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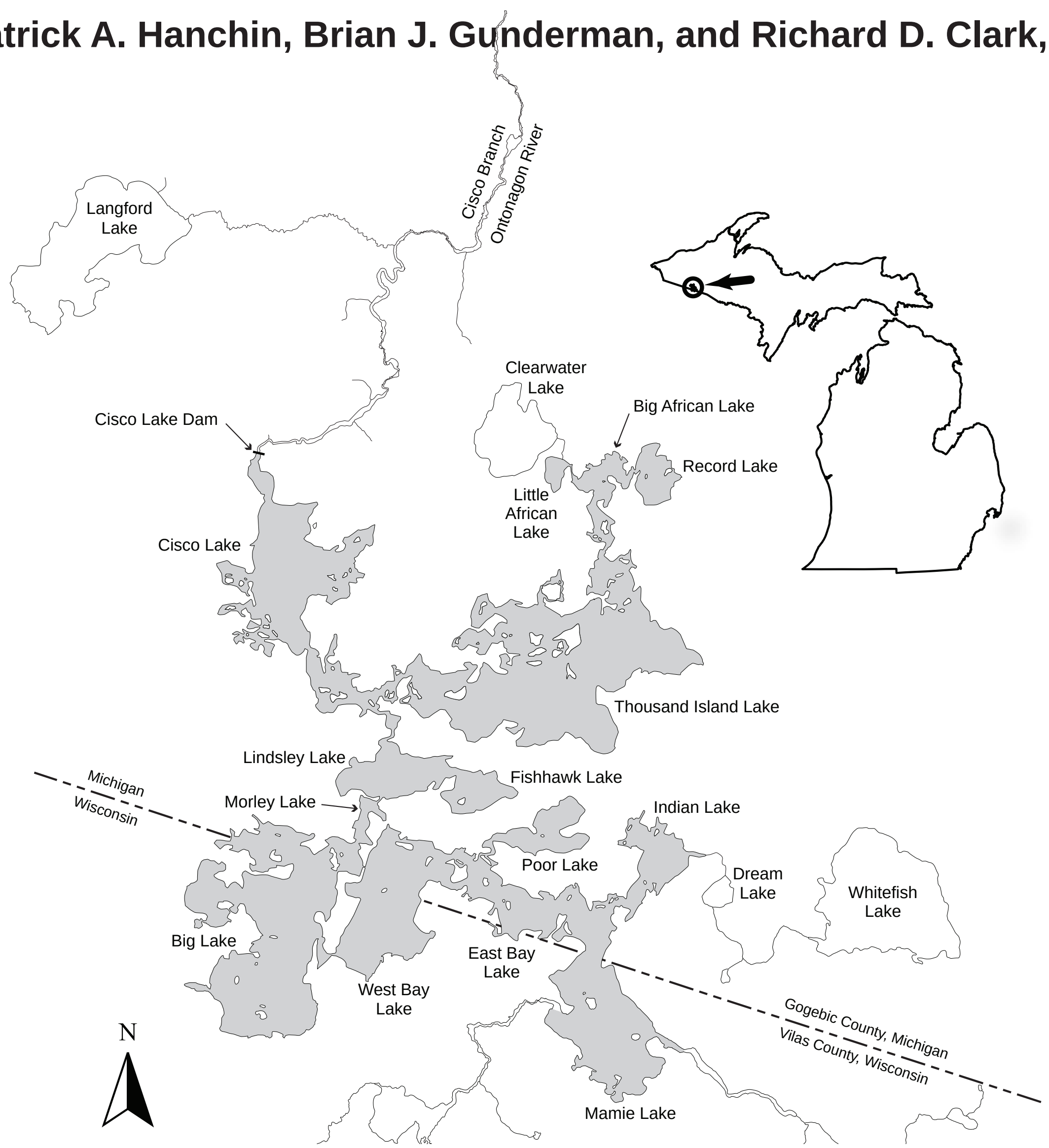

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Table of Contents

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The Fish Community and Fishery of the Cisco Lake Chain, Gogebic County, Michigan and Vilas County, Wisconsin with Emphasis on Walleyes, Northern Pike, and Muskellunge

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Introduction

Michigan Department of Natural Resources (MDNR), Fisheries Division surveyed fish populations and angler catch and effort on the Cisco Lake Chain, Gogebic County, Michigan and Vilas County, Wisconsin from April 2002 through February 2003. This work was part of a statewide Large Lakes Program designed to improve assessment and monitoring of fish communities and fisheries in Michigan's largest inland lakes (Clark et al. 2004).

