	–	1	–	2	5	–	–	–	4	–	–	–	–
12	112	1	–	1	–	–	2	2	–	–	2	3	1	–	–	–
13	346	–	8	6	–	–	2	9	4	–	–	2	–	1	–	–
14	317	–	28	11	–	–	5	6	25	–	–	–	–	1	–	–
15	366	–	32	22	–	–	9	–	10	–	–	–	–	–	–	–
16	361	–	28	18	–	–	9	6	3	–	–	–	–	–	–	–
17	413	–	55	24	–	–	9	3	–	–	–	–	–	–	–	–
18	614	–	47	27	–	–	11	–	1	–	–	–	–	–	–	–
19	425	–	55	25	–	–	4	2	–	–	–	–	–	–	–	–
20	230	–	36	23	–	–	1	–	–	–	–	–	1	–	–	–
21	160	–	10	27	–	–	–	–	–	–	–	–	2	–	–	–
22	149	–	1	23	–	–	–	–	–	–	–	–	1	–	–	–
23	71	–	–	22	–	–	–	–	–	–	–	–	4	–	1	–
24	34	–	–	15	–	–	–	–	–	–	–	–	–	–	–	–
25	21	–	–	6	–	–	–	–	–	–	–	–	–	–	–	–
26	2	–	–	8	–	–	–	–	–	–	–	–	–	–	–	–
27	4	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
28	1	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–
29	1	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–
30	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
31	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
32	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
34	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
35	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
36	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
37	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
38	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
39	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
41	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
42	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Table 5.–Continued.

	Species															
Inch group	Walleye	Yellow perch	White sucker	Northern pike	Rock bass	Bluegill	Smallmouth bass	Largemouth bass	Rainbow trout	Pumpkinseed	Muskellunge	Brown bullhead	Redhorse spp.	Black bullhead	Silver redhorse	Common shiner
43	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
44	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
45	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
46	–	–	–	–	–	–	–	–	–	–	3	–	–	–	–	–
47	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
48	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
Total	3,836	110	304	270	67	85	57	54	43	23	14	14	11	8	1	1

Table 6.–Estimates of abundance, annual angler exploitation rates, and annual mortality rates for South Manistique Lake walleyes, northern pike, and smallmouth bass using methods described in text. Symmetrical 95% confidence intervals for estimates are given in parentheses, where applicable.

Parameter	Walleye	Northern pike	Smallmouth bass
Number tagged	2,812	35	46
Total voluntary tag returns	596	11	4
Number of legal-size[a] fish			
Multiple-census estimate	5,505	164	229
	(4,906–6,105)	(35–356)	(110–348)
Single-census estimate	6,473	846	282
	(5,437–7,509)	(35–1,809)	(46–555)
Michigan model prediction[b]	6,357		
	(1,348–29,981)	–	–
Number of adult[c] fish			
Multiple-census method	7,558	1,907	
	(6,705–8,412)	(124–4,475)	–
Single-census estimate	7,898	2,881	
	(6,642–9,154)	(124–6,159)	–
Michigan model prediction[d]	8,440		
	(1,997–35,669)	–	–
Wisconsin model prediction[e]	13,183		
	(4,327–40,160)	–	–
Annual exploitation rates			
Based on reward tag returns	28%	32%	4%
Based on harvest/abundance[f]	95%	605%	42%
	(68%–121%)	(0%–1,292%)	(0%–121%)
Based on harvest/abundance[g]	80%	117%	34%
	(55%–105%)	(0%–261%)	(0%–104%)
Annual mortality rates	29%	48%	25%

[a] Walleyes ≥ 15 in, northern pike ≥ 24 in, and smallmouth bass ≥ 14 in.
[b] Michigan model prediction of legal walleye abundance based on lake area, N = 21.
[c] Fish of legal-size and sexually mature fish of sub-legal size on spawning grounds.
[d] Michigan model prediction of adult walleye abundance based on lake area, N = 35.
[e] Wisconsin model prediction of adult walleye abundance for lakes with natural reproduction, N = 185.
[f] Multiple-census estimate of legal-size walleye abundance.
[g] Single-census estimate of legal-size walleye abundance.

