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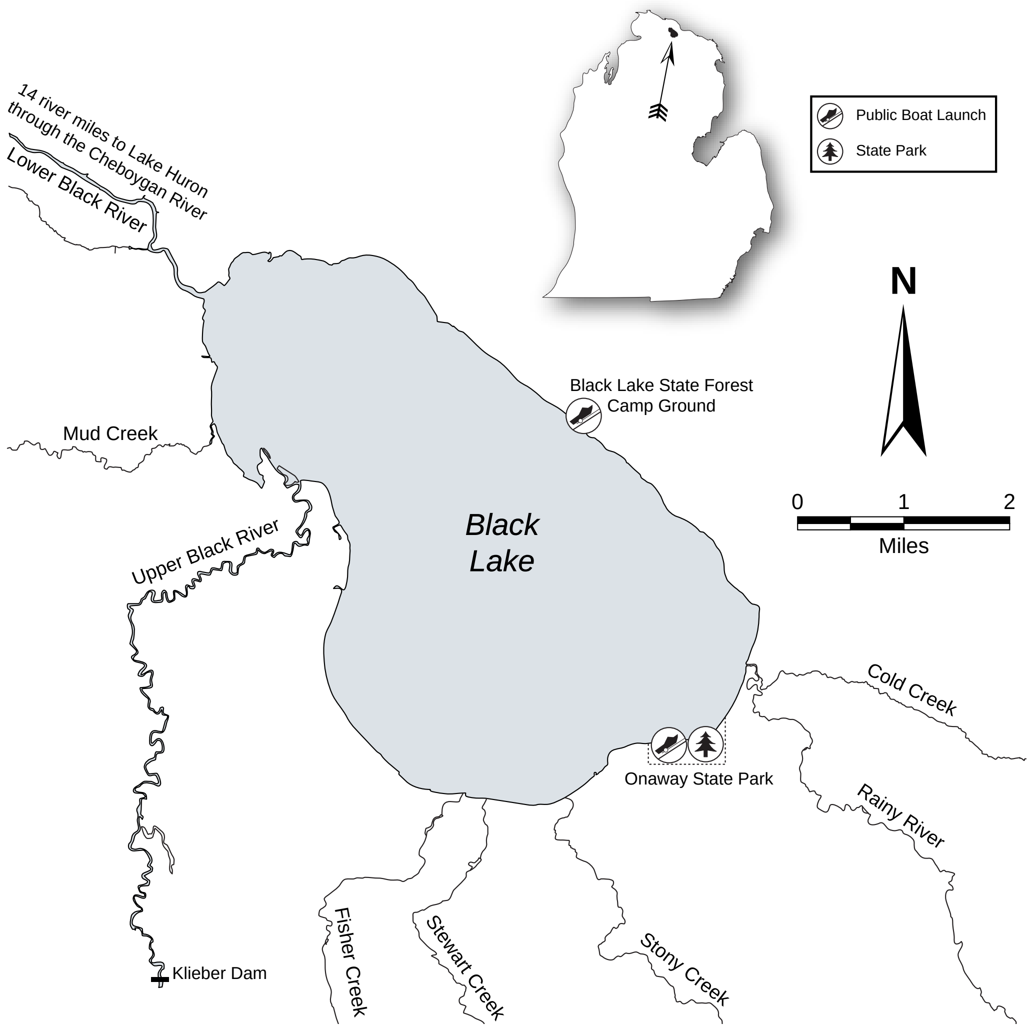

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Michigan Department of Natural Resources
Fisheries Special Report 56, 2011

The Fish Community and Fishery of Black Lake, Cheboygan, and Presque Isle Counties, Michigan with Emphasis on Walleye, Northern Pike, and Smallmouth Bass

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Introduction

The Michigan Department of Natural Resources (DNR), Fisheries Division surveyed fish populations and angler catch and effort at Black Lake, Cheboygan and Presque Isle counties, Michigan from April 2005 through March 2006. 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 goal of the Large Lakes Program is to produce statistics for important fishes to help detect major changes in their populations over time. The program has three primary objectives. The first objective is to produce consistent indices of abundance and estimates of annual harvest and fishing effort for important fishes. Important fishes are defined as species susceptible to trap or fyke nets and/or those readily harvested by anglers. The second objective is to produce growth and mortality statistics to evaluate effects of fishing on species that support valuable fisheries. This usually involves targeted sampling to collect, sample, and mark sufficient numbers of fish. We selected walleye (scientific names for all fish species in the report are found in Appendix 1), northern pike, and smallmouth bass as special-interest species in this survey of Black Lake. The final objective is 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 Black Lake.

The Large Lakes Program will maintain consistent sampling methods over lakes and time subsequently building a database of fish population and harvest statistics to directly evaluate differences among lakes or changes within a lake over time. Black Lake was the fifteenth lake surveyed under the protocols of the program. However, we utilized statistics from all surveyed lakes (n=20) for comparison. The sample size for these types of comparisons varies throughout the report as some statistics could not be estimated for every lake and/or species.

Although the lake sturgeon, a threatened species in Michigan, is a popular fish species found in Black Lake, it is only briefly mentioned in this document. The lake sturgeon population in Black Lake is relatively abundant compared to most other lake sturgeon populations found in Michigan, and the population has been studied and managed aggressively since the 1970s by DNR, Michigan State

University, and Central Michigan University. Readers interested in knowing more about the Black Lake sturgeon population should refer to the following references: Vondett 1957; Vondett and Williams 1961; Baker 1980; Hay-Chmielewski 1987; Baker and Borgeson 1999; Smith and Baker 2005; Smith and King 2005a, 2005b; Scribner and Baker 2007.

Fish stocking in Black Lake originally dates back to 1903 and includes a variety of species, ages, and sizes of fish. Most stocking efforts occurred in the early twentieth-century when fish management relied heavily upon stocking practices. Rainbow and brown trout were stocked at various sizes from 1938 through 1943. Largemouth bass fry were stocked in 1903, smallmouth bass adults from 1940 to 1942, rock bass adults from 1939 to 1942, and yellow perch in various years in the 1920s and 1930s.

The earliest stocking of walleye occurred from 1903 to 1910 when nearly 12 million fry were stocked. Adult walleye were stocked from 1937 to 1942, and in 1947, with fewer than 1,000 walleyes stocked over this time period. Some of these adult stocking efforts were from walleyes transferred from below the Cheboygan Dam and released throughout different parts of the inland waterway and in Black Lake. This management practice was discontinued due to the high expense involved in relation to the number of fish transferred. Stocking of walleye did not resume again until 1989, when the Black Lake Association and Northern Michigan Walleye Association stocked over 50,000 fall fingerlings from 1989 through 1993 (Table 1).

Beyond fish stocking, early fish management consisted of removals of undesirable species and brush shelter installations. Eleven tons of undesirable fish, mainly white suckers, were removed from Black Lake by commercial trapping in 1939 and 1940. Nearly 200 brush shelters were placed in the lake from 1933 through 1953, but their effectiveness was questioned because many washed ashore. Fish community surveys were made by seining and using gill nets in 1937 and 1939. Many of the fish species currently in Black Lake were documented in the late 1930s surveys, including walleye and northern pike.

Low effort fish community surveys conducted by the Michigan Department of Conservation (MDOC) in 1952, 1960, and 1969 provided little insight into fish populations. For example, the 1969 survey employed night electrofishing gear and targeted adult muskellunge in the northern end of the lake and Lower Black River. Only one small muskellunge was observed but northern pike were numerous.

A late May through early June 1970 fish community survey on Black Lake utilizing trap nets and low netting effort captured few game fish. Species captured included northern pike, smallmouth and largemouth bass, walleye, brook trout, pumpkinseed, and rock bass. A follow-up survey the next year using gill nets captured the same species. A total of 86 walleyes were collected, which ranged in length from 14 to 18 in TL reflecting slow growth of walleye when compared to the statewide average. In 1976, a fish community analysis on Black Lake occurred in mid-June and walleye growth was again determined to be relatively slow, as was growth of northern pike, when compared to statewide averages.

Trap nets were used to evaluate the Black Lake fish community in May 1980. Forty-six trap-net lifts captured low numbers of a variety of fish. The collection included 32 walleyes, 208 northern pike, 3 brook trout, 1 muskellunge, and 1 cisco. Northern pike ranged from 15 to 38 in TL, with most less than 24 in. A similar survey with similar effort in May 1982 provided little additional information on the Black Lake fish community.

The most intensive fish community survey of Black Lake prior to 2005 was conducted by DNR Fisheries Division in mid October of 1991. The purpose of the survey was to evaluate the walleye population by tagging adults and collecting data on survival of clipped walleyes stocked by the Black Lake Association and Northern Michigan Walleye Association (Table 1). Thirty-nine Great Lakes trap nets with 300-ft leads were used in the survey. A total of 310 walleyes were captured, but none were from the private stocking effort. No population estimate was derived from the tagging effort.

Another fish community survey during May 1997 consisted of 49 large-mesh trap-net lifts and 11 gill-net lifts. Rusty crayfish *Orconectes rusticus* were established in Black Lake at the time of this survey. The survey results indicated that Black Lake contained a fairly healthy and diverse fish community. Walleye reproduction appeared to be sustaining the population. Walleyes in the 16 to 18 in range dominated the species catch, yet the overall catch was low. The long shoals of such lakes and short leads on trap nets may have led to poor sampling efficiency. Shoals are defined as extensive shallow areas where short net leads may be insufficient. Seven year classes of walleye were found and overall growth was slightly slower than the statewide average. Yellow perch were considered numerous with the majority of the captured fish in the 6–8 in range. Rock bass were numerous with most 5–11 in. Smallmouth bass ranged from 8 to 18 in and over half of the fish were larger than legal size (14 in). Brook trout, cisco, and pumpkinseed were also collected in the survey. Northern pike were considered to be doing well based on the catch and were represented by relatively good numbers of 19–28 in fish. The chances of anglers catching larger pike in Black Lake were considered fair. Results of the 1997 survey presented the picture of a diverse fishery.

Between 1997 and 2008, the DNR evaluated young walleye recruitment in Black Lake seven times (Table 2) using night electrofishing of the shoreline in the fall when young walleyes may enter the shoal area. Varying effort was used annually over different habitats and shoreline reaches. A fair year class was noted for 1997, good year classes were found in 1998 and 2000, and weak year classes were produced in 2005 through 2008. No information was available on year-class strength for 2001 through 2003. The shoreline was also electrofished for lake sturgeon in August 1999, and though walleyes were not collected, field notes indicated that "many young walleye were observed" possibly indicating a good 1999 year class.

The most intensive fish community survey at Black Lake to date is the current study, which was conducted in April 2005. This involved the use of statewide crews from DNR Fisheries Division (see **Methods**).

Study Area

Black Lake lies along the Cheboygan–Presque Isle county line in the northeastern part of Michigan's Lower Peninsula and is 6 miles north of the town of Onaway. The lake is the tenth largest inland lake in the state of Michigan by surface acreage (10,113 acres; Breck 2004) and has 18 miles of shoreline. The Black Lake watershed includes more than 350,000 acres representing 38% of the entire Cheboygan River watershed, to which it belongs. Black Lake is fed by a variety of small creeks and rivers (Figure 1). The largest tributary is the Upper Black River, which enters the lake on the west shore. This river provides suitable spawning habitat for various species of fish that live in Black Lake, including lake sturgeon, walleye, and redhorse sucker. Rainy River is the next largest tributary and it enters the lake on the southeast shore. It also provides some spawning habitat for Black Lake fish, particularly for walleyes and suckers. Other tributaries, such as Stony, Stewart, and Fisher creeks, enter the lake at the south end, and Mud Creek enters the lake on the northwest shore. Many of these tributaries are used seasonally by game fish for spawning, and spring fishing closures are in place on both the Upper Black and Rainy rivers to protect spawning fish. Little Mud Creek, Stony Creek, and parts of the Rainy and Upper Black rivers are also considered Michigan designated trout streams. Tower Dam (built in 1922), on the Upper Black River is 10 miles upstream from Black Lake, and Klieber Dam (built in 1949) is 6 miles upstream on the same river. Lower Black River is the lake outlet on the north shore and it flows towards the Cheboygan River and eventually Lake Huron. Alverno Dam, constructed in 1903 on the Lower Black River, prevents upstream fish passage. Black Lake fish are able to migrate freely into the Lower Black River as far as the dam which is approximately seven river miles downstream of Black Lake. Lower Black River also provides some spawning habitat for Black Lake species such as lake sturgeon, muskellunge, walleye, and sucker.

Standard State of Michigan fishing regulations apply for most game fish in Black Lake, with the exception of lake sturgeon which is regulated by a limited quota fishery. The commercial harvest of minnows in Black Lake and its tributaries (inlets only) is prohibited based on a long standing Fisheries Order.

A public access site on the south shore of the lake within Onaway State Park has a hard-surfaced ramp with sufficient water depth to accommodate large watercraft, 20 parking spaces, and a public toilet. Various other smaller public boat launch sites are found around the lake and on rivers which provide access to Black Lake. Launching of watercraft is limited at some of these sites during low water periods.

The shoreline of Black Lake is largely developed with private residences, and there is little public riparian land except at the state park, near the Upper Black River mouth, and along the northeast shore where a state forest campground exists. There were 161 riparian residences in 1939 on Black Lake (including 10 resorts and 1 hotel), and there are approximately 500 at present (counted from Yahoo Maps© satellite image). The bathymetry of Black Lake was mapped in the late 1930s and was considered a mesotrophic (moderately biologically productive) lake with a maximum depth of 50 ft. The lake has large areas of shallow shoals, consisting primarily of sand, that drop off sharply into deeper waters. Shoal width ranges from 330 ft wide to a quarter-mile wide based on 1939 estimates. Approximately 29% of Black Lake is less than 10 ft deep, nearly 9% is 10–20 ft deep, 17% is 20–30 ft deep, and 45% of Black Lake is water greater than 30 ft deep (Figure 2). Maximum depth is around 50 ft and mean depth around 23 ft.

Two limnological profiles for dissolved oxygen and water temperature exist for Black Lake, one from early July 1939 and one from mid-July 2007. Both surveys indicated declining temperature and oxygen throughout the water column and no thermocline. Thermal stratification is probably amplified in warmer and calmer summers in Black Lake (less mixing of warmer surface water). The substrate of Black Lake consists mainly of sand, with some gravel in the nearshore areas while marl, muck, and sand can be found in deeper water. Water of Black Lake is typically stained dark. When surveyed in the late 1930s, 45 types of aquatic vegetation were observed at 13 stations. Currently, aquatic vegetation is relatively sparse in Black Lake except at various locations where silt is the primary substrate, such as at the mouth of the Upper Black River. Emergent beds of rush can be found in various protected areas near shore. Sampling conducted in 1939 at 16 sites documented 55 invertebrates per square foot of lake bottom. Secchi disk readings were 12–15 ft deep and surface alkalinity ranged from 144 to 164 ppm. (MDOC unpublished data).

Methods

Fish populations in Black Lake were sampled with trap nets, fyke nets, and electrofishing gear during April 11–29, 2005. We used three boats daily, each with a three-person crew, for more than 2 weeks, with each boat tending 10–15 nets. Fyke nets were 6 ft x 4 ft with 2-in stretch mesh and 70- to 100-ft leads. Trap nets were 8 ft x 6 ft x 3 ft with 2-in 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 shoreline. Duration of net sets ranged from 1 to 4 nights, but most were 1 night. Electrofishing was conducted at night as an additional collection method. 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 sites using handheld global positioning systems (GPS). Additionally, we set multiple gear types (gill, fyke, and trap nets) during October 10–14, 2005 to increase the sample size of recaptured tagged adult walleyes.

Fish Community

To describe the status of the fish community field personnel identified all fish captured and calculated percent catch by species, catch per unit effort (CPUE), and species length frequencies. Total length of all walleyes, northern pike, and smallmouth bass was measured to the nearest 0.1 in. For other fish, lengths were measured to the nearest 0.1 in for subsamples of up to 200 fish per boat. 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 measurements of fish on their initial capture occasion. Walleyes and northern pike with flowing gametes were classified as male or female; fish with no flowing gametes were classified as unknown sex. For smallmouth bass, sex determination was usually not possible because we sampled several weeks prior to their spawning season.

We used a Microsoft Access© computer database to store and retrieve data collected during the tagging operation. We calculated mean 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).

Walleye, Northern Pike, and Smallmouth Bass

Abundance.–We estimated the abundance of legal-size walleye, northern pike, and smallmouth bass using mark-and-recapture methods. Walleyes (≥15 in), northern pike (≥24 in), and smallmouth bass (≥14 in) were fitted with individually numbered monel-metal jaw tags. To assess tag loss, tagged fish were double-marked by also clipping the left pelvic fin. By design, reward ($10) and nonreward tags were to be applied in an approximate 1:1 ratio for all three species. However, the actual ratio for walleye turned out to be 1.77:1. Large tags (size 16) used on large northern pike (≥36 in) were all nonreward.

Initial tag loss was assessed during the marking period as the proportion of recaptured clipped 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) also reported netting-induced tag loss for walleye. All fish that lost tags during netting recapture were retagged, and were accounted for in the total number of marked fish at large.

We used two different methods for estimating abundance from mark-and-recapture data, one derived from marked-unmarked ratios during the spring survey (multiple census) and the other derived from marked-unmarked ratios from the angler survey (single census).

For the multiple-census estimate, the Schumacher-Eschmeyer formula for daily recaptures during the tagging operation (Ricker 1975) was adapted for our purposes:

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

where N_1 = multiple-census population estimate (number of legal-size fish); C_d = total number of fish caught during day d; R_d = number of recaptures during day d; M_d = number of marked fish available for recapture at start of day d; and d = day (ranging from d_1 to d_n).

