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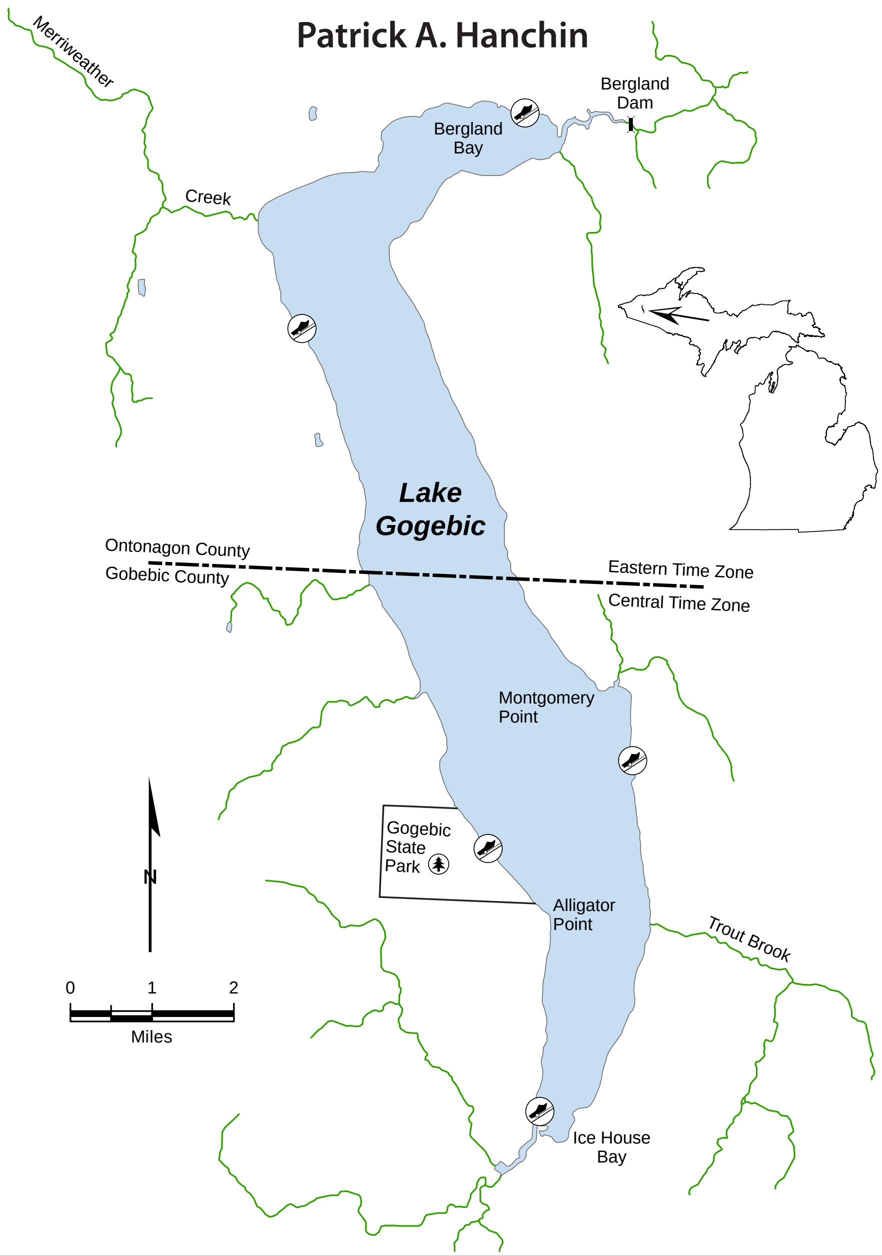
The Fish Community and Fishery of Lake Gogebic, Gogebic and Ontonagon Counties, Michigan in 2005-06 with Emphasis on Walleye, Northern Pike, and Smallmouth Bass

Patrick A. Hanchin



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Michigan Department of Natural Resources
Fisheries Special Report 58, 2011

The Fish Community and Fishery of Lake Gogebic, Gogebic and Ontonagon Counties, Michigan in 2005-06 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 Lake Gogebic, Gogebic and Ontonagon counties, Michigan from April 2005 through March 2006. This work was part of the Large Lakes Program, which is the assessment and monitoring program for fish communities and fisheries in Michigan's largest inland lakes (Clark et al. 2004).

The Large Lakes Program has three primary objectives. The first objective is to produce indices of abundance and estimates of annual harvest and fishing effort for walleye *Sander vitreus*, northern pike *Esox lucius*, smallmouth bass *Micropterus dolomieui*, and muskellunge *Esox masquinongy*. Because these species support valuable fisheries, the second goal is to produce growth and mortality statistics to evaluate the effects of fishing on these species. This involves targeted sampling to collect, sample, and mark sufficient numbers of fish. We selected walleye, northern pike, and smallmouth bass as target species in this survey of Lake Gogebic. The third goal is to evaluate the suitability of various statistical estimators for use in large lakes. For example, comparisons were made among four types of abundance and three types of exploitation rate estimators in this survey of Lake Gogebic. The Large Lakes Program will maintain consistent sampling methods over lakes and time, which will allow the evaluation of differences in fish population and harvest statistics among lakes or changes within a lake over time. Lake Gogebic was the sixteenth lake to be surveyed as part of the Large Lakes Program.

Study Area

Lake Gogebic is a natural lake in Gogebic and Ontonagon counties, Michigan with a watershed of approximately 160 square miles (Eschmeyer 1941a). Reports of the surface area vary from source to source. Eschmeyer (1941a) reported 14,781 acres, Hanes (1961) and Laarman (1976) reported 12,800 acres, FERC (2003) reported 14,080 acres at a maximum operating level of 1,296.2 ft, and Breck (2004) reported 13,127 acres. One goal of the Large Lakes Program is to compare various measures of productivity among lakes, such as number of fish per acre or harvest per acre, so an accurate measure of lake size is important. Thus far in the Large Lakes Program, we have used lake acreages derived using computerized digitizing equipment and USGS topographical maps (Breck 2004). Breck (2004) overlaid the boundaries of lake polygons from a Geographical Information System with aerial photos of the lakes using ArcView©, and the two matched well.

The Lake Gogebic watershed is within the Western Upper Peninsula ecoregion (Eagle et al. 2005). This ecoregion is primarily forested (81%) and wetlands (11%), with some agricultural land (2%), urban land (2%), and a mix (4%) of grassland, shrubland, and alvar (limestone plain with thin soil and sparse vegetation). Forest types include northern hardwoods, aspen, pines, and lowland conifers. The geology of the region consists of igneous and metamorphic bedrock of the Precambrian Shield. Numerous exposures of Precambrian bedrock are found throughout the ecoregion. The ecoregion contains several extensive outwash plains, which contain soils of acidic sand and gravels that have little organic material. The relatively nutrient-poor, rocky, acidic soils result in water bodies with generally low productivity.

Lake Gogebic is fed by the Slate River, Gillis, Bingham, Hendrick, Merriweather, Knute, and Montgomery creeks, and Trout Brook (Figure 1). Lake Gogebic is connected to Sun Dance Lake via the Slate River and Pelton Creek, to Cup Lake via Trout Brook, and to Victoria Reservoir via the West Branch of the Ontonagon River. Although Victoria Reservoir is connected to the Ontonagon River, there is no upstream fish passage over Victoria Dam.

The water level of Lake Gogebic is controlled, in part, by operation of Bergland Dam on the West Branch of the Ontonagon River near the mouth of Lake Gogebic. The dam was constructed in 1906 by the Victoria Copper Mining Company to provide for seasonal storage for the downstream Victoria Reservoir, which housed a hydraulic power plant for mining. Disputes over the water level on Lake Gogebic began the year after construction of the dam (for fear of the mill flooding during the spring melt), and continued for about a century. A legal lake level was established in 1961; however, disputes between the power company, property owners, and the DNR continued through the 1990's, and were ultimately resolved with the relicensing of the Bond Falls Project (FERC project no. 1864) in 2003. Today, the dam is owned and operated by the Upper Peninsula Power Company (UPPCo). The dam is approximately 179 ft long and 4 ft high, situated between concrete retaining walls (UPPCo 1987). It is constructed of 24 bays, each approximately 7 ft wide, with wooden stoplogs between steel I-beams (FERC 2003). Water level elevations are maintained between 1,293.7 and 1,296.2 ft throughout the year (FERC 2003). The average annual outflow is 169 cfs, with average monthly flows ranging from 77 cfs in August to 321 cfs in April (FERC 2003). Currently, the UPPCO maintains specific seasonal and monthly minimum, maximum, and end-of-the-month target reservoir elevations and year-round minimum instream flows (ranging from 30 cfs to 50 cfs, depending on the time of the year). Mean and maximum depths of the lake are 21 and 35 ft, respectively, and 29% of the surface area is less than 15 ft deep (Figure 2).

Lake Gogebic has approximately 33 miles of shoreline including islands, which is largely developed with private residences. Eschmeyer (1941a) reported around 200 cottages, though there were approximately 450–500 homes and cottages (counted from Google Earth© satellite image; http://earth.google.com) in 2008. At least 25 species of aquatic vegetation were identified in Lake Gogebic (Eschmeyer 1941a), but recent vegetation surveys were not available. There are numerous public access sites on the lake, including the Lake Gogebic State Park, Bergland Township Park, Ontonagon County Park, Gogebic County Park, and a DNR public access site on the southeastern shore. Most shoal area has sand and gravel substrate, and organic sediments are more common in deeper areas. Cobble and small boulders are prevalent on the eastern shore, and are scattered through other parts of the lake. Aquatic vegetation is not abundant in Lake Gogebic, and is limited by the stained water to shoal areas. Shallow bays and flooded areas near inlets have the most abundant aquatic vegetation.

Lake Gogebic rarely stratifies thermally, and does so only during extreme summer heat. Eschmeyer (1941a) reported secchi disk depths ranging from 2 to 9 feet, and in August of 1974 secchi disk depth was 10 ft (DNR Fisheries Division, unpublished data). Eschmeyer (1941a) reported adequate and equal levels of dissolved oxygen from the surface to the bottom. Similarly, in 1973 dissolved oxygen ranged from 12 mg/L at the surface to 6 mg/L at the bottom (DNR Fisheries Division, unpublished data), and in 1974 dissolved oxygen ranged from approximately 6.3 mg/L at the surface to 6.0 at the bottom (26 ft).

Eschmeyer (1941a) reported abundant invertebrates in Lake Gogebic, which were largely comprised of mayfly nymphs, small clams, and midge larvae. The composition of the invertebrate fauna has not been studied extensively in recent years, though large mayfly hatches remain common. Additionally, mystery snails (*Ampullaria sp.*) have been recently found in Lake Gogebic, and there was a die-off in 2006. These snails are popular in the aquarium trade, and may have been introduced through the release of unwanted pets. Although the effects of mystery snails have yet to be determined, it appears they may displace native snails and alter aquatic food webs (Gunderman and Baker 2008). The fish community of Lake Gogebic includes species typical of mesotrophic lakes in this northern, forested region. Families of fish include, but are not limited to, *Catostomidae, Centrarchidae, Cottidae, Cyprinidae, Esocidae, Lotidae, Ictaluridae, Percidae,* and *Salmonidae (including subfamily Coregoninae)*.

Throughout the history of fisheries management on Lake Gogebic, public concerns have been considerable, and substantial time and effort have been put forth to deal with these problems, whether real or perceived. Although the range of concerns is extensive and often amusing (one letter objected to Lake Gogebic walleye fry being sold "all over the world"), the recurring focus is on the low number of walleyes and yellow perch, and the small size of walleye. Laarman (1976) provided a list of early (1900 to 1945) fish stocking in Lake Gogebic, which included the following species: walleye, northern pike, muskellunge, lake trout, smallmouth bass, largemouth bass, yellow perch, black crappie, and bluegill. Since then, walleyes have been stocked repeatedly, and there have been numerous attempts at forage fish introductions in Lake Gogebic (Table 1). There have been twenty-three State of Michigan Master Angler awards taken from Lake Gogebic from 1990–2005, including nineteen yellow perch, two black crappies, one rock bass, and one walleye.

Methods

Fish populations in Lake Gogebic were sampled with fyke nets April 13–28, 2005. Fyke nets were 6 ft x 4 ft with 3/4-in stretch mesh and 70- to 100-ft leads. Nets were located to target walleye and northern pike (nonrandomly), though efforts were made to cover the entire lake. Duration of net sets ranged from 1–3 nights, but most were 1 night. Latitude and longitude were recorded for all net locations using handheld global positioning systems (GPS). In addition to the spring survey, we conducted a standardized (Wehrly et al., in press) summer survey using fyke nets, trap nets, gill nets, seines, and electrofishing gears.

Fish Community

We described the status of the fish community in terms of species present, catch per unit effort (CPUE), percent by number, and length frequencies. Mean CPUE in fyke nets was calculated 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). We calculated the percentages by number of fish collected in each of three feeding guilds: 1) species that are primarily piscivores; 2) species that are primarily pelagic planktivores and/or insectivores; and 3) species that are primarily benthivores. These indices will be used to compare fish communities among lakes or within the same lake over time, especially in the future when more large lake surveys using similar methods are available for comparison. Of the species collected, we classified walleye, northern pike, smallmouth bass, and burbot as piscivores; rock bass, pumpkinseed, yellow perch, black crappie, golden shiner, common shiner, creek chub, and cisco as pelagic planktivores-insectivores; and white sucker, black bullhead, and brown bullhead as benthivores.

Walleye, Northern Pike, and Smallmouth Bass

Size structure and sex ratio.–Total lengths of all walleye, northern pike, and smallmouth bass were 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 work crew. Crews ensured that lengths were taken over the course of the survey to account for any temporal trends in the size structure of fish collected. Size-structure data for target species (walleye, northern pike, and smallmouth bass) only included fish on their initial capture occasion. Walleye and northern pike with flowing gametes were classified as male or female; fish with no flowing gametes were classified as unknown sex. We were unable to accurately determine the sex of smallmouth bass due to the timing of the survey. Comparison of size structure data was made using a one-way analysis of variance.

Abundance.–We estimated the abundance of adult walleyes and northern pike, legal-size walleyes, northern pike, and smallmouth bass, and yellow perch (≥7 in) using mark-recapture methods. Adult fish were defined as those greater than legal size, or less than legal size, but of identifiable sex by the extrusion of gametes. Legal-size walleye (≥15 in), northern pike (≥24 in), and smallmouth bass (≥14 in) were fitted with monel-metal jaw tags (National Band and Tag© size 10 and 12). Yellow perch were marked with a left pelvic fin clip. Tagged fish were also marked by clipping the left pelvic fin in order to assess tag loss. Reward ($10) and nonreward tags were applied in an approximate 1:1 ratio. Large tags (size 16) that were used on large northern pike (≥36 in) were all nonreward. All marked fish were released away from the nets, toward the center of the lake.

Initial tag loss was assessed during the marking period as the proportion of recaptured fish of legal size without tags. This tag loss was largely caused by entanglement with nets, and thus was not used to adjust exploitation estimates. Newman and Hoff (1998) reported similar netting-induced tag loss. 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-recapture data, one derived from marked-unmarked ratios during the spring netting survey (multiple census) and the other derived from marked-unmarked ratios from the angler survey (single census). For the multiple-census estimates, we used the following Schumacher-Eschmeyer formula for daily recaptures, from Ricker (1975):

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

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

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

U_d = number of unmarked fish caught during day d;

R_d = number of recaptures during day d;

M_d = number of marked fish available for recapture at start of day d;

d = day (ranging from d_1 to d_n).

The variance formula was,

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

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

Variance of 1/N is:

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

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

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

For the single-census estimates, the ratio of marked-unmarked fish was obtained by the creel clerk in the companion angler survey and by technicians during the standard summer netting survey of Lake Gogebic. We used the Chapman modification of the Petersen method with the minimum number of recaptures necessary for an unbiased estimate set a priori at three (Ricker 1975):

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

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

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

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

R = number of recaptures in second sample.

The variance formula was:

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

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

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

N_a = estimated number of adult walleye 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 = single-census estimate of legal-size walleye or northern pike.

Variance was calculated as:

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

There were several prior abundance estimates for walleye in Lake Gogebic to help gauge how many to mark (Table 2). Additionally, we used three regression equations, one developed from Wisconsin lakes, and two from Michigan lakes, to provide estimates of walleye abundance. These regressions predict adult or legal-size walleye abundance based on lake size and were derived from historic abundance estimates made in each state over the past 20–25 years. The following equation for adult walleye in Michigan was based on 31 abundance estimates:

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

where N is the estimated number of adult walleyes and A is the surface area of the lake in acres. For Lake Gogebic, the equation gives an estimate of 29,458 adult walleyes, with a 95% prediction interval (Zar 1999) of 5,377 to 161,378. The equation for adult walleyes in the Treaty-ceded territory of Wisconsin was based on 185 estimates:

$$\log_e(N) = 01.5923 + 0.9489 \times \log_e(A),\ R^2 = 0.56, \qquad P < 0.0001,$$

where N is the estimated number of adult walleye and A is the surface area of the lake in acres. The equation gives an estimate of 39,753 walleyes, with a 95% prediction interval of 12,812 to 123,348 for Lake Gogebic. The equation for legal-size walleye in Michigan was based on 32 estimates:

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

where N is the estimated number of legal-size walleyes and A is the surface area of the lake in acres. The equation gives an estimate of 18,579 legal-size walleyes, with a 95% prediction interval of 3,877 to 89,037 for Lake Gogebic. Based on all of the existing abundance estimates, we thought that marking a minimum of 5,000 legal-size walleyes would be sufficient. We did not set tagging goals for northern pike or smallmouth bass, but simply tagged all legal-size fish encountered 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 the time of marking and fish growth occurred during the recapture period, it was necessary to reduce the number of unmarked fish by the estimated number that recruited to legal size during the recapture period. For example, to make this adjustment for walleye we determined the annual growth of slightly sublegal fish (i.e., 14.0–

14.9-in fish) from mean length-at-age data. We then divided by the length of the growing season in months (6; Schneider et al. 2000) 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 angler survey. The largest size of sublegal walleye 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 angler survey resulting in a final ratio of marked to unmarked fish. This final ratio was used to make the single-census abundance estimate.

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

Growth.–We used dorsal spines to age walleye and smallmouth bass, and dorsal fin rays to age northern pike because they do not require sacrificing fish, are easy to collect, and are more accurate than scales for aging older fish. Otoliths have been shown to be the most accurate and precise aging structure for older walleye (Heidinger and Clodfelter 1987; Koscovsky and Carline 2000; Isermann et al. 2003) and otoliths or cleithra for northern pike (Casselman 1974; Harrison and Hadley 1979), but collecting these structures would have required killing fish, which would greatly reduce the number of marked fish at large. Results from several studies comparing aging structures for walleye agreed that spines were quicker to remove than scales, but they did not agree that spines were more accurate than scales (Campbell and Babaluk 1979; Kocovsky and Carline 2000; Isermann et al. 2003). Errors in ages from spines were often related to misidentifying the first annulus in older fish (Ambrose 1983; Isermann et al. 2003). There is also considerable disagreement as to whether spines or scales were more precise for walleye age estimation. Erickson (1983) and Campbell and Babaluk (1979) found that spines were more precise, Belanger and Hogler (1982) found spines and scales were equally precise, and Kocovsky and Carline (2000) found scales were more precise. Because northern pike older than 6 years are notoriously difficult to age with scales (Carlander 1969), we used dorsal fin rays. Studies have demonstrated that fin rays are a valid aging structure for a number of species (Skidmore and Glass 1953; Ambrose 1983), including northern pike (Casselman 1996), but no comparisons have been made to statistically compare accuracy and precision of fin rays to other aging structures for northern pike. Sample size goals were 20 male and 20 female fish per inch group for walleye and northern pike, and 20 per inch group for smallmouth bass.

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 40–80x magnification with transmitted light and were photographed with a digital camera. Two technicians independently aged samples, and ages were considered final when independent estimates were in agreement. Samples in dispute were aged by a third technician. Disputed ages were considered final when the third technician agreed with one of the first two. Samples were discarded if three technicians disagreed on age, though occasionally an average age was used when ages assigned to older fish (≥ age 10) were within ±10% of each other.

After a final age was identified for all samples, age-length keys (Devries and Frie 1996) were constructed and weighted mean lengths-at-age were calculated. Mean lengths-at-age were compared to those from previous surveys of Lake Gogebic 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. In addition, mean length-at-age data were fit to a von Bertalanffy growth equation using nonlinear regression, and the total length at infinity (L_∞) was estimated for use as an index of growth potential. All growth curves were forced through the origin.

Mortality.–Catch-at-age was calculated for walleyes, northern pike, and smallmouth bass and total annual mortality rates were estimated using catch-curve analyses with assumptions described by

Ricker (1975). The goal was to estimate total mortality for fish of legal size for comparison with fishing mortality, which was only estimated for fish of legal size. When choosing age groups to be included in the analyses, several potential problems were considered. First, an assumption of catch-curve analysis is that the mortality rate is uniform with age over the full range of age groups. Fish were collected with gears different from those used in the fisheries and the size (age) of recruitment in the fisheries was controlled by minimum-size-limit regulations. For fish smaller than the minimum size limit (MSL), mortality is M+H; for larger fish, mortality is M+H+F, where M, H, and F are natural, hooking (from catch and release), and fishing mortality, respectively. Thus, from the standpoint of uniformity in mortality, age groups used in a single catch curve should contain fish that are either all smaller than, or all larger than the minimum size limit in the fishery, or the minimum size acceptable to anglers in the absence of a minimum size limit. Because walleye and northern pike exhibit sexual dimorphism (Carlander 1969, 1997), we computed separate catch curves for males and females. Finally, walleye and northern pike were collected in the act of spawning, so we had 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 only included age groups that were judged to be mostly mature, which was based on their relative abundance, mean length-at-age, and percent maturity by size.

Angler exploitation was estimated using three methods: 1) the percentage 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 observed in the angler survey that had lost tags (fin clip and no tag) divided by all fish observed in the angler survey that had been tagged, including fish that had lost their tag. Standard errors were calculated assuming a binomial distribution (Zar 1999).

In the first method, exploitation rate was estimated as the percentage of reward tags returned by anglers, adjusted for tag loss. We made the assumption that mortality was negligible and that near 100% of reward tags on fish caught by anglers would be returned. Tag returns were encouraged with a monetary reward ($10) denoted on approximately 50% of the tags. Tag return forms were made available at boater access sites, at DNR offices, and from the clerk working on the lake. Additionally, tag return information could be submitted online at the DNR web site (http://www.michigandnr.com/taggedfish/). All tag-return data were entered into the database for verification against data collected during the tagging operation. Letters were sent to all anglers with information on the length and sex of the tagged fish, and the location and date of tagging. Return rates were calculated separately for reward and nonreward tags, and separate exploitation rates were calculated by inch group and sex. Minimum sample size (number tagged) was set at 100 for each inch group, with the intention of combining inch groups that did not meet the minimum sample size into a “plus” group (i.e., 20 in and above).