Table 7.–Weighted mean lengths and sample sizes by age and sex for walleyes collected from South Manistique Lake, April 22 to May 1, 2003. Standard deviation is in parentheses.

Age	Mean length						Number aged		
	Males		Females		All fish[a]		Males	Females	All fish[a]
2	–		–		11.4	(0.5)	–	–	2
3	13.9	(0.8)	13.4	(0.0)	13.5	(0.9)	11	2	21
4	15.6	(1.2)	17.0	(0.7)	15.9	(1.4)	18	17	51
5	15.8	(1.3)	18.5	(1.2)	17.1	(1.8)	11	16	33
6	17.6	(–)	20.2	(0.5)	19.7	(0.9)	1	8	10
7	19.1	(0.6)	19.9	(1.1)	19.4	(0.8)	4	4	8
8	18.5	(1.2)	21.1	(1.3)	19.8	(1.8)	7	8	17
9	18.8	(0.7)	21.8	(0.9)	19.9	(1.6)	9	8	17
10	18.2	(–)	20.3	(–)	18.8	(0.9)	1	1	2
11	18.7	(0.7)	22.9	(1.0)	21.0	(2.2)	5	12	19
12	20.7	(1.0)	24.4	(1.1)	22.1	(2.1)	4	10	16
13	22.4	(1.7)	25.0	(1.5)	23.6	(2.0)	2	6	8
14	21.3	(–)	23.2	(0.5)	22.6	(1.0)	1	3	4
15	–		26.0	(1.9)	26.0	(1.9)	–	5	5

[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 South Manistique Lake, April 22 to May 1, 2003. Standard deviation is in parentheses.

Age	Mean length						Number aged		
	Males		Females		All fish[a]		Males	Females	All fish[a]
1	13.2	(–)	–		13.3	(0.0)	1	–	2
2	14.6	(1.1)	17.2	(1.7)	16.7	(1.9)	3	9	41
3	19.9	(1.9)	20.7	(1.8)	20.2	(2.1)	11	15	46
4	22.2	(2.0)	24.1	(1.1)	23.6	(2.2)	2	5	26
5	21.3	(0.5)	–		22.5	(1.5)	2	–	5
6	23.0	(0.9)	22.8	(–)	23.9	(2.6)	2	1	6
7	–		29.8	(–)	24.8	(3.8)	–	1	4
8	–		–		–		–	–	–
9	–		–		28.6	(–)	–	–	1
10	29.1	(–)	–		29.1	(–)	1	–	1

[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 and muskellunge collected from South Manistique Lake, April 22 to May 1, 2003. Standard deviation is in parentheses.

Age	Smallmouth bass			Muskellunge		
	Mean length		N	Mean length		N
2	11.4	(–)	1	–		–
3	14.4	(–)	1	–		–
4	13.8	(0.8)	3	38.5	(–)	1
5	16.1	(0.7)	10	33.9	(1.5)	3
6	17.1	(0.8)	3	–		–
7	17.6	(0.4)	5	–		–
8	17.7	(0.9)	2	–		–
9	18.6	(0.0)	2	46.8	(–)	1
10	–		–	45.9	(0.5)	3
11	19.6	(0.3)	3	42.1	(4.9)	4
12	–		–	–		–
13	18.8	(0.3)	2	–		–

Table 10.–Catch-at-age estimates (apportioned by age-length key) by sex for walleyes, northern pike, and smallmouth bass from South Manistique Lake, April 22 to May 1, 2003.

Age	Year class	Walleye			Northern pike			Smallmouth bass
		Males	Females	All fish[a]	Males	Females	All fish[a]	All fish[a]
1	2002	–	–	–	1	–	3	–
2	2001	–	–	18	3	20	88	2
3	2000	340	9	437	28	24	95	3
4	1999	674	115	1,009	3	9	50	7
5	1998	404	183	807	3	0	9	19
6	1997	39	129	173	3	1	10	5
7	1996	170	61	194	0	1	6	8
8	1995	218	120	284	0	–	0	3
9	1994	322	125	299	0	–	2	3
10	1993	62	20	47	1	–	1	0
11	1992	178	121	235	–	–	–	4
12	1991	30	33	92	–	–	–	0
13	1990	5	14	28	–	–	–	2
14	1989	4	31	39	–	–	–	–
15	1988	–	9	9	–	–	–	–
Total		2,446	970	3,671	42	55	264	56

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

Table 11.–Movement of fish tagged in South Manistique Lake and re-captured during the spring survey (April 22 to May 1, 2003). Percent of total recaptured fish is in parentheses.