The Large Lakes Program has three primary objectives. First, we want to produce consistent indices of abundance and estimates of annual harvest and fishing effort for important fishes. Initially, important fishes are defined as species susceptible to trap or fyke nets and/or those readily harvested by anglers. Our goal is to produce statistics for important fishes to help detect major changes in their populations over time. Second, we want to produce 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 walleye *Sander vitreus*, northern pike *Esox lucius*, and muskellunge *Esox masquinongy* as special-interest species in this survey of the Cisco Lake Chain. 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.

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 for direct evaluation of differences between lakes or changes within a lake over time. The Cisco Lake Chain is only the sixth lake to be sampled under the protocols of the program, thus, we were sometimes limited in our ability to make valid comparisons. Of course, as our program progresses we will eventually have a large body of netting data collected under the same conditions in the future.

Study Area

The Cisco Lake Chain is within the Ontonagon River watershed in southern Gogebic County, Michigan and northern Vilas County, Wisconsin. The Michigan portion is in the Western Lake Superior Fisheries Management Unit and the Lake Superior Basin. The Cisco Lake Chain consists of 14 interconnected lakes with a combined surface area of around 4,000 acres. The most recent hydroelectric license for the Cisco Lake Dam reported an area of 4,025 acres (FERC 2003), while Breck (2004) reported 3,987 acres. Eleven lakes (Cisco Lake, Thousand Island Lake, Little African Lake, Big African Lake, Record Lake, Lindsley Lake, Fishhawk Lake, Morley Lake, Poor Lake, Indian Lake, and East Bay Lake) are entirely within Michigan, two lakes (Big Lake and West Bay Lake) are partially in Michigan and Wisconsin, and one lake (Mamie Lake) is entirely in Wisconsin (Figure 1).

Three streams flow into the southern end of the Cisco Lake Chain: Helen Creek, Spring Creek, and an unnamed stream that arises in Whitefish Lake. The Cisco Branch Ontonagon River flows out of Cisco Lake at the northern end of the chain.

The Cisco Lake Dam controls the water level in the Cisco Lake Chain. The Copper District Power Company constructed this dam in 1931 to provide water for their hydroelectric facility at Victoria Dam on the West Branch Ontonagon River. In addition, logging companies may have constructed wooden dams at the outlet prior to this date (MDNR, Fisheries Division files). The Upper Peninsula Power Company (UPPCo) acquired ownership of the Cisco Lake Dam and the Victoria hydroelectric facility in 1948.

The Cisco Lake Dam raises lake levels in the chain by 4–5 feet. The elevated lake levels increase the ability of boaters to travel between different lakes within the chain. Fluctuations in lake levels are relatively minor. For example, the target elevation range for Cisco Lake under the current dam operating license is 1,683.4–1,683.9 ft above sea level.

The vast majority of the shoreline of the Cisco Lake Chain is privately owned, and the area has become popular for vacation home development. Waters throughout the Cisco Lake Chain are relatively shallow. Of the lakes in Michigan, the two largest and most extensively surveyed are Thousand Island and Cisco lakes (Deephouse 1993a and 1993b). Thousand Island Lake is the deepest lake in the chain with a maximum depth of 40 ft, but Cisco Lake has a maximum depth of only 21 ft and waters greater than 20 ft deep comprised less than 5% of the surface area and volume in Cisco Lake (Figures 2 and 3). Water depths throughout the rest of the Cisco Lake Chain are generally more like Cisco Lake with little water greater than 20 ft deep. Logs and submerged vegetation are abundant along most of the shoreline. Cobble and boulders are common in the southern lakes of the chain, while sand is the dominant substrate in Thousand Island and Cisco lakes. Organics and sand are the major substrate types in the smaller lakes and bays within the chain. Water chemistry analyses conducted in Thousand Island and Cisco lakes have found pH values of 6.7–7.9 and surface alkalinities of 36–55 ppm. Many of the lakes in the Cisco Lake Chain thermally stratify during the summer, and dissolved oxygen levels in the hypolimnetic portions of these basins can drop below 1 ppm (MDNR files).