Although we did not truly assess nonreporting, we did compare the actual number of tag returns to the expected number (X) based on the ratio:

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

N_t = Number of tags observed in creel;

N_c = Number of fish observed in creel;

H = Total expanded harvest of species.

Individual tags observed by the creel clerk were verified to see if they were subsequently reported by anglers; however, this is not a true estimate of nonreporting because there is the possibility that anglers believed the necessary information was obtained by the creel clerk during the interview, and further reporting to the DNR was unnecessary. Release rates for legal-size fish were estimated from tag returns that indicated (via check box) fish were released.

In the second and third methods, exploitation was calculated as the estimated annual harvest from the angler survey divided by the multiple- and single-census abundance estimates for legal-size fish. For proper comparison with the single-census abundance of legal-size fish as existed in the spring, the estimated annual harvest was adjusted for fish that would have recruited to legal size over the course of the angler survey. This adjustment was based on the percentage of fish observed in the angler survey that were determined to have been sublegal at the time of the spring survey (See *Abundance* subsection of the *Methods* section). Confidence limits (95%) were calculated for these exploitation estimates assuming a normal distribution, and summing the variances of the abundance and harvest estimates.

Recruitment.–We obtained population data for fish in Lake Gogebic during only one year, and so could not rigorously evaluate year-class strength. However, we suggest that some insight about the relative variability of recruitment can be gained by examining the amount of variation explained by the age variable (R^2) in the 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.

Movement.–Fish movement during the spring survey was evaluated by comparing the distance between points of capture and recapture. We used the Haversine formula to calculate great-circle distances between two points on a sphere from their latitudes and longitudes (Sinnott 1984). Fish movements were also assessed in a descriptive manner by examining the location of angling capture versus the location of initial capture at tagging. Capture locations provided by anglers were often vague; thus, statistical analysis of distance moved would be questionable. Instead, we identified conspicuous movement, such as to another lake or connected river.

Angler Survey

Fishing harvest seasons during this survey were May 15, 2005–February 28, 2006 for walleye and northern pike, and May 27 through December 31, 2005 for smallmouth and largemouth bass. Minimum size limits were 15 in for walleye, 24 in for northern pike, 14 in for smallmouth and largemouth bass, and 42 in for muskellunge. Daily bag limit was five fish in any combination of walleyes, northern pike, smallmouth bass, or largemouth bass, and one for muskellunge. Harvest was permitted all year for other species present and no minimum size limits were imposed. The daily bag limit for yellow perch was 50. The daily bag limit for "sunfish", including black crappie, bluegill, pumpkinseed, and rock bass was 25 in any combination. The daily bag limit for lake whitefish and lake herring was 12 in combination. Direct contact angler surveys were conducted during the open-water period – May 15 to September 30, 2005, and the ice-cover period – December 22, 2005 through March 27, 2006.

Field methods.–A progressive-roving design was used for both the open-water and ice-cover periods (Lockwood 2000b). One clerk working from a boat or snowmobile conducted angler interviews. During the open-water period, fishing boats were counted from an airplane, and during the ice-cover period open-ice anglers and occupied shanties were counted by the clerk working from a snowmobile. Both weekend days and three randomly-determined weekdays were selected for counting and interviewing; no holidays were sampled. One of two possible count orders was randomly selected each scheduled day. Counting began at Marker 1 and proceeded along the path ending at Marker 8, or counting began at Marker 8 and proceeded along the path ending at Marker 1 (Figure 3; Table 3). Time of count was randomized to cover daylight times within the sample period.

Interview starting time, location, and direction were randomized daily. For example, the clerk may have started interviewing at 3:00 pm, at the top of section 120, moving in a southerly direction

(Figure 3). Minimum fishing time prior to interview (incomplete-trip interview) was 1 h (Lockwood 2004; Clark et al. 2004). All roving interview data were collected by individual angler to avoid party size bias (Lockwood 1997), though the number of anglers in each party was recorded on one interview form for each party. Although this survey was designed to collect roving interviews, completed-trip interviews were noted. Interview information collected included: date, fishing mode, start time of fishing trip, interview time, species targeted, bait used, number of fish harvested by species, number of fish caught and released by species, length of harvested walleyes, northern pike, and smallmouth bass, and applicable tag numbers. One of two shifts was selected each sample day for interviewing (Table 4).

Estimation methods.–Catch and effort estimates were made using a multiple-day method (Lockwood et al. 1999). Expansion values ("F" in Lockwood et al. 1999) are the number of hours within sample days (Table 4). Effort is the product of mean counts for a given period day type, days within the period, and the expansion value for that period. Thus, the angling effort and catch reported are for those periods sampled, no expansions were made to include periods not sampled (e.g., 0100 to 0400 hours).

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

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

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

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

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

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

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

Results[1]

Fish Community

A total of 24,816 fish comprised of 15 species were collected (Table 5). Total sampling effort was 426 fyke-net lifts. The total catch included 18,229 walleyes, 3,558 northern pike, and 130 smallmouth bass which made up approximately 74%, 5%, and 0.5% of the total catch, respectively. Other fish species collected in order of abundance of total catch were: white sucker, yellow perch, rock bass, pumpkinseed, black crappie, common shiner, burbot, cisco, golden shiner, creek chub, black bullhead, and brown bullhead. Walleye were the most numerous species collected, with a mean length of 14.9 in. The overall fish community composition in fyke nets was 79% piscivores, 7% pelagic planktivores-insectivores, and 14% benthivores (Table 5).

Walleye, Northern Pike, and Smallmouth Bass

Size structure and sex ratio.–The percentages of legal-size walleyes, northern, and smallmouth bass were 40, 18, and 47, respectively (Table 6). The population of spawning walleyes was dominated by 12- to 17-in walleye, which made up 83% of the catch. The population of spawning northern pike was dominated (69% of total catch) by 18- to 23-inch fish, though the distribution extended to 42 in. Large pike (≥ 30 in) were present, although they made up only 3% of the total catch. Although we did not handle many smallmouth bass, the population was comprised mainly of 12- to 17-inch fish, which made up 87% of the catch. Male walleyes outnumbered females in the spring survey by a ratio of 12.4 : 1 when all sizes were considered, but only by a ratio of 4.6 : 1 when legal-size fish were considered. Less than one percent of all walleyes were of unknown sex. Males typically outnumber females in surveys of spawning walleye (Carlander 1997). Male northern pike outnumbered females by a ratio of 1.2 : 1 when all sizes were considered, but females outnumbered males by a ratio of 2.6 : 1 when fish of legal size were considered. Eleven percent of all northern pike were of unknown sex.

Abundance.–Crews tagged a total of 5,702 tags on legal-size walleyes (2,784 reward and 2,918 nonreward tags) and clipped fins of 8,768 sublegal walleyes. Twenty-four recaptured walleyes were observed to have died, or lost their tag during the spring netting survey; thus, the effective number tagged was 5,678. The angler survey clerk observed a total of 391 walleye on Lake Gogebic, of which 30 were marked (had a fin clip or a tag). One hundred and sixty-six of the unmarked walleyes were deemed to be sublegal fish that grew over the minimum size limit during the fishing season so the effective number of walleyes observed by the creel clerk (C) was 225. The estimated number of legal-size walleyes was 7,789 using the multiple-census method and 41,402 using the single-census method (Table 7). The estimated number of adult walleyes was 32,190 using the multiple-census method, and 103,916 using the single-census method. The coefficient of variation was 0.08 for the multiple-census estimate of legal-size walleye, was 0.05 for the multiple-census estimate of adult walleyes, and was 0.16 for both of the single-census estimates.

Crews tagged 205 legal-size northern pike in Lake Gogebic (81 reward and 124 nonreward tags) and clipped fins of 916 sublegal northern pike. No recaptured northern pike died or lost their tag during the spring netting. The creel clerk observed 22 northern pike, of which 4 were marked. The number of unmarked northern pike was reduced by 7 to adjust for fish that grew into the minimum acceptable size during the fishing season so the effective number of legal-size northern pike observed by the creel clerk (C) was 15. The estimated number of legal-size northern pike was 813 (CV = 0.36) using the multiple-census method, and was 659 (CV = 0.34) using the single-census method. The estimated number of adult northern pike was 4,538 (CV = 0.29) using the multiple-census method and 3,271 (CV = 0.34) using the single-census method (Table 7).

[1] Confidence limits for estimates are provided in relevant tables, but not in the text.

Crews tagged 60 legal-size smallmouth bass in Lake Gogebic (17 reward and 43 nonreward tags) and clipped fins of 68 sublegals. No recaptured smallmouth bass died or lost their tag during the spring netting. The creel clerk observed 128 smallmouth bass, of which 3 were marked. The number of unmarked smallmouth bass was reduced by 18 to adjust for fish that grew into legal size during the fishing season so the effective number of legal-size smallmouth bass observed by the creel clerk (C) was 110. The estimated number of legal-size smallmouth bass was 1,693 (CV = 0.44) using the single-census method. Given the high CV, and the small number of fish marked, we did not consider this a valid estimate of smallmouth bass abundance. The minimum number of recaptures was not obtained for an unbiased multiple-census estimate.

We fin-clipped 520 yellow perch greater than 6.9 in and the creel clerk observed 606, of which 4 were marked. The number of unmarked yellow perch was reduced by 44 to adjust for fish that grew into the minimum acceptable size during the fishing season so the effective number of yellow perch observed by the creel clerk (C) was 562. The estimated number of 7-inch and larger yellow perch was 58,655 (CV = 0.41) using the single-census method. Given the high CV, the relatively small number of fish marked, and the low number of recaptures, we are not very confident in this estimate for yellow perch. However, given the paucity of abundance estimates in the state of Michigan, we will use it for comparison.

Growth.–Technicians aged 285 walleyes (Table 8), 414 northern pike (Table 9), and 78 smallmouth bass (Table 10). The overall mean growth index for walleye was -2.6. Walleye mean lengths-at-age were equal to the statewide average for age 2, but deviations generally increased with increasing age. Females had higher mean lengths-at-age than males, with the largest differences occurring at the older ages when males were reaching their maximum age. Females had much higher growth potential, with an L_∞ value of 26.3 in compared to 19.3 in for males. The L_∞ for all walleyes was 23.8 in. For northern pike, the overall mean growth index was -1.4. Mean lengths-at-age were lower than the statewide average for all ages except age-8 (Table 9). Like walleye, female northern pike had higher mean lengths-at-age than males, except for ages 6 and 7, which had small sample sizes for females. The growth potential for females (L_∞ = 56 in) was higher than for males (L_∞ = 28 in), even though the value for females was illogical. Overall, mean length-at-age data fit to a von Bertalanffy growth curve produced an L_∞ value of 51 in. Contrary to walleye and northern pike, smallmouth bass had higher mean lengths-at-age than the statewide average. The mean growth index was +0.6 and L_∞ was 19 in (Table 10).

Mortality.–For walleye, the aged subsample was apportioned to 14,504 fish (Table 11), which differs slightly from the number of unique walleyes measured (Table 5) as a result of rounding in the age-length key. Ages 5 and older were used in the catch-curve analyses to represent the legal-size walleye population (Figure 4) because: 1) average length of walleye at age 5 was greater than legal size, so most age-5 fish were legal-size at the beginning of fishing season; and 2) relative abundance of fish younger than age 5 did not appear to be represented in proportion to their expected abundance (Figure 4; Table 11). The catch-curve regression was significant ($P < 0.05$) and produced a total instantaneous mortality rate for legal-size fish of 0.646 (Figure 4). This corresponds to an annual mortality rate of 48%.

Anglers returned a total of 439 tags (230 reward and 209 nonreward) from harvested walleyes, and 7 tags (3 reward and 4 nonreward) from released walleyes, in Lake Gogebic in the year following tagging. The majority (91%) of walleye tag returns were reported from the open-water portion of the angling year (Table 12). The creel clerk observed two (of 18) recaptured walleyes that had lost tags during the angler survey; thus, the estimated tag loss rate was 11.1%. The reward tag return estimate of annual exploitation of walleye was 9.3% after adjusting for tag loss (Table 7). Anglers reported reward and nonreward tags at a similar rate (8.4% versus 7.3%). The reporting rate of nonreward tags relative to reward tags (λ *in* Pollock et al. 1991) was 87%. The creel clerk observed only one tagged walleye in the possession of an angler that was not subsequently reported. Overall, there was little evidence of nonreporting because the number of tags voluntarily returned by anglers (439) exceeded the expected number of returns (435) based on the ratio described previously in the **Methods** section. Based on all tagged walleyes known to be caught, the reported release rate was 1.6%. The estimated exploitation rate for walleye was 41.8% based on dividing harvest by the multiple-census abundance estimate, and 7.9% based on dividing harvest by the single-census angler survey abundance estimate (Table 7). Angler exploitation of walleye increased with increasing length (Figure 6), though there was little overall variation among inch groups. The exploitation rate increased from 7.4% on 16-in walleye to 12.3% on walleyes greater than or equal to 22 in. Exploitation of walleyes also differed between sexes, with an estimated 7.4% on males and 11.9% on females.

For northern pike, the aged subsample was apportioned to 1,123 fish (Table 11). We used ages 4 and older in the catch-curve analyses to represent the adult male northern pike population, and used ages 5 and older for the legal-size female and overall legal-size population (Figure 5). The catch-curve regressions were all significant ($P < 0.05$) and resulted in total annual mortality rates for males, females, and all northern pike of 72%, 46%, and 54%, respectively (Figure 5). Anglers returned a total of 31 tags (13 reward and 18 nonreward) from harvested northern pike, and 10 tags (5 reward and 5 nonreward) from released northern pike in Lake Gogebic in the year following tagging (Table 12). The creel clerk observed one tagged fish (nonreward) in the possession of an angler that was not subsequently reported to the DNR. The number of tags voluntarily returned by anglers from harvested fish (31) was less than the expected number of returns (43), though overall sample size (number tagged) was low. Most (90%) northern pike tag returns were reported from the open-water portion of the angling year. The clerk did not observe any lost tags in the angler survey, though only four recaptured northern pike were observed; thus, we used an average tag loss rate of 5% derived from previous Large Lake Program surveys. The resulting tag return estimate of northern pike exploitation was 16.9% (Table 7). Exploitation generally increased with length (Figure 7); however, sample sizes were small for each inch group. Inch groups were combined for fish 28 in and larger so that the number tagged exceeded 10 in that group. Overall, anglers reported reward tags at a higher rate than nonreward tags (22.2% versus 18.5%), and the reporting rate of nonreward tags relative to reward tags was 90.4%. Based on all tagged northern pike known to be caught, the reported release rate was 23.8%. The estimated exploitation rate for northern pike was 19.8% based on dividing harvest by the multiple-census abundance estimate, and 24.4% based on dividing harvest by the single-census angler survey abundance estimate (Table 7).

We did not survey at the best time of year to collect smallmouth bass, and not enough were tagged to make reliable estimates. However, anglers returned 11 of 60 tags (reward + nonreward) for an estimated exploitation rate of 19.3% (adjusted for an average tag loss rate of 5%), and they reported releasing 26.7% of legal-size smallmouth bass. For yellow perch, exploitation was 17.2% estimated by dividing harvest by abundance. In making this estimate, we assumed that harvested yellow perch were seven inches and larger.

Recruitment.–Walleye in Lake Gogebic were represented by 15 year classes (ages 1 through 15) in our samples, and the variability of year-class strength [based on the amount of variation explained by the age variable (R^2)] was 0.88 (Figure 4). Northern pike and smallmouth bass were represented by 11 (ages 1 through 11) and 9 year classes (ages 3 through 9, 11 and 12), respectively, and the amount of variation explained by the age variable was 0.89 and 0.59, respectively.

Movement.–Based on recaptures during the spring survey, walleyes moved considerably during the spawning migration. On average, walleyes were recaptured 1.4 miles (median = 0.9 miles) from their point of initial capture. The longest distance between point of initial capture and recapture was 10.1 miles. Northern pike also moved during the survey period. On average, recaptured northern pike were recaptured 1.5 miles (median = 0.3 miles) from their point of initial capture, with the longest distance between points being 6.9 miles. Based on angler tag returns, there was no movement of fish out of Lake Gogebic. All tag returns for walleye, northern pike, and smallmouth bass were reported as being captured in Lake Gogebic.

Angler Survey

Open-water period.–The clerk interviewed 2,486 anglers during the open-water period on Lake Gogebic. Most interviews (97%) were roving (incomplete-fishing trip). Anglers fished an estimated 101,372 hours and made 28,143 trips (Table 13). The total harvest of 15,689 fish consisted of ten different species. Harvest was dominated by yellow perch and walleye, which comprised 89% of the total catch. Yellow perch were most numerous, with an estimated harvest of 9,035 fish. Anglers harvested 4,851 walleyes and reported releasing 14,723 walleyes (75% of total walleye catch). Anglers harvested 145 northern pike, and reported releasing 3,435 (96% of total catch). Size composition of the released fish was not evaluated.

Ice-cover period.–The clerk interviewed 742 anglers during the ice-cover period of the angler survey, most of which (95%) were roving-type interviews. Anglers fished 15,484 hours and made 3,995 trips (Table 13). A total of 1,879 fish were harvested, comprised of seven species. Yellow perch and walleye were the most numerous, making up 57% and 29% of the harvest, respectively. Anglers released 571 walleyes (51% of total walleye catch), 320 northern pike (81% of total catch), and 377 yellow perch (26% of total catch). Ciscoes were detected as being harvested and released, though there were very few.

Annual totals.–In the annual period from May 15 through September 30, 2005 and December 12, 2005 through March 27, 2006, anglers fished 116,857 hours and made 32,138 trips to Lake Gogebic (Table 13). Of the total annual fishing effort, 87% occurred in the open-water period and 13% occurred during ice-cover period. Angler effort peaked in June, though it was similar throughout the summer (May through September). Angler effort dropped considerably during the ice-cover period. Average angler hours per day were 729 during the open-water period and 146 during the ice-cover period. The total annual harvest was 17,568 fish, of which 89% were taken in the open-water period. Harvest was predominantly yellow perch (10,107) and walleyes (5,399), which comprised 58% and 31% by number. The estimated total annual harvest of northern pike was 222, making up 1% of the total harvest. The harvest rate for walleyes was higher during the open-water period (0.048 per hour) as compared to the ice-cover period (0.035 per hour) as were the release rates (0.145 per hour versus 0.037 per hour). Similarly, the harvest rate for yellow perch was higher during the open-water period (0.089 per hour versus 0.069 per hour), and the release rate was higher during the open-water period (0.045 per hour versus 0.024 per hour).

Walleyes were the predominant species caught (harvested + released) at 20,693, with a catch rate of 0.18 per hour. Walleye catch rates were rather consistent from May through September, ranging only from 0.17 to 0.21 per hour, but they dropped considerably in the winter months and were only 0.01 per hour in March. Anglers released 74% of all walleyes caught. Estimated total annual catch of northern pike was 3,977, with a resulting catch rate of 0.03 per hour. Anglers released 94% of all northern pike caught. Yellow perch had the second highest catch at 15,057, with a resulting catch per hour of 0.13 per hour. It should be noted that catch rates are calculated with general effort, not targeted effort, and are therefore not necessarily indicative of the rate that an angler targeting one species may have experienced. Although no differentiation was made between sublegal and legal-size released fish, we assume that a large proportion of the released walleyes were sublegal.

There was no angler survey from October through mid-December, because it was thought that relatively little fishing occurred during that time of year, and ice conditions were unsafe. However, 21 walleyes and 2 northern pike tag returns were reported as being caught during this nonsurveyed period (Table 12), thus the actual harvest for walleye could have been about 5% higher (5,663) and the actual harvest of northern pike could have been about 6% higher (236). April and the first two weeks of May were not surveyed because walleye and northern pike seasons were closed.

Six species captured during spring netting operations were not detected in the angler catch – black bullhead, brown bullhead, burbot, creek chub, common shiner, and golden shiner.

Discussion

Fish Community

At the time of European settlement in the western Upper Peninsula, smallmouth bass were the dominant piscivore in Lake Gogebic, and their abundance was considered inexhaustible. Anglers reportedly came from all parts of the country to fish Lake Gogebic for smallmouth bass (Peterson 1995) and fishing was good. In fact, correspondence dated July 5, 1885 describes a party of 14 anglers catching 789 smallmouth bass in 7 hours. Northern pike were introduced as early as 1892 or 1898, along with a few adult muskellunge (Eschmeyer 1941a), and the turn of the century is about when walleyes, which were not native to the lake, were also first stocked in Lake Gogebic. Norcross (1986) reported evidence of an effort by a local business man to stock walleyes in Lake Gogebic in 1904. Approximately 300,000 walleye fry came by train (their origin is unknown, but some biologists suspected they were from a hatchery in Sault Sainte Marie) and were stocked in Bergland Bay. Officially, walleyes were introduced into Lake Gogebic by the DNR in 1913 through fry stocking. It is unknown where the fry originated from, though recent discussions with local historians (Edward Pearce, personal communication) indicated that they must have been from a nearby hatchery because a trip to Ironwood (approximately 30 miles) in those days "took all day." Two decades of northern pike stocking also followed the walleye introduction. Early in the 20^{th} century, anglers began to notice a decline in the black bass population, which continued until they were almost absent from the lake. Commensurate with the decline of smallmouth bass, northern pike and walleyes were increasing in abundance (Peterson 1995). By the 1930's, walleye had become the dominant piscivore, and significant declines in forage fish, panfish, and smallmouth bass were observed. Walleye spawning (egg-take) operations began on Lake Gogebic in 1971, primarily to provide fry for the lake itself; however, beginning in the 1970's, at least 29 different lakes in the western Upper Peninsula were stocked with walleye fry from Lake Gogebic.

Following the change in dominant predator species, the most significant fish community change in Lake Gogebic was the near disappearance of forage fish. Until 1900, minnows and shiners were reported as abundant in Lake Gogebic; however, Metzelaar (1928) reported their scarcity when ten seine hauls (120-ft seine) and two gill net sets failed to produce a single minnow. Similarly, Eschmeyer (1941a) reported that forage fish were extremely scarce, and diet analysis lent support to this observation, because walleye fed almost entirely on mayfly larvae and yellow perch, with ciscoes forming only a portion of the diets of larger walleye. Further, Eschmeyer (1950) reported walleye diet analysis from several years where fish (though mainly yellow perch) occurred in 80% of adult stomachs and made up 89% of the food volume. Metzelaar (1928) noted considerable cannibalism by walleye because the only fish observed in stomachs were walleye. Beyond the initial changes occurring in the early 20^{th} century, the fish community described by Eschmeyer (1941a) was similar to today in terms of common species, though some minnow species (western long-nosed dace, straw-colored shiner (most likely sand shiner), central mudminnow, trout perch, unidentified sticklebacks, unidentified topminnow) were present in low numbers that have not been collected recently.

As part of the Large Lakes Program, the DNR also surveyed Michigamme Reservoir (Hanchin et al. 2005a), Bond Falls Flowage (Hanchin 2009), and Peavy Pond (Hanchin 2011) using methods and gear similar to those employed on Lake Gogebic; thus, it should be reasonable to compare fish community composition among these lakes. The relative proportion of feeding guilds in Lake Gogebic was dominated by piscivores (79%); which was similar to Bond Falls Flowage (88%), but higher than Peavy Pond (46%) and Michigamme Reservoir (46%). The proportion of piscivores in Lake Gogebic was the second highest observed in the Large Lakes Program, and the population with the highest proportion of piscivores (Bond Falls Flowage) was biased high because walleye were targeted for collection using electrofishing, during which nontarget species were not netted.