Species	Recapture location		
	South Manistique	Big Manistique	North Manistique
Walleye	898 (98.1)	17 (1.9)	0 (0)
Northern pike	2 (100)	0 (0)	0 (0)
Smallmouth bass	3 (100)	0 (0)	0 (0)

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

Species	Recapture location		
	South Manistique	Big Manistique	North Manistique
Walleye	586 (98.3)	10 (1.7)	0 (0)
Northern pike	11 (100)	0 (0)	0 (0)
Smallmouth bass	4 (100)	0 (0)	0 (0)

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

		Month						
		May	June	July	August	September	October	Season
Species	Catch/hour	Number harvested						
Smallmouth bass	0.001 (0.002)	0 (0)	0 (0)	98 (196)	0 (0)	10 (21)	0 (0)	108 (197)
Walleye	0.046 (0.015)	1,857 (1,220)	1,393 (618)	1,732 (856)	507 (342)	132 (122)	108 (136)	5,729 (1,659)
Largemouth bass	0.002 (0.002)	0 (0)	0 (0)	114 (185)	96 (144)	23 (33)	44 (65)	276 (246)
Yellow perch	0.086 (0.037)	4,248 (3,772)	2,554 (1,486)	2,442 (1,230)	552 (406)	173 (299)	667 (781)	10,635 (4,337)
Northern pike	0.009 (0.005)	361 (384)	292 (276)	311 (302)	127 (159)	26 (38)	0 (0)	1,117 (585)
Bluegill	0.133 (0.039)	575 (890)	4,637 (2,059)	7,498 (3,092)	2,942 (1,692)	457 (368)	388 (422)	16,497 (4,215)
Pumpkinseed	0.014 (0.009)	0 (0)	395 (328)	969 (953)	350 (334)	29 (58)	0 (0)	1,742 (1,064)
Rock bass	0.004 (0.003)	0 (0)	380 (278)	101 (181)	0 (0)	0 (0)	0 (0)	480 (332)
Total harvested	0.295 (0.068)	7,041 (4,081)	9,650 (2,663)	13,263 (3,593)	4,574 (1,817)	850 (496)	1,207 (900)	36,584 (6,404)
		Number released						
Smallmouth bass	0.016 (0.007)	173 (231)	466 (387)	387 (466)	618 (361)	242 (199)	31 (61)	1,917 (771)
Largemouth bass	0.039 (0.017)	867 (1,448)	736 (641)	908 (630)	1,393 (754)	755 (491)	150 (270)	4,809 (1,946)
Walleye	0.059 (0.020)	1,108 (936)	3,810 (1,695)	1,144 (809)	712 (423)	557 (367)	0 (0)	7,331 (2,172)
Yellow perch	0.274 (0.072)	2,869 (2,068)	5,399 (2,330)	15,692 (5,756)	8,317 (3,331)	1,558 (936)	73 (110)	33,909 (7,404)
Northern pike	0.167 (0.047)	6,297 (3,737)	5,408 (2,032)	5,352 (2,366)	2,704 (1,045)	955 (560)	20 (41)	20,736 (5,010)
Bluegill	0.471 (0.133)	737 (839)	13,919 (6,821)	24,036 (10,578)	17,882 (6,201)	1,547 (867)	220 (440)	58,341 (14,090)
Pumpkinseed	0.023 (0.015)	0 (0)	455 (910)	1,255 (1,414)	1,140 (802)	0 (0)	0 (0)	2,850 (1,863)
Rock bass	0.015 (0.012)	0 (0)	1,079 (1,295)	552 (568)	149 (182)	52 (70)	0 (0)	1,832 (1,428)
Muskellunge	<0.001<(0.001)	0 (0)	44 (63)	0 (0)	0 (0)	0 (0)	0 (0)	44 (63)
Total released	1.063 (0.210)	12,050 (4,688)	31,317 (7,876)	49,324 (12,418)	32,916 (7,225)	5,666 (1,536)	494 (533)	131,768 (17,119)
Total (harvested & released)	1.358 (0.250)	19,091 (6,215)	40,967 (8,314)	62,587 (12,927)	37,490 (7,450)	6,516 (1,614)	1,701 (1,046)	168,352 (18,277)
		Fishing effort						
Angler hours		20,897 (11,451)	30,655 (7,087)	36,967 (10,112)	25,109 (6,584)	8,583 (3,107)	1,742 (1,109)	123,953 (18,380)
Angler trips		9,500 (7,911)	10,746 (5,888)	17,098 (7,293)	10,134 (6,040)	4,583 (2,829)	836 (583)	52,897 (13,973)

