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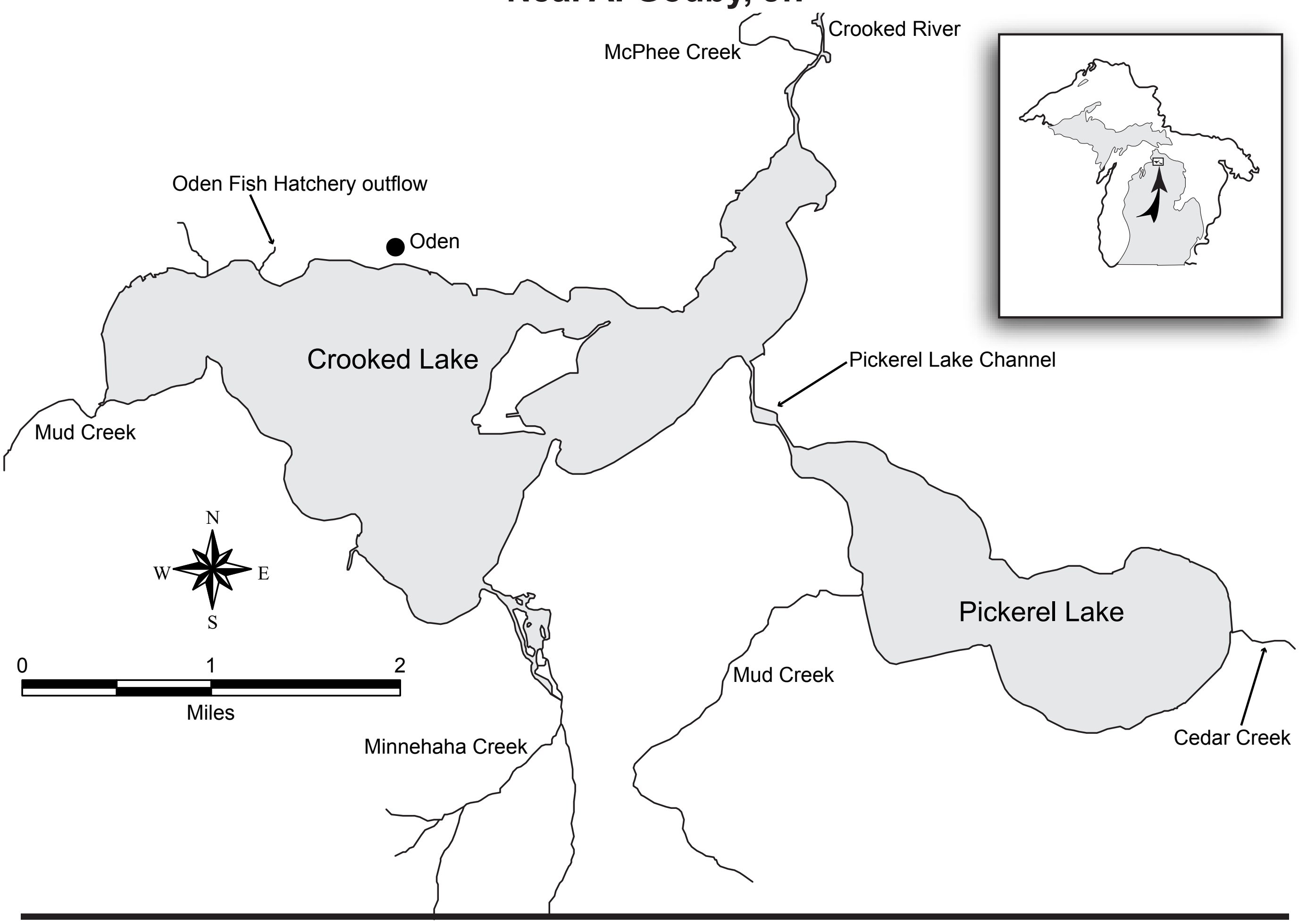

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The Fish Community and Fishery of Crooked and Pickerel Lakes, Emmet County, Michigan with Emphasis on Walleyes and Northern Pike

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Introduction

Michigan Department of Natural Resources (MDNR), Fisheries Division surveyed fish populations and angler catch and effort at Crooked and Pickerel lakes, Emmet County, Michigan from April 2001 through March 2002. This work was part of a new, statewide program designed to improve assessment and monitoring of fish communities and fisheries in Michigan's largest inland lakes. Known as the Large Lakes Program, it is currently scheduled to survey about four lakes per year over the next ten years (Clark et al. 2004).

The Large Lakes Program has three primary objectives. First, we want to produce consistent indices of abundance and estimates of annual harvest and fishing effort for important fishes. Initially, important fishes are defined as species susceptible to trap or fyke nets and/or those readily harvested by anglers. Our hope is to produce statistics for important fishes to help detect major changes in their populations over time. Second, we want to produce abundance estimates and sufficient growth and mortality statistics to be able to evaluate effects of fishing on special-interest species which support valuable fisheries. This usually involves targeting special-interest species with nets or other gears to collect, sample, and mark sufficient numbers. We selected walleyes *Sander vitreus* and northern pike *Esox lucius* as special-interest species in this survey of Crooked and Pickerel lakes. Finally, we want to evaluate the suitability of various statistical estimators for use in large lakes. For example, we applied and compared three types of abundance and two types of exploitation rate estimators for walleyes and northern pike in this survey of Crooked and Pickerel lakes.

The Large Lakes Program will maintain consistent sampling methods over lakes and time. This will allow us to build a body of fish population and harvest statistics to directly evaluate differences between lakes or changes within a lake over time. Because Crooked and Pickerel lakes were two of the first lakes to be sampled under the protocols of the program, we were sometimes limited in our ability to make valid comparisons in this report. For example, most types of quantitative comparisons between catch per effort in our netting operations and those of most other surveys would not be valid. Our netting targeted walleyes, northern pike, and other spring spawners during spawning. Most past netting surveys occurred later in the year. Of course, as our program progresses we will eventually have a large body of netting data collected under the same conditions.

Study Area

The size of Crooked and Pickerel lakes is about 3,400 acres, with sources disagreeing only slightly on size. Humphries and Green (1962) estimated 2,300 and 1,080 surface acres (3,380 acres total) for Crooked and Pickerel lakes, respectively by taking measurements from United States Geological Survey (USGS) topographical maps using handheld drafting tools. Michigan Digital Water Atlas[1] (2003) reported 2,352 and 1,082 acres (3,434 total acres) for Crooked and Pickerel lakes, respectively by using computerized digitizing equipment and USGS topographical maps. They overlaid the boundaries of the lake polygon from the Michigan Digital Water Atlas GIS layer with aerial photos of the lake using ArcView©, and the two matched well. In the Large Lakes Program, we will compare various measures of productivity among lakes, such as number of fish per acre or harvest per acre, so a measure of lake size is fairly important. Therefore, we will use the more modern estimate of 3,434 acres as the size of Crooked and Pickerel lakes in our analyses.

Pickerel Lake is fed by Mud and Cedar creeks and flows out to Crooked Lake through the Pickerel Lake channel (Figure 1). In addition to the Pickerel Lake channel, Crooked Lake is fed by Minnehaha Creek, Mud Creek that flows from Round Lake, and the creek that drains the outflow from springs at the Oden State fish hatchery. Crooked Lake

[1] A statewide program conducted by MDNR, Fisheries Division, Lansing to develop computerized maps and reference data for aquatic systems in Michigan.

flows out to Burt Lake through the Crooked River. Crooked and Pickerel lakes are part of the inland waterway that begins on Pickerel Lake and continues through Crooked Lake, the Crooked River, Burt Lake, the Indian River, Mullett Lake, and finally through the Cheboygan River to Lake Huron.

The shoreline is largely developed with private and commercial residences, though some public land exists in the form of nature preserves and State Forest. The maximum depth is about 50 ft in Crooked Lake and 75 ft in Pickerel Lake. The bathymetry is variable, with both shallow flats and deep holes. Percent area and percent volume by depth are presented in Figures 2, 3, 4, and 5 for Crooked and Pickerel lakes, respectively. Substrate in shallow areas is composed of sand, marl, clay, and rocks, while substrate in deeper water is marl and pulpy peat. Vegetation varies from sparse to moderate density, and includes a variety of submergent species, lily pads, and bulrushes. Stumps and submerged woody debris are also common in places. Maps of depth contours (and bottom types for Crooked Lake) were produced by MDNR, Institute for Fisheries Research. Both are available in the Michigan Digital Water Atlas.

The fish community of Crooked and Pickerel lakes includes species typical of this northern region. We listed common and scientific names of all fish species captured during this and previous studies of Crooked and Pickerel lakes in Appendix A. Henceforth, we will use only common names in the text. Families of fish found in the system include, but are not limited to, *Amiidae*, *Cyprinidae*, *Catostomidae*, *Centrarchidae*, *Clupeidae*, *Esocidae*, *Gadidae*, *Ictaluridae*, *Lepisosteidae*, and *Percidae*. The walleye and northern pike populations are generally characterized by average recruitment, slow growth, and high proportions of small fish. Inadequate forage has been suggested as a cause of the poor growth of predators. Growth rates of panfish species are generally good, likely due to their low density and reliance on an abundant lower trophic level of prey.

There was extensive commercial harvest of undesirable species in the 1950s and 1960s on both Crooked and Pickerel lakes. Fishing occurred in the winter using trap nets through the ice. Species harvested included suckers (white suckers and redhorse species), common carp, burbot, bowfin, and longnose gar.

Stocking in Crooked and Pickerel lakes occurred sporadically over the past 70 years, and has only recently taken place on a regular basis. In the 1930s and 1940s adult smallmouth bass were transferred from Lake Michigan to Crooked Lake with the help of commercial fishers. In the 1940s and 1950s walleyes, northern pike, yellow perch, and smallmouth bass were transported in the spring from below the Cheboygan River dam to Black, Burt, and Crooked lakes. Recently, walleyes have been stocked in Crooked or Pickerel lakes in 11 of the past 17 years, though amounts were not always significant (Table 1). Stocking of fingerlings has probably augmented the walleye population to some degree, but an oxytetracycline (OTC) stocking evaluation of Crooked Lake in the fall of 2000 showed that natural reproduction accounted for around 70% of the age-0 walleyes.

There have been 38 State of Michigan Master Angler awards taken from Crooked and Pickerel lakes from 1990–2002 (Table 2), including black bullhead, black crappie, bluegill, brook trout, hybrid sunfish, pumpkinseed, rock bass, and smallmouth bass.

Methods

We used the same methods on Crooked and Pickerel lakes as described by Clark et al. (2004) for Houghton Lake. We will give a complete overview of methods in this report, but will refer the reader to Clark et al. (2004) for details.

Briefly, we used nets and electrofishing gear to collect fish April–May to coincide with spawning of primary targets, walleyes and northern pike. All fish captured were identified to species and counted. Fishing effort was recorded by individual net, but not for electrofishing. Electrofishing was only used to increase the sample size of walleyes and northern pike tagged. Standard total lengths were measured for subsamples of each non-target species. All walleyes and northern pike were measured and legal-size fish were tagged with individually numbered jaw tags. Tagged fish were also fin clipped to evaluate tag loss. Angler catch and harvest surveys were conducted the year after tagging; one covered the summer fishery from April 28 through September 30, 2001 and one covered the winter fishery from January 1 through March 31, 2002. Tags on walleyes and northern pike observed during angler surveys were tallied and the ratios of marked to unmarked fish were used to calculate abundance estimates for walleyes and northern pike. In addition, voluntary tag recoveries were requested. All tags contained a unique number and a mailing address for a MDNR field station. To encourage voluntary tag returns, about 50% of tags were identified as reward tags, and we paid US$10 rewards to anglers returning them.

Our intention in this report is to present Crooked and Pickerel lakes as a single system. This is due both to the close physical connectivity between lakes, and the desire to present results in a clear and concise manner. Therefore, we will present fish community and population statistics for the entire system as a whole as computed from pooled data. Then, if it makes biological sense and sample sizes are sufficient, we will present statistics for each individual lake. Also, for some fish population statistics we tested for differences between lakes.

Angler surveys were designed to make estimates for each lake separately, without pooling data. Therefore, we calculated angler survey statistics for the system as a whole by summing statistics for the two lakes.

Fish Community

We described the status of the overall fish community in terms of species present, catches per unit effort, percents by number, and length frequencies. We also collected more detailed data for walleyes and northern pike as described below. We sampled fish populations in Crooked and Pickerel lakes with trap nets, fyke nets, and electrofishing gear from April 17 to 26, 2001. We used two boats daily to work nets, each with three-person crews, for 2 weeks. Each net-boat crew tended about 10 nets. Electrofishing runs were also occasionally made at night.

Fyke nets were 6 ft wide x 4 ft high with 2-in stretch mesh and 90- to 98-ft leads. Trap nets were 8 ft by 6 ft by 3 ft with 2-in stretch mesh and 90- to 98-ft leads. Duration of net sets was 1–2 nights, but most were 1 night. We used a Smith-Root® boat equipped with boom-mounted electrodes (DC) for electrofishing. Latitude and longitude were recorded for all net locations and electrofishing runs using GPS.

We identified species and counted all fish captured. For non-target species, we measured lengths to the nearest 0.1 in for sub-samples of up to 200 fish per work crew. Crews ensured that lengths were taken over the course of the survey to account for any temporal trends in the size structure of fish collected. We used Microsoft Access© to store and retrieve data collected during the tagging operation. Size-structure data only included fish on their initial capture occasion. We recorded mean catch per unit effort (CPUE) in fyke nets as an indicator of relative abundance, utilizing the number of fish per net night (including recaptures) for all net lifts that were determined to have fished effectively (i.e., without wave-induced rolling or human disturbance).

Schneider (2000) cautioned that trap net and fyke net collections provide “imperfect snapshots” of fish community composition in lakes. Yet, with proper consideration to gear biases and sampling time frames, some indices of species composition might provide useful insight into fish community dynamics. As one possible index, we calculated the percent by number of fish we collected in each of three feeding guilds: 1) species that are primarily piscivores; 2) species that are primarily pelagic planktivores and/or insectivores; and 3) species that are primarily benthivores. Perhaps, such an index will prove useful to compare fish communities between lakes or within the same lake over time, especially in the future when more large lake surveys using similar methods are available for comparison.

Walleyes and Northern Pike

Size Structure

All walleyes and northern pike were measured to the nearest 0.1 in. Size structure was characterized for purposes of comparison using percent over legal size. We assessed differences in length frequency data for Crooked and Pickerel lakes by comparing the distribution of lengths between lakes using the Kolmogorov-Smirnov asymptotic two-sample test. Additionally, differences in mean lengths were assessed using a two-sample t-test. Statistical significance was set at $\alpha = 0.05$.

Sex Composition

We recorded sex of walleyes and northern pike. Fish with flowing gametes were categorized as male or female, respectively. Fish with no flowing gametes were categorized as unknown sex.

Abundance

We estimated abundance of legal-size walleyes and northern pike using mark-and-recapture methods. Walleyes (≥15 in) and northern pike (≥24 in) were fitted with monel-metal jaw tags. In order to assess tag loss, we double-marked each tagged fish by clipping the left pelvic fin. We attempted to maintain approximately a 1:1 ratio of $10-reward : non-reward tags on fish tagged, but did not attempt to make the ratio exact. We did not think that an exact ratio was important, and maintaining an exact ratio would have been more difficult, given the multiple crews working simultaneously, and numbers of fish we tagged. Initial tag loss was assessed during the marking period as the proportion of recaptured fish of legal size without tags. This tag loss was largely caused by entanglement with nets, and thus was not used to adjust estimates of abundance or exploitation. Newman and Hoff (1998) reported similar concern for netting-induced tag loss. All fish that lost tags during netting recapture were re-tagged, and so were accounted for in the total number of marked fish at large.

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

For the multiple-census estimate, we used the Schumacher-Eschmeyer formula (±95% asymmetrical confidence limits) from daily recaptures during the tagging operation (Ricker 1975). The minimum number of recaptures necessary for an unbiased estimate was set a priori at four. For the single-census estimate, we used numbers of marked and unmarked fish seen by creel clerks in the companion angler survey as the “recapture-run” sample. The Chapman modification of the Petersen method (Ricker 1975) was used to generate population estimates (±95% asymmetrical confidence limits). Probability of tag loss was calculated as the number of fish in a recapture sample with fin clips and no tag divided by all fish in the recapture sample that had been tagged, including fish that had lost their tag. Standard errors were calculated assuming a binomial distribution (Zar 1999). If we detected annual tag loss, we adjusted the single-census abundance estimate by reducing the number of marked fish at large. For more details on methods for abundance estimates, see Clark et al. (2004).

No prior abundance estimates existed for either walleyes or northern pike in Crooked and Pickerel lakes to help us gauge how many fish to mark. For walleyes, we used a regression equation developed for Wisconsin lakes (Hansen 1989) to provide an a priori estimate of abundance. This regression predicts adult walleye abundance based on lake size. Parameters for this equation are re-calculated every year by Wisconsin Department of Natural Resources (WDNR). We used the same parameters used by WDNR in 2001 (Doug Beard, WDNR, personal communication):

$$\ln(N) = 1.6106 + 0.9472 \times \ln(A),$$

where N is the estimated number of walleyes and A is the surface area of the lake in acres. This equation was derived from abundance estimates on 179 lakes in northern Wisconsin. For Crooked and Pickerel lakes, the equation gives an estimate of 11,186 walleyes, with a 95% confidence interval of 3,702 to 33,799. The ‘confidence interval’ here is, more precisely, a prediction interval with 95% confidence (Zar 1999).

We determined our tagging goal by evaluating the effect of increasing the proportion tagged on the precision of the estimate (Clark et al. 2004). Based on this analysis, it was our judgment that marking 10% of the population achieved a good compromise between marking effort and precision, assuming the fraction marked was a function of marking effort (Figure 6). Thus, we set our tagging goal at 10% of the population or approximately 1,100 walleyes. We set no specific tagging goal for northern pike. We simply tagged as many northern pike as possible until the walleye goal was achieved.

It is important to recognize the difference between walleye abundance estimates from the Wisconsin regression equation and walleye abundance estimates we made. The Wisconsin equation predicts abundance of adult walleyes on the spawning grounds, while our primary, single-census estimate was only for walleyes 15 in or more in length. Wisconsin defined adult walleyes as legal size, or sublegal size of identifiable sex. Because we clipped fins and recorded recaptures of all walleyes, we were also able to make a direct multiple-census estimate of adult walleyes for comparison using the Schumacher-Eschmeyer formula and including the sublegal size and mature fish that were marked and recaptured.

We estimated numbers of adult walleyes from our single-census estimate by dividing our estimate of walleyes 15 in or larger by the proportion of adult walleyes on the spawning grounds that were 15 in or larger, using the equation in Clark et al. (2004).

Similar to walleyes, we defined adult northern pike as those 24 in or more in length or less than 24 in of identifiable sex. We estimated adult northern pike using the multiple-census and adjusted single-census methods as was done for walleyes.

We accounted for fish that recruited to legal size over the course of the angler survey by removing a portion of the unmarked fish observed by the creel clerk. The number of unmarked fish removed was based on a weighted average monthly growth for fish of slightly sublegal size (i.e., 14.0- to 14.9-in walleyes). For a detailed explanation of methods see Clark et al. (2004) and Ricker (1975). This adjusted ratio was used to make the primary (single-census) population estimate.

Mean Lengths at Age

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

Sample sizes for age analysis were based on historical length at age data from Crooked and Pickerel lakes and methods given in Lockwood and Hayes (2000). Our goal was to collect 15 male and 15 female walleyes per inch group and 16 male and 16 female northern pike per inch group in each lake.

Samples were sectioned using a table-mounted Dremel® rotary cutting tool. Sections approximately 0.5 mm thick were cut as close to the proximal end of the spine or ray as possible. Sections were examined at 40x-80x with transmitted light and were photographed with a digital camera. The digital image was archived for multiple reads. We aged approximately 15 fish per sex per inch group. Two technicians independently aged walleyes. Ages were considered correct when results of both technicians agreed. Samples in dispute were aged by a third technician. Disputed ages were considered correct when the third technician agreed with one of the first two. Samples were discarded if three technicians disagreed on age.

After a final age was identified for all samples, weighted mean lengths at age and age-length keys were computed for males, females, and all fish (males, females, and fish of unknown sex) for both walleyes and northern pike (Devries and Frie 1996). Age analysis was initially done separately for Crooked and Pickerel lakes. We tested for differences in mean lengths at age using a two-way analysis of variance, controlling for age as a covariate. Statistical significance was set at $\alpha = 0.05$.