Walleye, Northern Pike, and Smallmouth Bass

Size structure.–In Lake Gogebic, numerous surveys have been conducted during the walleye spawning season. These surveys have utilized the same gear (fyke nets), in nearly the same location, at the same time of the year (ice-out); thus, they should be appropriate for examining changes in size structure occurring over the time period. Norcross (1986) initially evaluated the length frequency of spawning walleyes collected during six years of netting during the spawning period on Lake Gogebic, noting a decline in the average length of legal-size (then 13 in) walleye. Over time we built upon this series, though data were not collected in some years (Table 14). During the longest continuous time series (1988 to 2005), the percentage of male walleyes greater than or equal to 15 in has varied considerably from 13% to 80%, with an average of 48% and median of 41%. Although, there was no significant correlation between the CPUE of male walleyes and the percentage of male walleyes greater than or equal to 15 in, these metrics appear to be out of phase during the time series (Figure 8). That is, periods of high CPUE seem to be paired with periods of low size structure, and vice-versa. This relationship suggests density-dependent growth in the walleye population. In the Large Lakes Program, adult walleye density has been negatively related to both mean growth index ($F = 6.85$, $df = 16$, $P = 0.02$) and the percentage of walleye greater than or equal to legal size ($F = 10.06$, $df = 16$, $P = 0.006$). Thus, inland walleye populations in Michigan tend to experience density-dependent growth, with Lake Gogebic being at the end of the continuum with high density and relatively slow growth. The current size structure of walleye in Lake Gogebic (40% legal size) was below the median (70%) and mean (70%) of legal-size walleye in spring surveys for 19 populations surveyed under the Large Lakes program. Additionally, it was the second lowest value observed next to the Cisco Chain (29%; Hanchin et al. 2009), also in Gogebic County.

One of the goals of the change to a 15-in MSL on walleye in 1996 was to increase size structure, so we evaluated the percentage of male walleyes greater than or equal to 15 inches in the spring surveys before and after the change. The percentage of male walleyes greater than or equal to 15 in was significantly higher ($F = 5.51$, $df = 17$, $P = 0.03$) in the nine years (1997–2005) following the change to a 15-in MSL, as compared to the nine years (1988–1996) prior when the 13-in MSL was in place. Thus, the higher size limit was successful with respect to the goal of increasing size structure, at least for male walleye.

Surveys and management efforts at Lake Gogebic have concentrated on walleye, so there is little historic data available for northern pike. However, previous surveys (spring 1996, summer 1997, and summer 1999) resulted in 0%, 4%, and 17% legal-size northern pike, respectively. The percentage of legal-size northern pike (18%) observed in 2005 was higher than all previous surveys, though it was below both the median (24%) and mean (28%) of legal-size northern pike in spring surveys for eighteen populations surveyed under the Large Lakes program. Northern pike size structure in Lake Gogebic was higher than in nearby Cisco Chain (Hanchin et al. 2009), Michigamme Reservoir (Hanchin et al. 2005a), Bond Falls Flowage (Hanchin 2009), and Peavy Pond (Hanchin 2011).

Sex ratio.–Eschmeyer (1950) reported a sex ratio (male:female) of 8.1:1 for Lake Gogebic spawning walleyes in 1947, and showed how the sex ratio can change during the spawning period. It is for this reason that the sex ratio from 1971 to 2005 (Table 14) varies so much (i.e., from 1.9 to 306.0), and is not necessarily representative of the true sex ratio in the population. The sex ratio is highly dependent upon the timing and duration of the survey, relative to the spawning period. Netting efforts early on in the spawning season are dominated by males, and netting efforts during the peak and end of spawning have a relatively higher proportion of females. Thus, we did not attempt to interpret any changes in the sex ratio over time for Lake Gogebic walleye.

Abundance.–Norcross (1986) evaluated the relative abundance of walleyes collected during fifteen years of spawning operations on Lake Gogebic. Building upon the time series, there are now over thirty years of relative abundance data collected during the spawning period (Table 14). Norcross (1986) concluded that the relative abundance of spawning male walleyes in Lake Gogebic peaked at four-year intervals, with the years 1974, 1978, 1982, and 1986 fitting this trend well; however, he remarked on the uniformity of the CPUE data for female walleye. Ultimately, the four-year peaks in male CPUE did not continue very well past 1986, and the variation in female CPUE (coefficient of variation = 0.84) was actually higher than that for males (coefficient of variation = 0.69). Although there can be large differences in the relative abundance of male and female walleye during the spawning period, the CPUE of males ($\log_e$-transformed) was related to the CPUE of females ($\log_e$-transformed) when the entire time series was evaluated ($F = 5.207$, $R^2 = 0.140$, $P = 0.029$), suggesting that the differences in relative abundance between sexes is largely due to behavior, and not true differences in abundance. Additionally, variation in some years may simply be due to the timing of the netting effort because males migrate onshore earlier than females. The spawning behavior of females also necessitates that caution be used when interpreting the CPUE. For example, spawning surveys recently have used little effort, because they were completed largely to assist the chamber of commerce with fish tagging. In these surveys, sampling before the peak spawning will result in a low CPUE of females, but sampling during the peak will result in a relatively high CPUE. These differences in CPUE should not be interpreted as changes in the true abundance of females.

Our multiple-census estimates for walleye were much lower than the single-census estimates for both legal-size fish and adult fish, which was consistent with results from most other large lakes (Clark et al. 2004, Hanchin et al 2005a, b, c, Hanchin and Kramer 2007). The single-census estimates also compared better to other independently-derived estimates. For example, the exploitation estimate derived using the single-census estimate was only 15% lower than the tag-return estimate, and the exploitation estimate derived using the multiple-census estimate was 349% higher. Multiple-census estimates made during the onshore spawning migration of species such as walleye and northern pike are likely biased low due to size selectivity and unequal vulnerability of fish to nearshore netting (Pierce 1997). Additionally, they have the potential problem of incomplete mixing, which is not a problem with the single-census method because it allows sufficient time for marked fish to fully mix with unmarked fish. In comparing surveys conducted similarly to ours, Pierce (1997) concluded that recapturing fish at a later time with a second gear type resulted in estimates that were more valid. Thus, based on comparisons with the independently-derived creel estimates, and the more rigorous evaluation by Pierce (1997), we consider that the single-census estimates are more accurate than the multiple-census ones for Lake Gogebic.

The single-census estimates of walleye abundance were higher than both the *a priori* Michigan and Wisconsin model estimates. Our single-census estimate for legal-size walleyes was about 123% higher than the Michigan model, and our single-census estimate for adult walleyes was about 161% higher than the Wisconsin model. Accordingly, the population density of walleye in Lake Gogebic was above average compared to other walleye lakes in Michigan and Wisconsin. Our single-census estimate for 15-in-and-larger walleyes in Lake Gogebic was 3.2 per acre. Density of legal-size walleye estimated recently for nineteen large lakes in Michigan has averaged 2.0 fish per acre (range = 0.4 to 4.6 fish per acre), though the median (1.6 fish per acre) is a better measure of central tendency for these data (DNR unpublished data). Population density of adult walleyes from our single-census estimate was 7.9 fish per acre, which is much higher than the average (3.2 fish per acre) and median (2.4 fish per acre) in nineteen large lakes surveyed thus far as part of the Large Lakes program.

Adult walleye density in Lake Gogebic is also much higher than the average density (2.2 adult walleye per acre) for 131 northern Wisconsin lakes having natural reproduction (Nate et al. 2000).

Norcross (1986) provided an overview of the abundance estimates made for Lake Gogebic walleye through 1984, and three more estimates have been made since that time. Overall, estimates have varied widely from 28,840 to 103,916 walleyes, though the size and sex of walleye marked has also varied. Some estimates were for primarily 13-inch males, and others were made for all adults capable of being identified as male or female. Additionally, methods have varied from multiple-census procedures made during the spawning period, to single-census procedures utilizing various techniques (angler survey, electrofishing, following year's netting survey) for the recapture sample. These differences in methods make interpretation difficult, but some inferences can be made. For example, the 1984 estimate (63,000) represented only male walleyes; however Norcross (1986) suggested that the true population might be around 125,000 walleye if the unaccounted females were considered. Similarly, the 1998 estimate of adult abundance (28,840) conducted by the Great Lakes Indian Fish and Wildlife Commission was much lower than any of the other five abundance estimates, and although there were a sufficient number of walleye both marked and observed for marks, only 220 females were marked, which resulted in an estimate of only 2,450 females. If we assume that the true sex ratio of the adult population is around 1:1, then a doubling of the estimate for males (27,795) results in approximately 56,000 adult walleye, which is more in line with other estimates. Our 2005 estimate (103,916), which had the largest effort, the most females tagged, and utilized a recapture method that is not biased towards males, likely accounted for females better than any previous estimate. Given that our estimate is similar to Norcross' (1986) estimate of around 125,000 adults, it provides some credibility to the suggestion of roughly doubling an estimate for males to arrive at an estimate for all adults (males and females). However, our 2005 estimate may have been larger than previous estimates because there was a high proportion (20%) of male walleye less than 13 inches in our marked sample. In most previous years (Table 14), male walleye less than 13 in accounted for a much lower percentage, and usually were not marked. Additionally, our 2005 estimate of adult walleye abundance was not a true mark-recapture estimate because we essentially made an estimate for legal-size walleye and then adjusted it to account for sublegal mature walleye that were on the spawning grounds. We are unsure how this would compare to a true mark-recapture estimate of adults, but if the catchability (nets and angling) of sublegal walleye was similar to legal-size walleye, the estimate should be relatively unbiased as compared to a true mark-recapture estimate of adult walleyes.

We were successful in obtaining valid abundance estimates for northern pike, though an ideal level of precision was not achieved for the single-census estimates. Assuming that the legal-size northern pike population was approximately 1,000 fish, and based on tagging around 200 fish, the recommended recapture sample in management studies (α = 0.05, P = 0.25; where P denotes the level of accuracy, and 1-α the level of precision) is 197 fish (Robson and Regier 1964). The corrected recapture sample observed by the creel clerk (15 fish) was well short of this recommendation. In fact, the sample size was so low, that even with the methodological biases known about multiple-census estimates (Pierce 1997) we consider the multiple-census estimates to be more reliable. They were, in fact, higher for both legal-size and adult northern pike. Pierce (1997) considered his multiple-census estimates of northern pike abundance as minimums, with the true abundances likely higher.

The multiple-census estimate for legal-size northern pike converts to a density of 0.06 per acre, which is below the average (0.16) and median (0.09) estimated recently in the Large Lakes Program. Nearby, Michigamme Reservoir and Bond Falls Flowage had only slightly higher densities of 0.13 and 0.08 per acre, respectively. The density of adult northern pike (0.35 per acre) is below the average (0.90) and median (0.46) estimated recently in the Large Lakes Program. Nearby, populations in the Cisco Chain, Peavy Pond, and Bond Falls Flowage had much higher densities of 2.9, 2.3, and 2.6 per acre, respectively. Craig (1996) gave a table of abundance estimates (converted to density) for northern pike from various investigators across North America and Europe, including one from

Michigan (Beyerle 1971). The sizes and ages of fish included in these estimates vary, but considering only estimates done for age 1 and older fish, the range in density was 1 to 29 fish per acre. Also, Pierce et al. (1995) estimated abundance and density of northern pike in seven small (<740 acres) Minnesota lakes. Their estimates of density ranged from 4.5 to 22.3 fish per acre for fish age 2 and older. Our estimates for adult northern pike in Lake Gogebic are essentially for fish age 3 and older, so they should be lower. Additionally, the lower density observed in Lake Gogebic is likely due to the larger size of the lake, and the lower relative proportion of spawning habitat as compared to the small Minnesota lakes that Pierce et al. (1995) surveyed.

Although we did not consider the abundance estimate for smallmouth bass to be valid, it was likely biased low because the independently-derived harvest estimate of 1,152 smallmouth bass is 68% of the abundance estimate. If we assume the tag-return estimate of exploitation (19.3%) is correct, the harvest estimate would convert to a population size of 5,969 smallmouth bass, for a density of 0.45 fish per acre. The empirical population estimate converts to a density of only 0.13 fish per acre which is low compared to other lakes in Michigan and elsewhere. Newman and Hoff (2000) reported 0.3 smallmouth bass (>16.0 in) per acre in Palette Lake, Wisconsin, and in seven Michigan lakes surveyed under the Large Lakes Program, legal-size smallmouth bass density has averaged 0.55 fish per acre, with a median value of 0.13. Given the low reliability of the population estimate, and the high harvest estimate relative to it, the smallmouth bass population in Lake Gogebic likely has an average density for a large inland lake.

The abundance estimate for yellow perch was considered unreliable based on the CV; however, there are so few abundance estimates for yellow perch available in Michigan that we will address it briefly. The estimate for yellow perch 7 in and larger converts to a density of 4.5 fish per acre, which appears within reason relative to other estimates from Michigan. Schneider et al. (2007) reported mark-recapture population estimates for yellow perch greater than 7 in from 14 Michigan lakes, which ranged from 0.6 to 62.8 fish per acre. However, few lakes had more than 20.0 yellow perch per acre, and many lakes had less than 5 per acre. The population estimates also showed extreme annual variation in some populations, as high as 30-fold, due to uneven recruitment.

Growth.–Mean lengths-at-age for walleye from our survey of Lake Gogebic were well below the statewide average, but were similar to most historic values from the lake, with the exception of 1990 (Table 15). The relatively slow growth of walleye in Lake Gogebic is well documented (Eschmeyer 1941a, Norcross 1986, Miller 2001), and has been attributed to the low abundance of forage fish, and density-dependent responses to changes in abundance (Eschmeyer 1941a, Norcross 1986). Numerous tag recoveries have documented slow growth, including a 15.5-inch walleye recovered at 19.0 in after 10 years (0.4 in per year), a 17.8-inch walleye recovered at 20.0 after 12 years (0.2 in per year), and a 16.5-inch walleye recovered at 18.5 in after 10 years (0.2 in per year; Norcross 1986).

Diet studies of Lake Gogebic walleye have found that they predominantly eat yellow perch and mayfly nymphs (Eschmeyer 1941a, Metzelaar 1928) with ciscoes forming only a portion of the diets of larger walleye. In fact, Eschmeyer (1950) reported diet analysis from several years in Lake Gogebic, where fish (mainly yellow perch) occurred in 80% of adult stomachs and made up 89% of the food volume. Cannibalism by walleye has also been noted several times (Metzelaar 1928, Eschmeyer 1950). Given that walleye are dependent on yellow perch as a primary food source, it follows that changes in either the yellow perch population size, or the walleye population size will have compensatory effects on walleye growth. As previously mentioned, the density-dependent growth of walleye is evidenced by the apparent phase differences between the relative abundance and size structure observed during the spawning period (Figure 8). Although there was no statistically significant relationship between these variables, it appears that when relative abundance is high size structure is relatively low. Mean lengths-at-age observed in 2005 suggest that walleye growth is at one of its low points, corresponding with the high density observed. Although the mean lengths-at-age were relatively low, the L_∞ value (24 in) was equal to the average for walleye in other Large

Lakes in Michigan (N = 19). However, there was a large disparity between males and females; thus, the 'average' walleye would not reach an asymptotic length of 24 in, rather it would depend on the sex.

Similar to walleye, mean lengths-at-age for northern pike were below the statewide average, but were similar to some other waters in the western Upper Peninsula (Table 16). As with walleye, statewide averages for northern pike were based entirely on scale aging, which probably overestimated mean lengths for older ages. The length at infinity (L_∞) value (51 in) for northern pike suggests that there is adequate growth potential in Lake Gogebic to produce large northern pike. Obviously, this theoretical value is based on the mathematical fit of data to a model, and is not necessarily what can be expected from the population. For example, crews measured over 1,000 northern pike and none exceeded 43 in. The average and median L_∞ for northern pike in other Large Lakes in Michigan (37 in) were much lower.

Contrary to walleye and northern pike, smallmouth bass in Lake Gogebic appear to grow better than other lakes in Michigan. The positive mean growth index suggests that smallmouth bass can perhaps take better advantage of prey items such as crayfish and mayfly nymphs relative to walleye. However, relative to the few other smallmouth bass populations surveyed effectively in the Large Lakes Program, Lake Gogebic is about average. The growth potential ($L\infty$ = 18.7 in) and mean growth index (+0.6) of smallmouth bass were both near the averages (19.1 in and +1.0, respectively) from other populations.

Mortality.–Total mortality of walleye in Lake Gogebic (50%) was higher than the average (41%) for eighteen populations surveyed in the Large Lakes Program, which have ranged from 24% to 57%. Mortality of walleye in Lake Gogebic has been estimated several times, though interpretation is hindered because different methods have been used for one or both sexes, with at times small sample sizes. Over the years, total annual mortality has ranged from 24% to 54%, with the latter being an estimate for only males. At first glance, it may appear that mortality has increased since first being estimated in the 1940's (Table 2), and in fact, Miller (1995) suggested that mortality was increasing due to increased fishing pressure. However, all potential sources of bias must be considered. First, in 1989, technicians began aging walleye from Lake Gogebic using sectioned dorsal spines, rather than scales. Because scales may underestimate ages relative to dorsal spines (Kocovsky and Carline 2000), mortality may have actually been underestimated in the past. It is difficult to say for certain if this happened, but if the oldest fish in a sample are mistakenly assigned to slightly younger ages it would decrease the slope of a catch curve, hence underestimating mortality. Second, some of the earlier samples were dominated by males, which generally have lower mortality rates than females. Schneider et al. (1976) estimated total mortality of male and female walleyes in Lake Gogebic using tag returns observed over a period of several years and reported annual mortality for males (19.6%) as a little more than one half that for females (34.6%). Schneider thought the difference was largely due to higher exploitation of females (12.6% vs. 7.3%). In 2005, we observed higher annual mortality for males (52.1%) than females (40.9%), even though exploitation (based on reward tag returns) was higher for females (11.9%) as compared to males (7.4%). Unfortunately, we do not know the extent to which the various biases affected our mortality estimates, but acting together they probably can account for most of the observed differences between the earlier and more recent mortality estimates.

Our three estimates of walleye exploitation varied considerably; 9.3% from tag returns, 41.8% using harvest divided by the multiple-census abundance estimate, and 7.9% using harvest divided by the single-census abundance estimate. The much higher estimate derived using the multiple-census abundance estimate is further evidence that abundance is underestimated using multiple-census methods. Also, the fact that the exploitation estimate derived from the single-census abundance estimate is lower than the tag return estimate, which we consider a minimum, suggests that we could have either overestimated abundance, or underestimated harvest. It is difficult to say which is more likely because the harvest per acre of walleye (0.41) was lower than the average (0.51) from the Large Lakes Program, but the density was much higher.

Using 9.3% as our best estimate, the exploitation rate for walleye in Lake Gogebic was lower than the average (15%) and median (12%) for populations surveyed in the Large Lake Program (N = 19), which ranged from 4% to 35%. Compared to the most recent (1984, 1993) estimates from Lake Gogebic, current exploitation on walleye has decreased (Table 2). However, we do not know what effect the change from a 13 to 15 in minimum in size limit would have on exploitation. For example, if smaller (13 to 14.9 in) walleye are easier to catch than larger (>14.9 in) walleye, the exploitation may have been higher in the 1980's and 1990's simply due to the different catchability of the small walleye that were available for harvest under that size limit. Miller (1995) noted that anglers caught and returned larger (≥ 14 in) walleye at a slightly higher rate than smaller (12 to 14 in) walleye, but he used relative proportions from the length frequencies, rather than actual estimates of exploitation by inch group. We found that exploitation was highest at the low (15 in) and high (22+ in) inch groups (Figure 6), which lends support to the idea that exploitation could have been higher on 13- and 14-inch walleye under the 13-in MSL. Release rates seemed to reflect the exploitation rates by inch group, which suggests that anglers were not releasing any inch group of legal-size walleye more than any other, but were instead releasing them in proportion to how many were caught. The higher exploitation that we observed on larger inch groups was likely influenced by the fact that female walleye were exploited at a rate 1.6 times higher than male walleye. Schneider et al. (1976) reported higher return rates for females (12.6%) as compared to males (7.3%) over a period of several years in Lake Gogebic, and based on their return rates, exploitation was around 1.7 times higher on females. Schneider et al. (1976) suggested that the higher rate on females may have been a result of more aggressive feeding, and consequently, higher vulnerability to angling.

Regardless of whether angler exploitation has truly decreased in Lake Gogebic, of the three primary sources of mortality (fishing, spearing, and natural causes) it is clear that natural mortality is the largest component. In 2005, exploitation by tribal members was estimated as 2.4%, as determined by dividing the known quantity of adult walleye speared (2,545) by the adult walleye population estimate, and was 3.3% as determined by dividing the known quantity of 15-inch and larger walleye speared (1,378) by the legal-size walleye population estimate. By adding the spearing exploitation of legal-size walleyes to the angling exploitation of legal-size walleyes (9.3%), we estimate a total fishing exploitation of 12.6% in 2005. Given the total mortality estimate of 48%, natural causes are clearly the largest source of mortality in Lake Gogebic. Schneider (1976) also concluded that most of the annual mortality was due to natural causes in Lake Gogebic. Although the spearing exploitation of 15-in and larger walleye in 2005 was not large, the difference in spearing exploitation on adult versus legal-size walleye can be higher. In 1998, spearing exploitation on adult walleye, as determined by dividing the known quantity of walleye speared (2,057) by the total population estimate, was 7.1%; however, spearing exploitation was almost double (14.1%) on walleye greater than or equal to 15 in. This was likely a result of the relatively low abundance at that time, because spearing is not considered to be self-regulating (Hansen et al. 2000).

Total mortality of northern pike in Lake Gogebic (54%) was about average (50%) relative to nineteen northern pike populations surveyed as part of the Large Lakes program in Michigan. It is also higher than Diana's (1983) estimated total annual mortality from two other Michigan lakes, Murray Lake (24.4%) and Lac Vieux Desert (36.2%). Other western Upper Peninsula lakes—Bond Falls Flowage, Cisco Lake Chain, Michigamme Reservoir, and Peavy Pond—had mortality rates of 48%, 64%, 63%, and 56%, respectively. In Minnesota, Pierce et al. (1995) reported a range of total mortality for northern pike in seven small (< 300 acres) lakes from 36% to 65%. They also summarized total mortality for adult northern pike from a number of lakes across North America; estimates ranged from a low of 19% (Mosindy et al. 1987) to a high of 91% (Kempinger and Carline 1978), with the majority of lakes between 35% and 65%.