Table 14.–Angler survey estimates for winter 2003–04 from South Manistique Lake. Survey period was from December 27, 2003 through March 28, 2004. Two standard errors are given in parentheses.

		Month			
		December–January	February	March	Season
Species	Catch/hour	Number harvested			
Rainbow trout	0.002 (0.003)	0 (0)	40 (47)	0 (0)	40 (47)
Lake herring	0.002 (0.004)	37 (74)	0 (0)	0 (0)	37 (74)
Walleye	0.048 (0.024)	709 (387)	172 (107)	26 (47)	908 (405)
Yellow perch	0.293 (0.156)	4,121 (2,575)	1,261 (721)	107 (99)	5,490 (2,676)
Northern pike	0.013 (0.008)	170 (114)	62 (60)	9 (16)	241 (130)
Bluegill	0.018 (0.021)	0 (0)	0 (0)	336 (385)	336 (385)
Pumpkinseed	0.001 (0.001)	0 (0)	0 (0)	18 (27)	18 (27)
Total harvested	0.377 (0.167)	5,038 (2,608)	1,534 (733)	498 (402)	7,070 (2,739)
		Number released			
Smallmouth bass	0.001 (0.002)	0 (0)	26 (35)	0 (0)	26 (35)
Largemouth bass	0.002 (0.004)	0 (0)	8 (15)	36 (67)	44 (68)
Walleye	0.123 (0.050)	1,375 (637)	591 (354)	336 (311)	2,302 (792)
Northern pike	0.076 (0.029)	920 (360)	446 (247)	66 (70)	1,432 (442)
Pumpkinseed	0.002 (0.004)	0 (0)	0 (0)	36 (72)	36 (72)
Yellow perch	0.104 (0.093)	1,625 (1,671)	244 (166)	83 (135)	1,952 (1,684)
Total released	0.309 (0.121)	3,920 (1,824)	1,314 (464)	557 (360)	5,791 (1,916)
Total (harvested + released)	0.687 (0.230)	8,959 (3,182)	2,848 (868)	1,054 (539)	12,861 (3,342)
		Fishing effort			
Angler hours		11,714 (3,083)	5,576 (2,179)	1,444 (1,213)	18,733 (3,965)
Angler trips		3,519 (1,396)	1,687 (651)	712 (604)	5,918 (1,655)

Table 15.–Angler survey estimates for summer and winter 2003–04 from South 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.

