STATE OF MICHIGAN
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The Fish Community and Fishery of Long Lake, Presque Isle and Alpena Counties, Michigan in 2004-05 with Emphasis on Walleye, Northern Pike, and Smallmouth Bass

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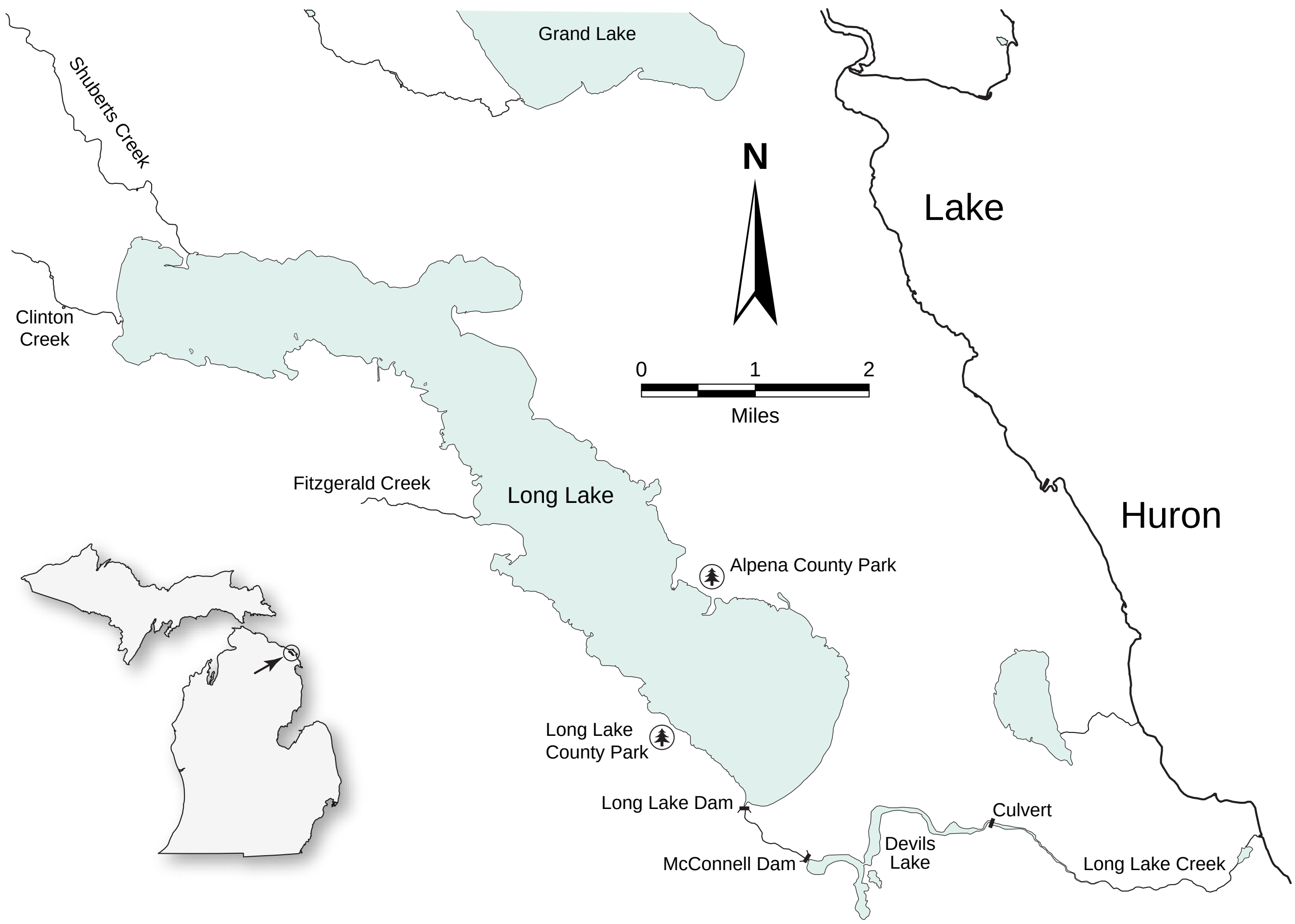

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FISHERIES DIVISION
SPECIAL REPORT 53

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Michigan Department of Natural Resources
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The Fish Community and Fishery of Long Lake, Presque Isle and Alpena Counties, Michigan in 2004–05 with Emphasis on Walleye, Northern Pike, and Smallmouth Bass

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Introduction

The Michigan Department of Natural Resources (MDNR), Fisheries Division surveyed fish populations and angler catch and effort at Long Lake, Presque Isle and Alpena counties, Michigan from April 2004 through March 2005. This work was part of the Large Lakes Program, which is designed to improve assessment and monitoring of fish communities and fisheries in Michigan's largest inland lakes (Clark et al. 2004).

The Large Lakes Program has three primary objectives. First, we want to produce consistent indices of abundance and estimates of annual harvest and fishing effort for important fishes. Initially, important fishes were defined as species susceptible to trap or fyke nets and/or those readily harvested by anglers. Our goal is to produce statistics for important fishes to help detect major changes in their populations over time. Second, we want to produce growth and mortality statistics to evaluate effects of fishing on species which support valuable fisheries. This usually involves targeted sampling to collect, sample, and mark sufficient numbers of fish. We selected walleye *Sander vitreus*, northern pike *Esox lucius*, and smallmouth bass *Micropterus dolomieui* as special-interest species in this survey of Long 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 Long Lake.

The Large Lakes Program will maintain consistent sampling methods over lakes and time. This will allow us to build a body of fish population and harvest statistics to directly evaluate differences among lakes or changes within a lake over time. Long Lake is the thirteenth lake to be sampled under the protocols of the program; thus, we were somewhat limited in our ability to make valid comparisons among lakes. As the program progresses, we will eventually have a large body of netting data collected under the same conditions that will facilitate comprehensive analyses.

Study Area

Long Lake lies along the Alpena and Presque Isle county line in the northeastern part of Michigan's Lower Peninsula. It is 5,342 acres in size (Breck 2004) and is situated about 7 miles north of the town of Alpena. Long Lake is fed by a variety of small creeks (Figure 1). The largest tributary is Shuberts Creek, which enters the lake on the northwest shore. Other tributaries, such as Clinton and Mindack creeks, enter the northwest arm of the lake, while Fitzgerald and Long Lake Park creeks enter the lake in the middle reaches. Most of these tributaries are used by game fish seasonally for spawning. In fact, springtime fishing closures are in place on Shuberts and Clinton creeks. The outlet (Long Lake Creek) can be found on the south shore which flows towards Lake Huron. There are two dams in the outlet; one at the head of the stream stabilizes the level of the lake, while the lower dam at one time formed a fish rearing pond. The main Long Lake dam was built in 1936, and the legal lake level (650.89 ft) was established by court order in 1948.

A public access site exists along the western shore of the lake. It consists of a hard surfaced ramp with sufficient water depth to accommodate large watercraft, has 10 parking spaces, a public toilet, and is handicap accessible. A county owned ramp exists on the southeast shore which provides ample parking for anglers. Three smaller unimproved access sites can be found throughout the lake including one in East Bay. Launching of watercraft can be questionable at some of these sites during low water periods.

The shoreline of Long Lake is largely developed with private residences, thus there is little public riparian land. There were 228 riparian residences in 1939, and there are approximately 750 at present (counted from Google Earth© satellite image). The bathymetry of Long Lake was mapped between 1935 and 1936, and the maximum depth was recorded as 25 feet. The bathymetry is rather uniform, with most of the lake between 10 to 20 feet deep (Figure 2). The relatively shallow depth of Long Lake, together with pronounced exposure to winds, allows for repeated mixing of its water. Thus, thermal stratification does not occur often, except during periods of extreme summer heat. The substrate of Long Lake consists of mainly sand, gravel, and cobble in the near-shore areas while marl and muck can be found in deeper water. Water clarity of Long Lake is typically high, although the shallow nature of the lake often leads to reduced clarity through wave action. When surveyed in the 1930's, various species of aquatic vegetation were common, particularly of the genus C*hara* (muskgrass), while near-shore vegetation was rare. Currently, aquatic vegetation is sparse in Long Lake. Emergent beds of rush can be found in various protected areas near shore. The Long Lake Association installed 364 brush shelters in Long Lake from 1942 through 1952 to provide fish cover and improve angling.

Historical alkalinity tests in the late 1930s gave a range of 110 to 141 parts per million of calcium carbonate. Temperature and dissolved oxygen profiles in June of 1939 demonstrated no thermal stratification and consistent saturated oxygen levels throughout the water column. More recently, Long Lake limnological parameters have been surveyed on various occasions: from 1973 to 1979, in 1989, 1993, 1994, and 2004. Detailed results for most of these samples can be found in TMI Environmental Services (1994). Earliest surveys in the 1970s indicated elevated levels of surface phosphorus and average levels at the bottom. Dissolved oxygen and temperature values were typical for summer waters of a well mixed shallow lake system. The water had low salt content and was moderately hard and alkaline with an average of 178 ppm and 140 ppm of calcium carbonate, respectively. High nutrient concentrations were observed and were suggested to be from excessive watershed inputs. Aquatic invertebrates such as mayflies, alderflies, and midges were all common as were a variety of zooplankton species. The zooplankton community was said to reflect that of a nutrient rich environment. The final conclusion from the 1973 survey indicated that Long Lake was severely enriched from overland and other types of nutrients.

Additional water quality analyses of Long Lake were made by the Northeastern Council of Governments in 1979. Chlorophyll-a measurements increased from 1.03 parts per billion in spring to 4.6 parts per billion in the summer. Summer thermal stratification did not occur at Long Lake. Total phosphorus had an overall mean of 0.10 parts per million, while total alkalinity averaged 123 parts per million.

Alpena Community College conducted water quality monitoring of Long Lake in early June of 1989. Results indicated that Long Lake reached a quality level that had been fairly steady over the last decade. Again, no thermocline was established in Long Lake although dissolved oxygen levels declined near the bottom. Alkalinity was measured at 165 parts per million. Results suggested that Long Lake was maintaining its mesotrophic status and was not approaching eutrophy as suggested by the 1979 survey.

Results of the early to mid 1990s limnology surveys again indicated thorough mixing of the lake, and the lack of a thermocline (TMI Environmental Services 1994). Oxygen and temperature levels remained highly suitable for fish survival. Lake waters were nonacidic and alkaline in nature. Phosphorus levels were lowest in the spring and highest during the summer which would be expected. Lead levels in the water and fish were considered negligible. Results from planktonic algae sampling indicated that Long Lake was still at mesotrophic status.

Another detailed limnological survey of Long Lake was made by Fusilier and Fusilier (2001) in 2001. Tests performed on the samples included total phosphorus, total nitrate nitrogen, total alkalinity, pH, conductivity, chlorophyll-a, water clarity, temperature, and dissolved oxygen. Late summer sampling found uniform oxygen and temperature throughout the water column. Total alkalinity was 95 to 108 parts per million in spring, and 122 to 124 parts per million in the summer. These values classify Long Lake as a moderately hard water lake. Nitrate nitrogen concentrations were found to be low, indicating that nitrate, rather than phosphorus, was limited during both the spring and summer (Fusilier and Fusilier 2001). The level of Chlorophyll-a was found to be low in Long Lake, which suggested low algal densities. Secchi disk readings measured in Long Lake from 1992 and 2001 ranged from 13 to 19 feet, and indicated a general decline over the time period.

Various water parameters were measured by the MDNR Fisheries Division on Long Lake in mid-June 2004. A dissolved oxygen and temperature profile showed suitable dissolved oxygen levels for fish throughout the water column, and nearly uniform water temperature (72–73ºF). Total alkalinity was 120 parts per million, well within the typical range for this type of lake. Chlorophyll-a measurement was 1.4 parts per billion. Secchi-disk reading was over 8 feet indicating fair water clarity. Although this indicates lower water clarity than observed from 1992 to 2001, Long Lake experiences occasional mixing during high wind events, which results in higher turbidity.

The fish community of Long Lake includes species typical of northern Michigan. We listed common and scientific names of all fish species captured during this study in the Appendix. Families of fish include, but are not limited to; *Cyprinidae, Catostomidae, Centrarchidae, Esocidae, Ictaluridae, Percidae, and Salmonidae*.

Fish stocking in Long Lake has involved a variety of species, ages, and sizes dating back to 1905 (Table 1). Lake trout fry stocking was attempted in 1910, and largemouth bass, bluegill, rock bass, crappie, and pumpkinseed were stocked in varying numbers and sizes from 1905 through the middle of the twentieth century. Yellow perch were also stocked on occasion during this period. Smallmouth bass were stocked by the State of Michigan from 1933 through 1945; some of the bass were adult fish from Lake Huron.

Northern pike fingerlings were released directly into Long Lake in 1964 and annually from 1976 to 1985 (Table 1). A pike spawning and rearing marsh, established in 1963 at the mouth of Fitzgerald Creek, was maintained by the MDNR and the local lake association. The MDNR released northern pike fry directly into the marsh in most years, until 1985 when adult pike were allowed to enter the marsh for spawning. Use of this marsh was discontinued after 1985 due to concerns over flooded timber on adjacent private land.

The earliest walleye stocking efforts using fry and fingerlings were made from 1910 to 1914, followed by fry and fingerling introductions in the 1930s (Table 1). Stocking of this species did not resume until 2004, after which a combination of fry, spring fingerlings, and fall fingerlings have been stocked annually. Fry were 0.5 inches long, spring fingerlings were 1.7 inches long, and fall fingerlings were 3.7 inches long. All walleyes stocked in Long Lake by the MDNR during this period were marked with oxytetracycline in order to determine the contribution of stocked fish to the overall population. The Long Lake Association has also stocked more than 19,000 fall fingerling walleyes in Long Lake from 2004 through 2007.

There have been six State of Michigan Master Angler award fish taken from Long Lake from 1992–2006, including northern pike, channel catfish, black bullhead, yellow perch, and smallmouth bass.

Methods

Fish populations in Long Lake were sampled with trap nets, fyke nets, and electrofishing gear from April 7 to 22, 2004. We used three boats daily, each with a three-person crew, for 2 weeks. Each net-boat crew tended 10–15 nets, and electrofishing was used at night as an additional collection method for walleye. Fyke nets were 6 ft x 4 ft with 2-inch stretch mesh and 70- to 100-ft leads. Trap nets were 8 ft by 6 ft by 3 ft with 2-inch stretch mesh and 70- to 100-ft leads. Nets were located to target walleye and northern pike (nonrandom), though we also made an effort to cover the entire lake. Duration of net sets ranged from 1–3 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 hand-held global positioning systems (GPS). Concurrent with our survey of Long Lake, we surveyed nearby Grand Lake using identical methods. Additionally, we conducted a standardized survey using multiple gears (P. A. Hanchin, personal communication) from June 23–27 on Grand and Long lakes.

Fish Community

We described the status of the overall fish community in terms of species present, catch per unit effort, percent by number, and length frequencies. Total lengths of all walleyes, northern pike, and smallmouth bass were measured to the nearest 0.1 inch. For other fish, lengths were measured to the nearest 0.1 inch 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. Size-structure data for target species (walleye, northern pike, and smallmouth bass) only included fish on their initial capture occasion. Walleyes and northern pike with flowing gametes were identified as male or female; 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.

We used a Microsoft Access© computer database to store and retrieve data collected during the tagging operation. We calculated mean catch per unit effort (CPUE) in fyke nets as an indicator of relative abundance, utilizing the number of fish per net night (including recaptures) for all net lifts that were determined to have fished effectively (i.e., without wave-induced rolling or human disturbance).

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

rock bass, bluegill, pumpkinseed, yellow perch, and rainbow trout as pelagic planktivores; insectivores; and suckers, bullheads, and carp as benthivores.

Walleye, Northern Pike, and Smallmouth Bass

Abundance.–We estimated the abundance of legal-size walleyes and northern pike using mark-and-recapture methods. Walleyes (≥15 inch), northern pike (≥24 inch), and smallmouth bas (≥14 inch) were fitted with monel-metal jaw tags. To assess tag loss, tagged fish were double-marked by clipping the left pelvic fin. Reward ($10) and nonreward tags were applied in an approximate 1:1 ratio. We did not think that an exact ratio was important; maintaining an exact ratio would have been difficult given the multiple crews and numbers of fish tagged. Large tags (size 16) that were used on large northern pike (≥36 inch) were all nonreward.

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

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

$$N = \frac{\sum_{d=1}^{n} C_d M_d^{\,2}}{\sum_{d=1}^{n} R_d M_d}$$

where,

N = multiple-census population estimate (number of legal or adult fish);

$C_d = U_d + R_d$ = total number of fish caught during day d;

U_d = number of unmarked fish caught during day d; R_d = number of recaptures during day d;

M_d = number of marked fish available for recapture at start of day d; and d = day (ranging from d_1 to d_n).

