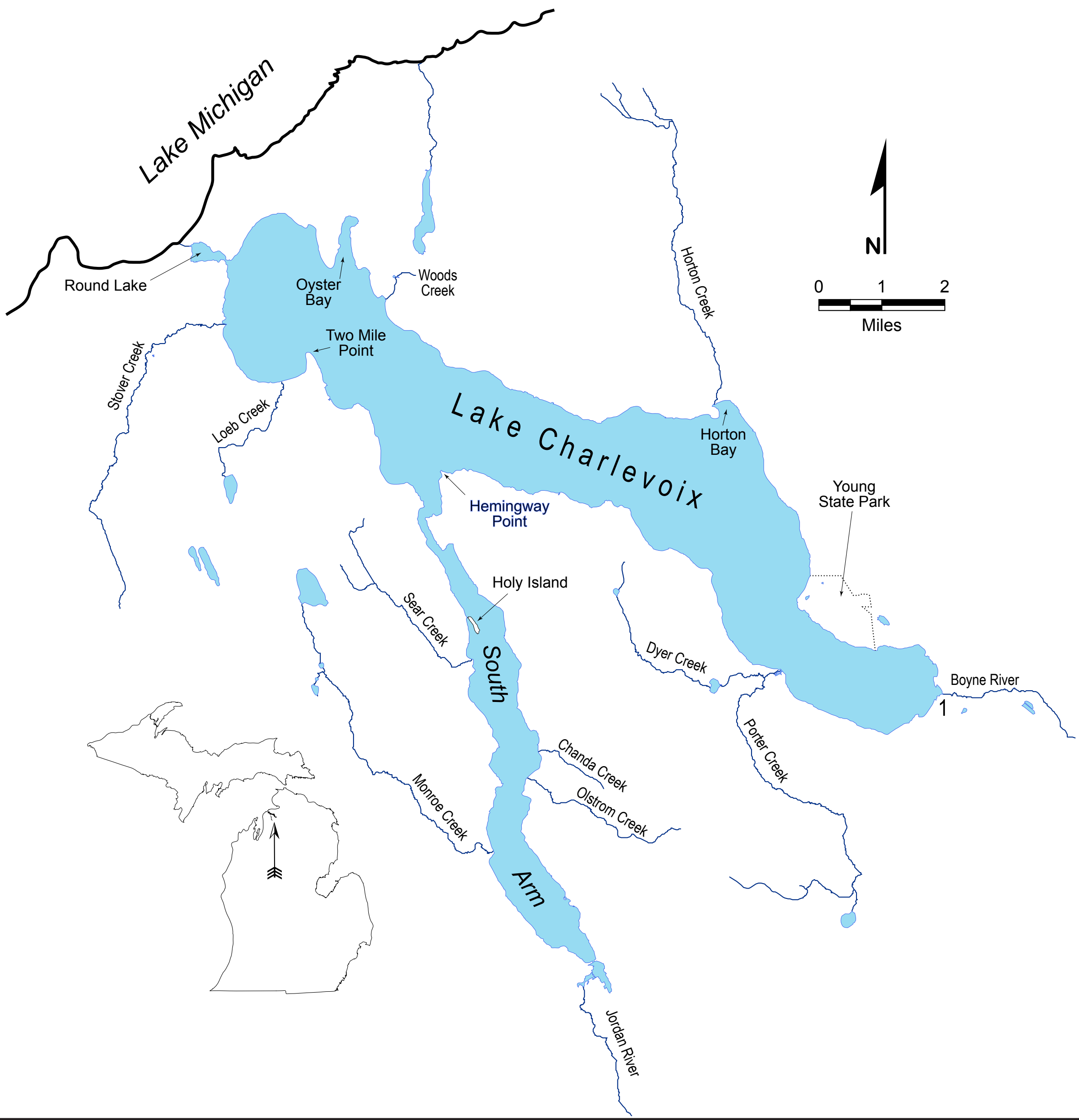
STATE OF MICHIGAN
DEPARTMENT OF NATURAL RESOURCES

FR11

December 2015

The Fish Community and Fishery of Lake Charlevoix, Charlevoix County, Michigan in 2006-07

Patrick A. Hanchin



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FISHERIES DIVISION
FISHERIES REPORT 11

Suggested Citation Format

Hanchin, P. A. 2015. The fish community and fishery of Lake Charlevoix, Charlevoix County, Michigan in 2006-07. Michigan Department of Natural Resources, Fisheries Report 11, Lansing.

For information or assistance on this publication, contact:

MICHIGAN DEPARTMENT OF NATURAL RESOURCES,
Fisheries Division
PO BOX 30446
LANSING, MI 48909
517-373-1280

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Michigan Department of Natural Resources
Fisheries Report 11, 2015

The Fish Community and Fishery of Lake Charlevoix, Charlevoix County, Michigan in 2006-07

Patrick A. Hanchin

Michigan Department of Natural Resources, Charlevoix Fisheries Research Station, 96 Grant Street, Charlevoix, Michigan 49720

Introduction

The Michigan Department of Natural Resources (DNR), Fisheries Division surveyed fish populations and angler catch and effort at Lake Charlevoix, Charlevoix County, Michigan from April 2006 through March 2007. 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 (scientific names for all fish species in the report are found in Appendix), northern pike, smallmouth bass, and muskellunge. The second objective is to produce growth and mortality statistics to evaluate the effects of fishing on these species. The third objective is to evaluate the suitability of various statistical estimators for use in large lakes. For example, comparisons were made among three types of abundance and three types of exploitation rate estimators in this survey of Lake Charlevoix. 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 Charlevoix was the 17th lake surveyed under the protocols of the program. However, since 20 lakes had been surveyed at the time the report was written, statistics from all surveyed lakes were used for comparison. The sample size for these types of comparisons varies throughout the report since some statistics could not be estimated for a lake and/or species.

Study Area

Lake Charlevoix is a natural lake in Charlevoix County, Michigan with a watershed of approximately 233,837 acres (365 square miles; Cronk and Olinik-Damstra 2007). The watershed is within the Northern Lower Peninsula ecoregion (Eagle et al. 2005). This ecoregion is characterized by a composition primarily of forests (67%) and wetlands (20%), with some agricultural land (4%), urban land (2%), and a mix (7%) of open grasslands, sparsely vegetated areas, beaches and rock areas. Forest types include northern hardwoods, aspen, oak, pine, and lowland conifer. The geology of the region consists primarily of thick, sandy glacial deposits with underlying bedrock (including sandstone, shale, limestone and dolomite). Specific to the Lake Charlevoix watershed, land cover is primarily forested (46%), with agriculture (18%), grassland (12%), wetland (11%), surface water (8%), and urban shrubs making up the remaining 5% (Cronk and Olinik-Damstra 2007). The majority of soils in the Lake Charlevoix watershed are sand, loamy sand and sandy loam. The number of growing degree days (area-weighted average) for the Lake Charlevoix watershed is 2,107 (Breck 2004).

Lake Charlevoix is the fourth largest inland lake in Michigan, with a surface area of 17,268 acres (Breck 2004), divided into two distinct basins. Using the town of Ironton as an approximate split between the two basins, the main basin is 14,548 acres and the south basin is 2,720 acres. The main basin is larger, deeper, and more oligotrophic, while the south basin is relatively shallow, with abundant aquatic vegetation. The main basin is occasionally referred to as two separate basins—the north basin (from Boyne City to Hemingway Point) and the main basin (from Hemingway Point to Charlevoix). For the purpose of comparisons in this report, reference will be made to three basins.

The main tributaries to Lake Charlevoix are the Boyne and Jordan rivers, and Woods, Horton, Dyer, Porter, Olstrom, Chanda, Monroe, Sear, Loeb, and Stover creeks (Figure 1). Several of these tributaries have resident salmonid populations and the larger ones (Boyne and Jordan rivers) support potamodromous runs of steelhead, Chinook salmon and coho salmon. Rainbow smelt and suckers also migrate into some tributaries to spawn. The Lake Charlevoix outlet is the Pine River, which flows into Round Lake, and then out of Round Lake into Lake Michigan. Lake Charlevoix is connected to Patricia Lake via the Jordan River and Deer Creek, though there is no upstream fish passage over the Patricia Lake Dam. Mean and maximum depths of Lake Charlevoix as a whole are 57 and 122 ft, respectively, and 12% of the lake is less than 15 ft deep (Figure 2). The south basin is much shallower than the main and north basins, with a maximum depth of 42 ft, and a mean depth of around 25 ft.

Lake Charlevoix has approximately 56 miles of shoreline, which is largely developed with private residences. There are three major urban areas (Boyne City, East Jordan, and Charlevoix) and eight public boat launches on the lake. Most shoal areas have sandy substrate, though rock and gravel are also present. Organic sediments are more common in deeper areas. A few locations are also inundated with slab wood and old timbers from sawmill operations that existed on the lake. Aquatic vegetation is not abundant in the main and north basins, largely due to depth, but is abundant in the south basin.

Water quality in Lake Charlevoix has been surveyed triennially since 1987 (Cronk and Olinik-Damstra 2007). Over the seven water quality surveys during this period, dissolved oxygen averaged 11.9 ppm (range 10.0–13.0), pH averaged 8.0 (range 7.6–8.4), total nitrogen averaged 580 ppb (range 332–910), and total phosphorous averaged 6.8 ppb (range 1.0–20.0). Lake Charlevoix is classified as oligotrophic based on measurements of secchi disk depth and chlorophyll-a concentration; thus nutrient levels are relatively low. Water clarity has been increasing and chlorophyll-a concentrations have been dropping since the early 1990s, corresponding with the discovery of zebra mussels in Lake Michigan in 1989 (Cronk and Olinik-Damstra 2007). Although quagga mussels have not been officially identified as being established in Lake Charlevoix, given their establishment on Gull Island reef in Lake Michigan off of Charlevoix in 2000, it is likely that they are present.

The fish community of Lake Charlevoix is relatively diverse, largely due to the lake's connection with Lake Michigan. Families of fish known to currently exist in Lake Charlevoix include, but are not limited to, *Amiidae, Catostomidae, Centrarchidae, Clupeidae, Cottidae, Cyprinidae, Esocidae, Fundulidae, Gadidae, Gasterosteidae, Gobiidae, Ictaluridae, Lepisosteidae, Osmeridae, Percichthyidae, Percidae, Percopsidae, Petromyzontidae, Salmonidae* (including subfamily *Coregoninae),* and *Sciaenidae*.

The history of fisheries management on Lake Charlevoix is long, and has largely consisted of fish stocking. Laarman (1976) provided a list of early (1894 to 1973) fish stocked in Lake Charlevoix, which included the following species: lake whitefish, common carp, smallmouth bass, largemouth bass, walleye, brook trout, rainbow trout, brown trout, and lake trout. Since then, mainly lake trout, brown trout, rainbow trout, and walleyes have been stocked (Table 1). Lake Charlevoix produces large fish of numerous species and there have been 67 State of Michigan, Master Angler awards reported from 1990 through 2006, including awards for 21 channel catfish, 14 smallmouth bass, 8 Chinook salmon, 3 white suckers, 3 walleyes, 3 bluegills, 2 northern pike, 2 longnose gars, 2 brown trout, 2 freshwater drums, 1 white perch, 1 yellow bullhead, 1 black crappie, 1 redhorse sucker, 1 rainbow smelt, 1 bowfin, and 1 burbot.

Methods

Fish populations in Lake Charlevoix were sampled with trap nets, fyke nets, and electrofishing gear during April 3–22, 2006. Trap nets were 8 ft x 6 ft x 3 ft with 2-inch stretch mesh and 70- to 100-ft leads, and fyke nets were 6 ft x 4 ft with 3/4-inch stretch mesh and 70- to 100-ft leads. A Smith-Root® boat equipped with boom-mounted electrodes (DC) was used for electrofishing. Nets were located to target walleyes and northern pike (nonrandomly), though efforts were also made to cover the entire lake. Duration of net sets ranged from one to three nights, but most were one night. Latitude and longitude were recorded for all net locations using hand-held global positioning system (GPS) devices. In addition to the spring survey, a standardized (Wehrly et al., in press) survey was conducted June 6–15 using fyke nets, trap nets, 125-ft experimental gill nets (25-ft panels of 1.5-, 2.0-, 2.5-, 3.0-, and 4.0-inch mesh), 1,000-ft Great Lakes gill nets (ten 50-ft panels of 1.5- to 6-inch mesh repeated twice), seines, and electrofishing gear. A hydroacoustic survey (details later in Methods) was conducted June 5–7 in order to obtain approximate estimates of fish density and a supplemental gill-net (600 ft by 6 ft nylon nets with 100-ft panels of 3-, 3.5-, and 4.0-inch stretch mesh repeated twice) survey was conducted October 10–13 in order to collect walleyes for the recapture sample of a population estimate.

Fish Community

The status of the overall fish community was described in terms of species present, catch per unit effort, percent by number, and length frequencies. Mean catch per unit effort (CPUE) in trap and fyke nets was calculated as an indicator of relative abundance, using 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). Fish were categorized into 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, and percentages in each guild were calculated. 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. Species collected were classified as follows:

Piscivores	Benthivores	Pelagic planktivores-insectivores
Bowfin	Black bullhead	Black crappie
Burbot	Brown bullhead	Bluegill
Channel catfish	Common carp	Brook trout
Largemouth bass	Freshwater drum	Brown trout
Lake trout	Longnose sucker	Common shiner
Longnose gar	Quillback	Gizzard shad
Northern pike	Round goby	Pumpkinseed
Sea lamprey	Sculpin	Rainbow trout
Smallmouth bass	Silver redhorse	Rock bass
Walleye	White sucker	White perch
		Yellow perch

Size Structure and Sex Ratio

Total lengths of all target species (walleye, northern pike, smallmouth bass, lake trout, and lake whitefish) were measured to the nearest 0.1 in. For other fish, lengths were measured to the nearest 0.1 inch for subsamples of up to 200 fish per work crew. Crews ensured that lengths were taken over the course of the survey to account for any temporal trends in the size structure of fish collected. Size-structure data for target species only included fish on their initial capture occasion. Walleyes and northern pike with flowing gametes were identified as male or female; fish with no flowing gametes were designated as unknown sex. The sex of smallmouth bass could not be accurately determined due to the timing of the survey. The sex of lake whitefish was identified by internal inspection of the gonads.

Abundance

The abundance of legal-sized walleyes, northern pike, and smallmouth bass was estimated using mark-and-recapture methods. Walleyes (≥15 inches), northern pike (≥24 inches), and smallmouth bass (≥14 inches) were fitted with Monel-metal jaw tags. To assess tag loss, tagged fish were double-marked by clipping the left pelvic fin. Reward ($10) and nonreward tags were applied in an approximate 1:1 ratio. Large tags (size 16) that were used on large northern pike (≥36 inches) were all nonreward.

Initial tag loss was assessed during the marking period as the proportion of recaptured fin-clipped fish of legal size without tags. This tag loss was largely caused by entanglement with nets, and thus was not used to adjust estimates of abundance or exploitation. Newman and Hoff (1998) experienced similar conditions of 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.

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

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

N_1 = multiple-census population estimate (number of legal-sized fish);

C_d = total number of fish caught during day d;

R_d = number of recaptures during day d;

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

d = day (ranging from d_1 to d_n);

The variance formula for N_1 was,

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

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

Variance of $1/N_1$ was calculated as:

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

The minimum number of recaptures necessary for an unbiased estimate was set a priori at four. Asymmetrical 95% confidence intervals for the estimate of N_1 were computed as:

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

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

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

For the single-census estimate, the recapture sample was defined as the number of marked and unmarked fish observed in the companion angler survey, the standardized summer survey, and the fall gill-net survey. The minimum number of recaptures necessary for an unbiased estimate was set a priori at three, and the Chapman modification of the Petersen method was used to generate population estimates using the following formula from Ricker (1975):

$$N_2 = \frac{(M+1)(C+1)}{R+1},$$

N_2 = single-census population estimate (numbers of legal-sized 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.

Variance of N_2 was calculated as:

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

Asymmetrical 95% confidence limits for the estimate of N_2 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_2 above (Ricker 1975).

Numbers of adult walleyes and northern pike were estimated from the single-census estimates by dividing the estimates for legal-sized fish by the proportion of legal-sized fish on the spawning grounds, using the formula:

$$N_a = \frac{N_{leg} + N_{sub}}{N_{leg}} \times N_2,$$

N_a = estimated number of adult walleyes or northern pike;

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

N_{leg} = number of legal-sized fish caught;

N_2 = single-census estimate of legal-sized walleyes or northern pike.

Variance for N_a was calculated as:

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

There were no prior abundance estimates for walleyes, northern pike, or smallmouth bass in Lake Charlevoix to help gauge how many fish to mark. However, two regression equations developed for Michigan lakes were used to provide initial estimates of walleye abundance. These regressions predicted legal-sized and adult walleye abundance based on lake size and were derived from historic abundance estimates made in Michigan over the past 20 years. The following equation for legal-sized walleyes was based on 21 abundance estimates for 21 different lakes:

$$\ln(N) = 0.542338 + 0.979441 \times \ln(A),\ R^2 = 0.74,\ P < 0.0001,$$

where N is the estimated number of legal-sized walleyes and A is the surface area of the lake in acres. For Lake Charlevoix, the equation gives an estimate of 24,303 legal-sized walleyes, with a 95% prediction interval (Zar 1999) of 5,013 to 117,834.

The second equation for adult walleyes was based on 31 estimates for 31 different lakes:

$$\ln(N) = 0.370993 + 1.046117 \times \ln(A),\ R^2 = 0.80,\ P < 0.0001,$$

where N is the estimated number of adult walleyes and A is the surface area of the lake in acres. The equation gives an estimate of 39,244 adult walleyes, with a 95% prediction interval (Zar 1999) of 7,067 to 217,920 for Lake Charlevoix. Based on these a priori abundance estimates, a marking goal of approximately 2,400 legal-sized walleyes (≈10%) of the legal-sized population was set. Specific tagging goals for northern pike and smallmouth bass were not set, but rather crews tagged as many as possible until the walleye goal was achieved.

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

The coefficient of variation (CV) was calculated for each abundance estimate (single- and multiple-census) and estimates with a CV less than or equal to 0.40 were considered to be reliable (Hansen et al. 2000).

Hydroacoustic Survey

The intent of the hydroacoustic survey on Lake Charlevoix was to derive an approximate estimate of fish density within the lake and to compare densities among the different basins. The acoustic survey was conducted the week prior to the standardized survey so that catches in deep water (50–100 ft) gill nets could be used as indicators of species composition for the hydroacoustic survey. Methods similar to those described in Warner et al. (2008) were used, as described briefly below.

A 24-ft boat with a bow-mounted echosounder (DT-X split beam, 129 kHz, 6.9° half-power beam width) was used for acoustic data collection. The echosounder was calibrated prior to the survey using a 32-mm tungsten carbide sphere with a theoretical target strength (TS) = -40.6 dB, and following methods described in Foote et al. (1987) and MacLennan and Simmonds (1992). Data collection began one hour after sunset and was completed at least one hour before sunrise. Vessel speed ranged from 3 to 5 mph and wave height during surveys was less than 1 ft. A zig-zag sampling design was used (Figure 3), with transects ranging from 0.4 to 2.0 miles in length. A data threshold of -80 dB, a pulse duration of 0.4 ms, and a ping rate of 2-5 pings • s^{-1} was employed during the survey. Acoustic data were divided into analysis grid cells with a distance of 500 m and depth of 10 m. Data were analyzed with Echoview 4.6 software.

Fish density (fish/ha) was estimated for each segment in the zig-zag design by multiplying the quotient of the areal backscattering coefficient (ABC, in $m^2 \bullet m^{-2}$) and the mean backscattering cross section (σ, in m^2) by 10^4 (m^2/ha) (Brandt 1996; Warner et al. 2008). Mean backscattering cross sections for each 10-m depth layer were calculated over the range of -76 to -30 dB from single targets detected using split beam method two with a TS threshold of -77 dB, a pulse length determination level of 6 dB, minimum normalized pulse length of 0.8, maximum normalized pulse length of 1.8, beam compensation of 6 dB, and maximum angular standard deviation of 1.0. The volume backscattering coefficient (S_v) and TS thresholds used should have been sufficient to include scattering from the smallest young-of-year fish present in Lake Charlevoix at the time of the survey. The range used is slightly larger than the range reported for young-of-year rainbow smelt in Lake Champlain (Parker-Stetter et al. 2006). However, the Lake Champlain survey was conducted in September in contrast to this survey which was conducted in June when young-of-year fish were smaller. The calibration offset value (difference between observed and expected TS of the calibration sphere) was determined using Echoview and was applied to the TS data. Single target detections of large (≥ 12 inches) fish were determined using a lower threshold of -36 dB based on Love's equation (Love 1971). Although this threshold may have resulted in the underestimation of small targets such as age-0 alewife or smelt, they were not of primary interest in this exploratory survey. Total fish density for each segment was the sum of densities in the individual depth layers. Acoustic data < 0.5 m from bottom and <1.0 m below the surface were excluded from analyses because of bottom detection limitations, transducer depth and associated near-field conditions, and to minimize the effect of surface noise.