We compared our mean lengths at age to those from previous surveys of Crooked and Pickerel lakes and other large lakes. Also, we computed a mean growth index to compare our data to State of Michigan averages as described by Schneider et al. (2000). Basically, the mean growth index is the average of deviations between the observed mean length and the quarterly statewide average length. In addition, we fit mean length at age data to a von Bertalanffy growth equation using nonlinear regression, and calculated the total length at infinity (L_{∞}) for use as an index of growth potential. All growth curves were forced through the origin. The total length at infinity is a mathematically-derived number representing the length that an average fish approaches if it lives to age infinity, and grows according to the von Bertalanffy curve (Ricker 1975).

Mortality

We estimated instantaneous total mortality rates using a catch-curve regression (Ricker 1975). We used age groups where the majority of fish in each age group were sexually mature, recruited to the fishery (≥ minimum size limit), and represented on the spawning grounds in proportion to their true abundance in the population. For a more detailed explanation of age group selection criteria see Clark et al. (2004). When sufficient data were available, we computed separate catch curves for males and females to determine if total mortality differed by sex. A catch curve was also computed for all fish that included males, females, and fish of unknown sex.

We estimated angler exploitation rates using two methods: 1) the percent of reward tags returned by anglers; and 2) the estimated harvest divided by estimated abundance. We compared these two estimates of exploitation and converted them to instantaneous fishing mortality rates.

In the first method, exploitation rate was estimated as the fraction of reward tags returned by anglers adjusted for tag loss. We did not assess tagging mortality or incomplete reporting of reward tags. We made the assumption that mortality was negligible and that near 100% of reward tags would be returned.

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

In the second method, we calculated exploitation as the estimated annual harvest from the angler survey divided by the estimated abundance of legal-size fish from the single-census abundance estimate. For proper comparison with the abundance of legal-size fish as existed in the spring, the estimated annual harvest was adjusted for fish that would have recruited to legal size over the course of the creel survey (Clark et al. 2004).

Recruitment

We considered relative year-class strength as an index of recruitment. Year-class strength of walleyes is often highly variable, and factors influencing year-class strength have been studied extensively (Chevalier 1973; Busch et al. 1975; Forney 1976; Serns 1982a, 1982b, 1986, and 1987; Madenjian et al. 1996; and Hansen et al. 1998). Density-dependent factors, such as size of parent stock, and density-independent factors, such as variability of spring water temperatures, have been shown to correlate with success of walleye reproduction. In addition, stocking walleyes can affect year-class strength, but stocking success has also been highly variable, depending on the size and number of fish stocked, level of natural reproduction occurring, and other factors (Laarman 1978; Fielder 1992; Li et al. 1996a; Li et al. 1996b; and Nate et al. 2000).

We obtained population data in Crooked and Pickerel lakes for only one year, and so could not rigorously evaluate year-class strength as did the investigators cited in the previous paragraph. However, we suggest that valuable insight about the relative variability of recruitment can be gained by examining the properties of our catch-curve regressions for walleyes and northern pike. For example, Maceina (2003) used catch-curve residuals as a quantitative index of the relative year-class strength of black crappie and white crappie in Alabama reservoirs. He showed that residuals were related to various hydrological variables in the reservoirs.

As Maceina (2003), we assumed the residuals of our catch-curve regressions were indices of year-class strength. For walleyes, we used correlation analysis and linear regression between catch-curve residuals and environmental variables to determine if there was a relationship. Additionally, we used the approach of Isermann et al. (2002) and calculated the recruitment coefficient of determination (RCD) to index recruitment variability.

Movement

Fish movements were assessed in a descriptive manner by examining the location of angling capture versus the location of initial capture at tagging. Capture locations provided by anglers were often vague; thus, statistical analysis of distance moved would be questionable. Instead, we identified conspicuous movement such as to another lake or connected river.

Angler Survey

Fishing harvest seasons for walleyes and northern pike during this survey were April 28, 2001–March 15, 2002. Minimum size limits were 15 in for walleyes and 24 in for northern pike. Daily bag limit was five fish of any combination of walleyes, northern pike, smallmouth bass, or largemouth bass.

Fishing harvest seasons for smallmouth bass and largemouth bass were May 26 through Dec 31, 2001. Minimum size limit was 14 in for both smallmouth bass and largemouth bass.

Harvest was permitted all year for all other species present. No minimum size limits were imposed for other species. Bag limit for yellow perch was 50 per day. Bag limit for "sunfishes", including black crappie, bluegill, pumpkinseed, and rock bass was 25 per day in any combination.

Direct contact angler creel surveys were conducted during one spring–summer period – April 28 to September 30, 2001, and one winter period – January 1, 2002 through March 31, 2002. Ice cover in the winter requires different methods from the summer surveys.

Summer

We used an aerial-roving design for the summer survey (Lockwood 2000b). Fishing boats were counted by aircraft and one clerk working from a boat collected angler interview data. Survey period was from April 28 through September 30, 2001. Both weekend days and three randomly selected weekdays were selected for counting and interviewing during each week of the survey season. No interview data were collected on holidays; however, aerial counts were made on holidays. Holidays during the period were Memorial Day (May 28, 2001), Independence Day (July 4, 2001), and Labor Day (September 3, 2001). Counting and interviewing were done on the same days (with exception to previously discussed holidays), and one instantaneous count of fishing boats was made per day. For sampling purposes, Crooked and Pickerel lakes were each treated as separate sections (Figure 7). All count and interview data were collected and recorded by section. Similarly, effort and catch estimates were made by section and summed for lake-wide estimates.

Two different aerial counting paths were used (Figure 7), selection of which was randomized. The pilot flew one of the two randomly selected predetermined routes using GPS coordinates. Each flight was made at 500–700 ft elevation and took approximately 10 min to complete at an air speed of about 85 mph. Counting was done by the contracted pilot and only fishing boats were counted (i.e., watercrafts involved in alternate activities, such as water skiing, were not counted). Time of count was randomized to cover daylight times within the sample period. Count information for each count was recorded on a lake map similar to Figure 7. This information included: date, count time, and number of fishing boats in each section.

Minimum fishing time prior to interview (incomplete-trip interview) was 1 h (Lockwood 2004). Historically, minimum fishing time prior to interviewing has been 0.5 h (Pollock et al. 1997). However, recent evaluations have shown that roving interview catch rates from anglers fishing a minimum of 1 h are more representative of access interview (completed-trip interview) catch rates (Lockwood 2004). Access interviews include information from complete trips and are appropriate standards for comparison.

All roving interview data were collected by individual angler to avoid party size bias (Lockwood 1997). When all anglers within a section were interviewed during a sample day, the clerk roamed the remaining sections interviewing anglers.

While this survey was designed to collect roving interviews, the clerk occasionally encountered anglers as they completed their fishing trips. The clerk was instructed to interview these anglers and record the same information as for roving interviews – noting that the interview was from a completed trip.

Interview information collected included: date, section, fishing mode, start time of fishing trip, interview time, species targeted, bait used, number of fish harvested by species, number of fish caught and released by species, length of harvested walleyes and northern pike, and applicable tag number. Catch and release of smallmouth bass, largemouth bass, walleyes, northern pike, and muskellunge were recorded. Number of anglers in each party was recorded on one interview form for each party.

One of two shifts was selected each sample day for interviewing (Table 3). Interview starting location (section) and order were randomized daily. Interview forms, information, and techniques used during summer survey period were the same as those used during the winter survey period. When anglers reported fishing in more than one lake, the clerk recorded the lake where they spent most of that trip fishing.

Winter

We used a progressive-roving design for winter surveys (Lockwood 2000b). One clerk working from a snowmobile collected count and interview data. Both weekend days and three randomly selected weekdays were selected for sampling during each week of the survey season. No holidays were sampled. Holidays during winter sampling period were: New Year's Day (January 1, 2002), Martin Luther King Day (January 15, 2002), and President's Day (February 19, 2002). The clerk followed a randomized count and interview schedule. One of two shifts was selected each sample day (Table 3). Crooked and Pickerel lakes were each treated as separate sections (Figure 7). All count and interview data were collected and recorded by section. Similarly, effort and catch estimates were made by section and summed for lake-wide estimates. Starting location (section) and direction of travel were randomized for both counting and interviewing. Scanner-ready interview and count forms were used.

Progressive (instantaneous) counts of open-ice anglers and occupied shanties were made once per day. Count information collected included: date, section, fishing mode (open ice or shanty), count time, and number of units (anglers or occupied shanties) counted.

Similar to summer interview methods, minimum fishing time prior to interviewing was 1 h. When anglers reported fishing in more than one lake, the clerk recorded the lake where they spent most of that trip fishing. No anglers were interviewed while counting (Wade et al. 1991). Additional interviewing instructions and interview information collected followed methods for the summer survey period.

Estimation Methods

Catch and effort estimates were made by section using multiple-day method (Lockwood et al. 1999). Expansion values ("F" in Lockwood et al. 1999) are given in Table 3. These values are the number of hours within sample days. Effort is the product of mean counts by section for a given period day type and days within the period and the expansion value for that period. Thus, the angling effort and catch reported here are for those periods sampled, no expansions were made to include periods not sampled (e.g., 0100 to 0400 hours). Lake-wide estimates were the sum of section estimates for each given time period and day type.

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

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

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

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

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

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

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

As a routine part of interviewing, the creel clerk recorded presence or absence of jaw tags and fin clips, tag numbers, and lengths of walleyes and northern pike. These data were used to estimate tag loss and to determine the ratio of marked to unmarked fish for single-census abundance estimates.

Results

We will give confidence limits for various estimates in relevant tables, but not in the text.

Fish Community

We collected 20 species of fish with fyke nets, trap nets, and electrofishing gear (Table 4). Total sampling effort was 63 trap-net lifts, 49 fyke-net lifts, and 2 electrofishing runs. We captured 997 walleye and 285 northern pike.

Other species collected in order of abundance were: rock bass, white sucker, bluegill, smallmouth bass, brown bullhead, pumpkinseed, bowfin, yellow perch, largemouth bass, yellow bullhead, longnose gar, burbot, black bullhead, black crappie, brown trout, alewife, common carp, and rainbow trout. We caught a higher percentage of large, spring-spawning fish than previous surveys (Tables 5 and 6) due to the targeted effort for spawning walleye and northern pike. Walleye, white sucker, and northern pike accounted for almost 44% of the total catch. A general survey of Crooked and Pickerel lakes in 1989 collected 17 species using trap nets, fyke nets, and gill nets. The 1989 survey was conducted in late May and early June, thus catch was more dominated by rock bass and yellow perch. Bluegill, black crappie, pumpkinseed, and yellow perch were also present in low abundance in the 1989 survey.

The abundance of rock bass in our survey was impressive. CPUE for rock bass was 19.4 and 21.3 fish per lift for trap nets and fyke nets, respectively (Table 4). Bluegill was the next most abundant panfish species in nets. CPUE for bluegills was 4.7 and 9.6 fish per lift for trap nets and fyke nets, respectively. CPUE for yellow perch seemed relatively low at 0.2 and 0.3 fish per lift for trap nets and fyke nets, respectively.

The fish community composition in Crooked and Pickerel lakes was 24.0% fish predators, 49.0% pelagic planktivores-insectivores, and 27.2% benthivores (Table 4). Of the species collected, we classified walleyes, northern pike, smallmouth bass, largemouth bass, bowfin, longnose gar, burbot, and brown trout as fish predators; rock bass, bluegill, pumpkinseed, yellow perch, black crappie, alewife, and rainbow trout as pelagic planktivores-insectivores; and white suckers, brown bullheads, yellow bullheads, black bullheads, and common carp as benthivores.

Size structures of fish measured in our spring netting and electrofishing catches are presented in Table 5. The size structure of smallmouth bass was high, with 62% of those collected in our spring survey being of legal size. In general, the size of panfish species was impressive (Table 5); mean lengths for rock bass, yellow perch, and bluegill were 7.5, 8.9, and 7.1 in, respectively. The size score (Schneider 1990) for bluegill was 5.8, which ranks as “Good”, and puts it in the 90th percentile of the 303 lakes that were used to develop that index. We discuss the potential biases that our gear may impose on interpreting size structure in the **Discussion** section.

Walleyes and Northern Pike

<u>Size Structure</u>

Size structure of walleyes and northern pike measured in our spring netting and electrofishing catches are presented in Table 5. The percentages of walleyes and northern pike that were legal size were 53 and 4, respectively. The population of spawning walleyes was dominated by 13- to 16-in walleyes, with proportionally few walleyes over 20 in. Similarly, most northern pike were from 16 to 22 in and few fish were larger than 23 in. Numbers of legal-size pike were extremely low, with only 5% and 3% in Crooked and Pickerel lakes, respectively.

Walleye length frequency distributions differed significantly (Kolmogorov-Smirnov asymptotic test statistic = 3.900; P = 0.0001) between Crooked and Pickerel lakes; however, the shape of the distributions did not differ (Kolmogorov-Smirnov asymptotic test statistic = 1.017; P = 0.2520) when the distributions were centered for length. The mean difference in walleye length between the lakes was 0.8 in, with Crooked Lake being larger than Pickerel Lake on average.

Northern pike length frequency distributions differed significantly (Kolmogorov-Smirnov asymptotic test statistic = 2.635; P = 0.0001) between Crooked and Pickerel lakes; however, the shape of the distributions did not differ (Kolmogorov-Smirnov asymptotic test statistic = 0.742; P = 0.6410) when the distributions were centered for length. The mean difference in northern pike length between the lakes was 1.6 in, with Crooked Lake being larger than Pickerel Lake on average.

<u>Sex Composition</u>

Male walleyes outnumbered females in our spring survey, which is typical for walleyes (Carlander 1997). Of all walleyes captured, 74.5% were male, 16.8% were female, and 8.7% were unknown sex. Of legal-size walleyes captured, 72.3% were male, 25.9% were female, and 1.8% were of unknown sex. The sex composition of walleyes did not differ between Crooked and Pickerel lakes. For example, the largest difference was for percent of legal-size male walleyes, with Crooked Lake at 75.5% and Pickerel Lake at 68.4%.

The sex ratio for northern pike appeared more balanced than for walleyes, however many fish were of unknown sex. Of all northern pike captured, 27.4% were male, 23.0% were female, and 49.6% were unknown sex. Of 11 legal-size northern pike captured, none were male, 27.3% were female, and 72.7% were unknown sex. Males typically outnumber females in spring spawning surveys (Priegel and Krohn 1975; Bregazzi and Kennedy 1980; Clark et al. 2004). The sex composition of northern pike was similar between Crooked and Pickerel lakes. Considering all fish of identifiable sex, Crooked Lake had 49% males and Pickerel Lake had 57% males.

Abundance

We tagged a total of 278 legal-size walleyes in Crooked Lake (151 reward and 127 non-reward tags) and 224 in Pickerel Lake (106 reward and 118 non-reward tags). We clipped fins of 448 sublegal-size walleyes in Crooked and Pickerel lakes. No walleyes were observed to have lost their tags during the spring netting/electrofishing survey.

Creel clerks observed a total of 220 walleyes, of which 11 were marked. We reduced the number of unmarked walleyes in the single-census calculation by 36 fish to adjust for sublegal-size fish that grew over the minimum size limit during the fishing season. The creel clerk observed one fish that had a fin clip, but no tag. This fish was determined to have been legal size at the time of tagging; thus, it had apparently lost its tag. Based on this sample of 11 recaptured fish, the estimate of tag loss is 9.1%, with a standard error of 9.1. Based on the small sample of recaptured fish (N = 11), and the fact that we have not observed tag loss in other lakes surveyed using these same methods, we believe the estimate of tag loss was high. If tag loss was actually lower, our corrected abundance estimate would be low.

The estimated number of legal-size walleyes in Crooked and Pickerel lakes was 4,825 using the multiple-census method and 7,049 using the single-census method (Table 7). The estimated number of adult walleyes was 9,552 using the multiple-census method and 12,346 using the single-census method (Table 7). The CV for all estimates was less than 0.40 which Hansen et al. (2000) considered indicative of reliable estimates.

We could not compute a reliable single-census walleye abundance estimate for Pickerel Lake, because we obtained only one recapture. Thus, it was not possible to compare single-census estimates between lakes. Multiple-census estimates of legal-size walleyes were 5,078 (2,936–18,796) for Crooked Lake and 1,123 (802–1,871) for Pickerel Lake. These multiple-census estimates for each lake only represent walleye abundance during spring spawning. The relative abundance between lakes is probably different during other times of the year (Rasmussen et al. 2002).

We tagged a total of 11 legal-size northern pike (1 reward and 10 non-reward tags) and clipped fins of 265 sublegal-size northern pike in Crooked and Pickerel lakes. No northern pike were observed to have lost their tags during the spring netting/electrofishing survey. Similar to walleyes, we combined raw data for Crooked and Pickerel lakes to make abundance estimates. Insufficient recaptures were obtained for individual lakes during both the spring survey and the creel survey. Thus, individual lake estimates for northern pike were not possible. The creel clerk observed four northern pike of which none were tagged. We reduced the number of unmarked northern pike in the single-census calculation by one fish to adjust for a sublegal-size fish that grew over the minimum size limit during the fishing season. There was no tag loss for northern pike observed by the creel clerk.

We could not estimate the number of legal-size northern pike using the multiple-census method due to insufficient recaptures. We estimated 48 legal-size northern pike using the single-census method (Table 7). The estimated number of adult northern pike was 1,921 using the multiple-census method and 628 using the single-census method (Table 7). The multiple-census estimate of adult northern pike had a CV < 0.40 and was considered reliable (Hansen 2000), but the single-census estimates of legal-size and adult northern pike (both CV = 0.61) were not.

Mean Lengths at Age

For walleyes, there was 40.8% agreement between the first two technicians. For fish that were aged by a third reader, agreement was with first reader 64.4% of the time and with second reader 35.6% of the time; thus, there appeared to be some bias among readers. This bias was apparently due to identification of the first annulus. Only 4.9% of samples were discarded due to poor agreement; thus, at least two out of three readers agreed 95.1% of the time. Our reader agreement for walleye spines was somewhat lower than other studies. Clark et al. (2004) achieved 52.9% reader agreement, Hanchin et al. (2005) found 67.6%, Isermann et al. (2003) achieved 55%, and Kocovsky and Carline (2000) achieved 62% reader agreement.

For northern pike, there was 60.2% agreement between the first two technicians. For fish that were aged by a third reader, agreement was with first reader 56.8% of the time and with second reader 43.2% of the time; thus, there appeared to be little bias among readers. Most discrepancies in assigned ages were due to identification of the first annulus. Only 3.2% of samples were discarded due to poor agreement; thus, at least two out of three readers agreed 96.8% of the time. Clark et al. (2004) found 72.4% agreement, and Hanchin et al. (2005) reported 81.5% agreement between the initial two readers of northern pike fin rays.

Female walleyes had higher mean lengths at age than males (Table 8). This is typical for walleye populations in general (Colby et al. 1979; Carlander 1997; Kocovsky and Carline 2000). We obtained sufficient sample sizes for a simple comparison of means through age 9, and females were over 2 in longer than males at age 9 (Table 8).

We calculated a mean growth index for walleyes of -3.1, which means walleyes in our sample from Crooked and Pickerel lakes appeared to grow substantially slower than the state average. However, this difference was likely due, at least in part, to biases between aging methods. State average mean lengths were estimated by scale aging, and Kocovsky and Carline (2000) found that ages estimated from scales were younger than ages estimated from spines for the same fish. If so, this would cause estimated mean lengths at age of scale-aged fish to be larger than spine-aged fish. Eventually, the Large Lakes Program will obtain enough data to recalculate new state averages based on spines, if we continue to use them, which will improve future comparisons.

Mean length at age data for male, female, and all walleyes were fit to a von Bertalanffy growth curve. Male, female, and all walleyes had L_∞ values of 18.1, 20.7, and 18.6 in, respectively.

Our analysis of variance indicated no significant difference in walleye mean length at age between Crooked and Pickerel lakes ($F = 0.664$, $P = 0.4320$). Additionally, there was no significant lake × age interaction ($F = 0.247$, $P = 0.6300$).