The variance formula was,

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

where,

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

Variance of 1/*N* is:

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

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

$$\frac{1}{\frac{1}{N} \pm t(\sigma)}$$

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

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

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

where,

N = single-census population estimate (numbers of legal-size fish);

M = number of fish caught, marked and released in first sample;

C = total number of fish caught in second sample (unmarked + recaptures);

and *R* = number of recaptures in second sample.

We calculated the variance as:

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

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

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

where,

N_a = estimated number of adult walleyes or northern pike;

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

N_{leg} = number of legal fish caught; N = single-census estimate of legal-size walleyes or northern pike.

We calculated the variance as:

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

There were no prior abundance estimates for walleye, northern pike, or smallmouth bass in Long Lake to help us gauge how many fish to mark. However, we used two regression equations developed for Michigan lakes to provide initial estimates of walleye abundance. These regressions predict legal and adult walleye abundance based on lake size and were derived from historic abundance estimates made in Michigan over the past 20 years. The following equation for adult walleye 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 Long Lake, the equation gives an estimate of 11,114 adult walleyes, with a 95% prediction interval (Zar 1999) of 2,613 to 47,273.

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 8,241 legal walleyes, with a 95% prediction interval (Zar 1999) of 1,733 to 39,185 for Long Lake. Based on these a priori abundance estimates, we thought that marking approximately 800 legal-size walleyes (≈10%) of the population would be sufficient. We did not set a specific tagging goal for northern pike or smallmouth bass, but rather tagged as many as possible until the walleye goal was achieved.

For the single-census estimate, we accounted for fish that recruited to legal size during the angler survey based on the estimated weighted average monthly growth for fish of slightly sublegal size. That is, because we were estimating the abundance of legal-size fish at time of marking (spring) and growth of fish occurred during the recapture period, it was necessary to reduce the number of unmarked fish by the estimated number that recruited to legal size during the recapture period. For example, to make this adjustment for walleye we determined the annual growth of slightly sublegal fish (i.e., 14.0- to 14.9-inch fish) from mean length-at-age data. We then divided by the length of the growing season in months (6) and rounded to the nearest 0.1 inch. This average monthly growth was used as the criteria to remove unmarked fish that were observed in the creel. The largest size of a sublegal fish at tagging was 14.9 inch; thus, an average monthly growth of 0.2 inch would result in all unmarked fish less than or equal to 15.1 inch caught during the first full month (June) after tagging to be removed from analysis. Adjustments were made for each month of the creel survey resulting in a final ratio of marked to unmarked fish. This final ratio was used to make the single-census population estimate.

We calculated the coefficient of variation (CV = standard deviation/mean) for each abundance estimate (single- and multiple-census) and considered estimates with a CV less than or equal to 0.40 to be reliable (Hansen et al. 2000).

Growth.–We used dorsal spines to age walleyes and smallmouth bass, and dorsal fin rays to age northern pike because we thought they provided the best combination of ease of collection in the field and accuracy and precision of age estimates. We considered ease of collection important because our staff worked in cold, windy conditions, dealt with large numbers of fish, and tagged fish in addition to measuring and collecting structures. Otoliths have been shown to be the most accurate and precise ageing structure for older walleyes (Heidinger and Clodfelter 1987; Koscovsky and Carline 2000; Isermann et al. 2003) and otoliths or cleithra for northern pike (Casselman 1974; Harrison and Hadley 1979), but collecting these structures would have required killing the fish and we were tagging and releasing fish for later recapture. Results from several studies comparing aging structures for walleye agreed that spines were quicker to remove than scales, but they do not agree that spines are more accurate than scales (Campbell and Babaluk 1979; Kocovsky and Carline 2000; Isermann et al. 2003). Errors in ages from spines were often related to misidentifying the first annulus in older fish (Ambrose 1983; Isermann et al. 2003). There is also considerable disagreement as to whether spines or scales were more precise for walleye age estimation. Erickson (1983) and Campbell and Babaluk (1979) found that spines were more precise, Belanger and Hogler (1982) found spines and scales were equally precise, and Kocovsky and Carline (2000) found scales were more precise. Since northern pike older than 6 years are notoriously difficult to age with scales (Carlander 1969), in recent years, MDNR field technicians and biologists have been using dorsal fin rays. Dorsal rays are as quick and easy to remove in the field as spines for walleye. Studies have demonstrated that fin rays are a valid aging structure for a number of species (Skidmore and Glass 1953; Ambrose 1983), including northern pike (Casselman 1996), but no comparisons have been made to statistically compare accuracy and precision of fin rays to other aging structures for northern pike. Our sample size goal was to collect 20 male and 20 female fish per inch group for walleye and northern pike. For smallmouth bass, we had a target of 20 fish per inch group.

Samples were sectioned using a table-mounted high-speed rotary cutting tool. Sections approximately 0.02-inch thick were cut as close to the proximal end of the spine or ray as possible. Sections were examined at 40x–80x magnification with transmitted light and were photographed with a digital camera. The digital image was archived for multiple readers. Two technicians independently aged samples, and ages were considered final when independent estimates were in agreement. Samples in dispute were aged by a third technician. Disputed ages were considered final when the third technician agreed with one of the first two. Samples were discarded if three technicians disagreed on age, though occasionally an average age was used when ages assigned to older fish (≥ age 10) were within plus or minus 10% of each other.

After a final age was identified for all samples, we calculated weighted mean lengths-at-age and age-length keys (Devries and Frie 1996) for male, female and all (males, females, and fish of unknown sex) walleyes and northern pike. Weighted mean lengths at age and age-length keys were computed for smallmouth bass without partitioning for sex. We compared the mean lengths-at-age to those from previous surveys of Long Lake and to other large lakes. We also computed a mean growth index to compare the data to Michigan state averages, as described by Schneider et al. (2000a). The mean growth index is the average of deviations (by age group) between the observed mean lengths and statewide seasonal average lengths. 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.

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

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

In the first method, exploitation rate was estimated as the fraction of reward tags returned by anglers, adjusted for tag loss. We made the assumption that mortality was negligible and that near 100% of reward tags on fish caught by anglers would be returned. Although we did not truly assess nonreporting, we did compare the actual number of tag returns to the expected number (X) based on the ratio:

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

where,

Nt = Number of tags observed in creel;

Nc = Number of fish observed in creel;

H = Total expanded harvest of species.

Additionally, we checked individual tags observed by the creel clerk to see if they were subsequently reported by anglers. This last step is also not a true estimate of nonreporting because there is the possibility that anglers believed the necessary information was obtained by the creel clerk, and further reporting to the MDNR was unnecessary.

Voluntary tag returns were encouraged with a monetary reward ($10) denoted on approximately 50% of the tags. Tag return forms were made available at boater access sites, at MDNR offices, and from creel clerks. Additionally, tag return information could be submitted on-line at the MDNR web site. All tag return data were entered into the database so that they could be efficiently linked to and verified against data collected during the tagging operation. We developed linked documents in Microsoft Word® computer software so that payment vouchers and letters to anglers were automatically produced with relevant information from the database. Letters were sent to all anglers with information on the length and sex of the tagged fish, and the location and date of tagging. Return rates were calculated separately for reward and nonreward tags. In addition to data on harvested fish, we estimated the release rate of legal fish by adding a question to the tag return form asking if the fish was released.

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 fish that would have recruited to legal size over the course of the creel survey based on the percentage of fish observed in the creel survey that were determined to have been sublegal at the time of the spring survey (See *Abundance* subsection of the **Methods** section). We calculated 95% confidence limits for these exploitation estimates assuming a normal distribution, and summing the variances of the abundance and harvest estimates.

Recruitment.–We considered relative year-class strength as an index of recruitment, and used the residuals from the catch-curve regressions as indices of year-class strength (Maceina 2003). We explored relationships among year-class strength and various environmental variables by using correlation analyses. The significance levels ($\alpha = 0.10$) were adjusted with a Bonferroni correction of alpha for multiple comparisons (Sokal and Rohlf 1995) to limit overall experimentwise error. Historic weather data were obtained from the National Weather Service observation station in Alpena, Michigan (station 200166). 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 walleye and northern pike during this survey were April 24, 2004–March 15, 2005. Minimum size limits were 15 inches for walleye and 24 inches for northern pike. Daily bag limit was five fish in any combination of walleyes, northern pike, smallmouth bass, or largemouth bass, with no more than two northern pike. Fishing harvest seasons for smallmouth bass and largemouth bass were May 29 through December 31, 2004. Minimum size limit was 14 inches for both smallmouth and largemouth bass.

Harvest was permitted all year for other species present and no minimum size limits were imposed. The bag limit for yellow perch was 50 per day and for "sunfishes", including black crappie, bluegill, pumpkinseed, and rock bass it was 25 per day in any combination. The bag limit for cisco (lake herring) *Coregonus artedi* was 12 inches combination with lake whitefish.

Direct contact angler creel surveys were conducted during one spring–summer period - April 24 to October 13, 2004, and one winter period - December 17, 2004 through March 26, 2005.

Summer.–We used a roving-roving design for the summer survey (Lockwood 2000b). Fishing boats were counted by one clerk working from a boat while another clerk working from another boat collected angler interview data. Both weekend days and three randomly determined weekdays were selected for counting and interviewing during each week of the survey season. No count or interview data were collected on holidays. Holidays during the period were Memorial Day (May 31, 2004), Independence Day (July 4, 2004), and Labor Day (September 6, 2004). Counting and interviewing were done on the same days, and one instantaneous count of fishing boats was made per day.

The starting location (point 1 or 2) and direction (clockwise or counter-clockwise) for counts were randomized (Figure 1). Only fishing boats were counted (i.e., watercraft involved in alternate activities, such as water skiing, were not counted). Time of count was randomized to cover daylight times within the sample period. Count information for each count was recorded on standard creel survey count forms, and included date, count time, and number of fishing boats.

Minimum fishing time prior to interview (incomplete-trip interview) was 1 h (Lockwood 2004). Historically, minimum fishing time prior to interviewing has been 0.5 h (Pollock et al. 1997). However, recent evaluations have shown that roving interview catch rates from anglers fishing a minimum of 1 h are more representative of access interview (completed-trip interview) catch rates (Lockwood 2004). Access interviews include information from complete trips and are appropriate standards for comparison. All roving interview data were collected by individual angler to avoid party size bias (Lockwood 1997), though the number of anglers in each party was recorded on one interview form for each party. While this survey was designed to collect roving interviews, 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, fishing mode, start time of fishing trip, interview time, species targeted, bait used, number of fish harvested by species, number of fish caught and released by species, length of harvested walleyes, northern pike, and smallmouth bass, and applicable tag number. One of two shifts was selected each sample day for interviewing (Table 2).

Winter.–We used a roving-roving design for winter surveys (Lockwood 2000b). One clerk working from a snowmobile collected count data while another clerk working from a snowmobile collected interview data. Both weekend days and 3 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, 2005), Martin Luther King Day (January 17, 2005), and President’s Day (February 21, 2005). The clerks followed a randomized count and interview schedule. One of two shifts was selected each sample day (Table 2). Starting location (Figure 1) and direction of travel were randomized for both counting and interviewing. Scanner-ready interview and count forms were used.

Progressive counts of open-ice anglers and occupied shanties were made once per day. Count information collected included: date, fishing mode (open ice or shanty), count time, and number of units (anglers or occupied shanties) counted. Similar to summer interview methods, minimum fishing time prior to interviewing was 1 h for all incompleted-trip interviews. Interview starting location and direction were randomized daily. Interview forms, information, and techniques used during the summer 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. Thus, the angling effort and catch reported here are for those periods sampled, no expansions were made to include periods not sampled (e.g., 0100 to 0400 hours).

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 completed-trip interviews and $\overline{R}$ the mean-of-ratios estimator for n_2 incompleted-trip interviews. Estimated variance s_w^2 was calculated as:

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

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

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

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

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, and smallmouth bass. 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 7,669 fish of 14 species (Table 3). Total sampling effort was 261 trap-net lifts, 228 fyke-net lifts, and one electrofishing run. We captured 837 walleyes, 397 northern pike, and 1,076 smallmouth bass. Other fish species collected in order of abundance of total catch were: rock bass, white sucker, yellow perch, brown bullhead, pumpkinseed, black bullhead, bluegill, common

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

carp, rainbow trout, black crappie, and largemouth bass. Rock bass comprised 29.2% of the catch by number, and mean length of this species was 7.1 inches. White suckers and yellow perch comprised 24.0% and 10.8% of the catch by number, respectively. Mean length of yellow perch was 8.1 inches. Largemouth bass and black crappie were present in Long Lake, yet rather uncommon based on survey catches. The overall fish community composition in Long Lake was 30% piscivores, 42% pelagic planktivores-insectivores, and 28% benthivores (Table 3).

The percentage of walleyes, northern pike, and smallmouth bass that were legal size was 86, 35, and 66, respectively (Table 4). The population of spawning walleyes was dominated by 15- to 21-inch walleyes, with none greater than 27 in. Northern pike were widely distributed among 11- to 40-inch groups, with 61% between 20 and 30 inches. Large pike (≥30 inch) were present, making up 7% of the total catch. Smallmouth bass were predominately (81%) in the 12- to 17-inch groups, though fish over 20 inches were collected.

Male walleyes outnumbered females in our spring survey, which is typical for walleye (Carlander 1997). Of all walleyes captured, 62% were male, 24% were female, and 14% were of unknown sex. Of legal-size walleyes captured, 71% were male, 28% were female, and 1% were of unknown sex. The sex ratio for northern pike appeared more balanced than walleye; however, many fish were of unknown sex. Of all northern pike captured, 34% were male, 37% were female, and 29% were of unknown sex. Of legal-size northern pike captured, 16% were male, 63% were female, and 21% were of unknown sex. We did not identify the sex of enough smallmouth bass to accurately report the ratio of males to females.

Walleye, Northern Pike, and Smallmouth Bass

Abundance.–We placed a total of 643 tags on legal-size walleyes (383 reward and 260 nonreward tags) and clipped fins of 106 sublegal walleyes. Two recaptured walleyes were observed to have died, or lost their tag during the spring netting/electrofishing survey; thus, the effective number tagged was 641.

The angler survey clerk observed a total of 28 walleyes on Long Lake, of which four were marked (had a fin clip, or a tag). In our summer netting survey, we observed an additional 8 walleyes, of which one was marked. We reduced the number of unmarked walleyes in the single-census calculation by three fish to adjust for sublegal fish that grew over the minimum size limit during the fishing season. We did not observe any walleyes that had lost tags during the creel survey; thus, we used an average tag loss rate of 5%, derived from previous surveys.

The estimated number of legal-size walleyes was 2,760 using the multiple-census method and 3,649 using the single-census method (Table 5). The estimated number of adult walleyes was 2,842 using the multiple-census method, and 3,695 using the single-census method. The coefficient of variation was 0.11 for the two multiple-census estimates, and 0.34 for the single-census estimates.

We tagged 119 legal-size northern pike in Long Lake (80 reward and 39 nonreward tags). We did not observe any mortality or tag loss during the spring netting survey. We also clipped fins of 230 sublegal northern pike. The creel clerk observed 19 northern pike, of which two were marked. In the summer netting survey we observed an additional two northern pike, of which neither were marked. We reduced the number of unmarked northern pike in the single-census calculation by seven to adjust for sublegal fish that grew over the minimum size limit during the fishing season. We did not observe any northern pike that had lost tags during the creel survey; thus, we used an average tag loss rate of 5%, derived from previous surveys.

The estimated number of legal-size northern pike was 599 (CV=0.16) using the multiple-census method, and was 600 (CV=0.45) using the single-census method. The estimated number of adult northern pike was 1,887 (CV=0.16) using the multiple-census method and 1,348 (CV=0.45) using the single-census method (Table 5).

We tagged 673 legal-size smallmouth bass in Long Lake (398 reward and 275 nonreward tags). One recaptured fish was observed to have lost its tag during the spring netting; thus, the effective number tagged was 672. We also clipped fins of 358 sublegal smallmouth bass. The creel clerk observed 133 smallmouth bass, of which eight were tagged. In the summer netting survey we observed an additional 28 smallmouth bass, of which none were marked. We reduced the number of unmarked smallmouth bass by 22 in the single-census calculation 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-size smallmouth bass was 9,940 (CV=0.29) using the multiple-census method and 10,469 (CV=0.31) using the single-census method (Table 5).

Growth.–For walleye, there was 76% agreement between the first two spine readers. For fish that were aged by a third reader (and not discarded), agreement was with first reader 54% of the time and with second reader 46% of the time; thus, there appeared to be little bias among readers. Nine percent of samples were discarded due to poor agreement, and an average age was used 1% of the time. At least two out of three readers agreed 91% of the time.

Female walleyes had higher mean lengths at age than males in Long Lake (Table 6). Females were at least 0.9 inches longer than males (age 9) and maximally 2.1 inches longer at age 8. This sexually dimorphic growth is typical for walleye (Colby et al. 1979; Carlander 1997; Kocovsky and Carline 2000). We calculated a mean growth index for all walleyes of -0.5. 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 19.5, 26.6, and 22.4 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 (and not discarded), agreement occurred with the first reader 78% of the time and with the second reader 22% of the time; thus, there appeared to be some bias among readers. One percent of samples were discarded due to poor agreement, thus at least two out of three readers agreed 99% of the time.