Growth

Dorsal spines were used to age walleyes and smallmouth bass, and dorsal fin rays were used to age northern pike. Otoliths have been shown to be the most accurate and precise aging structure for older walleyes (Heidinger and Clodfelter 1987; Koscovsky and Carline 2000; Isermann et al. 2003) and otoliths or cleithra for northern pike (Casselman 1974; Harrison and Hadley 1979), but collecting these structures would have required killing fish, which would have greatly reduced the number of marked fish at large. Results from several studies comparing aging structures for walleyes were in agreement that spines were quicker to remove than scales, but there was nonagreement that spines are more accurate than scales (Campbell and Babaluk 1979; Kocovsky and Carline 2000; Isermann et al. 2003). Errors in ages from spines were often related to misidentifying the first annulus in older fish (Ambrose 1983; Isermann et al. 2003). There is also considerable disagreement as to whether spines or scales were more precise for walleye age estimation. Erickson (1983) and Campbell and Babaluk (1979) found that spines were more precise, Belanger and Hogler (1982) found spines and scales were equally precise, and Kocovsky and Carline (2000) found scales were more precise.

Dorsal fin rays were used for northern pike since pike older than 6 years are notoriously difficult to age with scales (Carlander 1969). Studies have demonstrated that fin rays are a valid aging structure for a number of species (Skidmore and Glass 1953; Ambrose 1983; Mills and Chalanchuk 2004), including northern pike (Casselman 1996), but no comparisons have been made to statistically compare accuracy and precision of using fin rays compared to other aging structures for northern pike. Sample size goals were 20 male and 20 female fish per inch group for walleyes and northern pike, and 20 per inch group for smallmouth bass.

Fin ray and spine samples were sectioned using a table-mounted high-speed rotary cutting tool. Sections approximately 0.02-inch thick were cut as close to the proximal end of the spine or ray as possible. Sections were examined at 40x-80x magnification with transmitted light and were photographed with a digital camera. Two technicians independently aged samples and ages were considered final when independent estimates were in agreement. When age readings from the two technicians were in dispute, the structures 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 all 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 growth indices were calculated by comparing the data to Michigan state averages derived using spines/fin rays (author's unpublished data). The mean growth indices of Lake Charlevoix populations were calculated as the average of deviations (by age group) between the observed mean lengths and statewide seasonal average lengths.

Angler Survey

Fish harvest seasons during this survey were April 29, 2006–March 15, 2007 for walleyes, northern pike, and muskellunge, and May 27 through December 31, 2006 for smallmouth and largemouth bass. Minimum size limits were 15 inches for walleyes, 24 inches for northern pike, 14 inches for smallmouth and largemouth bass, and 42 inches for muskellunge. Daily bag limit was five fish in any combination of walleyes, northern pike, smallmouth bass, or largemouth bass (but no more than two northern pike), 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 crappies, bluegills, pumpkinseeds, 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, April 29 to September 30, 2006, and the ice-cover period, January 18 through March 24, 2007.

Field methods–A progressive-roving design was used for the open-water period and a roving-roving design was used for the ice-cover period (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 plus 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. The lake was divided into three sections: main, south, and north basins, and each section was sampled every scheduled day. Starting location within a particular section and direction of travel were randomized for both counting and interviewing. Counting began at way point 1 and proceeded along the path ending at way point 17, or counting began at way point 17 and proceeded along the path ending at way point 1 (Figure 4). Time of count was randomized within the daylight times of the sample period.

Interview starting time, location, and direction were randomized daily. Minimum fishing time prior to interview (incomplete-trip interview) was 1 h (Clark et al. 2004; Lockwood 2004). All interview data were collected by individual angler to avoid party size bias (Lockwood 1997), though the number of anglers in each party was recorded on one interview form for each party. While this survey was designed to collect roving interviews, 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 tag numbers, if applicable. One of two shifts was selected each sample day for interviewing (Table 2).

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 2). 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%) conducted during summer and winter survey periods were of a single type (either at an access site or from a boat roving on the lake). 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 the same interview type, the appropriate catch-rate estimator for that interview type (Lockwood et al. 1999) was used on all interviews. When less than 80% were of a single interview type, a weighted average of catch rate (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 $\overline{R}$ is the mean-of-ratios estimator for n_2 incompleted-trip interviews. Estimated variance of the catch rate (R_w) 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 was expressed as both angler hours and angler trips. An angler trip was defined as the period an angler was at a lake (fishing site) and actively fishing. When an angler left the lake or stopped fishing for a significant period of time (e.g., when an angler left the lake to eat lunch), the trip ended. Movement between fishing spots, however, was considered part of the fishing trip. Mail or telephone surveys typically report angling effort as angler days (Pollock et al. 1994). Angler trips differ from angler days because multiple trips can be made within a day. Historically, Michigan angler creel data averaged 1.2 trips per angler day (DNR Fisheries Division, unpublished data).

All estimates are given with ± 2 SE, which provide 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 was more appropriately described as 75% confidence limits due to severe departure from normality of catch rates. For walleyes, northern pike, and smallmouth bass the initial harvest estimates were expanded by adjusting for the nonsurveyed period based on the percentage of tag returns from the nonsurveyed period. Additionally for proper comparison with the abundance estimate, the harvest for these species was further adjusted for the percentage of sublegal fish that grew over the minimum size limit during the course of the fishing season.

Mortality

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

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

Using the first method, exploitation rate was estimated as the fraction of reward tags at large that were returned by anglers, adjusted for tag loss. The tag loss adjustment was made by reducing the number of available reward tags by the percentage of tags estimated to have been lost over the course of the creel survey. Tagging mortality (from handling) was assumed to be negligible as was the nonreporting rate for reward tags on fish caught by anglers. Although actual nonreporting was not assessed (for all tags, reward and nonreward), the actual number of tag returns was compared to the expected number (X) based on the ratio:

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

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

Additionally, individual tags observed by the creel clerk were verified to see if they were subsequently reported by anglers. This step was also not a true estimate of nonreporting because there is the possibility that anglers believed the necessary information was obtained by the creel clerk, and further reporting to the DNR was unnecessary. Tags observed by the creel clerk that were not voluntarily reported by the angler were added to the voluntary tag returns for exploitation estimates.

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

In the second and third methods, exploitation rates were calculated as the adjusted harvest estimate from the angler survey (H_a from above) divided by the multiple- and single-census abundance estimates for legal-sized fish. Also, for proper comparison with the abundance estimates of fish that were legal size in the spring, the harvest estimate was reduced to account for fish that grew to legal size over the course of the creel survey. The reduction of harvest was based on the percentage of fish observed in the creel survey that were determined to have been sublegal at the time of the spring survey (See *Abundance* subsection of the *Methods* section), but were expected to have grown and reached legal size by the time they were caught later in the season. Confidence limits (95%) were calculated for these exploitation estimates using the variances from the abundance and harvest estimates, and assuming a normal distribution.

Movement

Fish movement during the spring survey was evaluated by comparing the distance between points of capture and recapture. Distances between capture locations were calculated as straight lines using the haversine formula (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. Analysis of variance was used to determine differences in minimum distance moved by fish of different sexes and different sizes at initial capture. Deviation in latitudes between capture locations was used to determine north-south movement.

Results[1]

Fish Community

A total of 13,707 fish representing 31 species were collected in the spring survey (Table 3). Total sampling effort was 320 trap-net lifts, 163 fyke-net lifts, and 2 electrofishing runs. The total catch included 2,703 walleyes, 876 northern pike, and 522 smallmouth bass which made up approximately 20%, 6%, and 4% of the total catch, respectively. Other abundant fish species collected in order of abundance of total catch were: white sucker, rock bass, bullhead species, yellow perch, and bowfin. The overall fish community composition was 55% benthivores, 31% piscivores, and 14% pelagic planktivores-insectivores (Table 3).

Size Structure and Sex Ratio

The percentages of legal-sized walleyes, northern pike, and smallmouth bass were 93, 53, and 69, respectively (Table 4). The population of spawning walleyes exhibited a bi-modal length distribution, with peaks at the 19- and 26-inch groups. The largest walleye collected was 32.8 inches and 3% of all walleyes were > 30 in. Seven percent of all walleyes were of unknown sex. The population of spawning northern pike was dominated by 22- to 25-inch fish, though smaller fish (11-21 inches TL) were present. Large pike (≥30 inches) were relatively abundant, making up 18% of the total catch. Smallmouth bass were rather evenly distributed from 12 to 19 inches, with a few fish in the 21 inch group. Male walleyes outnumbered females by a ratio of 1.3 : 1 for all fish in the spring survey as well as for the legal-sized portion of the catch. Male northern pike outnumbered females by a ratio of 1.3 : 1 when all sizes were considered, but females outnumbered males by a ratio of 2.0 : 1 when fish of legal size were considered. Seventeen percent of all northern pike were of unknown sex. Lake whitefish collected in the summer had a sex ratio of 0.9 males per female.

Abundance

Crews placed a total of 1,947 tags on legal-sized walleyes (1,071 reward and 876 nonreward tags) and fin-clipped 20 sublegal adults for a total of 1,967 marked (with jaw tag or fin clip) adult walleyes. One recaptured walleye died, and eight lost their tags during the spring netting survey; thus, the effective number tagged (M) was 1,938. The angler survey clerk observed a total of 227 walleyes on Lake Charlevoix, of which 38 were marked (R; had a fin clip or a tag). The initial C was reduced by 30 (13.2%) to adjust for sublegal fish that grew over the minimum size limit during the fishing season (final C = 197). The estimated number of legal-sized walleyes was 4,335 using the multiple-census method and 9,844 using the single-census method (Table 5). The estimated number of adult walleyes was 4,318 using the multiple-census method, and 9,859 using the single-census method. The coefficient of variation was 0.06 for both of the multiple-census estimates, and was 0.14 for both of the single-census estimates.

Crews tagged 319 legal-sized northern pike in Lake Charlevoix (142 reward and 177 nonreward tags) and clipped 205 sublegal adults for a total of 524 marked adult northern pike. Four recaptured northern pike lost their tag during the spring netting; thus, the effective number tagged (M) was 315. The creel clerk observed 20 northern pike, of which 10 were marked (R; had a fin clip or a tag). The initial C was reduced by two (10%) to adjust for sublegal fish that grew over the minimum size limit during the fishing season (final C = 18). The estimated number of legal-sized northern pike was 264 (CV = 0.09) using the multiple-census method, and was 546 (CV = 0.19) using the single-census

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

method. The estimated number of adult northern pike was 690 (CV = 0.09) using the multiple-census method and 903 (CV = 0.19) using the single-census method (Table 5).

Crews tagged 345 (*M*) legal-sized smallmouth bass in Lake Charlevoix (199 reward and 146 nonreward tags). No recaptured smallmouth bass died or lost their tag during the spring netting. The creel clerk observed 221 smallmouth bass, of which 8 were marked (*R*; had a fin clip or a tag). The initial *C* was reduced by 43 (19.5%) to adjust for sublegal fish that grew over the minimum size limit during the fishing season (final *C* = 178). The estimated number of legal-sized smallmouth bass was 3,846 (CV = 0.24) using the multiple-census method, and was 6,882 (CV = 0.31) using the single-census method.

Hydroacoustic Survey

The hydroacoustic survey covered approximately 39 miles on Lake Charlevoix, resulting in a degree of coverage of 7.5. The calibration offset value was 1.64 dB. Although analysis of acoustic data was conducted using the metric system, fish densities are reported using English units. Total fish density (fish per acre) for all species and size groups varied spatially in Lake Charlevoix. Average fish density was 196.0 ± 36.9 (mean ± SE) in the north basin, 478.5 ± 110.0 in the main basin, and 1,315.0 ± 505.6 in the south basin. The lake-wide average was 411.0 ± 72.8; however, the majority of the total fish targets were composed of small (≤7 inches) fish (TS ≤ 40 dB; Figure 5). Density estimates for large (>12 inches) fish were much lower. Mean fish densities for large fish were 0.02 ± 0.02 in the north basin, 0.11 ± 0.08 in the main basin, and 12.6 ± 12.6 in the south basin. The lake-wide average density of large fish was 0.59 ± 0.55. High standard errors for the large fish density estimates resulted from there being numerous analysis cells where fish were not detected. Based, on the deep-water gill-net catch (Table 6), the majority of fish targets were yellow perch, which accounted for 53.3% of the total catch. The majority of the large fish targets were lake whitefish, which accounted for 30.6% of the total catch. Relatively few burbot and lake trout were collected from the deep water. Shallow-water gill nets caught mostly yellow perch and white suckers, which accounted for 62.9% and 23.9% of the total catch by number, respectively (Table 7). Walleyes accounted for 5.6% of the total shallow-water catch, and the remaining 7.6% was made up by rock bass, brown trout, northern pike, lake whitefish, burbot, and smallmouth bass.

Growth

Technicians aged 437 walleyes (Table 8), 387 northern pike (Table 9), 154 smallmouth bass (Table 10), 56 lake whitefish (Table 11), and 7 lake trout. The overall mean growth index for walleyes was +2.9 when compared to the statewide average derived from scales and +3.0 when compared to the statewide average derived using dorsal spines. Walleye mean length-at-age data were higher than the statewide averages for all ages, with a maximum deviation of 4.7 inches at age 9. Females had higher mean length-at-age statistics than males, with the larger differences occurring at older ages. For northern pike, the overall mean growth index was +2.5 when compared to the statewide average derived from scales and +2.8 when compared to the statewide average derived using dorsal fin rays. Mean length-at-age data were higher than the statewide average for all ages, and female northern pike had higher mean length-at-age statistics than males. Smallmouth bass had higher mean lengths-at-age than the statewide average, and the mean growth index was +1.7. Lake whitefish mean length-at-age data differed between males and females, but not consistently. Only four year classes of lake trout were collected, with mean lengths for ages 2 through 5 being 10.9, 19.2, 22.6, and 23.1 inches, respectively.

Angler Survey

Open-water period–The clerk interviewed 1,997 anglers during the open-water period on Lake Charlevoix. Most interviews (96%) were roving (incomplete-fishing trip). Anglers fished an estimated 50,536 hours and made 18,173 trips (Table 12). The total harvest of 15,694 fish consisted of seven different species. Harvest was dominated by yellow perch and smallmouth bass, which accounted for 88% of the total harvest. Yellow perch were most numerous, with an estimated harvest of 12,213 fish. Anglers harvested 996 walleyes and reported releasing 942 (49% of total walleye catch). Anglers harvested 123 northern pike, and reported releasing 278 (69% of total catch). Size composition of the released fish was not evaluated. A total of 32,998 fish were caught and released, which consisted of 14 species. Yellow perch were the most numerous released fish (19,382) followed by smallmouth bass (7,124). It is worth noting that given the start date (April 29) of the 2006 creel survey, the early spring yellow perch fishery was missed. During and prior to the netting survey, which took place April 3–22, crews observed numerous (10-20 daily) fishing boats and talked with several anglers that were catching limits (50) of yellow perch.

Ice-cover period–The clerk interviewed 407 anglers during the ice-cover period of the angler survey, most of which (83%) were roving-type interviews. Anglers fished 6,590 hours and made 1,917 trips (Table 13). A total of 3,977 fish were harvested, composed of four species. Yellow perch were the most numerous, making up 96% of the harvest. Anglers harvested 22 walleyes and reported releasing none. Harvest of northern pike was not detected, though 51 were reported as released. Rainbow smelt were detected in the harvest, though there were very few.

Annual totals–In the periods from April 29 to September 30, 2006, and January 18 to March 24, 2007, anglers fished 57,126 hours and made 20,090 trips to Lake Charlevoix. Of the total annual fishing effort, 88% occurred in the open-water period and 12% occurred during ice-cover period. Angler effort peaked in June, though it did not vary much throughout the summer (May through September). Angler effort dropped considerably during the ice-cover period; average angler hours per day was 326 during the open-water period and 100 during the ice-cover period. The total annual harvest was 19,671 fish, of which 80% were taken in the open-water period. Harvest was predominantly yellow perch (16,023) and smallmouth bass (1,594), which accounted for 81% and 8% by number. The estimated total annual harvest of walleyes and northern pike was 1,018 and 123, respectively, making up 5% and 0.6% of the total harvest. The harvest rate for walleyes was six times higher during the open-water period (0.020 per hour) as compared to the ice-cover period (0.003 per hour). In contrast, the harvest rate for yellow perch was more than two times higher during the ice-cover period (0.578 per hour versus 0.242 per hour), and the release rate was more than three times higher during the ice-cover period (1.260 per hour versus 0.384 per hour). There was no angler survey from October through mid-January, because it was thought that relatively little fishing occurred during that time of year and ice conditions were unsafe. However, 3.5% of walleye and 2.6% of smallmouth bass tag returns were reported as being caught during this nonsurveyed period, thus the actual harvest for walleyes could have been about 3.5% higher (1,054) and the actual harvest of smallmouth bass could have been about 2.6% higher (1,635). After being further adjusted for the percentage of sublegal fish that grew over the minimum size limit during the fishing season (see *Abundance* section), the total expanded harvest (H_a) for walleyes, northern pike, and smallmouth bass was 915, 111, and 1,317, respectively.

Yellow perch were the predominant species caught (harvested + released) at 43,707, with a resulting catch per hour of 0.765. The total catch of walleyes was 1,960, with a catch rate of 0.034 per hour. Walleye catch rates were inconsistent throughout the year, ranging from 0.001 in January-February to 0.073 per hour in June. Anglers released 48% of all walleyes caught. Estimated total annual catch of northern pike was 452, with a resulting catch rate of 0.008 per hour. Anglers released 73% of all northern pike caught. 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-sized released fish, it was assumed that a large proportion of the released walleyes were sublegal.

Mortality

For walleyes, the aged subsample was used to project ages onto 2,108 fish (Table 14), which differs slightly from the number of unique walleyes measured (Table 3) due to rounding in the age-length key. Ages 4 and older were used in the catch-curve analyses to represent the legal-sized male walleye population (Figure 6) since 1) the average length of male walleyes at age 4 was greater than legal size, so most age-4 fish were of legal size at the beginning of fishing season; and 2) relative abundance of fish younger than age 4 did not appear to be represented in proportion to their expected abundance (Figure 6; Table 14). The catch-curve regression was significant ($P < 0.05$) and produced a total instantaneous mortality rate for legal-sized male walleyes of 0.262, which corresponds to an annual mortality rate of 23%. Regressions for female and all (males, females, and unknown sex) walleyes were not significant.

Anglers returned a total of 143 tags (84 reward and 59 nonreward) from harvested walleyes and 7 tags (reward) from released walleyes in the year following tagging (Table 15). Additionally, seven (five reward and two nonreward) tagged walleyes in the possession of anglers were observed during the creel survey and these fish were not subsequently reported. During the angler survey the creel clerk observed 2 (of 38) recaptured walleyes that had lost tags; thus, the estimated tag loss rate was 5.3%. The estimate of annual exploitation of walleyes from reward tag returns was 8.8% after adjusting for tag loss (Table 5). Anglers reported reward tags at a slightly higher rate than nonreward tags (8.5% versus 6.8%), and the number of tags voluntarily returned by anglers (150) was lower than the expected number of returns (176) based on the ratio described previously in the **Methods** section. Based on all tagged walleyes known to be caught, the reported release rate was 4.4%. The estimated exploitation rate for walleyes was 21.1% based on dividing harvest by the multiple-census abundance estimate, and 9.3% based on dividing harvest by the single-census abundance estimate (Table 5).

For northern pike, the aged subsample was used to project ages onto 606 fish (Table 14). Ages 2 and older were used in the catch-curve analyses to represent adult male northern pike, ages 4 and older were used for females, and ages 3 and older were used for the overall population of legal-sized northern pike (Figure 7). The catch-curve regressions for males and all fish combined were significant ($P < 0.05$) and resulted in total annual mortality rates of 39%, and 29%, respectively. Anglers returned a total of nine tags (four reward and five nonreward) from harvested northern pike, and three tags (one reward and two nonreward) from released northern pike in Lake Charlevoix in the year following tagging (Table 15). During the angler survey the creel clerk observed 1 (of 10) recaptured northern pike that had lost its tag; thus, the estimated tag loss rate was 10%. The estimate of annual exploitation of northern pike from reward tag returns was 3.2% after adjusting for tag loss (Table 5). Anglers reported reward and nonreward tags at a similar rate (3.5% versus 4.0%), and the number of tags voluntarily returned by anglers (9) was lower than the expected number of returns (62) based on the ratio described previously in the **Methods** section. Based on all tagged northern pike known to be caught, the reported release rate was 25%. The estimated exploitation rate for northern pike was 35.3% based on dividing harvest by the multiple-census abundance estimate, and 20.3% based on dividing harvest by the single-census abundance estimate (Table 5).