The variance formula for N_1 was:

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

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

Variance of $1/N_1$ is:

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

The minimum number of recaptures necessary for an unbiased estimate was set a priori at four (Ricker 1975). Asymmetrical 95% confidence intervals for the estimate of N were computed as:

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

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

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

For the single-census estimate, the recapture sample was defined as the number of marked and unmarked fish observed by creel clerks in the companion angler survey, by technicians during the October netting survey, and by a biologist during a summer fishing tournament on Black Lake. The minimum number of recaptures necessary for an unbiased estimate was set a priori at three (Ricker 1975), and we used the Chapman modification of the Petersen method to generate population estimates with a variance using the following formulas from Ricker (1975):

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

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

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 and a variance of adult walleyes and northern pike from the single-census estimates by dividing the estimates for legal-size fish by the proportion of legal-size fish on the spawning grounds, using the formula:

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

where N_a = estimated number of adult walleyes or northern pike; N_{sub} = number of sublegal and mature fish (<15 in for walleye, or <24 in for northern pike) caught; N_{leg} = number of legal-size fish caught; N_2 = single-census estimate of legal-size walleyes or northern pike.

We calculated the variance as:

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

There were no prior abundance estimates for walleye, northern pike, or smallmouth bass in Black 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 walleyes was based on 31 abundance estimates for 31 different lakes:

$$\ln(N) = 0.3710 + 1.0461 \times \ln(A),\ R^2 = 0.80,\ P < 0.0001,$$

where N is the estimated number of adult walleyes and A is the surface area of the lake in acres. For Black Lake, the equation gives an estimate of 22,423 adult walleyes, with a 95% prediction interval (Zar 1999) of 4,139 to 121,470.

The second equation for legal walleyes was based on 21 estimates for 21 different lakes:

$$\ln(N) = 0.5423 + 0.9794 \times \ln(A),\ R^2 = 0.74,\ P < 0.0001,$$

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 14,391 legal walleyes, with a 95% prediction interval (Zar 1999) of 3,032 to 68,297 for Black Lake. Based on these a priori abundance estimates, we thought that marking approximately 1,400 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 used in the formula by the estimated number that recruited to legal size during the recapture period. For example, to make this adjustment for walleye we determined the annual growth of slightly sublegal fish (i.e., 14.0–14.9 in fish) from mean length-at-age data. We then divided by the length of the growing season in months (6) and rounded to the nearest 0.1 in. This average monthly growth was used as the criteria to remove unmarked fish that were observed in the creel. The largest size of a sublegal fish at tagging was 14.9 in; thus, an average monthly growth of 0.2 in would result in all unmarked fish ≤ 15.1 in caught during the first full month (June) after tagging to be removed from 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 calculate the single-census population estimate.

We calculated the coefficient of variation (CV) 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 ages determined from dorsal spines of walleyes and smallmouth bass, and dorsal fin rays of northern pike because these structures 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 staff worked in cold, windy conditions, dealt with large numbers of fish, and tagged fish in addition to measuring and collecting structures. Otoliths are the most accurate and precise ageing structure for older walleyes (Heidinger and Clodfelter 1987; Kocovsky and Carline 2000; Isermann et al. 2003) and otoliths or cleithra for northern pike (Casselman 1974; Harrison and Hadley 1979), but collecting these structures requires killing the fish and we were tagging and releasing fish for later recapture. Results from several studies comparing aging structures for walleyes documented that spines were quicker to remove than scales, but they did not show that spines provided more accurate ages than scales (Campbell and Babaluk 1979; Kocovsky and Carline 2000; Isermann et al. 2003). Errors in age assignments made from spines were often related to misidentifying the first annulus in older fish (Ambrose 1983; Isermann et al. 2003). There was also considerable disagreement among authors as to whether spines or scales were more precise for walleye age estimation. Erickson (1983), and Campbell and Babaluk (1979) found that spines were more precise; Belanger and Hogler (1982) found spines and scales were equally precise; and Kocovsky and Carline (2000) found scales were more precise. Because northern pike older than 6 years are notoriously difficult to age with scales (Carlander 1969), DNR staff have recently started using dorsal fin rays. Dorsal rays are as quick and easy to remove in the field as spines for walleyes. 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 exist to statistically compare accuracy and precision of fin rays to other aging structures for northern pike. Our sample size goal was to collect fin rays or spines from 20 male and 20 female fish per inch group for walleye and northern pike. For smallmouth bass, we targeted 20 fish per inch group.

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

After a final age was identified for all samples, 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 by sex. We compared the mean lengths-at-age to those from previous surveys of Black 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. (2000). The mean growth index is the average of deviations (by age group) between the observed mean lengths and statewide seasonal average lengths.

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

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

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

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

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

Additionally, we checked individual tags observed by the creel clerk to see if they were subsequently reported by anglers. This step was 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 DNR was unnecessary. Tags observed by the creel clerk that were not voluntarily reported by the angler were added to the voluntary tag returns for exploitation estimates.

Voluntary tag returns were encouraged with a monetary reward ($10) denoted on approximately 50% of the tags (64% for walleye). Tag return forms were available at boater access sites, at DNR offices, and from creel clerks. Additionally, tag return information could be submitted on-line at the DNR website. All tag return data were entered into the database to efficiently link to and verify against data collected during the tagging operation. We developed linked documents in Microsoft Word® computer software so that payment vouchers for anglers who submitted reward tag data and letters to all anglers who contributed tag returns were automatically produced. Letters sent to anglers contained information on the length and sex of the tagged fish, and the location and date of tagging. Return rates were calculated separately for reward and nonreward tags, unadjusted for tag loss. The reporting rate of nonreward tags relative to reward tags (λ; Pollock et al. 1991) was calculated as the fraction of nonreward tags harvested and reported divided by the fraction of reward tags harvested and reported (with available tags adjusted for short-term tag loss and mortality during tagging. In addition to data on harvested fish, we estimated the release rate of legal fish from responses to a question on the tag return form asking if the fish was released. The release rate was calculated as the total number of tag returns reported as released divided by all of the tagged fish known to have been caught (voluntary returns and unreported tags observed in the creel survey).

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

Movement.–Fish movements were assessed in a descriptive manner by examining the location of angling capture versus the initial tagging location. 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. Analysis was completed with all tag returns received up to the date the report was written (approximately October 1, 2008).

Angler Survey

Fishing harvest season for walleye and northern pike during this survey was April 30, 2005–March 15, 2006. Fishing harvest season for smallmouth bass and largemouth bass was May 28 through December 31, 2005. Minimum size limits were 15 in for walleye, 24 in for northern pike, and 42 in for muskellunge. Minimum size limit was 14 in for both smallmouth and largemouth bass. Daily bag limit was five fish in any combination of walleye, northern pike, smallmouth bass, or largemouth bass, with no more than two northern pike. The daily bag limit for muskellunge was one fish.

Harvest was permitted all year for other species and no minimum size limits were in place. The bag limit for yellow perch was 50 per day and for sunfishes, including black crappies, bluegills, pumpkinseeds, and rock bass, it was 25 per day in any combination. The bag limit for coregonids (ciscoes and lake whitefish) was 12 in any combination.

Direct contact angler creel surveys were conducted during one spring–summer period (April 30 to October 20, 2005) and one winter period (January 4 through March 26, 2005).

Summer.–We used an aerial-roving survey design for the summer survey (Lockwood 2000a). Fishing boats were counted by aerial flights (Figure 3) while one clerk working from a 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. Counting and interviewing were done on the same days, and one instantaneous count of fishing boats was made per day.

The creel interview direction (clockwise or counter-clockwise) was randomized (Figure 4). 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 was recorded on standard creel survey count forms, and included date, count time, and number of fishing boats.

For the roving creel survey the 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 for individual anglers to avoid party size bias (Lockwood 1997), though the number of anglers in each party was recorded on one interview form. Although 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, muskellunge, and smallmouth bass, and tag numbers, if present. One of two shifts was selected each sample day for interviewing (Table 3).

Winter.–We followed a progressive-roving design for the winter angler survey (Lockwood 2000a). One clerk worked full time to collect angler-creel data. Both weekend days and three randomly selected weekdays were selected for sampling during each week of the survey season. No holidays were included in the survey. The clerk followed a randomized count and interview schedule. One of two shifts was selected each sample day (Table 3). Starting location and direction of travel were randomized for both counting and interviewing. Progressive counts of open ice and shanty anglers were made once per day. Survey period for both counts and interviews was January 4 through March 26, 2006. 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 incomplete-trip interviews. Interview starting location and direction were randomized daily. Interview forms, information, and techniques used during the winter survey period were the same as those used during the summer survey period.

Estimation methods.–Catch and effort estimates were made by lake section using a multiple-day method (Lockwood et al. 1999). Expansion values ("F" in Lockwood et al. 1999) are given in Table 3. These values are the assumed number of fishing hours within sample days. Effort is the product of mean counts by section for a given period day type (i.e., weekday or weekend), days within the period, and the expansion value for that period. Thus, the angling effort and catch reported here are for those periods and shifts sampled; no expansions were made to include periods or shifts not sampled.

Most interviews (>80%) conducted 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) less 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 the same 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 of catch rate (Rw) 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 incomplete-trip interviews. Estimated variance s_w^2 of the catch rate was calculated as:

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

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

From the angler creel data collected, catch and harvest by species were estimated and angling effort was expressed as both angler hours and angler trips. An angler trip was defined as the period an angler was on the lake (fishing site) and actively fishing. When an angler left the lake or stopped fishing for a significant period of time (e.g., an angler leaving the lake to eat lunch), the trip was considered ended. Movement between fishing spots 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 averaged 1.2 trips per angler day (DNR Fisheries Division unpublished data).

All estimates are given with ± 2 SE, which provided 75 to 95% confidence intervals for estimates assuming the data had a normal distribution and that monthly sample sizes were greater or equal to 10 (Dixon and Massey 1957). All count samples exceeded minimum sample size (10) and two standard errors around effort estimates approximated 95% confidence limits. Most error bounds for catch and release, and harvest estimates also approximated 95% confidence limits. However, error bounds of estimates for rarely caught species were more appropriately described by 75% confidence limits due to severe departure of the data from normality.

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, muskellunge, and smallmouth bass. These data were used to estimate tag loss and to determine the ratio of marked to unmarked fish for single-census abundance estimates.

Based on voluntary tag returns, we were able to determine if harvest occurred outside of our creel survey period. Therefore, harvest was adjusted upward by the percentage of annual tag returns that were reported as harvested during a time of year when we did not survey. Additionally, we further adjusted harvest for sublegal target species that recruited to legal size over the course of the fishing season. This adjusted harvest (H_a) was used for calculating exploitation, which was described in the *Mortality* section.

Results[1]

Fish Community

We collected a total of 5,000 fish of 20 species (Table 4). Total sampling effort was 283 trap-net lifts, 171 fyke-net lifts, and 4 nighttime electrofishing runs. Of the game fish of special interest, we captured 1,057 walleyes, 1,312 northern pike, 1 muskellunge, and 116 smallmouth bass. Other fish species collected were rock bass, silver redhorse, white suckers, greater redhorse, brown bullheads, smallmouth bass, yellow perch, and others. Northern pike composed 26% of the overall catch and walleyes accounted for 21%. Rock bass composed 19% of the catch by number, and mean length of this species was 8.1 in. Another panfish, yellow perch, composed just over 2% of the total catch by number and had a mean length of 8.2 in. Other panfish such as bluegills and black crappies were caught in insignificant numbers, though it should be noted that the timing of the survey and gear types used were more selective for large-bodied fishes. Suckers (including redhorse and white) composed more than 21% of the total catch by number. Other nongame species such as bullheads, bowfin, and

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

gar composed nearly 7% of the total catch. Largemouth and smallmouth bass numbers were less than 3% of the catch. Incidental catches were documented for lake sturgeon, ciscoes, and muskellunge.

One goal of the overall survey was to obtain better information on the Black Lake muskellunge population. This was not accomplished because only one fish was collected. It is our opinion that the survey period was not conducive to muskellunge catches because this species does not inhabit the shallows and local rivers until later in the spring.

The percentages of captured walleye, northern pike, and smallmouth bass that were of legal size were 99, 32, and 96%, respectively (Table 5). The population of spawning walleyes was dominated by 15- to 19-in walleye, with none greater than 26 in. Northern pike were widely distributed among 9- to 42-in groups, with 68% between 21 and 26 in. Large pike (≥ 30 in) were numerically 2% of the total catch for northern pike. Smallmouth bass were predominately in the 14 to 19 inch groups, though fish over 20 in were collected. Male walleyes outnumbered females in our spring survey, which is typical (Carlander 1997). Of all walleyes captured, 89% were male, 11% were female, and less than 0.5% were of unknown sex. These percentages were identical when walleyes of legal size were considered. Of all northern pike captured, 60% were male, 26% were female, and 14% were of unknown sex. Of legal-size northern pike captured, 36% were male, 50% were female, and 14% 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 990 tags on legal-size walleyes (633 reward and 357 nonreward tags) and clipped fins of 5 sublegal walleyes. One of 11 walleyes recaptured during netting was observed to have lost its tag during the spring netting/electrofishing survey; thus, the effective number tagged (M) was 989 and long-term tag loss was calculated as 9.1%. In the entire recapture sample, we observed a total of 181 walleyes on Black Lake, of which 11 were marked (R; had a fin clip, or a tag). We reduced the total recapture sample (C) by 13 (7.2%) to adjust for sublegal fish that grew over the minimum size limit during the fishing season (final C = 168). The estimated number of legal-size walleyes was 7,442 (CV = 0.11) using the multiple-census method and 13,943 (CV = 0.27) using the single-census method (Table 6). The estimated number of adult walleyes was 8,252 (CV = 0.10) using the multiple-census method, and 14,013 (CV = 0.27) using the single-census method.

We placed 346 tags (163 reward and 183 nonreward tags) on legal-size northern pike in Black Lake. Eight northern pike died or lost tags during the spring netting survey so the effective number tagged (M) was 338. We also clipped fins of 746 sublegal northern pike. In the entire recapture sample, we observed a total of 54 northern pike, of which 3 were marked (R; had a fin clip, or a tag). We reduced the number of unmarked northern pike in the single-census recapture sample by 18 (33.3%) to adjust for sublegal fish that grew over the minimum size limit during the fishing season (final C = 36). We observed one of three recaptured northern pike that lost its tag during the various surveys; thus, tag loss rate was calculated as 33%. This tag loss estimate is based on few observations; however, it did not affect population estimates since tagged fish were also observed with a corresponding fin clip. It could, however, influence exploitation estimates because anglers don't report fin-clipped fish. The estimated number of legal-size northern pike was 883 (CV = 0.11) using the multiple-census method and 3,136 (CV = 0.42) using the single-census method. The estimated number of adult northern pike was 2,879 (CV = 0.04) using the multiple-census method and 8,826 (CV = 0.42) using the single-census method (Table 6).

We tagged 104 (M) legal-size smallmouth bass in Black Lake (53 reward and 51 nonreward tags) and clipped fins of 5 sublegal smallmouth bass. No recaptured smallmouth bass were observed to have lost tags or died during the spring netting survey. In the recapture sample, we observed 87 smallmouth bass, of which 5 (R) were marked. We reduced the number of unmarked smallmouth bass by 20 (23.0%) to adjust for sublegal fish that grew over the minimum size limit during the fishing season (C = 67). One out of five recaptured smallmouth bass observed in the various surveys had lost their tag; thus, tag loss was estimated at 20%. The estimated number of legal-size smallmouth bass was 1,093 (CV = 1.01) using the multiple-census method and 1,190 (CV = 0.36) using the single-census method (Table 6).

Growth.–Female walleyes had significantly greater mean lengths at age than males in Black Lake (Table 7). On average, females were at least 1.0 in longer than males (ages 4 and 5) and maximally 5.0 in longer at age 10. 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 Black Lake walleyes of -1.8 compared to statewide averages. Female northern pike had higher mean lengths-at-age than males (Table 8). At their least difference, the average length of females was 0.7 in longer than males (age 2), and at their greatest difference, females were 10.2 in 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 Black Lake northern pike of -0.3 compared to statewide averages. Mean lengths at age were calculated for 87 smallmouth bass from ages 2–9, 11, and 13 (Table 9). The mean growth index for Black Lake smallmouth bass was +2.3.

Mortality.–For walleye, we applied our age-length keys to fish caught in all gear types and we estimated catch-at-age using data from 883 males, 111 females, and 994 total walleyes (Table 10). We used ages 5 and older in the catch-curve analyses to represent the legal-size male population, and ages 6 and older in the catch-curve analyses to represent the legal-size female and total legal-size walleye populations (Figure 5). The catch-curve regressions for walleye were all significant ($P < 0.05$), and produced total instantaneous mortality rates of 0.651 for males, 0.701 for females, and 0.670 for all fish combined (Figure 5). These instantaneous rates corresponded to annual total mortality rates of 48% for males, 50% for females, and 49% for all walleyes combined.

Anglers returned a total of 89 tags (66 reward and 23 nonreward) from harvested walleyes and one tag (reward) from a released walleye in the year following tagging. The creel clerk observed 10 tagged fish during the creel survey period, 5 of which (1 reward and 4 nonreward) were not voluntarily reported caught by the anglers. The reward tag return estimate of annual exploitation for walleye was 11.6% after adjusting for 9.1% tag loss (Table 6). Anglers reported reward tags at a higher rate than nonreward tags (10.4% vs. 6.5%). The reporting rate of nonreward tags relative to reward tags (λ; Pollock et al. 1991) was 62%. The expected number of returns (126) was higher than the number voluntarily returned from harvested fish (89), providing some evidence of nonreporting of walleye tags. Based on all tagged walleyes known to be caught, the reported release rate was 1.1%. The estimated exploitation rate for walleye was 25.8% based on dividing harvest by the multiple-census abundance estimate, and 13.8% based on dividing harvest by the single-census creel survey abundance estimate.