Female northern pike generally had higher mean lengths-at-age than males (Table 7). At their least difference, females were 2.2 inches longer than males (age 2), and at their greatest difference, females were 11.9 inches longer (age 7). As with walleye, this is a typical pattern for northern pike (Carlander 1969; Craig 1996). We calculated a mean growth index for northern pike of +1.9. Male, female, and all northern pike had L_∞ values of 27.2, 39.7, and 37.1 inches, respectively.

For smallmouth bass, there was 72% agreement between the first two spine readers. For fish that were aged by a third reader (and not discarded), agreement occurred with the first reader 33% of the time and with the second reader 67% of the time; thus, there appeared to be some bias among readers. Three percent of samples were discarded due to poor agreement, and an average age was used three percent of the time. At least two out of three readers agreed 94% of the time.

We calculated a mean growth index for smallmouth bass of -0.3. Mean length at age data for smallmouth bass (Table 8) were fit to a von Bertalanffy growth curve, and the resulting L_∞ value was 18.9 inches.

Mortality.–For walleye, we estimated catch-at-age using data from 464 males, 179 females, and 751 total walleyes, including those fish of unknown-sex (Table 9). We used ages 6 and older in the catch-curve analyses to represent the legal-size male, female, and entire walleye population (Figure 3). We chose age 6 as the youngest age because: 1) average length of male, female, and all walleyes at age 6 was greater than legal size, so likely most age-6 fish were legal-size at the beginning of fishing season; and 2) relative abundance of fish younger than age 6 did not appear to be represented in proportion to their expected abundance (Figure 3; Table 9). The catch-curve regressions for walleye were all significant ($P < 0.05$), and produced total instantaneous mortality rates for legal-size fish of 0.865 for males, 0.712 for females, and 0.835 for all fish combined

(Figure 3). These instantaneous rates corresponded to annual mortality rates of 58% for males, 51% for females, and 57% for all walleyes combined.

Anglers returned a total of 45 tags (30 reward and 15 nonreward) from harvested walleyes, and two tags (one reward and one nonreward) from released walleyes, in Long Lake in the year following tagging. The creel clerk also observed one tagged fish in the possession of an angler that was not subsequently reported to the MDNR by the anglers. The reward tag return estimate of annual exploitation of walleyes was 8.6% after adjusting for 5% tag loss (Table 5). Anglers reported reward tags at a higher rate than nonreward tags (8.1% versus 6.2%), 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 73%. Based on all tagged walleyes known to be caught, the reported release rate was 4%. The estimated exploitation rate for walleye was 10.4% based on dividing harvest by the multiple-census abundance estimate, and 7.8% based on dividing harvest by the single-census creel survey abundance estimate (Table 5).

For northern pike, we estimated catch at age for 121 males, 128 females, and 351 total northern pike, including those fish of unknown-sex (Table 9). We used ages 3 and older in the catch-curve analyses to represent the adult male northern pike population (Figure 4), since there were not enough age groups of legal size to estimate mortality for legal northern pike. We chose age 3 as the youngest age because the relative abundance of age-3 fish appear to be represented in proportion to their expected abundance (Figure 4; Table 9). We used ages 3 and older in the catch-curve analyses to represent the legal-size female northern pike population (Figure 4). We chose age 3 as the youngest age because: 1) average length of female northern pike at age 3 was 24.1 inches, so likely most age-3 fish were legal-size at the beginning of fishing season; and 2) relative abundance of fish younger than age 3 did not appear to be represented in proportion to their expected abundance (Figure 4; Table 9). We used ages 4 and older in the catch-curve analyses to represent the total legal-size northern pike population (Figure 4). We chose age 4 as the youngest age because the average length of all northern pike at age 4 was 25.1 inches, so likely most age-4 fish were legal-size at the beginning of fishing season. The catch-curve regressions for male, female and all northern pike were significant ($P < 0.05$), and produced instantaneous mortality rates of 0.614 for males, 0.616 for females, and 0.646 for all northern pike combined. These instantaneous rates corresponded to annual mortality rates of 46% for adult males, 46% for legal-size females, and 48% for all northern pike of legal size combined.

Anglers returned a total of 16 tags (7 reward and 9 nonreward) from harvested northern pike, and six tags (four reward and two nonreward) from released northern pike in Long Lake in the year following tagging. The creel clerk did not observe any tagged fish in the possession of anglers that were not subsequently reported to the central office by the anglers. The tag return estimate of annual exploitation of northern pike was 14.2%, which was based on reward and nonreward returns. Anglers reported reward tags at a lower rate than nonreward tags (13.8% versus 28.2%), though the number of total returns of both types was low. The reporting rate of nonreward tags relative to reward tags (λ *in* Pollock et al. 1991) was 264%. Based on all tagged northern pike known to be caught, the reported release rate was 27%. The estimated exploitation rate for northern pike was 18.7% based on dividing harvest by the multiple-census abundance estimate, and 18.7% based on dividing harvest by the single-census creel survey abundance estimate (Table 5).

For smallmouth bass, we estimated catch-at-age for 1,049 fish of all sexes (Table 9). We used ages 5 and older in the catch-curve analyses to represent the legal-size smallmouth bass population (Figure 5). We chose age 5 as the youngest age because: 1) the average length-at-age 5 was 14.1 inches, so likely most age-4 fish were legal-size at the beginning of fishing season; and 2) relative abundance of fish younger than age 5 did not appear to be represented in proportion to their expected abundance (Figure 5; Table 9). The catch-curve regression for smallmouth bass was significant ($P < 0.05$; Figure 5), and resulted in a total instantaneous mortality rate of 0.280 and an annual mortality rate of 24%.

Anglers returned a total of 38 tags (27 reward and 11 nonreward) from harvested smallmouth bass, and 56 tags (39 reward and 17 nonreward) from released smallmouth bass in Long Lake in the year following tagging. The creel clerk observed one tagged fish (nonreward) in the possession of an angler that was not subsequently reported to the central office. The reward tag return estimate of annual exploitation of smallmouth bass was 7.1%. Anglers reported reward tags at a higher rate than nonreward tags (16.6% versus 10.2%), 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 59.2%. Based on all tagged smallmouth bass known to be caught, the reported release rate was 58.9%. The estimated exploitation rate for smallmouth bass was 14.7% based on dividing harvest by the multiple-census abundance estimate, and 14.0% based on dividing harvest by the single-census creel survey abundance estimate (Table 5).

Recruitment.–For walleye in Long Lake, variability in year-class strength [based on the amount of variation explained by the age variable (R^2)] was 0.89 (Figure 3). We did not find any relationships between climatological variables and walleye year-class strength in Long Lake, but water temperature and water quality data specific to the lake are lacking. For northern pike and smallmouth bass, the amount of variation explained by the age variable (R^2) was 0.90 and 0.85, respectively, and there were no relationships between climatological variables and year-class strength.

Movement.–Based on recaptures during the spring survey, there was no movement of walleye, northern pike, or smallmouth bass between Long Lake and Grand Lake, via Lake Huron. Additionally, there was no movement detected out of Long Lake based on angler tag returns.

Angler Survey

Summer.–The clerk interviewed 1,153 boating anglers during the summer 2004 survey on Long Lake. Most interviews (99%) were roving (incomplete-fishing trip). Anglers fished an estimated 29,950 hours and made 17,114 trips (Table 10). The total harvest of 5,673 fish consisted of six different species. Yellow perch were most numerous, with an estimated harvest of 3,530 fish. Anglers harvested 257 walleyes and reported releasing 140 walleyes (35% of total catch). Anglers harvested 143 northern pike, and reported releasing 602 (81% of total catch). Anglers harvested 1,696 smallmouth bass and released 5,745 smallmouth bass (77% of total catch). Size composition of the released fish was not evaluated.

Winter.–The clerk interviewed 31 open ice anglers and 186 shanty anglers during the winter portion of the angler survey. Most open ice (100%) and shanty (95%) interviews were roving type. Open ice and shanty anglers fished 4,944 hours. We were not able to estimate the number of trips during the winter period on Long Lake (Table 11). A total of 1,331 fish were harvested, and yellow perch were most numerous, with an estimated harvest of 1,257 fish. Anglers released 2,197 yellow perch (64% of total catch). Anglers also harvested 48 walleyes and 25 northern pike, and reported releasing 4 walleyes (8% of total catch), 45 northern pike (64% of total catch), and 56 smallmouth bass (100% of catch).

Annual totals.–In the annual period from April 24 through October 13, 2004 and December 17, 2004 through March 26, 2005, anglers fished 34,894 hours and made a minimum of 17,114 trips to Long Lake (Table 12). Of the total annual fishing effort, 86% occurred in the open-water summer period and 14% occurred during ice-cover winter period.

The total annual harvest was 7,004 fish. The estimated total annual harvest of yellow perch was 4,787, making up 68% of the total harvest. The estimated total annual harvest of walleye was 305, making up 4% of the total harvest. The only other species harvested were northern pike, smallmouth bass, bluegill, and largemouth bass at 168, 1,696, 20, and 5, respectively.

Yellow perch were the predominant species caught (harvested + released) at 16,013, with a resulting catch per hour of 0.46. The total catch of walleye was 449, with a catch rate of 0.013. Walleye catch peaked in July and September, and the highest catch rate was in the September–October period (0.024/h). Anglers released 32% of all walleyes caught. Estimated total annual catch of northern pike was 815, with a resulting catch rate of 0.023. Anglers released 79% of northern pike caught. Estimated total annual catch of smallmouth bass was 7,497, with a resulting catch rate of 0.215. Smallmouth bass catch peaked in July, but was rather consistent throughout the summer. It should be noted that catch rates are calculated with general effort, not targeted effort, and are therefore not necessarily indicative of the rate that an angler targeting one species may have experienced. 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.

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 one walleye tag return was reported from December, prior to the start of the winter creel survey. Thus, the total annual walleye harvest was actually about 2.2% higher than our direct survey estimate of 312 walleyes. No northern pike or smallmouth bass tag returns were reportedly caught during the nonsurveyed months (Table 13). The majority of April was not surveyed because walleye, northern pike, and smallmouth bass seasons are closed.

Six species that we captured during spring netting operations did not appear in the angler harvest were black bullhead, black crappie, common carp, rainbow trout, rock bass, and white sucker. One species (bowfin) was caught by anglers but was not present in our spring survey.

Discussion

Fish Community

Fish community surveys and observations are noted for Long Lake dating back to the 1920s. Field investigations in 1925 and 1926 found a fish community similar to what is found in Long Lake today. Bluegills were noted as rare, while some sunfish (pumpkinseeds) were present. Rock bass, northern pike, walleyes, and yellow perch were common. Interestingly, reports of lake whitefish spearing were noted. A fish community survey in 1957 utilizing gill nets noted the common presence of smallmouth bass, northern pike, and yellow perch. The 1966 fish community survey by the MDOC utilized gill nets and night electrofishing, and found that walleyes, smallmouth bass, yellow perch, white sucker, pumpkinseed, and rock bass were common. A more intensive fish community survey was made by the MDNR in late spring of 1982, which consisted of 33 experimental gill-net lifts and 122 trap-net lifts. The fish community was rated as having excellent sizes and numbers of yellow perch, walleye, and smallmouth bass, though northern pike were less abundant. Finally, a fisheries survey conducted in May of 2000 consisted of 6 large-mesh fyke-net lifts, 17 large-mesh trap-net lifts, and 13 experimental gill-net lifts. Results indicated that Long Lake continued to produce quality fish populations exhibiting good size distributions. Overall, the fish community of Long Lake has displayed consistent species composition over the last eighty years.

In our spring 2004 survey, we likely caught more large, mature fish of several species than would normally be caught in surveys that have historically been conducted later in spring or summer. This includes spring spawners such as walleyes, northern pike, white sucker, and smallmouth bass. Additionally, because of the mesh-size bias, smaller fish were not represented in our sample in proportion to their true abundance in the lake. This includes juveniles of all species as well as entire populations of smaller fishes known to exist in Long Lake (various species of minnows). For example, eighteen species of fish have been collected or observed in Long Lake in other surveys that were not collected in the spring survey of 2004 (see Appendix).

As part of the Large Lakes Program, the MDNR also surveyed Grand Lake (Hanchin 2011) using methods and gear similar to those employed on Long Lake. Thus, it should be reasonable to compare fish community composition indices for Long Lake to Grand Lake.

The fish community of Long Lake was similar to nearby Grand Lake, which had 28% piscivores, 34% planktivores-insectivores, and 38% benthivores. The similarities in fish community composition are a result of similarities in lake morphology and habitat between the two lakes. Additionally, the recent (up to the current surveys) management history on both lakes has not included fish stocking. Among other lakes surveyed as part of the Large Lakes Program, the relative proportion of feeding guilds in Long Lake was also similar to that of Crooked and Pickerel lakes, which were surveyed in 2001 (Hanchin et al. 2005c). Crooked and Pickerel lakes had 24% piscivores, 49% pelagic planktivores-insectivores, and 27% benthivores.

The size structure of walleyes in our spring survey (86% legal size) was above the average of legal-size walleyes (69%) in spring surveys for 14 populations surveyed under the Large Lakes Program. In spring surveys of Long Lake completed in 1982 and 2000, the percentage of legal-size walleyes was 77 and 69, respectively. Based on past surveys and the current survey, walleyes in Long Lake rarely attain lengths much greater than 25 inches.

The size structure of northern pike in our spring survey (35% legal size) was near the average (28%) of legal-size northern pike in spring surveys for thirteen populations surveyed under the Large Lakes Program. While we did not collect a large number of northern pike, the number of large (≥36 inch) fish was notable, and northern pike in Long Lake have the potential to reach trophy size. Size structure was similar in 1982 (39% legal size) and 2000 (29% legal size), and though no large (≥36 inch) northern pike were collected in those surveys, the sample sizes were small (less than 50 fish).

The size structure of smallmouth bass in our spring survey (66% legal size) was similar to the average percentage (65%) of legal-size smallmouth bass in spring surveys for twelve populations surveyed under the Large Lakes Program. Size structure from catch in trap and fyke nets was much lower in 1982 (17% legal size) and 2000 (25% legal size). Currently, smallmouth bass in Long Lake are likely to attain lengths of 18 inches and have the potential to reach 20 inches.

Male walleyes outnumbered females in our survey when all sizes, or when legal-size fish were considered. This is consistent with spring surveys of walleye in other lakes in Michigan and elsewhere, and is likely due to males maturing at earlier sizes and ages than females and to males having a longer presence on spawning grounds than females (Carlander 1997). The male : female ratio (2.6) that we observed was below the average (3.7) that we have observed in fourteen large lakes surveyed to date.

Contrary to walleyes, female northern pike outnumbered males in Long Lake, both when all sizes were considered (male : female = 0.9:1), and when legal fish were considered (0.3:1). In most other spring samples from large lakes, males make up the largest proportion of adult northern pike, but females make up the largest proportion of legal-size northern pike. The male to female sex ratio for adult northern pike (0.9) was just below the average (1.2) that we have observed in thirteen lakes surveyed in the Large Lakes Program. For northern pike from other lakes, males dominated sex composition in spawning-season samples, but not at other times of the year (Priegel and Krohn 1975; Bregazzi and Kennedy 1980).

Walleye, Northern Pike, and Smallmouth Bass

Abundance.–We were successful in obtaining both multiple-census and single-census estimates of walleye abundance (Table 5). For the multiple-census estimate, the minimum number of recaptures was obtained, and the estimate was considered reliable based on the CV. However, some conditions for an unbiased estimate may have been violated (see later discussion). For the single-census estimate, we had sufficient numbers of fish marked, but not enough observed for marks to achieve an ideal level of precision. Assuming that the legal walleye population was approximately 4,000 fish (single-census estimate), and based on tagging 643 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 335 fish (Robson and Regier 1964). Our corrected recapture sample of 33 fish was well short of this recommendation. Thus, even though we did not achieve an ideal level of precision, the CV was adequate for a reliable estimate.

The multiple-census estimate for walleye was lower than the single-census estimate for both legal-size fish and adult fish (Table 5), which is consistent with results from other large lakes where the multiple-census estimates have been lower than the single-census estimates (Clark et al. 2004, Hanchin et al 2005b). However, in Long Lake the differences between abundance estimates were not as great. In the present study, 95% confidence limits of the two estimates overlapped; precision was higher for the multiple-census estimates (Table 5).