The three estimates of northern pike exploitation for Lake Gogebic varied slightly (16.9% from tag returns, 19.8% using harvest divided by the multiple-census abundance estimate, and 24.4% using harvest divided by the single-census abundance estimate), but were all within reason. Using an average of the three estimates, it is safe to say that the exploitation rate on northern pike is approximately 20% in Lake Gogebic. Given the total mortality estimate, natural mortality appears to contribute slightly more than fishing mortality for northern pike. However, hooking mortality from released fish is unknown and could be significant given the relatively high percentage (24) of tagged northern pike that were released. Clark (1983) warned that voluntary release rates higher than 10% change the interpretation of conventional angler survey estimates of catch and fishing mortality. However, in the case of Lake Gogebic, if hooking mortality even approached 33%, which is the highest reported in literature for esocids (DuBois et al. 1994, Tomcko 1997), the tag return estimate of exploitation would only increase from 16.9% to 19.5%.

Compared to exploitation rates for northern pike from other lakes in Michigan and elsewhere, our tag return estimate for Lake Gogebic (16.9%) is average. The mean exploitation rate for northern pike from Large Lake surveys to date is 16.8% with a range of 3% to 31%. Nearby Bond Falls Flowage had a much higher exploitation rate of 26.8% (Hanchin 2009) and Michigamme Reservoir (Hanchin et al. 2005a) had a lower rate of 11.1%. Latta (1972) reported northern pike exploitation in two Michigan lakes, Grebe Lake at 12–23% and Fletcher Pond at 38%. Pierce et al. (1995) reported rates of 8% to 46% for fish over 20 in for seven lakes in Minnesota, and Carlander (1969) gave a range of 14% to 41% for a sample of lakes throughout North America.

It appears from the exploitation of northern pike by inch group (Figure 7) that angling selects for larger northern pike more than smaller ones. This trend held true at least for northern pike from 24 to 27.9 in—any trend beyond which would be speculation. In Peavy Pond (Hanchin 2011), the exploitation rate on northern pike also increased with increasing size, but the size groups evaluated were from 18 to 22+ in because there was no minimum size limit for northern pike in that system. Hanchin (2011) attributed the higher exploitation rate observed on larger northern pike to a higher harvest rate, rather than a higher catch rate, because the percentage of northern pike released decreased with increasing size. In Lake Gogebic, we found the same trend of decreasing release rates for legal-size northern pike (Figure 7), and although sample sizes were low, it follows that anglers are selecting for larger northern pike.

To our knowledge, this was the first attempt to estimate total mortality of smallmouth bass in Lake Gogebic. Our estimate of 22% for legal-size fish appears to be on the low side for the range for Midwestern waters reported in the literature. Forney (1961) reported estimates of 52%, 58%, and 18% total mortality for smallmouth bass in Oneida Lake, New York, and Paragamian and Coble (1975) reported 55% mortality for smallmouth bass in the Red Cedar River, Wisconsin. Clady (1975) reported total mortality estimates of 33% for smallmouth bass in a Michigan lake with no fishing, and 41% to 65% in a lake subject to simulated exploitation of 13% to 16%. Bryant and Smith (1988) reported 58% total mortality of adult smallmouth bass from Anchor Bay of Lake St. Clair. Total mortality of smallmouth bass in nine populations surveyed in the Large Lakes Program has averaged 33.8%, with a range of 22% to 45%. Thus, the estimate for Lake Gogebic is currently the lowest observed thus far in the Large Lakes Program. Our two estimates of the exploitation rate of smallmouth bass were quite different—19.3% from tag returns and 58.5% using harvest divided by the single-census abundance estimate. As mentioned previously in the *Abundance* section, the single-census abundance estimate was likely biased low, so the exploitation estimate derived using it is likely biased high. If we consider the tag-return estimate to be a minimum, the true exploitation rate on smallmouth bass is likely in the range of 20 to 25%. Compared to exploitation rates for smallmouth bass from other lakes in Michigan and elsewhere, our estimate for Lake Gogebic appears to be above average. Exploitation of smallmouth bass in nine populations surveyed in the Large Lakes Program has averaged 12.7%, with a range of 4.3 to 21.1%. Latta (1975) reported a range of 9% to 33% exploitation, with an average of 19%, for a sample of smallmouth bass populations throughout the Great Lakes region and the northeastern United States. In Oneida Lake, Forney (1972) reported 20% exploitation of adult smallmouth bass, and Paragamian and Coble (1975) reported 29% exploitation in the Red Cedar River of Wisconsin. In Michigan, Latta (1963) reported 22%

exploitation of smallmouth bass near Waugoshance Point in Lake Michigan, and Bryant and Smith (1988) reported a rate of 13% for smallmouth bass in Lake St. Clair.

Our exploitation estimate for yellow perch (17%) appeared reasonable, though it was an approximation because we had to make the assumption that harvested yellow perch were greater than or equal to seven in, and we also had low confidence in the abundance estimate. Exploitation estimates for yellow perch across North America vary greatly. Clady (1977) estimated 4.4% exploitation for yellow perch in Oneida Lake, New York, and Thomas and Haas (2005) estimated 14% exploitation for yellow perch in Michigan waters of Lake Erie. Isermann et al. (2005) reported exploitation rates for yellow perch in two South Dakota lakes of 7% and 61% during winter ice fisheries. Kempinger et al. (1975) reported a wide range in exploitation of yellow perch in Escanaba Lake, Wisconsin, which ranged from 2% to 34%. In Lake Winnibigoshish, Minnesota, which like Lake Gogebic is known for producing large yellow perch, exploitation of yellow perch longer than 9 in was reported as 62% (Radomski 2003).

Recruitment.–Although we obtained population data in Lake Gogebic for only one year, and could not rigorously evaluate year-class strength, insight about the relative variability of recruitment can be gained by examining the properties of the catch-curve regressions. For example, Maceina (2003) used catch-curve residuals as a quantitative index of the relative year-class strength of black crappie and white crappie in Alabama reservoirs, and showed that residuals were related to various hydrological variables in the reservoirs. Similarly, Isermann et al. (2002) used the coefficient of determination from catch curve regressions as an index of crappie recruitment variability.

Eschmeyer (1941a) reported that the source (stocking or natural) of walleye recruitment in Lake Gogebic was unknown, though he hypothesized that sustained natural reproduction was likely occurring very shortly after introduction. By 1950, Eschmeyer confirmed that walleye were reproducing effectively, and that stocking was contributing little or nothing to the fishery. In 1986, Norcross characterized the population as having consistent recruitment. Given the large number of year classes and relatively high R2 value from the catch curve, consistent recruitment appears to continue. The R2 value from the catch curve (0.88) was above the average (0.79) from other Michigan walleye populations surveyed as part of the Large Lakes program to date (N = 19), and was near the median value (0.87). Because walleyes have not been stocked since 1981, all current year classes are a result of natural reproduction. Previous interpretation of age frequency data from spawning walleyes in Lake Gogebic suggested that the modal age of males shifted between age three and age five, likely reflecting changes in year-class strength (Norcross 1986). In 2005, the modal age for males was four, though there was rather equal representation from ages 3-6 (Table 8). In fact, ages 3–6 have accounted for the majority of the male spawning population from 1976 through 2005 (Table 17), providing further evidence of consistent recruitment. The age distribution of female walleyes in 2005 appeared bimodal, with peaks at age 5 and age 10. Norcross (1986; Table 18) reported that very few females under age 6 are mature, but in our sample 34% of the females were less than age 6.

The Great Lakes Indian Fish and Wildlife Commission (GLIFWC) conducted fifteen fall recruitment surveys on Lake Gogebic from 1990 to 2005 (Figure 9). The catch per mile of age-0 walleyes has ranged from 0.8 to 205.8, with an average of 48.4. From these data, there appears to be some variability in year-class strength, though fall electrofishing can be a highly variable collection method regardless of actual year-class strength. In fact, the residual values from our catch curve regression were not significantly related to the catch per mile from GLIFWC's surveys (F = 1.96, P = 0.20, df = 9). This could be a result of sampling variability in the fall electrofishing, sampling variability in our spring netting, aging error, or a combination of these factors.

Variability in northern pike year-class strength (R2 = 0.85) was near the average (0.87) and median (0.88) from other Michigan northern pike populations surveyed as part of the Large Lakes program (N = 17). Smallmouth bass, however, had relatively high recruitment variability (R2 = 0.59). In other populations surveyed in the Large Lakes Program the R2 has averaged 0.77, with a median value of

0.85. However, we caution that the sample size for the catch curve of Lake Gogebic smallmouth bass was much lower than other surveys, which likely has an effect on the fit of the catch at age data.

Movement.–Historically, there were public concerns over the apparent mass emigration of game fish out of Lake Gogebic. A fishway was installed in 1934 at the Lake Gogebic outlet to allow upstream migration back into the lake, and although yellow perch and walleye were observed to use the lock, it never functioned consistently. In 1940, again in response to the concerns about fish emigration, a weir was constructed on the outlet and was operated for approximately two years. Regarding walleye alone, 56 migrated downstream and 53 migrated upstream into Lake Gogebic (Eschmeyer 1942). Thus, although there was movement of fish between Lake Gogebic and the West Branch of the Ontonagon River at times, there was no significant loss of fish. It is doubtful if conditions have changed appreciably since 1940. The recapture data from our spring netting shows that some walleye moved considerably within the lake during the spawning period. Eschmeyer (1950) similarly reported movement (minimum distance of 1 mile) during the spawning period in Lake Gogebic. There is only one report of walleye moving far from Lake Gogebic. In 1985, a walleye tagged in Lake Gogebic was caught in the Victoria Dam Flowage (DNR Fisheries Division, unpublished data).

Angler Survey

Summary.–The fishery of Lake Gogebic is typical of lakes in the western Upper Peninsula. The angler catch was dominated by walleyes and yellow perch, which comprised 71% of the total catch. The majority of both walleyes and northern pike caught were released, which is a result of the relatively low size structure for both of these species. The catch rate for walleye was rather consistent throughout the open-water period, though it was much lower during the ice-cover period. Overall, the open-water period accounted for most of the annual catch, harvest, and effort. In fact, the angling effort per day was five times higher in the open-water period. Overall, the fishery of Lake Gogebic is not very diverse, though this is similar to most other waters in the western Upper Peninsula. Ciscoes were caught and harvested, though in low number.

Historical comparisons.–A summary of the angler surveys conducted on Lake Gogebic from 1940 through 1977 was provided by Norcross (1986). Since Norcross' review, two additional angler surveys were conducted—one in 1998 (Lockwood 2000a), and the current study (2005). Angler effort has generally increased since the first angler survey was conducted in 1940 (Table 19). In addition to these angler surveys, angler effort was estimated from mail surveys in 1970 and 1973 as 26,480 and 42,300 days, respectively. Using current knowledge of the average number of trips per day (1.2 trip/day), and the average length of a trip (2.0 h/trip) from the 2005 angler survey, the 1970 and 1973 estimates equate to 63,552 and 101,520 hours of fishing effort, respectively. However, because these two estimates of angler effort were made using a totally different method, they are not useful for comparison.

Sendek and Ryckman (1978) reported that angler CPUE of yellow perch increased from the 1940's to the 1970's, while the CPUE of walleye decreased, and thought that it may have been due to true changes in abundance, or changes in fishing techniques and/or ability. With the addition of the recent angler surveys, this trend is still apparent. The harvest rate for walleye decreased from a high of 0.293 per hour in 1940 to a low of 0.046 per hour in 2005, while the yellow perch harvest rate increased from a low of 0.006 per hour in 1941 to a high of 0.153 in 1977. Although the catch rate for yellow perch decreased slightly over the past two angler surveys, the overall trend is supported by the contrasting percent composition of walleye and yellow perch in the angler harvest over time (Figure 10). Most likely, high harvest and harvest rates for walleye early on in the time series were high as a result of the initial boom of the walleye population. Additionally, the lower minimum size limit in the earlier years allowed for a higher number harvested. As the walleye population came more into balance, the yellow perch population expanded, which resulted in higher harvest and harvest rates for that species. The harvest of northern pike and smallmouth bass do not show any distinct trend over the same time series, though smallmouth bass are probably more abundant now than they were during the initial expansion of the walleye population. It is interesting that ciscoes were not detected during the 1940, 1941, 1976, and 1977 angler surveys, though they were in the 1998 and 2005 surveys. Perhaps they also have a cyclic predator-prey relationship with the walleye population.

During the 1998 angler survey, 98.9% of all released walleyes were sublegal (≤15 in), and there were 7.5 times as many sublegal walleyes caught during the open-water period compared to legal-size walleye (72,316 vs. 9,655). In 2005, although we did not evaluate the size composition of released walleyes, there were only about 3 times as many released walleyes as there were harvested walleyes. If we assume that most of the released walleyes were sublegal, this is additional evidence that walleye size structure has improved since the 1996 change from a 13-in minimum size limit.

Comparison to other large lakes.–In addition to the historic angler survey data for Lake Gogebic, comparisons with angler surveys from other large lakes can be useful. Thus far in the Large Lakes Program, 17 lakes have been surveyed which will be used for comparison. An estimated 101,372 angler hours occurred on Lake Gogebic during the angler survey, which corresponds to 7.7 hours per acre. This is well below the mean value for other lakes surveyed under the Large Lakes Program, but is only slightly below the median value (Table 20). The harvest for Lake Gogebic was 1.2 fish per acre, which is about one-seventh of the mean, and one-half of the median value for other large lakes. Michigan lakes with a high harvest per acre generally have popular bluegill/sunfish fisheries that bolster the total harvest.

For walleye, the estimated annual harvest from Lake Gogebic was 0.41 fish per acre, which is below the average (0.51 per acre) and median (0.45 per acre) for nineteen lakes surveyed as part of the Large Lakes Program. The average harvest of six other large Michigan Lakes (> 1,000 acres) reported by Lockwood (2000a) was 0.63 walleye per acre, ranging from 0.09 for Brevoort Lake to 1.68 for Chicagon Lake. These Michigan lakes were subject to similar gears and fishing regulations, including a 15-in minimum size limit. The low harvest per acre of walleye in Lake Gogebic is largely due to the small size structure of walleyes and low angler effort, because density and catch rates were above average. The harvest per hour (0.05) for walleye on Lake Gogebic was higher than the average (0.04) and median (0.04) values from 19 populations. Given that these harvest rates are calculated with general effort, the higher rate for Lake Gogebic is likely a reflection of the fact that anglers mainly target walleye in Lake Gogebic. As is the case in most walleye populations with a high proportion of sublegal fish, the catch rate of all walleye (0.18 per hour) was also much higher than the average (0.11 per hour) and median (0.07 per hour) values from other populations.

For northern pike, the estimated annual harvest was 0.02 fish per acre, which was below average compared to other waters in Michigan. The mean harvest in sixteen other lakes (having a 24-in minimum size limit) sampled in the Large Lakes Program was 0.08 northern pike per acre, ranging from 0.003 in North Manistique Lake (Hanchin and Kramer 2008) to 0.464 in Houghton Lake (Clark et al. 2004). The average harvest of seven other large Michigan lakes (>1,000 acres) reported by Lockwood (2000a) was 0.151 northern pike per acre, ranging from 0.002 per acre in Bond Falls Flowage to 0.654 per acre in Fletcher Pond. The lakes reported by Lockwood (2000a) were all subject to similar gears and fishing regulations, including a 24-in minimum size limit. Elsewhere, Pierce et al. (1995) estimated harvests from 0.7 to 3.6 per acre in seven smaller Minnesota lakes, which ranged from 136 to 628 acres in size and had no minimum size limit for northern pike.

The estimated annual harvest of smallmouth bass was 0.09 fish per acre, which was near the mean (0.10) from seventeen other lakes sampled in the Large Lakes Program. The mean harvest of seven other large (>1,000 acres) Michigan lakes (not including Gogebic) reported by Lockwood (2000a) was 0.08 smallmouth bass per acre, ranging from 0.03 in Brevoort Lake to 0.15 in Elk Lake. The lakes reported by Lockwood (2000a) were all subject to similar gears and fishing regulations, however, the surveys did not always include the entire open-water period. Yellow perch had an estimated annual harvest of 0.77 per acre in Lake Gogebic. In comparison, harvest per acre of yellow perch has averaged 2.6 per acre (median 1.4) in 19 populations surveyed in the Large Lakes Program. Thus, the fishery has a lower harvest compared to other large lakes, but Lake Gogebic is known for the large size of its yellow perch, rather than the high catch rates. In fact, 18% of the yellow perch harvested by anglers were greater than 12 in and over 2% of those harvested were greater than 14 in (Figure 11).

Walleye Size Limit Modeling

History.–Norcross (1986) conducted size limit modeling for Lake Gogebic walleye and recommended reducing the MSL from 13 in to 12 in because yield would remain the same while number harvested would increase. Miller (1995, 2001) simulated the effects of changing the size regulation on walleye from 13 in to: no size limit, 15 in, and a 10 to 15.9-inch harvest slot to see if the various regulations would achieve the objectives of increasing number of walleyes harvested, reducing the number of small fish in the population, and not harming recruitment. The simulation under no size limit did not achieve the size structure objectives, although the 15-inch MSL and slot limit did. The slot limit appeared to match the objectives, though the negative factors of its complication, potential enforcement difficulty, and predisposition for the harvest of small walleye weighed against it. The 15-inch MSL was considered the best option, and it was ultimately established in 1996, with evaluation to take place after at least 5 years (2001). Now, almost ten years after the change, it appears that the 15-inch MSL is working to some degree. The size structure of male walleyes from spring netting increased following the change, and there is some evidence that the proportion of sublegal walleye in the angler catch has decreased in the years following the change.

Current simulations.–Using data collected in 2005, we investigated the effect of changing the MSL on walleye back to 13 in, using the parameters in Appendix 2. At very low natural mortality [conditional natural mortality (cm) = 10%], yield was maximized with the 15-in MSL, but this level of natural mortality is not probable. As natural mortality was increased, yield was maximized with the 13-in MSL, though the differences in yield between the two size limits were small at intermediate levels (cm = 20–25%) of natural mortality. At the higher levels of natural mortality (cm = 30–35%) the 13-in MSL clearly resulted in higher yield. At high levels of natural mortality, the lower MSL would essentially allow anglers to harvest the fish, rather than letting them die. Although the 13-inch MSL will likely result in higher yield, given our best estimate of natural mortality (cm = 30%) and assuming an exploitation of about 20%, yield would only be about 11% higher with the 13-in MSL. Although the 13-in MSL would likely result in a higher walleye yield for Lake Gogebic, individual anglers never truly realize what total yield for a fishery is. Rather, anglers recognize things such as the size of harvested fish, or whether or not they reach a daily bag limit. Thus, it is important to examine how other parameters would change with the reduced MSL. Although it is somewhat intuitive, the number of fish harvested will always be greater with a lower MSL. Given a likely scenario for Lake Gogebic’s walleye population (cm = 30%, exploitation = 20%), the number of fish harvested would be about 44% higher under a 13-in MSL. Although this appears like a significant amount, we caution that the overabundance of small walleye in the angler catch has been perceived as a problem in the past (Norcross 1986). The obvious tradeoff for harvesting more walleyes under a lower MSL is that the average size of a harvested walleye will be lower. Given our assumptions, the average size of a harvested walleye will be 8% smaller under the 13-in limit (15.8 in versus 17.2 in). These last predictions are in fact almost identical to the predicted lengths for both regulations (15.7 in and 17.3 in) reported by Miller (2001). However, the average size of harvested walleye under both size limits may actually be lower than these estimates because the actual size of a harvested walleye as measured during our angler survey in 2005 was only 16.5 in.

Risk and uncertainty.–At very low natural mortality (cm = 10%), growth overfishing was evident with the 13-in MSL when exploitation exceeded 30%, which was not observed with the 15-in MSL. Growth overfishing takes place when harvest occurs at a high rate and at an early age of recruitment to the fishery so that the full growth potential of the population is not achieved. Thus, a 13-in MSL would present some risk in the event that exploitation were to increase dramatically, and natural mortality were to experience a compensatory reduction. In 2005 we estimated that exploitation was about 10%, though it could have been as high as 20% if there was significant nonreporting or undetected tag loss. On the contrary, there is little risk with the 13-in MSL if natural mortality is higher than we suspect because the 13-in MSL allows higher yields under this scenario.

Miller (2001) predicted a 27% increase in the total pounds of harvestable fish when simulating a switch from a 13-in MSL to a 15-in MSL. This is contrary to our findings that suggest higher yield under the 13-in limit. The differences in our predictions are likely a result of Miller's use of a lower rate for natural mortality (instantaneous = 0.27, cm = 24%), as well as his use of 10% hooking mortality and 5% harvest of sublegal walleye. At these lower rates of natural mortality, our simulations showed very little difference in yield between the two MSLs.

Our simulations showed that spawning stock biomass (per recruit) would be reduced approximately 20% under a 13-in MSL. It is difficult to predict what effect this would have on the walleye fishery because Lake Gogebic has consistently high walleye recruitment. There is the chance that a reduction of the spawning stock would have no effect if walleye year-class strength is determined primarily by spring weather conditions; however, the risk should be taken into consideration.

Summary

Relative to other lakes in Michigan, there is a wealth of information on the walleye population in Lake Gogebic. Information overwhelmingly points to a stable population with relatively low exploitation. Although there are occasional dominant year classes, there have been no documented year-class failures, suggesting that recruitment is extremely stable. The consistent recruitment is largely due to the large spawning stock and high-quality spawning grounds, though cannibalism is a likely regulating mechanism for the walleye population. Walleye growth has been consistently slow throughout the time series on Lake Gogebic, primarily due to the high abundance of walleye, and lack of forage fish. The major prey item for walleye in Lake Gogebic are yellow perch, walleye, and mayfly nymphs, and there is probably a cyclic predator-prey relationship between yellow perch and walleye. Attempts at stocking forage fish have all failed (Miller 2001), likely because of the considerable predation by walleye. In fact, the amount of forage fish that would be necessary to overcome the consumptive capacity of the predators is probably not feasible to achieve through stocking. Mortality was likely higher in 2005 than in the past, though it was still within acceptable limits. Given that different structures have been used to age walleye in the past, we suggest that additional mortality estimates should be made (perhaps at 5-year intervals) using catch curves derived from samples taken during the spawning period. Natural sources were the largest contributor to mortality on walleye, though spearing exploitation on legal-size (≥15 in) walleyes was higher than expected in one of the years it was estimated. Although the overall size structure of walleye is considered low, there are large walleyes (up to 30 in) in the population. In 2005, there were an estimated 3.2 legal-size walleye per acre and anglers harvested 0.4 per acre at a rate of 0.05 per hour fished. Although walleye density was above the average of other large lakes surveyed recently in Michigan, the harvest values were below average, which is a result of the low size structure and low angler effort. In contrast, the catch rate for all walleyes was much higher than average because there are many fish of sublegal size. The estimate of adult walleye abundance from the Michigan regression equation was 72% lower than the empirical estimate, and the prediction from the Wisconsin regression equation was 62% lower. Although Lake Gogebic has always had above average walleye density, our survey likely occurred during a peak in density. It is most reasonable to apply the Wisconsin regression equation for an approximate estimate of adult walleye abundance in Lake Gogebic. Both the current 15-in minimum size limit and the previous 13-in minimum size limit are viable options for Lake Gogebic, but considerable effort should be made to identify the public's desire, and the position from the DNR Law Enforcement Division prior to any proposed change. Additionally, the tradeoffs between both minimum size limits should be communicated thoroughly, especially given that in the mid-1990s the public was unhappy with the number of small walleyes being caught. The change to a 15-in minimum size limit appears to have had positive results on the size structure of walleyes, so perhaps the most important thing is to identify the management objectives for the walleye population in Lake Gogebic. When the size limit was changed to 15 in it was a safe decision because it was more restrictive, even though uncertainty existed in estimates of fishing and natural mortalities.