The fish community of the Cisco Lake Chain includes species typical of this northern, forested region. We listed common and scientific names of all fish species captured during this and previous studies of the Cisco Lake Chain in the Appendix. Henceforth, we will use only common names in the text. Families of fish include, but are not limited to, *Esocidae, Cyprinidae, Catostomidae, Centrarchidae, Percidae, and Ictaluridae.*

Past management activities in the Cisco Lake Chain have generally focused on improving the walleye fishery. Walleyes were stocked in Thousand Island and Cisco lakes during the late 1930s and early 1940s. After a long hiatus, walleye stocking resumed in 1983 (Table 1). Lake trout, muskellunge, and tiger muskellunge also have been stocked in the Cisco Lake Chain. Stunting of northern pike has been a continual problem, and there currently is no minimum size limit for northern pike in this system. State of Michigan Master Angler entries from the Cisco Lake Chain (1980–2005) have included eight muskellunge and two largemouth bass.

Methods

We used the same methods on the Cisco Lake Chain as described by Clark et al. (2004) for Houghton Lake. We will give an 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 in April–May to coincide with spawning of primary targets – walleyes, northern pike, and muskellunge. We identified all fish to species and enumerated them. Fishing effort was recorded by individual net, but not for electrofishing. Electrofishing was used to increase the sample size of target species. Standard total lengths were measured for subsamples of each nontarget species. All target species were measured and legal-sized 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 May 4 through October 31, 2002 and one covered the winter fishery from December 7, 2002 through February 26, 2003. Tags on target species observed during angler surveys were tallied and the ratios of marked to unmarked fish were used to calculate abundance estimates. 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 $10 rewards to anglers returning them.

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, northern pike, and muskellunge as described below. We sampled fish populations in the Cisco Lake Chain with fyke nets and electrofishing gear from April 21 to May 3, 2002. We did not use trap nets as described in Clark et al. (2004). We used four boats daily to work nets, each with three-person crews, for 2 weeks. Each net-boat crew tended 10–15 nets. Another electrofishing boat collected target species during the day, and some nights.

Fyke nets were 6 ft long x 4 ft in diameter with ¾-in stretch mesh (some with ½-in mesh) and 50- to 75-ft leads. Duration of net sets ranged from 1–4 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. Total lengths of all walleyes, northern pike, and muskellunge were measured to the nearest 0.1 in. For other fish, we measured lengths to the nearest 0.1 in for subsamples of up to 200 fish per work crew. Crews ensured that lengths were taken over the course of the survey to account for any temporal trends in the size structure of fish collected. Size structure was characterized for purposes of comparison using percent over legal size.

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).

Size Structure

All walleyes, northern pike, and muskellunge were measured to the nearest 0.1 in. We summarized numbers per inch group and percentages over legal size for the Cisco Lake Chain as a whole and for the north and south lake groups, and only included fish measured on their initial capture occasion. Even though northern pike had no legal minimum size limit in the Cisco Lake Chain, we used the statewide minimum size limit of 24 in as the size for analysis. We assessed differences in length frequency for the north and south lake groups by comparing the distribution of lengths between lakes using the Kolmogorov-Smirnov asymptotic two-sample test. Additionally, differences in overall mean lengths of samples were assessed using a two-sample t-test. Statistical differences were considered significant at α less than or equal to 0.05.