Our estimates of walleye abundance were not comparable (up to 74% lower) to the a priori Michigan model estimates; thus, we would expect the walleye population in Long Lake to have below average abundance. Accordingly, the population density of walleyes in Long Lake was below average compared to other lakes in Michigan. Using the modern acreage of 5,342, our single-census estimate for 15-inch-and-larger walleyes in Long Lake was 0.7 per acre. Density of legal-size walleyes estimated recently for fourteen large lakes in Michigan has averaged 2.0 fish per acre (median = 1.8), and has ranged from 0.4 to 4.6 fish per acre (MDNR, unpublished data). Density in nearby Grand Lake was similar at 0.6 fish per acre (Hanchin 2011). Population density of adult walleyes from our single-census estimate was also 0.7 fish per acre. Although largely anecdotal, MDNR biologists estimated an annual run of 4,000–8,000 walleyes in Shuberts Creek, a tributary to Long Lake in the early 1970s. At the time, there were concerns from the lake association regarding illegal harvest and stranding of spawning fish in various tributaries to Long Lake, including Shuberts, Clinton, and Mindack creeks. Thus, if the spawning runs in these creeks were approximately what the biologists estimated, the density of walleye in Long Lake must have been much higher in the early 1970s. Adult walleye abundance has averaged 3.3 fish per acre (median = 2.5) in fourteen large lakes surveyed thus far as part of the Large Lakes Program. Nate et al. (2000) reported an average density of 2.2 adult walleyes per acre for 131 Wisconsin lakes having natural reproduction.

We had mixed success in obtaining abundance estimates for northern pike (Table 5). For the multiple-census estimates, the minimum number of recaptures was obtained, and the estimates were considered reliable based on the CVs. Although the single-census estimates were comparable to the multiple-census, the CVs were greater than the maximum set for reliable estimates. Additionally, based on the number of fish marked, we did not observe enough fish in the recapture sample to achieve an ideal level of precision in the single-census estimates. Assuming that the legal northern pike population was approximately 600 fish, and based on tagging 119 fish, the recommended recapture sample in management studies (α = 0.05, *P* = 0.25; where *P* denotes the level of accuracy, and 1-α the level of precision) is 192 fish (Robson and Regier 1964). Our corrected recapture sample of 14 fish was well short of this recommendation.

Given that our single-census estimates for northern pike abundance were not reliable, we must use the multiple census estimates. Also, given the methodological biases known about multiple-census estimates (Pierce 1997), the multiple-census estimates were considered minimums, with the true abundances likely higher. Despite some uncertainty about the abundance of northern pike in Long Lake, the population density of legal northern pike is about average relative to other lakes in Michigan and elsewhere. Our multiple-census estimates of legal-size northern pike converted to a density of 0.1 fish per acre, which is identical to the average estimated recently for twelve large lakes in Michigan (range 0.01 to 0.5 fish per acre). Similarly, the density of adult northern pike is about average relative to other lakes in Michigan. While our density of adult northern pike (0.4 fish per acre) is below the average (1.0 fish per acre) for twelve large lakes in Michigan, it is similar to the median density (0.6), and we consider our estimate to be a minimum.

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 (<740 acres) Minnesota lakes. Their estimates of density ranged from 4.5 to 22.3 fish per acre for fish age 2 and older. Our estimates of numbers of adult northern pike in Long Lake are also for fish age 2 and older, and should be comparable. The lower density we observed in Long Lake may be due to the larger size of the lake, relative to the small Minnesota lakes that Pierce et al. (1995) surveyed, though limited spawning habitat could also be a factor.

We were successful in obtaining abundance estimates for smallmouth bass, and in fact, marked more of them than either walleyes or northern pike (Table 5). For the multiple-census estimate, the minimum number of recaptures was obtained, and the estimate was considered reliable based on the CV. For the single-census estimate, we had sufficient numbers of fish marked, but not enough observed for marks to achieve an ideal level of precision. Assuming that the legal smallmouth bass population was approximately 10,000 fish, and based on tagging 673 fish, the recommended recapture sample (α = 0.05, P = 0.25; where P denotes the level of accuracy, and 1-α the level of precision) is 883 fish (Robson and Regier 1964). Our corrected recapture sample of 139 fish was well short of this recommendation, though the CV was adequate for a reliable estimate.

The multiple- and single-census estimates for smallmouth bass were almost identical (Table 5), and each estimates lies within the other's confidence interval. Precision was also similar between the estimates. Our single-census estimate converts to a density of 2.0 smallmouth bass (≥14 inch) per acre, which appears rather high for a large lake. Bryant and Smith (1988) reported an abundance estimate for adult smallmouth bass in the Lake St. Clair - Detroit River system, which corresponds with a lake-wide density of about 3.5 fish per acre. Marinac-Sanders and Coble (1981) reported a density of 3.5 fish per acre for smallmouth bass larger than 9 inches in an 845-acre northern Wisconsin lake, while Clady (1975) estimated adult smallmouth bass density at 3.6, 13.4, and 25.1 fish per acre in three small (25–75 acre) western Upper Peninsula lakes. Engel et al. (1999) reported high densities, with an average density of 16.2 fish per acre for smallmouth bass ages 3–8 (approximately ≥8–9 inches) in a Wisconsin lake, while Newman and Hoff (2000) reported lower density [0.3 smallmouth bass (>16.0 inch)] in Palette Lake, Wisconsin. In four Michigan lakes surveyed under the Large Lakes Program, legal smallmouth bass density has been 1.0, 0.1, 0.1, and 0.5 fish per acre (Hanchin et al. 2007a, Hanchin and Kramer 2007, 2008a, Hanchin 2011). Thus, our density for Long Lake represents the highest density of 14-inch smallmouth bass observed in large Michigan lakes.

One assumption of the multiple-census method for estimating abundance that may have been 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 may not have sampled all spawning congregations in this large lake. An alternative explanation is that fishing effort was not randomly distributed over the population being sampled (Ricker 1975). As fish moved off the spawning grounds and were excluded from our sampling gear, this assumption may have been violated. In contrast to the multiple-census method, the single-census estimate from the creel survey is more likely to be accurate because it allowed sufficient time for marked fish to fully mix with unmarked fish. Additionally, for the single-census estimate it is not assumed that all spawning congregations were sampled in the initial tagging operation.

Pierce (1997) found that their multiple-census methods severely underestimated abundance of northern pike. He compared multiple-census estimates of northern pike abundance made with a single gear type (trap nets) to single-census estimates made with two gear types (marking with trap nets and recapturing several weeks later with experimental gill nets). He found that multiple-census estimates averaged 39% lower than single-census estimates. Our multiple-census estimates were 23–24% lower for walleye. Pierce (1997) concluded that 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.

Growth.–Agreement among readers for aging walleye spines (76%) was above average when compared to other studies. The average agreement between the first two readers of walleye spines from 18 large lakes in Michigan was 59%. Reader agreement of walleye spines from other studies outside of Michigan (Isermann et al. 2003; Kocovsky and Carline 2000) were 55 to 63% between the initial two readers of walleye spines.

Mean lengths at age for walleye from our survey were similar to those from previous surveys of Long Lake, with the mean growth index being within the bounds of plus or minus 1.0 inches for all surveys (Table 14). Schneider et al. (2000a) suggests that growth indices in the range of plus or minus 1.0 inches are satisfactory for game fish, so recent walleye growth in Long Lake has been satisfactory. Walleye mean lengths at age in 2004 were higher than the State of Michigan average for ages 1 through 4, while mean lengths of fish older than 4 years were consistently lower than the State average (Table 14). However, this difference at older ages may be attributable to differences in aging techniques, and thus should be interpreted with caution. Walleyes appeared to grow slightly better in Long Lake than in Grand and Hubbard lakes (Table 14), though similar to South Manistique, Black, and Mullett lakes. The typical walleye observed in Long Lake reached legal size in its third year of life.

The values calculated for L_∞ provide some insight into the growth potential of individual fish in a population. While walleyes in Long Lake may grow well initially, the L_∞ value for all walleyes (22 inch) suggests that most walleyes will never reach trophy size. For comparison, the average L_∞ for walleyes in other large lakes in Michigan (N = 19) is 24 inches.

Reader agreement for aging northern pike fin rays (80%) was above average when compared to other lakes. The average agreement between the first two readers of northern pike fin rays from 17 large lakes in Michigan is 73%. Mean lengths at age for northern pike from our survey were, for the most part, similar to those from previous surveys of Long Lake (Table 15). In 1982 and 2000, the mean growth indices were +0.6 and +2.1 inches, respectively (Table 15). Based on the mean growth index, northern pike growth in Long Lake is rather good. Female pike typically attain legal size (24 inch) at age 3, while males attain this size at either age 4 or 5. As with walleye, state averages for northern pike were based entirely on scale aging, which probably overestimated mean lengths for older ages. The length at infinity (L_∞) value (37 inch) for all northern pike suggest that growth potential is about average for this species; the average and median L_∞ for northern pike in other large lakes in Michigan (N = 18) is 37 inches.

Our reader agreement for smallmouth bass was high (72%), though there are few other studies for comparison. Reader agreement (first two reads) in South and Big Manistique lakes was 58% and 64%, respectively, and was 79% in Grand Lake. Mean lengths at age for smallmouth bass were slightly larger than previous surveys of the lake, but were lower than other lakes in Michigan (Table 16). In surveys of Long Lake done in 1982 and 2000, the mean growth indices for smallmouth bass were -1.3 and -1.1, respectively. Overall, the mean growth index (-0.3) for smallmouth bass suggests that growth is satisfactory. The length infinity (L_∞) value (18.9 inches) for smallmouth bass suggests that growth potential is about average in Long Lake. The (L_∞) values for smallmouth bass in Grand, South Manistique, and Big Manistique lakes, also surveyed recently under Large Lakes Program protocols, were 19.3, 18.9 and 19.1 inches, respectively.

Mortality.–Total mortality of walleyes in Long Lake was higher than average, and small adult walleyes had relatively low abundance. While ages 3 or 4 are usually the most abundant in spring net catches, peak age groups in Long Lake were 6 and 7. This could be a result of higher age of maturity, poor year classes, or high mortality of younger age groups. A higher age at maturity does not seem likely given the satisfactory growth of walleyes in Long Lake. Rather, poor recruitment seems a more likely contributor to the relatively low abundance of younger age groups, and there is some evidence of that. The 1999 and 2000 year classes, which were relatively low in Long Lake (Table 9), were also relatively low in nearby Grand Lake (Hanchin 2011). Overall, thirteen year classes of walleye were represented (Table 9). This is at the lower range observed in spawning walleye populations in northern Michigan, though greater than Schneider's (Schneider et al. 2007) suggestion that healthy walleye populations have ten or more age groups.

Compared to total mortality estimates for walleye from other lakes in Michigan, our estimate of 57% is higher than the average (41%) from populations (N = 18) surveyed as part of the Large Lakes Program in Michigan, which have ranged from 24 to 57%. It is, in fact, the highest total annual mortality that we have observed thus far in the Large Lakes Program. Schneider (1978) summarized available estimates of total annual mortality for adult walleyes in Michigan and from lakes throughout Midwestern North America. Michigan estimates ranged from 20% in Lake Gogebic to 65% in the bays de Noc, Lake Michigan. North American estimates ranged from 31% in Escanaba Lake, Wisconsin to 70% in Red Lakes, Minnesota. Colby et al. (1979) summarized total mortality rates for walleye from a number of lakes across North America. These estimates ranged from 13 to 84% for fish age 2 and older, with the majority of lakes between 35% and 65%. In nearby Grand Lake, the annual mortality rate for all walleyes in 2004 was 48%, which was also considered relatively high.

Our three estimates of annual exploitation rate of walleye were rather similar; 8.6% from tag returns, 10.4% using harvest divided by the multiple-census abundance estimate, and 7.8% using harvest divided by the single-census abundance estimate. We consider the tag return estimate to be a minimum because we did not adjust for tagging mortality, or nonreporting. If these problems occurred to any degree, we would have underestimated exploitation (Miranda et al. 2002). We did not estimate tagging mortality, and we used an average tag loss rate of 5%.

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 half of the tags and comparing return rates of reward to nonreward tags. We found that reporting rate for reward tags (8.1%) was only slightly higher than for nonreward tags (6.2%). 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 returned nearly 100% of reward tags (Hanchin et al. 2005a). The reporting rate of nonreward tags relative to reward tags (λ) of 73% was below the average (82%) that we have observed in other walleye populations surveyed in the Large Lakes Program. There was obviously nonreporting of nonreward tags, but we do not have a good estimate of the nonreporting rate for either reward or nonreward tags. We found that one of the three reward tags (33%) observed by the creel clerk was not subsequently reported by the angler. This indicates that nonreporting of reward tags also occurred to some degree, but the small number of tagged fish observed by the creel clerk was not a large enough sample from which to draw convincing conclusions. Additionally, anglers may have believed that the necessary information regarding the tagged fish was obtained during the interview, and thus, may not have turned in the tag on their own. Overall, we found evidence that reporting was good in that the number of tags voluntarily returned by anglers was 105% of the expected number of returns based on the ratio described previously in the **Methods** section.

Because we believe the exploitation estimate from tag returns is a minimum, the upper confidence limits from the estimates derived by dividing harvest by abundance may provide an upper limit on the exploitation estimate. Using the average of the two estimates, the true annual exploitation rate of walleye in Long Lake is likely in the 10–15% range. Given the total mortality estimate (57%), natural mortality contributes more to total mortality than fishing sources in Long Lake.

Compared to exploitation rates for walleye from other lakes in Michigan, our estimate for Long Lake is comparable to the average (15%) exploitation rate for walleye from Large Lake surveys (N = 19), which ranged from 4 to 35%. Slightly higher than our estimate, Serns and Kempinger (1981) reported average exploitation rates of 24.6% and 27.3% for male and female walleyes respectively in

Escanaba Lake, Wisconsin during 1958–79. In general, the range of exploitation for walleye across its range is large. For example, Schneider (1978) gave a range of 5 to 50% for lakes in Midwestern North America, and Carlander (1997) gave a range of 5 to 59% for a sample of lakes throughout North America. Additionally, exploitation can vary over time for a single waterbody; in western Lake Erie, estimates ranged from 7.5 to 38.8% from 1989 through 1998 (Thomas and Haas 2000).

In 2003, we added a question to the tag return form asking anglers if they released walleyes. The reported release rate (4.2%) for walleyes of legal size is higher than we have recently observed in other Large Lake surveys. The reported release rate for walleyes of legal size in South Manistique, Big Manistique, and Grand lakes were 0.8%, 0.4%, and 1.5%, respectively.

Total mortality of northern pike in Long Lake was average, with ten year classes represented. Total mortality rates from northern pike populations (*N* = 19) surveyed as part of the Large Lakes Program in Michigan have ranged from 31 to 69%, with an average of 50%. Diana (1983) estimated total annual mortality for two other lakes in Michigan, Murray Lake (24.4%) and Lac Vieux Desert (36.2%). Pierce et al. (1995) estimated total mortality for northern pike in seven small (<300 acres) lakes in Minnesota to be 36 to 65%. They also summarized total mortality for adult northern pike from a number of lakes across North America; estimates ranged from a low of 19% (Mosindy et al. 1987) to a high of 91% (Kempinger and Carline 1978), with the majority of lakes between 35% and 65%.

Our three estimates of annual exploitation rate of northern pike were rather similar; 14% from tag returns and 19% using harvest divided by both of the abundance estimates. We found that reporting rate for reward tags was actually lower than for nonreward tags, which was likely due to the small number of northern pike tagged and returned. Additionally, the expected number of returns, based on the ratio observed in the creel survey, was identical to the number voluntarily returned from harvested fish.

Because we believe the exploitation estimate from tag returns is a minimum, the true annual exploitation rate of northern pike in Long Lake is likely in the 15–20% range. Based on this range, and our estimate of total mortality (48%), it appears that natural mortality contributes more to total mortality than fishing sources in Long Lake.

Compared to exploitation rates for northern pike from other lakes in Michigan and elsewhere, our tag return estimate for Long Lake is about average. The mean exploitation rate for northern pike from Large Lake surveys to date is 17% 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 inches for seven lakes in Minnesota. Carlander (1969) gave a range of 14 to 41% for a sample of lakes throughout North America.

This was the first attempt to estimate the total mortality of smallmouth bass in Long Lake. Our estimate of 32% for legal-size fish appears to be within the range for Midwestern waters reported in the literature. Forney (1961) reported estimates of 52%, 58%, and 18% total mortality for smallmouth bass in Oneida Lake, New York, while Paragamian and Coble (1975) reported 55% mortality for smallmouth bass in the Red Cedar River, Wisconsin. Clady (1975) reported total mortality estimates of 33% for smallmouth bass in a Michigan lake with no fishing, and 41–65% in a lake subject to simulated exploitation of 13–16%. Bryant and Smith (1988) reported 58% total mortality of adult smallmouth bass from Anchor Bay of Lake St. Clair. Total mortality of smallmouth bass in Long Lake was similar to the few other populations we have observed thus far in the Large Lakes Program. Total mortalities in Lake Leelanau (Hanchin et al. 2007a), Big Manistique Lake (Hanchin and Kramer 2007), South Manistique Lake (Hanchin and Kramer 2008a), and Grand Lake (Hanchin 2011) were 39%, 25%, 45%, and 36%, respectively.