For northern pike, we applied our age-length keys to fish caught in all gear types and we estimated catch at age for 660 males, 290 females, and 1,107 total northern pike, including those fish of unknown sex (Table 10). We used ages 4 and older in the catch-curve analyses to represent the adult male northern pike population (Figure 6), since there were not enough age groups of legal size to estimate mortality for legal northern pike. We chose age 4 as the youngest age because the relative abundance of age-4 fish appeared to be represented in proportion to their expected abundance (Figure 6; Table 10). We used ages 4 and older in the catch-curve analyses to represent the legal-size female northern pike population (Figure 6). We chose age 4 as the youngest age because: 1) average length of female northern pike at age 4 was 24.5 in, so likely most age-4 fish were of legal size at the beginning of fishing season; and 2) relative abundance of fish younger than age 4 did not appear to be represented in proportion to their expected abundance (Figure 6; Table 10). We used ages 5 and older in the catch-curve analyses to represent the total legal-size northern pike population (Figure 6). We chose age 5 as the youngest age because the average length of all northern pike at age 5 was 24.8 in, so likely most age-5 fish were of 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 0.869 for males, 0.861 for females, and 0.962 for all northern pike combined. These instantaneous rates corresponded to annual total mortality rates of 58% for adult males, 58% for legal-size females, and 62% for all northern pike of legal size combined.

Anglers returned a total of 28 tags (8 reward and 20 nonreward) from harvested northern pike, and 10 tags (6 reward and 4 nonreward) from released northern pike in the year following tagging. The creel clerk observed two tagged pike during the creel period of which one reward tag was not voluntarily reported by the angler. The tag return estimate of annual exploitation for northern pike was 12.9%, which was based on reward and nonreward returns because nonreward tags were returned at a higher rate than reward tags (11.2% vs. 5.0%). It was somewhat surprising that the reporting rate for reward tags was actually lower than for nonreward tags, given that our sample size (number of each type tagged) was not especially low. One explanation is that more nonreward tags may have been applied to fish in an area that was more easily exploited, or more heavily fished. There is a chance that this happened because some crews applied a series of tags of one type, before switching to the other type. The reporting rate of nonreward tags relative to reward tags (λ; Pollock et al. 1991) was 222%. The expected number of returns (29) was almost identical to the number voluntarily returned from harvested fish (28), providing some evidence of adequate reporting of northern pike tags. Based on all tagged northern pike known to be caught (reported by angler, or observed in creel survey), the reported release rate for legal-size northern pike was 25.6%. The estimated exploitation rate for northern pike was 39.6% based on dividing harvest by the multiple-census abundance estimate, and 11.1 % based on dividing harvest by the single-census creel survey abundance estimate.

For smallmouth bass, we estimated catch-at-age for 87 fish of all sexes (Table 10). We used ages 6 and older in the catch-curve analyses to represent the legal-size smallmouth bass population (Figure 7). We chose age 6 as the youngest age because the relative abundance of fish younger than age 6 did not appear to be represented in proportion to their expected abundance (Figure 7; Table 10). The catch-curve regression for smallmouth bass was significant ($P < 0.05$; Figure 5), and resulted in a total instantaneous mortality rate of 0.464 and an annual total mortality rate of 37%.

Anglers returned a total of six tags (three reward and three nonreward) from harvested smallmouth bass and four tags (two reward and two nonreward) from released smallmouth bass in Black 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. The reward tag return estimate of annual exploitation for smallmouth bass was 7.2%. Anglers reported nonreward and reward tags at a similar rate (5.7% vs. 5.9%). The reporting rate of nonreward tags relative to reward tags (λ; Pollock et al. 1991) was 104%, but the number of tags voluntarily returned by anglers (6) was less than one half of the predicted number of returns (15) based on the ratio described previously in the **Methods** section. Based on all tagged smallmouth bass known to be caught, the reported release rate was 40%. The estimated exploitation rate for smallmouth bass was 18.5% based on dividing harvest by the multiple-census abundance estimate, and 17.0% based on dividing harvest by the single-census creel survey abundance estimate (Table 6).

Movement.–Because our spring survey was only conducted in Black Lake, we could not detect any movement of walleye, northern pike, or smallmouth bass from Black Lake to other water bodies such as the Upper or Lower Black River during the spawning period. However, based on angler tag returns, 94% of tagged walleyes were recaptured in Black Lake, 5% were caught in the Lower Black River, and 1% (two tag returns) were captured in the Upper Black River, including one in the Moran Channel which is a short channel that is fed by the Upper Black River and empties into Black Lake. It is also known as the Harbor Light Canal, or “minnow hole.” For northern pike, 96% were caught in Black Lake, 2% (one tag return) were caught in the Lower Black River, near Alverno Dam, and 2%

(one tag return) were caught in the Moran Channel. We did not detect any movement of smallmouth bass out of Black Lake based on tag returns.

Angler Survey

Summer.–The clerk interviewed 1,535 boat anglers during the summer 2005 creel survey on Black Lake. Most interviews (94%) were roving (incomplete-fishing trip). Anglers fished an estimated 44,298 hours and made 16,535 trips (Table 11). The total harvest of 13,590 fish consisted of seven different species. Yellow perch were most numerous in catches, with an estimated harvest of 10,135 fish. Anglers harvested 1,625 walleyes and reported releasing 389 walleyes (19% of total walleye catch). Anglers harvested 331 northern pike, and reported releasing 1,403 (81% of total northern pike catch). Anglers harvested 263 smallmouth bass and released 1,680 smallmouth bass (87% of total smallmouth bass catch). Size composition of the released fish was not available.

Winter.–The clerk interviewed 104 open-ice anglers and 643 shanty anglers during the winter portion of the angler survey. Most open-ice (98%) and shanty (86%) interviews were roving type. Open-ice and shanty anglers fished 15,576 hours (Table 12). We were not able to estimate the number of trips during the winter period on Black Lake. A total of 5,172 fish were harvested, and yellow perch were most numerous, with an estimated harvest of 4,653 fish. Anglers released 8,333 yellow perch (64% of total yellow perch catch). Anglers also harvested 271 walleyes and 193 northern pike, and reported releasing 154 northern pike (44% of total northern pike catch) but did not release any walleyes.

Survey totals.–In the periods from April 30 through October 20, 2005 and January 4, 2006 through March 26, 2006, anglers fished 59,874 hours at Black Lake (tables 11 and 12). Of the total fishing effort, 74% occurred in the open-water period and 26% occurred during the ice-cover period. The total harvest was 18,762 fish. The estimated total harvest of yellow perch was 14,788, which was 79% of the total harvest for all species. The estimated total harvest of walleyes was 1,896, or 10% of the total harvest. Estimated harvest numbers of other game fish were 606 pumpkinseeds, 524 northern pike, 384 bluegills, 263 smallmouth bass, 245 rock bass, and 18 muskellunge.

Yellow perch were the predominant species caught (harvested + released) at 47,294, with a resulting catch per hour of 0.79. The total catch of walleyes was 2,285, with a catch rate of 0.038 fish per hour. Walleye catch peaked in June and July as did the catch rate for this species (0.058 fish/h). Anglers released 17% of all walleyes caught, which is a low percentage compared to the average (47%) estimate from 19 large lake surveys. Estimated total catch of northern pike was 2,081, with a resulting catch rate of 0.035 fish/h. Anglers released 75% of northern pike caught. Estimated total catch of smallmouth bass was 1,943, with a resulting catch rate of 0.032 fish/h. Smallmouth bass catch peaked in July.

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 fish released, we assume that a large proportion of the released walleyes and northern pike were sublegal.

We did not survey from October 21 through January 3, because we thought that relatively little fishing occurred during that time of year due to unstable ice conditions which prohibited significant fishing pressure. The majority of April was not surveyed because walleye, northern pike, and smallmouth bass seasons were closed. However, 8 of the 89 tag returns reported for harvested walleyes were caught during these nonsurveyed periods. Thus, the total walleye harvest may have actually been about 9% higher than our direct survey estimate, or 2,066 walleyes. No northern pike or smallmouth bass tag returns were reported during this period (Table 13). The harvest estimates for walleye, northern pike, and smallmouth bas were 1,918, 349, and 203, respectively after adjusting for sublegal fish that recruited to legal size over the course of the angling season.

Five species that we captured during spring netting operations did not appear in the angler harvest: black bullhead, brown bullhead, white sucker, black crappie, and cisco. One species, lake sturgeon, is regulated under a special lottery permit quota system for Black Lake.

Discussion

Fish Community

Fish community surveys and observations for Black Lake date back to the 1930s. Early field investigations, though limited in scope, documented a fish community similar to what is found in Black Lake today. Trap- and fyke-netting is challenging in Black Lake due to the extensive shoal habitat. Short lead lines on nets will tend to catch low numbers of fish and may not be good indicators of the overall fish community (diversity and relative abundance); however, the 2005 mark-recapture abundance estimates provided better information on the fish populations.

In past surveys bluegills, black crappies, and pumpkinseeds were noted as rare and rock bass, northern pike, walleye, and yellow perch were common. Walleyes have always been a component of the Black Lake fish community, although survey catch numbers have varied over time. An intensive fish community survey by the DNR in early 1990s evaluated private walleye stocking efforts in Black Lake. Results showed that natural reproduction overshadowed recent stocking efforts, although fish vulnerability to the survey gear was questionable. A fish community survey later in the decade (1997) found a sustainable walleye population with a variety of year classes present. In general, the fish community was rated as diverse. Since 1997 multiple fall walleye evaluations on Black Lake, primarily examining year-class strength, have documented a couple of good, and several weak year classes (Table 2). Overall, the fish community of Black Lake has displayed consistent species composition over the last 80 years.

In spring 2005, it is likely that more large, mature fish of several species were caught than would normally be caught in surveys conducted later in spring or summer. This includes spring spawning species such as walleye, 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 Black Lake (various species of minnows). For example, 16 species of fish have been collected or observed in Black Lake in other surveys that were not collected in the spring, 2005 survey (see Appendix and Table 4).

The size structure of walleyes in the spring survey (99% legal-size) was high relative to the average (70%) from 19 populations surveyed under the Large Lakes Program (DNR, unpublished data). This was consistent with angler reports at Black Lake which identified low numbers of sublegal walleyes in recent angler catches. Based on past and current surveys, walleyes in Black Lake rarely attain lengths much greater than 27 in.

The size structure of northern pike in the spring survey of Black Lake (32% legal-size) was near the average (28%) for 18 populations surveyed under the Large Lakes Program (DNR, unpublished data). Pike are relatively abundant in Black Lake, and many larger fish are available to anglers along with high numbers of small fish. Northern pike have the ability to reach large size in Black Lake as evidenced by the catch of female pike larger than 40 in. It takes a female northern pike at least 10 years to attain a length of 40 in based on length-age data.

The size structure of smallmouth bass in our spring survey (96% legal size) was much higher than the average (65%) for 17 populations surveyed under the Large Lakes Program. Currently, smallmouth bass in Black Lake have the potential to reach lengths of 20 in. This species is common in Black Lake but in lower relative abundance compared to other nearby large inland lakes.

Male walleyes outnumbered females when all sizes, or when legal-size fish were considered. This is consistent with spring surveys of walleyes in other lakes in Michigan and elsewhere, and is likely due to males maturing at smaller sizes and younger ages than females and also because males spend a longer time on spawning grounds than females (Carlander 1997), making them more vulnerable to being collected in survey gear. The male:female ratio (7.9:1) that we observed was above the average (4.4) when compared with the other 19 large lakes surveyed to date.

For northern pike, males outnumbered females when all sizes were considered (male:female = 2.3:1), but females outnumbered males (male:female = 0.7:1) when legal-size fish were considered. In most (13 out of 18) Large Lake Program surveys where a significant number of northern pike were collected, males composed the largest proportion of adult northern pike, but females were the largest proportion of legal-size northern pike. The male to female sex ratio for adult northern pike (2.3:1) was above the average (1.3:1) that we observed in 18 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 6). For both the single- and multiple-census estimates, the minimum numbers of recaptures for an unbiased estimate were obtained, and the estimates were considered reliable based on the CV. However, the single-census estimate had relatively low precision as a result of the small recapture sample. For example, assuming that the legal-size walleye population was approximately 14,000 fish (single-census estimate), and based on our tagging of around 1,000 fish, the recommended sample (*C* from Petersen formula) in management studies (α = 0.05, P = 0.25; where P denotes the level of accuracy, and 1–α the level of precision) is 845 fish (Robson and Regier 1964). Our corrected recapture sample of 168 fish was well short of this recommendation.

The multiple-census estimates for walleyes were lower than the single-census estimates for both legal-size and adult walleyes (Table 6), consistent with results from most other Large Lakes Program surveys (Clark et al. 2004; Hanchin et al. 2005a, b, c, 2007a; Hanchin and Kramer 2007, 2008a, b). Although 95% confidence limits of the two estimates overlapped, the point estimates were only within the bounds of the corresponding estimate's confidence interval in one of four cases (the multiple-census estimate of adult walleyes was within the 95% confidence interval of the single-census estimate).

The single-census estimate of legal-size walleye abundance was comparable (only 3% lower) to the a priori Michigan model estimate; thus, we would expect the walleye population in Black Lake to have about average abundance compared to lakes in the Michigan model. The population density of walleyes in Black Lake (1.4 per acre) was reasonably close to the average (2.0 per acre) and median (1.6 per acre) for 19 walleye populations surveyed in the Large Lakes Program. With respect to the distribution of density estimates observed thus far in the Large Lakes Program, the median appears to be a better measure of central tendency. Legal-size walleye density during 2004 surveys in nearby Grand Lake was lower at 0.6 fish per acre (Hanchin 2011), as it was for Long Lake at 0.7 fish per acre (Hanchin and Cwalinski 2011). Density was higher during 2001 surveys in Burt Lake at 1.9 per acre (Hanchin et al. 2005b), and in Crooked-Pickerel lakes at 2.1 per acre (Hanchin et al. 2005c). The population density of adult walleye in Black Lake from the single-census estimate (1.4 fish per acre) was identical to that for legal-size walleye, which again indicates the lack of younger walleyes. Adult walleye abundance has averaged 3.2 fish per acre (median = 2.4) in 19 large lakes surveyed thus far as part of the Large Lakes Program.

At the time of this writing, the legal-size and adult walleye populations in Black Lake are likely substantially lower than 1.4 fish per acre due to limited recent recruitment as observed in fall walleye indices (Table 2). The single-census estimate of adult walleye abundance was 38% lower than the a priori Michigan model estimate; thus, it was low with respect to an "average" adult walleye population in Michigan.

We had less success in estimating abundance of northern pike (Table 6). For the multiple-census estimates, the minimum numbers of recaptures were obtained, and the estimates were considered reliable based on the CVs. For the single-census estimates, the minimum number of recaptures (3) was just achieved, and the CVs were slightly higher than the maximum set for reliable estimates. Additionally, based on the number of fish marked, too few fish were recaptured to achieve the target level of precision in the single-census estimates. Assuming that the legal northern pike population was approximately 3,000 fish (single-census estimate), and based on our tagging of around 350 fish, the recommended sample (*C* from Petersen formula) in management studies (α = 0.05, P = 0.25; where P denotes the level of accuracy, and 1–α the level of precision) is 433 fish (Robson and Regier 1964). Our corrected recapture sample of 36 fish was well short of this recommendation.

While the single-census estimates for northern pike abundance were not necessarily reliable, the multiple census estimates were likely biased low. Pierce (1997) found that 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 and concluded that this was due to size selectivity of the sampling gear and unequal vulnerability of fish to nearshore netting. Our multiple-census estimates were 67–72% lower than our single-census estimates, probably for the same reasons. Pierce also concluded that recapturing fish at a later time with a second gear type resulted in estimates that were more valid than those made with a single gear type. Despite some uncertainty about the abundance of northern pike in Black Lake, the population density is likely average or above average relative to other lakes in Michigan. The single-census estimate of legal-size northern pike in this survey converted to a density of 0.3 fish per acre, which is slightly above the average (0.2 per acre) estimated for 18 large lakes in Michigan (range 0.01 to 0.5 fish per acre). Density of adult northern pike (0.9 fish per acre) was equal to the average for Large Lake Program surveys, and was higher than the median density (0.5 per acre).

Craig (1996) gives a table of abundance estimates (converted to density) for northern pike from various investigators across North America and Europe. The sizes and ages of fish included in these estimates varied, but considering only estimates 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. The estimates of numbers of adult northern pike in Black Lake were also for fish age 2 and older, and should be comparable. The lower density we observed may be due to the larger size of Black Lake relative to the small Minnesota lakes that Pierce et al. (1995) surveyed, though limited northern pike spawning habitat in Black Lake could also be a factor.

We had limited success in obtaining abundance estimates for smallmouth bass, likely due to the low number marked. For the multiple-census estimate, the minimum number of recaptures was obtained, but the CV was high. For the single-census estimate, we achieved the minimum number of recaptures and had an acceptable CV; however, the number of fish observed by the creel clerk (67) was well short of the recommended sample (422) to achieve the target level of precision for management studies (Robson and Regier 1964). Aside from the questionable reliability, the multiple- and single-census estimates for smallmouth bass were almost identical (Table 6), and each estimate lies within the other's confidence interval. Both estimates convert to a density of approximately 0.1 smallmouth bass (≥14 in) per acre, which is low compared to nearby large inland lakes. In five Michigan lakes surveyed under the Large Lakes Program, legal-size smallmouth bass density has been 1.0, 0.1, 0.1, 0.5, and 2.0 fish per acre (Hanchin et al. 2007a; Hanchin and Kramer 2007, 2008a;

Hanchin 2011; Hanchin and Cwalinski 2011). Thus, the density for Black Lake likely represents a low density of 14-in smallmouth bass. Despite this, smallmouth bass do well in Black Lake.