Walleyes, Northern Pike and Muskellunge

We treated the Cisco Lake Chain as a single large lake. That is, we pooled data for all lakes in the chain as if we had collected it from a single large lake. However, we did distribute our sampling effort across individual lakes in the chain to try to determine if separate walleye, northern pike, or muskellunge populations existed in different lakes or groups of lakes (Table 2). We assumed that if separate populations did exist, we could identify them first by the lack of overlap in their movement patterns as indicated by the mark and recapture of fish and second by demonstrating differences in their growth and mortality statistics. Our preliminary analysis suggested that two relatively distinct walleye populations existed in the Cisco Lake Chain, one occurring in a northern group of lakes and another occurring in a southern group of lakes. We could not find any similar lake-group distinctions for northern pike or muskellunge. Therefore, we pooled walleye data into north and south lake groups based on apparent differences in walleye populations and calculated separate walleye population statistics for each group as if the Cisco Lake Chain had consisted of only two large, individual lakes. We also tabulated some survey statistics of other fish species into the north and south walleye lake groups to help provide insight into why the walleye population groups were different. The north walleye lake group was 1,984 surface acres and consisted of Cisco Lake, Thousand Island Lake, Little African Lake, Big African Lake, Record Lake, Lindsley Lake, and Fishhawk Lake. The south walleye lake group was 2,003 surface acres and consisted of Morley Lake, Poor Lake, Indian Lake, East Bay Lake, Big Lake, West Bay Lake, and Mamie Lake (Table 2).

Sex composition.–We recorded sex of walleyes, northern pike, and muskellunge when flowing gametes were present. Fish with no flowing gametes were identified as unknown sex.

Abundance.–We estimated the abundance of walleyes, northern pike, and muskellunge using mark-and-recapture methods. We calculated estimates for the entire Cisco Lake Chain, with additional estimates for walleyes in the north and south lake groups. Walleyes (≥15 in), northern pike (≥18 in), and muskellunge (≥42 in) were fitted with monel-metal jaw tags. Because the Cisco Lake Chain has no minimum size limit for northern pike, we used the minimum size that we thought was acceptable for anglers to harvest as the minimum size for tagging. 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 : nonreward 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 the numbers of fish tagged. Large tags (size 12) that were used on large (≥36 in) northern pike and muskellunge were all nonreward.

Initial tag loss was assessed during the marking period as the proportion of recaptured fish of legal size without tags. This tag loss was largely caused by entanglement with nets, and thus was not used to adjust estimates of abundance or exploitation. Newman and Hoff (1998) reported similar 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-unmarked ratios during the spring survey (multiple census) and the other derived from marked-unmarked ratios from the angler survey (single census). For the multiple-census estimate, we used the Schumacher-Eschmeyer formula 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. For both the multiple- and single-census estimates of walleye abundance, we made separate estimates for the north and south lake groups of the Cisco Lake Chain and then added the two to make an estimate total abundance for the entire Cisco Lake Chain. We calculated the probability of tag loss 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).

The Wisconsin Department of Natural Resources (WDNR) has made several prior estimates of walleye abundance for Big, West Bay, and Mamie lakes. Adult walleye density generally ranged from four to six per acre in the lower lakes of the chain (Steve Gilbert, WDNR, personal communication). Additionally, we used a regression equation developed for Wisconsin lakes (Hansen 1989) to provide another a priori estimate of walleye abundance. This regression predicts adult walleye abundance based on lake size. Parameters for this equation are recalculated every year by the WDNR. We used the same parameters used by WDNR in 2002 (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 the Cisco Lake Chain as a whole, the equation gives an estimate of 12,883 (4,220–39,326) walleyes. The equation gives estimates of 6,651 (1,988–19,250) walleyes for the north lake group and 6,712 (2,005–19,417) walleyes for the south lake group. 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. Thus, we set our tagging goal at 10% of the entire Cisco Lake Chain walleye population, or approximately 1,300 walleyes. Because the regression estimate was made for adult walleyes, including some mature fish smaller than 15 inches, our goal of 1,300 was somewhat greater than 10% of the legal-size walleye population. We did not have specific tagging goals for each individual lake in the chain, but we distributed our survey effort among lakes according to lake size. We set no specific tagging goal for northern pike.