Female northern pike generally had higher mean lengths at age than males (Table 9). As with walleyes, this is typical for northern pike populations in general (Carlander 1969; Craig 1996). We obtained sufficient sample sizes for comparison through age 4, and females were almost 2 in longer than males at age 4 (Table 9).

We calculated a mean growth index for northern pike of -2.7, which means northern pike in our sample from Crooked and Pickerel lakes appeared to grow substantially slower than the state average. However, unknown biases associated with use of fin rays for aging makes this result dubious. As with walleyes, the Large Lakes Program will eventually age enough northern pike with fin rays to recalculate state averages for future comparisons.

Mean length at age data for male, female, and all northern pike were fit to a von Bertalanffy growth curve. Male, female, and all northern pike had L_∞ values of 22.4, 22.8, and 24.6 in, respectively.

Sample sizes of northern pike were insufficient to calculate meaningful mean lengths at age for individual lakes.

Mortality

For walleyes, we estimated catch at age for 705 males, 159 females, and 925 total walleyes, including those fish of unknown sex (Table 10). We used ages 6 and older in the catch-curve analysis to represent the legal-size population (Figure 8). We chose age 6 as the youngest age because: 1) average lengths of walleyes at age 6 was 15.3 in for males and 17.0 in for females (Table 8), so a high proportion of age-6 fish were legal size at the beginning of fishing season; and 2) relative abundance of fish younger than age 6 does not appear to be represented in proportion to their true abundance (Figure 8; Table 10), suggesting that fish (males and females) are not fully mature at age 5. We aged one fish to 15 years, but did not include this age group in analysis.

The catch-curve regressions for walleyes were all significant ($P < 0.05$), and produced total instantaneous mortality rates for legal-size fish of 0.7121 for males, 0.7485 for females, and 0.7047 for all fish (Figure 8). These instantaneous rates corresponded to annual mortality rates of 51% for males, 53% for females, and 51% for all fish combined. Thus for walleyes, total mortality was about equal for males and females.

The catch-curve regressions for walleyes did not differ between Crooked and Pickerel lakes ($F = 0.577$, $P = 0.4690$), and the lake × age interaction term was not significant ($F = 0.712$, $P = 0.4270$).

For northern pike, we estimated catch at age for 73 males, 62 females, and 274 total northern pike, including those fish of unknown sex (Table 10). The mean length of males did not exceed legal size (>24 in) for any age groups, thus, we used ages 3 through 5 in a catch-curve regression to represent the sublegal-size male northern pike population. The mean length of females only exceeded legal size for age groups 7 and 8, thus there were not enough age groups to do a catch curve for legal-size fish. For female northern pike and all northern pike, we used ages 3–6 in the catch-curve analysis. We chose age 3 as the youngest age because it is the first age group where the relative abundance of fish appears to be represented in proportion to their true abundance (Figure 9, Table 10).

The catch-curve regression of sublegal-size male northern pike was not significant, though it resulted in a total instantaneous mortality rate of 1.8688 (Figure 9). The regression for sublegal-size female northern pike was not significant and resulted in a total instantaneous mortality rate of 0.7444. The best catch-curve regression was for all northern pike ($P < 0.05$), which resulted in a total instantaneous mortality rate of 0.9959. These instantaneous rates corresponded to total annual mortality rates of 85% for sublegal-size males, 53% for sublegal-size females, and 63% for legal-size fish of all sexes. For northern pike, it appears that mortality was higher for sublegal-size males than for sublegal-size females, though neither regression was significant.

Sample sizes were not sufficient to estimate total mortality of northern pike for individual lakes.

Anglers returned a total of 72 tags (38 reward and 34 non-reward) from walleyes tagged in Crooked and Pickerel lakes (Table 11). The creel clerk did not observe any tagged fish in the possession of anglers that were not subsequently reported to the central office by the anglers. The combined estimated exploitation for walleyes in both lakes was 14.8% based on return of reward tags. After adjusting for tag loss (9.1%), this estimate increases slightly to 16.3%. Angler exploitation of walleyes was 29.3% (Table 7). The harvest estimate used here was adjusted first for tags reported during non-surveyed months, then for the proportion of harvested fish that were not of legal size at the time of tagging. Anglers reported both reward and non-reward tags at a similar rate (14.8% and 13.9%), but they likely did not fully report either one.

For each lake individually, anglers returned a total of 47 tags (23 reward and 24 non-reward) from walleyes tagged in Crooked Lake and 25 tags (15 reward and 10 non-reward) from walleyes tagged in Pickerel Lake in the year following tagging. Individual lake estimates for exploitation of walleyes were 15.2% and 14.2% for Crooked and Pickerel lakes, respectively.

Anglers did not return any tags from northern pike in the year following tagging. The creel clerk did not observe any tagged fish in the possession of anglers. We could not estimate exploitation of northern pike based on reward tag returns due to the absence of returns. The exploitation estimate based on harvest divided by abundance was 20.3% (Table 7). Our confidence in this estimate is low because few fish were marked, no marked fish were observed in the creel survey, and few northern pike were harvested. We will address possible violations to assumptions for exploitation estimates later in the **Discussion** section.

Recruitment

Variability in walleye year-class strength was relatively low in Crooked and Pickerel lakes, which can be seen in the statistics of the catch-curve regression. Residual values were small (see scatter of observed values around the regression line for all walleyes in Figure 8) and the amount of variation explained by the age variable (RCD) was high (R^2 = 0.94). Crooked and Pickerel lakes apparently had lower recruitment variability than Houghton Lake (R^2 = 0.86; Clark et al. 2004) and Michigamme Reservoir (R^2 = 0.87; Hanchin et al. 2005), which were surveyed as part of the same Large Lakes Program.

We tested for relationships between the residuals from the catch-curve regressions and data taken from the United States Historical Climatology Network (USHCN) weather station in Cheboygan, Michigan. Variables that we tested included: average monthly air temperatures, average monthly minimum air temperatures, average monthly maximum air temperatures, and average monthly precipitation. We did not find any environmental or climatological variables that were related to walleye year-class strength, though both regional climate data and water quality data specific to the lakes are lacking. Additionally, there was no relationship (F = 0.383, P = 0.5629) between the residuals from the catch-curve regression and the number of walleyes stocked in Crooked and Pickerel lakes, though walleyes were stocked in only three of the seven years used in the correlation.

For northern pike, variability in year-class strength was low in Crooked and Pickerel lakes, which can be seen in the statistics of the catch-curve regression. Though the catch-curve regression for all northern pike was based on only four age groups, the residual values were small (see scatter of observed values around the regression line for all northern pike in Figure 9), and the amount of variation explained by the age variable was high (R^2 = 0.997). Clark et al. (2004) similarly reported low recruitment variability for northern pike in Houghton Lake, Michigan (R^2 = 0.99).

Movement

A 17.6-in male walleye tagged on April 20, 2001 in Pickerel Lake was recaptured on April 21, 2001 by a crew on Crooked Lake. A total of 22 walleyes tagged in Pickerel Lake were recaptured during the spring netting survey. Thus, the movement of this single fish indicates at least some (around 5%) movement between lakes during the spawning run.

Based on voluntary tag returns during the year following tagging, there was significant movement of walleyes between Crooked and Pickerel lakes. Of walleyes that were tagged in Crooked Lake, 46 (97.9% of total returns) were reported as caught in Crooked Lake, and only 1 (2.1%) was reported as caught in Pickerel Lake (Table 12). In contrast, of walleyes tagged in Pickerel Lake, 12 (48.0% of total returns) were reported as caught in Pickerel Lake, and 13 (52.0%) were reported as caught in Crooked Lake. It appears that there was significant movement of adult walleyes from Pickerel Lake to Crooked Lake following the spawning period.

We could not assess movement of northern pike, as there were no northern pike tag returns.

Angler Survey

The results of the angler survey are reported separately for Crooked and Pickerel lakes in Appendices B and C. The results reported below are for the two-lake system as a whole.

Summer

The clerk interviewed 1,651 boating anglers during the summer 2001 survey on Crooked and Pickerel lakes. Most interviews (93%) were roving (incomplete-fishing trip).

Anglers fished an estimated 45,388 angler hours and made 24,071 angler trips (Table 13 and Appendices B and C).

The total harvest from Crooked and Pickerel lakes was 10,190 fish and consisted of eight different species (Table 13 and Appendices B and C). Bluegills were most numerous with an estimated harvest of 3,213, and no reported releases. Anglers harvested 2,177 walleyes and 3 northern pike, and reported releasing 8,912 walleyes (80% of total catch) and 1,844 (99.8% of total catch) northern pike. Anglers harvested 178 smallmouth bass and released 1,122 (86% of total catch). We do not know what proportion of the released fish was of legal size. In future surveys, we recommend distinguishing between sublegal- and legal-size fish released.

Winter

The clerk interviewed 245 open-ice anglers and 277 shanty anglers on Crooked and Pickerel lakes. Most open-ice (83%) and shanty (84%) interviews were roving type. Open-ice and shanty anglers fished 10,496 angler hours and made 3,519 trips on Crooked and Pickerel lakes (Table 14 and Appendices B and C).

A total of 3,433 fish were harvested and comprised five species. Anglers harvested 100 walleyes, and reported releasing 94 (48% of total catch). Anglers harvested 10 northern pike, and released 143 (93% of total catch). Anglers also harvested 3,246 yellow perch, 67 white suckers, and 10 brown trout. A total of 1,786 fish were caught and released.

Annual Totals for Summer and Winter

In the annual period of May 2001 through March 2002, anglers fished 55,884 hours and made 27,590 trips to Crooked and Pickerel lakes (Table 15 and Appendices B and C). Of the total annual fishing effort, 81% occurred in the open-water summer period and 19% occurred during ice-cover winter period. Anglers made 18,959 trips and fished 34,469 hours on Crooked Lake, compared to 8,631 trips and 21,415 hours on Pickerel Lake.

Yellow perch and walleye were the most numerous species caught (harvested + released) in Crooked and Pickerel lakes at 12,219 and 11,283, respectively. Resulting catch rates (catch per h including released fish) for yellow perch and walleyes were 0.2186 and 0.2019, respectively. A total of 2,000 northern pike were caught, resulting in a catch rate of 0.0358. 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 experience.

Nine species that we captured during spring netting operations did not appear in the angler harvest: alewife, black bullhead, bowfin, brown bullhead, burbot, common carp, longnose gar, rainbow trout, and yellow bullhead.

The total annual harvest in Crooked and Pickerel lakes was 13,623 fish. Yellow perch were the most commonly harvested species at 6,310, followed by bluegill at 3,213. All panfish (black crappie, bluegill, pumpkinseed, rock bass, and yellow perch) made up 81% of the total harvest. Panfish were harvested in the highest numbers from July through September, although winter harvest of yellow perch was also significant. There were no bluegill, pumpkinseed, or rock bass harvested during the winter months from either lake. Harvest of panfish species other than yellow perch was higher in Pickerel Lake than in Crooked Lake (Figure 10). The percentages of bluegills, pumpkinseed, and rock bass harvested that were taken from Pickerel Lake were 66%, 68%, and 54%, respectively.

The estimated total annual harvest of walleyes was 2,277, with 1,931 coming from Crooked Lake and 346 from Pickerel Lake. The majority of walleyes were harvested in the summer months of July and August (Table 15 and Appendices B and C), which is understandable as walleyes are known to feed more extensively during the open-water season (Craig 1987). The same pattern was found for smallmouth and largemouth bass, with no reported catches during winter months even incidentally (harvest of smallmouth and largemouth bass would have been illegal January–March). Harvest of northern pike was almost non-existent with an estimated 3 from Crooked Lake and 10 from Pickerel Lake. Harvest of smallmouth bass was also low, with 138 from Crooked Lake and 40 from

Pickerel Lake. Anglers released 80% of all walleyes caught, 99% of northern pike, and 86% of smallmouth bass. Although we did not differentiate between sublegal- and legal-size released fish, we assumed that a large proportion of the walleyes and northern pike released were sublegal size. This assumption was corroborated by the size structures of both species, which contained high proportions of sublegal-size fish (Table 5). In the spring survey, the proportions of walleyes and northern pike that were sublegal size were 47% and 96%, respectively.

We did not survey from October 1 through December 31, because we thought that relatively little fishing occurred during that time of year. However, six walleye tag returns (8.3% of total annual returns) were reported as caught in October (Table 11). Thus, it appears that we may have missed some angler effort, and consequently underestimated the total annual walleye harvest from Crooked and Pickerel lakes. Total annual walleye harvest from Crooked and Pickerel lakes was actually about 8.3% higher than our direct survey estimate, of 2,467 walleyes. We did not survey during April because both walleye and northern pike seasons were closed at that time.

Discussion

Fish Community

The seasonal and gear biases associated with our survey preclude comparisons of population and community indices to other general management surveys of Michigan lakes. Because of the mesh-size bias, smaller fish would not be represented in our sample in proportion to their true abundance in the lake. This would include juveniles of all species as well as entire populations of smaller fishes known to exist in Crooked and Pickerel lakes such as various species of shiners, darters, minnows, and other smaller fishes. For example, a 1954 survey (Table 6) using a seine found sand shiners, common shiners, bluntnose minnows, banded killifish, and logperch.

Because of the seasonal bias, we likely caught more large, mature fish of several species than would normally be caught in general management surveys that have historically been conducted later in spring or summer. This would include spring spawners such as walleyes, northern pike, white sucker, and yellow perch.

As part of the Large Lakes Program we recently surveyed Houghton Lake (Clark et al. 2004) and Michigamme Reservoir (Hanchin et al. 2004) using methods similar to this survey. However, we used nets with smaller mesh sizes in Michigamme Reservoir, so the results of the Houghton Lake survey are the only ones that can be directly compared to this survey. For example, it should be reasonable to compare fish community composition indices for Crooked and Pickerel lakes to those for Houghton Lake.

The fish community composition of Crooked and Pickerel lakes was vastly different from that of Houghton Lake. We observed 24.0% fish predators, 49.0% pelagic planktivores-insectivores, and 27.2% benthivores in Crooked and Pickerel lakes versus 61.3%, 30.1%, and 9.1%, respectively, for Houghton Lake. Presumably, reasons for these differences are related to differences in lake morphologies and habitats. For example, maximum depths of Crooked and Pickerel lakes are 50 ft and 75 ft, respectively, whereas the maximum depth of Houghton Lake is only 22 ft. Also, a much greater proportion of the water volume of Crooked and Pickerel lakes is deeper than 20 ft (about 55%) than Houghton Lake (<0.1%). These depth-volume characteristics probably favor production of a greater proportion of pelagic species in Crooked and Pickerel lakes.

Walleyes and Northern Pike

<u>Size Structure</u>

The size structures of both walleyes and northern pike in Crooked and Pickerel lakes contained relatively high proportions of smaller fish. The mean length of our walleye sample was 15.1 in, and 71% of fish were between 13 and 17 in. The largest walleye in our sample was 22.6 in. By comparison, the mean length of walleyes collected in Houghton Lake was 16.4 in, and 72% of fish were between 14 and 19 in (Clark et al. 2004). The largest walleye they collected was 29.1 in. In both distributions, the mean appeared to be a good measure of central tendency.

The mean length of our northern pike sample was 18.5 in, and 71% of fish were between 15 and 22 in. The largest northern pike in our sample was 31.8 in. By comparison, the mean length of northern pike collected in Houghton Lake was 20.9 in, and 71% of fish were between 17 and 25 in (Clark et al. 2004). The largest northern pike they collected was 41.4 in. In both distributions, the mean appeared to be a good measure of central tendency.

Based on the length frequency distributions alone, the growth potential of walleyes and northern pike in Crooked and Pickerel lakes appears to be poor. Walleyes are unlikely to attain lengths greater than 20 in, and northern pike rarely reach lengths greater than 24 in. We discuss possible reasons for, and ramifications of, these results in the *Mean Lengths at Age* section.

Sex Composition

Male walleyes outnumbered females for fish of legal size and for all fish. We were unable to find any previous information concerning sex composition from Crooked and Pickerel lakes for comparison. Sex of walleyes is readily determined during the spawning season by extruding gametes, but at other times of the year sex determination would require dissection of the fish, which is not part of past sampling protocols.

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

Male northern pike outnumbered females in Crooked and Pickerel lakes when all sizes were considered, though the proportions were similar. When only legal-size fish were considered, females outnumbered males, though the sample was composed of only 11 fish, 8 of which were of unidentified sex. This disparity between sex composition of all northern pike and those of legal size is likely due to faster growth in females. Higher natural mortality of males as reported by Craig (1996) would also contribute to this disparity. In fact, mortality of male northern pike was higher than females, though both estimates of mortality were uncertain. Clark et al. (2004) and Hanchin et al. (2005) found the same disparity in sex ratio of all northern pike versus northern pike of legal size in other Michigan lakes.

For northern pike from other lakes, males dominate sex composition in spawning-season samples, but not at other times of the year (Priegel and Krohn 1975; Bregazzi and Kennedy 1980). Bregazzi and Kennedy (1980) sampled northern pike with gill nets set throughout the year in Slapton Ley, a eutrophic lake in southern England. Sex ratios during the February and March spawning period ranged from 6:1 to 8:1 (male to female), but the overall sex ratio for an entire year of sampling was not significantly different from 1:1.

Abundance

We were generally successful in obtaining abundance estimates for walleyes in Crooked and Pickerel lakes (Table 7). For the multiple-census estimate, we obtained the minimum number of recaptures; however, we may have violated some conditions for an unbiased estimate that are discussed later. For the single-census estimate, we did not have sufficient numbers of fish observed for marks. Assuming that the legal-size walleye population was approximately 7,000 fish, and based on tagging around 500 fish, the recommended recapture sample to observe for marks in management studies ($\alpha = 0.05$, $p = 0.25$; where: p denotes the level of accuracy, and $1\text{-}\alpha$ the level of precision) is approximately 800 fish (Robson and Regier 1964). Our corrected recapture sample of 184 fish was short of this recommendation, and the recommendation for preliminary studies and management surveys ($\alpha = 0.05$, $p = 0.50$).

We think our single-census estimates were more reliable than our multiple-census estimates. Single-census estimates compared more favorably to other independently-derived estimates and had less serious methodological biases. The multiple-census estimates for walleyes were lower than the single-census estimates for both legal-size fish and adult fish (Table 7); however the 95% confidence limits between the two types of estimates overlapped considerably. Precision was similar between the single-census and the multiple-census estimates (Table 7). Confidence limits were within 52.9% of the single-census estimate, and within 54.3% of the multiple-census estimate.

Our single-census estimate appeared more accurate than the multiple-census estimate when judged in relation to the independently-derived harvest estimate for both lakes combined. For example, our adjusted (for non-surveyed months, and fish that were sublegal size at marking) harvest estimate of 2,063 legal-size walleyes would represent an exploitation rate of 43% if our multiple-census population estimate of 4,825 legal-size walleyes was accurate (Table 7). The harvest estimate fits better with the single-census population estimate of 7,049, producing an exploitation of 29%.

Both our multiple-census estimate of 9,553 adult walleyes and our single-census estimate of 12,346 adult walleyes were close to the Wisconsin regression estimate of 11,186 (Table 7). Our multiple-census estimate was 15% lower, and our single-census estimate was 9% higher. Clark et al. (2004) and Hanchin et al. (2005) also found estimates from the Wisconsin regression for walleyes in Houghton Lake and Michigamme Reservoir, Michigan were reasonably close to single-census estimates.

Population density of walleyes in Crooked and Pickerel lakes was about average compared to other lakes in Michigan and elsewhere. Our single-census estimate for 15-in and larger walleyes in Crooked and Pickerel lakes was 7,049 or 2.1 per acre. Lockwood (1998, unpublished data) used the single-census method to estimate abundance of 15-in and larger walleyes on 16,630-acre Mullett Lake, and reported a density of 0.8 per acre. Clark et al. (2004) estimated 2.9 legal-size walleyes per acre in Houghton Lake, Michigan, and Hanchin et al. (2005) reported 1.5 legal-size walleyes per acre in 6,400-acre Michigamme Reservoir. Nate et al. (2000) reported an average density of 2.2 adult walleyes per acre for 131 Wisconsin lakes having natural reproduction.

A different single-census method has been used for walleyes since the mid-1980s on smaller lakes in Wisconsin, Michigan, and Minnesota (Hansen 1989, Rose et al. 2002). These authors recaptured marked fish with electrofishing gear several days after the fish were marked. Results of these estimates were used to create the Wisconsin regression equation, which predicts Crooked and Pickerel lakes should have 11,186 spawning walleyes or 3.3 adult walleyes per acre. Population densities from our multiple-census estimate and single-census estimate of adult walleyes were 2.8 and 3.6 per acre, respectively.