Our three estimates of the annual exploitation rate of smallmouth bass were somewhat different; 7% from tag returns, 15% using harvest divided by the multiple-census abundance estimate, and 14% using harvest divided by the single-census abundance estimate. As for walleye, we consider the tag return estimate to be a minimum. We did not make a true estimate of nonreporting, but the number of tags voluntarily returned by anglers exceeded (112%) the predicted number of returns based on the ratio described previously in the **Methods** section. If we use the exploitation estimate from tag returns as a minimum, and those estimates derived from harvest divided by abundance as a maximum, the likely range of exploitation is between 7% and 15%.

Between 1933 and 1942, the Michigan Department of Conservation (now MDNR) transplanted adult smallmouth bass to Long Lake from a commercial fishing operation in Lake Huron (Shetter 1942). In August of 1940, Shetter (1942) tagged 200 of these smallmouth bass, which averaged about 10 inches. From this sample, conclusions were made that about 25% of the transplanted fish were captured within the year by anglers. It is likely that the lower exploitation we observed in 2004 is a result of a higher release rate among today's "catch and release" bass anglers. In fact, the high reported release rate (59%) was higher than any values observed in the Large Lakes Program to date (Hanchin and Kramer 2007, 2008a; Hanchin 2011).

Compared to exploitation rates for smallmouth bass from other lakes in Michigan and elsewhere, our estimate for Long Lake appears to be average. Latta (1975) reported a range of 9 to 33% exploitation, with an average of 19%, for a sample of smallmouth bass populations throughout the Great Lakes region and the northeastern United States. In Oneida Lake, Forney (1972) reported 20% exploitation of adult smallmouth bass, while Paragamian and Coble (1975) reported 29% exploitation in the Red Cedar River of Wisconsin. In Michigan, Latta (1963) reported 22% exploitation of smallmouth bass near Waugoshance Point in Lake Michigan, and Bryant and Smith (1988) reported a rate of 13% for smallmouth bass in Lake St. Clair.

Recruitment.–Year-class strength of walleye 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 Long 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 walleye 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.

Walleyes in Long Lake were represented by 13 year classes (ages 1 through 13) in our samples. Variability in year-class strength was low (R^2 = 0.91; Figure 3) relative to other large lakes. In other Michigan walleye populations surveyed as part of the Large Lakes Program to date (N = 19), the R^2 has ranged from 0.50 to 0.98, with an average of 0.80. Given that walleyes were not stocked in any year corresponding with year classes we collected, it appears that natural reproduction occurs regularly in Long Lake. Accordingly, relatively strong walleye year classes have been detected recently in fall electrofishing surveys in years when no walleyes were stocked (MDNR, unpublished data). While natural reproduction of walleye is sufficient to maintain the current population, the fishery likely experiences low success resulting from poor year classes in some years.

Northern pike were represented by ten year classes (ages 1 through 10) in our samples. Variability in year-class strength was about average (R^2 = 0.90; Figure 4). In other Michigan northern pike populations surveyed as part of the Large Lakes Program (N = 16) the R^2 has ranged from 0.67 to 1.00, with an average of 0.89.

Smallmouth bass were represented by 12 year classes (ages 2 - 11, 13, and 14) in our samples. Variability in year-class strength appeared about average (R^2 = 0.85), though we have few lakes for comparison. In four lakes surveyed as part of the Large Lakes Program, the R^2 values were 0.91, 0.90, 0.61, and 0.89.

Movement.–The lack of fish movement detected was expected given the shallow water near the low-head dam on Long Lake, and the fact that the outlet of Long Lake is nearly dry for much of the year. The outlet of nearby Grand Lake is similarly dry most of the year. Thus, fish movement would likely only take place during the spring, when the outlets have adequate flow. Even during the spring, there is still a low probability of a fish successfully migrating downstream over three low-head dams in Long Lake Creek to Lake Huron. However, the downstream movement of smallmouth bass from Long Lake to Lake Huron was noted by Shetter (1942). Based on the smallmouth bass tagged in 1940, at least 1% of the tagged fish migrated out of Long Lake and into Lake Huron (Shetter 1942). Although we are uncertain which dams, if any, were present on Long Lake Creek in 1942, it appears that downstream movement of fish was possible then, and may be today. In other large lakes we have documented movement of smallmouth bass among connected lakes (Hanchin and Kramer 2007, 2008a).

Angler Survey

Summary.–The fishery of Long Lake is dominated by yellow perch and smallmouth bass, which comprised 93% of the total annual harvest. The open-water period accounted for 74% of the annual yellow perch harvest, and harvest was highest in September/October. Smallmouth bass were harvested primarily during the open-water period, and provided consistent catch rates (0.21–0.37 per hour) throughout the year. Walleye and northern pike contributed to the fishery of Long Lake, but to a much lesser extent than yellow perch and smallmouth bass. Walleyes were harvested throughout the year, but most readily from July through October. Catch rate for walleye was highest in September/October (0.02 per hour), and overall it was low. Considering the number of days in the summer (173) and winter (100) periods, the angling effort per day was much higher in the summer (173 angler hours per day) than in the winter period (49 angler hours per day). Overall, the fishery of Long Lake is not very diverse, especially in the winter when yellow perch, walleye, and northern pike were the only species harvested. A few other species provide angling opportunity throughout the year, though not to any large degree.

Historical comparisons.–The oldest harvest and effort estimates for Long Lake were reported by Laarman (1976). A special creel survey was conducted in 1936, a general creel survey, designed only to measure the success of anglers who were actually interviewed, was conducted from 1938 to 1964, and mail surveys were used to assess the fishery in 1970 and 1973. Most of the fish caught in 1936 were yellow perch, which comprised 86% of the winter catch, and 69% of the summer catch. Walleye comprised 4% of the total catch in the winter, and 3% in the summer, while northern pike comprised 10% of the winter catch, and 9% of the summer catch. Other species observed in low abundance were rock bass, pumpkinseed, bluegill, smallmouth bass, and largemouth bass. Perhaps the greatest difference between the fishery in 1936 and 2004 is the abundance of smallmouth bass in the current fishery. While anglers may not have targeted smallmouth bass as much as they do today, the abundance was likely lower in 1936.

Fishery data from the general creel survey (1938–64) suggest a slightly changing fishery. During this period, yellow perch comprised 69% of the total harvest in Long Lake, followed by northern pike (8%), smallmouth bass (7%), and walleye (6%). Various other species made up the remainder of the catch, with whitefish and cisco (lake herring) being some of the most interesting species. Based on the 1936 angler catch, the percentage of the total catch that was comprised of smallmouth bass appeared to have doubled over the period. Although it is difficult to draw conclusions based on a single-year survey (1936), the trend of increasing smallmouth bass abundance appears to have continued, as shown by the angler catch in 1970 and 1973. The estimated angler catch during 1970 was 72,040 yellow perch, 14,150 walleyes, and 10,640 bass, thus smallmouth bass comprised approximately 11% of the angler catch. Angler effort at Long Lake, estimated from mail surveys, was 33,340 days in 1970, and 26,910 days in 1973. Using current knowledge of the average number of trips per day (1.2 trip/day), and the average length of a trip (2.5 h/trip) from the 2004 angler survey, the 1970 and 1973 estimates equate to 100,020 and 80,730 hours of fishing effort, respectively. These estimates are much higher than our 2004–05 estimate of 34,894 total angler hours; thus, it appears that either effort has decreased, or these two methods are not directly comparable.

Comparison to other large lakes.–In addition to the historic creel survey data for Long Lake, comparisons with creel surveys from other large lakes can be useful. Thus far in the Large Lakes Program, we have surveyed 13 lakes which we will use for comparisons.

We estimated 34,894 angler hours occurred on Long Lake during the creel survey. This corresponds to 6.5 hours per acre, which is below the median and mean value for other large lakes in Michigan (Table 17). The harvest for Long Lake was 1.3 fish per acre, which is also low relative to other large lakes. Michigan lakes with a high harvest per acre generally have popular bluegill/sunfish fisheries that bolster the total harvest.

For walleye, our estimated annual harvest from Long Lake was 0.06 fish per acre, which is low relative to the average (0.52 per acre) and median (0.45 per acre) for nineteen lakes surveyed as part of the Large Lakes Program. It is tied with Grand Lake as the lowest observed in the Large Lakes Program. The highest value from other large lakes was 1.61 fish per acre for South Manistique Lake (Hanchin and Kramer 2008a). The average harvest of six other large Michigan lakes (>1,000 acres) reported by Lockwood (2000a) was 0.63 walleyes per acre, ranging from 0.09 for Brevoort Lake to 1.68 for Chicagon Lake. These Michigan lakes were subject to similar gears and fishing regulations, including a 15-inch-minimum size limit. The low harvest per acre of walleye in Long Lake is likely due to a combination of low lake productivity, low angler effort, and low walleye density.

For northern pike, our estimated annual harvest from Long Lake was 0.03 fish per acre. This was also below average compared to other waters in Michigan and elsewhere. The average harvest in fifteen other lakes sampled in the Large Lakes Program was 0.08 northern pike per acre, ranging from 0.003 in North Manistique Lake (Hanchin and Kramer 2008b) to 0.464 in Houghton Lake (Clark et al. 2004). The average harvest of seven other large Michigan lakes (>1,000 acres) reported by Lockwood (2000a) was 0.151 northern pike per acre, ranging from 0.002 per acre in Bond Falls Flowage to 0.654 per acre in Fletcher Pond. These Michigan lakes all were subject to similar gears and fishing regulations, including a 24-inch 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.

In contrast to walleye and northern pike, the smallmouth bass fishery in Long Lake is quite good. The total catch (harvest + release) in Long Lake was 7,497 fish, which exceeded the total annual catch of smallmouth bass in Lake Leelanau (5,792; Hanchin et al 2007a), Grand Lake (3,559; Hanchin 2011), Houghton Lake (3,049; Clark et al. 2004), Crooked and Pickerel lakes (1,300; Hanchin et al. 2005c), and Burt Lake (796; Hanchin et al. 2005b). Annual harvest of smallmouth bass in Long Lake was 0.32 per acre, which is above average compared to other waters in Michigan. The average harvest in other lakes surveyed in the Large Lakes Program (N = 13) was 0.11 smallmouth bass per acre, ranging from 0.007 in Burt Lake (Hanchin et al. 2005b) to 0.416 in the Cisco Chain (Hanchin et al. 2007b). The average harvest of seven other large Michigan lakes (>1,000 acres) reported by Lockwood (2000a) was 0.088 smallmouth bass per acre, ranging from 0.026 per acre in Brevoort Lake to 0.146 per acre in Elk Lake. The total catch (harvest + released) per hour of smallmouth bass in Long Lake was 0.21, which is the highest observed thus far in the Large Lakes Program. In other lakes (N = 13) the mean catch per hour was 0.06, with a range of 0.01 to 0.21. Thus, even with the biases resulting from calculating catch rates with general fishing effort, the smallmouth bass fishery in Long Lake appears to be high quality.

Yellow perch are another species that offers considerable fishing opportunity in Long Lake. The estimated annual harvest of yellow perch was 0.9 per acre. In comparison, harvest per acre of yellow perch was 3.4 for Burt Lake (Hanchin et al. 2005b), 2.5 in Houghton Lake (Clark et al 2004), 1.8 in Crooked and Pickerel lakes (Hanchin et al 2005c), and 1.6 in Grand Lake (Hanchin 2011). The associated harvest rate for yellow perch in Long Lake was 0.14 per hour, compared to 0.44 per hour for Burt Lake, 0.27 per hour for Grand Lake (Hanchin 2011), 0.11 per hour for Crooked and Pickerel lakes (Hanchin et al. 2005c), and 0.10 per hour for Houghton Lake (Clark et al. 2004). Although yellow perch anglers in Long Lake release many fish (that are presumably too small), the fishery compares fairly well with other large lakes that have well-known yellow perch fisheries.

Summary

Walleyes are the second most abundant large predator in Long Lake. However, the walleye fishery in 2004–05 was below-average with respect to other large lakes in Michigan. Long Lake contained an estimated 0.7 legal walleyes per acre and anglers harvested 0.06 per acre at a rate of 0.01 per hour fished. These are among the lowest values estimated recently for large lakes in Michigan. Anecdotal evidence suggests that the walleye population may have been larger in the past. The population does not appear to be limited by poor natural reproduction, but is rather maintaining an equilibrium corresponding with the productivity of the lake, and the abundance of other fish predators, particularly smallmouth bass. Additionally, the walleye population in 2004 was likely experiencing a low point as a result of some weak year classes. While, naturally-occurring low year classes are likely the cause of the relatively low abundance of young walleyes that we observed, we were surprised by the high estimate of total mortality. Given that angling mortality of walleyes was low in 2004, natural mortality was apparently a large source of mortality in the walleye population. We are unsure why natural mortality would be so high, but managers should be vigilant of potential illegal harvest during spawning runs in tributaries to Long Lake. Although the illegal harvest of spawning fish is largely anecdotal, it would not be represented in our estimates of fishing mortality, and thus would be mistakenly identified as natural mortality.

The estimates of legal and adult walleye abundance were much lower than the estimates made a priori with the Michigan regression equations, further evidence that walleye abundance is below average given the area of the lake. However, 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. If these models are used to estimate abundance for management purposes, the confidence intervals and uncertainty of the estimates should be recognized.

Northern pike had the lowest abundance of the three predator species targeted in this survey. The population in Long Lake has an average density of legal-size northern pike, but a low density of adult northern pike. Given the low density, the population has better than average growth. Only 0.03 northern pike per acre were harvested at a rate of 0.005 per hour. Both these figures are low compared to those in other large lakes. Total mortality is acceptable; thus, we must assume that while natural reproduction is relatively consistent, the total number of recruits produced is consistently low.

Contrary to the walleye and northern pike fisheries, the smallmouth bass fishery in Long Lake is exceptional. With a density of 2.0 smallmouth bass per acre, anglers harvested more smallmouth bass than walleye and northern pike combined. Anglers harvested 0.32 smallmouth bass per acre at a rate of 0.05 per hour, and caught 0.21 smallmouth bass per hour, which are above-average numbers for large lakes in northern Michigan. The catch-and-release component of the smallmouth bass fishery in Long Lake is considerable, with 59% of legal smallmouth bass being released after being caught. Population density of smallmouth bass is similar to other large, northern Michigan lakes, though there are few populations for comparison. Total mortality and growth rates are in acceptable ranges and natural reproduction appears consistent from year to year.

The number of fish harvested per acre in Long Lake was below average for other large lakes in Michigan, which is a result of relatively low fishing effort on a lake with low productivity. Long Lake is primarily a smallmouth bass and perch fishery, with less significant walleye and northern pike fisheries. The yellow perch fishery in Long Lake is rather good, but was still less productive (harvest of 0.9 per acre) than the average (3.3 per acre) and median (1.8 per acre) for thirteen large lakes surveyed recently.

Stocking does not appear to be necessary to maintain any of the fish populations or fishery in Long Lake even though both the walleye and northern pike populations are currently at low densities. It would appear that the predator population could tolerate augmentation given the relatively high abundance of prey such as yellow perch and white suckers; however, the only predator species with distinctly above-average growth is northern pike. Thus, augmenting the northern pike population would be the most biologically sound option, though the social acceptance of this action would need to be assessed. Additionally, the traditional method of operating a spawning marsh to augment northern pike populations is labor intensive, and not necessarily cost effective. If walleye stocking were considered as a management option, it should be kept at a level that will prevent potential harmful effects from density-dependent interactions such as increased competition for food or cannibalism. This is especially true given that even relatively small adult populations can produce large year classes under optimal environmental conditions.