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 sampling, marked fish may not have mixed completely with the total population at large, and we did not sample all spawning congregations in this large lake. Alternately, the sampling effort was not randomly distributed over the population being sampled (Ricker 1975); fish moved off the spawning grounds and were excluded from the sampling gear, violating an assumption of the estimate method. In contrast to the multiple-census method, the single-census estimate from the creel survey is more likely to be accurate because sufficient time elapsed for marked fish to fully mix with unmarked fish prior to resampling. Additionally, the validity of the single-census estimate does not depend on sampling all spawning congregations in the initial tagging operation.

Growth.–Mean lengths at age for walleyes from our survey varied from those of previous surveys of Black Lake. The mean growth index ranged from -1.8 to +0.4 based on surveys between 1991 and 2005. (Table 14). Schneider et al. (2000) suggested that growth indices in the range of ±1.0 in are satisfactory for game fish, so recent walleye growth in Black Lake has been slow. Walleye mean lengths at age in 2005 were higher than the state of Michigan average for ages 3 and 4 fish, but mean lengths of fish older than 4 were consistently lower than the state average (Table 14). This may be attributed to higher densities of larger walleye, and lower densities of younger ones. However, differences at older ages may be attributable to differences in aging techniques, and thus should be interpreted with caution. Age interpretation of fish using scales tends to underestimate walleye ages, while other techniques such as using otoliths and spines tend to be more accurate. We used dorsal spines during this survey as aging structures. Walleyes in Black Lake grew about the same as those in Burt Lake and slightly better than walleyes in Grand Lake for fish less than age 9 (Table 14). Based on a small three-fish sample, Black Lake walleyes reached legal size in their third year of life, which is relatively early. No age-1 or age-2 walleyes were collected during the 2005 survey, thus growth rates for these age groups were not attainable.

Mean lengths at age for northern pike from our survey were lower than those from previous surveys of Black Lake (Table 15). Based on the mean growth index, 2005 northern pike growth in Black Lake is near average compared to pike populations statewide. The growth index has been in the normal range (±1.0 in) for pike since 1982. Female pike in Black Lake typically attain legal size (24 in) at age 4, and males attain this size at either age 5 or 6. As with walleye, state averages for northern pike were based entirely on scale aging, which probably overestimated mean lengths for older ages.

Mean lengths-at-age for smallmouth bass in 2005 and 1999 were larger than in 1980 for ages 2–5, and were considerably higher than other nearby Michigan lakes or the state average (Table 16). The growth index of smallmouth bass in Black Lake was +2.3 in.

Mortality.–Total annual mortality of walleye in Black Lake was higher than average, and small adult walleyes had relatively low abundance. In other lakes with good walleye recruitment (Hanchin et al. 2008; Hanchin and Kramer 2008a; Hanchin 2009) age 3 fish comprise a higher portion of spring net catches, but age-3 walleyes were nearly absent in Black Lake. Poor recruitment likely contributed to the relatively low abundance of younger age groups. The 2002 and 2003 year classes appeared to be very weak based on the lack of age-2 and age-3 walleyes during the 2005 survey—no age-2 walleyes (2003 year class) were collected. Despite their lower vulnerability to the sampling gear (due to mesh size), we expected that age-2 walleyes would have been collected if they were present in the system. Further, only seven age-3 walleyes were collected in the entire survey, indicating a very weak 2002 year class as well. Overall, 11 year classes of walleye were represented in the total catch (Table 10). This is at the lower end of the range observed in spawning walleye populations in northern

Michigan, though it is within the level of 10 or more age groups suggested by Schneider et al. (2007) as indicative of healthy walleye populations.

The total annual mortality estimate for Black Lake walleyes (49%) is higher than the average (41%; range=24–57%) from populations (N = 18) surveyed as part of the Large Lakes Program in Michigan. 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. Estimates from other states ranged from 31% in Escanaba Lake, Wisconsin to 70% in Red Lakes, Minnesota. Colby et al. (1979) summarized annual total mortality rates for walleyes from a number of other lakes across North America. These estimates ranged from 13 to 84% for fish age 2 and older, with the majority falling between 35 and 65%. In nearby Grand and Long lakes (Presque Isle County, Michigan), the annual mortality rate for walleyes was relatively high in 2004 at 48% and 57% respectively (Hanchin 2011; Hanchin and Cwalinski 2011). Annual total mortality rate in Burt Lake, Michigan (38%; Hanchin et al. 2005b) was much lower than the Black Lake estimate.

The three estimates of annual exploitation rate of walleye were quite different; 11.6% from tag returns, 25.8% using harvest divided by the multiple-census abundance estimate, and 13.8% 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, and if these occurred to any degree, we would have underestimated exploitation (Miranda et al. 2002). We did not make a true estimate of tag nonreporting, but we attempted to get some measure by offering a $10 reward on half of the tags and comparing return rates of reward to nonreward tags. Reporting rate for reward tags was generally higher than for nonreward tags. Clark et al. (2004) used the same type of 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 62% for Black Lake was below the average (82%) that we have observed in other walleye populations surveyed in the Large Lakes Program. There was almost certainly nonreporting of nonreward tags, but we lack 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, which indicates that nonreporting of reward tags also occurred to some degree. However, the sample of tagged fish observed by the creel clerk was too small to draw convincing conclusions. Additionally, the angler 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. We found additional evidence of nonreporting in that the number of tags voluntarily returned by anglers from harvested walleyes (89) was less than the expected number (126) of returns.

Estimates derived by dividing harvest by abundance resulted in possible upper bounds on a range for angler exploitation. Because of the apparent biases associated with the multiple-census estimates, we believe the exploitation estimate derived using the single-census abundance estimate is more precise. Thus, the true annual exploitation rate of walleye during the 2005–06 angling season was likely in the range of 12–14%. Compared to exploitation rates for walleyes from other lakes (N=19) in our Michigan large lakes surveys, our estimate for Black Lake was near both the average (15%) and median (12%). Serns and Kempinger (1981) reported higher average exploitation rates of 24.6% and 27.3% for male and female walleyes respectively in Escanaba Lake, Wisconsin during 1958–79. In general, exploitation rates vary widely for walleye across its range. For example, Schneider (1978) gave a range of 5–50% for lakes in Midwestern North America, and Carlander (1997) gave a range of 5–59% for a sample of lakes throughout North America. Additionally, exploitation can vary over time for a single water body; in western Lake Erie estimates ranged from 7.5 to 38.8% from 1989 through 1998 (Thomas and Haas 2000).

The reported release rate (1.1%) for legal-size walleyes was similar to the mean (2.1%) and median (1.5%) recently observed in other large lake surveys (N = 11; lower N since we did not start asking this question when the program began). The reported release rates for legal-size walleyes in nearby Grand and Long lakes were 1.5% and 4.2%, respectively. Given that the annual total mortality estimate for the Black Lake walleye population was 49% and fishing plus hooking mortality was around 15%, the estimate for natural mortality would be about 34%.

Annual total mortality of northern pike (62%) in Black Lake was above average. Annual total mortality rates from northern pike populations (N = 19) surveyed as part of the Large Lakes Program in Michigan 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 annual total mortality for northern pike in seven small (<300 acres) lakes in Minnesota at 36–65%. They also summarized annual total mortality for adult northern pike from a number of lakes across North America; estimates ranged from a low of 19% to a high of 91%, with the majority between 35 and 65%. It would be expected that annual total mortality of northern pike in a smaller lake would be high and mortality in larger lakes (such as Black Lake) would be lower. However, Black Lake annual total mortality of pike was higher than expected.

The three estimates of annual exploitation rate of northern pike were quite different; 12.9% from tag returns, 39.6% using harvest divided by the multiple-census abundance estimate, and 11.1% using harvest divided by the single-census abundance estimate. In most Large Lake Program surveys, exploitation derived from the multiple-census abundance estimates have been the highest, likely resulting from the methodological biases (see previous discussion). The exploitation derived from the multiple-census estimate appears too high, and exploitation derived from the single-census estimate appears too low, especially because it is lower than our tag-return estimate of exploitation, which we believe is a minimum. This suggests that we either underestimated harvest, or overestimated the abundance of northern pike using the single-census method. The harvest of northern pike per acre (0.05) was below the average (0.08) observed in other large lake surveys. Conversely, the density of northern pike (0.3 per acre) derived from the single-census estimate was higher than both the mean (0.2 per acre) and median (0.1 per acre) from other large lake surveys, suggesting that the Black Lake density likely was overestimated. This conclusion appears likely given the lower reliability of the single-census estimate due to the low number of recaptures and the poor CV. Although the single-census estimate of legal-size northern pike abundance may have been overestimated, it was likely not as severe as the underestimation using the multiple-census method. Accounting for all potential biases, the true annual exploitation rate of northern pike in Black Lake was likely in the range of 13–20%. Based on this range and our estimate of annual total mortality (62%), it appears that natural mortality causes significantly more mortality than fishing in Black Lake.

Compared to exploitation rates for northern pike from other lakes in Michigan, the estimate from tag returns for Black Lake is about average. The median exploitation rate for northern pike from large lake surveys to date is 15% with a range of 8–31%. Latta (1972) reported northern pike exploitation in two Michigan lakes, Grebe Lake (12–23%) and Fletcher Pond (38%). Pierce et al. (1995) reported rates of 8–46% for fish over 20 in for seven lakes in Minnesota. Carlander (1969) gave a range of 14–41% for a sample of lakes throughout North America.

This was the first attempt to estimate the annual total mortality of smallmouth bass in Black Lake. The estimate of 33% for legal-size fish was on the low end of the range for Midwestern waters reported in the literature. Forney (1961) reported estimates of 52, 58, and 18% annual total mortality for smallmouth bass in Oneida Lake, New York, and Paragamian and Coble (1975) reported 55% mortality for smallmouth bass in the Red Cedar River, Wisconsin. Clady (1975) reported annual 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% annual total mortality of adult smallmouth bass from Anchor Bay of Lake St. Clair. Annual total mortality of smallmouth bass in Black Lake was similar to the few other populations 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), Grand Lake (Hanchin 2011), and Long Lake (Hanchin and Cwalinski 2011) were 39, 25, 45, 36, and 32%, respectively.

Estimates of the annual exploitation rate of smallmouth bass were different; 7.2% from tag returns, 18.5% using harvest divided by the multiple-census abundance estimate, and 17.0% using harvest divided by the single-census abundance estimate. As with walleye and northern pike, we consider the tag return estimate to be a minimum. If the exploitation estimate from tag returns is considered a minimum value, and those estimates derived from harvest divided by abundance as near the maximum, the likely range of exploitation is between 7 and 18%. Compared to exploitation rates for smallmouth bass from other lakes in Michigan and elsewhere, the estimate for Black Lake appears to be low. Latta (1975) reported a range of 9–33% 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, and Paragamian and Coble (1975) reported 29% exploitation in the Red Cedar River, 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 parental stock abundance, and density-independent factors, such as variability of spring water temperatures, influence walleye recruitment. In addition, walleye stocking can affect year-class strength, but stocking success is also 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 Black Lake for only one year, and so could not rigorously evaluate year-class strength. However, some insight about the relative variability of recruitment can be gained by examining the amount of variation explained by the age variable in catch curve regressions. For example, Isermann et al. (2002) used the coefficient of determination from catch curve regressions as a quantitative index of the recruitment variability in crappie populations.

Walleyes collected in Black Lake represented 11 year classes (ages 3 through 13), and the coefficient of determination for the catch curve regression using ages 6–13 (1992–99 year classes) appeared average (R^2 = 0.80; Figure 5) relative to other large lakes. In other walleye populations surveyed as part of the Large Lakes Program to date (N = 19), the catch curve R^2 value has ranged from 0.50 to 0.98, with an average of 0.79. Given that walleyes were not stocked in significant numbers in most years corresponding with year classes we collected, it appears that natural reproduction occurs regularly in Black Lake, though it may have been low in recent years. Recent fall walleye evaluations utilizing night electrofishing lend support to our contention that recent walleye year classes in Black Lake have been weak (Table 2). Natural reproduction of walleyes was typically sufficient to maintain the population in most years but poor year classes will affect the fishery in future years.

Northern pike were represented by 10 year classes (ages 1 through 10) in this survey and the coefficient of determination for the catch curve regression using ages 5–10 (1995–2000 year classes) was high (R^2 = 0.96; Figure 6), indicating low variability in year class strength. In other Michigan northern pike populations surveyed as part of the Large Lakes Program (N = 17) the R^2 has ranged from 0.67 to 0.99, with an average of 0.89.

There were 10 year classes of smallmouth bass (ages 2–9, 11, and 13) found in this survey. The coefficient of determination for the catch curve regression using ages 6–13 (1992–99 year classes) was moderate (R^2 = 0.72) compared to values from other surveys, though we have few lakes for comparison. In six lakes surveyed as part of the Large Lakes Program, the catch curve R^2 values have averaged 0.81, ranging from 0.61 in South Manistique Lake (Hanchin and Kramer 2008a) to 0.91 in Lake Leelanau (Hanchin et al. 2007a).

Movement.–Walleyes remained in Black Lake for the most part, although some moved downstream into the Lower Black River following the spawning season. This downstream movement is found in other Michigan systems with large rivers, such as Muskegon Lake (Hanchin et al. 2007b) and Peavy Pond (Hanchin, in press). Interestingly, 71% of the walleye tag returns from the Lower Black River were caught in the fall (October and November). Previous tagging studies (Eschmeyer 1950; Crowe 1958) reported generally similar movement of walleyes tagged in Black Lake. Based on 136 walleyes tagged in 1942, 19 recoveries were made through 1948, including 58% from Black Lake, 37% from points downstream, and 5.3% (one tag return) from the Upper Black River about 12 miles from the lake (Eschmeyer 1950). In 1956, 93.8% of 112 tag returns came from Black Lake, followed by 2.7% from the Lower Black River, 1.8% from the Upper Black River (one just below Klieber Dam), and 1.8% from Mud Creek (Crowe 1958). Although we did not receive any tag returns from fish that went through, or over Alverno Dam, Eschmeyer (1950) reported three recaptured walleyes (16% of all returns) that migrated from Black Lake downstream past Alverno Dam to the Cheboygan River.

Northern pike demonstrated movement patterns similar to walleye, and the tag return from the Lower Black River caught near Alverno Dam represented the farthest fish movement observed in this study. Movements could not be generalized from the scant tag-return data for smallmouth bass.

Angler Survey

In 2005 the recreational fishery of Black Lake was dominated by yellow perch, followed by walleye, which together composed 87% of the total harvest. The open-water period accounted for 69% of the yellow perch harvest, and harvest was highest in August. Walleye harvest was highest during the open-water period and particularly in June and July when harvest rates were also highest for this species. Total number of walleyes released throughout the creel period was low (389 fish) and was attributed to the low number of sublegal fish in the population. Smallmouth bass were only caught during the open-water period, mostly during June through September. There was a relatively high estimated number of released smallmouth bass (1,680) during the creel survey. Northern pike harvest was low and accounted for less than 3% of the total harvest for all species. Fair numbers of northern pike were released throughout the creel period (1,557 fish) possibly due to the high number of sublegal pike thought to be in the lake based on spring survey catches (Table 5). The highest catch rates of northern pike were in July and August. Considering the number of days in the summer (174) and winter (82) creel periods, the angling effort per day was higher in the summer (255 angler hours per day) than in the winter period (190 angler hours per day). Overall, the fishery of Black Lake was not very diverse, especially in the winter when yellow perch, walleye, and northern pike were the primary species harvested. A few other species provide angling opportunity throughout the year, though not to any large degree. Poor panfish numbers, with the exception of yellow perch, keep harvest diversity low in Black Lake.

Historical comparisons.–The oldest harvest and effort estimates for Black Lake were reported by Laarman (1976). General creel surveys were attempted at the lake during the following periods: 1928–39, 1940–45, 1946–51, 1952–57, and 1958–64; however, the number of anglers interviewed during each of these periods was low (92, 479, 1,298, 1,298, and 1,586, respectively). Overall catch per hour ranged from 0.16 to 0.85 fish per hour. The catch rate from the 2005–06 creel period was 0.96 fish per hour. According to Laarman (1976), yellow perch, rock bass, walleye, and northern pike dominated the catch during the earlier surveys.

Angler effort at Black Lake, estimated from mail surveys, was 40,930 days in 1970, and 55,350 days in 1973. To compare these mail-survey estimates with ours, we used current estimates of the average number of trips per day (1.2 trip/day; DNR Fisheries Division unpublished data), and the average length of a completed trip (5.7 h/trip for open-water period and 6.7 h/trip for ice-cover period) from the 2005 angler survey, and calculated that one angler day should equate to 7.4 or 8.0 angler hours (1.2 · 5.7 or 6.7). Thus, the 1970 and 1973 estimates equate to at least 279,961 and 378,594 hours of fishing effort, respectively, using the smaller trip length. These estimates are much higher than our 2005–06 estimate of 59,874 total angler hours; thus, it appears that either effort has decreased dramatically, or these two methods are not directly comparable, or both.

The estimated annual catch based on the 1970 Black Lake mail survey was 73,640 yellow perch, 6,860 walleye, 840 bass, 6,440 panfish, 5,040 northern pike, 14,000 smelt, and 1,820 brook trout. The reported catch of smelt is likely an error because smelt have never been reported in the lake based on standard surveys and reports. These fish could have been young ciscoes that were mistaken for smelt. The yellow perch total catch estimate (harvest plus throwbacks) from the 2005–06 survey was 47,294 fish. The total walleye catch for the same period was 2,285, and northern pike total catch was 2,081. These three species were all caught in lower numbers in Black Lake in the recent creel period compared to the mail estimates from 1970. The catch of bass (largemouth and smallmouth) was 1,957 fish in the recent creel period which was considerably higher than in 1970. An increase in the catch of bass could be attributed to anglers catching fewer of the preferred species (such as walleye and yellow perch) and incidentally catching more bass. It could also be explained by an increasing smallmouth bass population in Black Lake. Bass thrive in lakes where water clarity has increased due to zebra mussel infestation, which has occurred at Black Lake in the recent decade. It's also possible that there is simply an increased interest in bass fishing by Black Lake anglers.