For smallmouth bass, the aged subsample was used to project ages on 505 fish (Figure 8, Table 14). Ages 3 and older were used in the catch-curve analyses to represent legal-sized smallmouth bass, which resulted in a significant ($P < 0.05$) catch-curve regression and total annual mortality rate of 25%. Anglers returned a total of 39 tags (28 reward and 11 nonreward) from harvested smallmouth bass, and 12 tags (7 reward and 5 nonreward) from released smallmouth bass in Lake Charlevoix in the year following tagging (Table 15). During the angler survey the creel clerk did not observe any recaptured smallmouth bass that had lost tags; however, an average tag loss rate of 5% was used, based on previous Large Lake Program surveys. The estimate for annual exploitation of smallmouth bass from tag returns was 15.3% (Table 5). Anglers reported reward tags at a higher rate than for nonreward tags (17.6% versus 11.0%), and the number of tags voluntarily returned by anglers (51) was lower than the expected number of returns (59). The reported release rate was 22.6%. The estimated exploitation rate for smallmouth bass was 34.2% based on dividing harvest by the multiple-census abundance estimate, and 19.1% based on dividing harvest by the single-census abundance estimate (Table 5). Annual mortality for lake whitefish collected in the summer was estimated at 23% using ages 3–9 and 12. Ages 10 and 11 were not included because no fish were collected from these age groups and they were considered missing year classes.

Movement

During the spring survey, 562 recaptured walleyes moved an average of 1.3 miles (median = 0.8) and a maximum of 7.9 miles between points of initial capture and where they were recaptured. Movement generally followed a northerly direction, with 67% of recaptures taking place north of initial capture locations and 33% being south. Longitudinal movement did not differ as much, with 58% of recaptures taking place west of capture locations and 42% being east. Recaptured northern pike (N= 170) moved an average of 1.3 miles (median = 0.7 miles) and a maximum of 8.1 miles from their point of initial capture. Similar to walleyes, northern pike movement generally followed a northerly direction, with 65% of recaptures taking place north of initial capture locations and 35% being south. Longitudinal movement was greater for pike than for walleyes, with 63% of recaptures taking place west of capture locations and 37% being east. Fifteen recaptured smallmouth bass moved an average of 1.8 miles (median = 0.8 miles) and a maximum of 10.1 miles from their point of initial capture.

Based on first-year angler tag returns, 97% of tagged walleye were captured in Lake Charlevoix, 3% were caught in Round Lake and the Pine River, and less than 1% (one tag return) was captured in Lake Michigan (Table 16). It is assumed that the walleyes caught in Round Lake and the Pine River were headed to Lake Michigan; thus they are included in a total for walleyes migrating to Lake Michigan. For northern pike, all first-year tag returns were reported from Lake Charlevoix. Most (94%) smallmouth bass were caught in Lake Charlevoix, though 4% came from Round Lake and the Pine River, and 2% (one tag return) came from Lake Michigan.

Analysis also included an examination of tag returns received through the time this report was written (October 2009). Based on that time series, 88% of tagged walleyes were captured in Lake Charlevoix, 9% were caught in Round Lake and the Pine River, and 3% were captured in Lake Michigan (Figure 9, Table 17). Of the walleye tag returns from Round Lake, the Pine River channel, and Lake Michigan (N = 41), 73% were females and 27% were males. Female walleyes moved 2.3 ± 1.2 miles farther than males ($F = 3.44$, $P = 0.06$, $df = 315$), with the average for males and females being 3.2 and 5.5 miles, respectively. Also, size of fish was positively related to distance moved ($F = 56.36$, $P < 0.001$, $df = 315$). That is, larger fish moved farther than smaller fish, on average. For the 2006–2009 data set northern pike were all reported from Lake Charlevoix, and smallmouth bass were caught in Lake Charlevoix (92%), Round Lake and the Pine River (5%), and Lake Michigan (3%).

Discussion

Fish Community

Numerous surveys have been conducted on Lake Charlevoix using various gear types at different times of the year. Although this lack of standardization makes comparisons difficult, some changes related to the actively managed species were apparent. Lake trout were historically one of the dominant predators in Lake Charlevoix and stocking was used as a tool to rebuild populations following their collapse in Lake Charlevoix, just as in the Great Lakes. A summer gill net survey in 1979 showed that 82% of the lake trout were from prior (1975 and 1976) Lake Charlevoix stocking events and 5% were from Lake Michigan stocking. Similarly, in 1990, 99% (N = 68) of lake trout in a gill net/trawl survey were stocked. Of the 44 lake trout for which stocking location could be determined, 43 (all of which were age 1 and 3) had been stocked in Lake Charlevoix and one (age-5) had been stocked in Lake Michigan at Penn Dixie (now Bay Harbor). Biologists speculated that the absence of older lake trout in Lake Charlevoix was a result of movement to Lake Michigan. In support of that speculation, fish stocked in Lake Charlevoix represented 17% of all coded-wire-tagged lake trout (≥25 inches) in the Charlevoix/Petoskey area of Lake Michigan in 1995.

Although stocking efforts produced a lake trout fishery in Lake Charlevoix for many years, there is some evidence of a recent decline. Gill nets used in different surveys varied somewhat in mesh size and length; however, in four years when sampling was performed between 1975 and 2006, similar nets were used in the fall to characterize adult fish populations (Figure 10). Lake trout catch per effort was consistently low over the series; however, considerably higher lake trout CPUEs were recorded during a spring gill-net survey in 1984 that resulted in 16.5 adult lake trout per 500 ft of net and a spring gill-net survey in 1992 that caught 26.5 lake trout per 500 ft.

Brown trout in Lake Charlevoix showed trends similar to lake trout. Brown trout stocking in Lake Charlevoix began in early 1970s (Laarman 1976) and produced a popular fishery in the 1980s and early 1990s. In the early 1990s, the fishery appeared to decline which led to numerous revival efforts (Johnson and Rakoczy 2004). However, the last year of substantial brown trout harvest in Lake Michigan waters off Charlevoix was probably 1993 (4,044)—in the three following years the harvest was less than 1,000 per year (Johnson and Rakoczy 2004). The port of Charlevoix brown trout harvest bottomed out at 11 fish in 1996. In 1998, biologists concluded that whether due to escapement, decreased forage base, stocking strategy, size at stocking, or predator presence/absence, brown trout were not providing enough return to justify the cost of continued stocking. However, largely due to public demand to try to revive a once impressive fishery, a final effort was initiated in 1999, stocking advanced-growth brown trout. This effort was unsuccessful, and brown trout stocking was ultimately abandoned in 2005.

Walleyes were present in Lake Charlevoix from the 1940s through the 1970s, though based on survey catches, abundance never reached significant levels. For example, a trap-net survey in the spring of 1970 caught only 10 walleyes, though the same nets collected 254 northern pike. In 1980, DNR biologists recommended stocking walleyes in the south basin of Lake Charlevoix since there was a niche present for them. The suggestion was made to use a lake spawning strain since there is some rocky shoreline present in Lake Charlevoix and the Jordan River was thought to be too cold for successful reproduction. In the spring of 2006, crews electrofished the Jordan River from Lake Charlevoix to Rogers Road and did not collect any walleyes. Walleye stocking in Lake Charlevoix began in 1984 in modest numbers which increased over time, though stocking levels have never exceeded the recommended level (25-100 spring fingerlings per acre) for Michigan waters (Dexter and O'Neal 2004). At some point in the late 1980s surveys indicated an increase in walleye abundance in Lake Charlevoix (Figure 10). Coinciding with increasing gill-net catches, anglers also began to target walleyes more often in Lake Charlevoix. In the 1990 survey, just six years after the first walleye stocking, the CPUE of walleyes was nearly three times that of lake trout and walleyes ranging in size from 13 to 21 in were caught. Two years later, a spring trap-net survey collected walleyes from 10 to 27 in. Thus, it appeared that walleyes were surviving initially, and those that survived were growing well.

Besides some of the changes to actively-managed species, the overall fish community in Lake Charlevoix today has both similarities and differences to the community described by Laarman (1976). Some minnow species that had been collected in the past have not been collected recently, though this could be because recent surveys using seines have not been extensive. A few species (e.g., longear sunfish and white bass), which were regularly observed in surveys during the 1950s and 1960s, were not represented in the 2006 survey. Also, black crappies were regularly caught in trap nets in a 1979 survey, though only five were collected in the 2006 survey. Prey fish in Lake Charlevoix have always appeared to be rather abundant. In 1967, nine 10-min bottom trawls resulted in 1,702 smelt (ranging from 3.9 to 10.4 inches) and 12,535 alewives (3 to 6.5 inches). Additionally, in a 1979 trap-net survey over 1,300 alewives were collected, and in a 1990 trawl survey 2,023 alewives and 1,147 smelt were collected. No smelt were collected in the spring survey of 2006, though trap-net mesh sizes were too large for most smelt. Though smelt were collected in seemingly high numbers as recently as 1990, the smelt population has declined from when it supported a large ice fishery, and when large smelt runs were common in Lake Charlevoix from the 1930s to the 1960s. The smelt declines in Lake Charlevoix correspond with those occurring in Lake Michigan.

Size Structure and Sex Ratio

For Lake Charlevoix, there are few surveys conducted during the walleye spawning season to use for comparison to the current survey. A few gill-net surveys collected ample numbers of walleyes, but the issue of gear selectivity precludes proper comparison. However, from comparisons to other walleye populations in large lakes, it is apparent that the walleye population of Lake Charlevoix has high size structure. The current size structure of walleyes in Lake Charlevoix (93% legal size) was well above the median (71%) and mean (71%) of legal-sized walleyes in spring surveys for 20 populations surveyed under the Large Lakes Program. High walleye size structure was also observed in the Muskegon River population (Hanchin et al. 2007) which is connected to Lake Michigan. The high size structure is likely a product of low walleye density and abundant prey species such as smelt and alewives. Low density and abundant prey also likely contribute towards the high size structure of northern pike, of which the percentage of legal-sized fish was almost twice the average from other populations surveyed in the Large Lakes Program.

The predominance of male walleyes that was observed in the spring survey is typical in surveys of spawning walleyes (Carlander 1997) although the sex ratio was not as skewed towards males as it has been in other populations. The average number of males per female in populations surveyed in the Large Lakes Program is 4.4, compared to 1.3 for Lake Charlevoix. The northern pike population demonstrated the typical trend of adult males outnumbering adult females, and legal-sized females outnumbering legal-sized males.

Abundance

The multiple-census estimates for walleyes were much lower than the single-census estimates for both legal-sized fish and adult fish, which is consistent with estimates from most other large lakes (Clark et al. 2004; Hanchin et al. 2005a, b, c; Hanchin and Kramer 2007; Hanchin 2011). The single-census estimates were closer to other independently-derived estimates. For example, the exploitation estimate derived using the single-census estimate was only 6% higher than the tag-return estimate, while the exploitation estimate derived using the multiple-census estimate was 140% higher. Multiple-census estimates made during the onshore spawning migration of species such as walleyes and northern pike are likely biased low due to size selectivity and unequal vulnerability of fish to near-shore netting (Pierce 1997). Multiple-census methods also are more likely affected by incomplete mixing of marked and unmarked fish, which is not a problem with the single-census method since 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), the single-census estimates are considered more accurate than the multiple-census ones for Lake Charlevoix.

The single-census estimates of walleye abundance were lower than the a priori estimates from the predictive regression (Michigan model). The single-census estimate for legal-sized walleyes was 59% lower than the Michigan model, and the single-census estimate for adult walleyes was 75% lower. I believe the Michigan regression equation overestimates walleye abundance in Lake Charlevoix, largely because of the vast area of deep water, which is not ideal walleye habitat. Accordingly, the population density of walleyes in Lake Charlevoix was below average compared to other walleye lakes in Michigan. The single-census estimate for 15-in-and-larger walleyes in Lake Charlevoix was 0.6 per acre. Density of legal-sized walleyes estimated recently for 20 large lakes in Michigan has averaged 2.0 fish per acre (range = 0.4 to 4.6 fish per acre), though given the positive skew of the data (values are concentrated towards the lower densities) the median (1.8 fish per acre) is a better measure of central tendency (DNR unpublished data). Density of adult walleyes from the single-census estimate (0.6 fish per acre) was lower than the average (3.2 fish per acre) and median (2.4 fish per acre) in 20 large lakes surveyed in the Large Lakes Program, as well as the average (2.2 adult walleyes per acre) for 131 northern Wisconsin lakes having natural reproduction (Nate et al. 2000). However, the single-census estimate of adult walleye abundance was not a true mark-recapture estimate since the recapture method (angler survey) potentially did not allow for the examination of sublegal adult walleyes. Rather, it was an estimate for legal-sized walleyes that was adjusted to account for sublegal mature walleyes that were on the spawning grounds. It is uncertain how this would compare to a true mark-recapture estimate of adults, but if the catchability (in nets and by angling) of sublegal walleyes was similar to legal-sized walleyes, the estimate should be relatively unbiased as compared to a true mark-recapture estimate of adult walleyes.

Although overall walleye density in Lake Charlevoix is below average, walleyes are likely present at above average density in the south basin at certain times of the year. If the abundance estimate is apportioned by the percentage of legal walleyes collected in the south basin of Lake Charlevoix (64%), then at certain times of the year the walleye density in the south basin is around 2.3/acre. It is uncertain exactly when this higher walleye density exists, but it is likely just prior to, during, and immediately following spawning. Over the course of the summer, as walleyes move to the deeper waters of the main basin and Lake Michigan the density in the south basin likely decreases.

The single-census estimates for northern pike were considered more accurate than the multiple-census ones for the same reasons given for walleye estimates. In fact, the multiple-census estimate for legal-sized northern pike was even lower than the actual number marked. The single-census estimate for legal-sized northern pike converts to a density of 0.03 per acre, which is below the average (0.18) and median (0.10) estimated for northern pike in other lakes in the Large Lakes Program. Nearby, Burt Lake (Hanchin et al. 2005b) and Crooked-Pickerel lakes (Hanchin et al. 2005c) had similar northern pike densities of 0.05 and 0.01 per acre, respectively. The density of adult northern pike (0.05 per acre) was way below the average (0.91) and median (0.56) estimated for other lakes in the Large Lakes Program. 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 varied, 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 aged 2 and older. The lower northern pike density observed in Lake Charlevoix 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.

Abundance estimates for smallmouth bass were similar to those for walleyes and northern pike in that the single-census estimate was considered to be more accurate than the multiple-census one. The single-census estimate for legal-sized smallmouth bass converts to a density of 0.40 per acre, which is near the average (0.57) and median (0.40) estimated for other lakes in the Large Lakes Program. It is also similar to Newman and Hoff's (2000) reported 0.3 smallmouth bass (>16.0 inches) per acre in Palette Lake, Wisconsin.

Hydroacoustic Survey

Hydroacoustics were used on Lake Charlevoix to determine overall fish density estimates. A primary goal was to see if acoustic estimates corresponded with other independently-derived estimates such as those from angler harvest, gill nets, and mark-recapture population studies. The acoustic estimates of total fish density were within the ranges reported in other hydroacoustic assessments, but were near the middle to low end of the spectrum. There were no other hydroacoustic estimates from other lakes surveyed in the Large Lakes Program for comparison.

The highest density of fish in Lake Charlevoix occurs in the productive waters of the south basin. The density of larger fish in the south basin was 630 times greater than that for the north basin, and was 21 times greater than the lake-wide estimate. These results are similar to observations of fish density from the distribution of fish in the spring netting survey. Given this spatial difference in fish density, the hydroacoustic estimate of fish density for each basin is more informative than the lake-wide estimate. This is supported by the mark-recapture population estimates for legal-sized walleyes, northern pike, and smallmouth bass, which when combined (17,272 fish) equate to approximately 1.0 fish per acre, an estimate that is higher than the lake-wide hydroacoustic estimate.

The gill nets used to validate the hydroacoustic survey were all set on the bottom in deep water in order to target lake whitefish and lake trout; thus, species and size composition could not be adequately assigned to the acoustic data. A more appropriate effort to determine species composition would have included suspended gill nets and/or mid-water trawling. However, very few suspended targets were observed in the acoustic data. Species composition from the deep-water gill nets demonstrated that lake whitefish likely accounted for the largest component of hydroacoustic density estimates, and that there are relatively few lake trout. Yellow perch were abundant in both deep-water and shallow gill nets, and they likely made up a good portion of the fish detections from the hydroacoustic survey.

Growth

Mean length-at-age data for walleyes were well above both statewide averages and those from nearby lakes occupying similar latitude (Table 18). The walleye population in Lake Charlevoix has also exhibited above-average growth in the past. In May of 1992, twelve walleyes were aged, with age-4 walleyes (N = 8) having a mean length of 18.8 inches and a growth index of +3.0. Similarly, walleyes collected from anglers in 1993 reached legal size in their second year (mean length = 16.6 in, N = 63) and reached a mean length of 21.1 inches (N = 11) at age 4. Perhaps the most impressive growth was observed in 1991 when walleyes collected from anglers (N = 30) had mean lengths of 18.8 and 21.3 inches at ages 3 and 4, respectively. Although these fish were collected at various times throughout the summer, they represented growth indices of +4.4 and +5.1, based on June-July statewide mean length-at-age data. The tremendous growth of walleyes in Lake Charlevoix likely results from their below-average density and abundant prey base in both Lake Charlevoix and the nearshore waters of Lake Michigan. Similar walleye growth was observed by Hanchin et al. (2007) for Muskegon Lake, which is also open to Lake Michigan. In fact, it is more appropriate to compare mean length-at-age data for the Lake Charlevoix walleye population to those from other Great Lakes populations (Table 19), which all have a rather similar mean growth index.

Although there have been no diet studies of Lake Charlevoix walleyes, the apparent high relative abundance of smelt and alewives in the lake, at least during part of the year, suggest that they would make up a considerable component of their diet. A diet study of lake trout was conducted in 1979 based on fish in gill-net catches. Based on the stomachs containing fish, 69% of the lake trout had been feeding on smelt and 31% had been feeding on alewives. Although walleyes favor shallower habitat than lake trout, in the late summer and fall walleyes are known to congregate in the main basin of Lake Charlevoix, occupying habitat where alewives and smelt would be available. In the spring, smelt congregating near tributaries would also be available to walleyes. Finally, yellow perch populations are also occasionally high in Lake Charlevoix and would be another abundant potential prey source for walleyes.

Similar to walleyes, mean length-at-age data for northern pike were well above statewide averages, and were also larger than for pike in other waters in the northern Lower Peninsula (Table 20). Smallmouth bass in Lake Charlevoix exhibited the best growth of northern Lower Peninsula large lakes surveyed recently (Table 21). In contrast, age 2-4 smallmouth bass (N = 57) from Lake Charlevoix in 1985 averaged 2.2 in below the statewide average. Although there are no statewide average mean length-at-age data established for lake whitefish, the mean length-at-age data were higher for lake whitefish in Lake Charlevoix than for those collected from the Lake Michigan management unit WFM-05, which is adjacent to Lake Charlevoix. Considering ages 3–9, the average deviation between the Lake Charlevoix lake whitefish and those from Lake Michigan was +2.8 inches. The only age group for which Lake Michigan lake whitefish had a higher (+0.6 inches) mean length-at-age was age group 2. These results should be interpreted with caution because the lake whitefish from Lake Michigan were aged by various readers from other agencies and it is possible that the differences in mean length-at-age may have resulted from differences in aging techniques.

Angler Survey

Summary–The fishery of Lake Charlevoix is rather diverse, and somewhat typical of large lakes in the northern Lower Peninsula. The angler catch was dominated by yellow perch and smallmouth bass, which together accounted for 83% of the total catch. Approximately equal numbers of walleyes and northern pike were harvested as were caught and released, which is a result of the relatively high size structure for both of these species. In populations with lower size structure, the number of walleyes and northern pike caught and released is usually higher than the number harvested. The catch rate for walleyes varied throughout the open-water period, with a peak in June; the catch rate 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 angler effort (h) per day was 3.3 times higher in the open-water period than for the ice-cover period (326 vs. 100). Potamodromous species such as Chinook salmon and steelhead contribute towards the diversity of the fishery, in addition to other species such as freshwater drum.

Historical comparisons–A variety of creel surveys that have taken place on Lake Charlevoix over the years provide insight into changes in the fishery. Historically, aerial ice shanty counts were conducted in northern Michigan around the same time (mid-February) each winter. For Lake Charlevoix, the shanty counts depict the steep decline in angler effort in response to reductions in the smelt fishery (Figure 11). Beginning in the late 1920s, Lake Charlevoix supported large populations of smelt. The winter fishery for smelt was especially popular and Lake Charlevoix was the site of “Smeltania,” a city of shanties on the ice near Boyne City. There were three major booms in the Lake Charlevoix smelt population, which generally occurred in the 1930s, 1950s, and early 1980s. During the depression era of the 1930s, many Lake Charlevoix anglers were financially motivated as smelt could be sold for $0.01 a piece to wholesalers who shipped them all over the country (Morgridge 2010). In the 1960s, the shanty counts dropped considerably, coinciding with the collapse in the smelt population. Aerial shanty counts were discontinued in the 1980s and the only recent counts were made in the winter of 2007. There are several differences between the historic shanty counts and those made in 2007 that preclude proper comparison. First, shanty counts for 2007 were completed on the ice, rather than from an airplane. Additionally, 2007 counts were made in only one site (main basin, south basin, or north basin) per day, and included only occupied shanties. However, by combining shanty counts from three consecutive days (one for each site) the maximum number of occupied shanties on Lake Charlevoix in the winter of 2007 was around 12 per day. By using an average ratio of occupied to unoccupied shanties from Michigan (1:2.8; DNR Fisheries Division, unpublished data), the estimate for 2007 can be expanded to approximately 34 shanties. Thus, even with accounting for differences in methods, it appears that winter angling effort is much lower in 2007 than it was in the late 1970s (mean = 67 shanties from 1975–77). It is unclear how the popularity of portable shanties would affect comparisons since portable shanties are almost always occupied, but the ratio of occupied to unoccupied shanties may have changed over time.