Northern pike are much less abundant than walleye in Lake Gogebic. In fact, considering our estimates of adult abundance, there are about 20 times as many walleye as northern pike. Additionally, the density of both adult and legal-size northern pike is lower than in most large Michigan lakes, and size structure is low. Accordingly, measures of angler harvest and catch rates were below average relative to other large lakes. Growth and mortality of northern pike were within acceptable limits, and were relatively similar to other lakes in the western Upper Peninsula. Smallmouth bass density was low relative to walleye, but surprisingly the exploitation rate was higher than that for both walleye and northern pike. Perhaps, smallmouth bass are easier to catch during the summer months when angling effort is high. The harvest per acre of smallmouth bass was near the average for other large lakes in Michigan and the catch rate for smallmouth bass was higher than average. Mortality of smallmouth bass appeared high, though we are not completely confident in our estimate. Regardless, angling mortality likely accounts for a considerable portion of the total annual mortality of smallmouth bass. Yellow perch are heavily preyed upon by the walleye population, resulting in a low-density population that supports low catch rates, but the opportunity to catch large yellow perch. In general, the hours fished per acre and total number of all fish harvested per acre were lower than other large lakes in Michigan. Angler survey data indicated increased angling effort over the past 65 years, though perhaps a plateau has been reached.

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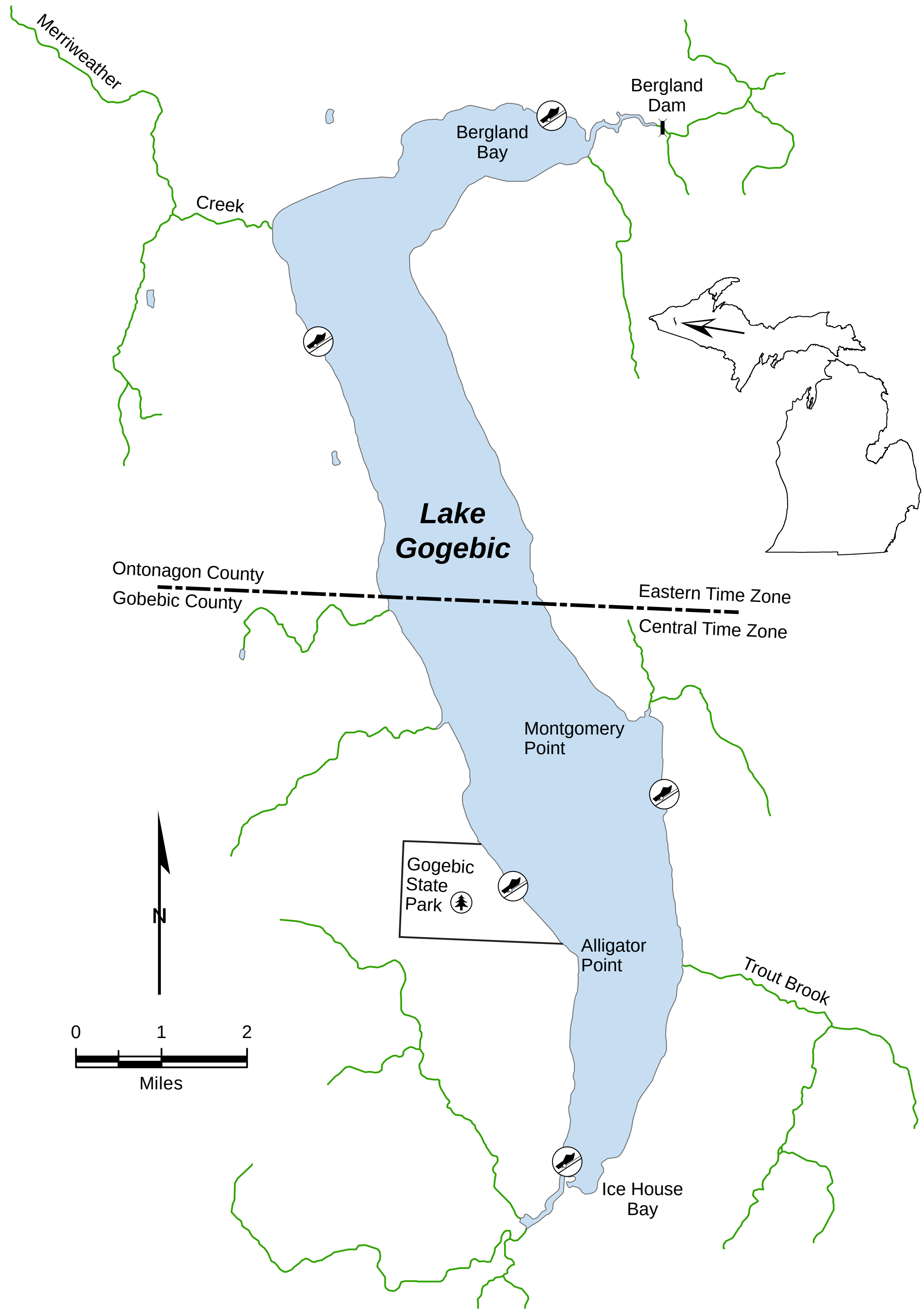

Figure 1.–Map of Lake Gogebic, Gogebic and Ontonagon counties, Michigan.

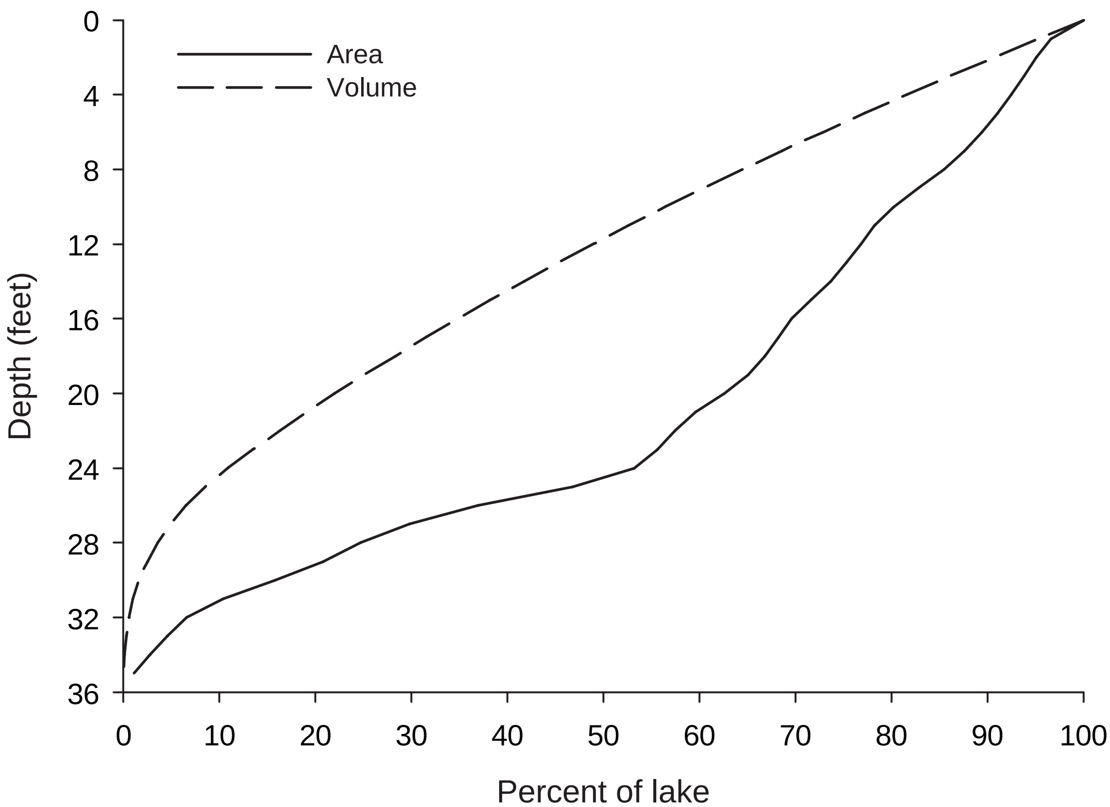

Figure 2.–Percent of lake surface area and volume equal to or greater than a given depth for Lake Gogebic. Data taken from DNR Digital Water Atlas (Breck 2004).

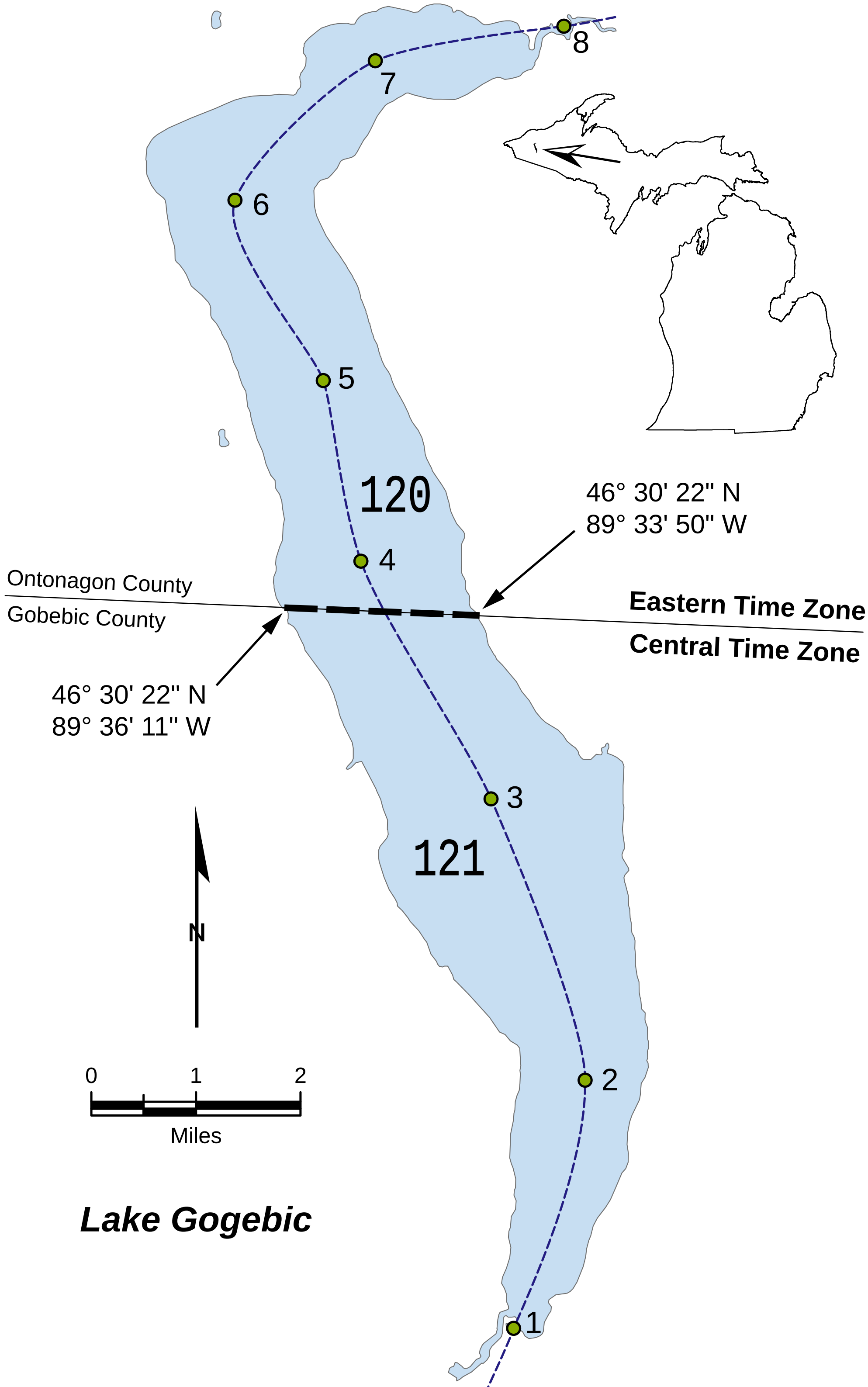

Figure 3.–Counting path and associated count path way points for the Lake Gogebic, summer 2005 and winter 2006 survey. Coordinates for counting path way points are provided in Table 2. Sections (120 and 121) are separated by a line between the coordinates (46° 30’ 22” N latitude, 89° 36’ 11” W longitude) and (46° 30’ 22” N latitude, 89° 33’ 50” W longitude).

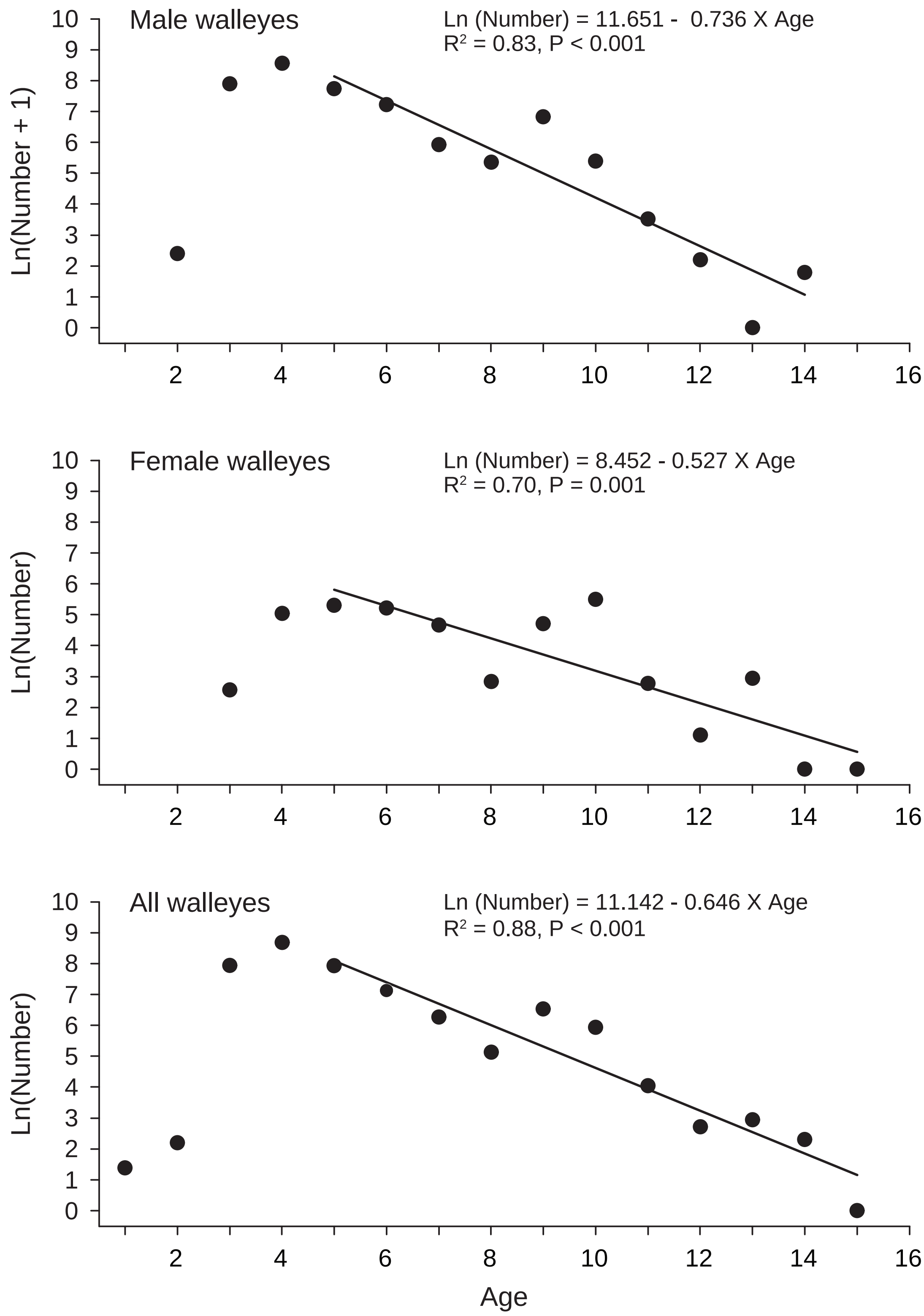

Figure 4.–Plot of observed catch [ln(number) or ln(number + 1)] versus age for legal-size (≥ 15 in) walleyes in Lake Gogebic. Line is a plot of the regression equation given.

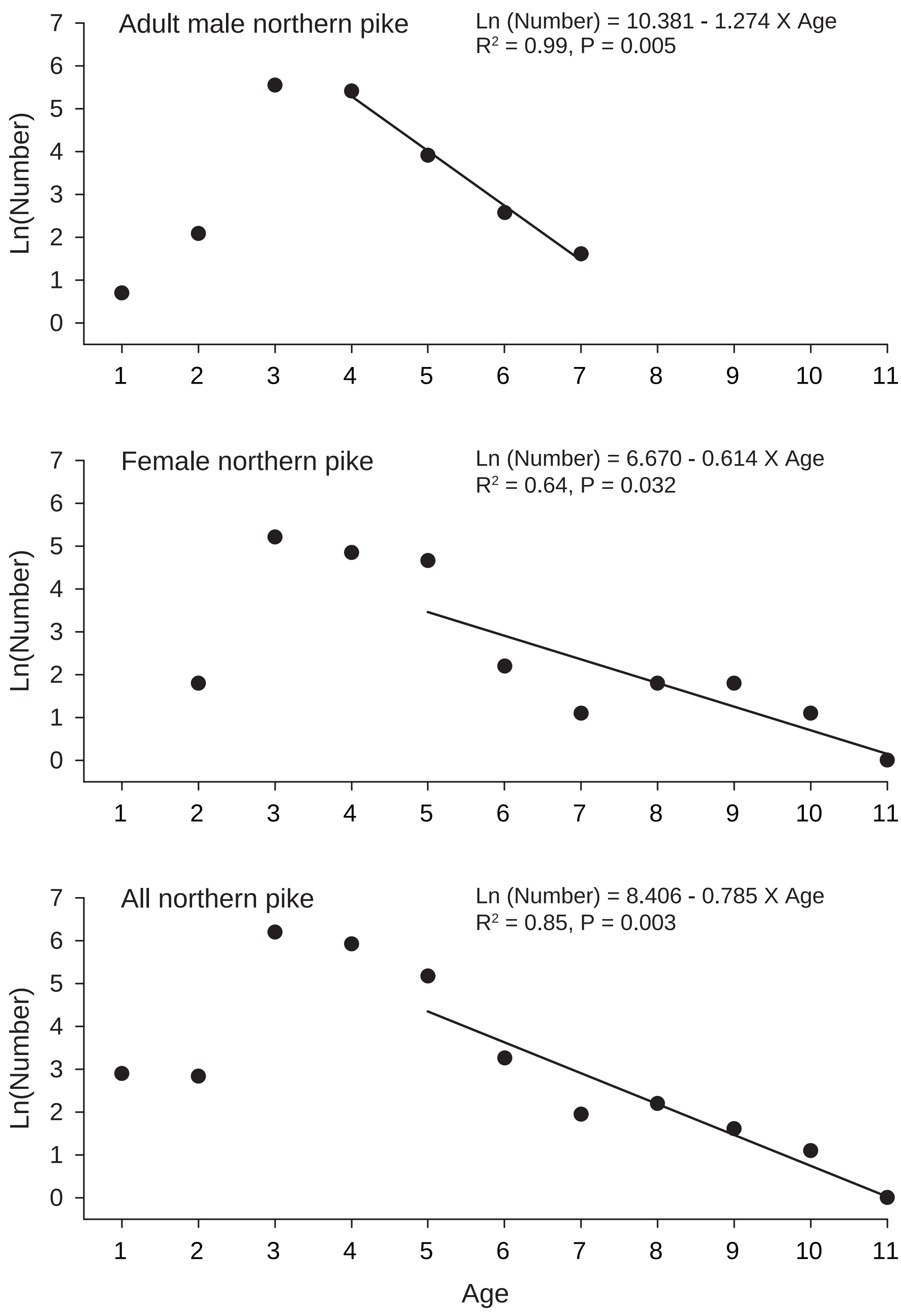

Figure 5.–Plot of observed catch [ln(number)] versus age for adult male, legal-size (≥ 24 in) female, and all legal-size (males, females, and unknown sex) northern pike in Lake Gogebic. Line is a plot of the regression equation given.

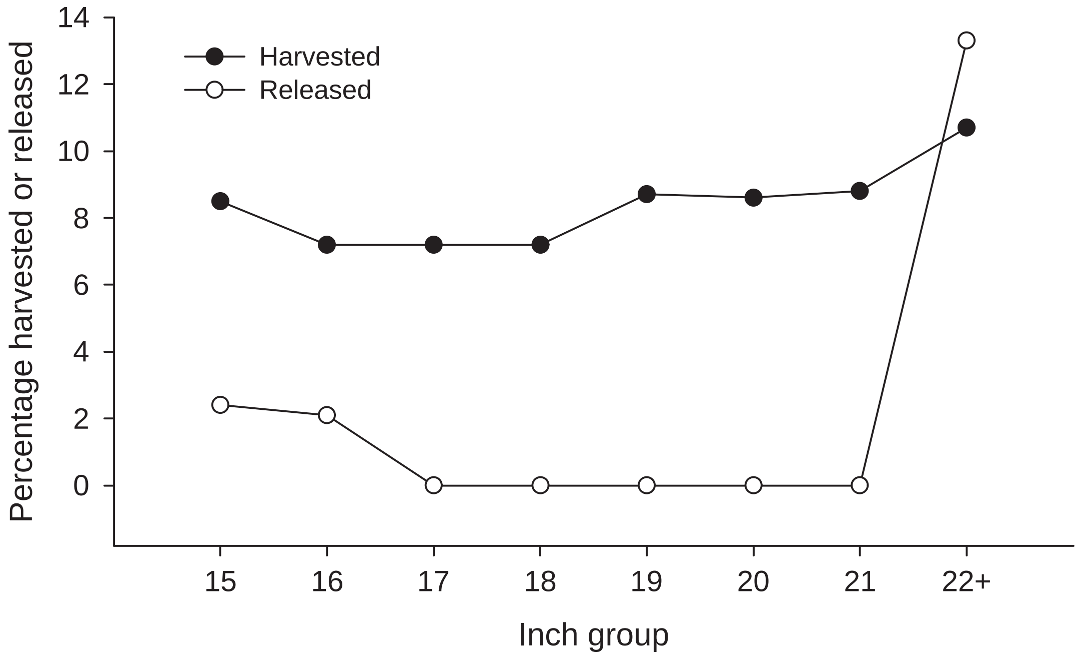

Figure 6.–Percentage of tagged walleyes that were harvested and percentage of caught walleye that were released by inch group, based on tag returns from Lake Gogebic in the year following tagging.