		Month									
		May	June	July	August	September	October	Dec.–January	February	March	Season
Species	C/H	Number harvested									
Rainbow trout	<0.001 (0.001)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	40 (47)	0 (0)	40 (47)
Lake herring	<0.001 (0.001)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	37 (74)	0 (0)	0 (0)	37 (74)
Smallmouth bass	0.001 (0.001)	0 (0)	0 (0)	98(196)	0 (0)	10 (21)	0 (0)	0 (0)	0 (0)	0 (0)	108 (197)
Walleye	0.047 (0.013)	1,857 (1,220)	1,393 (618)	1,732 (856)	507 (342)	132 (122)	108 (136)	709 (387)	172 (107)	26 (47)	6,637 (1,708)
Yellow perch	0.113 (0.039)	4,248 (3,772)	2,554 (1,486)	2,442 (1,230)	552 (406)	173 (299)	667 (781)	4,121 (2,575)	1,261 (721)	107 (99)	16,124 (5,096)
Northern pike	0.010 (0.004)	361 (384)	292 (276)	311 (302)	127 (159)	26 (38)	0 (0)	170 (114)	62 (60)	9 (16)	1,359 (599)
Bluegill	0.118 (0.034)	575 (890)	4,637 (2,059)	7,498 (3,092)	2,942 (1,692)	457 (368)	388 (422)	0 (0)	0 (0)	366 (385)	16,833 (4,233)
Largemouth bass	0.002 (0.002)	0 (0)	0 (0)	114 (185)	96 (144)	23 (33)	44 (65)	0 (0)	0 (0)	0 (0)	276 (246)
Rock bass	0.003 (0.002)	0 (0)	380 (278)	101 (181)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	480 (332)
Pumpkinseed	0.012 (0.008)	0 (0)	395 (328)	969 (953)	350 (334)	29 (58)	0 (0)	0 (0)	0 (0)	18 (27)	1,760 (1,064)
Total harvested	0.306 (0.063)	7,041 (4,081)	9,650 (2,663)	13,263 (3,593)	4,574 (1,817)	850 (496)	1,207 (900)	5,038 (2,608)	1,534 (733)	498 (402)	43,654 (6,965)
		Number released									
Smallmouth bass	0.014 (0.006)	173 (231)	466 (387)	387 (466)	681 (361)	242 (199)	31 (61)	0 (0)	26 (35)	0 (0)	1,943 (772)
Largemouth bass	0.034 (0.014)	867 (1,448)	736 (641)	908 (630)	1,393 (754)	755 (491)	150 (270)	0 (0)	8 (15)	36 (67)	4,852 (1,947)
Walleye	0.068 (0.019)	1,108 (936)	3,810 (1,695)	1,144 (809)	712 (423)	557 (367)	0 (0)	1,375 (637)	591 (354)	336 (311)	9,633 (2,312)
Northern pike	0.155 (0.041)	6,297 (3,737)	5,408 (2,032)	5,352 (2,366)	2,704 (1,045)	955 (560)	20 (41)	920 (360)	446 (247)	66 (70)	22,168 (5,030)
Muskellunge	<0.001 (0.001)	0 (0)	44 (63)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	44 (63)
Rock bass	0.013 (0.010)	0 (0)	1,079 (1,295)	522 (568)	149 (182)	52 (70)	0 (0)	0 (0)	0 (0)	0 (0)	1,832 (1,428)
Bluegill	0.409 (0.113)	737 (839)	13,919 (6,821)	24,036 (10,578)	17,882 (6,201)	1,547 (867)	220 (440)	0 (0)	0 (0)	0 (0)	58,341 (14,090)
Pumpkinseed	0.020 (0.013)	0 (0)	455 (910)	1,255 (1,414)	1,140 (802)	0 (0)	0 (0)	0 (0)	0 (0)	36 (72)	2,886 (1,864)
Yellow perch	0.251 (0.063)	2,869 (2,068)	5,399 (2,330)	15,692 (5,756)	8,317 (3,331)	1,558 (936)	73 (110)	1,625 (1,671)	244 (166)	83 (135)	35,861 (7,593)
Total released	0.964 (0.175)	12,050 (4,688)	31,317 (7,876)	49,324 (12,418)	32,916 (7,225)	5,666 (1,536)	494 (533)	3,920 (1,824)	1,314 (464)	557 (360)	137,559 (17,226)
Total (harvested + released)	1.270 (0.212)	19,091 (6,215)	40,967 (8,314)	62,587 (12,927)	37,490 (7,450)	6,516 (1,614)	1,701 (1,046)	8,959 (3,182)	2,848 (868)	1,054 (539)	181,213 (18,581)
		Fishing effort									
Angler hours		20,897 (11,451)	30,655 (7,087)	36,967 (10,112)	25,109 (6,584)	8,583 (3,107)	1,742 (1,109)	11,714 (3,083)	5,576 (2,179)	1,444 (1,213)	142,686 (18,803)
Angler trips		9,500 (7,911)	10,746 (5,888)	17,098(7,293)	10,134 (6,040)	4,583 (2,829)	836 (583)	3,519 (1,396)	1,687 (651)	712 (604)	58,815 (14,071)