For the open-water period, there is only one survey to which the 2006 estimate can be compared. Angler effort during the open-water period decreased from 79,788 hours in 1996 to 50,536 hours in 2006. Although the previously successful brown trout fishery in Lake Charlevoix was in the final stages of decline by 1996, there was still some remnant interest in the fishery which could, in part, explain the higher effort at that time. Alternatively, the lack of a lake trout fishery in 2006 could explain some of the difference as well.

Total annual angling effort on Lake Charlevoix estimated with mail surveys from 1971 to 1973 averaged 45,355 and ranged from 33,840 to 53,380 angler days. To compare these estimates with those observed in 2006-07, the current average number of trips per day (1.2 trip/day; DNR Fisheries Division, unpublished data) and the average length of a completed trip (3.1 h/trip for the annual period) from the 2006-07 angler survey were multiplied to estimate the average length of an angler day (1.2 * 3.1 = 3.7 angler hours). Thus, the 1971 to 1973 average equates to around 167,814 hours of fishing effort. This estimate is much higher than the 2006-07 estimate of 57,126 total angler hours; thus, it appears either that effort has decreased dramatically, these two methods are not directly comparable, or both.

In addition to changes in angler effort, changes in the harvest rates and species composition are noticeable for the various creel surveys that have been conducted on Lake Charlevoix. Laarman (1976) reported results from generalized creel surveys conducted by conservation officers on Lake Charlevoix from 1928 to 1964; however, the surveys were only designed to measure the success of those interviewed. During this broad range of years anglers caught mostly yellow perch and rainbow smelt, which accounted for 41 to 82%, and 11 to 40% of the total harvest, respectively. Other species harvested in order of decreasing abundance were rock bass, smallmouth bass, lake whitefish, cisco, and northern pike. Walleyes accounted for less than 1% of the total harvest during these creel surveys. More recently, a volunteer survey of 32 anglers in the spring of 1991 used log books to obtain information on trout catch rates and a comparison of brown trout strains. Anglers made 138 trips for 543 angler hours and caught 103 brown trout (0.19 per hour) and 4 lake trout (0.08 per hour). Because the effort was species specific and the fact that volunteers could have been more likely to catch trout, comparison to other survey designs is limited. In 1993, 1994, and 1995 from April through September, Lake Charlevoix anglers were interviewed to determine species composition and catch rates (no angler or boat counts were completed). In 1996 a full creel survey was conducted from May through September, and in 2006-07 the current creel survey was conducted during both the open-water and ice-cover periods. Because harvest estimates were not completed for 1993–1995 surveys, the best comparison that can be drawn with 2006-07 is one evaluating the harvest rate of key species and the percentage of the total harvest that each comprised. For this comparison, the 1991 volunteer survey and the 2006-07 ice-cover period were not included. While the trends in harvest per hour of lake trout, brown trout, and walleyes are not obvious, it appears that brown trout abundance declined over the period, walleyes increased, and lake trout varied and declined near the end of the series (Figure 12). For lake trout and walleyes, these trends roughly matched the relative abundance in fall gill-net catches (Figure 10). The apparent decline in the brown trout and lake trout fisheries corresponds with a decrease in the percentage of anglers targeting trout. From 1993 through 1995, on average 47% of interviewed anglers were targeting trout and salmon. In contrast, during the open-water periods in 1996 and 2006 only 27% and 10% of anglers, respectively, targeted trout and salmon. While the trout fisheries were declining, the walleye fishery was becoming more popular; the percentage of anglers targeting walleyes increased from an average of 16% from 1993 through 1995, to 28% in 1996, and 36% in 2006. In all of the creel surveys from 1993 to 2006, yellow perch accounted for the greatest portion of the total harvest at 41%, 65%, 92%, 64%, and 78%, respectively.

Comparison to other large lakes–In addition to the historic angler survey data for Lake Charlevoix, comparisons with angler surveys from other large lakes are useful. An estimated 51,126 angler hours occurred on Lake Charlevoix during the angler survey, which corresponds to 3.3 hours per acre. This is well below the mean and median values for other lakes surveyed under the Large Lakes Program (Table 22). The large size and vast area of deep water in Lake Charlevoix make it difficult to fish for most species. Additionally, much of the boating activity on Lake Charlevoix is for recreation, rather than angling. The harvest per acre (1.1) for Lake Charlevoix was 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 walleyes, the estimated annual harvest from Lake Charlevoix was 0.06 fish per acre, which is below the average (0.53 per acre) and median (0.45 per acre) for 19 lakes surveyed as part of the Large Lakes Program. The average harvest in six other large Michigan lakes (> 1,000 acres) reported by Lockwood (2000a) was 0.63 walleyes per acre, ranging from 0.09 for Brevoort Lake to 1.68 for Chicagon Lake. These Michigan lakes were all subject to fishing by anglers using similar gear types and fishing under similar regulations such as a 15-in minimum size limit. The low harvest per acre of walleyes in Lake Charlevoix is a result of the relatively low abundance, the large size of the lake, and the migratory nature of the population. The harvest per hour (0.02) for walleyes was half of the average (0.04) and median (0.04) values from 19 populations, and the catch rate of all walleyes (0.03 per hour) was also much lower than the average (0.11 per hour) and median (0.07 per hour) values from other populations.

For northern pike, the 2006-07 estimated annual harvest from Lake Charlevoix was 0.007 fish per acre, which was below average compared to other waters in Michigan. The average harvest in 17 lakes (having a 24-inch minimum size limit) sampled in the Large Lakes Program was 0.09 (median = 0.03) northern pike per acre, ranging from 0.003 in North Manistique Lake (Hanchin and Kramer 2008) to 0.46 in Houghton Lake (Clark et al. 2004). The average harvest in seven other large Michigan lakes (> 1,000 acres) reported by Lockwood (2000a) was 0.15 northern pike per acre, ranging from 0.002 per acre in Bond Falls Flowage to 0.65 per acre in Fletcher Pond. The lakes reported by Lockwood (2000a) were all subject to fishing by anglers using similar types of gear and fishing under similar regulations, including a 24-inch minimum size limit. Elsewhere, Pierce et al. (1995) estimated harvests from 0.7 to 3.6 per acre in seven smaller Minnesota lakes, which ranged from 136 to 628 acres in size and had no minimum size limit for northern pike. Similar to the situation for walleyes, the low harvest per acre of northern pike in Lake Charlevoix resulted from a relatively small population occupying a vast lake with below average fishing effort.

The estimated annual harvest of smallmouth bass was 0.10 fish per acre, which was approximately equal to the average (0.11) and median (0.09) from 17 lakes sampled in the Large Lakes Program. The average harvest for eight large (>1,000 acres) Michigan lakes 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 fishing by anglers using similar types of gear and fishing under similar regulations, however, the surveys did not always include the entire open-water period. Because of high release rates of smallmouth bass, a better parameter for among-lake comparisons is the catch per hour (harvested + released). The average open-water catch rate for smallmouth bass from 17 lakes sampled in the Large Lakes Program was 0.08 per hour (median = 0.06 per hour); thus, the rate of 0.17 per hour for Lake Charlevoix is more than twice the average catch rate. Since these catch rates are calculated with general effort, the value for each lake may be biased low if smallmouth bass are not highly targeted. That is not the case in Lake Charlevoix where 28.9% of open-water anglers were targeting smallmouth bass.

Mortality

An estimate of the total mortality of all walleyes in Lake Charlevoix was not possible since the catch curve regression was not statistically significant, though the estimate for males (23%) provided some indication that overall mortality was low. The average and median values for 18 populations surveyed in the Large Lakes Program were almost double at 41%. 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%). If this were the case for walleyes in Lake Charlevoix, total mortality of females would be around 41%, which is more comparable to the values observed in other large lakes. Schneider thought the difference in Lake Gogebic was largely due to higher exploitation of females (12.6% vs. 7.3%). In Lake Charlevoix, higher exploitation was observed for males (9.5%) than females (5.6%), likely due to the higher proportion of females migrating to Lake Michigan where angling effort is much lower for walleyes.

The estimates of walleye exploitation from both tag returns and harvest divided by the single-census abundance estimate were similar, but that derived from harvest divided by the multiple-census abundance estimate was much higher. Although the higher estimate derived using the multiple-census abundance estimate could be due to overestimating harvest, it is more likely a result of underestimating abundance with the multiple-census method. Using 8.8% as the best estimate, the exploitation rate for walleyes in Lake Charlevoix is lower than the average (15%) and median (12%) for populations surveyed in the Large Lake Program (N = 19), which ranged from 4% to 35%. Although a total mortality estimate was only obtained for males, it is clear that natural mortality is a larger component than angling for walleyes in Lake Charlevoix. Schneider et al. (1976) also concluded that most of the annual mortality of walleyes in Lake Gogebic was due to natural causes.

Total mortality of northern pike in Lake Charlevoix (29%) was well below the average (50%) and median (49%) values from northern pike populations surveyed as part of the Large Lakes Program in Michigan. It was also below the range (36% to 65%) of total mortality for northern pike in seven small (< 300 acres) Minnesota lakes reported by Pierce et al. (1995), and was below the range (35% to 65%) for the majority of North American lakes summarized by Pierce at al. (1995). The three estimates of northern pike exploitation for Lake Charlevoix varied considerably (3.2% from tag returns, 35.3% using harvest divided by the multiple-census abundance estimate, and 20.3% using harvest divided by the single-census abundance estimate). The tag-return estimate appears low, and the other exploitation estimates had wide confidence intervals. Although the confidence interval for the multiple-census abundance estimate was rather small, this method is known to underestimate abundance for northern pike (Pierce 1997). The high variance of the abundance estimates and the harvest estimates introduced uncertainty into the exploitation estimates derived from them. The tag-return estimate of exploitation can be used as a minimum, but it does not necessarily improve the understanding of northern pike exploitation since there was evidence of nonreporting, a high release rate, and tag loss. Although there is uncertainty regarding northern pike exploitation, it does not appear to be excessive given the relatively low total mortality, and the fact that the length frequency of the population shows no evidence of cropping above the minimum size limit. Hooking mortality from released fish is unknown though it is likely insignificant. Clark (1983) warned that voluntary release rates higher than 10% change the interpretation of conventional angler survey estimates of catch and fishing mortality, and for Lake Charlevoix a relatively high percentage (25) of tagged northern pike caught were released. However, in the case of Lake Charlevoix, even if hooking mortality 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 3.2% to 3.5%. Compared to exploitation rates for northern pike from other lakes in Michigan and elsewhere, the tag return estimate for Lake Charlevoix is obviously low. The mean and median exploitation rates for northern pike from Large Lake Program surveys to date are 16.8% and 15.2%, respectively. Latta (1972) reported northern pike exploitation in two Michigan lakes, Grebe Lake at 12–23% and Fletcher Pond at 38%. Pierce et al. (1995) reported rates of 8% to 46% for fish over 20 inches for seven lakes in Minnesota, and Carlander (1969) gave a range of 14% to 41% for a sample of lakes throughout North America.

The estimate of total mortality for smallmouth bass in Lake Charlevoix (25%) appears to be on the low side of the range for populations reported in the literature. Forney (1961) reported estimates of 52%, 58%, and 18% total mortality for smallmouth bass in Oneida Lake, New York, while Paragamian and Coble (1975) reported 55% mortality for smallmouth bass in the Red Cedar River, Wisconsin. Clady (1975) reported total mortality estimates of 33% for smallmouth bass in a Michigan lake with no fishing, and 41%–65% in a lake subject to simulated exploitation of 13%–16%. Bryant and Smith (1988) reported 58% total mortality of adult smallmouth bass from Anchor Bay of Lake St. Clair. Total mortality of smallmouth bass in nine populations surveyed in the Large Lakes Program has averaged 34%, with a median value of 36%, and a range of 22%–45%.

Although total mortality is relatively low, compared to smallmouth bass from other lakes in Michigan and elsewhere, the estimated exploitation rate for Lake Charlevoix appears to be about average. For the same reasons mentioned for walleyes and northern pike, smallmouth bass exploitation is likely between the tag-return estimate (15.3%) and the estimate derived using the single-census abundance estimate (19.1%). 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 a 20% exploitation rate of adult smallmouth bass, while Paragamian and Coble (1975) reported a 29% exploitation rate in the Red Cedar River of Wisconsin. In Michigan, Latta (1963) reported a 22% exploitation rate 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.

Movement

Given the large size of Lake Charlevoix and its connection to Lake Michigan, fish have the potential of moving long distances. Although considerable movement to Lake Michigan was not documented, the fishery in the nearshore areas around Lake Charlevoix is directed primarily at lake trout and salmon, which generally occupy deeper water than walleyes. The analysis of walleye tag returns through the time of report writing suggested more movement to Lake Michigan than the analysis of tag returns obtained in the first year alone. Additionally, since tag returns from Lake Michigan were not adjusted for effort, it is possible that greater than 12% of walleyes spawning in Lake Charlevoix move to Lake Michigan following spawning. In the Muskegon River population (Hanchin et al. 2007) 50% of walleye tag returns were from Lake Michigan and connecting waters (outside of the Muskegon River system). Most Lake Michigan walleye returns in the Lake Charlevoix study were from the vicinity of the Pine River channel, though one was from Little Traverse Bay (minimum distance moved = 30 miles) and one was from Bells Bay (minimum distance moved = 18 miles). Some of the movement behaviors documented for Lake Charlevoix walleyes have been observed elsewhere. The tendency for walleyes and northern pike to move north after being tagged is likely a result of movement to the deeper water of the main basin, or it may reflect a "downstream" movement following spawning. Hanchin et al. (2007) noted rapid downstream movement of the Muskegon River walleye population following spawning. Also, the greater distances moved by female walleyes in Lake Charlevoix has been documented in other Great Lakes populations (Schram et al. 1992; Wang et al. 2007).

Northern pike all appeared to remain in Lake Charlevoix, though this apparent lack of movement to Lake Michigan could simply be an artifact of the low number tagged and little targeted effort for northern pike in Lake Michigan. Only 10 walleye tag returns were reported from Lake Michigan, though 1,938 tagged walleyes were released. If the same percentage of northern pike moved to Lake Michigan and were caught, one would expect fewer than two returns. Smallmouth bass were found to move into Lake Michigan, though as for walleyes, it is uncertain if the percentage is underestimated due to the low fishing effort directed at smallmouth bass in the nearshore areas of Lake Michigan. Of the smallmouth bass moving to Lake Michigan, considerable movement was documented for a few individuals. Two smallmouth bass were caught in Lake Michigan at Waugoshance Point (minimum distance moved approximately 50 miles) and one was caught in the south end of East Grand Traverse Bay near Traverse City, MI (minimum distance moved approximately 55 miles). Latta (1963) and Kaemingk (2008) also reported some smallmouth bass moving large distances in northern Lake Michigan; however, Latta's study of smallmouth bass at Waugoshance Point found results similar to ours for Lake Charlevoix, with the smallmouth bass having a strong tendency to remain within a limited area. Kaemingk (2008) argued that the Beaver Island archipelago population was perhaps part of a larger population that included Waugoshance Point and portions of the northern shore of Lake Michigan.

Summary

In reviewing the surveys and management history of Lake Charlevoix, it is clear that the fish community has undergone significant changes. Several fish species have been stocked at rather high levels, though their success was often short-lived. Brown trout stocking was successful initially, though poor returns from 2000 to 2004 ultimately resulted in its cancelation. Lake trout stocking was successful and produced a good fishery, though recent evidence suggests that the returns do not warrant the expense of continued stocking. Both the current angler harvest data and the deepwater gill-net catch data indicate the trend relatively low lake trout abundance. The success of rainbow trout stocking efforts has been difficult to assess. Numerous rainbow trout were caught in this netting survey, though few were detected in the angler survey. Most rainbow trout in the Lake Charlevoix system are caught in the Jordan and Boyne rivers, in addition to Lake Michigan. The one certain stocking success for Lake Charlevoix has been for walleyes.

Early introductions of walleye (prior to 1938) did not appear to create much of a fishery, and the efforts in the 1950s appeared to create only a short-term fishery. It is quite possible that predation on age-0 walleyes by the smelt population early on prevented the successful recruitment of walleyes (Mercado-Silva et al. 2007). Although stocking records are lacking during the 1970s, minor walleye stocking resumed in 1984 and numbers of fish stocked increased through the 1990s and 2000s. Surveys in the 1990s showed that stocking efforts in the mid 1980s fared well, and based on the 2006 survey, the current walleye population in Lake Charlevoix is also doing well, with an above average seasonal density, relative to other large lakes in Michigan. As the population has increased, natural reproduction has likely occurred to some degree, though not enough to sustain the fishery. On several occasions in the past, biologists have noted congregations of walleyes in Deer Creek, a tributary to the Jordan River (DNR, unpublished data), though in 2006 a single day of electrofishing the Jordan River from Lake Charlevoix to Rogers Road resulted in no walleyes. Although the occasional presence of a spawning run offers some hope for natural reproduction, none has ever documented to any significant degree. At the time of this survey walleye recruitment was erratic, likely due to varying numbers stocked and/or surviving, and the lack of natural reproduction. Contributions from both stocking and recruitment should be monitored regularly to assess if the population becomes self-sustaining.

The popularity of the Lake Charlevoix walleye fishery has increased along with its population, though both harvest per acre and harvest per hour are still below averages for other large lakes in

Michigan. Although angler exploitation is currently low, the fishery should be occasionally monitored as its reputation for trophy walleyes will undoubtedly attract interest. The high relative abundance of large walleyes is a result of the abundant prey species available in Lake Charlevoix and the nearshore areas of Lake Michigan. While the migratory nature of the population will protect it to some degree, it will still remain vulnerable to exploitation around and shortly after the spawning period.

Northern pike are much less abundant than walleyes in Lake Charlevoix. In fact, considering the estimates of adult abundance, there are about 11 times more walleyes as there are northern pike. Just as for walleyes, the density of both adult and legal-sized northern pike is lower than in most large Michigan lakes. Also similar to walleyes is the high size structure of northern pike, with the percentage of legal-sized northern pike being almost twice the average from other large lakes in Michigan. Measures of angler harvest and catch rates were below average relative to other large lakes. Growth of northern pike is fast and overall mortality is low.

Smallmouth bass in Lake Charlevoix have a slightly lower density than walleyes, but surprisingly the exploitation rate is higher than for walleyes and northern pike. Smallmouth bass are easier to catch (than walleyes) during the open-water period; the catch rate of all smallmouth bass was more than four times higher than that for walleyes, even though more anglers were targeting walleyes. The percentages of fish migrating to Lake Michigan were similar between walleyes and smallmouth bass. Long-range movement of smallmouth bass from Lake Charlevoix was documented, though a relatively small percentage of fish appeared to move out of Lake Charlevoix. The harvest per acre of smallmouth bass was near the average for other large lakes in Michigan and the catch rate for all sizes of smallmouth bass was twice the average. Overall mortality of smallmouth bass was low, though angling mortality accounted for a considerable portion of the total mortality.

Acknowledgements

I thank the many Michigan Department of Natural Resources employees who collected the data for this study. I thank Gerald Casey who made the tagging operation and angler survey a success. I thank Samuel Noffke for many hours on the water and ice interviewing anglers. I thank Cathy Sullivan and Daniel Traynor for data entry and tag return processing, Alan Sutton for assisting in preparation of angler survey estimates and figures, and Zhenming Su for designing the angler survey. I also thank Randall Claramunt for designing the hydroacoustic survey and for providing estimates of fish density. I thank Mark Tonello, Samuel Noffke, and Philip Schneeberger for reviewing the manuscript, and I thank anglers who provided assistance by returning tags and responding to creel clerks. This work was funded by the Federal Aid to Sport Fish Restoration Project F-81, Study 230725 (75%) and the Game and Fish Fund of the State of Michigan (25%).