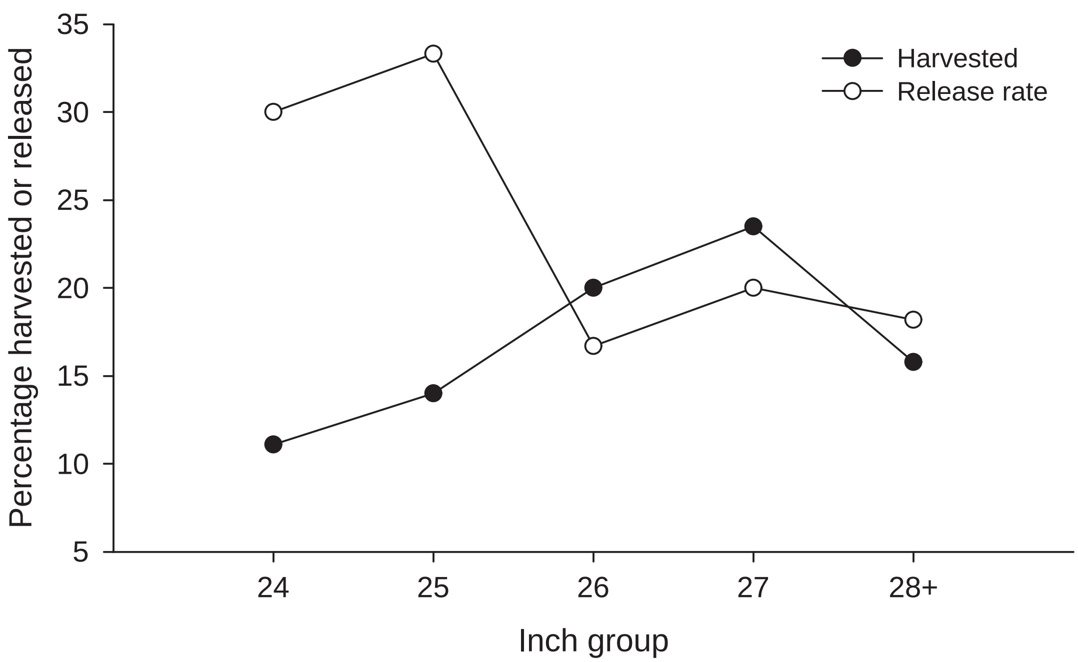

Figure 7.–Percentage of tagged northern pike that were harvested and percentage of caught northern pike that were released by inch group, based on tag returns from Lake Gogebic in the year following tagging.

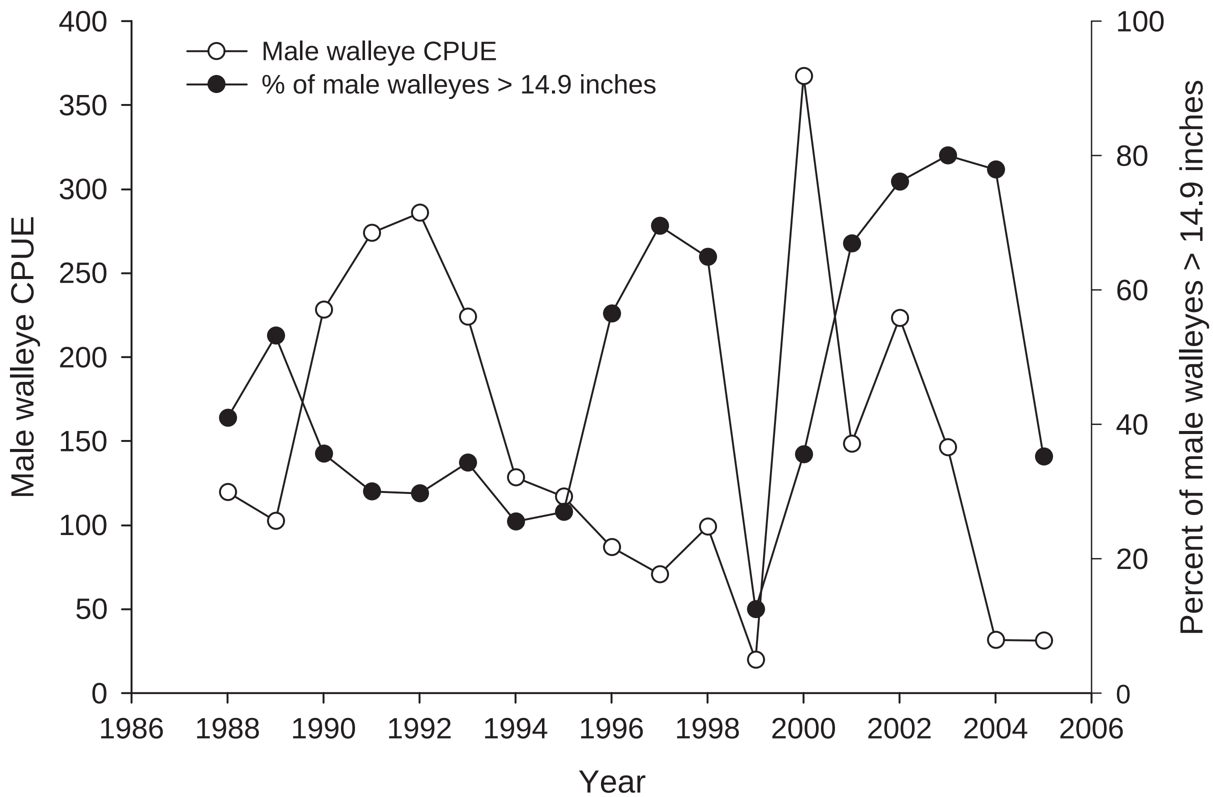

Figure 8.–Plot of male walleye catch per unit effort (CPUE; number per fyke-net night) during spawning period versus the percentage of male walleye collected that were greater than 14.9 inches.

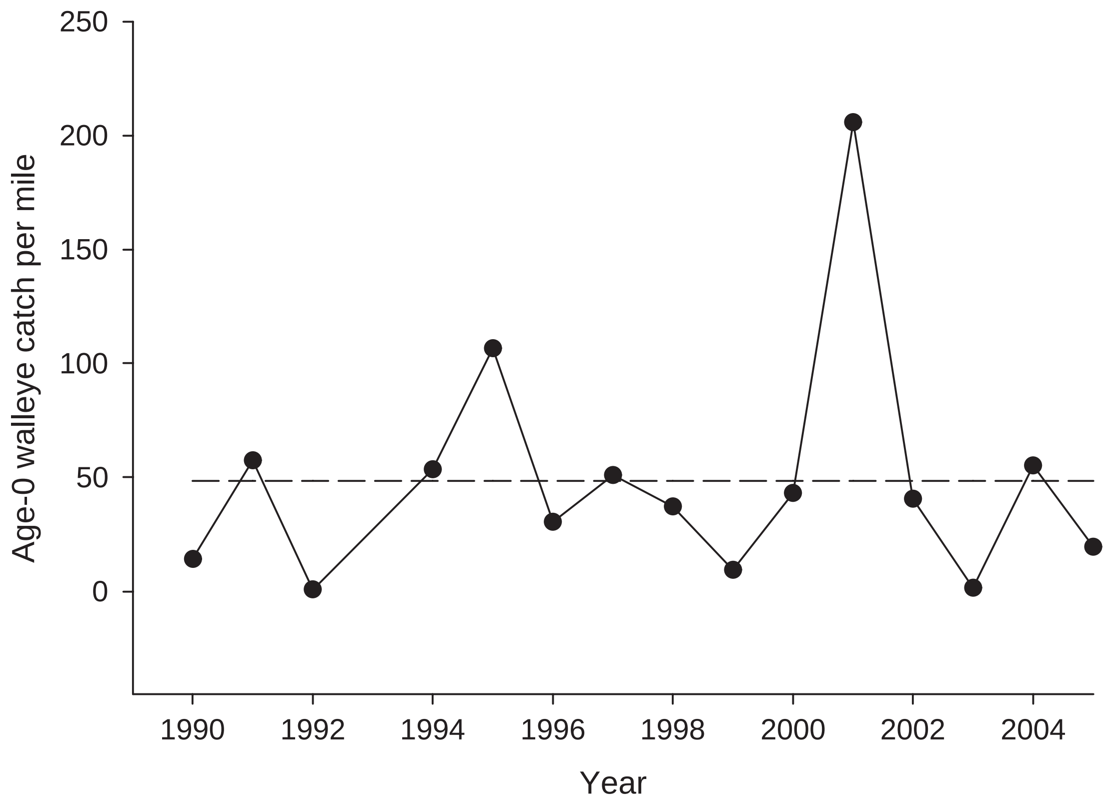

Figure 9.–Number of age-0 walleye caught per mile in fall electrofishing surveys of Lake Gogebic conducted by the Great Lakes Indian Fish and Wildlife Commission. The horizontal line represents the average (48.4 per mile) from 1990 to 2005 (missing year 1993).

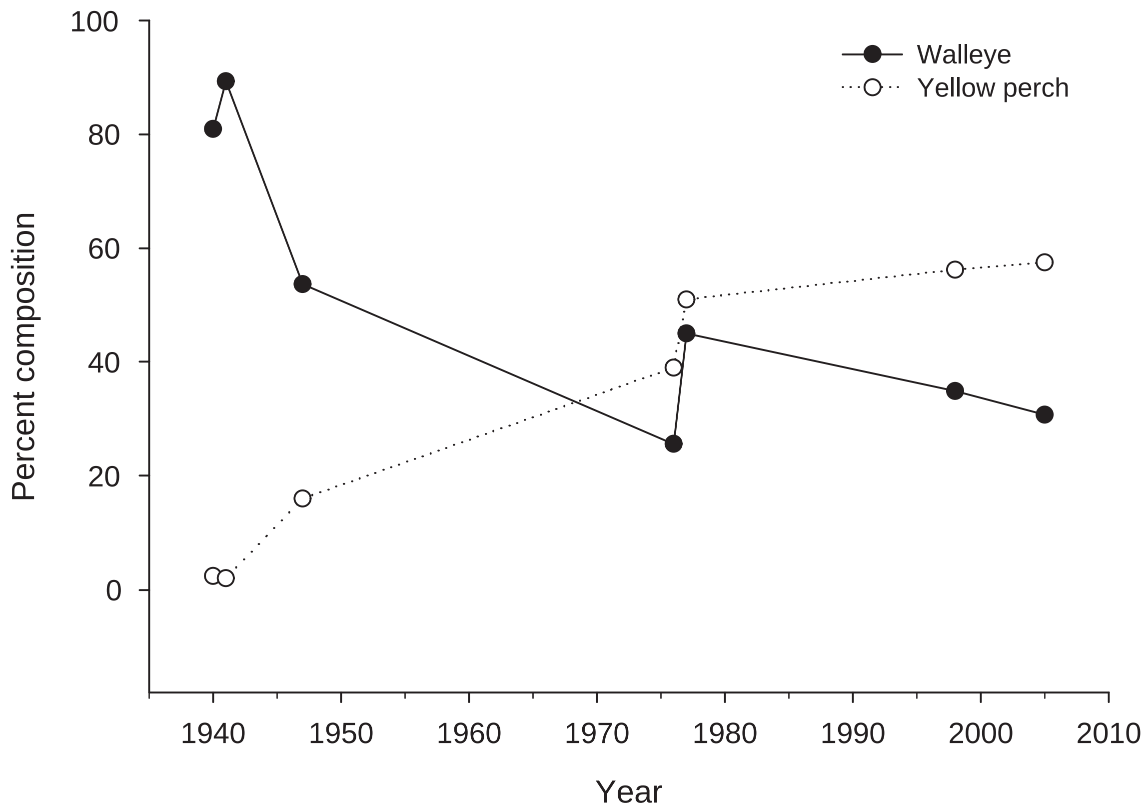

Figure 10.–Percent composition of walleye and yellow perch in angler catch from various angler surveys conducted on Lake Gogebic from 1940 to 2005.

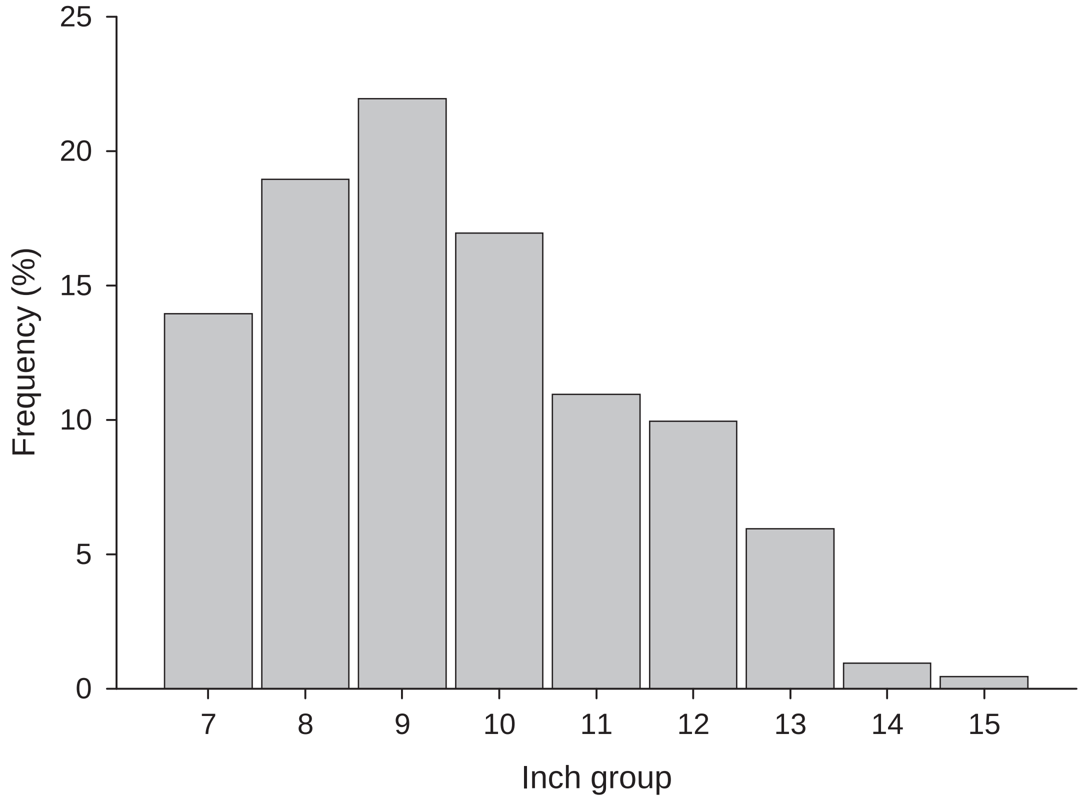

Figure 11.–Length-frequency of yellow perch harvested by anglers during the 2005-06 creel survey on Lake Gogebic.

Table 1.–Number[a] and size of fish stocked in Lake Gogebic 1892 through 2005.

Year(s)	Species	Quantity[b]	Life stage
1892–1914	Lake trout	780,000	Fry
1898	Northern pike	84	Adult
1898	Muskellunge	18	Adult
1924	Silver trout	30,000	Unknown
1904–1940	Walleye	28,450,000	Fry
1942	Minnows	6,000	Adult
1910–1937	Smallmouth bass	10,250	Fingerling
1906–1933	Largemouth bass	10,000	Fingerling
1929–1937	Yellow perch	51,000	Fingerling
1931–1945	Bluegill	117,400	Unknown
1940	Black crappie	5,250	Fingerling
1941	Bluegill	45,000	Fingerling
1967	Rainbow trout	6,000	Adults
1969	Rainbow trout	5,000	Adults
1972	Walleye	1,600,000	Fry
1974	Walleye	500,000	Fry
1975	Walleye	2,000,000	Fry
1976	Walleye	2,000,000	Fry
1977	Walleye	1,000,000	Fry
1978	Walleye	850,000	Fry
1979	Walleye	600,000	Fry
1980	Walleye	422,000	Fry
1981	Walleye	500,000	Fry
1988	Emerald shiner	31,250	Adult
1988	Sand shiner	31,250	Adult
1996	Fathead minnow	1,200,000	Unknown
1997	Fathead minnow	8,400 lbs	Adult
1998	Spottail and emerald shiners	1,000	Adult

[a] Approximate number stocked for early years because discrepancies exist in records.
[b] Number stocked, or pounds where indicated

Table 2.–Estimates of population size, exploitation, natural mortality, and total annual mortality for Lake Gogebic walleyes from 1947 to 2005.

Year[a]	Size marked	Population estimate (number)	Exploitation[b] (%)	Natural mortality[c] (%)	Total mortality (%)
1947	–	–	4.0	20.0	24.0[d]
1976	13 inch	56,084	5.7	22.0	27.7[e]
1977	13 inch	38,540[f]	7.2	20.5	27.7[e]
1984	13 inch males	63,000	20.0	18.2	38.2[e]
1993	13 inch males	62,497	20.9	32.6	53.5[e]
1998	Adults	28,840	–	–	–
2005	Adults	103,916[g]	8.9[h]	38.7	47.6

[a] Past reports have discrepancies in the dates for various estimates of exploitation and mortality. In this report we use the year in which the fish were marked or collected.
[b] Minimum estimates based on angler tag returns.
[c] Estimated as total mortality minus exploitation.
[d] Mortality estimated from angler tag returns in years following tagging.
[e] Estimates made for male walleye.
[f] Although estimate was 38,540, authors suggested that true population was more like 65,000.
[g] Adult (≥15 in, or of identifiable sex from gamete extrusion in the spring) walleye.
[h] Exploitation in 2005 is for walleye ≥15 in.

Table 3.–Coordinates for the Lake Gogebic summer 2005 angler survey. See Figure 3 for general flight path and numbered locations.

Marker	Latitude	Longitude
1	46° 24.43' N	89° 32.97' W
2	46° 26.52' N	89° 32.25' W
3	46° 28.82' N	89° 33.52' W
4	46° 30.73' N	89° 35.22' W
5	46° 32.22' N	89° 35.77' W
6	46° 33.68' N	89° 36.93' W
7	46° 34.90' N	89° 35.32' W
8	46° 35.25' N	89° 33.07' W

Table 4.–Survey periods, sampling shifts, and expansion value "F" (number of fishing hours within a sample day) for the Lake Gogebic angler survey, spring 2005 through winter 2006.

Survey period	Sample shift (h)		F
May	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
December 22–31	0700–1530	0930–1800	12
January	0700–1530	0930–1800	11
February	0700–1530	0930–1800	11
March 1–27	0600–1430	1030–1900	13

Table 5.–Fish collected from Lake Gogebic using a total sampling effort of 426 fyke-net lifts during April 13–28, 2005.

Species	Total catch[a]	Percent by number	Mean fyke-net CPUE[a,b]	Length range (in)	Average length (in)[c]	Number measured[c]
Walleye	18,229	73.5	38.8	5.2–30.2	14.9	14,502
White sucker	3,558	14.3	7.9	6.5–23.3	18.4	462
Northern pike	1,294	5.2	2.7	7.5–42.0	21.3	1,123
Yellow perch	1,168	4.7	2.6	3.4–14.2	10.1	958
Rock bass	373	1.5	0.8	3.2–11.5	8.5	347
Smallmouth bass	130	0.5	0.3	8.1–19.1	14.2	129
Pumpkinseed	48	0.2	0.1	2.5–8.8	6.4	48
Black crappie	6	<0.1	<0.1	9.2–14.2	11.6	6
Common shiner	3	<0.1	<0.1	5.5–6.6	6.0	3
Burbot	2	<0.1	<0.1	10.0–14.5	12.3	2
Cisco	1	<0.1	<0.1	15.0	15.0	1
Golden shiner	1	<0.1	<0.1	4.3	4.3	1
Creek chub	1	<0.1	<0.1	7.5	7.5	1
Black bullhead	1	<0.1	<0.1	8.0	8.0	1
Brown bullhead	1	<0.1	<0.1	6.3	6.3	1

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

Table 6.–Number of fish per inch group collected from Lake Gogebic, April 13–28, 2005.

	Species														
Inch group	Walleye	White sucker	Northern pike	Yellow perch	Rock bass	Smallmouth bass	Pumpkinseed	Black crappie	Common shiner	Burbot	Cisco	Golden shine	Creek chub	Black bullhead	Brown bullhead
1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
3	–	–	–	1	3	–	8	–	–	–	–	–	–	–	–
4	–	–	–	36	10	–	–	–	–	–	–	1	–	–	–
5	6	–	–	91	10	–	7	–	2	–	–	–	–	–	–
6	–	1	–	64	35	–	6	–	1	–	–	–	–	–	1
7	–	–	1	47	72	–	20	–	–	–	–	–	1	–	–
8	–	1	6	49	60	1	6	–	–	–	–	–	–	1	–
9	–	–	4	55	97	1	–	1	–	–	–	–	–	–	–
10	35	1	5	93	50	–	–	1	–	1	–	–	–	–	–
11	908	–	2	236	10	8	–	2	–	–	–	–	–	–	–
12	1,736	1	2	221	–	30	–	–	–	–	–	–	–	–	–
13	3,504	2	4	61	–	28	–	1	–	–	–	–	–	–	–
14	2,579	1	5	4	–	16	–	1	–	1	–	–	–	–	–
15	1,433	17	13	–	–	12	–	–	–	–	1	–	–	–	–
16	1,279	53	35	–	–	16	–	–	–	–	–	–	–	–	–
17	1,482	107	61	–	–	10	–	–	–	–	–	–	–	–	–
18	799	106	102	–	–	6	–	–	–	–	–	–	–	–	–
19	287	74	182	–	–	1	–	–	–	–	–	–	–	–	–
20	187	59	164	–	–	–	–	–	–	–	–	–	–	–	–
21	142	29	117	–	–	–	–	–	–	–	–	–	–	–	–
22	70	9	112	–	–	–	–	–	–	–	–	–	–	–	–
23	31	1	101	–	–	–	–	–	–	–	–	–	–	–	–
24	11	–	64	–	–	–	–	–	–	–	–	–	–	–	–
25	5	–	44	–	–	–	–	–	–	–	–	–	–	–	–
26	3	–	25	–	–	–	–	–	–	–	–	–	–	–	–
27	–	–	17	–	–	–	–	–	–	–	–	–	–	–	–
28	3	–	18	–	–	–	–	–	–	–	–	–	–	–	–
29	1	–	9	–	–	–	–	–	–	–	–	–	–	–	–
30	1	–	6	–	–	–	–	–	–	–	–	–	–	–	–
31	–	–	6	–	–	–	–	–	–	–	–	–	–	–	–
32	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–
33	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–
34	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
36	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–
37	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
38	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–
39	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–
40	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
41	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
42	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
43	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
44	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total	14,502	462	1,123	958	347	129	48	6	3	2	1	1	1	1	1

Table 7.–Estimates of abundance, angler exploitation rates, and instantaneous fishing mortality rates for Lake Gogebic walleyes and northern pike 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 tagged	5,702	205	60
Total tag returns[a]	447	42	15
Number of legal-size[b] fish			
Multiple-census estimate	7,789 (6,429–9,149)	813 (168–1,457)	Not valid
Single-census estimate	41,402 (29,285–60,424)	659 (293–1,157)	1,693 (693–4,183)
Michigan model prediction[c]	18,579 (3,877–89,037)	–	–
Number of adult[d] fish			
Multiple-census method	32,190 (28,757–35,624)	4,538 (1,713–7,363)	–
Single-census estimate	103,916 (73,503–151,660)	3,271 (1,455–7,825)	–
Michigan model prediction[e]	29,458 (5,377–161,378)	–	–
Wisconsin model prediction[f]	39,753 (12,812–123,348)	–	–
Annual exploitation rates			
Based on reward tag returns	9.3%	16.9%	19.3%
Based on harvest/multiple-census abundance	41.8% (30.3–53.4%)	19.8% (1.8–37.8%)	–
Based on harvest/single-census abundance	7.9% (4.7–11.0%)	24.4% (3.2–45.6%)	58.5% (2.2–114.8%)
Total annual mortality rates	48%	54%	22%

[a] Voluntary tag returns plus tags observed by creel clerk that were not returned by anglers.
[b] Walleye ≥15 in, and northern pike ≥24 in.
[c] Michigan model prediction of legal-size walleye abundance based on lake area, N = 32.
[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 = 31
[f] Wisconsin model prediction of adult walleye abundance based on lake area, N = 185.