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

	Species		
Month	Walleye	Northern pike	Smallmouth bass
4	0 (0.0)	0 (0.0)	0 (0.0)
5	150 (25.2)	1 (9.1)	1 (25.0)
6	211 (35.4)	5 (45.4)	0 (0.0)
7	106 (17.8)	3 (27.3)	0 (0.0)
8	39 (6.5)	1 (9.1)	0 (0.0)
9	16 (2.7)	0 (0.0)	1 (25.0)
10	2 (0.3)	0 (0.0)	0 (0.0)
11	0 (0.0)	0 (0.0)	0 (0.0)
12	25 (4.2)	0 (0.0)	0 (0.0)
1	29 (4.9)	0 (0.0)	1 (25.0)
2	18 (3.0)	1 (9.1)	1 (25.0)
3	0 (0.0)	0 (0.0)	0 (0.0)
Total	596	11	4

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

		Lake / Survey							
Age	Statewide average[a]	South Manistique 2003[b]	South Manistique 2000[c]	South Manistique 1988[d]	South Manistique 1995[e]	Big Manistique 2003[b]	Gogebic 1999	Michigamme Reservoir 2001[b]	Lake Michigamme 2002[f]
2	10.4	11.4 (2)	11.2 (10)	10.6 (20)	10.5 (13)	12.6 (36)		8.3 (9)	8.3 (2)
3	13.9	13.5 (21)	14.3 (13)	12.6 (20)	13.9 (8)	15.3 (40)	11.4 (1)	12.5 (76)	10.4 (4)
4	15.8	15.9 (51)	17.1 (11)	15.2 (19)	14.3 (17)	18.2 (25)	13.0 (1)	14.0 (90)	11.9 (1)
5	17.6	17.1 (33)	18.0 (13)	16.8 (8)	15.7 (8)	19.2 (11)	13.8 (34)	14.8 (41)	12.7 (5)
6	19.2	19.7 (10)	19.1 (15)	18.0 (6)	16.4 (12)	19.7 (6)	16.4 (2)	15.5 (91)	15.1 (2)
7	20.6	19.4 (8)	19.1 (6)	19.3 (8)	18.4 (11)	20.1 (26)	16.7 (1)	16.2 (64)	14.5 (1)
8	21.6	19.8 (17)	21.7 (4)	21.0 (4)	20.1 (6)	19.8 (14)	17.1 (10)	16.8 (20)	16.7 (1)
9	22.4	19.9 (17)	21.5 (5)	21.8 (3)	20.3 (4)	20.9 (18)	17.0 (3)	18.7 (15)	
10	23.1	18.8 (2)	21.6 (3)	23.0 (1)	22.5 (4)	21.5 (6)	17.8 (7)	19.4 (15)	21.4 (1)
11		21.0 (19)			23.0 (2)	21.5 (12)	17.3 (2)	20.3 (12)	
12		22.1 (16)			25.4 (2)	22.3 (10)		18.7 (19)	18.4 (1)
13		23.6 (8)				23.2 (8)	20.1 (3)	19.9 (9)	
14		22.6 (4)				22.8 (7)		19.3 (11)	
15		26.0 (5)			23.8 (1)	26.0 (2)		20.2 (3)	
16						25.2 (1)		19.5 (3)	22.3 (1)
17								20.5 (1)	
Mean growth index[g]		-0.8	-0.2	-0.3	-1.8	+0.4	-3.3	-3.2	-5.3