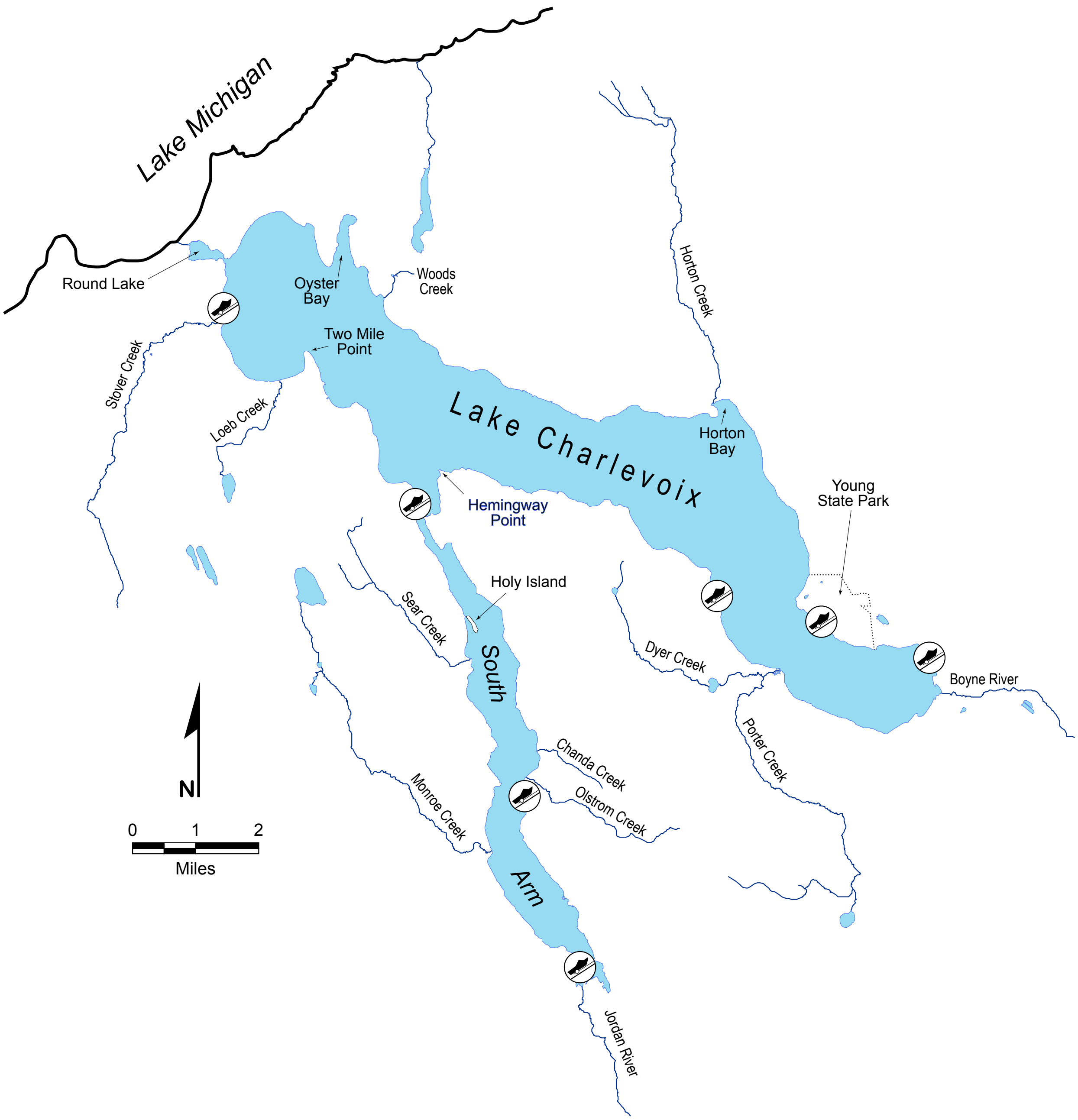

Figure 1.–Map of Lake Charlevoix, Charlevoix County, Michigan.

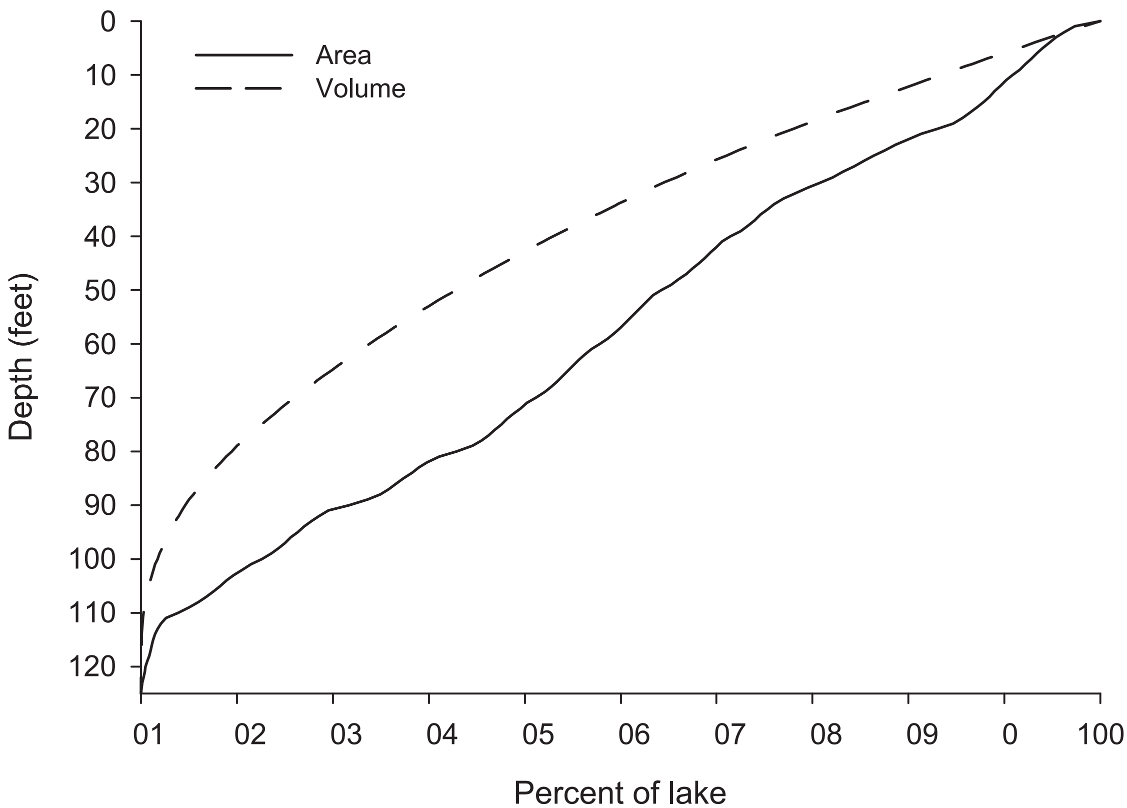

Figure 2.–Percent of lake surface area and volume equal to or greater than a given depth for Lake Charlevoix. Data taken from DNR Digital Water Atlas (Breck 2004).

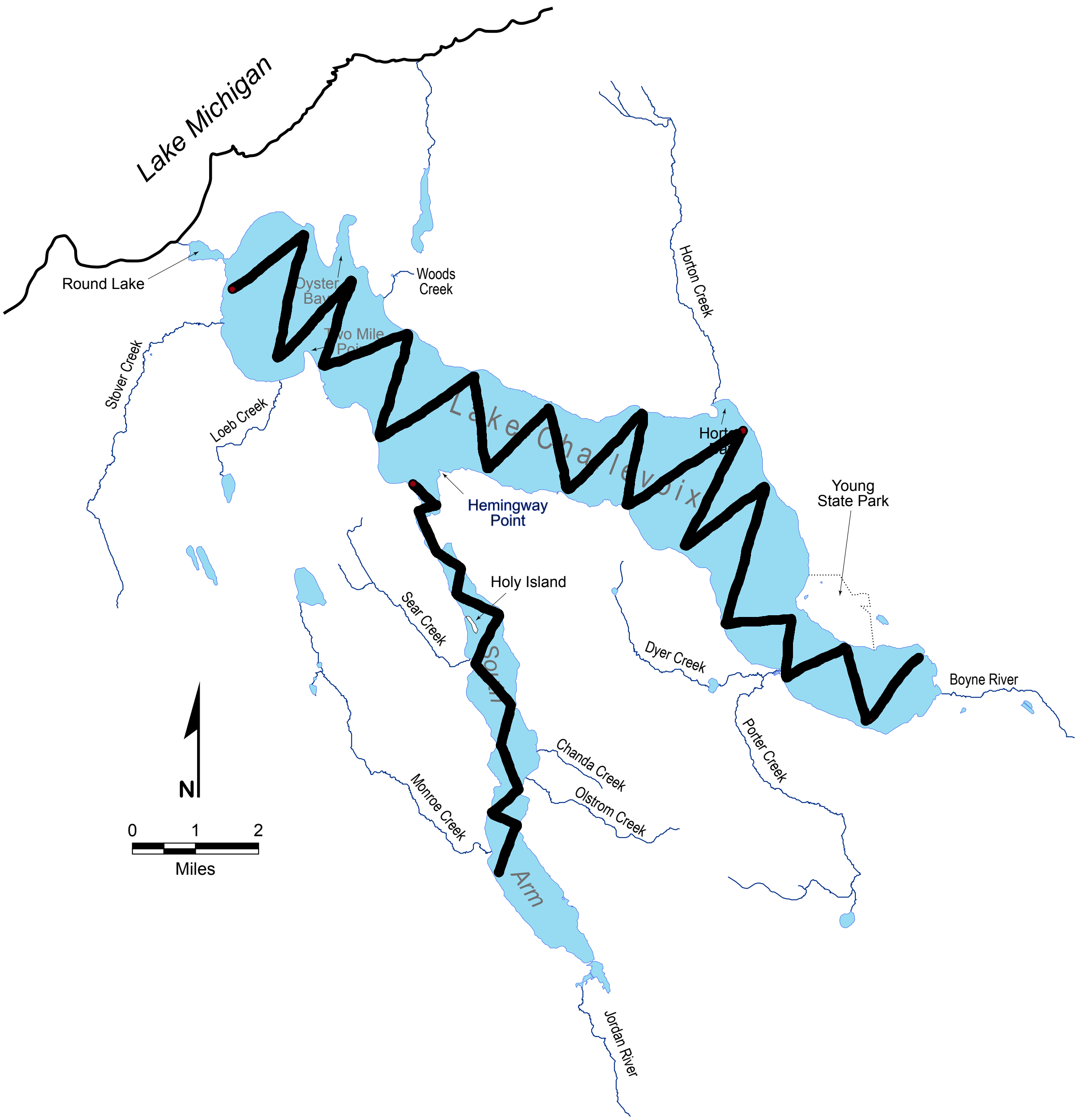

Figure 3.–Strata used in design and analysis of the Lake Charlevoix acoustic survey.

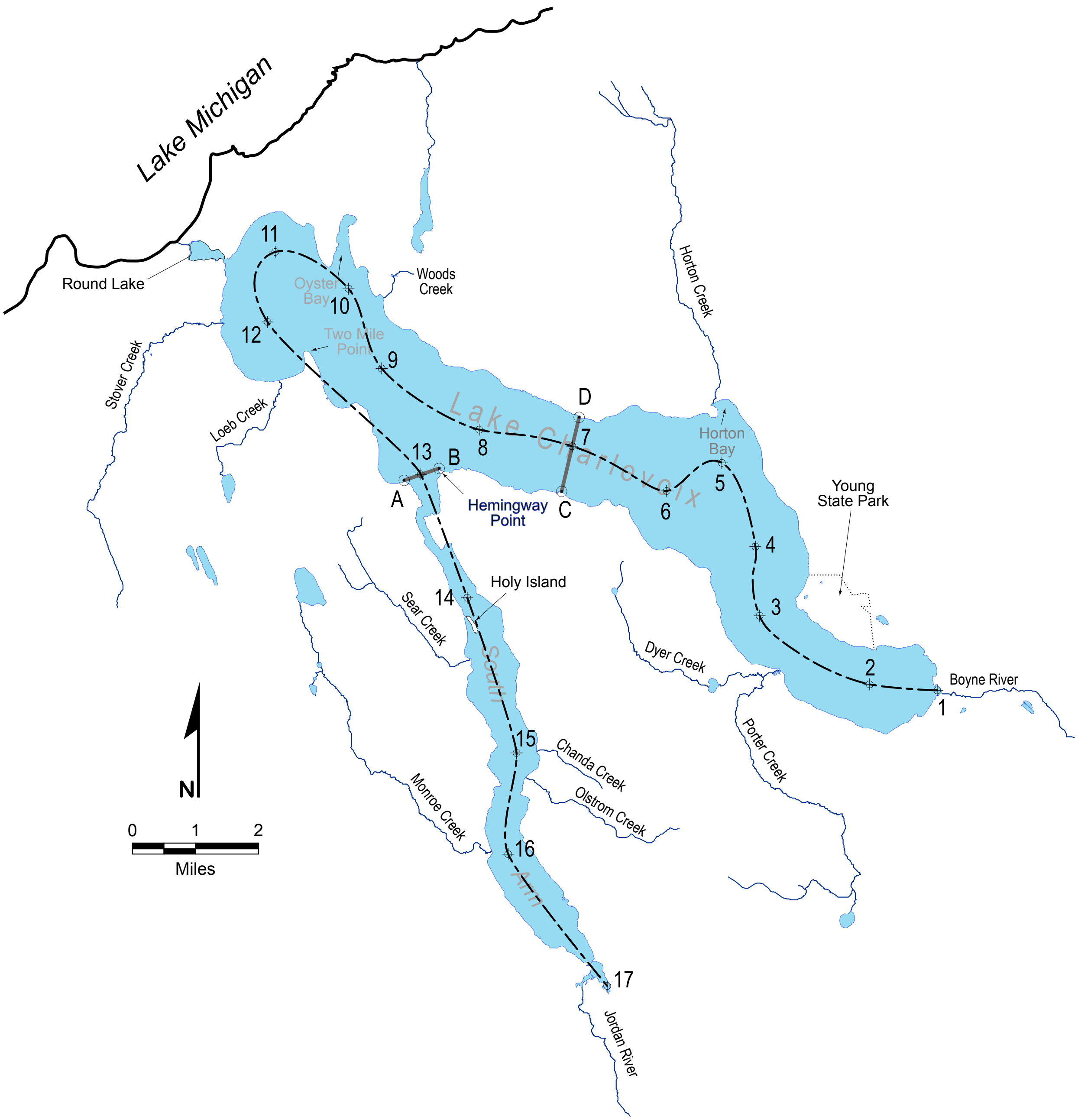

Figure 4.–Counting path and associated count pathway points for the Lake Charlevoix, summer 2006 and winter 2007 survey.

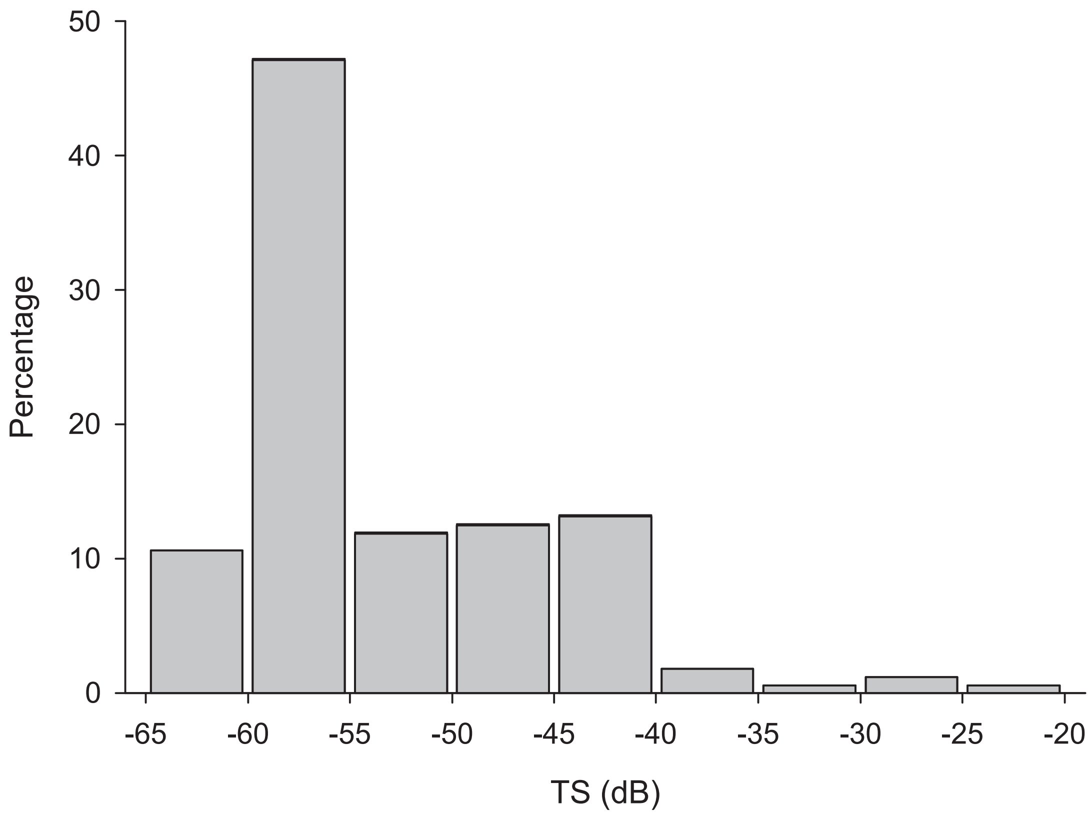

Figure 5.–Distribution of target strengths by 10-m depth layers for the Lake Charlevoix hydroacoustic survey. Cells with zero target strength detections were not included.

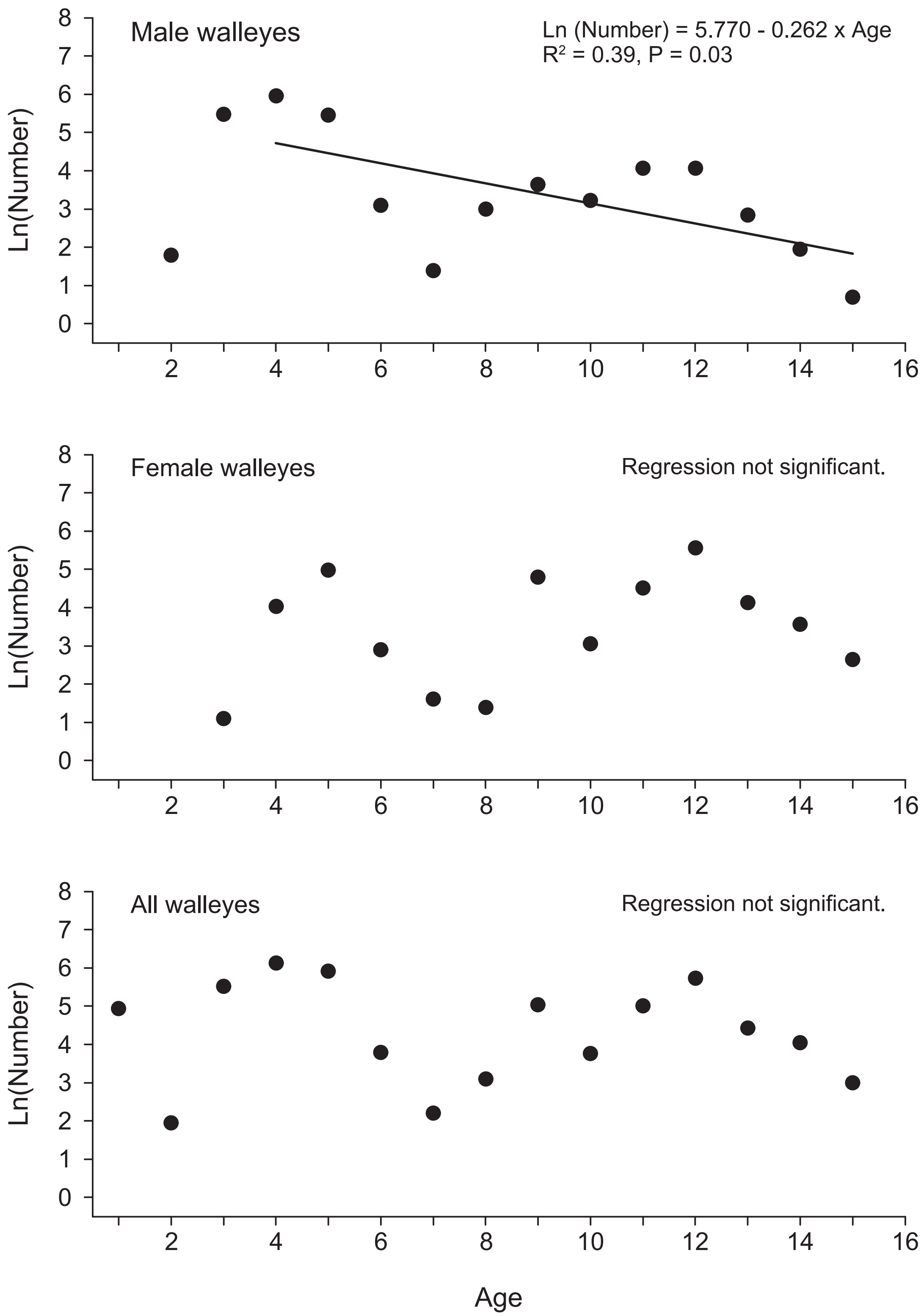

Figure 6.–Plots of ln(observed number) versus age for legal-sized male, female, and all (including males, females, and unknown sex) walleyes in Lake Charlevoix. Line is a plot of regression equation given beside graph, where significant.