Comparison to other large lakes.–In addition to the historic creel survey data for Black Lake, comparisons with creel surveys from other large lakes can be useful. Thus far in the Large Lakes Program, we have surveyed 14 lakes and have similar data from an additional 5 water bodies which we will use for comparisons (thus, N=19). We estimated 59,874 angler hours occurred on Black Lake during the 2005–06 creel survey. This corresponds to 5.9 hours per acre, which is well below the median and mean values for other large lakes in Michigan (Table 17). The harvest for Black Lake was 1.9 fish per acre, which is low relative to other large lakes. Michigan lakes with a high harvest per acre (e.g., Muskegon Lake, the Cisco chain, Houghton Lake) generally have popular bluegill/sunfish fisheries that bolster the total harvest.

The estimated walleye harvest from Black Lake was 0.19 fish per acre, which is less than half the average (0.51 per acre) and median (0.45 per acre) for 19 lakes we use in comparison. This is not unexpected because walleye population estimates for Black Lake were relatively low. The highest value from other large lakes was 1.61 fish per acre for South Manistique Lake (Hanchin and Kramer 2008a). The average harvest from six other large Michigan lakes (> 1,000 acres) reported by Lockwood (2000b) 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 gear types and fishing regulations, including a 15 in minimum size limit. The low harvest per acre of walleye in Black Lake is likely due to a combination of low angler effort and current low walleye abundance.

For northern pike, the estimated annual harvest from Black Lake was 0.05 fish per acre. This was also below average compared to other waters in Michigan and elsewhere. The average harvest in sixteen 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 (2000b) was 0.151northern 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 gear types and fishing regulations, including a 24 in minimum size limit. Elsewhere, Pierce et al. (1995)

estimated harvests from 0.7 to 3.6 northern pike per acre in seven smaller Minnesota lakes. These lakes ranged from 136 to 628 acres in size and had no minimum size limits for northern pike. The low harvest of Black Lake northern pike during creel periods is likely attributable to excessive numbers of sublegal fish and low fishing pressure. Despite this, the pike population appears to be near the desired population level for numbers in Black Lake based on angler needs and survey catches.

The smallmouth bass fishery in Black Lake is fair. The total catch (harvest + release) in Black Lake was 1,943 fish, which is below the total annual catch of smallmouth bass in Lake Leelanau (5,792; Hanchin et al. 2007a), Grand Lake (3,559; Hanchin 2011), and Houghton Lake (3,049; Clark et al. 2004), but greater than Crooked and Pickerel lakes (1,300; Hanchin et al. 2005c), and Burt Lake (796; Hanchin et al. 2005b). Annual harvest of smallmouth bass in Black Lake was 0.03 per acre, which is below average compared to other waters in Michigan. The average harvest in other lakes surveyed in the Large Lakes Program (N = 19) was 0.10 smallmouth bass per acre, ranging from 0 in North Manistique Lake (Hanchin and Kramer 2008b) to 0.416 in the Cisco Chain (Hanchin et al. 2008). The average harvest of seven other large Michigan lakes (> 1,000 acres) reported by Lockwood (2000b) 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 smallmouth bass fishery in Black Lake appears to be near the desired population level, but will likely always be a less popular fishery compared to walleye, yellow perch, and northern pike.

Yellow perch are another species that offers considerable fishing opportunity in Black Lake. The estimated annual harvest of yellow perch was 1.5 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 Black Lake was 0.25 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 Black 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

Walleye are the most abundant large predator in Black Lake, despite the fact they are believed to be at lower densities compared to previous years. The walleye fishery in 2005–06 was below average with respect to other large lakes in Michigan. In Black Lake there were an estimated 1.4 legal-size walleyes per acre and anglers harvested 0.19 per acre at a rate of 0.03 per hour fished. These are among the lowest values estimated for large lakes in Michigan. More alarming for Black Lake anglers and managers is the miniscule catch of sublegal fish. Only 389 walleye, most of which are assumed to have been sublegal, were caught and released during the 2005–06 creel survey which suggests the potential for a further decline of legal-size walleye catch in coming years. The walleye population in 2005–06 was likely experiencing a low point as a result of several recent weak year classes. Although weak year classes are likely the cause of the relatively low abundance of young walleye, we were surprised by the high estimate of annual total mortality for larger walleye. 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 Black Lake. Although reports of illegal harvest of spawning fish are anecdotal, fish taken illegally would not be represented in our estimates of fishing mortality, and thus would be mistakenly identified as natural mortality. However, natural mortality could be elevated because high summer water temperatures, as are recorded in Black Lake, can often increase mortality rates, especially in lakes with extensive shoal areas that are susceptible to fast warming. Other factors (fish eating birds, disease, old age, etc.) can also lead to high natural mortality rates. On the other hand, it could be that violations of assumptions with catch curve analysis, which is how this mortality rate was estimated, resulted in an overestimate of annual total mortality. If age 11–13 fish are removed from the catch curve because of low sample sizes at these ages, the resulting mortality dips to 39%. Thus, the mortality estimates are open to some interpretation.

Anecdotal and mail survey evidence suggests that the Black Lake walleye population may have been larger in the past. As stated previously in our report, recruitment of young walleyes has declined in Black Lake in recent years. Natural reproduction has sustained walleyes in Black Lake for most of the last century. Recently, fisheries managers were asked by stakeholders to provide insight into the recent decline of young walleyes in Black Lake. During these interactions, anglers have voiced their opinions as to the reason for this decline. Their list included: poaching, commercial netting of bait and young walleye, cormorants, zebra mussels, and environmental conditions. Often, the reason for a decline in a fishery is the cumulative effect of several factors, even if some factors have greater importance than others. We believe that zebra mussels and unfavorable spring weather conditions have had the most profound effect on recruitment of young walleyes in Black Lake during recent years.

Zebra mussels filter feed on phytoplankton in the water column. Phytoplankton is the main food source of zooplankton, which in turn is necessary for the survival of many young fish, particularly walleyes. Zebra mussels colonized Black Lake and they may have changed not only the water clarity (and walleye feeding patterns), but also planktonic and benthic food web dynamics in the lake.

Changes in plankton communities may have also hindered walleye recruitment at other large water bodies such as Lake Ontario's Bay of Quinte (Hoyle et al. 2008). In other lakes Secchi disk readings have increased following zebra mussel invasion. Long-term monitoring at Black Lake has shown a general increase in water clarity (Tip of the Mitt Watershed Council 2010.) since 1997. Sampling by the same group has shown a significant decline of chlorophyll-a concentration in Black Lake from 1990 through 2005. Chlorophyll-a is the green pigment present in plant life and is necessary for photosynthesis. The amount of chlorophyll-a in the water is linked to the base of the food chain of which all fish (and zebra mussels) depend upon. However, some nearby lakes or water bodies have exhibited large year classes of naturally-reproduced walleyes in the presence of invasive zebra mussels (Saginaw Bay 2004–06; Crooked–Pickerel lakes 2007). Perhaps potential shifts in plankton communities due to zebra mussels have yet to occur in these other water bodies, at least to the extent that walleye reproduction would be negatively affected.

Fish-eating birds, such as cormorants, have been observed on Black Lake in recent years. Avian predation may help explain some of the increased annual total mortality rates for Black Lake walleye, but it is probably not a significant factor. Efforts are ongoing in Michigan to control cormorant populations, particularly through hazing and shooting projects in nearby waters (Thunder Bay, Long and Grand lakes, Les Cheneaux Islands). These efforts are conducted under the authority of the United States Fish and Wildlife Service's depredation order allowing controlled reduction in the number of cormorants.

Poaching is rumored to be a problem for spawning walleyes in and around Black Lake. DNR Law Enforcement Division has been aware of this alleged activity for decades and has responded to tips and complaints in recent years, though with limited success. Walleyes are very susceptible to poaching during the spring, both in the lake and in rivers where fish congregate to spawn. Fishing closures already exist for the tributary reaches in order to protect spawning fish (e.g., Upper Black River from Klieber Dam to Red Bridge [April 1 through June 15]; and Rainy River from North Allis Road to mouth [April 1 through May 14]). In addition, the walleye fishing season does not begin until the end of April to protect many spawning fish.

A fair number of walleyes may migrate into the lower Black River from Black Lake to spawn. It is highly probable that many of the young walleyes produced in the lower river (outlet) do not return to Black Lake because they are unable to pass Alverno Dam.

Finally, some anglers believe the commercial harvest of minnows in the lower Black River is detrimental to the Black Lake walleye population. Proponents of this theory base their argument on two contentions: 1) sorting of seined fish by commercial harvesters does not occur and thus game fish are taken; and 2) minnows are harvested, thus forage is absent for the Black Lake walleye populations. We believe minnow harvest to be very insignificant to the walleye population. Minnows are harvested only in the lower Black River. The number of young walleyes harvested is probably minimal, if not zero. Most young walleyes from the lower Black River would not tend to move back upstream to Black Lake. Additionally, there is no permitted commercial harvest of minnows in Black Lake itself or its tributaries (inlets). Minnow harvest closures on inland water bodies are a rarity in northeast Michigan and the Black Lake closure was established decades ago without any biological basis. Walleye populations have been strong in recent years at nearby water bodies (Grand, Long, and Burt lakes) where commercial minnow harvests occur routinely. Many factors can lead to poor walleye growth including inadequate forage. Walleyes in Black Lake (from the 2005–06 survey) exhibited slightly slower growth than the statewide average, but growth was within the range of natural variation. Poor growth could result from a variety of factors, including density dependent factors, competition with other game fish, lack of appropriate prey, suboptimal temperatures, disease, parasites, etc. During 2005–06, adult walleyes dominated the population and large fish were relatively abundant. As these fish leave the fishery (through harvest and natural mortality), very few young fish will replace them based on the catch of young walleyes in recent years. We believe that walleye growth rates will surge as densities become lower.

The effect of spring weather conditions on the development of walleye year-class strength has been well documented (Busch et al. 1975; Forney 1976; Madenjian et al. 1996). Annual recruitment in wild walleye populations may be highly variable, with year classes often suppressing each other through predation and competition (Chevalier 1973). Many wild walleye populations can have two to four missing year classes successively, followed by one or two very large year classes. Managers have hoped for one or more of these successful year classes in Black Lake in recent years, but it has yet to occur. The reasons for recent wild walleye year class failures may never be understood due to the large number of factors that could be involved. It is also not known what percentage of spawning walleyes use the lake compared to inlet and outlet streams. Success at different sites could be highly variable, and is quite unpredictable.

Northern pike were the second most abundant Black Lake predator fish based on our abundance estimates. The population in Black Lake has an above average density of legal-size northern pike, but an average density of adult northern pike when compared to other large inland lakes in Michigan. Growth of this species is average and overall the population is healthy in Black Lake. Annual total mortality is deemed high, but acceptable. The Black Lake northern pike population will likely fluctuate due to annual variations in spring water levels and flooded vegetation, the preferred spawning habitat for this species.

The third most common large predator in Black Lake was the smallmouth bass. It is common in Black Lake but less abundant than in other nearby large inland lakes. Smallmouth bass do well in clear water as they are visual open-water feeders. The invasion of zebra mussels in Black Lake has increased water clarity and made more suitable habitat for smallmouth bass. In addition, rusty crayfish have now invaded Black Lake and are likely preyed upon by smallmouth bass. Rusty crayfish feed on important aquatic vegetation by shredding. To control rusty crayfish, it will be important to maintain quality smallmouth bass populations (and lake sturgeon) which are top predators on crayfish.

Finally, muskellunge is a relatively rare predator fish in the Black Lake ecosystem. It is popular as a sport fish in the Lower Black and Cheboygan rivers, but many of these riverine muskellunge probably inhabit Black Lake during portions of the year. We only captured one muskellunge during the spring netting survey, but recognize that we surveyed nearly a month prior to when this species inhabits the nearshore areas and would be vulnerable to sampling gear. It is a goal of the local fisheries management unit to get better estimates of the muskellunge population and harvest levels, at least for those fish utilizing the Lower Black River. Spring sampling efforts may be increased in future years targeting for this species.

The number of fish (all species) harvested per acre in Black Lake in 2005–06 was below average for other large lakes in Michigan, which is a result of relatively low fishing effort on a lake with currently low walleye stocks. Black Lake is primarily a fishery for walleye, northern pike, and perch fishery, with less significant muskellunge and smallmouth bass fisheries. The yellow perch fishery in Black Lake is rather good and may become more important in the future if the walleye population declines.

Temporary supplemental stocking may be necessary to maintain the walleye fishery in Black Lake because the current density is at a low level and natural reproduction has been low in recent years. A recent management prescription made by the DNR recommends stocking 150,000 spring fingerling walleyes (1–2”) for three successive years to supplement the population. This plan will be accompanied by fall walleye evaluations (when the fish reach 5–7 in) to determine stocking effectiveness. Stocked walleyes should be marked with oxytetracycline, which will enable managers to track their survival and determine relative contribution of stocked versus wild age-0 fish. Growth rates of adult fish should also be examined over time to look for any possible effects. Stocking of walleyes will be dependent on the ability of the state of Michigan to raise and stock fish while adequately addressing growing concerns regarding the potential to spread pathogens.

Populations of the remaining Black Lake fish community appear to be in good shape, or at least in the range of natural, annual variability. Little is known about the muskellunge population, and more information could be gained about this top predator through occasional targeted sampling and angler reports.

Acknowledgements

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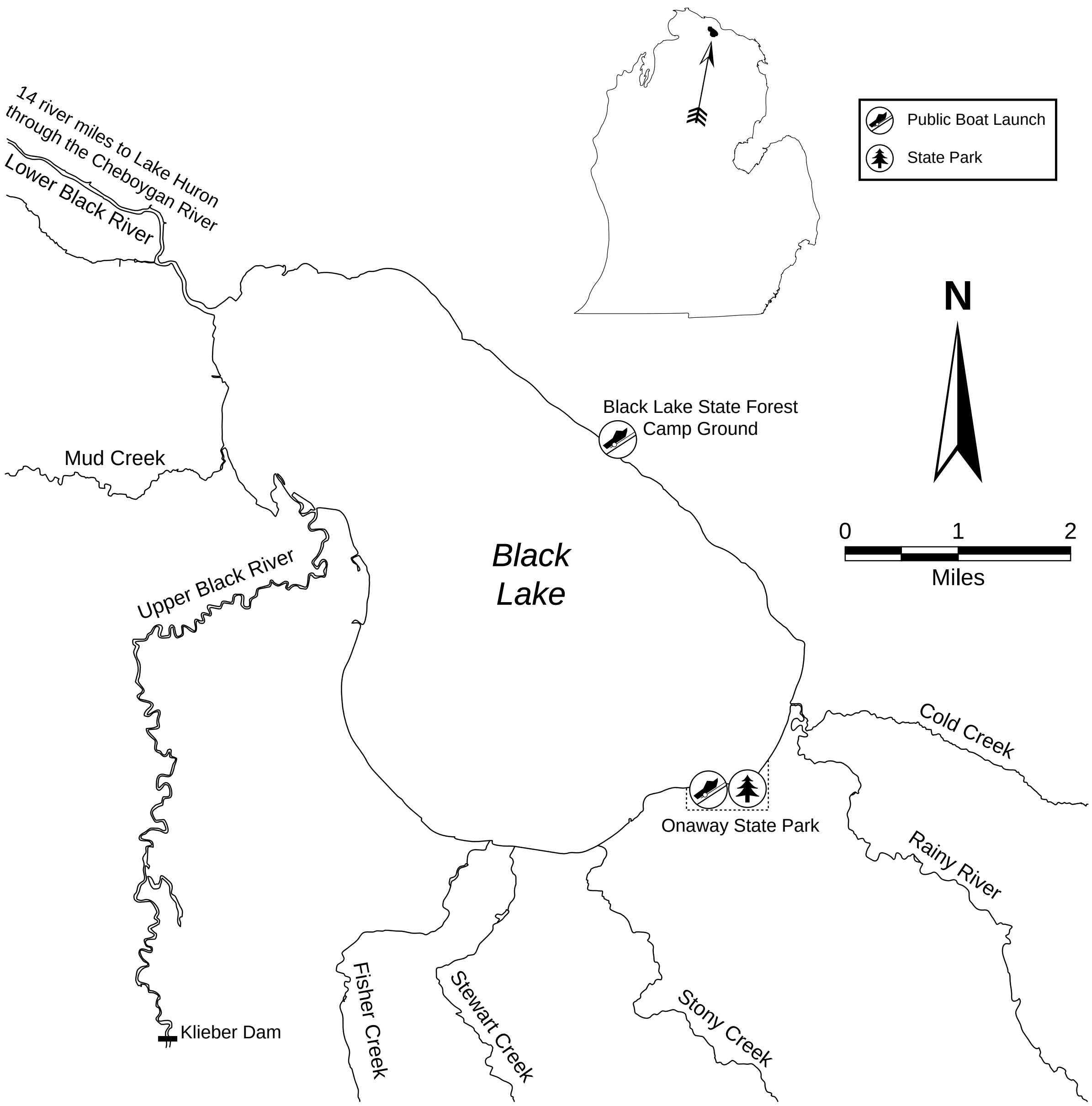

Figure 1.–Map of Black Lake, Cheboygan and Presque Isle counties, Michigan.