Table 8.–Weighted mean total lengths (in) and sample sizes by age for walleyes collected from Lake Gogebic, April 13–28, 2005. Standard deviation is in parentheses.

Age	Mean length			Number aged		
	Males	Females	All fish[a]	Males	Females	All fish[a]
1	–	–	5.6 (0.0)	–	–	2
2	10.5 (–)	–	10.5 (–)	1	–	1
3	12.9 (0.8)	14.1 (1.4)	12.9 (0.9)	19	4	24
4	13.7 (0.8)	15.8 (1.0)	14.0 (1.1)	25	21	50
5	15.1 (1.1)	16.9 (1.5)	15.4 (1.6)	18	27	46
6	16.9 (0.8)	18.6 (1.2)	17.3 (1.2)	16	22	38
7	16.3 (0.5)	19.1 (1.6)	17.5 (1.3)	4	12	16
8	17.2 (0.8)	18.5 (0.0)	17.6 (0.9)	3	2	5
9	18.0 (0.7)	20.7 (1.6)	18.6 (1.3)	23	15	38
10	18.1 (1.0)	21.6 (1.1)	20.5 (2.0)	6	41	48
11	19.4 (0.7)	21.6 (0.9)	20.2 (1.2)	3	3	7
12	20.9 (–)	23.8 (1.4)	21.6 (1.4)	1	2	3
13	–	22.2 (3.1)	22.4 (3.0)	–	4	4
14	21.3 (–)	29.0 (–)	22.1 (2.4)	1	1	2
15	–	25.6 (–)	25.6 (–)		1	1

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

Table 9.–Weighted mean total lengths (in) and sample sizes by age for northern pike collected from Lake Gogebic, April 13–28, 2005. Standard deviation is in parentheses.

Age	Mean length			Number aged		
	Males	Females	All fish[a]	Males	Females	All fish[a]
1	9.7 (1.3)	–	9.7 (1.5)	2	–	14
2	14.3 (1.6)	15.6 (2.5)	14.7 (2.3)	8	5	14
3	18.6 (2.0)	20.0 (2.0)	19.6 (1.8)	66	75	144
4	21.6 (2.2)	22.5 (2.6)	21.7 (2.2)	56	58	114
5	25.3 (2.0)	26.0 (3.2)	25.4 (2.9)	27	69	98
6	25.1 (1.6)	24.6 (5.4)	24.3 (3.6)	6	6	12
7	26.4 (1.1)	23.0 (–)	24.8 (1.8)	3	1	4
8	–	30.1 (7.5)	32.6 (7.1)	–	4	6
9	–	37.7 (1.6)	37.2 (1.7)	–	4	4
10	–	40.9 (1.6)	40.9 (1.6)	–	3	3
11	–	39.1 (–)	39.1 (–)	–	1	1

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

Table 10.–Weighted mean total lengths (in) and sample sizes by age for smallmouth bass (males and females combined) collected from Lake Gogebic, April 13–28, 2005. Standard deviation is in parentheses.

Age	Mean length	N
3	12.0 (1.2)	16
4	13.2 (0.7)	30
5	14.8 (0.8)	9
6	16.1 (0.9)	8
7	16.8 (1.2)	3
8	17.1 (0.7)	5
9	17.9 (0.4)	2
10	–	0
11	18.7 (0.0)	2
12	17.9 (0.2)	3

Table 11.–Catch at age estimates (apportioned by age-length key) by sex for walleye, northern pike, and smallmouth bass from Lake Gogebic, April 13–28, 2005.

Age	Year class	Walleye			Northern pike			Smallmouth bass
		Males	Females	All fish[a]	Males	Females	All fish[a]	All fish[a]
1	2004	–	–	4	2	–	18	–
2	2003	10	–	9	8	6	17	–
3	2002	2,662	13	2,796	256	182	488	25
4	2001	5,202	155	5,846	223	127	373	50
5	2000	2,286	201	2,760	50	105	176	16
6	1999	1,367	184	1,238	13	9	26	16
7	1998	373	106	523	5	3	7	4
8	1997	211	17	169	–	6	9	9
9	1996	923	111	682	–	6	5	4
10	1995	219	243	375	–	3	3	0
11	1994	33	16	57	–	1	1	2
12	1993	8	3	15	–	–	–	5
13	1992	–	19	19	–	–	–	–
14	1991	5	1	10	–	–	–	–
15	1990	–	1	1	–	–	–	–
16	1989	–	–	–	–	–	–	–
17	1988	–	–	–	–	–	–	–
18	1987	–	–	–	–	–	–	–
19	1986	–	–	–	–	–	–	–
20	1985	–	–	–	–	–	–	–
Total		13,299	1,070	14,504	557	448	1,123	131

[a]All fish includes males, females, and fish of unknown sex.

Table 12.–Voluntary angler tag returns (reward and nonreward, harvested and released combined) from walleye and northern pike by month for the year following tagging in Lake Gogebic. Tags observed by creel clerk, but not reported by angler are not included. Percentage of total is in parentheses.

	Species	
Month	Walleye	Northern pike
4	57 (12.8)	0 (0)
5	87 (19.5)	19 (46.3)
6	129 (28.9)	7 (17.1)
7	60 (13.5)	5 (12.2)
8	35 (7.8)	1 (2.4)
9	17 (3.8)	4 (9.8)
10	20 (4.5)	1 (2.4)
11	2 (0.4)	0 (0)
12	15 (3.4)	2 (4.9)
1	22 (4.9)	1 (2.4)
2	2 (0.4)	1 (2.4)
3	0 (0)	0 (0)
Total	446	41

Table 13.–Angler survey estimates for 2005–06 angler survey on Lake Gogebic. Survey period was May 15 through September 30, 2005 and December 22, 2005 to March 27, 2006. Catch per hour (C/H) is harvest and release rate, respectively (fish per hour). Two standard errors are given in parentheses.

Species	C/H	Month								Annual	Winter	Winter	Summer	Summer
		May	Jun	Jul	Aug	Sep	Dec–Jan	Feb	Mar	Ttoal	C/H	Total	C/H	Total
	Harvested													
Cisco	0.0001	0	0	0	0	0	9	0	0	9	0.0006	9	0	0
	(0.0001)	(0)	(0)	(0)	(0)	(0)	(14)	(0)	(0)	(14)	(0.0007)	(14)	(0)	(0)
Smallmouth bass	0.0099	87	466	104	318	178	0	0	0	1,152	0	0	0.0114	1,152
	(0.0040)	(103)	(299)	(87)	(247)	(176)	(0)	(0)	(0)	(447)	(0)	(0)	(0.0047)	(447)
Walleye	0.0462	374	965	1,202	1,141	1,169	515	33	0	5,399	0.0354	548	0.0479	4,851
	(0.0115)	(241)	(444)	(443)	(475)	(764)	(286)	(27)	(0)	(1,159)	NAN	(287)	(0.0129)	(1,123)
Yellow Perch	0.0865	987	849	3,139	3,131	930	726	95	250	10,107	0.0692	1,072	0.0891	9,035
	(0.0221)	(858)	(478)	(1,318)	(1,341)	(630)	(362)	(85)	(172)	(2,251)	NAN	(410)	(0.0251)	(2,213)
Northern pike	0.0019	25	41	48	6	25	68	8	0	222	0.0049	77	0.0014	145
	(0.0010)	(38)	(50)	(48)	(13)	(32)	(65)	(10)	(0)	(108)	NAN	(66)	(0.0009)	(86)
Black crappie	0.0000	6	0	0	0	0	0	0	0	6	0	0	0.0001	6
	(0.0001)	(9)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(9)	(0)	(0)	(0.0001)	(9)
Bluegill	0.0004	0	0	0	0	47	0	0	0	47	0	0	0.0005	47
	(0.0007)	(0)	(0)	(0)	(0)	(85)	(0)	(0)	(0)	(85)	(0)	(0)	(0.0008)	(85)
Largemouth bass	0.0001	17	0	0	0	0	0	0	0	17	0	0	0.0002	17
	(0.0003)	(34)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(34)	(0)	(0)	(0.0003)	(34)
Pumpkinseed	0.0019	46	104	20	19	29	0	4	0	222	0.0002	4	0.0022	218
	(0.0015)	(72)	(141)	(40)	(37)	(50)	(0)	(8)	(0)	(175)	(0.0004)	(8)	(0.0018)	(175)
Rock bass	0.0030	24	79	96	0	0	147	2	0	349	0.0097	149	0.0020	199
	(0.0029)	(37)	(128)	(158)	(0)	(0)	(259)	(5)	(0)	(331)	(0.0143)	(259)	(0.0021)	(206)
White sucker	0.0003	0	18	0	0	0	20	0	0	38	0.0013	20	0.0002	18
	(0.0004)	(0)	(36)	(0)	(0)	(0)	(26)	(0)	(0)	(44)	(0.0012)	(26)	(0.0004)	(36)
Total harvested	0.1503	1,565	2,523	4,609	4,614	2,378	1,486	142	250	17,568	0.1213	1,879	0.1548	15,689
	(0.0292)	(902)	(745)	(1,404)	(1,444)	(1,011)	(534)	(91)	(172)	(2,602)	(0.0487)	(568)	(0.0330)	(2,539)

Table 13.–Continued.

Species	C/H	Month								Annual	Winter	Winter	Summer	Summer
		May	Jun	Jul	Aug	Sep	Dec–Jan	Feb	Mar	Ttoal	C/H	Total	C/H	Total
	Released													
Cisco	0.0000	0	0	0	0	0	5	0	0	5	0.0003	5	0	0
	(0.0001)	(0)	(0)	(0)	(0)	(0)	(10)	(0)	(0)	(10)	(0.0006)	(10)	(0)	(0)
Smallmouth bass	0.0591	438	4,030	790	1,368	256	12	4	8	6,905	0.0015	24	0.0679	6,882
	(0.0253)	(475)	(2,634)	(397)	(804)	(231)	(23)	(7)	(12)	(2,832)	(0.0011)	(27)	(0.0295)	(2,832)
Walleye	0.1309	2,778	3,532	3,057	3,409	1,947	502	43	26	15,294	0.0369	571	0.1452	14,723
	(0.0313)	(1,673)	(1,411)	(1,169)	(1,306)	(1,323)	(265)	(49)	(25)	(3,112)	NAN	(270)	(0.0366)	(3,100)
Northern pike	0.0321	683	1,194	716	434	407	228	74	18	3,755	0.0207	320	0.0339	3,435
	(0.0092)	(478)	(571)	(406)	(281)	(322)	(176)	(73)	(37)	(969)	NAN	(194)	(0.0105)	(949)
White sucker	0.0003	0	12	0	0	0	18	0	8	38	0.0017	26	0.0001	12
	(0.0004)	(0)	(24)	(0)	(0)	(0)	(30)	(0)	(15)	(41)	(0.0016)	(34)	(0.0002)	(24)
Rock bass	0.0128	20	307	445	424	235	46	19	0	1,496	0.0042	65	0.0141	1,431
	(0.0085)	(40)	(378)	(362)	(716)	(404)	(92)	(38)	(0)	(981)	(0.0052)	(99)	(0.0098)	(976)
Bluegill	0.0009	0	0	0	8	99	0	0	0	107	0	0	0.0011	107
	(0.0014)	(0)	(0)	(0)	(16)	(166)	(0)	(0)	(0)	(167)	(0)	(0)	(0.0017)	(167)
Pumpkinseed	0.0034	0	0	0	0	390	0	8	0	398	0.0005	8	0.0038	390
	(0.0046)	(0)	(0)	(0)	(0)	(535)	(0)	(15)	(0)	(536)	(0.0009)	(15)	(0.0053)	(535)
Yellow Perch	0.0424	586	376	1,342	1,499	770	292	8	77	4,950	0.0243	377	0.0451	4,573
	(0.0147)	(662)	(286)	(752)	(831)	(806)	(359)	(9)	(85)	(1,601)	(0.0089)	(369)	(0.0166)	(1,558)
Total released	0.2819	4,506	9,451	6,349	7,141	4,105	1,103	155	137	32,947	0.0901	1,395	0.3113	31,553
	(0.0538)	(1,921)	(3,079)	(1,545)	(1,906)	(1,742)	(489)	(98)	(98)	(4,742)	(0.0405)	(509)	(0.0635)	(4,714)
Total (harvested and released)	0.4323	6,071	11,974	10,958	11,756	6,483	2,589	297	387	50,515	0.2114	3,273	0.4660	47,242
	(0.0712)	(2,123)	(3,168)	(2,087)	(2,391)	(2,014)	(724)	(133)	(198)	(5,409)	(0.0744)	(763)	(0.0835)	(5,355)
Angler hours		15,430	26,438	21,496	21,765	16,243	9,547	2,790	3,147	116,857		15,484		101,372
		(6,442)	(7,108)	(4,030)	(4,114)	(8,515)	(3,687)	(1,088)	(1,377)	(14,641)		(4,083)		(14,060)
Angler trips		4,649	7,012	7,173	4,757	4,552	2,697	511	787	32,138		3,995		28,143
		(1,996)	(2,487)	(1,600)	(1,021)	(2,895)	(1,522)	(241)	(400)	(4,969)		(1,592)		(4,707)

Table 14. Walleye catch statistics for spring netting (1971–2005) including total catch by sex, sex ratio, effort (fyke-net nights), catch per unit effort (CPUE; number per fyke-net night), and percent (%) males greater than or equal to 15 inches.

	Number		Sex ratio		CPUE		Males (%)	
Year	Males	Females	(M:F)	Effort	Males	Females	≥15 in	<13 in
1971	1,514	148	10.2	83	18.2	1.8	–	–
1972	1,395	737	1.9	36	38.8	20.5	–	–
1973	–	–	–	–	–	–	–	–
1974	15,104	466	32.4	175	86.3	2.7	–	–
1975	2,299	340	6.8	64	35.9	5.3	–	–
1976	4,273	259	16.5	109	39.2	2.4	50.3	–
1977	5,727	336	17.0	58	98.7	5.8	82.8	2.2
1978	9,362	447	20.9	76	123.2	5.9	–	–
1979	5,600	504	11.1	67	83.6	7.5	–	–
1980	7,953	260	30.6	109	73.0	2.4	–	–
1981	5,115	285	17.9	83	61.6	3.4	59.6	–
1982	7,083	572	12.4	36	196.8	15.9	–	–
1983	6,479	514	12.6	77	84.1	6.7	–	–
1984	7,130	283	25.2	83	85.9	3.4	–	–
1985	6,117	270	22.7	80	76.5	3.4	35.6	24.3
1986	11,047	283	39.0	87	127.0	3.3	27.9	14.9
1987	8,785	275	31.9	70	125.5	3.9	–	–
1988	5,387	150	35.9	45	119.7	3.3	41.0	11.0
1989	3,078	318	9.7	30	102.6	10.6	53.2	30.7
1990	3,880	299	13.0	17	228.2	17.6	35.6	29.5
1991	8,220	72	114.2	30	274.0	2.4	30.0	24.0
1992	2,573	53	48.5	9	285.9	5.9	29.7	11.1
1993	5,376	283	19.0	24	224.0	11.8	34.3	0.1
1994	10,275	502	20.5	80	128.4	6.3	25.5	18.9
1995	3,508	88	39.9	30	116.9	2.9	27.0	45.0
1996	2,343	55	42.6	27	86.8	2.0	56.5	4.0
1997	2,120	91	23.3	30	70.7	3.0	69.5	6.0
1998	989	29	34.1	10	98.9	2.9	64.9	18.1
1999	200	9	22.2	10	20.0	0.9	12.5	26.5
2000	3,672	12	306.0	10	367.2	1.2	35.5	1.5
2001	742	23	32.3	5	148.4	4.6	66.9	8.6
2002	1,117	57	19.6	5	223.4	11.4	76.1	0.9
2003	732	46	15.9	5	146.4	9.2	80.0	5.2
2004	158	10	15.8	5	31.6	2.0	77.9	3.8
2005	13,304	1070	12.4	426	31.2	2.5	35.2	19.6
Mean	5,078	269.0	33.4	61.5	119.4	5.7	48.2	14.6
Median	4,694	272.5	20.7	40.5	98.8	3.4	41.0	11.1

Table 15.–Mean total lengths (in) of walleyes (males and females combined) from the 2005 survey of Lake Gogebic compared to previous surveys. Number of walleye aged in parentheses.

Age	State average[a]	Year					
		2005[b]	1998[b]	1990[b]	1985[c]	1977[c]	1976[c]
2	10.4	10.5 (1)		11.3 (24)	9.1 (2)	8.9 (4)	11.0 (25)
3	13.9	12.9 (24)		13.8 (24)	11.4 (64)	12.1 (62)	13.0 (60)
4	15.8	14.0 (50)	12.7 (21)	15.4 (7)	12.8 (144)	13.7 (43)	14.3 (44)
5	17.6	15.4 (46)	14.0 (2)	17.5 (39)	14.3 (138)	15.3 (63)	15.7 (23)
6	19.2	17.3 (38)		18.7 (51)	15.9 (144)	16.6 (38)	16.6 (21)
7	20.6	17.5 (16)	16.2 (14)	18.3 (13)	17.7 (70)	17.3 (20)	17.8 (22)
8	21.6	17.6 (5)	18.1 (1)	19.5 (22)	18.4 (31)	18.1 (16)	18.5 (23)
9	22.4	18.6 (38)	15.5 (1)	20.3 (8)	20.0 (6)	19.3 (11)	19.4 (16)
10	23.1	20.5 (48)	16.5 (2)	19.6 (10)	22.1 (2)	20.0 (6)	20.7 (41)
11		20.2 (7)		19.4 (2)	22.8 (3)	21.3 (1)	21.7 (48)
12		21.6 (3)	18.5 (1)	21.2 (3)		23.3 (3)	23.1 (17)
13		22.4 (4)		24.5 (6)		24.8 (2)	25.0 (11)
14		22.1 (2)		22.7 (5)		25.1 (1)	25.3 (3)
15		25.6 (1)		22.8 (2)			24.0 (1)
16				18.2 (1)			26.3 (2)
17				21.0 (1)			
Mean growth index[d]		-2.6	-3.8	-1.0	-2.9	-2.7	-2.0

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

Table 16.–Mean total lengths (in) of northern pike (males and females combined) from the 2005 survey of Lake Gogebic compared to surveys on nearby lakes. Number of northern pike aged in parentheses.

		Lake/Year				
Age	State average[a]	Lake Gogebic 2005[b]	Peavy Pond 2004[b]	Bond Falls Flowage 2003[b]	Cisco Lake Chain 2002[b]	Michigamme Reservoir 2001[b]
1	11.7	9.7 (14)	10.2 (75)	12.2 (11)	11.1 (57)	
2	17.7	14.7 (14)	15.3 (132)	17.4 (52)	15.8 (167)	16.0 (94)
3	20.8	19.6 (144)	18.4 (92)	20.1 (73)	17.8 (177)	18.8 (118)
4	23.4	21.7 (114)	19.9 (65)	22.3 (79)	19.2 (274)	20.6 (64)
5	25.5	25.4 (98)	22.0 (60)	22.8 (20)	21.6 (111)	21.3 (51)
6	27.3	24.3 (12)	25.0 (41)	23.7 (3)	22.5 (37)	25.3 (35)
7	29.3	24.8 (4)	27.0 (15)	27.3 (5)	25.5 (24)	25.6 (21)
8	31.2	32.6 (6)	34.1 (8)	33.6 (6)	21.6 (7)	27.5 (3)
9		37.2 (4)	32.7 (4)	37.3 (3)	28.6 (5)	36.3 (4)
10		40.9 (3)	34.9 (4)	35.1 (1)		
11		39.1 (1)				34.0 (1)
12						
Mean growth index		-1.4	-1.9	-0.6	-4.0	-2.7

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

Table 17.–Age frequency (%) of spawning male walleyes in fyke-net catches from 1976–2005.

Year	Age group															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1976	0.8	10.4	24.9	18.3	9.5	8.3	8.7	7.9	4.1	4.1	2.5	–	–	–	–	–
1977	–	1.8	28.2	19.5	28.2	14.1	4.5	2.3	1.4	–	–	–	–	–	–	–
1981	–	6.3	11.1	17.5	27.8	20.6	24.5	8.7	4.5	0.4	–	–	–	–	–	–
1985	–	0.3	11.4	25.9	24.3	24.5	8.7	4.5	0.4	–	–	–	–	–	–	–
1986	–	–	20.8	20.3	29.4	20.8	4.1	3.5	1.0	–	–	–	–	–	–	–
1989	–	3.3	30.4	9.8	9.8	16.3	2.2	9.8	4.3	7.6	1.1	2.2	1.1	2.2		
1990	–	–	23.5	23.5	5.9	9.8	7.8	4.9	6.9	2.0	4.9	2.0	1.0	2.0	2.9	1.0
1995	–	–	–	31.8	18.2	13.6	13.6	11.4	6.8	4.5	–	–	–	–	–	–
1996	–	–	8.5	1.7	57.1	6.2	5.0	9.8	4.9	4.7	1.0	1.2	–	–	–	–
2005	–	0.1	20.0	39.1	17.2	10.3	2.8	1.6	6.9	1.6	0.2	0.1	–	<0.1	–	–

Table 18.–Age frequency (%) of spawning female walleyes in fyke-net catches from 1976–2005.