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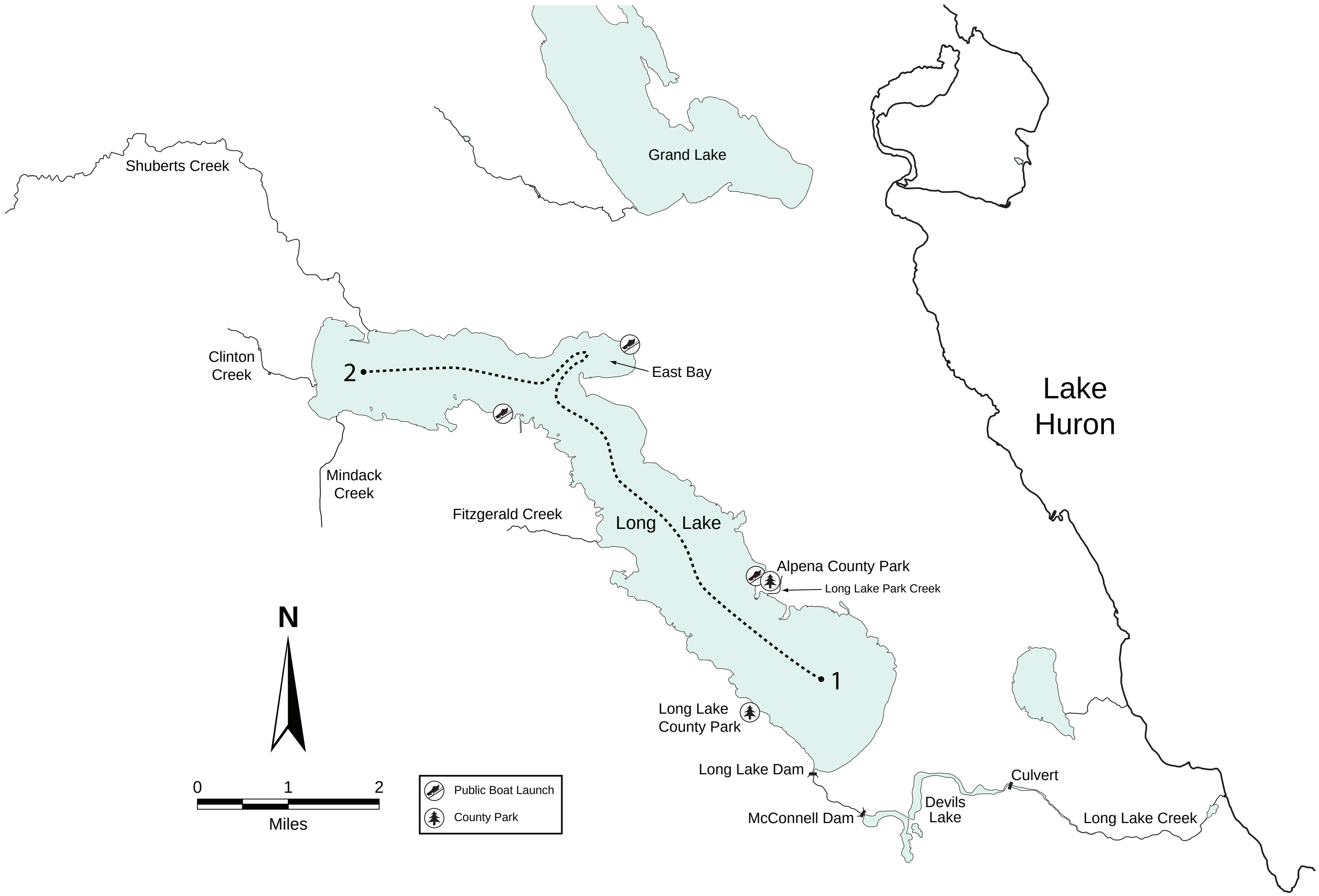

Figure 1.–Map of Long Lake, Presque Isle and Alpena counties, Michigan. Line represents the counting and interviewing path for the creel survey.

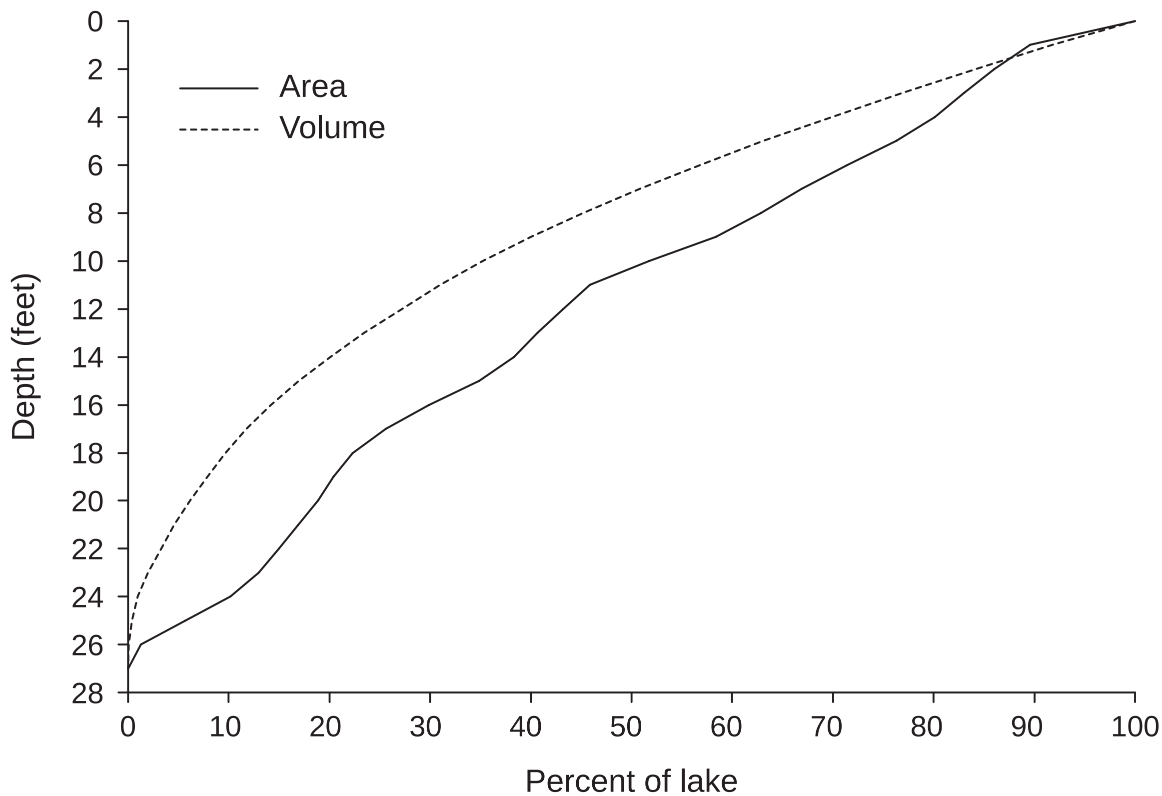

Figure 2.–Percent of lake surface area and volume equal to or greater than a given depth for Long Lake. Data taken from MDNR Digital Water Atlas (Breck 2004).

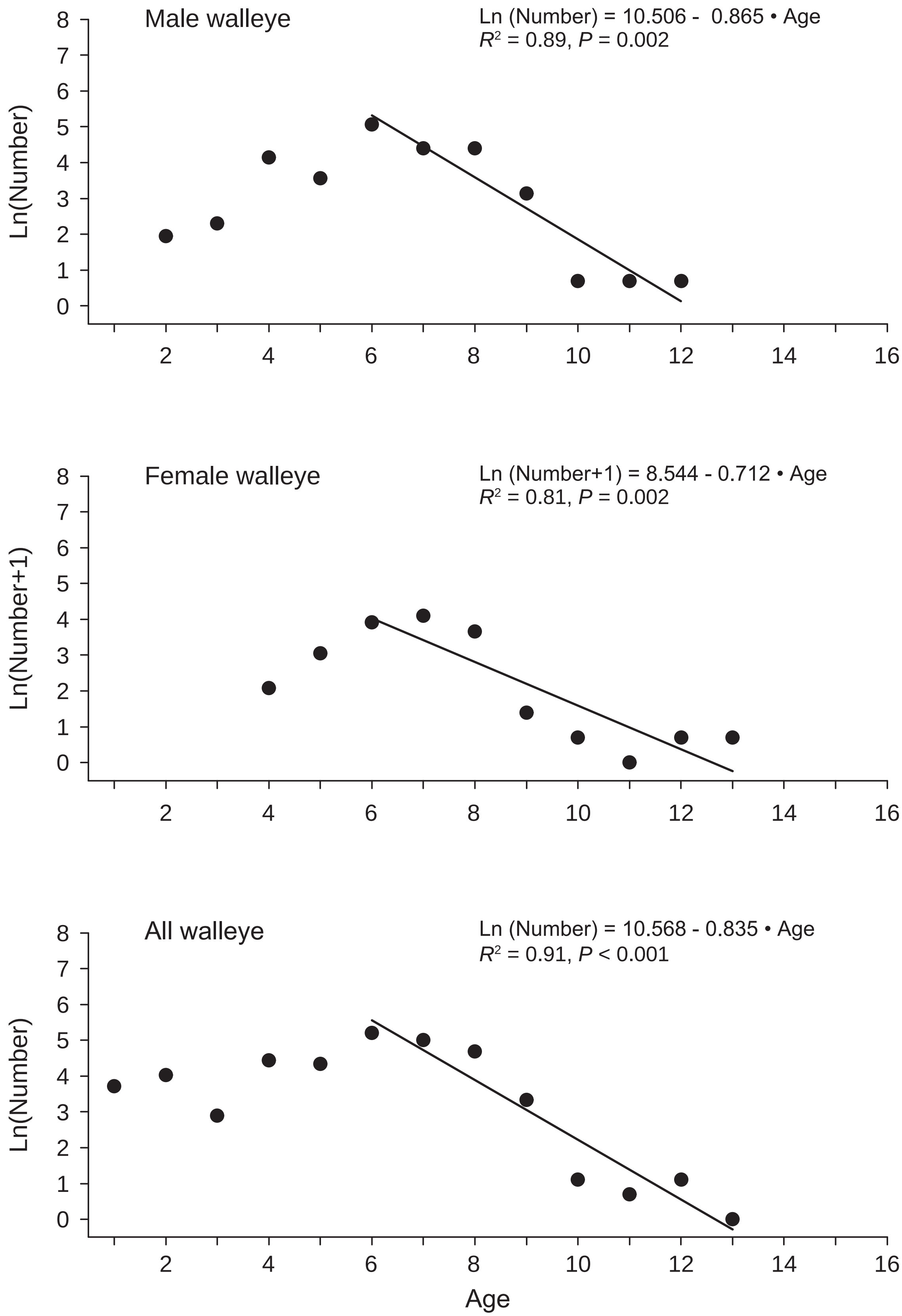

Figure 3.–Plots of observed ln(number) versus age for male, female, and all (including males, females, and unknown sex) walleye in Long Lake. Lines are plots of the regression equations shown.

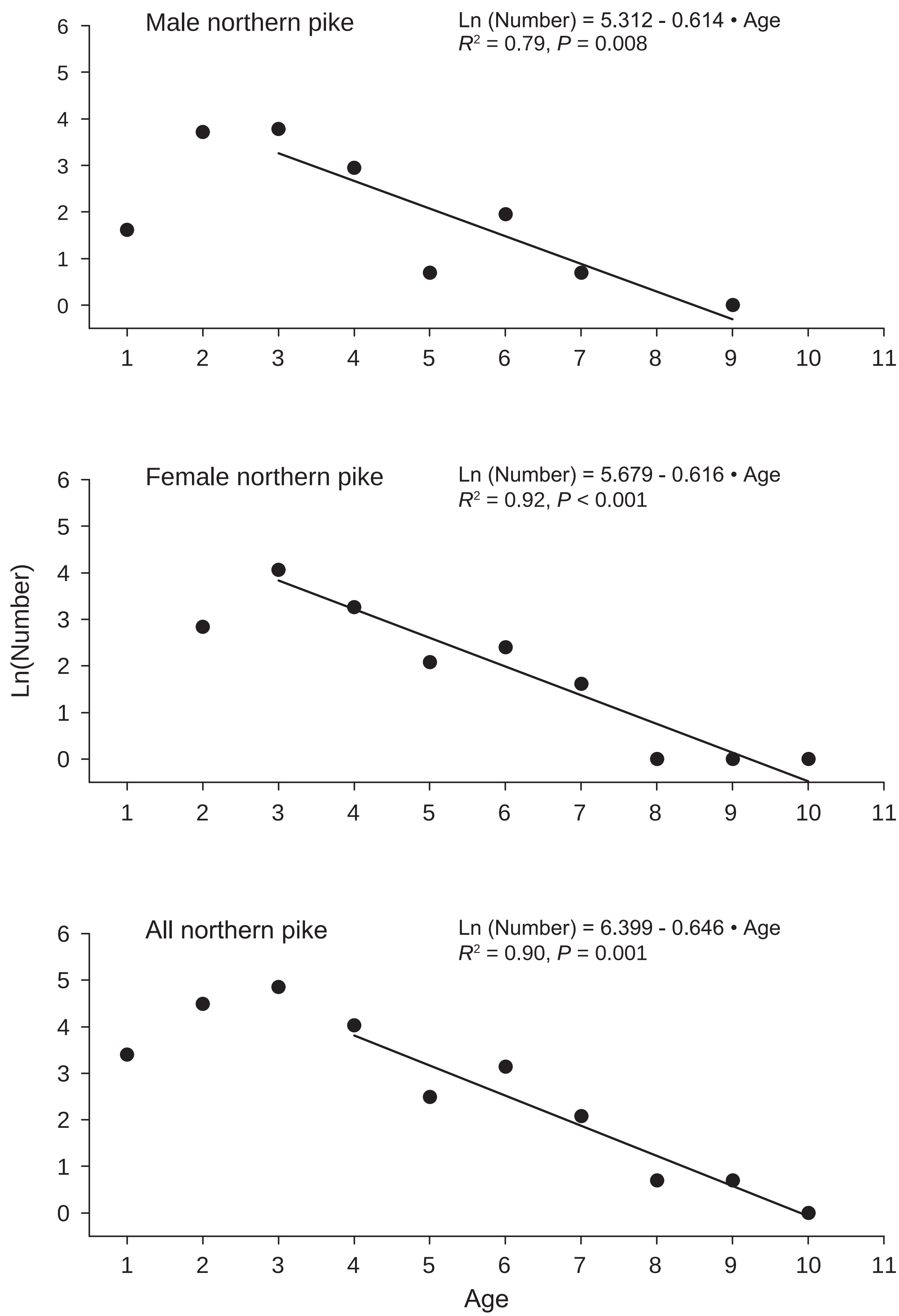

Figure 4.–Plots of observed ln(number) versus age for male, female, and all (including males, females, and unknown sex) northern pike in Long Lake. Lines are plots of the regression equations shown.

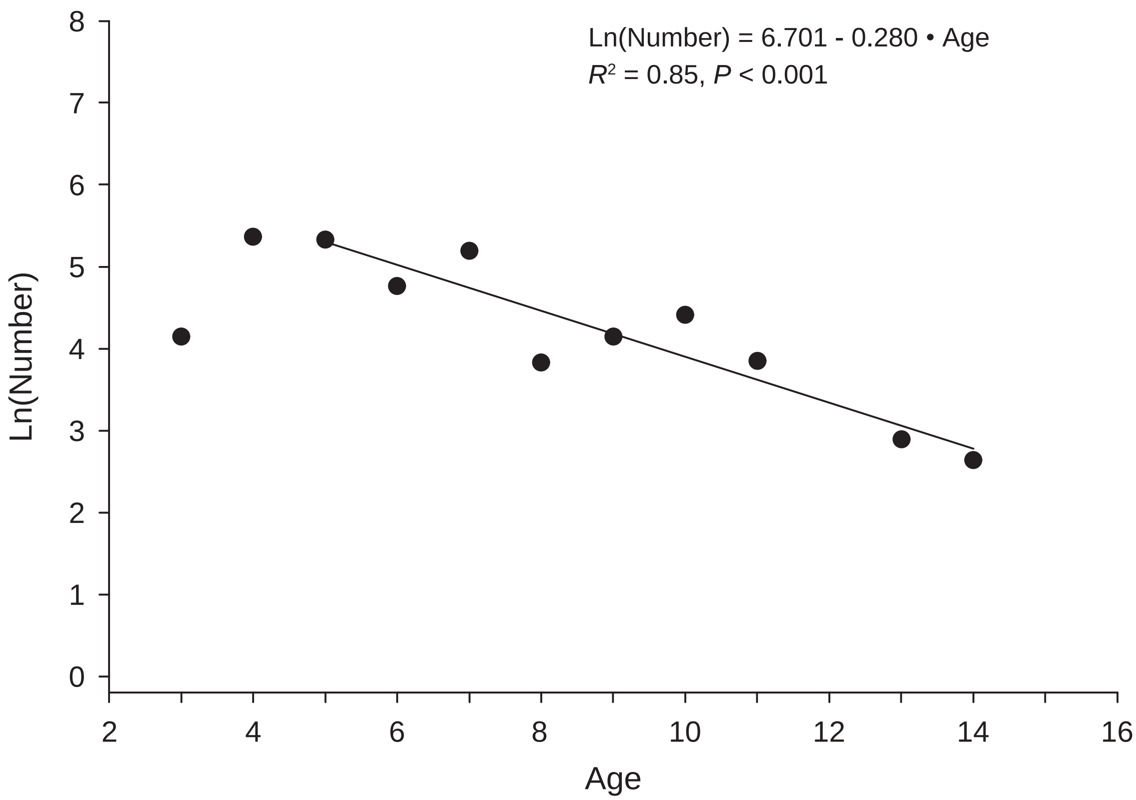

Figure 5.–Plots of observed ln(number) versus age for smallmouth bass in Long Lake. Line is plot of regression shown.

Table 1.–Number and size of fish stocked in Long Lake from 1905 through 2006.