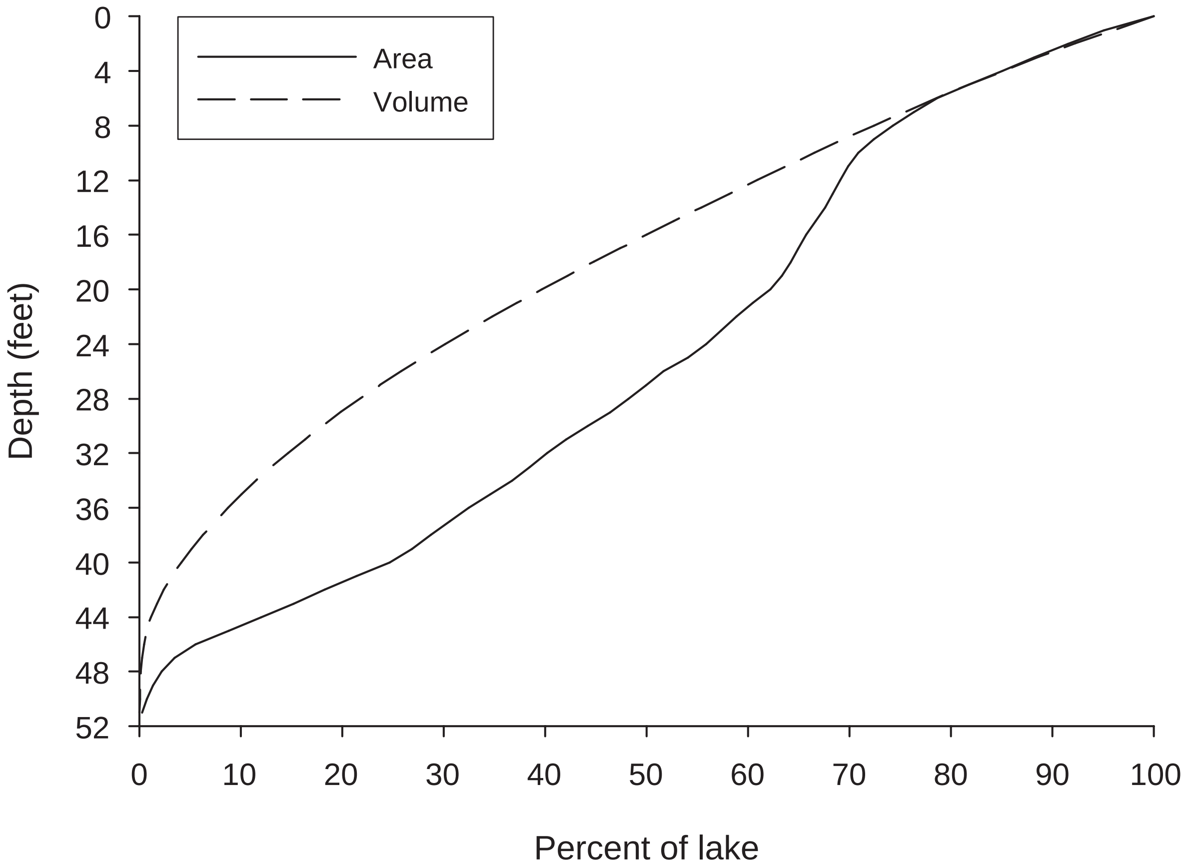

Figure 2.–Figure 2.–Percent of lake surface area or volume equal to or greater than a given depth for Black Lake. Data taken from Michigan Department of Natural Resources Digital Water Atlas (Breck 2004).

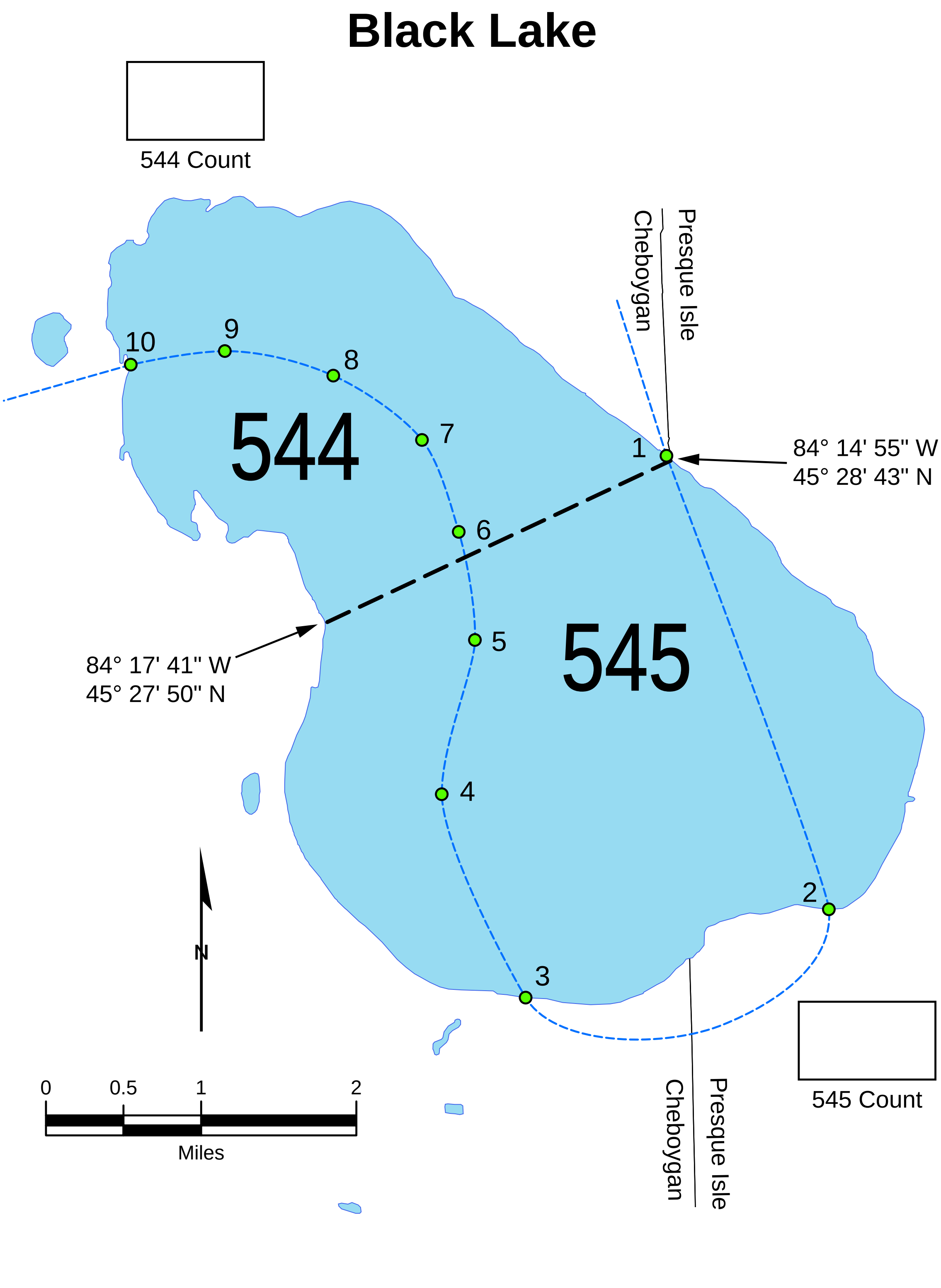

Figure 3.–Counting path and associated count pathway points for the Black Lake summer 2005 and winter 2006 aerial creel surveys. Grids 544 and 545 are separated by a heavy dashed line (between the coordinates 84° 17' 41" W by 45° 27' 50" N on the west side and 84° 14' 55" W by 45° 28' 43" N on the east side), which was used to separate anglers fishing in each grid.

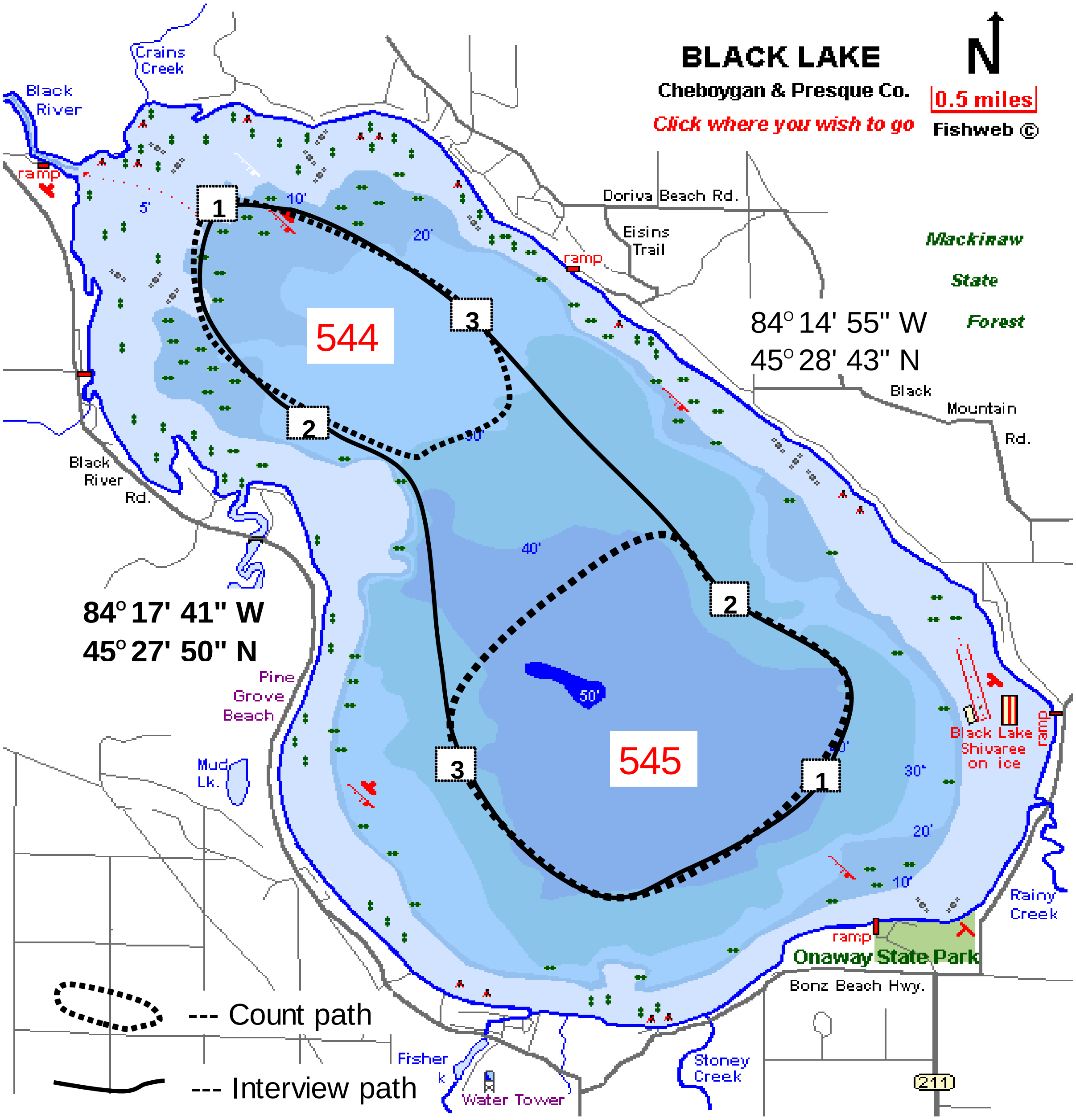

Figure 4.–Creel clerk interview path for the Black Lake angler survey.

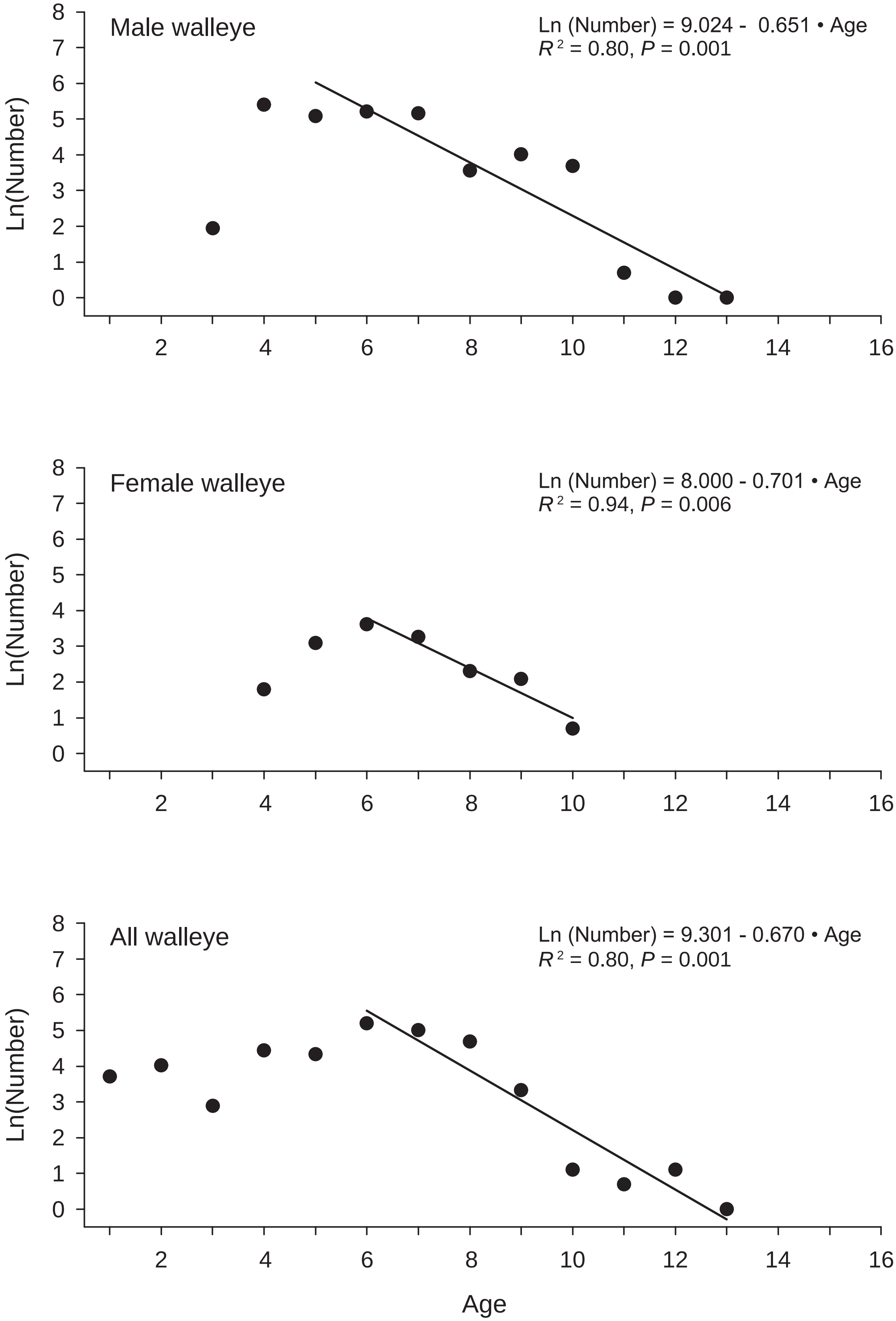

Figure 5.–Plots of ln(number) versus age for legal-sized male, female, and all (including males, females, and unknown sex) walleyes in Black Lake. Lines are plots of regression equations (given beside each graph) for fish of ages fully recruited to sampling gear.

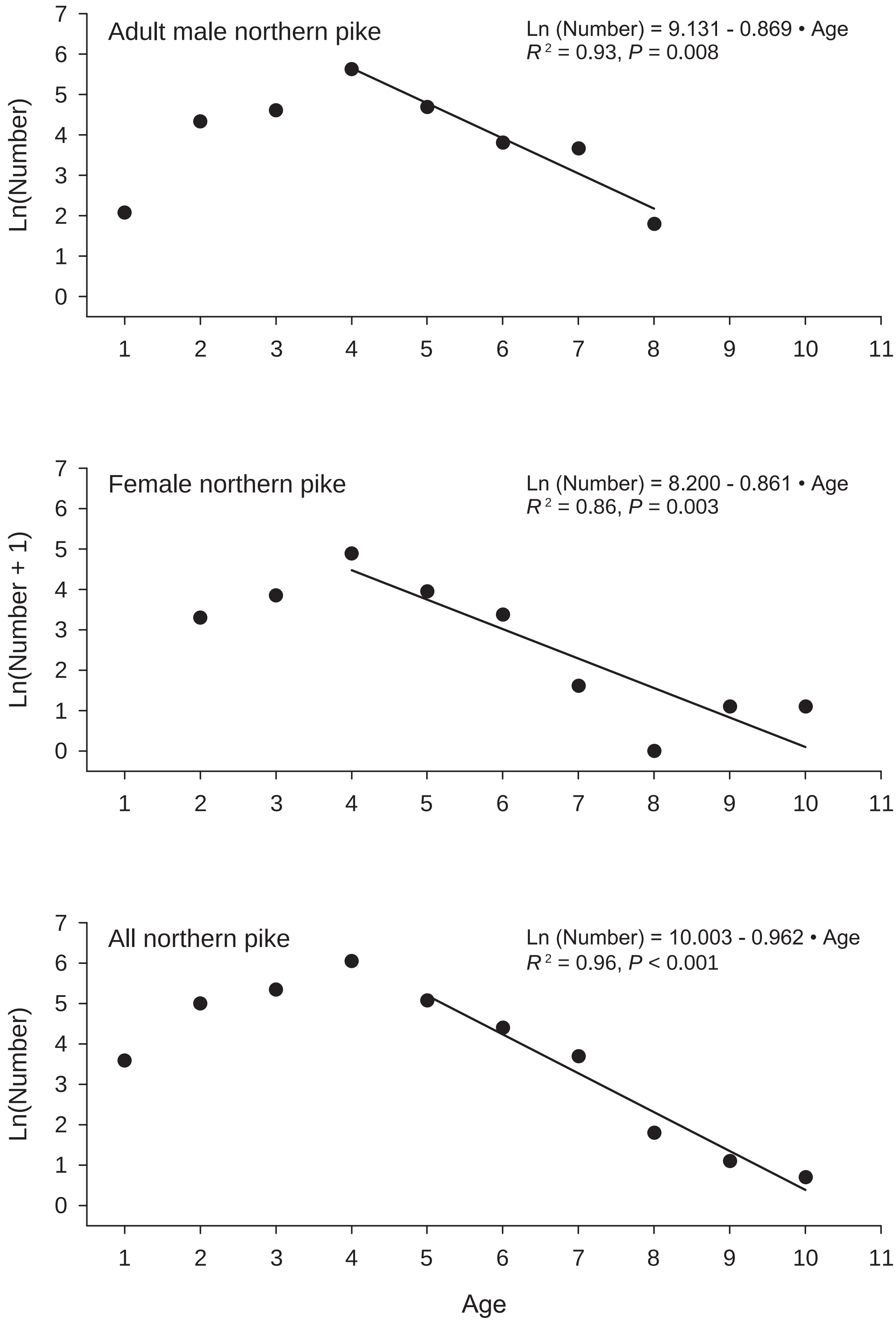

Figure 6.–Plots of ln(number) or ln(number + 1) versus age for adult male, legal-sized female, and legal-sized all (including males, females, and unknown sex) northern pike in Black Lake. Lines are plots of regression equations (given beside each graph) for fish of ages fully recruited to sampling gear.