It is important to recognize the difference between walleye abundance estimates from the Wisconsin regression equation and the 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 greater than or equal to 15 in. WDNR defined adult walleyes as legal sized, or sublegal sized of identifiable sex, many of which would be smaller than 15 in. 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 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 greater than or equal to 15 by the proportion of adult walleyes on the spawning grounds that were greater than or equal to 15 in, using the equation in Clark et al. (2004).

Similar to walleyes, we defined adult northern pike as those greater than or equal to 24 in or less than 24 in, but of identifiable sex. In this case, we used the statewide size limit for defining adult northern pike so that we had an estimate suitable for comparison to other lakes surveyed using identical methods. We estimated adult northern pike using the multiple-census and adjusted single-census methods as was done for walleyes. For muskellunge, we intended to use methods similar to those used for northern pike, though we did not expect to collect many fish.

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., 14.0–14.9-in walleyes). For a detailed explanation of our methods to adjust for in-season recruitment, see Clark et al. (2004) and Ricker (1975). This adjusted ratio was used to make the primary (single census) population estimate.

Abundance estimates were considered reliable if the coefficient of variation (CV=standard deviation/estimate) was less than 0.40 which Hansen et al. (2000) considered indicative of reliable estimates.

Mean lengths at age.–We used dorsal spines to age walleyes and dorsal fin rays to age northern pike and muskellunge. 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 ageing walleyes and northern pike.

We based sample sizes for age analysis on historical length at age data from the Cisco Lake Chain and the methods given in Lockwood and Hayes (2000). We attempted to collect samples throughout the chain. Our goal was to collect 50 male and 50 female walleyes per inch group, 30 male and 30 female northern pike per inch group, and all muskellunge encountered. We aged subsamples of the total number of structures collected. To represent mean lengths at age for the north and south lake groups, we randomly selected ageing structures from fish collected from lakes in each group. We selected 15 fish per inch group for both sexes of each species in each lake group. We also aged fish of unknown sex, when we collected less than 15 fish per inch group of either sex. We pooled the two lake group samples to represent the Cisco Lake Chain as a whole.

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 40–80x magnification with transmitted light and were photographed with a digital camera. The digital image was archived for multiple reads. Two technicians independently aged samples. 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, though occasionally an average age was used when ages assigned to older fish (≥age 10) were within plus or minus 10% of each other.

After a final age was identified for all samples, 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 walleyes, northern pike, and muskellunge (Devries and Frie 1996).

We tested for differences in mean lengths at age between the north and south lake groups using a two-way analysis of variance, controlling for age as a covariate. Statistical significance was set at α = 0.05. We compared our mean lengths at age to those from previous surveys of lakes within the Cisco Lake Chain and to other large lakes. Also, we computed a mean growth index to compare our data to Michigan state averages as described by Schneider et al. (2000). The mean growth index is the average of deviations between the observed mean lengths and statewide seasonal average lengths.

Mortality.–We estimated instantaneous total mortality rates for walleyes, northern pike, and muskellunge from catch-curve regressions (Ricker 1975). We calculated catch-curve regressions for the Cisco Lake Chain as a whole and if sample sizes were sufficient, for the north and south lake groups separately. We assessed differences in the catch curve regressions between the north and south lake groups using analysis of covariance ($\alpha \leq 0.05$). 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 three methods: 1) the percent of reward tags returned by anglers; 2) the estimated harvest divided by the multiple-census estimate of abundance; and 3) the estimated harvest divided by the single-census estimate of abundance. We compared these three estimates of exploitation and converted them to instantaneous fishing mortality rates.

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

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

where, N_t was the number of tags observed in creel, N_c was the number of fish observed in creel, H was the total expanded harvest of the species being evaluated.

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

Voluntary tag returns were encouraged with a monetary reward ($10) denoted on approximately ½ of the tags. Tag return forms were available at boater access sites, at MDNR offices, and from creel clerks. Additionally, tag return information could be submitted online 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 nonreward tags.