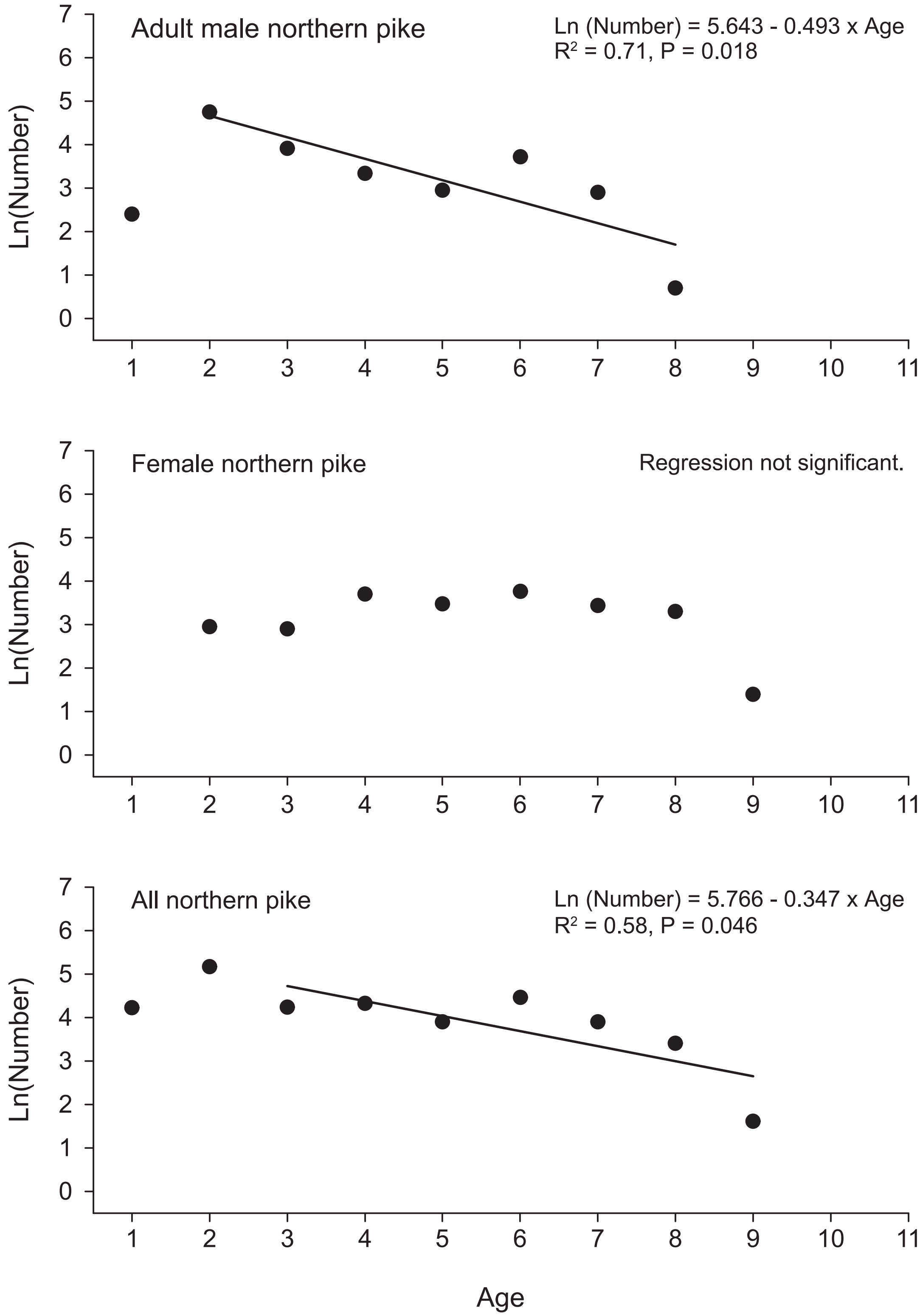

Figure 7.– Plots of ln(observed number) versus age for adult male, legal-sized female, and legal-sized all (including males, females, and unknown sex) northern pike in Lake Charlevoix. Lines are plots of regression equations given beside each graph, where significant.

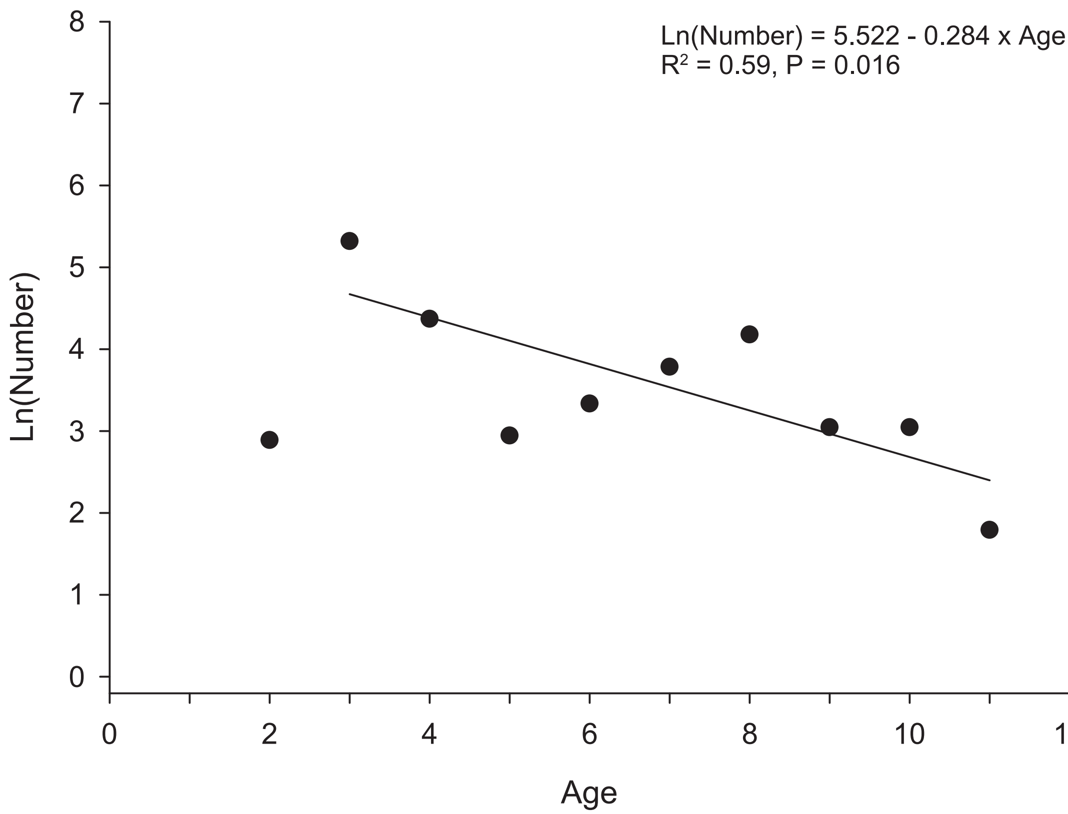

Figure 8.– Plot of ln(observed number) versus age for age-3 and older smallmouth bass in Lake Charlevoix. Line is a plot of the regression equation provided.

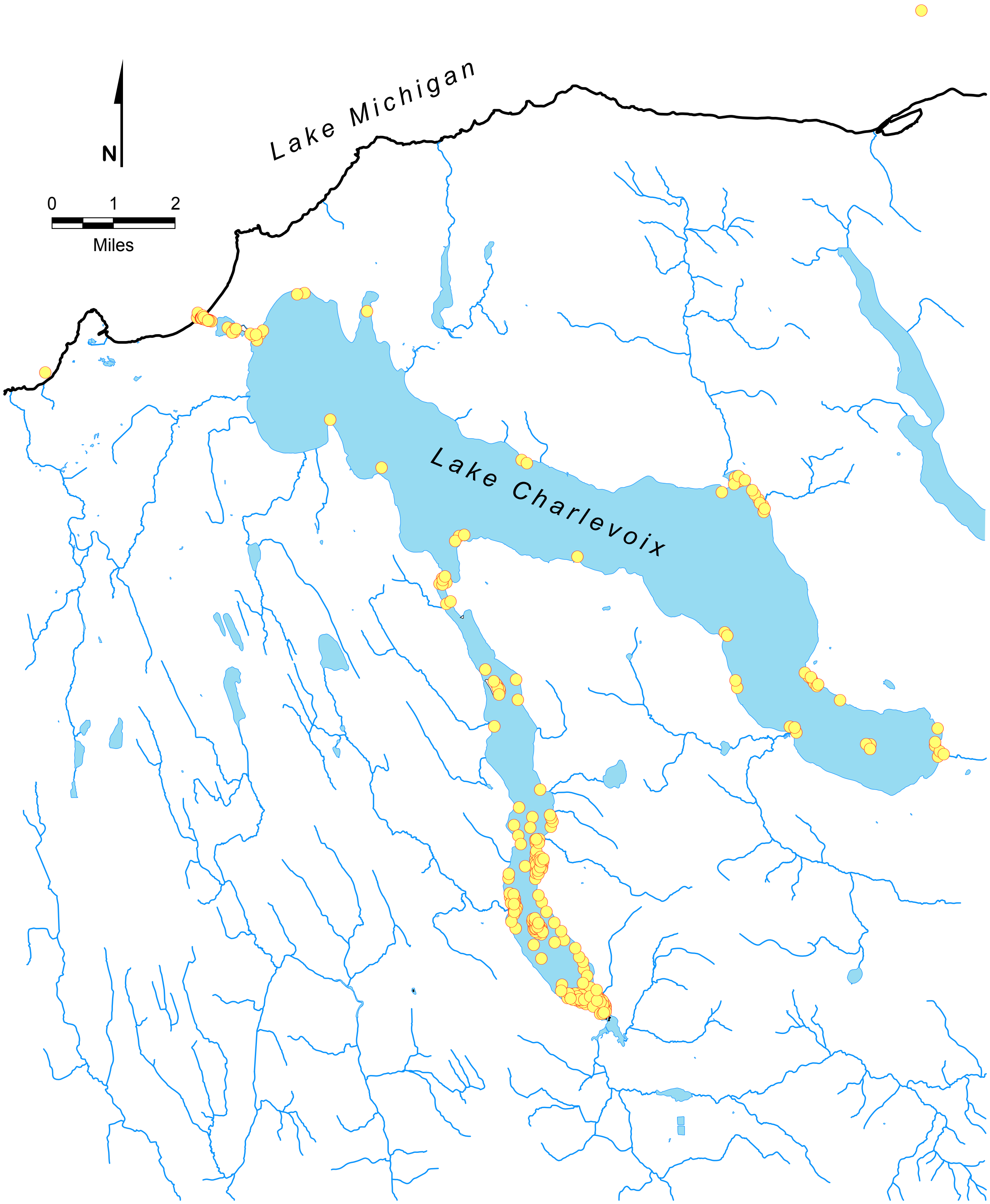

Figure 9.– Walleye tag returns (yellow circles) through October of 2009 from the spring 2006 tagging event in Lake Charlevoix.

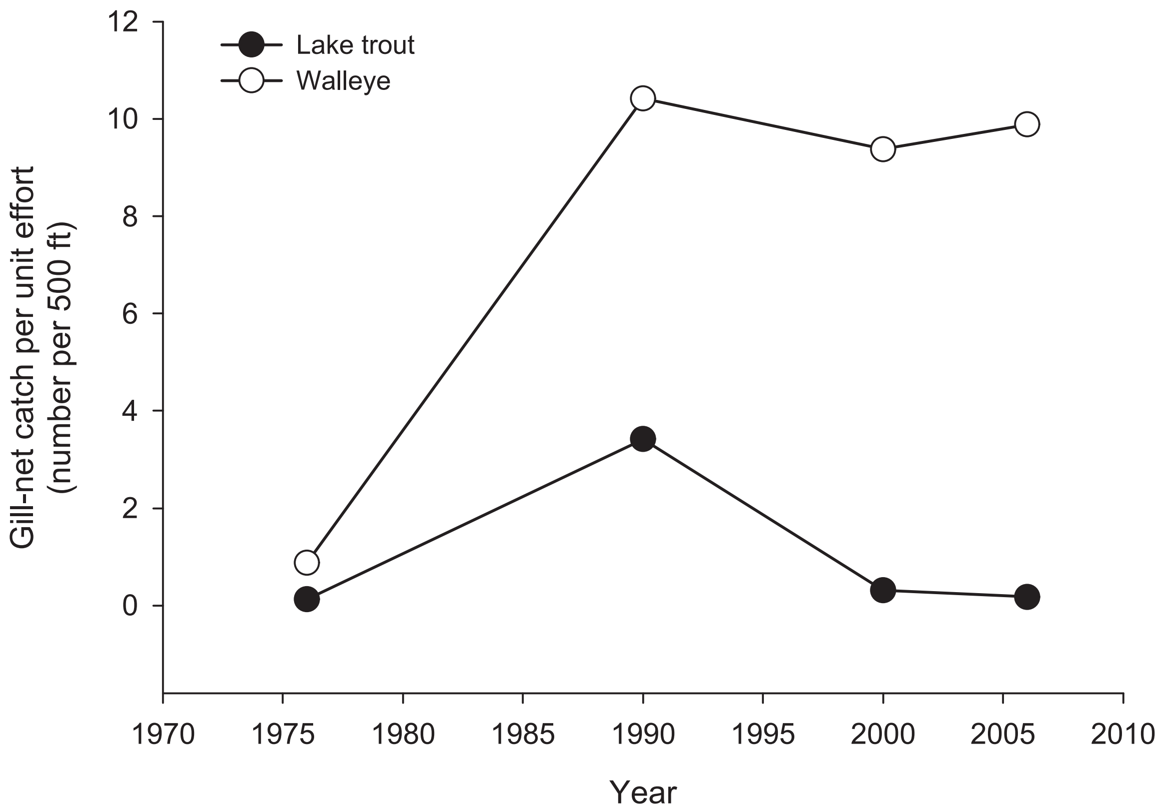

Figure 10.–Gill-net catch per unit effort (number per 500 ft) of lake trout and walleyes in fall surveys of Lake Charlevoix.

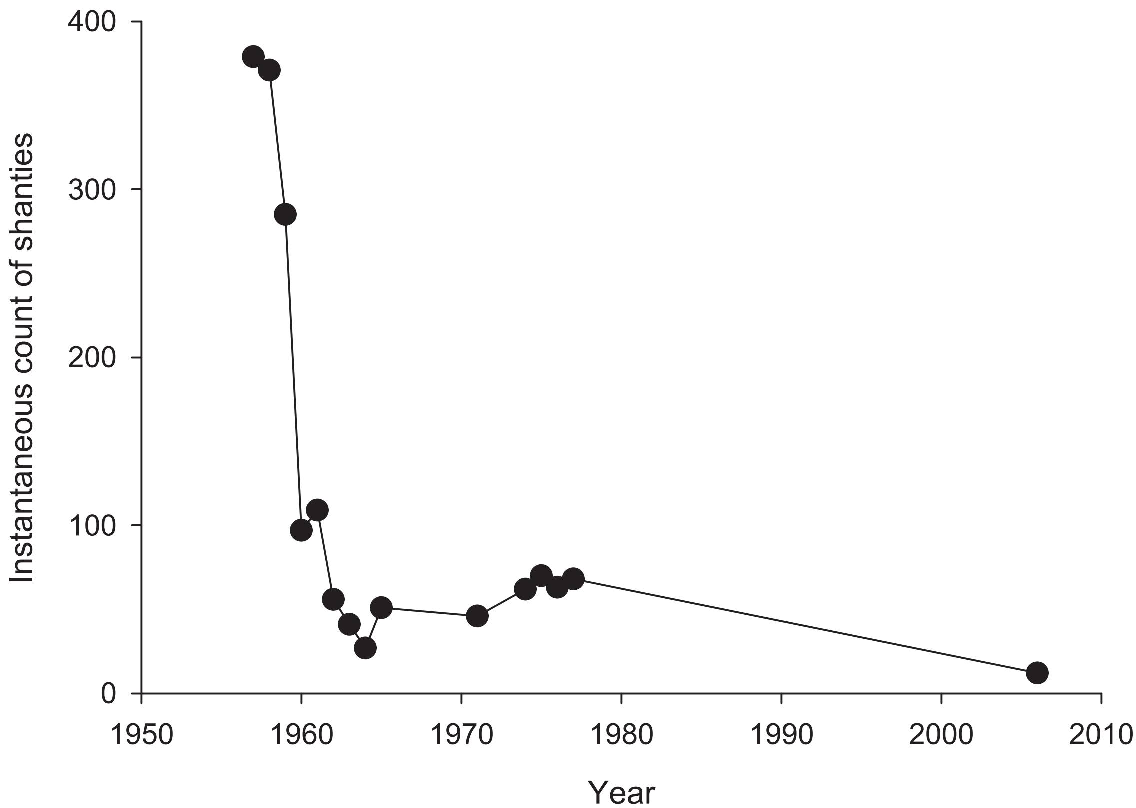

Figure 11.–Number of ice shanties counted on Lake Charlevoix from 1957 to 2006. Counts were made on a single day near the middle of February.

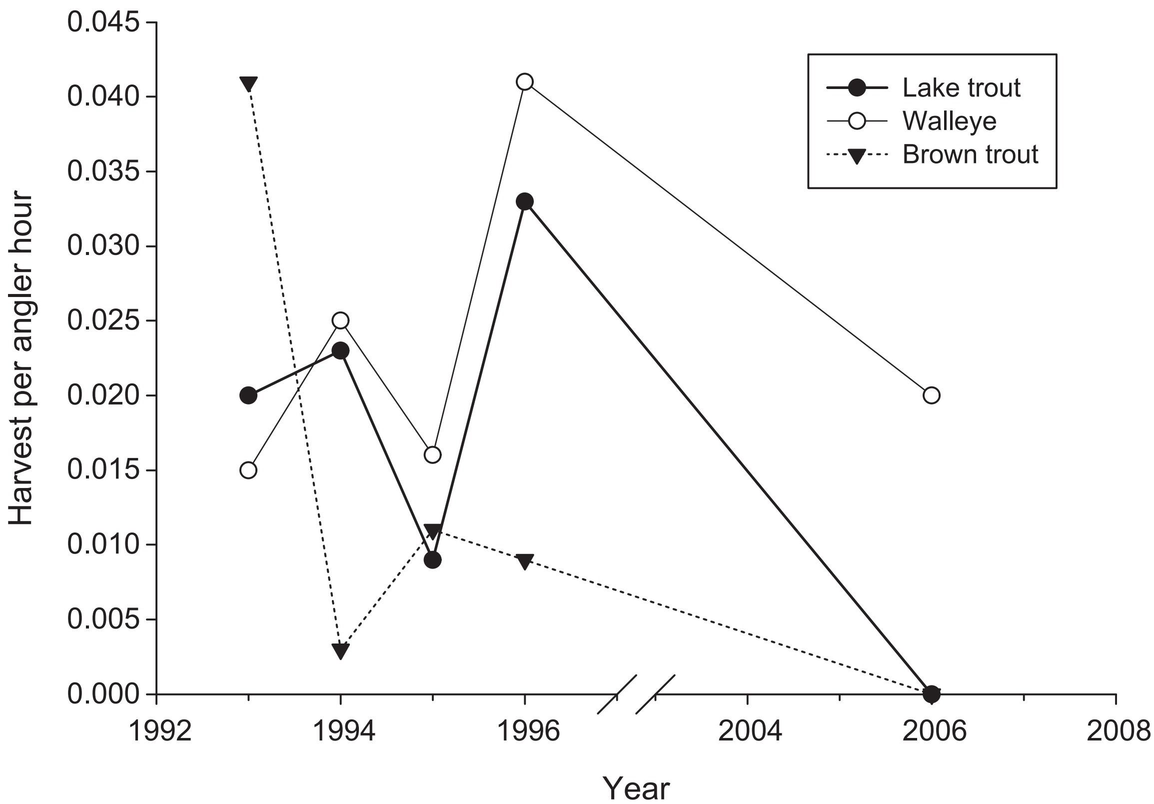

Figure 12.– Plot of harvest rates (number per angler hour) for lake trout, walleyes, and brown trout from Lake Charlevoix.

Table 1.–Number and size of fish stocked in Lake Charlevoix 1979 through 2007.

Year	Species	Number	Average size (in)
1979	Brown trout	10,129	6.7
	Rainbow trout	40,000	4.6
	Lake trout	40,000	5.0
1980	Brown trout	10,000	7.0
	Rainbow trout	59,781	7.5
	Lake trout	50,000	5.0
1981	Brown trout	17,600	6.3
	Rainbow trout	99,600	5.7
	Lake trout	80,000	5.3
		990	29.0
1982	Brown trout	30,000	6.8
		4,506	10.0
		856	20.0
	Rainbow trout	1,992	15.8
	Lake trout	85,000	5.2
1983	Brown trout	30,500	5.3
	Rainbow trout	60,000	6.8
	Lake trout	73,000	5.2
1984	Brown trout	30,000	5.9
	Rainbow trout	34,000	6.8
	Walleye	4,100	1.6
1985	Brown trout	11,300	7.0
	Rainbow trout	35,003	6.5
	Lake trout	25,000	5.1
	Walleye	500	1.5
1986	Atlantic salmon	22,201	7.2
	Brown trout	36,623	6.2
		50,000	2.9
	Rainbow trout	50,000	7.5
	Lake trout	95,000	6.5
	Walleye	20,000	1.4
1987	Brown trout	71,720	7.3
		40,000	3.3
	Lake trout	86,670	6.4
	Walleye	20,500	2.0
1988	Brown trout	132,478	5.9
	Lake trout	100,691	5.8
	Walleye	42,000	2.2
1989	Brown trout	75,000	7.8
	Rainbow trout	34,906	7.8
	Walleye	60,000	1.8
1990	Brown trout	104,996	5.6
	Lake trout	100,000	5.4
1991	Brown trout	79,413	7.1
	Lake trout	100,000	5.8
	Walleye	80,000	2.0

Table 1.–Continued.