We were less successful in obtaining abundance estimates for northern pike (Table 7), which was largely due to the small number of legal-size northern pike that were marked. We were unable to make a multiple-census estimate for legal-size northern pike due to the absence of recaptures during the spring survey. We also did not observe any legal-size northern pike recaptures during the creel survey, but the single-census method (Chapman modification of the Petersen formula) allows for an estimate because one is added to the number of recaptures for an unbiased estimate. Using our estimate of the legal-size northern pike population of approximately 50 fish, and knowing that we tagged approximately 10 fish, the recommended recapture sample to observe for marks in preliminary studies and management surveys ($\alpha = 0.05$, $p = 0.50$; where: p denotes the level of accuracy, and $1-\alpha$ the level of precision) is approximately 33 fish (Robson and Regier 1964). Our corrected recapture sample of three fish was well short of this recommendation. The high CV (0.61) of this estimate corroborates the low precision, and ultimately its low reliability.

The single-census estimate of adult northern pike was also unreliable, due to its direct calculation from the estimate for legal-size fish. Our most reliable estimate for northern pike was the multiple-census estimate of adults. Confidence intervals for estimates of adult abundance were broad (Table 7). For example, while the single-census estimate was considerably lower than the multiple-census estimate, 95% confidence limits for the two estimates overlapped. Precision was better for the single-census than for the multiple-census estimate, but this was likely due to the low number of fish handled. Confidence limits were within 120% of the single-census estimate and within 227% of the multiple-census estimate. Because we had only a single reliable estimate for northern pike, it is not prudent to use the set of estimates for Crooked and Pickerel lakes for broad comparisons between methods.

Despite low confidence in our single-census estimate, it appeared accurate when judged in relation to the independently-derived harvest estimate. Our corrected harvest estimate of 10 legal-size northern pike fits with an abundance estimate of 48 fish, producing a reasonable exploitation rate of 20.3%.

Population density of northern pike in Crooked and Pickerel lakes was low compared to other lakes in Michigan and elsewhere. Craig (1996) reported densities for northern pike from across North America and Europe ranging from 1 to 29 fish per acre (considering only estimates done for age-1 and older fish). Also, Pierce et al. (1995) estimated abundance and density of northern pike in seven small (<300 ha) Minnesota lakes. Their estimates of density ranged from 4.5 to 22.3 per acre for fish age 2 and older. Our estimates of numbers of adult northern pike in Crooked and Pickerel lakes would essentially be for fish age 2 and older, and should be comparable, but our single-census estimate converted to a density of only 0.01 per acre. Clark et al. (2004) reported an adult northern pike density of 1.6 per acre for Houghton Lake, Michigan, and Hanchin et al. (2005) reported 2.0 for Michigamme Reservoir, Michigan. Our estimate for Crooked and Pickerel lakes is much lower than either of these estimates, which were considered low-density populations.

There are several potential sources of error in our multiple-census estimates of walleye and northern pike abundances. One assumption of the method is that marked fish become randomly mixed with unmarked fish. Over the course of our netting operation marked fish were probably not mixing completely with the total population at large. An alternative description of this condition is that fishing effort is randomly distributed over the population being sampled (Ricker 1975). As fish moved off the spawning grounds and were excluded from our sampling gear, we violated this assumption. In contrast to the problems associated with the multiple-census method, the single-census estimate from the creel survey is likely to be more accurate, because it allows sufficient time for the marked fish to fully mix with unmarked fish. Additionally, it does not matter if all spawning congregations are sampled in the initial tagging operation.

Our multiple-census estimates were 23–31% lower than single-census estimates for walleyes, but the multiple-census estimate was 206% higher for adult northern pike (single comparison). As previously mentioned, the single-census estimate for northern pike was uncertain and likely an underestimate. Our results for walleyes were similar to those of Pierce (1997) who found that multiple-census methods underestimated abundance. He compared multiple-census estimates of northern pike abundance made with a single gear type (trap nets) to single-census estimates made with two gear types (marking with trap nets and recapturing several weeks later with experimental gill nets). He found that multiple-census estimates averaged 39% lower than single-census estimates. Pierce concluded that gear-size selectivity and unequal vulnerability of fish to nearshore netting make multiple-census estimates consistently low. He also concluded that recapturing fish at a later time with a second gear type resulted in estimates that were more valid. Clark et al. (2004) and Hanchin et al. (2005) also found that multiple-census methods underestimated walleye and northern pike abundance relative to single-census methods.

Clark et al. (2004) described how to improve accuracy and precision of abundance estimates on Houghton Lake by increasing either the number of fish tagged or recaptured, but noted that even marginal improvements would be very costly. The system of Crooked and Pickerel lakes, however, is only about one sixth the size of Houghton Lake.

Based on our experience in this study, we believe it would be possible, but costly, to improve the precision of the walleye abundance estimates for Crooked and Pickerel lakes. Obtaining more precise estimates would require: 1) marking more fish; 2) recapturing more marked fish; or 3) both. Confidence limits on our bi-census estimate of 7,049 legal-size walleyes were ± 53% of the estimate (Table 7), which is about what would be predicted given that 502 fish, or 7% of the population, were marked (Figure 6). We collected and marked 494 walleyes (>98%) with two, 10-net, three-person work crews. To simplify these cost/benefit exercises of improving precision, we did not consider fish collected using electrofishing gear. The average number of fish marked per three-person crew was approximately 250 over the course of the 2-week survey. In order to achieve precision of ± 20%, it would be necessary to mark about 2,115 walleyes (30% of the population; Figure 6). Assuming that the number of fish marked per crew did not diminish with increasing number of crews, this would have taken eight netting crews with 24 people and over 80 nets working on the lake during the two weeks after ice-out. This amount of necessary effort would more than quadruple the effort used on the survey. Hanchin et al. (2005) and Clark et al. (2004) estimated twofold and sixfold increases in necessary effort when doing the same exercise for improving the precision of abundance estimates.

Improving precision by increasing the number of fish recaptured would also be costly. Based on the formula for confidence limits, a supplemental recapture effort using nets, electrofishing gear, or additional angler survey clerks would have to obtain an eightfold increase in the number of marked and unmarked fish observed in the recapture run to improve precision to about ± 20%. This would require several additional angler-survey clerks or a substantial netting and/or electrofishing effort, which would be cost prohibitive.

Mean Lengths at Age

Mean lengths at age for walleyes from our survey were lower than those from previous surveys of Crooked and Pickerel lakes (Table 16). It appears that growth has possibly declined over time. The mean growth index for walleye in Crooked and Pickerel lakes was -1.1, -1.7, and -2.5 in 1971, 1972, and 1989, respectively (MDNR Fisheries Division, unpublished data). Schneider (2000) suggested that growth indices in the range of ± 1.0 in are satisfactory for game fish, so walleye growth in Crooked and Pickerel lakes has not been satisfactory in the past. Continuing that trend, the mean growth index of -3.2 observed in 2001, is well below satisfactory. Walleye mean lengths at age in 2001 were also lower than the state average for all ages except age 2 (Table 16).

When comparing our mean lengths at age to other surveys, it is important to note that we used different aging structures. A likely bias of comparing mean lengths at age calculated from scales and spines is that more of the larger, older fish would be incorrectly assigned to younger ages when scales are used. Thus, mean lengths would be overestimated for a scale-aged sample. Clark et al. (2004) and Hanchin et al. (2005) both found similar differences in mean lengths at age calculated using spines and scales.

The values we calculated for L_∞ provide some insight into the growth potential of a population. The L_∞ for male walleyes was 18.1 in, only 3.1 in greater than the minimum size limit; thus males likely make up only a small percentage of the harvestable walleye population in Crooked and Pickerel lakes. L_∞ for female walleyes was 20.7 in, which was 2.6 in greater than that of males. Obviously, female walleyes have greater growth potential than males. L_∞ for all walleyes (18.6 in) was between that of males and females.

The L_∞ value for Crooked and Pickerel lake walleyes was similar to that of Michigamme Reservoir (20.1 in), which was surveyed as part of this program, but was lower than that of Houghton Lake (26.6 in).

The slow growth of walleyes in Crooked and Pickerel lakes is likely due to the low productivity of the system. Additionally, recruitment is rather consistent and stocking has been occurring regularly, which may increase competition for scarce prey. In fact, walleye stocking increased significantly during the years following those used for mean length at age comparison. For example, a total of 17,050 walleye fingerlings were stocked in Crooked and Pickerel lakes from 1985 to 1990, compared to 595,450 from 1991 to 2001 (Table 1).

Mean lengths at age for northern pike from our survey were lower on average than those from previous surveys of Crooked and Pickerel lakes, though few comparisons were available (Table 17). The mean growth indices were -1.1, -0.5, and -1.8 in 1971, 1972 and 1989, respectively (MDNR Fisheries Division unpublished data), compared to the 2001 estimate of -2.7. Our estimated mean lengths at age for northern pike were also lower than state averages. The northern pike population is slow-growing, though in the past growth has been characterized as satisfactory. As with walleyes, state averages for northern pike were based entirely on scale aging, which probably overestimates mean lengths for older ages. Unfortunately, biases of finray aging are unknown.

The L_∞ for male northern pike was 22.4 in, which is 1.6 in lower than the minimum size limit; thus males likely compose little or none of the harvestable northern pike population in Crooked and Pickerel lakes. L_∞ for female northern pike was 22.8 in, 1.2 in less than the minimum size limit, indicating that the average female does not have the potential to reach legal size. L_∞ for all northern pike (24.6 in) was greater than that of either males or females. However, this estimate was affected by a few old fish. In fact, the majority of northern pike in Crooked and Pickerel lakes never reach legal size (Table 9). It is possible that the few large fish we see in Crooked and Pickerel lakes are transients from Burt Lake or Mullett Lake. Both of the latter are known to have higher walleye and northern pike growth rates than Crooked and Pickerel lakes. Also, movement from Burt and Mullett lakes into Crooked and Pickerel lakes has been documented for walleyes. The L_∞ values for Crooked and Pickerel lake northern pike are much lower than those from other large lakes surveyed as part of this program. The L_∞ value for Michigamme Reservoir northern pike was 40.2 in, and L_∞ for Houghton Lake northern pike was 45.0 in.

Mortality

To our knowledge, this was the first attempt to estimate total mortality of walleyes from Crooked and Pickerel lakes. We determined that total mortality was about average, with at least 12 year classes represented. Regarding longevity, the maximum age that we observed for male walleyes (15) was 4 years older than for females (11), suggesting that males might be longer lived.

Compared to total mortality estimates for walleyes from other lakes in Michigan and elsewhere, our estimate of 51% is about average. Clark et al. (2004) estimated total mortality of walleyes in Houghton Lake to be 46%, and Hanchin et al. (2005) estimated total mortality of walleyes in Michigamme Reservoir to be 37%. Schneider (1978) summarized available estimates of total annual mortality for adult walleyes in Michigan. They ranged from 20% in Lake Gogebic to 65% in the bays de Noc, Lake Michigan. Schneider also presented estimates from lakes throughout Midwestern North America, other than Michigan. They ranged from 31% in Escanaba Lake, Wisconsin to 70% in Red Lakes, Minnesota. Colby et al. (1979) summarized total mortality rates for walleyes from a number of lakes across North America. They ranged from 13% to 84% for fish age 2 and older, with the majority of lakes between 35% and 65%.

In addition to displaying average total mortality, the age structure of our walleye sample contained fair numbers of fish older than age 10, suggesting that overharvest of walleyes was not occurring.

Our estimate of the annual exploitation rate of walleyes was 16.3% from tag returns and 29.3% based on estimated harvest/abundance. Both estimates were in a reasonable range, lower than the estimates of total mortality. We consider the tag return estimate to be a minimum because we did not adjust for tagging mortality or non-reporting, and if these occurred to any degree, we would have underestimated exploitation (Miranda et al. 2002). We did adjust for tag loss, which resulted in an increase of 10% over the unadjusted estimate. Kallemeyn (1989) reported a 27% increase in an estimate for exploitation of walleyes when adjusting for loss of Carling tags. We attempted to measure non-reporting of tags by offering a $10 reward on about half of the tags and comparing return rates of reward to non-reward tags. We found that reporting rate for reward tags in Crooked and Pickerel lakes was only slightly higher than for non-reward tags. Clark et al. (2004) used the same tags and reward amount in Houghton Lake and did not observe much difference in return rates of reward and non-reward tags. Our reward amount was relatively low compared to those used by other authors (Miranda et al. 2002).

We also checked to see if all the tags observed by our creel clerk in the possession of anglers were subsequently reported, and they were. The true exploitation rate for walleyes in Crooked and Pickerel lakes is likely between our two estimates; the midpoint of which is 22.8%.

The MDNR previously estimated walleye exploitation in Crooked Lake from tag returns in 1952. They had an 11% return rate of 249 tagged walleyes (non-reward tags) in the first calendar year. Although our estimate of angler exploitation was higher than that in 1952, it does not necessarily represent a true increase. We likely had higher returns because of the high visibility of our study and the use of reward tags.

Compared to exploitation rates for walleyes from other lakes in Michigan and elsewhere, our estimate of 16.3% to 29.3% for Crooked and Pickerel lakes is about average. For example, Thomas and Haas (2000) estimated angler exploitation rates from western Lake Erie at 7.5% to 38.8% from 1989 through 1998, and Serns and Kempinger (1981) reported average exploitation rates of 24.6% (male) and 27.3% (female) for walleyes in Escanaba Lake, Wisconsin 1958–79. Schneider (1978) gave a range of 5% to 50% for lakes in Midwestern North America, and Carlander (1997) gave a range of 5% to 59% for a sample of lakes throughout North America.

This was the first attempt to estimate total mortality of northern pike from Crooked and Pickerel lakes. Compared to total annual mortality estimates for northern pike from other lakes in Michigan and elsewhere, our estimate of 63% was above average. Clark et al. (2004) estimated total annual mortality for northern pike in Houghton Lake, Michigan to be 51%, and Hanchin et al. (2005) reported 63% for Michigamme Reservoir. Diana (1983) estimated total annual mortality for two other lakes in Michigan, Murray Lake at 24.4% and Lac Vieux Desert at 36.2%. Pierce et al. (1995) estimated total mortality for northern pike in seven small (<300 acres) lakes in Minnesota to be 36% to 65%. Pierce et al. also summarized total mortality for adult northern pike from a number of lakes across North America and they ranged from a low of 19% (Mosindy et al. 1987) to a high of 91% (Kempinger and Carline 1978), with the majority of lakes between 35% and 65%.

There were nine age classes of northern pike represented in our sample (Table 9), though only a small proportion of fish were older than age 5. This apparent drop in the relative abundance of older fish does not appear to correspond with their attainment to legal size. Instead, the age structure suggests that significant mortality is occurring prior to the average fish reaching legal size. Thus, natural mortality likely contributes more to total mortality than fishing mortality for northern pike.

Although our exploitation estimate of 20.3% for northern pike was statistically weak, it was reasonable, ranking as average compared to rates from other lakes in Michigan and elsewhere. Latta (1972) reported northern pike exploitation in two Michigan lakes, Grebe Lake at 12–23% and Fletcher Pond at 38%. Pierce et al. (1995) reported rates of 8% to 46% for fish over 20 in for seven lakes in Minnesota. Carlander (1969) gave a range of 14% to 41% for a sample of lakes throughout North America. Finally, Clark et al. (2004) reported rates of exploitation from 18.2% to 44.7% for northern pike in Houghton Lake, Michigan.

Recruitment

We collected walleyes from 12 year classes in Crooked and Pickerel lakes (ages 2 through 12, and 15). Of these, at least 11 consecutive year classes (ages 2–12) were present in appreciable numbers. Also, year-class strength for legal-size fish was rather consistent from 1989 through 1995, the years included in our catch-curve regression. On the other hand, numbers of walleyes stocked from 1989 through 1995 were very inconsistent (Table 1). Significant numbers were stocked in only two years (1991 and 1994), while none were stocked in three years (1992, 1993, and 1995). This, and the fact that we found no relationship between the number stocked and the catch-curve residuals, suggested that stocking contributes little to this population and fishery. In addition, a previous evaluation of walleye stocking success was conducted on Crooked Lake by MDNR in 2000. They estimated that natural reproduction accounted for 70% of age-0 walleyes (MDNR, Fish Collection System).

For northern pike, eight year classes (ages 1 through 8) were represented in our samples. Year-class strength was relatively consistent from 1995 through 1998, the years included in our catch-curve regression. While there were no multiple-year recruitment indices to gauge variability in year-class strength for northern pike, our single-year sample suggested recruitment was consistent in Crooked and Pickerel lakes.

Movement

The walleye movement patterns that we observed suggested fish may move into Pickerel Lake to spawn. This is an upstream movement through the Pickerel Lake channel, which makes sense given the riverine spawning tendency of many walleye populations. The movement out of Pickerel Lake following the spawning period suggests either that walleyes are returning to their summer feeding grounds, or that conditions in Crooked Lake are for some reason more favorable. In comparison, walleyes tagged in Crooked Lake in 1952 were captured in numerous parts of the inland waterway, but most came from Burt and Crooked lakes.

Although we documented movement of walleyes between Crooked and Pickerel lakes, we do not necessarily know the timing or duration of movement. While it is interesting to know the seasonal movement patterns of walleyes within the system, movements associated with spawning are the most important. Our study did not allow us to determine if walleyes demonstrated site fidelity in spawning. Knowledge of site fidelity would have potential implications in the allocation of walleye harvest, and thus should be considered in future research. Future efforts should involve extensive collection of spawning walleyes in the years after marking.

Angler Survey

Comparisons Between Crooked and Pickerel Lakes

Results of our angler survey showed some differences between lakes. Total annual angler effort on Crooked Lake was greater than on Pickerel Lake, but hours fished per acre were greater on Pickerel Lake (19.8 versus 14.7). Furthermore, hours fished per acre on Pickerel Lake were greater than on Crooked Lake during the summer (17.5 versus 11.2), but hours fished per acre on Crooked Lake were slightly greater during the winter (3.4 versus 2.3).

Harvest rates of panfish other than yellow perch were much higher on Pickerel Lake. Harvest per acre of these species was also much higher on Pickerel Lake. Harvest rates of yellow perch were similar between the lakes (Appendices B and C), and harvest per acre was almost identical. While panfish were readily caught in both lakes, it appears that angling for panfish was better in Pickerel Lake.

In contrast, while the number of walleyes released was similar between lakes, more were harvested in Crooked Lake. This suggests that there were more walleyes in Crooked Lake, and specifically more walleyes of legal size. Accordingly, the average size of walleyes in our spring survey was greater in Crooked Lake. Additionally, both the harvest rate (Crooked = 0.06; Pickerel = 0.02) and the harvest per acre (Crooked = 0.8; Pickerel = 0.3) of walleyes were higher for Crooked Lake.

Historical Comparisons

A general creel census in the 1940s and 1950s included Crooked and Pickerel lakes, but was designed to measure only the success of anglers who were actually interviewed and estimates were not expanded for the total catch of all anglers. These general census estimates would not be directly comparable to our estimates. However, considering the general census alone, from 1942 to 1953 panfish species dominated the catch on Crooked Lake. Biologists reported that the catch per h of legal-size fish was substantially above the state average, which they attributed to the high percentage of yellow perch in the catch. Walleyes and northern pike made up only 3% and 5% of the total catch in the 1940s and 1950s. In comparison, walleyes composed 36%, and northern pike 6% of the total catch in our 2001 angler survey of Crooked Lake. So either walleyes have increased in abundance or anglers have become more efficient at harvesting them.

Lockwood (MDNR, unpublished data) reported results from a 1975 winter creel survey of Crooked and Pickerel lakes. He used methods similar to those used in our survey, thus results are comparable. The months of February and March were surveyed, though it is unknown exactly how many days in each month were surveyed. Total angler hours and trips (with two standard errors) were 8,950 (2,325) and 2,768 (735) compared to our totals for February and March of 4,883 (1,539) and 1,503 (600). In the 1975 survey, 91% of the angler effort took place on Crooked Lake, compared to 70% in 2001. Catch of walleyes and northern pike were similar between both surveys. Anglers caught 125 (186) walleyes and 27 (56) northern pike in February and March of 1975 on Crooked and Pickerel lakes, while they caught 160 (96) walleyes and 103 (80) northern pike in February and March of 2001. Because effort was apparently much greater in 1975, the similar walleye catch between years suggests that the walleye population has increased since 1975. Accordingly, the catch rate for walleyes in February and March of 2001 was over twice that of 1975 (0.0328 versus 0.0140).