Species	Dates[1]	Size	Number	Source
Lake trout	1910	Fry	24,000	State
Largemouth bass	1905–1914	Fry and fingerling	102,575	State
	1938–1944	Fingerling	25,250	State
	1980	Fingerling	2,500	Private
Bluegill	1934–1943	Fingerling	358,500	State
	1980	Fingerling	2,500	Private
Smallmouth bass	1933–1945	Fingerling and adult	28,510	State
Black crappie	1938	Yearling	180	State
Rock bass	1938	Yearling	200	State
Pumpkinseed	1938	Yearling	220	State
Yellow perch	1921	Fingerling	17,650	State
	1933–1943	Fingerling and adult	442,856	State
	1953	Adult	2,000	State
Northern pike	1964	Fingerling	2,000	State/private
	1976	Fingerling	4,800	State/private
	1977	Fingerling	15,000	State/private
	1978	Fingerling	20,000	State/private
	1979	Fingerling	31,800	State/private
	1980	Fingerling	300	State/private
	1981	Fingerling	20,000	State/private
	1982	Fingerling	200	State/private
	1983	Fingerling	25,000	State/private
	1984	Fingerling	20,000	State/private
	1985	Fingerling	15,000	State/private
Walleye	1910–1914	Fry	1,200,000	State
	1933–1940	Fry and fingerling	3,429,050	State
	2004[2]	Fall fingerling	3,900	State
	2004	Fall fingerling	12,350	Private
	2005[2]	Spring fingerling	57,000	State
	2005	Fall fingerling	2,070	Private
	2006[2]	Fry	1,550,000	State
	2006	Fall fingerling	2,781	Private

Table 2.–Survey periods, sampling shifts, and expansion value "F" (number of fishing hours within a sample day) for the Long Lake angler survey, spring 2004 through winter 2005.

Survey period	Sample shifts (h)		F
April 24–May 31	0600–1430	1330–2200	16
June	0600–1430	1330–2200	16
July	0600–1430	1300–2130	16
August	0630–1500	1230–2100	15
September	0630–1500	1200–2030	14
October 1–13	0630–1500	1100–1930	13
December 17–January 31	0700–1530	1100–1930	13
February	0700–1530	1100–1930	13
March 1–26	0700–1530	1100–1930	13

Table 3.–Fish collected from Long Lake using a total sampling effort of 261 trap-net lifts, 228 fyke-net lifts, and one electrofishing run from April 7 to April 22, 2004.

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]
Rock bass	2,243	29.2	4.9	3.2	3.6–10.5	7.1	750
White sucker	1,840	24.0	2.2	4.9	8.7–21.8	16.9	375
Smallmouth bass	1,076	14.0	2.3	1.5	8.1–20.5	15.1	1,047
Walleye	837	10.9	1.9	1.0	7.3–27.1	17.1	750
Yellow perch	831	10.8	2.3	0.8	3.2–13.8	8.1	549
Northern pike	397	5.2	0.8	0.7	9.9–40.5	22.1	352
Brown bullhead	238	3.1	0.3	0.7	6.7–15.9	12.4	236
Pumpkinseed	80	1.0	0.1	0.2	3.3–8.4	6.4	80
Black bullhead	57	0.7	<0.1	0.2	6.7–15.1	10.7	57
Bluegill	57	0.7	0.1	0.1	3.8–8.9	6.0	56
Common carp	10	0.1	<0.1	<0.1	28.2–33.9	30.5	10
Rainbow trout	1	<0.1	<0.1	0.0	23.2–23.2	23.2	1
Black crappie	1	<0.1	<0.1	0.0	11.8–11.8	11.8	1
Largemouth bass	1	<0.1	<0.1	0.0	17.3–17.3	17.3	1

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

Table 4.–Number of fish per inch group caught and measured in spring netting on Long Lake, April 7 to 22, 2004.

Inch group	Species: Rock bass	White sucker	Smallmouth bass	Walleye	Yellow perch	Northern pike	Brown bullhead	Pumpkinseed	Black bullhead	Bluegill	Common carp	Rainbow trout	Black crappie	Largemouth bass
3	4	–	–	–	1	–	–	1	–	1	–	–	–	–
4	24	–	–	–	2	–	–	7	–	4	–	–	–	–
5	116	–	–	–	22	–	–	18	–	25	–	–	–	–
6	175	–	–	–	113	–	1	29	1	16	–	–	–	–
7	226	–	–	12	142	–	4	18	5	6	–	–	–	–
8	141	1	3	31	124	–	4	7	5	4	–	–	–	–
9	58	5	11	–	66	1	16	–	6	–	–	–	–	–
10	6	4	13	–	41	1	43	–	15	–	–	–	–	–
11	–	22	59	3	27	12	33	–	10	–	–	–	1	–
12	–	41	119	18	8	12	15	–	6	–	–	–	–	–
13	–	23	153	37	3	5	38	–	5	–	–	–	–	–
14	–	10	137	5	–	13	63	–	2	–	–	–	–	–
15	–	12	136	41	–	6	19	–	2	–	–	–	–	–
16	–	21	186	83	–	12	–	–	–	–	–	–	–	–
17	–	53	119	187	–	16	–	–	–	–	–	–	–	1
18	–	56	86	181	–	15	–	–	–	–	–	–	–	–
19	–	66	22	88	–	21	–	–	–	–	–	–	–	–
20	–	44	3	39	–	23	–	–	–	–	–	–	–	–
21	–	17	–	15	–	24	–	–	–	–	–	–	–	–
22	–	–	–	7	–	33	–	–	–	–	–	–	–	–
23	–	–	–	1	–	36	–	–	–	–	–	1	–	–
24	–	–	–	–	–	34	–	–	–	–	–	–	–	–
25	–	–	–	1	–	15	–	–	–	–	–	–	–	–
26	–	–	–	–	–	24	–	–	–	–	–	–	–	–
27	–	–	–	1	–	14	–	–	–	–	–	–	–	–
28	–	–	–	–	–	6	–	–	–	–	2	–	–	–
29	–	–	–	–	–	4	–	–	–	–	1	–	–	–
30	–	–	–	–	–	5	–	–	–	–	5	–	–	–
31	–	–	–	–	–	3	–	–	–	–	1	–	–	–
32	–	–	–	–	–	–	–	–	–	–	–	–	–	–
33	–	–	–	–	–	2	–	–	–	–	1	–	–	–
34	–	–	–	–	–	4	–	–	–	–	–	–	–	–
35	–	–	–	–	–	3	–	–	–	–	–	–	–	–
36	–	–	–	–	–	3	–	–	–	–	–	–	–	–
37	–	–	–	–	–	1	–	–	–	–	–	–	–	–
38	–	–	–	–	–	2	–	–	–	–	–	–	–	–
39	–	–	–	–	–	1	–	–	–	–	–	–	–	–
40	–	–	–	–	–	1	–	–	–	–	–	–	–	–
41	–	–	–	–	–	–	–	–	–	–	–	–	–	–
42	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total	750	375	1,047	750	549	352	236	80	57	56	10	1	1	1

Table 5.–Estimates of abundance, angler exploitation rates, and instantaneous fishing mortality rates for Long Lake walleye, northern pike, and smallmouth bass. Asymmetrical 95% confidence intervals for estimates are given in parentheses, where applicable.

Parameter	Walleye	Northern pike	Smallmouth bass
Number tagged	643	119	673
Total tag returns	47	22	94
Number of legal-size[a] fish			
Multiple-census estimate	2,760 (2,243–3,587)	599 (447–907)	9,940 (6,117–26,508)
Single-census estimate	3,649 (1,684–7,299)	600 (219–1,449)	10,469 (5,621–21,154)
Michigan model prediction[b]	8,241 (1,733–39,185)	NA	NA
Number of adult[c] fish			
Multiple-census method	2,842 (2,288–3,751)	1,887 (1,416–2,826)	–
Single-census estimate	3,695 (1,705–7,389)	1,348 (492–3,255)	–
Michigan model prediction[d]	11,114 (2,613–47,273)	NA	NA
Annual exploitation rates			
Based on reward tag returns	8.6%	14.2%[e]	7.1%
Based on harvest/abundance[f]	10.4% (4.7%–16.0%)	18.7% (4.7%–32.7%)	14.7% (5.0%–24.5%)
Based on harvest/abundance[g]	7.8% (1.2%–14.5%)	18.7% (0%–39.6%)	14.0% (4.3%–23.7%)
Annual mortality rates	57%	48%	24%

[a] Walleyes greater than or equal to 15 in, northern pike greater than or equal to 24 in, smallmouth bass greater than or equal to 14 in.
[b] Michigan model prediction of legal walleye abundance based on lake area (N=21 lakes).
[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 lakes).
[e] Based on reward and nonreward tag returns.
[f] Multiple-census estimate of legal-size fish abundance.
[g] Single-census estimate of legal-size fish abundance.

Table 6.–Weighted mean lengths and sample sizes by age and sex for walleyes collected from Long Lake, April 7 to 22, 2004. Standard deviation is in parentheses.

	Mean length			Number aged		
Age	Males	Females	All fish	Males	Females	All fish
1	–	–	8.1 (0.4)	–	–	22
2	13.8 (0.2)	–	12.9 (1.0)	3	–	47
3	15.3 (0.0)	–	14.6 (1.0)	5	–	12
4	16.1 (0.3)	17.1 (0.2)	16.4 (0.6)	19	4	24
5	16.5 (0.6)	18.0 (0.7)	17.3 (1.0)	8	9	17
6	17.7 (0.6)	19.2 (0.9)	18.0 (0.9)	20	21	42
7	18.0 (0.7)	19.3 (1.0)	18.5 (1.0)	14	26	41
8	18.3 (0.7)	20.4 (1.3)	19.1 (1.4)	15	22	39
9	18.8 (0.9)	19.7 (1.6)	19.1 (0.9)	8	2	10
10	20.6 (0.0)	22.2 (–)	21.1 (0.9)	1	1	2
11	20.7 (0.0)	–	20.7 (0.0)	1	0	1
12	20.0 (0.0)	25.2 (–)	21.7 (3.0)	1	1	2
13	– (–)	27.1 (–)	27.1 (–)	–	1	1

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

Table 7.–Weighted mean lengths and sample sizes by age and sex for northern pike collected from Long Lake, April 7 to 22, 2004. Standard deviation is in parentheses.

	Mean length			Number aged		
Age	Males	Females	All fish[a]	Males	Females	All fish[a]
1	13.1 (0.6)	–	12.5 (1.0)	3	–	19
2	17.7 (1.9)	19.9 (1.8)	17.7 (2.5)	36	16	85
3	21.4 (1.8)	24.1 (1.8)	22.8 (2.3)	38	53	114
4	23.4 (1.2)	26.4 (2.3)	25.1 (2.2)	16	27	49
5	24.1 (4.0)	27.7 (4.9)	27.7 (4.7)	2	8	12
6	26.0 (1.8)	32.1 (3.5)	29.3 (4.4)	5	10	20
7	24.8 (–)	36.7 (1.5)	33.9 (5.6)	1	4	8
8	–	40.5 (–)	33.9 (9.3)	–	1	2
9	29.7 (–)	31.9 (–)	30.8 (1.6)	1	1	2
10	–	39.0 (–)	39.0 (–)	–	1	1

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

Table 8.–Weighted mean lengths and sample sizes for smallmouth bass collected from Long Lake, April 7 to April 22, 2004. Standard deviation is in parentheses.

Age	Mean length		N
3	11.4	(1.1)	14
4	12.7	(1.0)	32
5	14.1	(0.8)	27
6	15.1	(0.9)	14
7	16.2	(1.0)	20
8	16.9	(0.6)	6
9	16.8	(0.7)	8
10	17.9	(0.7)	13
11	18.4	(0.6)	10
12	–		–
13	18.6	(0.5)	5
14	18.5	(1.0)	4

Table 9.–Catch-at-age estimates (apportioned by age-length key) by sex for walleye, northern pike, and smallmouth bass collected from Long Lake from April 7 to April 22, 2004.

Age	Year class	Walleye			Northern pike			Smallmouth bass
		Males	Females	All fish[a]	Males	Females	All fish[a]	All fish[a]
1	2003	–	–	41	5	–	30	–
2	2002	7	–	56	41	17	89	13
3	2001	10	–	18	44	58	128	63
4	2000	63	7	85	19	26	56	213
5	1999	35	20	76	2	8	12	206
6	1998	158	49	181	7	11	23	117
7	1997	81	59	149	2	5	8	180
8	1996	81	38	108	0	1	2	46
9	1995	23	3	28	1	1	2	63
10	1994	2	1	3	–	1	1	82
11	1993	2	0	2	–	–	–	47
12	1992	2	1	3	–	–	–	0
13	1991	–	1	1	–	–	–	18
14	1990	–	–	–	–	–	–	14
Total		464	179	751	121	128	351	1,049

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

Table 10.–Angler survey estimates for summer 2004 from Long Lake. Survey period was from April 24 through October 13, 2004. Two standard errors are given in parentheses.

Species	Catch/hour	Apr-May	Jun	Jul	Aug	Sep-Oct	Season
		Number harvested					
Smallmouth bass	0.057 (0.022)	102 (197)	462 (260)	267 (198)	382 (238)	483 (292)	1,696 (536)
Walleye	0.009 (0.005)	0 (0)	29 (43)	94 (96)	51 (58)	82 (81)	257 (145)
Yellow perch	0.118 (0.053)	0 (0)	0 (0)	650 (498)	1,380 (943)	1,500 (871)	3,530 (1,377)
Northern pike	0.005 (0.003)	0 (0)	5 (11)	60 (62)	24 (37)	54 (65)	143 (97)
Bluegill	0.001 (0.001)	0 (0)	0 (0)	0 (0)	0 (0)	20 (40)	20 (40)
Largemouth bass	<0.001 (<0.001)	0 (0)	0 (0)	5 (9)	0 (0)	0 (0)	5 (9)
Brown bullhead	0.001 (0.001)	0 (0)	0 (0)	0 (0)	0 (0)	22 (45)	22 (45)
Total harvest	0.189 (0.065)	102 (197)	496 (263)	1,075 (548)	1,838 (975)	2,161 (926)	5,673 (1,489)
		Number released					
Smallmouth bass	0.192 (0.0706)	684 (823)	755 (408)	1,586 (854)	1,394 (889)	1,327 (599)	5,745 (1,650)
Walleye	0.005 (0.005)	67 (133)	0 (0)	37 (44)	0 (0)	36 (43)	140 (147)
Northern pike	0.020 (0.009)	47 (72)	74 (76)	164 (119)	97 (79)	221 (136)	602 (223)
Bowfin	<0.001 (<0.001)	0 (0)	10 (19)	0 (0)	0 (0)	0 (0)	10 (19)
Rock bass	0.005 (0.005)	0 (0)	0 (0)	25 (50)	92 (143)	22 (45)	139 (158)
Brown bullhead	<0.001 (<0.001)	0 (0)	0 (0)	12 (25)	0 (0)	0 (0)	12 (25)
Bluegill	0.010 (0.010)	0 (0)	0 (0)	6 (12)	96 (113)	200 (254)	302 (278)
Pumpkinseed	0.002 (0.002)	0 (0)	0 (0)	34 (53)	20 (41)	10 (20)	65 (70)
Yellow perch	0.302 (0.132)	0 (0)	14 (29)	3,386 (2,487)	3,514 (2,044)	2,115 (1,103)	9,029 (3,403)
Total released	0.536 (0.174)	797 (837)	853 (417)	5,250 (2,634)	5,212 (2,238)	3,931 (1,290)	16,045 (3,806)
Total (harvest + release)	0.725 (0.211)	899 (859)	1,349 (493)	6,325 (2,690)	7,050 (2,442)	6,093 (1,588)	21,717 (4,086)
		Fishing effort					
Angler hours		3,589 (4,458)	4,277 (1,173)	8,650 (2,943)	8,561 (3,322)	4,874 (1,780)	29,950 (6,642)
Angler trips		2,051 (2,625)	2,444 (1,018)	4,943 (2,168)	4,892 (2,327)	2,785 (1,286)	17,114 (4,438)

Table 11.–Angler survey estimates for winter 2005 from Long Lake. Survey period was from December 17, 2004 through March 26, 2005. Two standard errors are given in parentheses. Angler trips could not be estimated.

Species	Catch/hour	Dec	Jan	Feb	Mar	Season
		Number harvested				
Walleye	0.010 (0.010)	0 (0)	26 (41)	23 (28)	0 (0)	48 (50)
Yellow perch	0.254 (0.137)	119 (174)	935 (576)	178 (135)	25 (42)	1,257 (618)
Northern pike	0.005 (0.007)	0 (0)	6 (13)	19 (29)	0 (0)	25 (32)
Total harvest	0.269 (0.139)	119 (174)	967 (577)	219 (141)	25 (42)	1,331 (621)
		Number released				
Smallmouth bass	0.011 (0.016)	0 (0)	6 (13)	3 (5)	47 (78)	56 (80)
Walleye	0.001 (0.002)	0 (0)	4 (8)	0 (0)	0 (0)	4 (8)
Northern pike	0.009 (0.009)	0 (0)	0 (0)	29 (35)	16 (24)	45 (42)
Yellow perch	0.444 (0.245)	0 (0)	1,736 (1,067)	461 (319)	0 (0)	2,197 (1,113)
Total released	0.466 (0.248)	0 (0)	1,746 (1,067)	493 (321)	63 (82)	2,302 (1,117)
Total (harvest + release)	0.735 (0.305)	119 (174)	2,714 (1,213)	712 (350)	87 (92)	3,633 (1,278)
		Fishing effort				
Angler hours		608 (459)	2,167 (684)	1,809 (643)	360 (296)	4,944 (1,086)

Table 12.–Angler survey estimates for summer and winter 2004–05 from Long Lake. Survey period was April 24 through October 13, 2004 and December 17, 2004 through March 26, 2005. Two standard errors are given in parentheses.