Year	Species	Number	Average size (in)
1992	Brown trout	65,910	6.8
	Lake trout	100,000	5.2
	Walleye	92,000	1.6
1993	Brown trout	73,778	7.1
	Rainbow trout	500	11.4
	Lake trout	96,000	5.8
	Walleye	150,000	1.6
1994	Brown trout	90,235	6.6
	Lake trout	100,000	5.7
	Walleye	73,400	1.9
1995	Brown trout	79,968	7.3
	Lake trout	77,250	3.4
	Walleye	92,200	1.5
1996	Brown trout	73,112	7.1
1997	Brown trout	56,355	6.4
	Lake trout	80,879	6.5
	Walleye	130,000	1.2
1998	Brown trout	48,800	5.9
	Rainbow trout	9,770	7.5
1999	Brown trout	24,800	8.4
	Lake trout	134,296	6.5
	Walleye	3,200,000	0.4
		96,000	1.0
2000	Brown trout	25,000	7.9
	Lake trout	100,140	6.6
2001	Brown trout	19,024	8.6
	Lake trout	100,040	6.3
	Walleye	106,155	1.5
2002	Brown trout	25,000	7.8
	Rainbow trout	10,000	7.4
	Lake trout	133,256	6.5
2003	Brown trout	25,000	8.0
	Lake trout	111,543	6.0
	Walleye	101,478	1.4
2004	Brown trout	25,000	8.4
	Rainbow trout	3,593	6.8
	Lake trout	101,092	5.8
	Walleye	3,000	2.3
2005	Rainbow trout	6,160	6.3
	Lake trout	100,000	6.0
	Walleye	9,900	2.3
2006	Lake trout	100,997	5.2
	Walleye	106,274	1.4
2007	Lake trout	173,222	5.9
	Walleye	90,800	2.1

Table 2.–Survey periods, sampling shifts, and expansion value "F" (number of fishing hours within a sample day) for the Lake Charlevoix angler survey, spring 2006 through winter 2007.

Survey period	Sample shift (h)		F
April 28–30	0600–1430	1130–2000	16
May	0600–1430	1300–2130	16
June	0600–1430	1330–2200	16
July	0600–1430	1330–2200	16
August	0600–1430	1300–2130	16
September	0700–1530	1230–2100	14
January 18–31	0800–1630	1030–1900	11
February	0800–1630	1130–2000	12
March 1–24	0700–1530	1130–2000	13

Table 3.–Fish collected from Lake Charlevoix using a total sampling effort of 320 trap-net lifts, 163 fyke-net lifts, and 2 electrofishing runs April 3–22, 2006.

Species	Total catch [a]	Percent by number	Mean CPUE [a, b]		Length		Number measured [c]
			trap-net	fyke-net	Range (in)	Average (in) [c]	
White sucker	4,922	35.9	10.9	5.3	5.9–25.1	18	1,190
Walleye	2,703	19.7	6.5	1.6	7.9–32.8	21.6	2,107
Rock bass	1,586	11.6	3.7	1.9	2.7–11.2	5.9	898
Brown bullhead	1,244	9.1	3.8	0.2	6.3–14.1	11.2	107
Bullhead	1,178	8.6	3.5	<0.1	5.9.–11.2	9.2	3
Northern pike	876	6.4	2.5	0.2	11.2–44.0	24.4	606
Smallmouth bass	522	3.8	1.4	0.2	10.7–21.1	15.7	504
Yellow perch	195	1.4	0.3	0.2	4.9–13.1	8.3	202
Bowfin	117	0.9	0.3	<0.1	14.8–30.2	23.2	117
Black bullhead	89	0.6	0.3	0	8.0–14.0	11.3	89
Rainbow trout	72	0.5	0.1	0.1	7.1–31.2	12.6	72
Common carp	33	0.2	0.1	0	21.0–35.8	26.9	33
Largemouth bass	33	0.2	0.1	0	10.9–17.9	15.2	16
Quillback	23	0.2	0.1	0	18.1–25.0	20.9	23
Round goby	17	0.1	<0.1	0	3.4–5.8	4.5	17
Silver redhorse	16	0.1	<0.1	0	20.2–27.7	25.1	16
Bluegill	14	0.1	<0.1	<0.1	4.1–8.0	5.8	14
Lake trout	13	0.1	<0.1	0	5.9–31.6	8.5	13
White perch	11	0.1	<0.1	0	12.1–13.0	12.7	11
Common shiner	10	0.1	<0.1	0	5.0–6.6	5.8	10
Pumpkinseed	5	<0.1	<0.1	0	4.4–5.5	4.9	5
Freshwater drum	5	<0.1	<0.1	<0.1	18.8–21.3	19.8	5
Black crappie	5	<0.1	<0.1	0	5.5–13.2	9.2	5
Channel catfish	3	<0.1	<0.1	0	25.6–27.0	26.4	3
Brook trout	3	<0.1	<0.1	0	9.1–14.4	11	3
Gizzard shad	3	<0.1	<0.1	0	13.5–18.1	16.5	3
Longnose gar	2	<0.1	<0.1	0	22.1–29.6	25.9	2
Sculpin	2	<0.1	<0.1	0	4.3–4.6	4.5	2
Burbot	2	<0.1	<0.1	0	12.5–14.6	13.6	2
Brown trout	1	<0.1	<0.1	0	22	22	1
Longnose sucker	1	<0.1	0	<0.1	18.7	18.7	1
Sea lamprey	1	<0.1	<0.1	0	20	20	1

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

Table 4.–Number of fish per inch group collected from Lake Charlevoix, April 3–22, 2006.

Inch group	Species															
	White sucker	Walleyes	Rock bass	Brown bullhead	Bullhead	Northern pike	Smallmouth bass	Yellow perch	Bowfin	Black bullhead	Rainbow trout	Common carp	Largemouth bass	Quillback	Round goby	Silver redhorse
2	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–
3	–	–	39	–	–	–	–	–	–	–	–	–	–	–	3	–
4	–	–	121	–	–	–	–	1	–	–	–	–	–	–	9	–
5	1	–	317	–	1	–	–	14	–	–	–	–	–	–	5	–
6	4	–	256	1	–	–	–	29	–	–	–	–	–	–	–	–
7	6	1	112	–	–	–	–	48	–	–	6	–	–	–	–	–
8	9	11	36	3	–	–	–	36	–	3	24	–	–	–	–	–
9	14	93	10	6	–	–	–	35	–	7	22	–	–	–	–	–
10	15	33	3	22	1	–	6	23	–	17	2	–	1	–	–	–
11	14	1	3	49	1	2	27	9	–	36	2	–	1	–	–	–
12	18	–	–	23	–	11	48	6	–	18	1	–	–	–	–	–
13	19	1	–	2	–	19	73	1	–	6	–	–	1	–	–	–
14	18	4	–	1	–	20	63	–	1	2	–	–	2	–	–	–
15	31	19	–	–	–	20	52	–	3	–	–	–	5	–	–	–
16	68	119	–	–	–	15	51	–	4	–	–	–	3	–	–	–
17	225	154	–	–	–	17	48	–	3	–	–	–	3	–	–	–
18	239	178	–	–	–	5	74	–	5	–	–	–	–	3	–	–
19	264	216	–	–	–	16	42	–	1	–	–	–	–	2	–	–
20	191	158	–	–	–	34	17	–	11	–	1	–	–	6	–	1
21	49	159	–	–	–	28	3	–	16	–	–	1	–	8	–	1
22	4	142	–	–	–	46	–	–	8	–	1	–	–	3	–	–
23	–	83	–	–	–	53	–	–	16	–	–	3	–	–	–	1
24	–	80	–	–	–	52	–	–	9	–	3	2	–	–	–	3
25	1	105	–	–	–	39	–	–	7	–	1	6	–	1	–	3
26	–	140	–	–	–	29	–	–	9	–	2	2	–	–	–	4
27	–	133	–	–	–	32	–	–	12	–	3	10	–	–	–	3
28	–	123	–	–	–	29	–	–	9	–	1	2	–	–	–	–
29	–	94	–	–	–	28	–	–	2	–	1	4	–	–	–	–
30	–	48	–	–	–	22	–	–	1	–	–	–	–	–	–	–
31	–	11	–	–	–	25	–	–	–	–	2	2	–	–	–	–
32	–	1	–	–	–	10	–	–	–	–	–	–	–	–	–	–
33	–	–	–	–	–	16	–	–	–	–	–	–	–	–	–	–
34	–	–	–	–	–	13	–	–	–	–	–	–	–	–	–	–
35	–	–	–	–	–	5	–	–	–	–	–	1	–	–	–	–
36	–	–	–	–	–	6	–	–	–	–	–	–	–	–	–	–
37	–	–	–	–	–	7	–	–	–	–	–	–	–	–	–	–
38	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–
39	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
40	–	–	–	–	–	4	–	–	–	–	–	–	–	–	–	–
41	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
42	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
43	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
44	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–
Total	1,190	2,107	898	107	3	606	504	202	117	89	72	33	16	23	17	16

Table 4.–Extended.

Inch group	Bluegill	Lake trout	White perch	Common shiner	Pumpkinseed	Freshwater drum	Black crappie	Channel catfish	Brook trout	Gizzard shad	Longnose gar	Sculpin	Burbot	Brown trout	Longnose sucker	Sea lamprey
	Species															
2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4	1	–	–	–	3	–	–	–	–	–	–	2	–	–	–	–
5	7	1	–	5	2	–	1	–	–	–	–	–	–	–	–	–
6	5	10	–	5	–	–	1	–	–	–	–	–	–	–	–	–
7	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
8	1	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–
9	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–
10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
12	–	–	7	–	–	–	1	–	–	–	–	–	1	–	–	–
13	–	–	4	–	–	–	1	–	–	1	–	–	–	–	–	–
14	–	–	–	–	–	–	–	–	1	–	–	–	1	–	–	–
15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
18	–	–	–	–	–	1	–	–	–	2	–	–	–	–	1	–
19	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–
20	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	1
21	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–
22	–	–	–	–	–	–	–	–	–	–	1	–	–	1	–	–
23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
24	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
25	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
26	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
27	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
29	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
30	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
31	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
34	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
36	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
37	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
38	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
39	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
41	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
42	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total	14	13	11	10	5	5	5	3	3	3	2	2	2	1	1	1

Table 5.–Estimates of abundance, angler exploitation rates, and instantaneous fishing mortality rates for Lake Charlevoix walleyes, northern pike, and smallmouth bass using the different methods described in text. Asymmetrical 95% confidence intervals for estimates are given in parentheses, where applicable.

Parameter	Walleyes	Northern pike	Smallmouth bass
Number tagged	1,947	319	345
Total tag returns	157	12	53
Number of legal-sized[a] fish			
Multiple-census estimate	4,335 (3,841 – 4,976)	264 (224 – 322)	3,846 (2,529 – 8,022)
Single-census estimate	9,844 (7,222 – 13,765)	546 (310 – 1,036)	6,882 (3,695 – 13,906)
Michigan model prediction[b]	24,303 (5,013 – 117,834)	–	–
Number of adult[c] fish			
Multiple-census method	4,318 (3,817 – 4,971)	690 (585 – 843)	–
Single-census estimate	9,859 (7,233 – 13,786)	903 (512 – 1,713)	–
Michigan model prediction[d]	39,244 (7,067 – 217,920)	–	–
Annual exploitation rates			
Based on reward tag returns	8.8%	3.2%	15.3%
Based on harvest/abundance[e]	21.1% (13.6% – 28.6%)	35.3% (0% – 70.6%)	34.2% (15.8% – 52.7%)
Based on harvest/abundance[f]	9.3% (5.2% – 13.3%)	20.3% (0% – 41.8%)	19.1% (6.4 – 31.9%)
Total annual mortality rates	No estimate	29%	25%

[a] Walleyes ≥ 15 in, northern pike ≥ 24 in, and smallmouth bass ≥ 14 in.
[b] Michigan model prediction of legal walleye abundance based on lake area, N = 32.
[c] Fish of legal size and sexually mature fish of sublegal size on spawning grounds.
[d] Michigan model prediction of adult walleye abundance based on lake area, N = 31.
[e] Multiple-census estimate of legal-sized walleye, northern pike, and smallmouth bass abundance.
[f] Single-census estimate of legal-sized walleye, northern pike, and smallmouth bass abundance.

Table 6.–Fish collected from Lake Charlevoix using a total sampling effort of 15,000 ft of Great Lakes bottom gill nets set in 1,000-ft gangs (2 X 500 ft) at depths ranging from 50 to 100 ft June 12–15, 2006.

Species	Total catch	Percent by number	Catch per 500 ft	Length	
				range (in)	average (in)
Yellow perch	96	53.3	3.20	4.1–9.8	6.4
Lake whitefish	55	30.6	1.83	9.0–24.6	19.0
Burbot	8	4.4	0.27	16.6–26.8	21.9
Lake trout	7	3.9	0.23	9.0–25.4	18.9
White sucker	6	3.3	0.20	17.4–19.3	18.2
Brown trout	3	1.7	0.10	8.6–10.7	9.5
Smallmouth bass	2	1.1	0.07	16.5–19.4	18.0
Round whitefish	1	0.6	0.03	15.2	15.2
Rainbow smelt	1	0.6	0.03	6.8	6.8
Alewife	1	0.6	0.03	6.9	6.9

Table 7.–Fish collected from Lake Charlevoix using a total sampling effort of 3,000 ft of experimental bottom gill nets set in 500-ft gangs at depths ranging from 10 to 50 ft June 12–15, 2006.

Species	Total catch	Percent by number	Catch per 500 ft	Length	
				range (in)	average (in)
Yellow perch	134	62.9	22.3	4–8	6.2
White sucker	51	23.9	8.5	8–20	16.7
Walleye	12	5.6	2.0	9–20	14.8
Rock bass	7	3.3	1.2	4–6	5.5
Brown trout	4	1.9	0.7	9–23	14.5
Northern pike	2	0.9	0.3	24–25	25.0
Lake whitefish	1	0.5	0.2	–	17.5
Burbot	1	0.5	0.2	–	11.5
Smallmouth bass	1	0.5	0.2	–	10.5

Table 8.–Weighted mean total lengths (in) and sample sizes by age and gender for walleyes collected from Lake Charlevoix, April 3–22, 2006. Standard deviations in parentheses.

Age	Mean length			Number aged		
	Males	Females	All fish [a]	Males	Females	All fish [a]
1	–	–	9.7 (0.5)	–	–	37
2	14.9 (0.4)	–	14.8 (0.4)	6	–	6
3	16.9 (0.6)	17.9 (0.5)	16.9 (0.6)	33	2	35
4	18.8 (1.1)	20.3 (0.9)	19.1 (1.2)	39	26	65
5	20.3 (1.0)	21.9 (1.0)	21 (1.4)	29	40	69
6	22.3 (0.5)	22.7 (1.0)	22.5 (0.8)	5	6	11
7	23.1 (–)	24.3 (0.7)	23.8 (0.7)	1	2	3
8	22.3 (0.8)	25.5 (–)	22.6 (1.3)	4	1	5
9	24.7 (1.5)	26.4 (1.6)	26 (1.7)	15	26	41
10	22.8 (1.2)	25.9 (0.8)	24.3 (2.1)	7	4	11
11	24.6 (1.4)	26.4 (1.9)	25.7 (1.9)	22	17	39
12	25.1 (1.5)	28.2 (1.4)	27.6 (1.9)	27	48	75
13	25.2 (1.9)	28 (2.2)	27.5 (2.5)	7	13	20
14	27.5 (0.9)	29.1 (1.3)	28.5 (1.3)	6	9	15
15	28.7 (1.9)	27.9 (1.7)	28.2 (1.6)	2	3	5

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

Table 9.–Weighted mean total lengths (in) and sample sizes by age and gender for northern pike collected from Lake Charlevoix, April 3–22, 2006. Standard deviations in parentheses.

	Mean length						Number aged		
Age	Males		Females		All fish [a]		Males	Females	All fish [a]
1	13.9	(0.8)	–		14.4	(1.7)	6	–	46
2	20.1	(2.5)	23.6	(1.4)	20.7	(2.8)	74	20	104
3	22.8	(1.5)	27.1	(2.2)	24.3	(2.5)	21	15	36
4	23.9	(1.3)	27.8	(1.4)	26.4	(2.4)	13	29	44
5	24.9	(1.2)	30.7	(2.6)	28.7	(3.5)	9	22	32
6	25.1	(1.7)	31.4	(3.1)	28.5	(4.2)	20	34	58
7	26.1	(1.4)	32.6	(3.5)	30.4	(4.3)	10	25	36
8	30.2	(–)	33.8	(3.1)	33.4	(3.1)	1	24	26
9	–		36.6	(3.0)	35.6	(3.5)	–	4	5

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

Table 10.–Weighted mean total lengths (in) and sample sizes for smallmouth bass (males and females combined) collected from Lake Charlevoix, April 3–22, 2006. Standard deviations in parentheses.

Age	Mean length		N
2	11.5	(0.5)	10
3	13.4	(1.1)	56
4	15.5	(0.9)	23
5	16.6	(0.4)	6
6	17.4	(0.5)	8
7	18.2	(0.8)	13
8	18.8	(0.5)	16
9	19.3	(0.7)	9
10	19.8	(0.6)	10
11	19.8	(0.6)	3

Table 11.–Mean total lengths (in) and sample sizes by age and gender for lake whitefish collected from Lake Charlevoix, June 6–15, 2006. Standard deviations in parentheses.

	Mean length						Number aged		
Age	Males		Females		All fish [a]		Males	Females	All fish [a]
1	9.0	(–)	–		9.0	(–)	1	–	1
2	–		–		9.4	(–)	–	–	1
3	15.0	(1.1)	13.8	(1.8)	14.4	(1.7)	3	6	10
4	16.9	(2.5)	19.0	(0.7)	17.9	(2.0)	4	4	8
5	19.2	(1.1)	20.2	(0.9)	19.9	(1.0)	3	6	9
6	20.0	(0.4)	20.5	(1.2)	20.2	(0.9)	7	7	14
7	24.4	(0.3)	22.8	(1.2)	23.6	(1.2)	2	2	4
8	21.2	(3.2)	22.6	(0.1)	21.8	(2.4)	3	2	5
9	22.7	(0.4)	–		22.7	(0.4)	3	–	3
10	–		–		–		–	–	–
11	–		–		–		–	–	–
12	–		22.7	(–)	22.7	(–)	–	1	1

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

Table 12.–Angler survey estimates for summer 2006 from Lake Charlevoix. Survey period was from April 29 through September 30, 2006. Catch per hour is harvest and release rate, respectively (fish per hour). Two standard errors are given in parentheses.

Species	Catch per hour	Month Apr–May	Jun	Jul	Aug	Sep	Season
		Number harvested					
Walleye	0.0197	199	464	229	77	28	996
	(0.0071)	(164)	(232)	(164)	(79)	(55)	(342)
Northern pike	0.0024	62	16	44	0	0	123
	(0.0024)	(79)	(24)	(89)	(0)	(0)	(121)
Smallmouth bass	0.0315	0	997	262	157	178	1,594
	(0.0087)	(0)	(314)	(165)	(128)	(132)	(399)
Yellow Perch	0.2417	2,873	1,093	1,402	2,532	4,312	12,213
	(0.0756)	(2,213)	(664)	(960)	(1,480)	(2,039)	(3,551)
Rock bass	0.0091	0	287	146	27	0	460
	(0.0056)	(0)	(239)	(127)	(54)	(0)	(276)
Channel catfish	0.0011	0	55	0	0	0	55
	(0.0012)	(0)	(61)	(0)	(0)	(0)	(61)
Chinook salmon	0.0050	0	0	0	13	240	253
	(0.0041)	(0)	(0)	(0)	(26)	(203)	(205)
Total harvested	0.3105	3,134	2,912	2,084	2,805	4,758	15,694
	(0.0800)	(2,220)	(809)	(1,000)	(1,489)	(2,054)	(3,608)
		Number released					
Walleye	0.0186	66	446	292	138	0	942
	(0.0084)	(68)	(312)	(225)	(124)	(0)	(410)
Northern pike	0.0055	128	77	46	27	0	278
	(0.0029)	(108)	(65)	(48)	(54)	(0)	(146)
Smallmouth bass	0.1410	1,130	3,201	1,549	828	416	7,124
	(0.0353)	(834)	(981)	(796)	(366)	(264)	(1,580)
Yellow Perch	0.3835	3,937	3,700	2,296	4,849	4,600	19,382
	(0.1121)	(3,097)	(2,307)	(957)	(2,678)	(2,011)	(5,201)
Bluegill	0.0219	914	74	69	8	41	1,106
	(0.0364)	(1,828)	(69)	(99)	(16)	(61)	(1,833)
Rock bass	0.0579	0	1,305	901	722	0	2,928
	(0.0173)	(0)	(563)	(397)	(419)	(0)	(807)
Rainbow trout	0.0001	0	0	0	0	5	5
	(0.0002)	(0)	(0)	(0)	(0)	(9)	(9)
Common white sucker	0.0017	39	47	0	0	0	86
	(0.0013)	(46)	(44)	(0)	(0)	(0)	(64)
Lake trout	0.0006	0	31	0	0	0	31
	(0.0009)	(0)	(45)	(0)	(0)	(0)	(45)
Brown bullhead	0	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)

Table 12.–Continued.