Conversely, the February and March catch of bluegill in Crooked and Pickerel lakes was 2,435 (1,228) in 1975 compared to zero in February and March of 2001. We found it interesting that there were no bluegill, pumpkinseed, or rock bass harvested during the winter months from either Crooked or Pickerel lakes. These species were commonly harvested during the summer months. The creel clerk substantiated the fact that currently, winter angler effort is almost entirely for yellow perch and walleye. He also communicated the anecdotal evidence that there was considerable angler harvest of panfish in the recent past. Thus, the large discrepancy between estimates suggests a possible reduction in panfish abundance since 1975.

Comparisons to Other Large Lakes

In general, surveys conducted in Michigan in the past 10 years used the same methods we used on Crooked and Pickerel lakes, but most of them still differ from our survey in seasonal time frame. For example, few other surveys were done in consecutive summer and winter periods. Regardless, for comparison, we used recent angler survey results for Michigan's large inland lakes from 1993 through 1999 as compiled by Lockwood (2000a) and results for Michigan's Great Lakes waters in 2001 compiled by Rakoczy and Wesander-Russell (2002).

We estimated 55,884 angler hours occurred on Crooked and Pickerel lakes from May 2001 through March 2002. This total effort was lower than other large lakes (Table 18), but the effort per surface area is rather high. Only Houghton Lake and Fletcher Pond had higher effort per acre.

For walleyes, our estimated annual harvest (adjusted for months not surveyed) from Crooked and Pickerel lakes was 0.7 fish per acre. This harvest was about average relative to other waters in Michigan. The average harvest of six other large Michigan lakes (>1,000 acres) reported by Lockwood (2000a) was 0.9 walleyes per acre, ranging from 0.1 per acre in Brevoort Lake, Mackinac County to 2.4 per acre in Chicagon Lake, Iron County.

These Michigan lakes were all subject to similar gear and fishing regulations, including a 15-in minimum size limit.

For northern pike, our estimated annual harvest from Crooked and Pickerel lakes was 0.004 fish per acre. This harvest was well below average compared to other waters in Michigan and elsewhere. The average harvest of seven other large Michigan lakes (>1,000 acres) reported by Lockwood (2000a) was 0.2 northern pike per acre, ranging from fewer than 0.1 per acre in Bond Falls Flowage, Gogebic County to 0.7 per acre in Fletcher Pond, Alpena County. These Michigan lakes were all subject to similar gear and fishing regulations, including a 24-in minimum size limit. Elsewhere, Pierce et al. (1995) estimated harvests from 0.7 to 3.6 per acre in seven, smaller Minnesota lakes. These lakes ranged from 136 to 628 acres in size and had no minimum size limits for northern pike.

The estimated annual harvest per acre of panfish, including yellow perch, bluegill, pumpkinseed, rock bass, and crappie, was 3.2 for Crooked and Pickerel lakes. Harvest per acre was greatest for yellow perch at 1.8, followed by bluegill at 0.9. In comparison, Houghton Lake had 17.8 panfish harvested per acre, and Michigamme Reservoir had 1.1 panfish harvested per acre. Acknowledging the difficulties associated with our lack of information on targeted effort, the catch rate for panfish in Crooked and Pickerel lakes was 0.3035 per h, compared to 0.7138 per h for Houghton Lake, and 0.1331 per h for Michigamme Reservoir.

Management Implications

The walleye fishery in Crooked and Pickerel lakes should be characterized as one with average natural reproduction, population density, harvest, and mortality rates; but with below average individual growth. Fish up to age 12 were well represented in our sample, and most of the year classes in our sample were from years in which no stocking or low stocking rates occurred. This indicated good to average natural reproduction. The population density was 3.6 adult walleyes per acre. The harvest was 0.7 walleyes per acre and harvest per h was 0.041. The annual exploitation rate was 16.3% to 29.3%, and the total annual mortality was 51%. Compared to other walleye fisheries in Michigan and elsewhere, these estimates were about average. On the other hand, slow growth was indicated by mean lengths at age that were well below average, producing a mean growth index of -3.1.

Stocking does not appear to be benefiting the walleye population or fishery in Crooked and Pickerel lakes. In fact, given the slow growth we found, stocking might do more harm than good. Harmful effects would be primarily from density-dependent interactions, such as increased competition for food or cannibalism. For example, Li et al. (1996a) found that in places where walleye year-class strength was increased from stocking, the mean weight of individual fish decreased. Our results for Crooked and Pickerel lakes suggest that growth might have decreased following stocking. Therefore, it is possible that eliminating or reducing stocking might improve walleye growth in the system.

The northern pike fishery in Crooked and Pickerel lakes should be characterized as one with well below average population density, harvest, and individual growth. Natural reproduction appears consistent, but must be low level, given the low population density. Relative to other northern pike populations in Michigan and elsewhere, our estimates of population density and harvest of 0.01 and 0.004 fish per acre, respectively, were very low. Mean lengths at age were also low, with a mean growth index of -2.7. The total annual mortality rate we estimated for northern pike was relatively high, but angler exploitation did not appear to be a large component of this mortality. Thus, the current minimum size limit for northern pike may be of little value (Noble and Jones 1999). Essentially, the minimum size limit is high enough that most fish die from natural, or hooking mortality before they exceed the length limit.

In 2003, a set of lakes were selected where there would be no size limit on northern pike. At the time, managers did not have adequate data on Crooked and Pickerel lakes for consideration. While there were no strict criteria for selection of lakes to include in this regulation, populations generally had consistent recruitment, slow growth, and low size structure with a large proportion of fish of sublegal size. The current northern pike population in Crooked and Pickerel lakes is consistent with the general criteria for having no size limit. Results from our spring netting showed that there were very few pike at or above the current minimum size limit of 24 in. Additionally, growth was slow, and very few legal-size pike were caught or harvested. Harvest per acre was well below average compared to other waters in Michigan, and the high release rate (99%) for northern pike suggested that most were sublegal size.

Netting surveys conducted in Crooked and Pickerel lakes during the winters of 1954 and 1958 showed high numbers of legal-size northern pike at a time when the minimum size limit was only 14 in. Other factors, such as a loss of spawning habitat due to shoreline development, and improvements in fishing technology must be considered, but these older surveys indicated that the fishery could withstand as low as a 14-in minimum size limit, given the fishing effort present during the 1950s.

One characteristic of the northern pike population that currently does not support removal of the size limit is its apparent low density, which would be of concern if it is accurate. Unfortunately, there is much uncertainty in our abundance estimates because of the low number of recaptures. If the population truly has very low density, the value of the current regulation might be to conserve a very low density population. The removal of a size limit usually applies to populations that display slow growth due to high density. In such cases, the presence of high density suggests that natural reproduction is adequate to support increased exploitation, but we cannot be sure if reproduction is adequate in Crooked and Pickerel lakes.

Though angler exploitation appeared to be a small component of total mortality in our surveys, we are concerned about the accuracy of an estimate of exploitation that is based on such small sample sizes and is only for fish larger than 24 in. Additionally, the northern pike fishery in Crooked and Pickerel lakes might not be self-regulating. Hansen et al. (2000) reported that angling was self-regulating due to its dependence on density of fish. That is, they showed that when fish populations are low in a given lake, anglers move to other lakes where fish were more abundant. However, walleyes were the main focus and primary targets of the fisheries they studied. Northern pike in Crooked and Pickerel lakes are largely the bycatch of a sport fishery for walleyes. It is not likely that anglers would stop fishing Crooked and Pickerel lakes as they caught fewer pike, because they would continue to target walleyes. Thus, even if the abundance of northern pike declined, they would continue to suffer the same mortality as bycatch in the walleye fishery.

Another concern is that two of our more statistically reliable estimates indicated that removing the 24-in minimum size limit on northern pike would risk overfishing. Our estimate of 1,987 northern pike caught and released from our angler survey was essentially equal to the total abundance estimate of 1,921 adult northern pike from our multiple-census method. These two estimates are largely for the same 14- to 24-inch, sublegal-size fish, so these results suggested that nearly every adult fish in the population was caught and released. Thus, if the minimum size limit was removed and the anglers harvested those fish, the exploitation rate for northern pike would approach 100%.

The overall fishery in Crooked and Pickerel lakes is relatively good. The number of fish harvested per h was similar to nearby Burt and Mullett lakes, though the number of fish harvested per acre was much higher in Crooked and Pickerel lakes. We were surprised by the number of hours fished per acre, which was less than only Houghton Lake and Fletcher Pond among other large lakes surveyed using similar methods. The system produced considerable harvest of panfish as well as walleye.

Methods used for harvest, abundance, age and growth, and mortality estimates for walleyes performed fairly well, considering the size of Crooked and Pickerel lakes. Estimates for northern pike were hindered by the small number of legal-size fish collected. We are not yet able to determine which of the different methods for estimating abundance (multiple- or single-census) and fishing mortality (tag returns or harvest/abundance) are best for long-term use, though results from the two methods for estimating abundance were more similar for Crooked and Pickerel lakes than for other large lakes. Comparisons must be repeated on more lakes before conclusions can be made. Thus, the overall approach used in this study should be continued on other large lakes before significant changes are made.

Our estimates of adult walleye abundance were close to the estimate made a priori with the Wisconsin regression equation. Thus, in the short term, it seems reasonable to apply the Wisconsin regression to estimate walleye abundance in other Michigan lakes when abundance estimates are needed for management purposes. In the long term, MDNR should continue to work towards developing an improved regression by conducting abundance estimates in other Michigan lakes.

Acknowledgements

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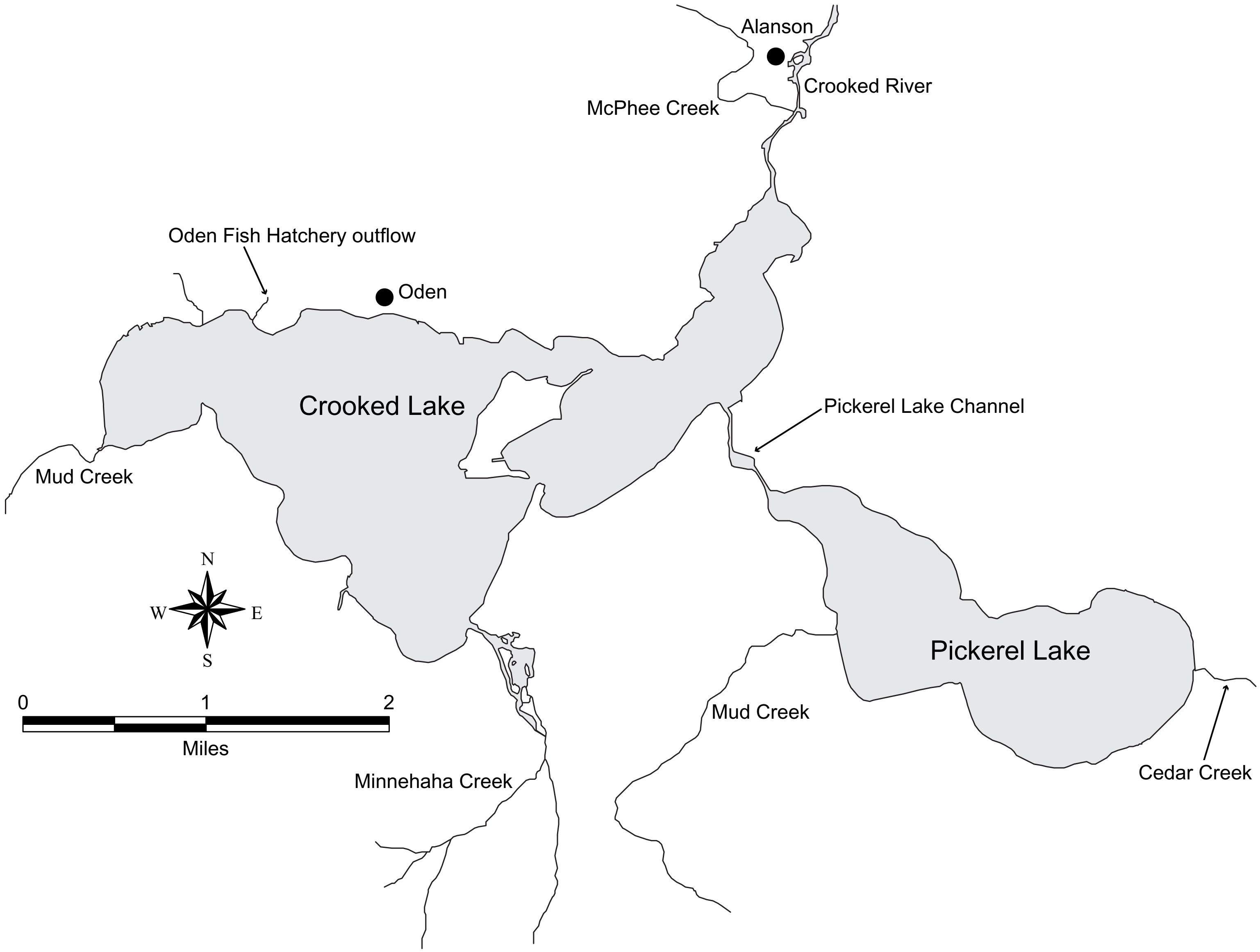


Figure 1.−Map of Crooked and Pickerel lakes, Emmet County, Michigan.

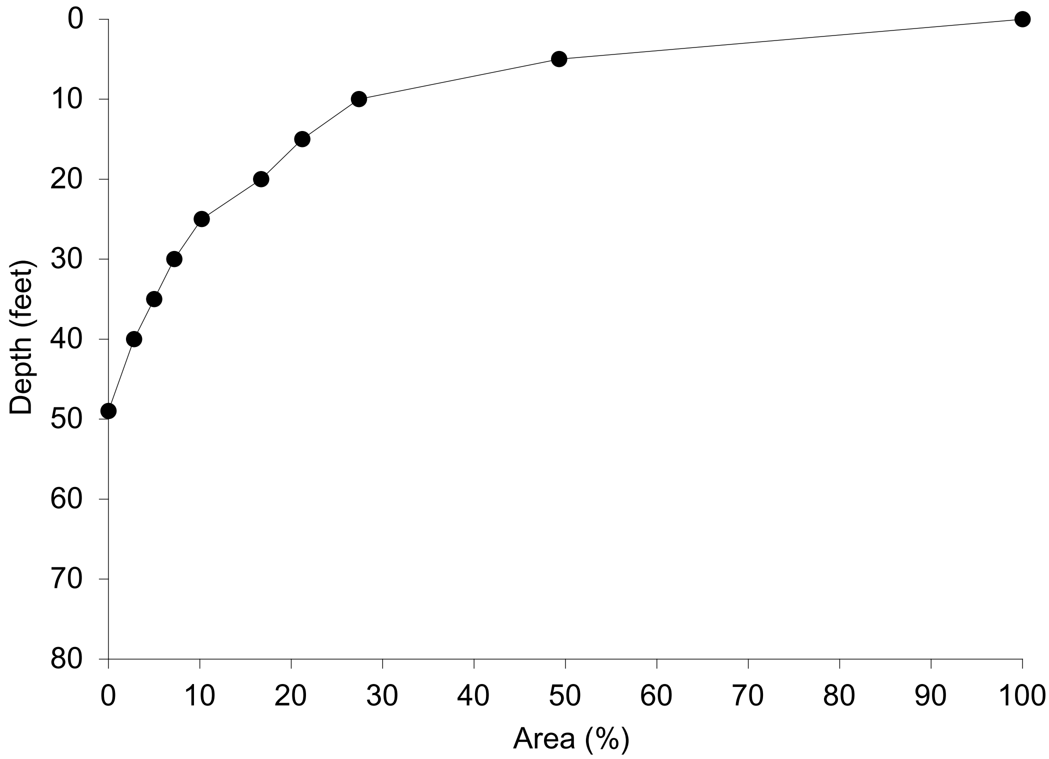


Figure 2.–Percentage of area by depth for Crooked Lake, Michigan. Data taken from MDNR Digital Water Atlas.

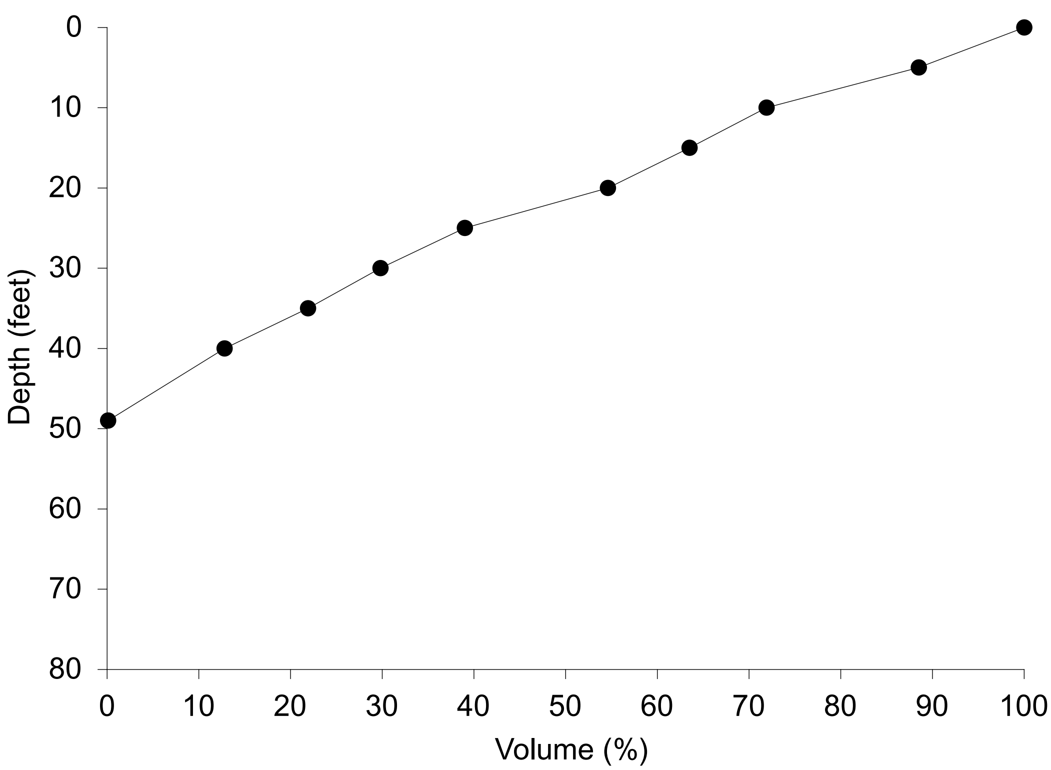


Figure 3.–Percent of volume by depth for Crooked Lake, Michigan. Data taken from MDNR Digital Water Atlas.

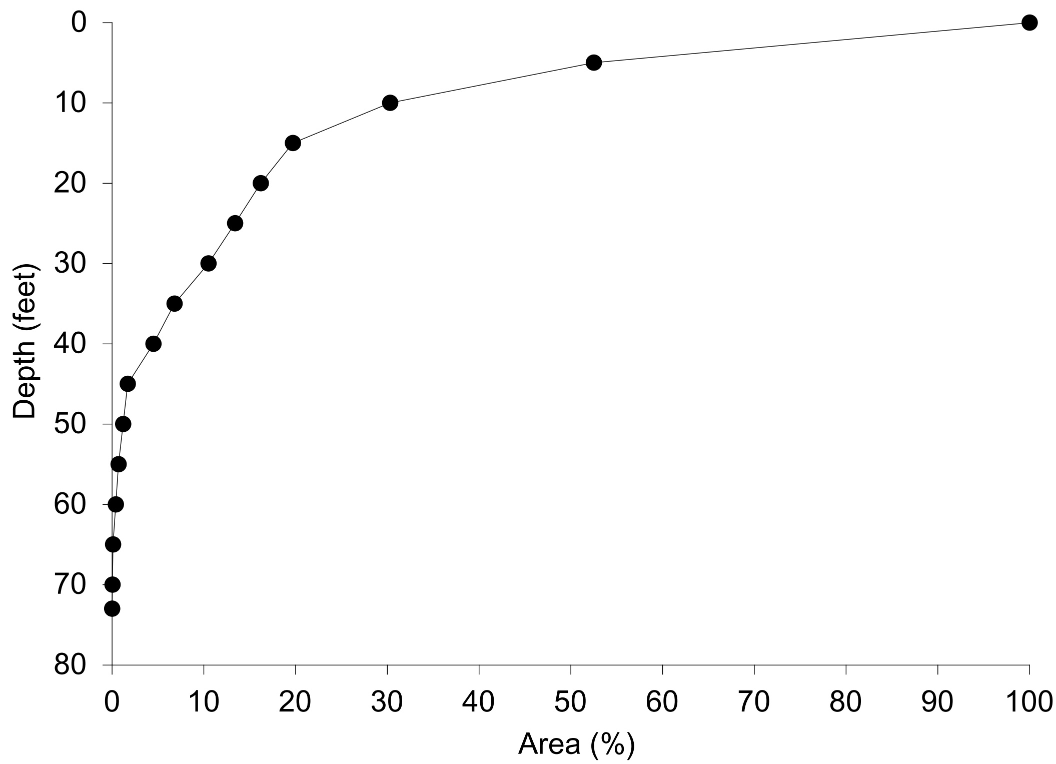


Figure 4.−Percent of area by depth for Pickerel Lake, Michigan. Data taken from MDNR Digital Water Atlas.