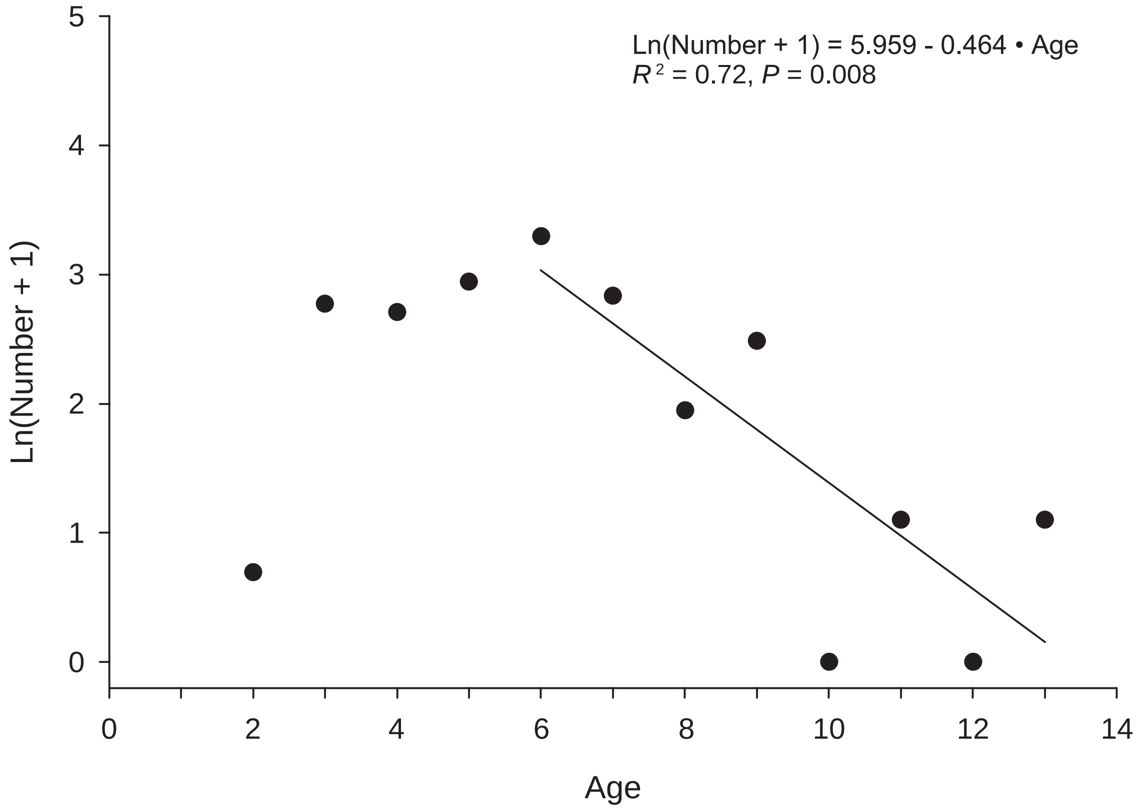

Figure 7.–Plots of ln(number + 1) versus age for legal-sized smallmouth bass in Black Lake. Line is plot of regression (equation given beside graph) for fish of ages fully recruited to sampling gear.

Table 1.–Number and size of walleyes stocked in Black Lake 1989–93. Fish were stocked by the Black Lake Association and the Northern Michigan Walleye Association through a private stocking permit.

Year	Number	Average size (in)
1989	10,000	–
1990	9,650	4.5
1991	11,000	4.5
1992	10,000	3.5
1993	10,000	3.5

Table 2.–Results of index surveys for walleye collected during nighttime electrofishing in the fall in Black Lake.

	Boomshocking		Walleyes collected				
			Age 0			Yearling	Adult
Year	Hours	Miles	N	per h	per mi	N	N
1997	2.33	2.50	3	1.3	1.2	4	5
1998	2.00	1.00	9	4.5	9.0	1	7
2000	9.50	–	45	4.7	–	10	25
2005	3.83	7.62	1	0.3	0.1	1	2
2006	4.00	8.10	0	0.0	0.0	1	5
2007	4.00	8.77	1	0.3	0.1	0	9
2008	4.00	8.03	0	0.0	0.0	0	2

Table 3.–Survey periods, sampling shifts, and expansion value “F” (number of fishing hours within a sample day) for the Black Lake angler survey, spring 2005 through winter 2006.

Survey period	Sample shift (h)		F
April 30–May 31	0600–1430	1230–2100	15
June	0600–1430	1330–2200	16
July	0600–1430	1330–2200	16
August	0600–1430	1230–2100	15
September	0700–1530	1130–2000	13
October 1–20	0700–1530	1030–1900	12
January 4–31	0700–1530	0930–1800	11
February	0700–1530	0930–1800	11
March 1–26	0600–1430	1030–1900	13

Table 4.–Fish collected in Black Lake from 283 trap-net lifts, 171 fyke-net lifts, and 4 electrofishing runs, during April 11–29, 2005.

	Total catch[a]		Mean CPUE[a,b]		Length (in)		Number
Species	N	Percent	Trap net	Fyke net	Range	Average[c]	measured
Northern pike	1,312	26.3	3.5	1.6	9.6–42.0	22.7	1,102
Walleye	1,057	21.1	2.6	1	14.7–25.5	17.6	995
Rock bass	938	18.8	2.3	1.6	3.4–13.4	8.1	836
Silver redhorse	567	11.3	1.7	0.3	13.2–28.2	25.3	512
White sucker	314	6.3	0.8	0.3	7.1–21.2	16.7	314
Greater redhorse	188	3.8	0.5	0.1	15.0–28.3	25.1	188
Brown bullhead	158	3.2	0.4	0.2	5.2–16.2	12.4	158
Smallmouth bass	116	2.3	0.3	0.2	11.4–21.1	17.1	110
Yellow perch	110	2.2	0.3	0.1	2.8–13.8	8.2	110
Bowfin	90	1.8	0.2	0.2	19.0–29.7	25.5	90
Black bullhead	67	1.3	0.2	0.1	7.8–15.1	12.8	67
Pumpkinseed	31	0.6	0.1	<0.1	3.2–8.5	5.9	31
Longnose gar	18	0.4	0.1	0	19.1–38.0	30.6	18
Yellow bullhead	10	0.2	<0.1	<0.1	10.0–14.0	12.5	10
Largemouth bass	8	0.2	<0.1	<0.1	15.0–17.5	16.2	8
Bluegill	7	0.1	<0.1	<0.1	5.1–9.9	6.3	7
Black crappie	3	0.1	<0.1	0	6.8–9.7	7.8	3
Lake sturgeon	3	<0.1	<0.1	0	60.0–66.0[d]	64.0	3
Cisco	2	<0.1	<0.1	0	8.5–12.0	10.3	2
Muskellunge	1	<0.1	<0.1	<0.1	36.6	36.6	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.
[d] Lengths were estimated since fish were caught in the heart of the trap nets.

Table 5.–Number of fish per inch group collected from Black Lake in netting surveys, April 11–29, 2005.

	Species																			
Inch group	Northern pike	Walleye	Rock bass	Silver redhorse	White sucker	Greater redhorse	Brown bullhead	Smallmouth bass	Yellow perch	Bowfin	Black bullhead	Pumpkinseed	Longnose gar	Yellow bullhead	Largemouth bass	Bluegill	Black crappie	Lake sturgeon	Cisco	Muskellunge
2	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–
3	–	–	10	–	–	–	–	–	1	–	–	1	–	–	–	–	–	–	–	–
4	–	–	53	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–
5	–	–	82	–	–	–	3	–	1	–	–	10	–	–	–	4	–	–	–	–
6	–	–	95	–	–	–	1	–	14	–	–	8	–	–	–	2	2	–	–	–
7	–	–	109	–	4	–	2	–	43	–	1	4	–	–	–	–	–	–	–	–
8	–	–	146	–	12	–	2	–	21	–	2	3	–	–	–	–	–	–	1	–
9	2	–	199	–	8	–	4	–	16	–	–	–	–	–	–	1	1	–	–	–
10	1	–	101	–	8	–	16	–	7	–	2	–	–	1	–	–	–	–	–	–
11	4	–	29	–	6	–	20	1	1	–	12	–	–	1	–	–	–	–	–	–
12	8	–	10	–	4	–	33	2	4	–	12	–	–	4	–	–	–	–	1	–
13	6	–	2	1	6	–	45	2	1	–	18	–	–	2	–	–	–	–	–	–
14	4	5	–	–	7	–	29	13	–	–	18	–	–	2	–	–	–	–	–	–
15	15	78	–	–	24	2	2	11	–	–	2	–	–	–	3	–	–	–	–	–
16	17	260	–	3	52	1	1	13	–	–	–	–	–	–	2	–	–	–	–	–
17	29	310	–	2	55	1	–	26	–	–	–	–	–	–	3	–	–	–	–	–
18	37	188	–	1	50	4	–	28	–	–	–	–	–	–	–	–	–	–	–	–
19	44	99	–	1	47	5	–	10	–	1	–	–	1	–	–	–	–	–	–	–
20	76	40	–	6	27	2	–	3	–	–	–	–	–	–	–	–	–	–	–	–
21	128	13	–	5	4	5	–	1	–	6	–	–	–	–	–	–	–	–	–	–
22	189	–	–	37	–	5	–	–	–	6	–	–	–	–	–	–	–	–	–	–
23	186	1	–	102	–	10	–	–	–	7	–	–	–	–	–	–	–	–	–	–
24	141	–	–	170	–	24	–	–	–	12	–	–	–	–	–	–	–	–	–	–
25	103	1	–	131	–	43	–	–	–	16	–	–	–	–	–	–	–	–	–	–

Table 5.–Continued.

Inch group	Species																			
	Northern pike	Walleye	Rock bass	Silver redhorse	White sucker	Greater redhorse	Brown bullhead	Smallmouth bass	Yellow perch	Bowfin	Black bullhead	Pumpkinseed	Longnose gar	Yellow bullhead	Largemouth bass	Bluegill	Black crappie	Lake sturgeon	Cisco	Muskellunge
26	46	–	–	46	–	54	–	–	–	15	–	–	–	–	–	–	–	–	–	–
27	23	–	–	7	–	29	–	–	–	18	–	–	–	–	–	–	–	–	–	–
28	9	–	–	3	–	3	–	–	–	6	–	–	3	–	–	–	–	–	–	–
29	10	–	–	–	–	–	–	–	–	3	–	–	3	–	–	–	–	–	–	–
30	4	–	–	–	–	–	–	–	–	–	–	–	4	–	–	–	–	–	–	–
31	6	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–
32	6	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–
33	2	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–
34	1	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–
35	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
36	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
37	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
38	1	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–
39	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
40	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
41	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
42	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–
66	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–
Total	1,102	995	836	512	314	188	158	110	110	90	67	31	18	10	8	7	3	3	2	1

Table 6.–Estimates of abundance, angler exploitation rates, and instantaneous fishing mortality rates for Black Lake walleye, northern pike, and smallmouth bass using the different methods described in text. Asymmetrical 95% confidence intervals for estimates are given in parentheses, where applicable.

Parameter	Walleye	Northern pike	Smallmouth bass
	Number of legal-size[a] fish		
Multiple-census estimate	7,442 (6,037–9,700)	883 (716–1,152)	1,093 (105–3,468)[b]
Single-census estimate	13,943 (8,090–25,775)	3,136 (1,284–7,749)	1,190 (564–2,722)
Michigan model prediction[c]	14,391 (3,032–68,297)	–	–
	Number of adult[d] fish		
Multiple-census estimate	8,252 (6,777–10,548)	2,879 (2,637–3,170)	–
Single-census estimate	14,013 (8,130–25,905)	8,826 (3,614–21,810)	–
Michigan model prediction[e]	22,423 (4,139–121,470)	–	–
	Annual exploitation rates (%) (adjusted for tag loss)		
Based on reward tag returns	11.6	12.9	7.2
Based on harvest/abundance[f]	25.8 (16.8–34.7)	39.6 (20.1–59.0)	18.5 (0–57.7)
Based on harvest/abundance[g]	13.8 (5.5–22.0)	11.1 (0.5–21.7)	17.0 (1.0–33.1)
Total annual mortality rates	49	62	33

[a] Walleyes ≥15 in, northern pike ≥24 in, and smallmouth bass ≥14 in.
[b] Symmetrical confidence interval was used; lower limit equal to the number of marked fish at large.
[c] Michigan model prediction of legal walleye abundance based on lake area, N = 21.
[d] Fish of legal-size and sexually mature fish of sublegal size on spawning grounds.
[e] Michigan model prediction of adult walleye abundance based on lake area, N = 35.
[f] Multiple-census estimate of legal-size walleye abundance.
[g] Single-census estimate of legal-size walleye abundance.

Table 7.–Weighted mean total lengths (in) and sample sizes by age and sex for walleyes collected from Black Lake, April 11–29, 2005. Standard deviation is in parentheses.

	Mean length			Number aged		
Age	Males	Females	All fish[a]	Males	Females	All fish[a]
3	15.3 (0.4)	–	15.3 (0.4)	3	–	3
4	16.1 (0.3)	17.1 (0.5)	16.3 (0.5)	21	5	26
5	16.9 (0.9)	17.9 (0.4)	17.3 (0.9)	14	13	27
6	17.5 (0.5)	18.7 (1.1)	17.8 (0.9)	11	23	34
7	18.2 (0.6)	19.9 (0.6)	18.7 (0.9)	16	16	32
8	19 (0.6)	20.3 (1.3)	19.3 (1)	5	7	12
9	18.7 (0.9)	20.3 (0.9)	19.1 (1.1)	7	6	13
10	19.5 (0.7)	24.5 (1.4)	19.9 (1.5)	11	2	13
11	20.6 (–)	–	20.6 (–)	1	–	1
12	21.4 (–)	–	21.4 (–)	1	–	1
13	21.1 (–)	–	21.1 (–)	1	–	1

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

Table 8.–Weighted mean total lengths (in) and sample sizes by age and sex for northern pike collected from Black Lake, April 11–29, 2005. Standard deviation is in parentheses.

	Mean length			Number aged		
Age	Males	Females	All fish[a]	Males	Females	All fish[a]
1	15.4 (0.9)	–	13.6 (1.8)	5	–	17
2	18.3 (1.5)	19.0 (1.7)	18.7 (1.8)	33	26	60
3	20.9 (1.5)	22.9 (1.6)	21.8 (1.6)	24	23	47
4	22.5 (1.1)	24.5 (1.6)	23.3 (1.5)	35	47	82
5	23.7 (1.3)	26.0 (1.8)	24.8 (1.8)	21	23	44
6	25.7 (2.4)	28.1 (2.9)	27.0 (2.9)	19	18	37
7	24.2 (1.2)	34.4 (4.2)	25.5 (3.5)	9	4	13
8	25.0 (2.4)	–	25.0 (2.4)	2	–	2
9		32.3 (0.8)	32.4 (0.6)	–	2	2
10		40.4 (3.0)	40.4 (3.0)	–	2	2

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

Table 9.–Weighted mean total lengths (in) and sample sizes for smallmouth bass (males and females combined) collected from Black Lake, April 11–29, 2005. Standard deviation is in parentheses.

Age	Mean length	Number aged
2	11.4 (–)	1
3	14.4 (0.7)	14
4	15.1 (1.2)	12
5	17.0 (0.8)	14
6	17.8 (0.8)	18
7	17.9 (0.6)	11
8	18.3 (0.5)	4
9	19.1 (0.8)	9
10	–	–
11	19.3 (0.0)	2
12	–	–
13	20.7 (0.6)	2

Table 10.–Catch at age estimates by sex for walleye, northern pike, and smallmouth bass from Black Lake, April 11–29, 2005. Ages assigned to fish collected from all gear types using age-length keys.