Species	Catch per hour	Month: Apr–May	Jun	Jul	Aug	Sep	Season
Channel catfish	0.0016	0	68	11	0	0	79
	(0.0015)	(0)	(71)	(22)	(0)	(0)	(75)
Chinook salmon	0.0012	0	0	0	24	39	63
	(0.0018)	(0)	(0)	(0)	(47)	(79)	(92)
Freshwater drum	0.0064	94	112	48	23	46	323
	(0.0045)	(187)	(85)	(50)	(30)	(73)	(226)
Other	0.0129	520	10	121	0	0	651
	(0.0136)	(673)	(16)	(124)	(0)	(0)	(685)
Total released	0.6530	6,827	9,071	5,333	6,619	5,147	32,998
	(0.1384)	(3,759)	(2,593)	(1,338)	(2,739)	(2,032)	(5,855)
Total (harvested + released)	0.9635	9,961	11,984	7,417	9,425	9,905	48,692
	(0.1760)	(4,366)	(2,717)	(1,670)	(3,118)	(2,890)	(6,878)
Angler hours		7,444	12,392	12,164	9,570	8,966	50,536
		(2,912)	(2,743)	(2,757)	(2,345)	(2,271)	(5,853)
Angler trips		2,330	3,958	5,022	3,274	3,589	18,173
		(1,269)	(–) [a]	(1,625)	(1,070)	(1,285)	(–) [a]

[a] Inadequate data to produce estimate.

Table 13.–Angler survey estimates for winter 2007 from Lake Charlevoix. Survey period was from January 18, 2007 through March 24, 2007. Catch per hour is harvest and release rate, respectively (fish per hour). Two standard errors are given in parentheses.

Species	Catch per hour	Month		Season
		Jan–Feb	Mar	
		Number harvested		
Walleye	0.0033	4	18	22
	(0.0059)	(7)	(37)	(38)
Yellow Perch	0.5781	2,562	1,248	3,810
	(0.4595)	(2,086)	(1,336)	(2,477)
Rainbow smelt	0.0026	0	17	17
	(0.0053)	(0)	(34)	(34)
Lake whitefish	0.0194	50	78	128
	(0.0256)	(79)	(136)	(158)
Total harvested	0.6035	2,616	1,361	3,977
	(0.4670)	(2,088)	(1,344)	(2,483)
		Number released		
Northern pike	0.0077	32	18	51
	(0.0088)	(39)	(37)	(53)
Yellow Perch	1.2598	6,516	1,786	8,302
	(1.0270)	(5,230)	(2,010)	(5,603)
Total released	1.2675	6,549	1,805	8,353
	(1.0290)	(5,230)	(2,010)	(5,603)
Total (harvested + released)	1.8710	9,165	3,166	12,330
	(1.2637)	(5,631)	(2,418)	(6,128)
Angler hours		4,090	2,501	6,590
		(2,240)	(2,016)	(3,014)
Angler trips		1,109	808	1,917
		(614)	(689)	(922)

Table 14.–Catch at age estimates (apportioned by age-length key) by sex for walleyes, northern pike, and smallmouth bass from Lake Charlevoix, April 3–22, 2006.

	Year	Walleyes			Northern pike			Smallmouth bass
Age	class	Males	Females	All fish [a]	Males	Females	All fish [a]	All fish [a]
1	2005	–	–	139	11	–	68	–
2	2004	6	–	7	115	19	175	18
3	2003	237	3	249	50	18	69	204
4	2002	384	56	459	28	40	75	79
5	2001	233	145	367	19	32	49	19
6	2000	22	18	44	41	43	86	28
7	1999	4	5	9	18	31	49	44
8	1998	20	4	22	2	27	30	65
9	1997	38	121	153	–	4	5	21
10	1996	25	21	43	–	–	–	21
11	1995	58	91	149	–	–	–	6
12	1994	58	261	307	–	–	–	–
13	1993	17	62	83	–	–	–	–
14	1992	7	35	57	–	–	–	–
15	1991	2	14	20	–	–	–	–
Total		1,111	836	2,108	284	214	606	505

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

Table 15.–Voluntary angler tag returns (reward and nonreward, harvested and released combined) from walleyes, northern pike, and smallmouth bass by month for the year following tagging in Lake Charlevoix. Tags observed by creel clerk, but not reported by angler are not included. Percentage of total is in parentheses.

Month	Species		
	Walleyes	Northern pike	Smallmouth bass
4	1 (0.7)	1 (8.3)	1 (2.0)
5	55 (36.0)	6 (50.0)	12 (23.5)
6	41 (27.3)	3 (25.0)	18 (35.3)
7	30 (20.0)	0 (0)	9 (17.6)
8	11 (7.3)	0 (0)	7 (13.7)
9	3 (2.0)	1 (8.3)	3 (5.9)
10	5 (3.3)	0 (0)	1 (2.0)
11	0 (0)	0 (0)	0 (0)
12	0 (0)	0 (0)	0 (0)
1	0 (0)	0 (0)	0 (0)
2	0 (0)	1 (8.3)	0 (0)
3	5 (3.3)	0 (0)	0 (0)
Total	151	12	51

Table 16.–Recapture locations of walleyes, northern pike, and smallmouth bass tagged in Lake Charlevoix based on voluntary angler tag returns (combined for reward and nonreward, harvested and released) during the angling season (April 29, 2006 to March 15, 2007) following tagging. Percent of total recaptured fish is in parentheses.

	Recapture location		
Species	Lake Charlevoix	Round Lake and Pine River	Lake Michigan
Walleyes	145 (97)	4 (3)	1 (<1)
Northern pike	12 (100)	0 (–)	0 (–)
Smallmouth bass	48 (94)	2 (4)	1 (2)

Table 17.–Recapture locations of walleyes, northern pike, and smallmouth bass tagged in Lake Charlevoix based on voluntary angler tag returns (combined for reward and nonreward, harvested and released) received through the time of report writing (October 2009). Percent of total recaptured fish is in parentheses.

	Recapture location		
Species	Lake Charlevoix	Round Lake and Pine River	Lake Michigan
Walleyes	279 (88)	30 (9)	10 (3)
Northern pike	30 (100)	0 (–)	0 (–)
Smallmouth bass	82 (92)	4 (5)	3 (3)

Table 18.–Mean total lengths (in) of walleyes (males and females combined) from the 2006 survey of Lake Charlevoix compared to other surveys from lakes in the northern lower peninsula of Michigan. Number aged in parentheses.

		Survey year/Lake						
	State	2006 [b]	2005 [b]	2004 [b]	2002 [b]	2001 [b]		1999 [c]
Age	average [a]	Lake Charlevoix	Black Lake	Grand Lake	South Lake Leelanau	Burt Lake	Crooked-Pickerel lakes	Intermediate Lake
1	8.3	9.7 (37)		7.3 (15)		6.8 (3)		9.5 (1)
2	12.2	14.8 (6)		11.8 (47)	9.9 (7)	11.0 (14)	12.1 (2)	11.9 (16)
3	14.4	16.9 (35)	15.3 (3)	13.6 (26)	13.3 (21)	14.1 (64)	12.5 (23)	14.4 (5)
4	15.8	19.1 (65)	16.3 (26)	14.8 (29)	14.9 (31)	16.1 (34)	13.7 (61)	15.4 (12)
5	17.2	21.0 (69)	17.3 (24)	15.3 (20)	15.0 (42)	17.3 (22)	14.9 (92)	17.7 (18)
6	18.7	22.5 (11)	17.8 (34)	16.5 (40)	15.9 (53)	17.8 (65)	15.8 (58)	19.1 (14)
7	19.6	23.8 (3)	18.7 (32)	17.2 (40)	17.0 (58)	19.0 (44)	16.4 (76)	22.9 (1)
8	20.3	22.6 (5)	19.4 (12)	18.3 (54)	17.3 (38)	19.4 (14)	17.3 (50)	24.5 (1)
9	21.2	26.0 (41)	19.1 (13)	20.3 (14)	18.3 (35)	20.7 (13)	17.1 (14)	26.6 (1)
10	21.8	24.3 (11)	20.0 (13)	20.6 (5)	17.4 (18)	21.8 (12)	18.4 (7)	
11		25.7 (39)	20.6 (1)	23.3 (4)	20.8 (32)	20.3 (7)	18.8 (5)	
12		27.6 (75)	21.4 (1)		21.1 (26)	21.5 (7)	18.8 (3)	
13		27.5 (20)	21.1 (1)	22.5 (8)	22.7 (2)	21.9 (7)	– (0)	
14		28.5 (15)		24.1 (2)		22.1 (2)	– (0)	
15		28.2 (5)		24.4 (4)		23.0 (4)	19.7 (1)	
16						21.3 (1)		
17						22.4 (1)		
18						22.7 (2)		
19								
20						22.2 (1)		
Mean growth index [d]		+3.0	-0.9	-1.4	-2.4	-0.5	-2.9	+0.3

[a] Jan–May averages (data on file), aged using dorsal spines.
[b] Fish collected in the spring and aged using dorsal spines.
[c] Fish collected in spring and aged using scales
[d] The mean deviation from the statewide quarterly average calculated for a given aging structure. Only age groups where N ≥ 5 were used.

Table 19.–Mean lengths of walleyes from the 2006 survey of Lake Charlevoix compared to other Great Lakes river-spawning populations. All populations were sampled in the spring. Number aged in parentheses.

Age	State average [a]	Mean lengths					
		Lake Charlevoix [b]	Muskegon River [b]	Grand River [c]	Cedar River [d]	Tittabawassee River [e]	Huron River [f]
2	10.4	14.8 (6)	–	–	–	–	13.7 (7)
3	13.9	16.9 (35)	17.1 (35)	16.4 (28)	–	–	16.2 (21)
4	15.8	19.1 (65)	20.6 (48)	18.2 (48)	19.6 (62)	20.6 (18)	19.0 (283)
5	17.6	21.0 (69)	22.0 (60)	20.5 (58)	20.6 (12)	20.8 (10)	20.2 (151)
6	19.2	22.5 (11)	22.5 (17)	22.2 (36)	22.7 (7)	21.3 (16)	21.7 (609)
7	20.6	23.8 (3)	23.7 (82)	23.6 (23)	23.8 (27)	23.2 (28)	22.5 (128)
8	21.6	22.6 (5)	24.1 (50)	24.3 (24)	23.9 (16)	24.4 (40)	23.2 (124)
9	22.4	26.0 (41)	24.7 (42)	26.3 (9)	24.2 (5)	24.7 (32)	24.6 (148)
10	23.1	24.3 (11)	26.6 (35)	27.4 (24)	26.1 (10)	24.9 (60)	24.5 (33)
11		25.7 (39)	26.2 (76)	28.3 (13)	25.1 (16)	25.7 (46)	25.2 (23)
12		27.6 (75)	27.9 (24)	29.7 (5)	26.8 (19)	–	26.6 (19)
13		27.5 (20)	24.9 (4)	–	27.5 (4)	–	26.5 (6)
14		28.5 (15)	–	31.1 (1)	27.4 (2)	–	24.6 (3)
15		28.2 (5)	30.2 (1)	–	–	–	–
16		–	27.8 (2)	–	–	–	24.7 (2)
17		–	27.7 (3)	–	–	–	25.1 (1)
18		–	25.8 (1)	–	–	–	–
Mean growth index [g]		+3.0	+3.4	+3.1	+2.9	+2.8	+2.3

[a] Jan–May averages from Schneider et al. (2000), aged using scales.
[b] Fish collected in 2006 and aged using dorsal spines.
[c] Fish collected in 1997 and aged using scales.
[d] Fish collected in 2002 and aged using dorsal spines.
[e] Fish collected in 2002 and aged using scales (Fielder and Thomas 2006).
[f] Fish collected in 2005 and aged using scales.
[g] The mean deviation from the statewide average, where $N \geq 5$.

Table 20.–Mean total lengths (in) of northern pike (males and females combined) from the 2006 survey of Lake Charlevoix compared to other surveys from lakes in the northern lower peninsula of Michigan. Number aged in parentheses.

		Survey year/Lake						
	State	2006 [b]	2005 [b]	2004 [b]	2002 [b]	2001 [b]		1999 [c]
Age	average [a]	Lake Charlevoix	Black Lake	Grand Lake	Lake Leelanau	Burt Lake	Crooked-Pickerel lakes	Intermediate Lake
1	11.8	14.4 (46)	13.6 (17)	12.3 (9)			10.9 (7)	13.1 (7)
2	17.1	20.7 (104)	18.8 (60)	17.6 (26)	17.5 (113)	17.4 (4)	16.1 (48)	18.9 (14)
3	20.5	24.3 (36)	21.8 (47)	23.5 (58)	20.1 (113)	21.6 (43)	19.2 (93)	21.9 (4)
4	22.8	26.4 (44)	23.2 (82)	25.0 (30)	23.1 (100)	23.5 (20)	20.3 (38)	24.4 (6)
5	24.9	28.7 (32)	24.6 (44)	26.8 (20)	23.8 (36)	24.2 (14)	22.1 (15)	25.8 (1)
6	26.6	28.5 (58)	26.8 (37)	27.0 (11)	30.9 (12)	28.6 (10)	22.8 (5)	27.0 (1)
7	28.5	30.4 (36)	25.3 (13)	35.3 (3)	27.5 (2)	28.8 (7)	25.7 (5)	34.4 (2)
8	31.9	33.4 (26)	25.3 (2)	27.4 (1)	32.9 (2)	29.6 (9)	30.8 (3)	
9		35.6 (5)	32.3 (2)	28.1 (2)	35.2 (1)	37.0 (2)		
10			40.4 (2)	41.3 (2)				
Mean growth index [d]		+2.8	+0.3	+1.4	+0.7	+0.2	-2.2	+1.2

[a] Jan–May averages (data on file), aged using dorsal fin rays.
[b] Fish collected in the spring and aged using dorsal spines.
[c] Fish collected in May and aged using scales
[d] The mean deviation from the statewide quarterly average calculated for a given aging structure. Only age groups where N ≥ 5 were used.

Table 21.–Mean total lengths (in) of smallmouth bass (male and females combined) from the 2006 survey of Lake Charlevoix compared to other surveys from lakes in the northern lower peninsula of Michigan. Number aged in parentheses.

		Survey year/Lake						
	State	2006 [b]	2005 [b]	2004 [b]		2002 [b]	1999 [c]	
Age	average [a]	Lake Charlevoix	Black Lake	Grand Lake	Long Lake	Lake Leelanau	Walloon Lake	Intermediate Lake
1							4.4 (18)	3.9 (1)
2	8.5	11.5 (10)	11.4 (1)	8.8 (53)			7.8 (47)	7.6 (22)
3	11.6	13.4 (56)	14.2 (14)	10.9 (73)	11.4 (14)	12.6 (21)	11.1 (12)	10.7 (30)
4	13.5	15.5 (23)	15.1 (12)	13.9 (32)	12.7 (32)	13.8 (62)	13.8 (15)	13.7 (24)
5	15.1	16.6 (6)	17.0 (14)	15.6 (23)	14.1 (27)	16.1 (58)		15.6 (13)
6	15.7	17.4 (8)	17.8 (18)	16.3 (17)	15.1 (14)	16.7 (25)	16.3 (9)	17.0 (15)
7	16.5	18.2 (13)	17.9 (11)	17.3 (15)	16.2 (20)	17.5 (21)	16.7 (7)	17.9 (10)
8	17.1	18.8 (16)	18.4 (4)	17.4 (6)	16.9 (6)	17.7 (14)	17.7 (6)	18.9 (12)
9	18.4	19.3 (9)	19.1 (9)	18.1 (9)	16.8 (8)	18.4 (7)	18.3 (10)	19.5 (8)
10	18.8	19.8 (10)	19.3 (2)	17.6 (2)	17.9 (13)	18.6 (12)	18.1 (2)	20.3 (2)
11		19.8 (3)		18.5 (7)	18.4 (10)	18.7 (2)		20.5 (5)
12				19.0 (7)		19.9 (2)		21.2 (4)
13			20.7 (13)	18.9 (5)	18.6 (5)	19.3 (2)		21.2 (1)
14				19.2 (2)	18.5 (4)			
15								
16								
17								
Mean growth index [e]		+1.7	+1.7	+0.2	-0.7	+0.6	+0.5	+1.1

[a] Jan–May averages (data on file), aged using dorsal spines.
[b] Fish collected in the spring and aged using dorsal spines.
[c] Fish collected in May and aged using scales
[d] The mean deviation from the statewide quarterly average calculated for a given aging structure. Only age groups where N ≥ 5 were used.

Table 22.–Comparison of recreational fishing effort and total harvest on Lake Charlevoix 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 (h)	Fish harvested (number)	Fish harvested per h	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
Lake Michigamme	Baraga, Marquette	4,292	May–Sep 2006	26,574	4,307	0.16	6.2	1.0
Peavy Pond	Iron	2,794	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				100,914	55,990	0.40	14.6	7.7
Median				58,500	15,577	0.31	8.4	2.1

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Samuel T. Noffke, Reviewer
Mark A. Tonello, Reviewer
Philip J. Schneeberger, Editor
Alan D. Sutton, Graphics
Ellen S. Grove, Desktop Publisher

Approved by Gary E. Whelan

Appendix–Fish species collected in Lake Charlevoix from 1959 through 2006.

Common name	Scientific name
Species collected in spring 2006 with trap nets, fyke nets, and electrofishing gear	
Black bullhead	*Ameiurus melas*
Black crappie	*Pomoxis nigromaculatus*
Bluegill	*Lepomis macrochirus*
Bowfin	*Amia calva*
Brook trout	*Salvelinus fontinalis*
Brown bullhead	*Ameiurus nebulosus*
Brown trout	*Salmo trutta*
Burbot	*Lota lota*
Channel catfish	*Ictalurus punctatus*
Common carp	*Cyprinus carpio*
Common shiner	*Luxilus cornutus*
Freshwater drum	*Aplodinotus grunniens*
Gizzard shad	*Dorosoma cepedianum*
Lake trout	*Salvelinus namaycush*
Largemouth bass	*Micropterus salmoides*
Longnose gar	*Lepisosteus osseus*
Longnose sucker	*Catostomus catostomus*
Mottled sculpin	*Cottus bairdi*
Northern pike	*Esox lucius*
Pumpkinseed	*Lepomis gibbosus*
Quillback	*Carpiodes cyprinus*
Rainbow trout	*Oncorhynchus mykiss*
Rock bass	*Ambloplites rupestris*
Round goby	*Neogobius melanostomus*
Sea lamprey	*Petromyzon marinus*
Silver redhorse	*Moxostoma anisurum*
Smallmouth bass	*Micropterus dolomieu*
Walleye	*Sander vitreus*
White perch	*Morone americana*
White sucker	*Catostomus commersonii*
Yellow perch	*Perca flavescens*
Additional species collected in summer 2006 with gill nets	
Lake whitefish	*Coregonus clupeaformis*
Round whitefish	*Prosopium cylindraceum*

Appendix–Continued.

Common name	Scientific name
Additional species collected in fall 1990 with gill nets and bottom trawls	
Cisco	*Coregonus artedi*
Johnny darter	*Etheostoma nigrum*
Ninespine stickleback	*Pungitius pungitius*
Rainbow smelt	*Osmerus mordax*
Slimy sculpin	*Cottus cognatus*
Spottail shiner	*Notropis hudsonius*
Trout perch	*Percopsis omiscomaycus*
White bass	*Morone chrysops*
Additional species collected in summer 1979 with gill nets	
Chinook salmon	*Oncorhynchus tshawytscha*
Additional species collected in fall 1976 with gill nets	
Coho salmon	*Oncorhynchus kisutch*
Additional species collected in summer 1975 with trap nets	
Atlantic salmon	*Salmo salar*
Additional species collected in summer 1959 with seines[a]	
Alewife	*Alosa pseudoharengus*
Banded killifish	*Fundulus diaphanus*
Blacknose shiner	*Notropis heterolepis*
Bluntnose minnow	*Pimephales notatus*
Creek chub	*Semotilus atromaculatus*
Golden shiner	*Notemigonus crysoleucas*
Iowa darter	*Etheostoma exile*
Logperch	*Percina caprodes*
Longear sunfish	*Lepomis megalotis*
Longnose dace	*Rhinichthys cataractae*
Mimic shiner	*Notropis volucellus*
Northern redbelly dace	*Phoxinus eos*
Sand shiner	*Notropis stramineus*

[a] Some fish may have been collected in Deer Creek and the lower Jordan River, but most were collected at creek mouths in Lake Charlevoix.