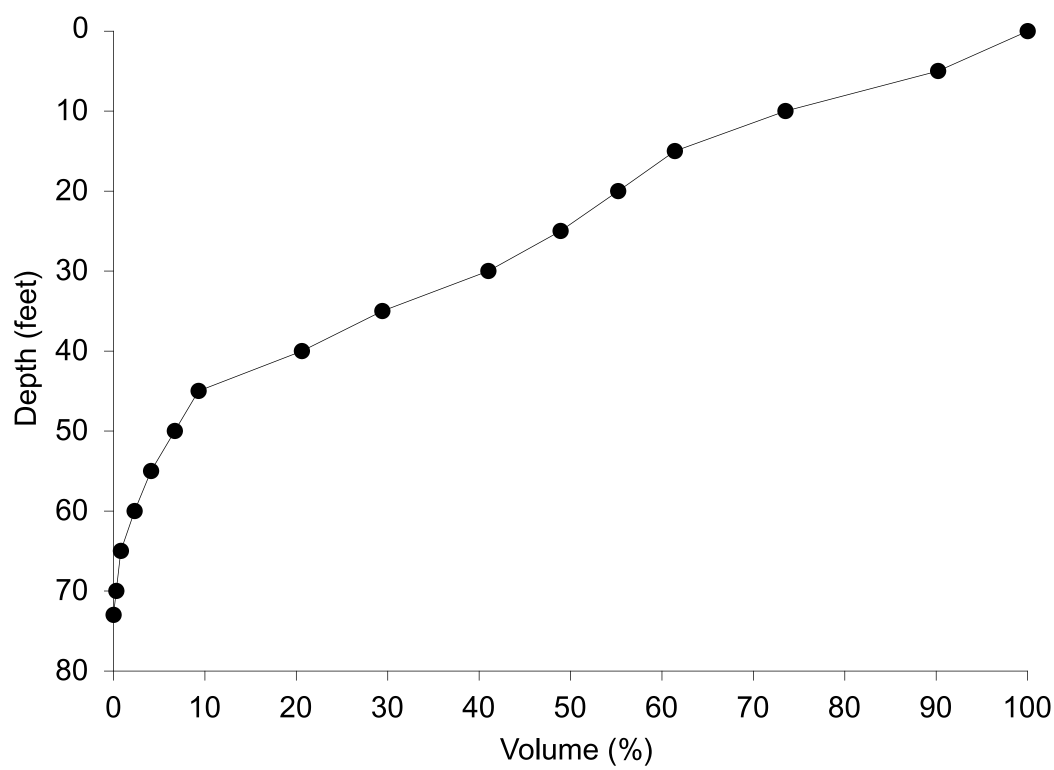


Figure 5.−Percent of volume by depth for Pickerel Lake, Michigan. Data taken from MDNR Digital Water Atlas.

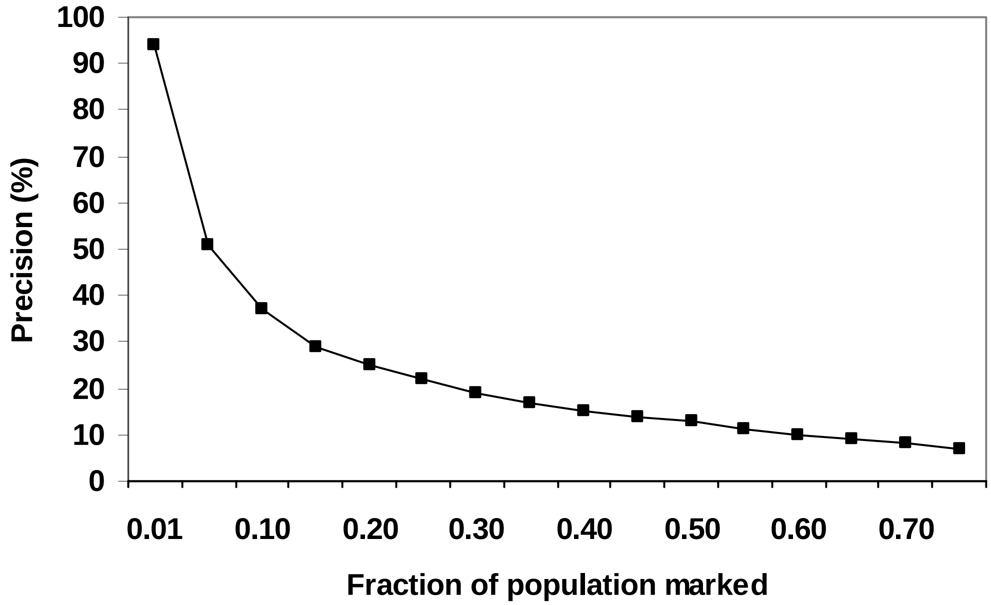


Figure 6.–Precision of walleye population estimate based on fraction of the population marked. Precision is expressed as a percentage and is the quotient of 2SE of the estimate with a given number marked and estimated population.

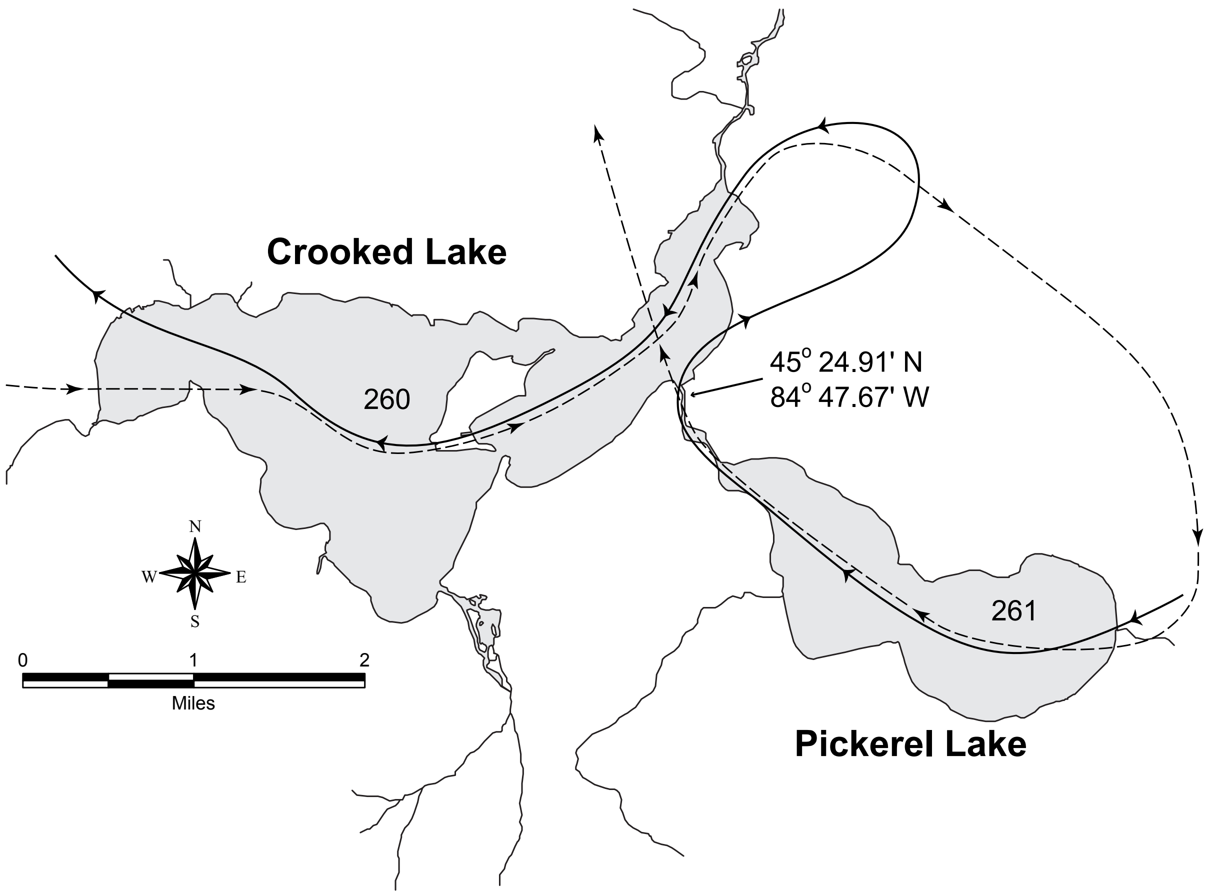


Figure 7.−Crooked Lake (site 260) and Pickerel Lake (site 261), and the latitude longitude point of separation used for summer 2001 and winter 2002 angler surveys. The two flight paths used for aerial counts are shown as dashed and solid lines.

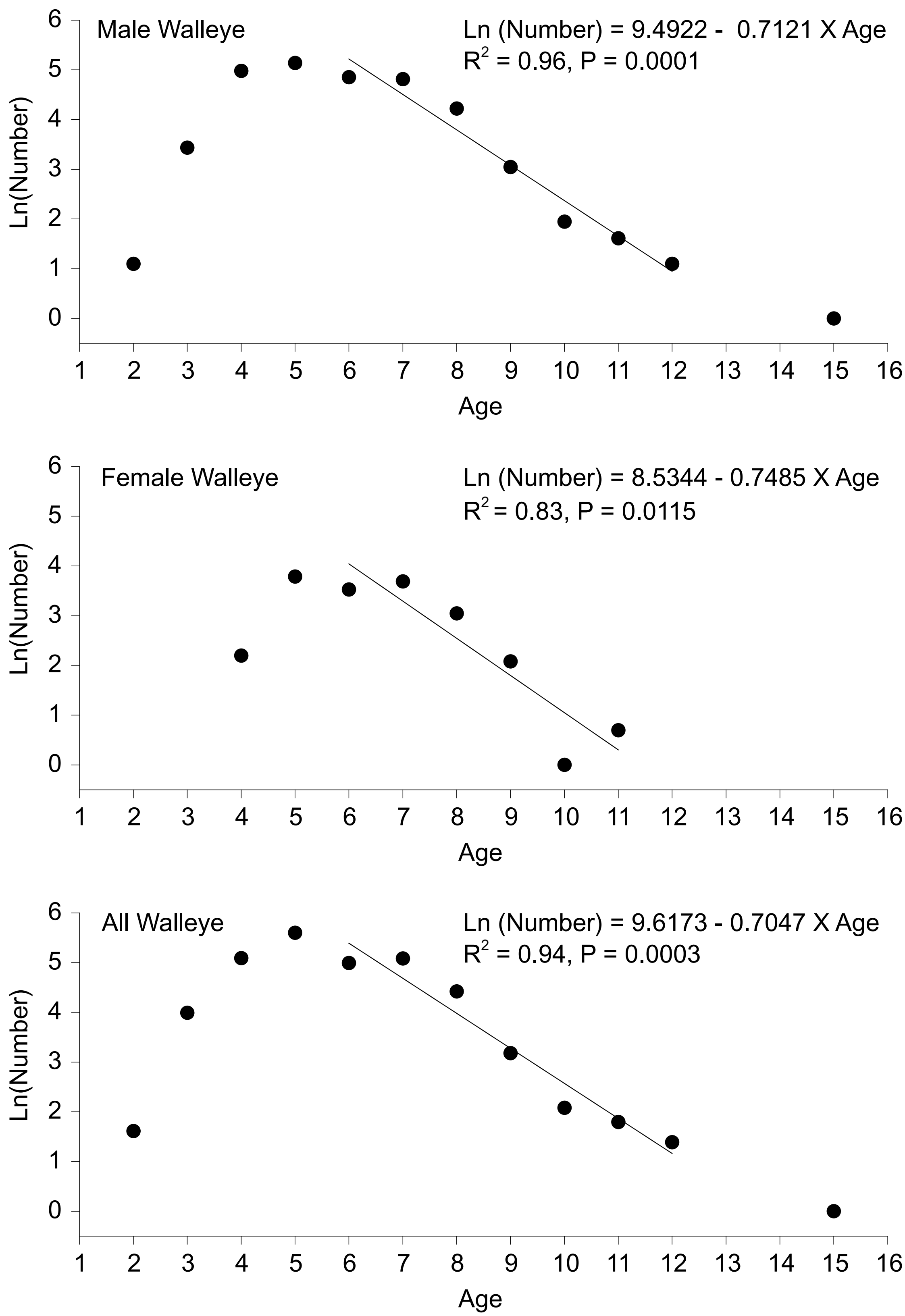
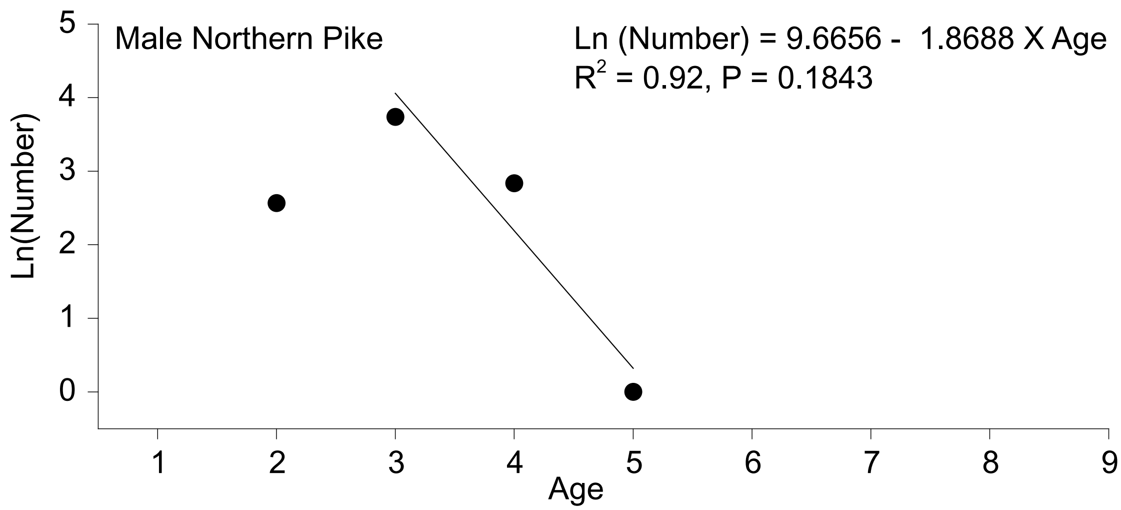
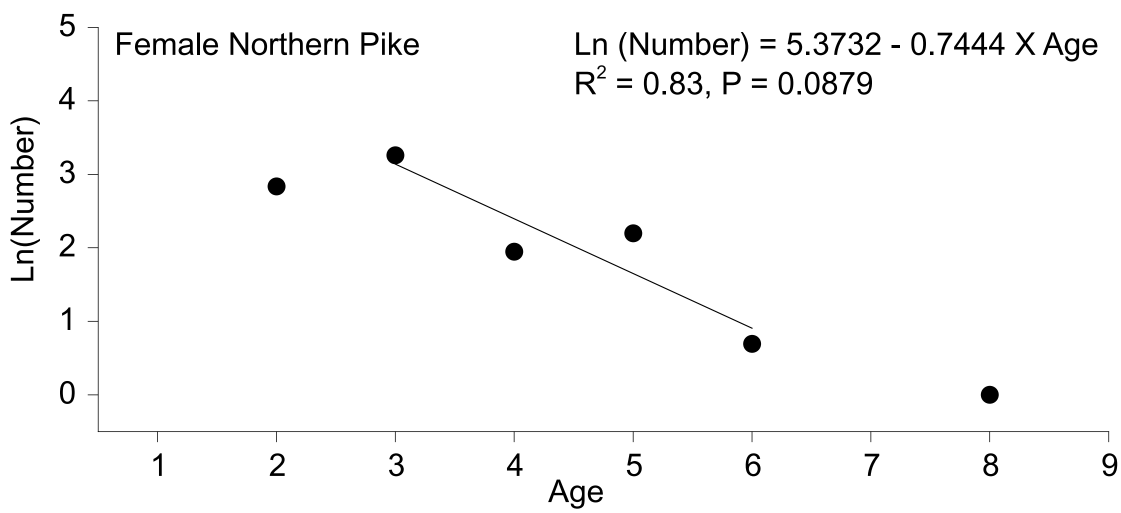


Figure 8.–Plots of observed 1n(number) versus age for male, female, and all (including males, females, and unknown sex) walleye in Crooked and Pickerel lakes. Lines are plots of regression equations given beside each graph.





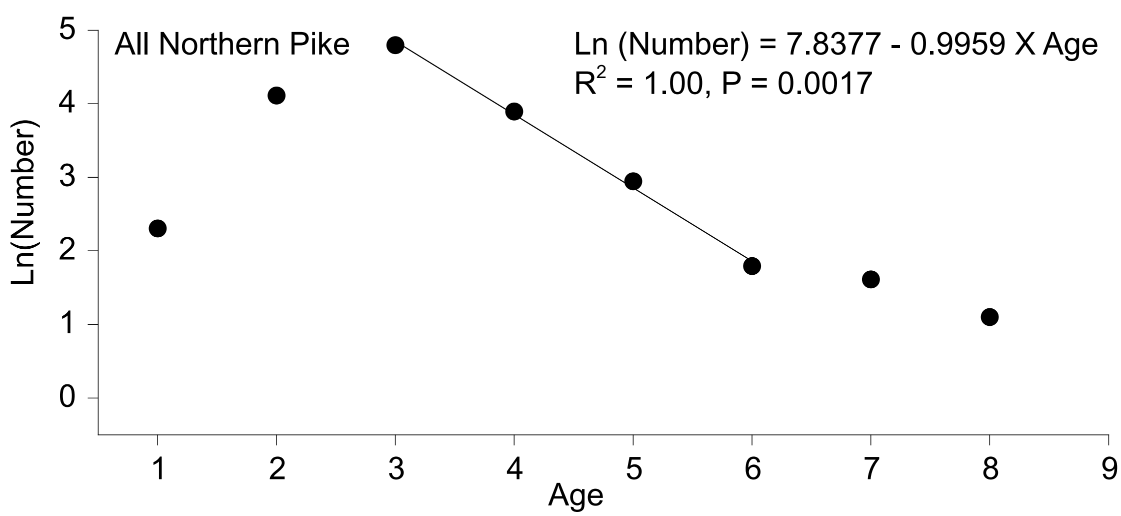


Figure 9.−Plots of observed 1n(number) versus age for male, female, and all (including males, females, and unknown sex) northern pike in Crooked and Pickerel lakes. Lines are plots of regression equations given beside each graph.