Year	Age group															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1976	–	–	–	–	–	0.8	0.8	3.4	5.1	26.3	35.6	14.4	8.4	2.5	0.8	1.7
1977	–	–	–	–	2.0	14.0	20.0	22.0	16.0	12.0	2.0	6.0	4.0	1.0	–	–
1981	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1985	–	–	–	–	4.4	15.5	46.7	13.3	8.9	4.4	6.7	–	–	–	–	–
1986	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1989	–	–	–	–	8.4	23.2	5.3	14.7	13.7	13.7	1.0	8.4	5.3	1.0	3.2	1.0
1990	–	–	–	0.9	0.9	24.3	37.4	6.9	13.0	5.2	4.3	–	0.9	3.5	1.7	0.9
1995	–	–	–	–	–	15.0	27.5	25.0	12.5	2.5	7.5	7.5	–	2.5	–	–
1996	–	–	–	–	43.9	12.2	4.9	29.3	7.3	–	–	–	–	2.4	–	–
2005	–	–	1.2	14.5	18.8	17.2	9.9	1.6	10.4	22.7	1.5	0.3	1.8	0.1	0.1	–

Table 19.–Comparison of recreational fishing effort and various catch rates from historic angler surveys on Lake Gogebic.

Year	Season surveyed	Angler hours	Walleye		Northern pike		Smallmouth bass		Yellow perch	
			total harvest	harvest/hr	total harvest	harvest/hr	total harvest	harvest/hr	total harvest	harvest/hr
1940	May–Oct	8,051	2,359	0.293	367	0.046	72	0.009	71	0.009
1941	May–Oct	16,923	4,835	0.286	376	0.022	58	0.003	107	0.006
1947	May–Oct	8,663	2,244	0.259	1,199	0.138	33	0.004	669	0.077
1976	May–Sep	17,225	1,515	0.086	362	0.023	1,077	0.069	2,059	0.131
1977	May–Oct	31,062	4,744	0.087	84	0.010	72	0.009	5,419	0.153
1998	May–Apr	129,552	9,294	0.077	590	0.005	1,613	0.013	14,949	0.123
2005	May–Mar	116,857	5,399	0.046	222	0.002	1,152	0.010	10,107	0.087

Table 20.–Comparison of recreational fishing effort and total harvest on Lake Gogebic to estimates from other selected Michigan lakes. Lakes are listed from highest to lowest total fishing effort.

Lake	County	Size (Acres)	Survey period	Fishing effort (Hours)	Fish harvested (Number)	Fish harvested per hour	Hours fished per acre	Fish harvested per acre
Houghton	Roscommon	20,075	Apr 2001– Mar 2002	499,048	386,287	0.77	24.9	19.2
Cisco Chain	Gogebic, Vilas	3,987	May 2002–Feb 2003	180,262	120,412	0.67	45.2	30.2
Muskegon	Muskegon	4,232	Apr 2002–Mar 2003	180,064	184,161	1.02	42.5	43.5
South Manistique	Mackinac	4,133	May 2003–Mar 2004	142,686	43,654	0.31	34.5	10.6
Burt	Cheboygan	17,395	Apr 2001–Mar 2002	134,205	68,473	0.51	7.7	3.9
Lake Leelanau	Leelanau	8,607	Apr 2002–Mar 2003	112,112	15,464	0.14	13.0	1.8
Lake Gogebic	Gogebic, Ontonagon	13,127	May 2005–Mar 2006	101,372	15,689	0.15	7.7	1.2
Big Manistique	Luce, Mackinac	10,346	May 2003–Mar 2004	88,373	71,652	0.81	8.5	6.9
Black Lake	Cheboygan, Presque Isle	10,113	Apr 2005–Mar 2006	59,874	18,762	0.31	5.9	1.9
Charlevoix	Charlevoix	17,268	Apr 2006–Mar 2007	57,126	19,671	0.34	3.3	1.1
Crooked and Pickerel	Emmet	3,434	Apr 2001–Mar 2002	55,894	13,665	0.24	16.3	4.0
Michigamme Reservoir	Iron	6,400	May 2001–Feb 2002	52,686	10,899	0.21	8.2	1.7
Long	Presque Isle, Alpena	5,342	Apr 2004–Mar 2005	34,894	7,004	0.20	6.5	1.3
Grand	Presque Isle	5,822	Apr 2004–Mar 2005	33,037	10,623	0.32	5.7	1.8
Peavy Pond	Iron	2,347	May 2004–Feb 2005	26,447	6,299	0.24	9.5	2.3
Bond Falls Flowage	Ontonagon	2,127	May–Oct 2003	21,182	3,193	0.15	10.0	1.5
North Manistique	Luce	1,709	May 2003–Mar 2004	10,614	7,603	0.72	6.2	4.4
Average				105,532	61,739	0.42	15.0	8.1
Median				58,500	17,113	0.31	8.5	2.3

References

Ambrose, J., Jr. 1983. Age determination. Chapter 16 *in* L. A. Nielson and D. L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Belanger, S. E., and S. R. Hogler. 1982. Comparison of five aging methodologies applied to walleye *Stizostedion vitreum vitreum* in Burt Lake, Michigan. Journal of Great Lakes Research 8:666-671.

Beyerle, G. B. 1971. A study of two northern pike-bluegill populations. Transactions of the American Fisheries Society 100:69-73.

Breck, J. E. 2004. Compilation of databases on Michigan lakes. Michigan Department of Natural Resources, Fisheries Technical Report 2004-2, Ann Arbor.

Campbell, J. S., and J. A. Babaluk. 1979. Age determination of walleye *Stizostedion vitreum vitreum* (Mitchill) based on the examination of eight different structures. Fisheries and Marine Services, Technical Report 849, Winnipeg, Manitoba.

Carlander, K. D. 1969. Handbook of freshwater fishery biology, Volume 1. Iowa State University Press, Ames.

Carlander, K. D. 1997. Handbook of freshwater fishery biology, Volume 3: life history data on ichthyopercid and percid fishes of the United States and Canada. Iowa State University Press, Ames.

Casselman, J. M., 1974. Analysis of hard tissue of pike *Esox lucius* L. with special reference to age and growth. Pages 13–27 *in* T. B. Begenal, editor. The aging of fish – proceedings of an international symposium. Unwin Brothers, Old Working, England.

Casselman, J. M. 1996. Age, growth, and environmental requirements of pike. Chapter 4 in J. F. Craig, editor. Pike biology and exploitation. Chapman & Hall Fish and Fisheries Series 19. Chapman & Hall, London.

Clady, M. D. 1977. Distribution and relative exploitation of yellow perch tagged on spawning grounds in Oneida Lake. New York Fish and Game Journal 24:168–177.

Clark, R. D. 1983. Potential Effects of Voluntary Catch and Release of Fish on Recreational Fisheries. North American Journal of Fisheries Management 3:306–314.

Clark, R. D., Jr., P. A. Hanchin, and R. N. Lockwood. 2004. The fish community and fishery of Houghton Lake, Roscommon County, Michigan with emphasis on walleye and northern pike. Michigan Department of Natural Resources, Fisheries Division Special Report 30, Ann Arbor.

Craig, J. F. 1996. Population dynamics, predation and role in the community. Chapter 8 *in* J. F. Craig, J. F. editor. Pike biology and exploitation. Chapman & Hall Fish and Fisheries Series 19. Chapman & Hall, London.

Devries, D. R., and R. V. Frie. 1996. Determination of age and growth. Pages 483–512 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques, second edition. American Fisheries Society, Bethesda.

Diana, J. S. 1983. Growth, maturation, and production of northern pike in three Michigan lakes. Transactions of the American Fisheries Society 112:38–46.

Dixon, W. J., and F. J. Massey, Jr. 1957. Introduction to statistical analysis. McGraw-Hill Book Company, Inc., New York.

DuBois, B., T. L. Margenau, R. S. Stewart, P. K. Cunningham, and P. W. Rassmussen. 1994. Mortality of Northern Pike Angled through Ice. North American Journal of Fisheries Management 14:769-75.

Eagle, A. C., E. M. Hay-Chmielewski, K. T. Cleveland, A. L. Derosier, M. E. Herbert, and R. A. Rustem, editors. 2005. Michigan's Wildlife Action Plan. Michigan Department of Natural Resources. Lansing, Michigan. 1592 pp. http://www.michigan.gov/dnrwildlifeactionplan

Erickson, C. M. 1983. Age determination of Manitoban walleye using otoliths, dorsal spines, and scales. North American Journal of Fisheries Management 3:176-181.

Eschmeyer, P. H. 1941a. Fisheries survey of Lake Gogebic, Ontonagon and Gogebic counties. Michigan Department of Conservation, Report 657.

Eschmeyer, P. H. 1941b. Notes on the natural reproduction of the walleyed pike in Lake Gogebic. Michigan Department of Conservation, Report 695.

Eschmeyer, P. H. 1942. A summary of results of the operation of the Lake Gogebic weir. Michigan Department of Conservation, Report 764.

Eschmeyer, P. H. 1950. The life history of the walleye in Michigan. Michigan Department of Conservation, Institute for Fisheries Research, Bulletin 3, Ann Arbor, 99 pp.

Eschmeyer, P. H., and W. R. Crowe. 1955. The movement and recovery of tagged walleye in Michigan, 1929–1953. Michigan Department of Conservation, Fisheries Research, Miscellaneous Publication No. 8, Ann Arbor, 32 pp.

Federal Energy Regulatory Commission. 2003. Order approving settlement and issuing new license, Project No. 1864-005.

Forney, J. L. 1961. Growth, movements and survival of smallmouth bass (Micropterus dolomieui) in Oneida Lake, New York. New York Fish and Game Journal 8:88-105.

Forney, J. L. 1972. Biology and management of smallmouth bass in Oneida Lake, New York. New York Fish and Game Journal 19:132-154.

Gunderman, B. J., and E. A. Baker. 2008. Ontonagon River Assessment. Michigan Department of Natural Resources, Fisheries Special Report 46, Ann Arbor.

Hanchin, P. A. 2009. The fish community and fishery of Bond Falls Flowage, Ontonagon County, Michigan in 2003 with emphasis on walleye and northern pike. Michigan Department of Natural Resources, Fisheries Special Report 50, Ann Arbor.

Hanchin, P. A. 2011. The fish community and fishery of Peavy Pond, Iron County, Michigan in 2004-05 with emphasis on walleye and northern pike. Michigan Department of Natural Resources, Fisheries Special Report 57, Lansing.

Hanchin, P. A., R. D. Clark, Jr., and R. N. Lockwood. 2005a. The fish community of Michigamme Reservoir, Iron County, Michigan with emphasis on walleye and northern pike. Michigan Department of Natural Resources, Fisheries Special Report 33, Ann Arbor.

Hanchin, P.A., R. D. Clark, Jr., R. N. Lockwood, and T.A. Cwalinski. 2005b. The fish community and fishery of Burt Lake, Cheboygan County, MI in 2001 with emphasis on walleye and northern pike. Michigan Department of Natural Resources, Fisheries Special Report 36, Ann Arbor.

Hanchin, P. A., R. D. Clark, Jr., and R. N. Lockwood, and N. A Godby, Jr. 2005c. The fish community and fishery of Crooked and Pickerel lakes, Emmet County, Michigan with emphasis on walleye and northern pike. Michigan Department of Natural Resources, Fisheries Special Report 34, Ann Arbor.

Hanchin, P. A., B. J. Gunderman, and R. D. Clark, Jr. 2009. The fish community and fishery of the Cisco Lake Chain, Gogebic County, Michigan and Vilas County, Wisconsin with emphasis on walleye, northern pike, and muskellunge. Michigan Department of Natural Resources, Fisheries Special Report 47, Ann Arbor.

Hanchin, P. A., and D. R. Kramer. 2007. The fish community and fishery of Big Manistique Lake, Mackinac County, Michigan in 2003-04 with emphasis on walleye, northern pike, and smallmouth bass. Michigan Department of Natural Resources, Fisheries Special Report 43, Ann Arbor.

Hanchin, P. A., and D. R. Kramer. 2008. The fish community and fishery of North Manistique Lake, Luce County, Michigan in 2003-04 with emphasis on walleye and northern pike. Michigan Department of Natural Resources, Fisheries Special Report 49, Ann Arbor.

Hanes, H.J. 1961. Gogebic Lake level control, Gogebic and Ontonagon counties – Report of Engineering Investigation. Michigan Department of Conservation, Engineering and Architecture.

Hansen, M. J., T. D. Beard, Jr., and S. W. Hewett. 2000. Catch rates and catchability of walleye in angling and spearing fisheries in northern Wisconsin lakes. North American Journal of Fisheries Management 20:109–118.

Harrison, E. J., and W. F. Hadley. 1979. A comparison of the use of cleithra to the use of scales for age and growth studies. Transactions of the American Fisheries Society 108: 452-456.

Heidinger, R. C., and K. Clodfelter. 1987. Validity of the otolith for determining age and growth of walleye, striped bass, and smallmouth bass in power cooling plant ponds. Pages 241–251 *in* R. C. Summerfelt and G. E. Hall, editors. Age and growth of fish. Iowa State University Press, Ames.

Isermann, D. A., W. L. McKibbin, and D. W. Willis. 2002. An analysis of methods for quantifying crappie recruitment variability. North American Journal of Fisheries Management 22:1124-1135.

Isermann, D. A., J. R. Meerbeek, G. D. Scholten, and D. W. Willis. 2003. Evaluation of three different structures used for walleye age estimation with emphasis on removal and processing times. North American Journal of Fisheries Management 23:625–631.

Isermann, D. A., D. W. Willis, D. O. Lucchesi, and B. G. Blackwell. 2005. Seasonal Harvest, Exploitation, Size Selectivity, and Catch Preferences Associated with Winter Yellow Perch Anglers on South Dakota Lakes. North American Journal of Fisheries Management 25:827–840.

Kempinger, J. J., and R. F. Carline. 1978. Dynamics of the northern pike population and changes that occurred with a minimum size limit in Escanaba Lake, Wisconsin. American Fisheries Society Special Publication 11, Bethesda, Maryland.

Kempinger, J. J., W. S. Churchill, G. R. Priegel, and L.M. Christenson. 1975. Estimate of abundance, harvest, and exploitation of the fish population of Escanaba Lake, Wisconsin, 1946–69. Wisconsin Department of Natural Resources, Technical Bulletin 84, Madison.

Kocovsky, P. M., and R. F. Carline. 2000. A comparison of methods for estimating ages of unexploited walleye. North American Journal of Fisheries Management 20:1044–1048.

Laarman, P.W. 1976. The sport fisheries of the twenty largest inland lakes in Michigan. Michigan Department of Natural Resources, Fisheries Research Report 1843, Ann Arbor.

Latta, W.C. 1963. The life history of the smallmouth bass, *Micropterus d. dolomieui*, at Waugoshance Point, Lake Michigan. Michigan Department of Conservation, Fisheries Research Bulletin No.5, Ann Arbor.

Latta, W. C. 1972. The northern pike in Michigan: a simulation of regulations for fishing. Michigan Academician 5:153–170.

Latta, W.C. 1975. Fishing regulations for smallmouth bass in Michigan. Michigan Department of Natural Resources, Fisheries Research Report 1834, Ann Arbor.

Lockwood, R. N. 1997. Evaluation of catch rate estimators from Michigan access point angler surveys. North American Journal of Fisheries Management 17:611–620.

Lockwood, R. N. 2000a. Sportfishing angler surveys on Michigan inland waters, 1993–99. Michigan Department of Natural Resources, Fisheries Technical Report 2000-3, Ann Arbor.

Lockwood, R. N. 2000b. Conducting roving and access site angler surveys. Chapter 14 *in* J. C. Schneider, editor. Manual of fisheries survey methods II: with periodic updates. Michigan Department of Natural Resources, Fisheries Special Report 25, Ann Arbor.

Lockwood, R. N. 2004. Comparison of access and roving catch rate estimates under varying within-trip catch-rates and different roving minimum trip lengths. Michigan Department of Natural Resources, Fisheries Research Report 2069, Ann Arbor.

Lockwood, R. N., D. M. Benjamin, and J. R. Bence. 1999. Estimating angling effort and catch from Michigan roving and access site angler survey data. Michigan Department of Natural Resources, Fisheries Research Report 2044, Ann Arbor.

Maceina, M. J. 2003. Verification of the influence of hydrologic factors on crappie recruitment in Alabama reservoirs. North American Journal of Fisheries Management 23:470–480.

Metzelaar, J. 1928. Preliminary report on Gogebic Lake, Michigan. Michigan Department of Conservation.

Miller, B.R. 1995. Status of the Lake Gogebic Walleye Fishery – 1995. Michigan Department of Natural Resources, Fisheries Division, Unpublished Report, Baraga.

Miller, B.R. 2001. Status of the Lake Gogebic Walleye Fishery, 1986 – 96. Michigan Department of Natural Resources, Fisheries Technical Report 97-6, Ann Arbor.

Mosindy, T. E., W. T. Momot, and P. J. Colby. 1987. Impact of angling on the production and yield of mature walleye and northern pike in a small boreal lake in Ontario. North American Journal of Fisheries Management 7:493–501.

Nate, N. A., M. A. Bozek, M. J. Hansen, and S. W. Hewett. 2000. Variation in walleye abundance with lake size and recruitment source. North American Journal of Fisheries Management 20:119–126.

Newman, S. P., and M. H. Hoff. 1998. Estimates of loss rates of jaw tags on walleye. North American Journal of Fisheries Management 18:202–205.

Newman, S. P., and M. H. Hoff. 2000. Evaluation of a 16-inch minimum length limit for smallmouth bass in Pallette Lake, Wisconsin. North American Journal of Fisheries Management 20:90-99.

Norcross, J. J. 1986. The walleye fishery of Michigan's Lake Gogebic. Michigan Department of Natural Resources, Fisheries Technical Report 86-9, Ann Arbor.

Peterson, L.D. 1995 Lake Gogebic: Where buffalo once roamed. Lake Gogebic Area Chamber of Commerce.

Pierce, R. B. 1997. Variable catchability and bias in population estimates for northern pike. Transactions of the American Fisheries Society 126:658–664.

Pierce, R. B., C. M. Tomcko, and D. Schupp. 1995. Exploitation of northern pike in seven small north-central Minnesota lakes. North American Journal of Fisheries Management 15:601–609.

Pollock, K. H., J. M. Hoenig, and C. M. Jones. 1991. Estimation of fishing and natural mortality when a tagging study is combined with a creel survey or port sampling. Pages 423–434 *in* Gutherie, D., J. J. Joenig, M. Holliday, C. M. Jones, M. J. Mills, S. A. Moberly, K. H. Pollock, and D. R. Talheim, editors. Creel and angler surveys in fisheries management. American Fisheries Society, Symposium 12, Bethesda, Maryland.

Pollock, K. H., C. M. Jones, and T. L. Brown. 1994. Mail surveys. Chapter 6 *in* Angler survey methods and their applications in fisheries management. American Fisheries Society Special Publication 25.

Radomski, P. 2003. Initial attempts to actively manage recreational fishery harvest in Minnesota. North American Journal of Fisheries Management 23:1329–1342.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 191.

Robson, D. S., and H. A. Regier. 1964. Sample size in Petersen mark-recapture experiments. Transactions of the American Fisheries Society 93:215–226.

Schneider, J. C., P.H. Eschmeyer, and W.R. Crowe. 1976. Longevity, survival and harvest of tagged walleye in Lake Gogebic, Michigan. Michigan Department of Natural Resources, Fisheries Research Report 1842, Ann Arbor.

Schneider, J. C., P. W. Laarman, and H. Gowing. 2000. Age and growth methods and state averages. Chapter 9 *in* Schneider, J. C. (editor) 2000. Manual of fisheries survey methods II: with periodic updates. Michigan Department of Natural Resources, Fisheries Special Report 25, Ann Arbor.

Schneider, J. C., R. P. O'Neal, and R. D. Clark, Jr. 2007. Ecology, management, and status of walleye, sauger, and yellow perch in Michigan. Michigan Department of Natural Resources, Fisheries Special Report 41, Ann Arbor.

Sendek, S.P., and J.R. Ryckman. 1978. Creel census on lakes Gogebic, Cisco, and Thousand Island. Michigan Department of Natural Resources, unpublished report.

Sinnott, R.W. 1984. Virtues of the Haversine. Sky and Telescope 68:159.

Skidmore, W. J., and A. W. Glass. 1953. Use of pectoral fin rays to determine age of white sucker. Progressive Fish Culturist 7:114-115.

Slipke, J.W., and M.J. Maceina. 2000. Fisheries Analysis and Simulation Tools (FAST) User's Guide. Auburn University, Auburn, Alabama.

Thomas, M. V., and R. C. Haas. 2005. Status of yellow perch and walleye in Michigan waters of Lake Erie, 1999–2003. Michigan Department of Natural Resources, Fisheries Research Report 2082, Ann Arbor.

Tomcko, C.M. 1997. A review of northern pike *Esox lucius* hooking mortality. Minnesota Department of Natural Resources Fish Management Report 32.

Upper Peninsula Power Company. 1987. Application for new license, Bond Falls Project, FERC Project Number 1864, Volume 1, Initial Statement, Exhibits A, B, C, D, F, G.

Wehrly, K. E., G. S. Carter, and J. E. Breck. In press. Standardized Sampling Methods for the Inland Lakes Status and Trends Program. Michigan Department of Natural Resources, Fisheries Special Report, Lansing.

Zar, J. H. 1999. Biostatistical analysis, 4th edition. Prentice Hall, Upper Saddle River, New Jersey.

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Appendix 1.–Fish species collected in Lake Gogebic 1947 through 2005.

Common name	Scientific name
Species collected in spring 2005 with fyke nets and electrofishing	
Black bullhead	*Ameiurus melas*
Black crappie	*Pomoxis nigromaculatus*
Brown bullhead	*Ameiurus nebulosus*
Burbot	*Lota lota*
Cisco	*Coregonus artedi*
Common shiner	*Luxilus cornutus*
Creek chub	*Semotilus atromaculatus*
Golden shiner	*Notemigonus crysoleucas*
Northern pike	*Esox lucius*
Pumpkinseed	*Lepomis gibbosus*
Rock bass	*Ambloplites rupestris*
Smallmouth bass	*Micropterus dolomieu*
Walleye	*Sander vitreus*
White sucker	*Catostomus commersonii*
Yellow perch	*Perca flavescens*
Additional species collected in previous surveys	
Blacknose shiner	*Notropis heterolepis*
Bluegill	*Lepomis macrochirus*
Brook trout	*Salvelinus fontinalis*
Central mudminnow	*Umbra limi*
Fathead minnow	*Pimephales promelas*
Johnny darter	*Etheostoma nigrum*
Lake whitefish	*Coregonus clupeaformis*
Longnose dace	*Rhinichthys cataractae*
Longnose sucker	*Catostomus catostomus*
Mottled sculpin	*Cottus bairdi*
Muskellunge	*Esox masquinongy*
Northern redbelly dace	*Phoxinus eos*
Spottail shiner	*Notropis hudonsius*

Appendix 2.–Parameters used to model various minimum size limits for Lake Gogebic.

Model = Fishery Analyses and Simulation Tool (Slipke and Maceina 2000) yield-per-recruit model
N_0 (number of age-0 recruits entering the population) = 1,000
b (slope from length-weight regression) = 3.03606
A (intercept from length-weight regression) = -5.14176
Maximum age = 15
L_∞ (asymptotic length in mm) = 604
K (von Bertalanffy growth coefficient) = 0.198
t_0 (theoretical age in years at zero length) = -0.319
W_∞ (asymptotic weight in g) = 2002.7881