Species	Catch/hour		Apr–May		Jun		Jul		Aug		Sep–Oct		Dec		Jan		Feb		Mar		Season	
			Number harvested																			
Smallmouth bass	0.049	(0.018)	102	(197)	462	(260)	267	(198)	382	(238)	483	(292)	0	(0)	0	(0)	0	(0)	0	(0)	1,696	(536)
Walleye	0.009	(0.005)	0	(0)	29	(43)	94	(96)	51	(58)	82	(81)	0	(0)	26	(41)	23	(28)	0	(0)	305	(153)
Yellow perch	0.137	(0.051)	0	(0)	0	(0)	650	(498)	1,380	(943)	1,500	(871)	119	(174)	935	(576)	178	(135)	25	(42)	4,787	(1,509)
Northern pike	0.005	(0.003)	0	(0)	5	(11)	60	(62)	24	(37)	54	(65)	0	(0)	6	(13)	19	(29)	0	(0)	168	(102)
Bluegill	0.001	(0.001)	0	(0)	0	(0)	0	(0)	0	(0)	20	(40)	0	(0)	0	(0)	0	(0)	0	(0)	20	(40)
Largemouth bass	<0.001	<(0.001)	0	(0)	0	(0)	5	(9)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	5	(9)
Brown bullhead	0.001	(0.001)	0	(0)	0	(0)	0	(0)	0	(0)	22	(45)	0	(0)	0	(0)	0	(0)	0	(0)	22	(45)
Total harvest	0.201	(0.060)	102	(197)	496	(263)	1,075	(548)	1,838	(975)	2,161	(926)	119	(174)	967	(577)	219	(141)	25	(42)	7,003	(1,613)
			Number released																			
Bowfin	<0.001	<(0.001)	0	(0)	10	(19)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	10	(19)
Smallmouth bass	0.166	(0.057)	684	(823)	755	(408)	1,586	(854)	1,394	(889)	1,327	(599)	0	(0)	6	(13)	3	(5)	47	(78)	5,801	(1,652)
Walleye	0.004	(0.004)	67	(133)	0	(0)	37	(44)	0	(0)	36	(43)	0	(0)	4	(8)	0	(0)	0	(0)	144	(147)
Northern pike	0.019	(0.007)	47	(72)	74	(76)	164	(119)	97	(79)	221	(136)	0	(0)	0	(0)	29	(35)	16	(24)	647	(227)
Rock bass	0.004	(0.005)	0	(0)	0	(0)	25	(50)	92	(143)	22	(45)	0	(0)	0	(0)	0	(0)	0	(0)	139	(158)
Brown bullhead	<0.001	<(0.001)	0	(0)	0	(0)	12	(25)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	12	(25)
Bluegill	0.009	(0.008)	0	(0)	0	(0)	6	(12)	96	(113)	200	(254)	0	(0)	0	(0)	0	(0)	0	(0)	302	(278)
Pumpkinseed	0.002	(0.002)	0	(0)	0	(0)	34	(53)	20	(41)	10	(20)	0	(0)	0	(0)	0	(0)	0	(0)	65	(70)
Yellow perch	0.322	(0.120)	0	(0)	14	(29)	3,386	(2,487)	3,514	(2,044)	2,115	(1,103)	0	(0)	1,736	(1,067)	461	(319)	0	(0)	11,226	(3,581)
Total released	0.526	(0.152)	797	(837)	863	(417)	5,250	(2,634)	5,212	(2,238)	3,931	(1,290)	0	(0)	1,746	(1,067)	493	(321)	63	(82)	18,356	(3,966)
Total (harvest + release)	0.727	(0.186)	899	(859)	1,359	(493)	6,325	(2,690)	7,050	(2,442)	6,093	(1,588)	119	(174)	2,714	(1,213)	712	(350)	87	(92)	25,360	(4,282)
			Fishing effort																			
Angler hours			3,589	(4,458)	4,277	(1,173)	8,650	(2,943)	8,561	(3,322)	4,874	(1,780)	608	(459)	2,167	(684)	1,809	(643)	360	(296)	34,894	(6,730)
Angler trips			2,278	(2,965)	2,321	(617)	4,902	(1,583)	5,034	(2,133)	2,889	(1,124)	402	(305)	1,428	(453)	1,183	(421)	237	(195)	20,673	(4,243)

Table 13.–Voluntary angler tag returns from walleye (reward and nonreward, harvested and released) by month for the year following tagging in Long Lake. Percentage of total is in parentheses.

Month	Species					
	Walleye		Northern pike		Smallmouth bass	
April	0	(0)	0	(0)	1	(1.1)
May	5	(10.6)	3	(13.6)	18	(19.1)
June	6	(12.8)	3	(13.6)	12	(12.8)
July	9	(19.1)	8	(36.4)	13	(13.8)
August	12	(25.5)	3	(13.6)	18	(19.1)
September	6	(12.8)	0	(0)	8	(8.5)
October	0	(0)	1	(4.5)	16	(17.0)
November	0	(0)	0	(0)	8	(8.5)
December	1	(2.1)	2	(9.1)	0	(0)
January	5	(10.6)	0	(0)	0	(0)
February	3	(6.4)	1	(4.5)	0	(0)
March	0	(0)	1	(4.5)	0	(0)
Total	47		22		94	

Table 14.–Mean lengths of Walleye from the 2004 survey of Long Lake, compared to other surveys. Number aged in parentheses.

		Lake															
Age	State average[a]	Long 2004[b]		Long 2000[c,d]		Long 1982[c,d]		Grand 2004[b,e]		Hubbard 2006[b, d]		South Manistique 2003[b, f]		Black 2005[b, d]		Mullett 1998[c, d]	
1	7.1	8.1	(22)					7.3	(15)	7.8	(5)					8.4	(1)
2	10.4	12.9	(47)	11.1	(3)	12.1	(14)	11.8	(47)	12.5	(12)	11.4	(2)			11.1	(38)
3	13.9	14.6	(12)	14.5	(13)	14.3	(10)	13.5	(26)	14.2	(20)	13.5	(21)	15.3	(3)	15.1	(31)
4	15.8	16.4	(24)	15.7	(9)	16.1	(17)	14.8	(29)	17.6	(15)	15.9	(51)	16.3	(26)	16.8	(19)
5	17.6	17.3	(17)	17.2	(3)	17.2	(16)	15.2	(20)	17.4	(19)	17.1	(33)	17.3	(27)	18.3	(28)
6	19.2	18.0	(42)	19.4	(2)	18.3	(20)	16.5	(40)	17.1	(16)	19.7	(10)	17.8	(34)	19.2	(33)
7	20.6	18.5	(41)	21.1	(1)	20.5	(10)	17.2	(40)	18.5	(11)	19.4	(8)	18.7	(32)	19.9	(21)
8	21.6	19.1	(39)			21.7	(6)	18.3	(54)	18.8	(16)	19.8	(17)	19.3	(12)	20.4	(27)
9	22.4	19.1	(10)	22.0	(2)	23.9	(2)	20.3	(14)	18.7	(17)	19.9	(17)	19.1	(13)	21.3	(31)
10	23.1	21.1	(2)	23.4	(2)			20.5	(5)	19.6	(10)	18.8	(2)	19.9	(13)	22.6	(26)
11		20.7	(1)					23.4	(4)	18.7	(7)	21.0	(19)	20.6	(1)	23.9	(20)
12		21.7	(2)	26.3	(1)					18.9	(18)	22.1	(16)	21.4	(1)	26.7	(4)
13		27.1	(1)					22.4	(8)	18.5	(4)	23.6	(8)	21.1	(1)		
14								24.2	(2)	19.0	(4)	22.6	(4)				
15								24.4	(4)	19.6	(1)	26.0	(5)				
16										20.1	(4)						
17										19.1	(4)						
Mean growth index[g]		-0.5		+0.3		+0.2		-1.6		-1.2		-0.8		-1.7		-0.1	

[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 the spring and aged using scales.
[d] MDNR unpublished data
[e] Hanchin 2011
[f] Hanchin and Kramer 2008a
[g] The mean deviation from the statewide quarterly average. Only age groups where N is greater than or equal to 5 were used.

Table 15.–Mean lengths of northern pike from the 2004 survey of Long Lake, compared to other surveys. Number aged in parentheses.

		Lake						
Age	State average[a]	Long 2004[b]	Long 2000[c, d]	Long 1982[c, d]	Grand 2004[b, e]	Hubbard 1996[c, d]	Black 2005[b, d]	Mullett 1998[c, d]
1	11.7	12.5 (19)			12.3 (9)	12.6 (1)	13.6 (17)	14.1 (2)
2	17.7	17.7 (85)	21.2 (6)	17.6 (9)	17.6 (26)	19.1 (6)	18.7 (60)	18.3 (4)
3	20.8	22.8 (114)	22.9 (1)	20.9 (17)	23.5 (58)	22.1 (9)	21.8 (47)	21.8 (29)
4	23.4	25.1 (49)	24.1 (5)	24.5 (8)	25.0 (30)	24.9 (18)	23.3 (82)	23.5 (37)
5	25.5	27.7 (12)	26.1 (1)	26.6 (6)	26.8 (20)	25.3 (8)	24.8 (44)	26.9 (19)
6	27.3	29.3 (20)		28.0 (6)	27.0 (11)	34.0 (5)	27.0 (37)	29.8 (16)
7	29.3	33.9 (8)		28.8 (1)	35.3 (3)	35.5 (2)	25.5 (13)	33.2 (8)
8	31.2	33.9 (2)		33.0 (2)	27.4 (1)		25.0 (2)	36.4 (3)
9		30.8 (2)			28.1 (2)	37.8 (2)	32.4 (2)	
10		39.0 (1)			41.3 (2)	36.1 (1)	40.4 (2)	
11								
Mean growth index[f]		+1.9	+2.1	+0.6	+1.0	+2.0	-0.1	+1.6

[a] Jan–May averages from Schneider et al (2000a), aged using scales.
[b] Fish collected in the spring and aged using fin rays.
[c] Fish collected in the spring and aged using scales.
[d] MDNR unpublished data
[e] Hanchin 2011
[f] The mean deviation from the statewide quarterly average. Only age groups where N is greater than or equal to 5 were used.

Table 16.–Mean lengths of smallmouth bass from the 2004 survey of Long Lake, compared to other surveys. Number aged in parentheses.

		Lake						
Age	State average[a]	Long 2004[b]	Long 2000[c, d]	Long 1982[c, d]	Grand 2004[b, e]	Big Manistique 2003[b, f]	Hubbard 1996[c, d]	Mullett 1998[c, d]
1	3.8		5.1 (2)	5.0 (2)			3.9 (1)	
2	7.5		6.6 (25)	7.4 (18)	8.8 (53)	10.2 (8)	9.4 (14)	7.3 (5)
3	10.8	11.4 (14)	9.1 (28)	8.8 (11)	10.9 (73)	12.1 (21)	11.5 (26)	11.2 (33)
4	12.6	12.7 (32)	10.6 (7)	10.5 (19)	13.9 (32)	14.0 (27)	13.7 (48)	13.7 (30)
5	14.4	14.1 (27)	12.3 (7)	12.1 (28)	15.6 (23)	15.3 (29)	15.1 (33)	15.5 (10)
6	15.3	15.1 (14)	14.1 (30)	14.2 (9)	16.3 (17)	16.6 (15)	16.2 (22)	16.5 (9)
7	16.3	16.2 (20)	15.7 (10)	15.2 (5)	17.3 (15)	17.6 (8)	17.1 (33)	17.1 (7)
8	17.3	16.9 (6)	16.7 (12)	16.2 (12)	17.4 (6)	17.6 (9)	18.0 (18)	17.9 (8)
9	18.1	16.8 (8)	17.8 (8)	17.6 (13)	18.1 (9)	18.1 (2)	18.5 (15)	18.4 (8)
10	18.9	17.9 (13)	18.5 (7)	17.4 (2)	17.6 (2)	19.9 (1)	19.0 (9)	19.0 (6)
11		18.4 (10)	18.8 (1)		18.5 (7)	17.9 (2)		19.6 (7)
12					19.0 (7)			20.0 (7)
13		18.6 (5)			18.9 (5)			
14		18.5 (4)			19.2 (2)			
Mean growth index[g]		-0.3	-1.1	-1.3	+0.8	+1.3	+0.9	+0.7

[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 the spring and aged using scales.
[d] MDNR unpublished data
[e] Hanchin 2011
[f] Hanchin and Kramer 2007
[g] The mean deviation from the statewide quarterly average. Only age groups where N is greater than or equal to 5 were used.

Table 17.–Comparison of recreational fishing effort and total harvest on Long Lake to those of other Michigan lakes surveyed as part of the Large Lakes Program. Lakes are listed from highest to lowest total fishing effort. Lake size was from Laarman (1976).

Lake	County	Size (acres)	Survey period	Fishing effort (hours)	Fish harvested (number)	Fish harvested per hour	Hours fished per acre	Fish harvested per acre
Houghton	Roscommon	20,075	Apr 2001–Mar 2002	499,048	386,287	0.77	24.9	19.2
Cisco Chain	Gogebic, Vilas	3,987	May 2002–Feb 2003	180,262	120,412	0.67	45.2	30.2
Muskegon	Muskegon	4,232	Apr 2002–Mar 2003	180,064	184,161	1.02	42.5	43.5
Burt	Cheboygan	17,120	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
Lake Leelanau	Leelanau	8,607	Apr 2002–Mar 2003	112,112	15,464	0.14	13.0	1.8
Big Manistique	Luce, Mackinac	10,346	May 2003–Mar 2004	88,373	71,652	0.81	8.5	6.9
Crooked and Pickerel	Emmet	3,434	Apr 2001–Mar 2002	55,894	13,665	0.24	16.3	4.0
Michigamme Reservoir	Iron	6,400	May 2001–Feb 2002	52,686	10,899	0.21	8.2	1.7
Long	Presque Isle, Alpena	5,342	Apr 2004–Mar 2005	34,894	7,004	0.20	6.5	1.3
Grand	Presque Isle	5,822	Apr 2004–Mar 2005	33,037	10,623	0.32	5.7	1.8
Bond Falls Flowage	Ontonagon	2,127	May 2003–Oct 2003	21,182	3,193	0.15	10.0	1.5
North Manistique	Luce	1,709	May 2003–Mar 2004	10,614	7,603	0.72	6.2	4.4
Average				118,851	72,545	0.47	17.6	10.1
Median				88,373	15,464	0.32	10.0	4.0

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Appendix

Appendix.–Fish species captured in Long Lake from 1925 through 2006 by MDNR crews using various gear types.

Common name	Scientific name
Species we collected in the spring 2004 survey.	
Black bullhead	*Ameiurus melas*
Black crappie	*Pomoxis nigromaculatus*
Bluegill	*Lepomis macrochirus*
Brown bullhead	*Ameiurus nebulosus*
Common carp	*Cyprinus carpio*
Largemouth bass	*Micropterus salmoides*
Northern pike	*Esox lucius*
Pumpkinseed	*Lepomis gibbosus*
Rainbow trout	*Oncorhynchus mykiss*
Rock bass	*Ambloplites rupestris*
Smallmouth bass	*Micropterus dolomieu*
Walleye	*Sander vitreus*
White sucker	*Catostomus commersonii*
Yellow perch	*Perca flavescens*
Additional species collected or observed in other surveys of Long Lake.	
Blackchin shiner	*Notropis heterodon*
Black crappie	*Pomoxis nigromaculatus*
Blacknose shiner	*Notropis heterolepis*
Bluntnose minnow	*Pimiphales notatus*
Brown trout	*Salmo trutta*
Channel catfish	*Ictalurus punctatus*
Common shiner	*Luxilus cornutus*
Emerald shiner	*Notropis atherinoides*
Iowa darter	*Etheostoma exile*
Johnny darter	*Etheostoma nigrum*
Killifish sp.	*Fundulus sp.*
Lake whitefish	*Coregonus clupeaformis*
Logperch	*Percina caprodes*
Rainbow darter	*Etheostoma caeruleum*
Rosyface shiner	*Notropis rubellus*
Sand shiner	*Notropis stramineus*
Spotfin shiner	*Notropis spilopterus*
Spottail shiner	*Notropis hudsonius*