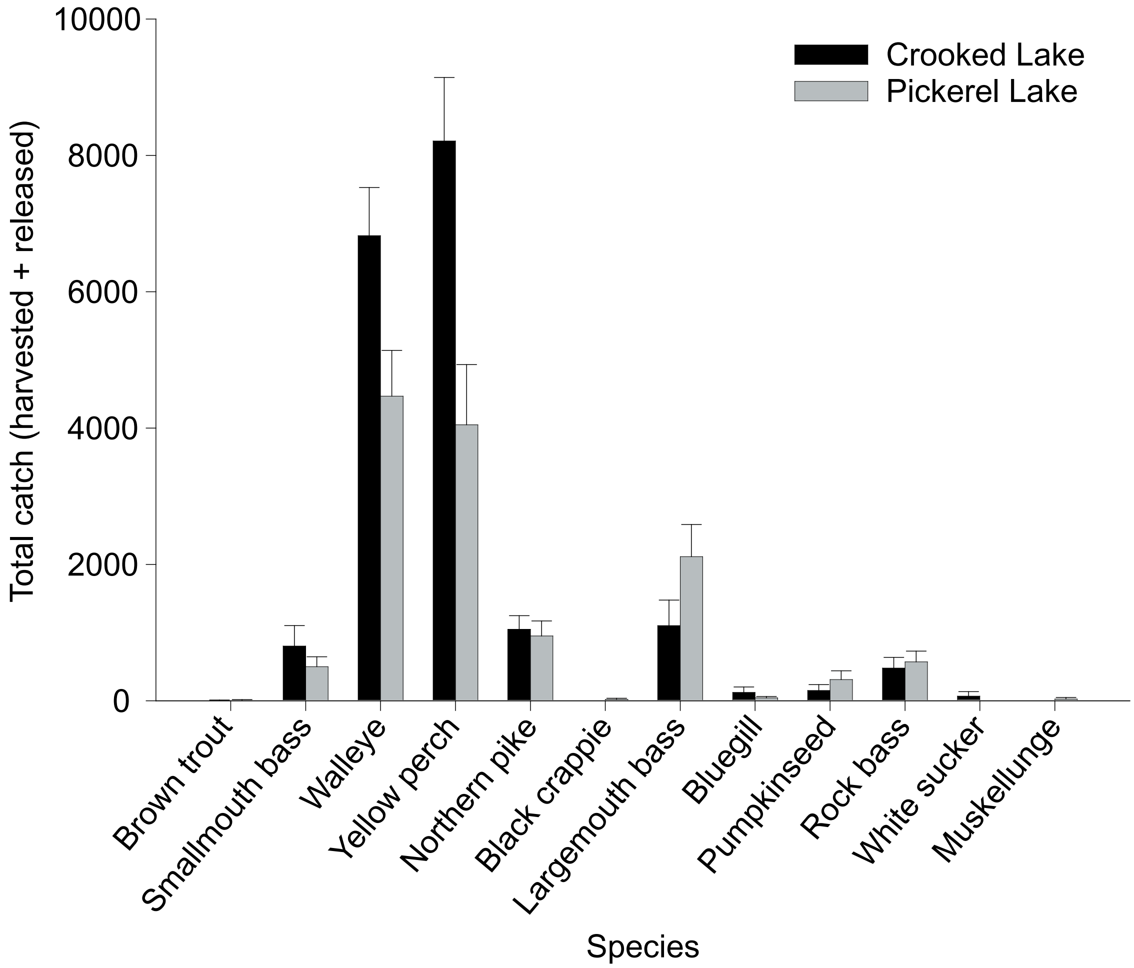


Figure 10.–Total annual catch (fish harvested + fish released) by species for Crooked and Pickerel lakes. Error bars represent 1 standard error.

Table 1.–Number and size of walleye fingerlings stocked into Crooked and Pickerel lakes from 1985 through 2001. Mean length is the weighted mean length of lots planted for year.

Year	Lake	Number stocked	Mean length (in)
1985	Crooked	5,500	1.5
	Pickerel	5,500	1.5
1986	Crooked	4,000	1.5
	Pickerel	0	na
1987	Crooked	0	na
	Pickerel	0	na
1988	Crooked	500	1.7
	Pickerel	0	na
1989	Crooked	750	1.5
	Pickerel	750	1.5
1990	Crooked	50	1.0
	Pickerel	0	na
1991	Crooked	75,000	2.0
	Pickerel	0	na
1992	Crooked	0	na
	Pickerel	0	na
1993	Crooked	0	na
	Pickerel	0	na
1994	Crooked	160,750	1.2
	Pickerel	50,000	1.9
1995	Crooked	0	na
	Pickerel	0	na
1996	Crooked	108,500	1.3
	Pickerel	25,000	1.2
1997	Crooked	0	na
	Pickerel	0	na
1998	Crooked	80,500	1.2
	Pickerel	28,000	1.2
1999	Crooked	2,700	1.5
	Pickerel	0	na
2000	Crooked	52,500	1.1
	Pickerel	12,500	1.2
2001	Crooked	0	na
	Pickerel	0	na

Table 2.–Number of Master Angler awards for Crooked and Pickerel lakes from 1990 through 2002.

Year	Lake	Species	Number
1990	Crooked	Rock bass	3
	Pickerel	Bluegill	1
1991	Crooked	–	0
	Pickerel	Hybrid sunfish	1
1992	Crooked	Bluegill	1
	Pickerel	Rock bass	1
1993	Crooked	Bluegill	1
	Pickerel	Bluegill	1
1994	Crooked	Smallmouth bass	1
		Bluegill	1
	Pickerel	Bluegill	1
1995	Crooked	–	0
	Pickerel	–	0
1996	Crooked	Black crappie	1
		Bluegill	1
	Pickerel	Bluegill	2
		Rock bass	1
1997	Crooked	Bluegill	2
		Brook trout	1
		Smallmouth bass	1
	Pickerel	Bluegill	1
		Pumpkinseed	1
1998	Crooked	Bluegill	2
	Pickerel	Bluegill	1
		Rock bass	2
1999	Crooked	–	0
	Pickerel	Smallmouth bass	1
		Rock bass	1
2000	Crooked	–	0
	Pickerel	Bluegill	1
2001	Crooked	Black bullhead	1
		Smallmouth bass	2
	Pickerel	Rock bass	2

Table 3.–Survey periods, sampling shifts, and expansion value “F” (number of fishing hours within a sample day) for Crooked and Pickerel lakes angler creel survey, spring 2001 through winter 2002.

Survey period	Sample shifts (h)		F
April 28–May 31	0600–1430	1330–2200	16
June	0600–1430	1330–2200	18
July	0600–1430	1300–2130	18
August	0630–1500	1230–2100	17
September	0630–1500	1200–2030	16
January 1–March 31, 2002	0700–1530	1100–1930	13

Table 4.–Fish collected from Crooked and Pickerel lakes using a total sampling effort of 63 trap-net lifts, 49 fyke-net lifts, and 2 electrofishing runs from April 17 to April 26, 2001.

Species	Total catch[a]	Percent by number	Mean CPUE[b]		Length (in)		Number measured
			Trap-net	Fyke-net	Range	Average	
Walleye	997	14.7	11.7	3.4	5.9–22.6	15.1	951
Northern pike	285	4.2	2.5	2.3	9.6–31.8	18.8	275
Rock bass	2,383	35.2	19.4	21.3	3.3–12.1	7.5	768
White sucker	1,676	24.7	21.7	2.7	10.0–24.0	18.6	353
Bluegill	830	12.3	4.7	9.6	3.3–10.2	7.1	229
Smallmouth bass	264	3.9	1.4	2.8	8.1–20.9	15.8	177
Brown bullhead	142	2.1	1.8	0.3	7.0–15.7	12.8	124
Pumpkinseed	71	1.0	0.4	0.8	4.3–10.2	7.1	56
Bowfin	49	0.7	0.5	0.3	13.0–32.0	22.0	40
Yellow perch	29	0.4	0.2	0.3	5.6–14.8	8.9	24
Largemouth bass	16	0.2	0.2	0.09	6.0–18.8	13.4	15
Yellow bullhead	11	0.2	0	0.2	11.2–14.8	13.3	6
Longnose gar	7	0.1	<0.1	<0.1	29.5–32.0	30.9	5
Burbot	5	<0.1	<0.1	<0.1	20.0–25.5	22.8	5
Black bullhead	3	<0.1	<0.1	0	11.9–12.2	12.1	3
Black crappie	2	<0.1	<0.1	0	6.3–11.4	8.8	2
Brown trout	2	<0.1	<0.1	0	6.8–12.3	9.6	2
Alewife	1	<0.1	<0.1	0	–	–	0
Common carp	1	<0.1	<0.1	0	13.7	13.7	1
Rainbow trout	1	<0.1	<0.1	0	23.2	23.2	1

[a] Includes recaptures.
[b] Number per trap-net or fyke-net night.

Table 5.–Number of fish per inch group caught and measured in spring netting and electrofishing operations on Crooked and Pickerel lakes, April 19 to May 4, 2001.

	Species																		
Inch group	Walleyes	Northern pike	Rock bass	White sucker	Bluegill	Smallmouth bass	Brown bullhead	Pumpkinseed	Bowfin	Yellow perch	Largemouth bass	Yellow bullhead	Longnose gar	Burbot	Black bullhead	Black crappie	Brown trout	Common carp	Rainbow trout
2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3	–	–	18	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4	–	–	61	–	9	–	–	2	–	–	–	–	–	–	–	–	–	–	–
5	1	–	183	–	44	–	–	6	–	1	–	–	–	–	–	–	–	–	–
6	3	–	82	–	42	–	–	18	–	1	1	–	–	–	–	1	1	–	–
7	1	–	83	–	57	–	1	19	–	10	–	–	–	–	–	–	–	–	–
8	1	–	104	–	57	3	1	9	–	3	–	–	–	–	–	–	–	–	–
9	11	3	114	–	16	–	4	1	–	2	–	–	–	–	–	–	–	–	–
10	9	3	74	2	1	–	6	1	–	3	–	–	–	–	–	–	–	–	–
11	18	10	47	3	–	2	14	–	–	2	2	1	–	–	1	1	–	–	–
12	75	2	2	2	–	14	20	–	–	1	7	1	–	–	2	–	1	–	–
13	131	2	–	1	–	22	48	–	2	–	–	1	–	–	–	–	–	1	–
14	201	6	–	4	–	26	23	–	–	1	–	3	–	–	–	–	–	–	–
15	201	15	–	12	–	25	7	–	–	–	1	–	–	–	–	–	–	–	–
16	139	30	–	24	–	22	–	–	–	–	2	–	–	–	–	–	–	–	–
17	90	31	–	45	–	29	–	–	1	–	1	–	–	–	–	–	–	–	–
18	37	40	–	65	–	18	–	–	–	–	1	–	–	–	–	–	–	–	–
19	20	38	–	83	–	14	–	–	2	–	–	–	–	–	–	–	–	–	–
20	10	25	–	57	–	2	–	–	4	–	–	–	–	1	–	–	–	–	–
21	2	30	–	39	–	–	–	–	7	–	–	–	–	1	–	–	–	–	–
22	1	20	–	14	–	–	–	–	9	–	–	–	–	1	–	–	–	–	–
23	–	9	–	–	–	–	–	–	8	–	–	–	–	–	–	–	–	–	1
24	–	3	–	2	–	–	–	–	3	–	–	–	–	1	–	–	–	–	–
25	–	2	–	–	–	–	–	–	2	–	–	–	–	1	–	–	–	–	–
26	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
27	–	1	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–
28	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
29	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–
30	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
31	–	1	–	–	–	–	–	–	–	–	–	–	3	–	–	–	–	–	–
32	–	–	–	–	–	–	–	–	1	–	–	–	1	–	–	–	–	–	–
33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
34	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
36	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
37	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
38	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
39	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total	951	275	768	353	229	177	124	56	40	24	15	6	5	5	3	2	2	1	1

Table 6.–General fish surveys conducted on Crooked and Pickerel lakes by MDNR, Fisheries Division.

Lake	Time period	Gears	Reference
Crooked Lake	1890	Unknown	MDNR files
Crooked Lake	August 16–31, 1954	Gill nets; seines	MDNR files
Pickerel Lake	June 10, 1971	Gill nets	MDNR files
Crooked Lake	June 16, 1972	Gill nets	MDNR files
Pickerel Lake	May 22–26, 1989	Trap and fyke nets	MDNR, Fish Collection System
Crooked Lake	May 30–June 9, 1989	Trap and fyke nets	MDNR, Fish Collection System
Crooked Lake	August 29–31, 2001	Electrofishing	MDNR, Fish Collection System

Table 7.–Estimates of abundance, angler exploitation rates, and instantaneous fishing mortality rates for walleyes and northern pike of Crooked and Pickerel lakes. Estimated 95% confidence intervals for estimates are given in parentheses.

	Walleyes	Northern pike
Number tagged	502	11
Total tag returns	72	0
Number of legal-sized[a] fish		
Multiple census method	4,825 (3,570–7,444)	No estimate[b]
Single-census method	7,049 (3,319–10,779)	48 (14–174)
Number of adult[c] fish		
Multiple census method	9,552 (7,294–13,833)	1,921 (1,134–6,278)
Single-census method	12,346 (5,856–18,836)	628 (14–1,383)
Wisconsin equation	11,186 (3,702–33,799)	na
Annual exploitation rates		
Based on reward tag returns	16.3%	No estimate[d]
Based on harvest/abundance[e]	29.3% (11.9%–46.8%)	20.3% (0%–55.8%)
Instantaneous fishing rates (F)		
Based on reward tag returns	0.2265	No estimate[f]
Based on harvest/abundance[c]	0.4087	No estimate[f]

[a] Walleyes ≥15 in and northern pike ≥24 in.
[b] Minimum recaptures not attained
[c] Estimated numbers of fish, both legal size and sexually mature sublegal size, on spawning grounds in April–May 2001.
[d] No tag returns.
[e] Single-census estimate of abundance.
[f] Unable to estimate total instantaneous mortality for legal fish.

Table 8.–Weighted mean lengths and sample sizes (number aged) by age and sex for walleyes collected from Crooked and Pickerel lakes, April 17 to April 26, 2001. Standard errors for mean lengths are in parentheses.

	Mean length (SE)			Number aged		
Age	Males	Females	All[a]	Males	Females	All[a]
2	12.7 (–)	–	12.1 (0.5)	1	–	2
3	12.8 (0.5)	–	12.5 (0.7)	12	–	23
4	13.7 (0.9)	14.4 (0.8)	13.7 (1.0)	49	8	61
5	14.5 (1.0)	15.4 (1.3)	14.9 (1.1)	44	40	92
6	15.3 (0.9)	17.0 (1.5)	15.8 (1.4)	28	28	58
7	16.0 (1.1)	17.4 (1.5)	16.4 (1.5)	39	35	76
8	16.7 (0.8)	18.6 (1.5)	17.3 (1.3)	30	18	50
9	16.3 (1.0)	18.4 (1.3)	17.1 (1.5)	7	7	14
10	18.2 (0.7)	19.6 (–)	18.4 (0.8)	6	1	7
11	18.0 (0.8)	20.3 (–)	18.8 (1.5)	3	2	5
12	19.2 (2.3)	–	18.8 (1.9)	3	–	3
13	–	–	–	–	–	–
14	–	–	–	–	–	–
15	19.7 (–)	–	19.7 (–)	1	–	1

[a]Includes fish of unknown sex.

Table 9.–Weighted mean lengths and sample sizes (number aged) by age and sex for northern pike collected from Crooked and Pickerel lakes, April 17 to April 26, 2001. Standard errors for mean lengths are in parentheses.

	Mean length (SE)			Number aged		
Age	Males	Females	All[a]	Males	Females	All[a]
1	–	–	10.9 (1.0)	–	–	7
2	16.1 (1.6)	16.5 (1.1)	16.1 (2.0)	12	17	48
3	18.1 (1.5)	19.3 (1.5)	19.2 (1.8)	32	23	93
4	19.7 (1.8)	21.6 (2.1)	20.3 (2.1)	14	8	38
5	21.9 (–)	21.8 (1.5)	22.1 (1.7)	1	10	15
6	–	22.2 (0.9)	22.8 (1.9)	–	2	5
7	–	–	25.7 (2.3)	–	–	5
8	–	31.8 (–)	30.8 (0.6)	–	1	3

[a] Includes fish of unknown sex.

Table 10.–Catch-at-age estimates (apportioned by length-age key) for walleyes and northern pike collected with trap and fyke nets and electrofishing gear from Crooked and Pickerel lakes, April 17 to April 26, 2001.

		Walleyes			Northern pike		
Age	Year-class	Males	Females	All[a]	Males	Females	All[a]
1	2000	–	–	–	–	–	10
2	1999	3	–	5	13	17	61
3	1998	31	–	54	42	26	121
4	1997	145	9	162	17	7	49
5	1996	170	44	270	1	9	19
6	1995	128	34	147	–	2	6
7	1994	123	40	161	–	–	5
8	1993	68	21	83	–	1	3
9	1992	21	8	24	–	–	–
10	1991	7	1	8	–	–	–
11	1990	5	2	6	–	–	–
12	1989	3	–	4	–	–	–
13	1988	–	–	0	–	–	–
14	1987	–	–	0	–	–	–
15	1986	1	–	1	–	–	–
Totals		705	159	925	73	62	274

[a] Includes fish of unknown sex.

Table 11.–Angler tag returns (reward and non-reward) for walleyes from Crooked and Pickerel lakes by month for the year following tagging.

Month	Number of tag returns	Percentage of total
1	0	0.0
2	2	2.8
3	1	1.4
4	2	2.8
5	13	18.1
6	7	9.7
7	21	29.2
8	11	15.3
9	9	12.5
10	6	8.3
11	0	0.0
12	0	0.0
Total	72	100.0

Table 12.–Number of tag returns by lake for walleyes tagged in Crooked and Pickerel lakes. Percent of total first-year tag returns is in parentheses.

	Lake recaptured	
Lake tagged	Crooked	Pickerel
Crooked	46 (97.9)	1 (2.1)
Pickerel	13 (52.0)	12 (48.0)

Table 13.–Angler survey estimates for summer 2001 from Crooked and Pickerel lakes. Survey period was April 28 through September 30, 2001. Two standard errors are given in parentheses.

Species	Catch/h		Apr–May	June	July	August	September	Season
			Number harvested					
Smallmouth bass	0.0039	(0.0024)	0 (0)	14 (27)	5 (3)	104 (84)	55 (63)	178 (108)
Walleyes	0.0480	(0.0140)	324 (155)	246 (176)	908 (495)	510 (211)	189 (97)	2,177 (595)
Yellow perch	0.0675	(0.0263)	6 (10)	1,007 (969)	465 (302)	680 (292)	906 (454)	3,064 (1,149)
Northern pike	0.0001	(0.0002)	3 (7)	0 (0)	0 (0)	0 (0)	0 (0)	3 (7)
Black crappie	0.0004	(0.0008)	0 (0)	0 (0)	18 (36)	0 (0)	0 (0)	18 (36)
Bluegill	0.0708	(0.0275)	21 (32)	181 (209)	1,454 (872)	1,150 (729)	407 (333)	3,213 (1,203)
Largemouth bass	0.0006	(0.0007)	0 (0)	10 (16)	0 (0)	0 (0)	17 (26)	27 (31)
Pumpkinseed	0.0101	(0.0070)	0 (0)	0 (0)	214 (217)	146 (165)	99 (152)	459 (312)
Rock bass	0.0232	(0.0101)	3 (7)	0 (0)	288 (232)	401 (235)	359 (295)	1,051 (443)
Total harvest	0.2245	(0.0471)	357 (158)	1,458 (1,007)	3,352 (1,094)	2,991 (865)	2,032 (663)	10,190 (1,850)
			Number caught and released					
Smallmouth bass	0.0247	(0.0147)	126 (84)	506 (582)	192 (209)	177 (132)	121 (158)	1,122 (657)
Largemouth bass	0.0030	(0.0036)	19 (28)	0 (0)	104 (157)	13 (23)	0 (0)	136 (161)
Walleyes	0.1964	(0.0457)	935 (426)	2,358 (1,157)	3,089 (1,103)	1,942 (752)	588 (344)	8,912 (1,849)
Northern pike	0.0406	(0.0135)	641 (309)	544 (369)	182 (141)	438 (294)	39 (40)	1,844 (582)
Muskellunge	0.0005	(0.0011)	0 (0)	0 (0)	24 (48)	0 (0)	0 (0)	24 (48)
Yellow perch	0.0962	(0.0342)	0 (0)	0 (0)	421 (345)	2,780 (1,341)	1,165 (536)	4,366 (1,484)
Total release	0.3614	(0.0675)	1,721 (532)	3,408 (1,346)	4,012 (1,193)	5,350 (1,570)	1,913 (656)	16,404 (2,532)
Total (harvest + release)	0.5859	(0.0926)	2,078 (555)	4,866 (1,681)	7,364 (1,619)	8,341 (1,793)	3,945 (933)	26,594 (3,137)
			Fishing effort					
Angler hours			6,017 (1,354)	8,738 (2,455)	15,812 (3,057)	9,423 (1,735)	5,398 (1,612)	45,388 (4,777)
Angler trips			2,738 (817)	2,502 (879)	13,705 (2,659)	3,164 (1,730)	1,917 (1,344)	24,071 (3,648)

Table 14.–Angler survey estimates for winter 2002 from Crooked and Pickerel lakes. Survey period was from January 1 through March 31, 2002. Two standard errors are given in parentheses.