		Walleye			Northern pike			Smallmouth bass
Age	Year class	Males	Females	All fish[a]	Males	Females	All fish[a]	All fish[a]
1	2004	–	–	–	8	–	36	–
2	2003	–	–	–	76	26	148	1
3	2002	7	–	7	100	46	209	15
4	2001	223	6	229	277	131	423	14
5	2000	161	22	183	109	51	159	18
6	1999	183	37	220	45	28	81	26
7	1998	175	26	201	39	4	40	16
8	1997	35	10	45	6	–	6	6
9	1996	55	8	63	–	2	3	11
10	1995	40	2	42	–	2	2	–
11	1994	2	–	2	–	–	–	2
12	1993	1	–	1	–	–	–	–
13	1992	1	–	1	–	–	–	2
14	1991	–	–	–	–	–	–	–
15	1990	–	–	–	–	–	–	–
Total		883	111	994	660	290	1,107	111

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

Table 11.–Angler survey estimates for summer 2005 from Black Lake. Survey period was from April 30 through October 20, 2005. Two standard errors are given in parentheses.

Species	Catch per hour	Month: Apr–May	Jun	Jul	Aug	Sep	Oct	Season
		Number harvested						
Bluegill	0.0087	0	237	47	82	17	0	384
	(0.0072)	(0)	(290)	(74)	(98)	(35)	(0)	(317)
Northern pike	0.0075	81	105	54	82	10	0	331
	(0.0042)	(85)	(121)	(65)	(84)	(19)	(0)	(183)
Pumpkinseed	0.0137	0	584	22	0	0	0	606
	(0.0154)	(0)	(679)	(45)	(0)	(0)	(0)	(680)
Rock bass	0.0055	0	128	113	4	0	0	245
	(0.0048)	(0)	(149)	(147)	(9)	(0)	(0)	(210)
Smallmouth bass	0.0059	0	58	109	54	43	0	263
	(0.0036)	(0)	(61)	(114)	(76)	(46)	(0)	(157)
Walleye	0.0367	104	510	747	227	37	0	1,625
	(0.0122)	(91)	(268)	(386)	(157)	(32)	(0)	(505)
Yellow Perch	0.2288	0	1,921	1,915	4,705	800	794	10,135
	(0.0823)	(0)	(1,337)	(1,341)	(2,647)	(846)	(715)	(3,438)
Total harvest	0.3068	185	3,542	3,008	5,155	906	794	13,590
	(0.0885)	(125)	(1,564)	(1,412)	(2,656)	(848)	(715)	(3,569)
		Number released						
Bluegill	0.0029	0	0	128	0	0	0	128
	(0.0034)	(0)	(0)	(152)	(0)	(0)	(0)	(152)
Gar	0.0017	0	0	45	31	0	0	76
	(0.0025)	(0)	(0)	(91)	(61)	(0)	(0)	(109)
Largemouth bass	0.0003	0	0	0	14	0	0	14
	(0.0005)	(0)	(0)	(0)	(22)	(0)	(0)	(22)
Muskellunge	0.0001	3	0	0	0	0	0	3
	(0.0001)	(6)	(0)	(0)	(0)	(0)	(0)	(6)
Northern pike	0.0317	53	114	658	393	128	58	1,403
	(0.0143)	(43)	(96)	(503)	(311)	(92)	(64)	(611)
Pumpkinseed	0.0374	0	10	1,123	517	8	0	1,658
	(0.0289)	(0)	(21)	(1,171)	(480)	(15)	(0)	(1,266)
Rock bass	0.0147	0	112	438	51	4	46	652
	(0.0126)	(0)	(225)	(495)	(77)	(8)	(68)	(554)
Smallmouth bass	0.0379	0	224	736	175	533	12	1,680
	(0.0140)	(0)	(197)	(473)	(118)	(263)	(20)	(588)
Walleye	0.0088	108	0	105	137	39	0	389
	(0.0056)	(126)	(0)	(105)	(162)	(79)	(0)	(244)
Yellow Perch	0.5457	11	2,620	5,193	10,548	3,490	2,311	24,173
	(0.1568)	(21)	(1,630)	(2,090)	(5,101)	(2,049)	(1,616)	(6,314)
Total released	0.6812	175	3,081	8,426	11,865	4,202	2,427	30,177
	(0.1684)	(135)	(1,661)	(2,551)	(5,138)	(2,070)	(1,619)	(6,526)
Total (harvested + released)	0.9880	360	6,623	11,434	17,020	5,109	3,221	43,766
	(0.2053)	(184)	(2,281)	(2,916)	(5,784)	(2,237)	(1,770)	(7,438)
Angler hours		4,952	8,002	15,401	10,009	4,099	1,836	44,298
		(1,833)	(1,719)	(3,597)	(2,598)	(1,086)	(951)	(5,300)
Angler trips		1,674	2,969	5,729	4,200	1,352	610	16,535
		(681)	(870)	(1,744)	(1,467)	(438)	(372)	(2,597)

Table 12.–Angler survey estimates for winter 2006 from Black Lake. Survey period was from January 4, 2006 through March 26, 2006. Two standard errors are given in parentheses.

Species	Catch per hour	Month: Jan	Feb	Mar	Season
		Number harvested			
Bowfin	0.0012	18	0	0	18
	(0.0024)	(37)	(0)	(0)	(37)
Longnose Gar	0.0008	0	13	0	13
	(0.0012)	(0)	(19)	(0)	(19)
Muskellunge	0.0012	18	0	0	18
	(0.0024)	(37)	(0)	(0)	(37)
Northern pike	0.0124	112	66	15	193
	(0.0068)	(69)	(66)	(22)	(98)
Redhorse	0.0003	5	0	0	5
	(0.0006)	(10)	(0)	(0)	(10)
Walleye	0.0174	186	29	57	271
	(0.0115)	(149)	(32)	(75)	(170)
Yellow Perch	0.2987	2,585	1,425	643	4,653
	(0.1213)	(1,079)	(1,044)	(582)	(1,610)
Total harvest	0.3320	2,924	1,533	715	5,172
	(0.1259)	(1,092)	(1,046)	(587)	(1,622)
		Number released			
Northern pike	0.0099	79	14	61	154
	(0.0080)	(89)	(24)	(78)	(121)
Yellow Perch	0.5350	5,470	1,038	1,825	8,333
	(0.2000)	(2,141)	(636)	(1,252)	(2,560)
Total released	0.5449	5,550	1,052	1,886	8,487
	(0.2013)	(2,142)	(636)	(1,255)	(2,563)
Total (harvested + released)	0.8769	8,474	2,584	2,600	13,659
	(0.2698)	(2,405)	(1,225)	(1,385)	(3,033)
Angler hours		8,718	4,915	1,942	15,576
		(2,141)	(2,103)	(1,412)	(3,316)
Angler trips		NA	NA	NA	NA

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

Month	Species		
	Walleye	Northern pike	Smallmouth bass
Apr	0 (0)	0 (0)	0 (0)
May	2 (2.2)	12 (31.6)	0 (0)
Jun	31 (34.4)	13 (34.2)	2 (20.0)
Jul	12 (13.3)	8 (21.1)	2 (20.0)
Aug	7 (7.8)	0 (0)	1 (10.0)
Sep	4 (4.4)	1 (2.6)	4 (40.0)
Oct	5 (5.6)	0 (0)	1 (10.0)
Nov	6 (6.7)	0 (0)	0 (0)
Dec	0 (0)	0 (10.0)	0 (0)
Jan	15 (16.7)	3 (7.9)	0 (0)
Feb	3 (3.3)	1 (2.6)	0 (0)
Mar	5 (5.6)	0 (10.0)	0 (0)
Total	90	38	10

Table 14.–Mean total lengths (in) of walleyes (males and females combined) from the 2005 survey of Black Lake compared to previous surveys at Black Lake or other lakes. Number aged in parentheses.

		Lake/Survey month and year						
	State	Black					Burt	Grand
Age	average[a]	Apr 2005[b]	Aug 1999[c]	May 1997[c]	Oct 1991[b]	Jun 1972[c]	Apr 2001[b]	Apr 2004[b]
1	7.1		10.7 (9)				6.8 (3)	7.3 (15)
2	10.4		13.6 (2)	10.6 (2)	11.6 (3)	13.8 (9)	11.0 (14)	11.8 (47)
3	13.9	15.3 (3)	15.6 (8)	14.6 (5)	14.4 (16)	15.1 (18)	14.1 (64)	13.6 (26)
4	15.8	16.3 (26)	17.1 (10)	15.7 (8)	15.6 (14)	16.1 (53)	16.1 (34)	14.8 (29)
5	17.6	17.3 (24)	17.9 (1)	16.6 (9)	17.6 (28)	18.2 (1)	17.3 (22)	15.3 (20)
6	19.2	17.8 (34)		17.9 (11)	19.7 (10)	18.7 (2)	17.8 (65)	16.5 (40)
7	20.6	18.7 (32)		18.9 (9)	20.2 (–)		19.0 (44)	17.2 (40)
8	21.6	19.4 (12)			21.1 (5)		19.4 (14)	18.3 (54)
9	22.4	19.1 (13)			22.3 (5)		20.7 (13)	20.3 (14)
10	23.1	20.0 (13)			22.4 (2)		21.8 (12)	20.6 (5)
11		20.6 (1)			23.0 (3)		20.3 (7)	23.3 (4)
12		21.4 (1)		26.4 (1)	23.7 (3)		21.5 (7)	
13		21.1 (1)					21.9 (7)	22.5 (8)
14							22.1 (2)	24.1 (2)
15							23.0 (4)	24.4 (4)
16							21.3 (1)	
17							22.4 (1)	
18							22.7 (2)	
19								
20							22.2 (1)	
Mean growth index[d]		-1.8	+0.4	-0.7	-0.3	-1.2	-0.8	-2.0

[a] Jan–May averages from Schneider et al. (2000), aged using scales.
[b] Fish aged using spines.
[c] Fish aged using scales.
[d] The mean deviation from the statewide quarterly average.

Table 15.–Mean total lengths (in) of northern pike (males and females combined) from the 2005 survey of Black Lake compared to previous surveys at Black Lake and other lakes. Number aged in parentheses.

		Lake/Survey month and year						
	State	Black						Fletcher Flood
Age	average[a]	Apr 2005[b]	Aug 1999[c]	May 1997[c]	Oct 1991[c]	May 1982	Jun 1976[c]	May 2005[b,c]
1	11.7	13.6 (17)	17.4 (9)		17.8 (15)	14.5 (4)	14.8 (2)	14.0 (1)
2	17.7	18.8 (60)	20.7 (11)	18.5 (24)	19.9 (22)	18.0 (25)	18.6 (13)	20.5 (26)
3	20.8	21.8 (47)	24.8 (4)	20.7 (22)	23.2 (39)	20.6 (37)	20.6 (30)	22.1 (37)
4	23.4	23.2 (82)	24.8 (1)	23.5 (42)	25.7 (13)	23.2 (23)	23.3 (8)	27.5 (52)
5	25.5	24.6 (44)		26.2 (15)	29.4 (1)	25.4 (11)	26.8 (2)	28.6 (28)
6	27.3	26.8 (37)	28.2 (1)	28.7 (9)	31.2 (4)	29.4 (3)		31.6 (14)
7	29.3	25.3 (13)		30.7 (2)		30.0 (4)		
8	31.2	25.3 (2)			34.7 (2)	34.2 (3)	33.6 (1)	
9		32.3 (2)		34.7 (1)		37.0 (2)	35.6 (1)	
10		40.4 (2)		36.3 (3)				
11				41.3 (1)				
Mean growth index[d]		-0.3	+0.7	+0.6	-0.2	+0.2	-1.3	+2.9

[a] Jan–May averages from Schneider et al. (2000), aged using scales.
[b] Fish aged using spines.
[c] Fish aged using scales
[d] The mean deviation from the statewide quarterly average.

Table 16.–Mean total lengths (in) of smallmouth bass (male and females combined) from the 2005 survey of Black Lake compared to other surveys. Number aged in parentheses.

		Lake/Survey month and year						
	State	Black			Grand	Hubbard	Long	Douglas
Age	average[a]	Apr 2005[b]	Aug 1999[c]	May 1980[c]	Apr 2004[b]	May 2006[c]	Apr 2004[c]	Jun 2000[c]
1	3.8		7.6 (20)			3.9 (1)		5.5 (10)
2	7.5	11.4 (1)	12.4 (3)		8.8 (53)	9.4 (14)		8.3 (31)
3	10.8	14.2 (14)	14.4 (2)	11.6 (13)	10.9 (73)	11.5 (26)	11.5 (14)	11.1 (8)
4	12.6	15.1 (12)	15.4 (4)	12.4 (13)	13.9 (32)	13.7 (48)	12.7 (32)	13.7 (13)
5	14.4	17.0 (14)	16.8 (6)	15.6 (22)	15.6 (23)	15.1 (33)	14.1 (27)	15.4 (3)
6	15.3	17.8 (18)		17.0 (7)	16.3 (17)	16.2 (22)	15.2 (14)	16.7 (4)
7	16.3	17.9 (11)		17.9 (9)	17.4 (15)	17.1 (33)	16.2 (20)	17.6 (3)
8	17.3	18.4 (4)		18.6 (2)	17.4 (6)	18.0 (18)	16.9 (6)	18.0 (1)
9	18.1	19.1 (9)		19.2 (4)	18.1 (9)	18.5 (15)	16.8 (8)	19.0 (5)
10	18.9	19.3 (2)		20.0 (3)	17.6 (2)	19.0 (9)	17.9 (13)	19.7 (2)
11					18.5 (7)		18.4 (10)	
12					19.0 (7)			
13		20.7 (13)			18.9 (5)		18.6 (5)	
14					19.2 (2)		18.4 (4)	
Mean growth index[d]		+2.3	+0.7	+2.5	+0.8	+0.9	-0.3	+0.2

[a] Jan–May averages from Schneider et al. (2000), aged using scales.
[b] Fish aged using spines.
[c] Fish aged using scales
[d] The mean deviation from the statewide quarterly average.

Table 17.–Comparison of recreational fishing effort and total harvest on Black Lake to estimates from other selected Michigan lakes. Lakes are listed from highest to lowest total fishing effort.

				Angling effort (h)		Fish harvested (number)		
Lake	County	Size (acres)	Survey period	Total	Per acre	Total	Per hour	Per acre
Houghton	Roscommon	20,075	Apr 2001–Mar 2002	499,048	24.9	386,287	0.77	19.2
Cisco Chain	Gogebic, Vilas	3,987	May 2002–Feb 2003	180,262	45.2	120,412	0.67	30.2
Muskegon	Muskegon	4,232	Apr 2002–Mar 2003	180,064	42.5	184,161	1.02	43.5
South Manistique	Mackinac	4,133	May 2003–Mar 2004	142,686	34.5	43,654	0.31	10.6
Burt	Cheboygan	17,395	Apr 2001–Mar 2002	134,205	7.7	68,473	0.51	3.9
Lake Leelanau	Leelanau	8,607	Apr 2002–Mar 2003	112,112	13.0	15,464	0.14	1.8
Big Manistique	Luce, Mackinac	10,346	May 2003–Mar 2004	88,373	8.5	71,652	0.81	6.9
Black	Cheboygan, Presque Isle	10,113	Apr 2005– Mar 2006	59,874	5.9	18,762	0.31	1.9
Crooked and Pickerel	Emmet	3,434	Apr 2001–Mar 2002	55,894	16.3	13,665	0.24	4.0
Michigamme Reservoir	Iron	6,400	May 2001–Feb 2002	52,686	8.2	10,899	0.21	1.7
Long	Presque Isle, Alpena	5,342	Apr 2004–Mar 2005	34,894	6.5	7,004	0.20	1.3
Grand	Presque Isle	5,822	Apr 2004–Mar 2005	33,037	5.7	10,623	0.32	1.8
Bond Falls Flowage	Ontonagon	2,127	May–Oct 2003	21,182	10.0	3,193	0.15	1.5
North Manistique	Luce	1,709	May 2003–Mar 2004	10,614	6.2	7,603	0.72	4.4
Average				114,638	16.8	68,704	0.46	9.5
Median				74,124	9.3	17,113	0.32	4.0

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Appendix

Appendix 1–Fish species collected in Black Lake in past and current fish surveys.

Common name	Scientific name
Black bullhead	*Ameiurus melas*
Black crappie	*Pomoxis nigromaculatus*
Blacknose shiner	*Notropis heterolepis*
Blackside darter	*Percina maculata*
Bluegill	*Lepomis macrochirus*
Bluntnose minnow	*Pimephales notatus*
Bowfin	*Amia calva*
Brook trout	*Salvelinus fontinalis*
Brown bullhead	*Ameiurus nebulosus*
Cisco	*Coregonus artedi*
Common shiner	*Luxilus cornutus*
Greater redhorse	*Moxostoma valenciennesi*
Green sunfish	*Lepomis cyanellus*
Iowa darter	*Etheostoma exile*
Johnny darter	*Etheostoma nigrum*
Lake sturgeon	*Acipenser fulvescens*
Lake whitefish	*Coregonus clupeaformis*
Largemouth bass	*Micropterus salmoides*
Longnose gar	*Lepisosteus osseus*
Mimic shiner	*Notropis volucellus*
Muskellunge	*Esox masquinongy*
Northern logperch	*Percina caprodes*
Northern pearl dace	*Margariscus nachtriebi*
Northern pike	*Esox lucius*
Pumpkinseed	*Lepomis gibbosus*
Rock bass	*Ambloplites rupestris*
Sand shiner	*Notropis stramineus*
Sculpin sp.	*Cottus sp.*
Silver lamprey	*Ichthyomyzon unicuspis*
Silver redhorse	*Moxostoma anisurum*
Smallmouth bass	*Micropterus dolomieu*
Spottail shiner	*Notropis hudsonius*
Walleye	*Sander vitreus*
White sucker	*Catostomus commersonii*
Yellow bullhead	*Ameiurus natalis*
Yellow perch	*Perca flavescens*