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

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

		Lake / Survey						
Age	Statewide average[a]	South Manistique 2003[b]	South Manistique 2000[f]	South Manistique 1988[c]	South Manistique 1995[d]	Bond Falls 1999[e]	Michigamme Reservoir 2001[b]	Lake Michigamme 2002[e]
2	17.7	16.7 (41)	18.7 (2)		19.8 (2)	17.5 (5)	16.0 (94)	17.1 (8)
3	20.8	20.2 (46)	20.8 (3)	21.8 (4)	20.8 (7)	19.6 (7)	18.8 (118)	19.4 (17)
4	23.4	23.6 (26)	23.0 (2)	23.1 (1)	24.0 (4)	21.5 (9)	20.6 (64)	23.6 (6)
5	25.5	22.5 (5)	23.8 (3)		24.3 (1)	23.7 (4)	21.3 (51)	22.8 (5)
6	27.3	23.9 (6)			36 (1)	31.7 (1)	25.3 (35)	28.5 (10)
7	29.3	24.8 (4)		32.9 (1)			25.6 (21)	34.8 (8)
8	31.2						27.5 (3)	31.5 (1)
9		28.6 (1)					36.3 (4)	32.1 (1)
10		29.1 (1)						
11							34.0 (1)	
12								
Mean growth index[g]		-1.6			-2.0	-2.1	-2.7	-0.5

[a] Jan–May averages from Schneider et al. (2000a), aged using scales.
[b] Fish collected in the spring and aged using spines.
[c] Fish collected in September and aged using scales.
[d] Fish collected in August/September and aged using scales.
[e] Fish collected in June and aged using spines.
[f] Fish collected in July and aged using spines.
[g] 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 South Manistique Lake to values for other selected Michigan lakes. Lakes are listed from highest to lowest total fishing effort. Lake size was from Laarman (1976).

Lake	County	Size (acres)	Survey period	Total fishing effort (hours)	Fish harvested (number)	Fish harvested per hour	Hours fished per acre	Fish harvested per acre
Houghton	Roscommon	20,075	Apr 2001–Mar 2002	499,048	386,287	0.77	24.9	19.2
Cisco Chain	Gogebic, Vilas	3,987	May 2002–Feb 2003	180,262	120,412	0.67	45.2	30.2
Muskegon	Muskegon	4,232	Apr 2002–Mar 2003	180,064	184,161	1.02	42.5	43.5
Fletcher Pond	Alpena, Montmorency	8,970	May 1997–Sep 1997	171,521	118,101	0.69	19.1	13.2
Burt	Cheboygan	17,120	Apr 2001–Mar 2002	134,205	68,473	0.51	7.8	4.0
South Manistique	Mackinac	4,133	May 2003–Mar 2004	142,686	43,654	0.31	34.5	10.6
Gogebic	Ontonagon, Gogebic	13,380	May 1998–Apr 1999	121,525	26,622	0.22	9.1	2.0
Lake Leelanau	Leelanau	8,607	Apr 2002–Mar 2003	112,112	15,464	0.14	13.0	1.8
Mullett	Cheboygan	16,630	May1998–Aug 1998	87,520	18,727	0.21	5.3	1.1
Crooked and Pickerel	Emmet	3,434	Apr 2001–Mar 2002	55,894	13,665	0.24	16.3	4.0
Michigamme Reservoir	Iron	6,400	May 2001–Feb 2002	52,686	10,899	0.21	8.2	1.7
Average				157,957	91,497	0.45	20.5	11.9

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Appendix

Appendix–Fish species captured in South Manistique Lake from 1988 through 2003 using various gear types.

Common name	Scientific name
Species collected in 2003 with fyke nets and electrofishing gear	
Black bullhead	*Ameiurus melas*
Bluegill	*Lepomis macrochirus*
Brown bullhead	*Ameiurus nebulosus*
Common shiner	*Notropis cornutus*
Largemouth bass	*Micropterus salmoides*
Mottled sculpin	*Cottus bairdii*
Muskellunge	*Esox masquinongy*
Northern pike	*Esox lucius*
Pumpkinseed	*Lepomis gibbosus*
Rainbow Trout	*Oncorhynchus mykiss*
Rock bass	*Ambloplites rupestris*
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, gill nets, and trap nets (1988)	
Bluntnose minnow	*Pimephales notatus*