Species	Catch/h	January	February	March	Season
		Number harvested			
Brown trout	0.0010 (0.0012)	0 (0)	3 (6)	7 (11)	10 (13)
Walleyes	0.0095 (0.0078)	24 (43)	66 (60)	10 (15)	100 (75)
Yellow perch	0.3093 (0.1771)	1,646 (1,416)	1,157 (509)	443 (371)	3,246 (1,550)
Northern pike	0.0010 (0.0013)	6 (10)	0 (0)	4 (9)	10 (13)
White sucker	0.0064 (0.0129)	0 (0)	0 (0)	67 (134)	67 (134)
Total harvest	0.3271 (0.1808)	1,676 (1,416)	1,226 (513)	531 (394)	3,433 (1,557)
		Number caught and released			
Brown trout	0.0006 (0.0011)	0 (0)	0 (0)	6 (11)	6 (11)
Walleyes	0.0090 (0.0078)	10 (20)	80 (74)	4 (6)	94 (77)
Northern pike	0.0136 (0.0112)	44 (75)	59 (48)	40 (63)	143 (109)
Yellow perch	0.1470 (0.0904)	501 (468)	580 (510)	462 (427)	1,543 (813)
Total catch and release	0.1702 (0.0951)	555 (474)	719 (517)	512 (432)	1,786 (823)
Total (harvest + release)	0.4972 (0.2299)	2,231 (1,493)	1,945 (728)	1,043 (584)	5,219 (1,761)
		Fishing effort			
Angler hours		5,613 (2,940)	3,777 (1,369)	1,106 (704)	10,496 (3,319)
Angler trips		2,016 (1,307)	1,156 (548)	347 (246)	3,519 (1,438)

Table 15.–Angler survey estimates for summer and winter 2001–02 from Crooked and Pickerel lakes. Survey period was April 28 to September 30, 2001 and January 1 to March 31, 2002. Two standard errors are given in parentheses.

		2001					2002			
Species	Catch/h	Apr–May	Jun	Jul	Aug	Sep	Jan	Feb	Mar	Season
		Number harvested								
Brown trout	0.0002 (0.0002)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3 (6)	7 (11)	10 (13)
Smallmouth bass	0.0032 (0.0020)	0 (0)	14 (27)	5 (3)	104 (84)	55 (63)	0 (0)	0 (0)	0 (0)	178 (108)
Walleyes	0.0407 (0.0115)	324 (155)	246 (176)	908 (495)	510 (211)	189 (97)	24 (43)	66 (60)	10 (15)	2,277 (600)
Yellow perch	0.1129 (0.0365)	6 (10)	1,007 (969)	465 (302)	680 (292)	906 (454)	1,646 (1,416)	1,157 (509)	443 (371)	6,310 (1,929)
Northern pike	0.0002 (0.0003)	3 (7)	0 (0)	0 (0)	0 (0)	0 (0)	6 (10)	0 (0)	4 (9)	13 (15)
Black crappie	0.0003 (0.0006)	0 (0)	0 (0)	18 (36)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	18 (36)
Bluegill	0.0575 (0.0223)	21 (32)	181 (209)	1,454 (872)	1,150 (729)	407 (333)	0 (0)	0 (0)	0 (0)	3,213 (1,203)
Largemouth bass	0.0005 (0.0005)	0 (0)	10 (16)	0 (0)	0 (0)	17 (26)	0 (0)	0 (0)	0 (0)	27 (31)
Pumpkinseed	0.0082 (0.0057)	0 (0)	0 (0)	214 (217)	146 (165)	99 (152)	0 (0)	0 (0)	0 (0)	459 (312)
Rock bass	0.0188 (0.0082)	3 (7)	0 (0)	288 (232)	401 (235)	359 (295)	0 (0)	0 (0)	0 (0)	1,051 (443)
White sucker	0.0012 (0.0024)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	67 (134)	67 (134)
Total harvest	0.2438 (0.0502)	357 (158)	1,458 (1,007)	3,352 (1,094)	2,991 (865)	2,032 (663)	1,676 (1,416)	1,226 (513)	531 (394)	13,623 (2,418)
		Number caught and released								
Brown trout	0.0001 (0.0002)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	6 (11)	6 (11)
Smallmouth bass	0.0201 (0.0119)	126 (84)	506 (582)	192 (209)	177 (132)	121 (158)	0 (0)	0 (0)	0 (0)	1,122 (657)
Largemouth bass	0.0024 (0.0029)	19 (28)	0 (0)	104 (157)	13 (23)	0 (0)	0 (0)	0 (0)	0 (0)	136 (161)
Walleyes	0.1612 (0.0371)	935 (426)	2,358 (1,157)	3,089 (1,103)	1,942 (752)	588 (344)	10 (20)	80 (74)	4 (6)	9,006 (1,851)
Northern pike	0.0356 (0.0112)	641 (309)	544 (369)	182 (141)	438 (294)	39 (40)	44 (75)	59 (48)	40 (63)	1,987 (592)
Muskellunge	0.0004 (0.0009)	0 (0)	0 (0)	24 (48)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	24 (48)
Yellow perch	0.1057 (0.0322)	0 (0)	0 (0)	421 (345)	2,780 (1,341)	1,165 (536)	501 (468)	580 (510)	462 (427)	5,909 (1,692)
Total catch and release	0.3255 (0.0585)	1,721 (532)	3,408 (1,346)	4,012 (1,193)	5,350 (1,570)	1,913 (656)	555 (474)	719 (517)	512 (432)	18,190 (2,663)
Total (harvest + release)	0.5693 (0.0875)	2,078 (555)	4,866 (1,681)	7,364 (1,619)	8,341 (1,793)	3,945 (933)	2,231 (1,493)	1,945 (728)	1,043 (584)	31,813 (3,597)
		Fishing effort								
Angler hours		6,017 (1,354)	8,738 (2,455)	15,812 (3,057)	9,423 (1,735)	5,398 (1,612)	5,613 (2,940)	3,777 (1,369)	1,106 (704)	55,884 (5,816)
Angler trips		2,783 (817)	2,502 (879)	13,705 (2,659)	3,164 (1,730)	1,917 (1,344)	2,016 (1,307)	1,156 (548)	347 (246)	27,590 (3,922)

Table 16.–Mean lengths for walleyes from Crooked and Pickerel lakes from our survey compared to previous surveys. Number aged in parentheses.

	State	Mean lengths from survey years							
Age	average[a]	2001[b]		1989[c]		1972[c]		1971[d]	
2	10.4	12.1	(2)	–	(0)	–	(0)	–	(0)
3	13.9	12.5	(23)	13.6	(3)	–	(0)	–	(0)
4	15.8	13.7	(61)	14.9	(4)	16.1	(2)	–	(0)
5	17.6	14.9	(92)	15.9	(9)	15.9	(2)	15.8	(4)
6	19.2	15.8	(58)	16.8	(5)	17.6	(2)	18.3	(10)
7	20.6	16.4	(76)	17.4	(2)	19.1	(10)	19.7	(15)
8	21.6	17.3	(50)	18.4	(4)	21.7	(3)	20.7	(5)
9	22.4	17.1	(14)	19.6	(1)			–	(0)
10	23.1	18.4	(7)					26.0	(1)
11		18.8	(5)						
12		18.8	(3)						
13		–	(0)						
14		–	(0)						
15		19.7	(1)						
Mean growth index[e]		-3.1		-2.5		-1.7		-1.1	

[a] Jan–May averages from Schneider et al. (2000).
[b] All fish aged with spines.
[c] Fish from Crooked Lake aged with scales.
[d] Fish from Pickerel Lake aged with scales.
[e] The mean deviation from the statewide quarterly average.
Only age groups where N ≥ 5 were used.

Table 17.–Mean lengths for northern pike from Crooked and Pickerel lakes from our survey compared to previous surveys. Number aged in parentheses.

Age	State average[a]	Mean lengths from survey years 2001[b]		1989[c]		1972[c]		1971[d]	
1	11.7	10.9	(7)	10.5	(1)	13.9	(1)	–	(0)
2	17.7	16.1	(48)	18.8	(4)	18.6	(5)	18.1	(36)
3	20.8	19.2	(93)	20.0	(8)	21.3	(12)	20.8	(15)
4	23.4	20.3	(38)	22.4	(2)	21.7	(2)	23.0	(3)
5	25.5	22.1	(15)			26.1	(1)	24.6	(6)
6	27.3	22.8	(5)			28.3	(2)	28.7	(2)
7	29.3	25.7	(5)						
8	31.2	30.8	(3)						
Mean growth index[e]		-2.7		-1.8		-0.5		-1.1	

[a] Jan–May averages from Schneider et al. (2000).
[b] Fish from Crooked and Pickerel Lake aged with fin rays.
[c] Fish from Crooked Lake aged with scales.
[d] Fish from Pickerel Lake aged with scales.
[e] The mean deviation from the statewide quarterly average.
Only age groups where N ≥ 5 were used.

Table 18.–Comparison of recreational fishing effort and total harvest on Crooked and Pickerel lakes to those of selected other Michigan lakes. Lakes are listed from highest to lowest total fishing effort. Lake size was from Laarman (1976).

Lake, County	Size (acres)	Survey period	Total fishing effort (h)	Fish harvested (number)	Fish harvested per h	Hours fished per acre	Fish harvested per acre
Michigan[a], many	–	Jan–Nov, 2001	2,684,359	677,360	0.25	–	–
Huron[a], many	–	Jan–Oct, 2001	1,807,519	1,057,819	0.59	–	–
Houghton, Roscommon	20,075	Apr 2001–Mar 2002	499,048	386,287	0.77	24.9	19.2
Erie[a], Wayne and Monroe	–	Apr–Oct, 2001	490,807	378,700	0.77	–	–
Superior[a], many	–	Apr–Oct, 2001	180,428	60,947	0.34	–	–
Fletcher Pond, Alpena and Montmorency	8,970	May–Sep, 1997	171,521	118,101	0.69	19.1	13.2
Burt, Cheboygan	17,120	Apr–Sep, 1993	134,957	20,734	0.15	7.9	1.2
Gogebic, Ontonagon and Gogebic	13,380	May 1998–Apr 1999	121,525	26,622	0.22	9.1	2.0
Mullett, Cheboygan	16,630	May–Aug, 1998	87,520	18,727	0.21	5.3	1.1
Crooked and Pickerel lakes, 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

[a] Does not include charter boat harvest or effort.

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Appendix A–Fish species captured in Crooked and Pickerel lakes from 1954 through 2001 by MDNR crews using various gear types.

Common name	Scientific name
Species we collected in 2001 with trap nets, fyke nets, and electrofishing gear	
Alewife	*Alosa pseudoharnegus*
Black bullhead	*Ameiurus melas*
Black crappie	*Pomoxis nigromaculatus*
Bluegill	*Lepomis macrochirus*
Bowfin	*Amia calva*
Brown bullhead	*Ameiurus nebulosus*
Brown trout	*Salmo trutta*
Burbot	*Lota lota*
Common carp	*Cyprinus carpio*
Largemouth bass	*Micropterus salmoides*
Longnose gar	*Lepisosteus osseus*
Northern pike	*Esox lucius*
Pumpkinseed	*Lepomis gibbosus*
Rainbow trout	*Oncorhynchus mykiss*
Rock bass	*Ambloplites rupestris*
Smallmouth bass	*Micropterus dolomieu*
Walleyes	*Sander vitreus*
White sucker	*Catostomus commersonii*
Yellow bullhead	*Ameiurus natalis*
Yellow perch	*Perca flavescens*
Additional species collected with trap nets (MDNR files 1959)	
Muskellunge	*Esox masquinongy*
Silver lamprey	*Ichthyomyzon unicuspis*
Additional species collected with seines (MDNR files 1954)	
Banded killifish	*Fundulus diaphanus menona*
Bluntnose minnow	*Pimephales notatus*
Central mudminnow	*Umbra lima*
Common shiner	*Luxilus cornutus*
Emerald shiner	*Notropis atherinoides*
Iowa darter	*Etheostoma exile*
Johnny darter	*Etheostoma nigrum*
Logperch	*Percina caprodes*
Mimic shiner	*Notropis volucellus*
Mottled sculpin	*Cottus bairdii*
Sand shiner	*Notropis stramineus*
Spottail shiner	*Notropis hudsonius*

Appendix B.–Angler survey estimates for summer and winter 2001-02 from Crooked Lake. Survey period was April 28 to September 30, 2001 and January 1 to March 31, 2002. Two standard errors are given in parentheses.

		2001					2002			
Species	Catch/hour	Apr-May	Jun	Jul	Aug	Sep	Jan	Feb	Mar	Season
		Number harvested								
Brown trout	0.0001 (0.0003)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	7 (11)	7 (11)
Smallmouth bass	0.0040 (0.0028)	0 (0)	14 (27)	0 (0)	69 (63)	55 (63)	0 (0)	0 (0)	0 (0)	138 (93)
Walleyes	0.0562 (0.0182)	272 (145)	113 (114)	841 (490)	466 (205)	142 (77)	21 (42)	66 (60)	10 (15)	1,931 (572)
Yellow perch	0.1268 (0.0438)	6 (10)	907 (962)	137 (166)	449 (224)	874 (451)	765 (616	813 (453)	383 (356)	4,334 (1,385)
Northern pike	0.0001 (0.0002)	3 (7)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3 (7)
Bluegill	0.0319 (0.0221)	6 (12)	0 (0)	703 (674)	159 (180)	233 (268)	0 (0)	0 (0)	0 (0)	1,101 (747)
Largemouth bass	0.0005 (0.0008)	0 (0)	0 (0)	0 (0)	0 (0)	17 (26)	0 (0)	0 (0)	0 (0)	17 (26)
Pumpkinseed	0.0043 (0.0051)	0 (0)	0 (0)	0 (0)	65 (91	84 (149)	0 (0)	0 (0)	0 (0)	149 (175)
Rock bass	0.0139 (0.0092)	3 (7)	0 (0)	0 (0)	227 (188)	250 (248)	0 (0)	0 (0)	0 (0)	480 (311)
White sucker	0.0019 (0.0039)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	67 (134)	67 (134)
Total harvest	0.2398 (0.0594)	290 (146)	1,034 (969)	1,681 (849)	1,435 (414)	1,655 (607)	786 (617)	879 (456)	467 (380)	8,227 (1,719)
		Number caught and released								
Smallmouth bass	0.0193 (0.0173)	89 (75)	469 (580)	14 (34)	73 (69)	19 (20)	0 (0)	0 (0)	0 (0)	664 (590)
Largemouth bass	0.0030 (0.0046)	0 (0)	0 (0)	104 (157)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	104 (157)
Walleyes	0.1417 (0.0419)	520 (318)	1,521 (949)	1,499 (686)	833 (310)	471 (302)	10 (20)	26 (25)	4 (6)	4,884 (1,289)
Northern pike	0.0303 (0.0123)	387 (252)	330 (245)	41 (58)	159 (157)	39 (40)	37 (74)	43 (44)	10 (15)	1,046 (401)
Yellow perch	0.1113 (0.0391)	0 (0)	0 (0)	335 (312)	2,041 (1,019)	915 (481)	297 (391)	103 (91)	147 (156)	3,838 (1,246)
Total catch and release	0.3055 (0.0695)	996 (412)	2,320 (1,138)	1,993 (772)	3,106 (1,078)	1,444 (569)	344 (398)	172 (103)	161 (156)	10,536 (1,934)
Total (harvest + release)	0.5453 (0.1048)	1,286 (437)	3,354 (1,495)	3,674 (1,148)	4,541 (1,155)	3,099 (832)	1,130 (734)	1,051 (468)	628 (411)	18,763 (2,588)
		Fishing effort								
Angler hours		3,810 (1,127)	5,425 (1,945)	8,912 (2,048)	5,323 (1,102)	2,972 (1,071)	4,594 (2,803)	2,806 (1,274)	627 (532)	34,469 (4,623)
Angler trips		1,900 (692)	1,612 (735)	10,032 (1,925)	1,492 (1,483)	1,126 (1,247)	1,749 (1,282)	849 (515)	199 (197)	18,959 (3,229)

Appendix C.–Angler survey estimates for summer and winter 2001-02 from Pickerel Lake. Survey period was April 28 to September 30, 2001 and January 1 to March 31, 2002. Two standard errors are given in parentheses.

Species	Catch/hour	2001 Apr-May	2001 Jun	2001 Jul	2001 Aug	2001 Sep	2002 Jan	2002 Feb	2002 Mar	Season
		Number harvested								
Brown trout	0.0001 (0.0003)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3 (6)	0 (0)	3 (6)
Smallmouth bass	0.0019 (0.0026)	0 (0)	0 (0)	5 (3)	35 (55)	0 (0)	0 (0)	0 (0)	0 (0)	40 (55)
Walleyes	0.0162 (0.0088)	52 (54)	133 (134)	67 (72)	44 (49)	47 (59)	3 (7)	0 (0)	0 (0)	346 (179)
Yellow perch	0.0923 (0.0645)	0 (0)	100 (113)	328 (252)	231 (187)	32 (48)	881 (1,275)	344 (233)	60 (105)	1,976 (1,343)
Northern pike	0.0005 (0.0006)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	6 (10)	0 (0)	4 (9)	10 (13)
Black crappie	0.0008 (0.0017)	0 (0)	0 (0)	18 (36)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	18 (36)
Bluegill	0.0986 (0.0469)	15 (30)	181 (209)	751 (553)	991 (706)	174 (198)	0 (0)	0 (0)	0 (0)	2,112 (942)
Largemouth bass	0.0005 (0.0008)	0 (0)	10 (16)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	10 (16)
Pumpkinseed	0.0145 (0.0123)	0 (0)	0 (0)	214 (217)	81 (138)	15 (29)	0 (0)	0 (0)	0 (0)	310 (259)
Rock bass	0.0267 (0.0154)	0 (0)	0 (0)	288 (232)	174 (141)	109 (160)	0 (0)	0 (0)	0 (0)	571 (315)
Total harvest	0.2520 (0.0896)	67 (61)	424 (273)	1,671 (690)	1,556 (760)	377 (267)	890 (1,275)	347 (233)	64 (105)	5,396 (1,701)
		Number caught and released								
Brown trout	0.0003 (0.0005)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	6 (11)	6 (11)
Smallmouth bass	0.0214 (0.0139)	37 (38)	37 (46)	178 (206)	104 (113)	102 (157)	0 (0)	0 (0)	0 (0)	458 (289)
Largemouth bass	0.0015 (0.0017)	19 (28)	0 (0)	0 (0)	13 (23)	0 (0)	0 (0)	0 (0)	0 (0)	32 (36)
Walleyes	0.1925 (0.0697)	415 (283)	837 (662)	1,590 (864)	1,109 (685)	117 (164)	0 (0)	54 (69)	0 (0)	4,122 (1,329)
Northern pike	0.0439 (0.0216)	254 (178)	214 (276)	141 (128)	279 (248)	0 (0)	7 (10)	16 (20)	30 (61)	941 (436)
Muskellunge	0.0011 (0.0022)	0 (0)	0 (0)	24 (48)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	24 (48)
Yellow perch	0.0967 (0.0558)	0 (0)	0 (0)	86 (147)	739 (871)	250 (236)	204 (257)	477 (502)	315 (398)	2,071 (1,145)
Total catch and release	0.3574 (0.1038)	725 (337)	1,088 (718)	2,019 (910)	2,244 (1,141)	469 (327)	211 (257)	547 (506)	351 (402)	7,654 (1,830)
Total (harvest + release)	0.6094 (0.1540)	792 (342)	1,512 (768)	3,690 (1,142)	3,800 (1,371)	846 (422)	1,101 (1,300)	894 (558)	415 (415)	13,050 (2,499)
		Fishing effort								
Angler hours		2,207 (751)	3,313 (1,498)	6,900 (2,270)	4,100 (1,340)	2,426 (1,205)	1,019 (888)	971 (499)	479 (461)	21,415 (3,530)
Angler trips		883 (434)	890 (482)	3,673 (1,835)	1,672 (890)	791 (501)	267 (253)	307 (186)	148 (146)	8,631 (2,225)