In the second method, we calculated exploitation as the estimated annual harvest from the angler survey divided by the various abundance estimates for legal-sized fish. For proper comparison with the single-census abundance of legal fish as existed in the spring, the estimated annual harvest was adjusted for fish that would have recruited to legal size over the course of the creel survey (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 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 and northern pike, we related year-class strength to various environmental variables by using correlation, simple linear, and multiple regression analyses. Historic weather data were obtained from the National Weather Service observation station in Watersmeet, Michigan. We did not have any historic water quality data specific to the Cisco Lake Chain itself. Variables that we tested included: average monthly air temperature, average monthly minimum air temperature, minimum monthly air temperature, average monthly maximum air temperature, maximum monthly air temperature, and total monthly precipitation.

Movement.–We assessed fish movements by comparing mark and recapture locations. Recapture locations provided by anglers were often too vague to describe movements within individual lakes, so we identified only the more conspicuous movements, such as from lake to lake or lake to connected river.

Angler Survey

State of Michigan fishing regulations applied to Cisco, Thousand Island, Little African, Big African, Record, Lindsley, Fishhawk, Poor, Indian, Morley, and East Bay lakes. Fishing harvest seasons for walleyes, northern pike, and muskellunge during this survey were May 15, 2002–February 28, 2003. Minimum size limits were 15 in for walleyes and 42 in for muskellunge. There was no minimum size limit 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 25, 2002 through Dec 31. Minimum size limit was 14 in for both smallmouth bass and largemouth bass.

Harvest was permitted all year for all other species present. Minimum size limit was eight inches for brook trout, with a daily limit of five fish, no more than three of which could be 15 in or greater. No minimum size limits were imposed for other species. Bag limit for lake whitefish and lake herring was 12 in combination. Bag limit for yellow perch was 50 per day. Bag limit for "sunfishes", including black crappie, bluegills, pumpkinseeds, and rock bass was 25 per day in any combination.

Michigan-Wisconsin boundary water regulations applied to Big, West Bay, and Mamie lakes. Fishing harvest seasons for walleyes and northern pike during this survey were May 4, 2002 to March 1, 2003. The minimum size limit for walleyes was 15 in, and there was no size limit for northern pike. The minimum size limit for muskellunge was 40 in, and the possession limit was one. The minimum size limit was 14 in for both smallmouth bass and largemouth bass, and the possession limit was five fish in any combination. Fishing harvest season for muskellunge was May 15 to November 30. The catch and release season for smallmouth and largemouth bass was from May 4 to June 14. The fishing harvest season for smallmouth and largemouth bass was June 15 to November 30.

Harvest was permitted all year for all other species present. Minimum size limit was eight inches for brook trout, with a daily limit of five. No minimum size limits were imposed for these other species. Bag limit for "sunfishes", including crappie, bluegills, pumpkinseeds, and yellow perch was 25 per day in any combination.

Direct contact angler creel surveys were conducted during one spring-summer period – May 4 to October 31, 2002, and one winter period – December 7, 2002 through February 26, 2003. General descriptions of summer and winter surveys are presented here with necessary specific information presented within the appropriate sections.

For sampling purposes in the angler survey, the Cisco Lake Chain was divided into 10 sections: Cisco, Lindsley-Fishhawk, Big, West Bay, East Bay, Mamie, Indian, Poor, Thousand Island, and Little Africa-Big Africa-Record (Figure 1; Table3). All count and interview data were collected and recorded by section. Similarly, effort and catch estimates were made by section and summed for lakewide estimates. Scanner-ready interview and count forms were used.

Both summer and winter surveys were designed to collect roving interviews. Minimum fishing time prior to interview (incomplete-trip interview) was 1 h (Lockwood 2004). When anglers reported fishing in more than one section, the clerk recorded the section number where they spent most of that trip fishing. All roving interview data were collected by individual angler to avoid party size bias (Lockwood 1997).

While both summer and winter surveys were 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. Similar to roving interviews, all access interview data were collected by individual angler.

Count information collected included: date, grid, fishing mode (fishing boat, open ice, or occupied shanty), count time, and number of fishing boats counted. Interview information collected included: date, section, fishing mode (fishing boat open ice, or shanty), 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.

Summer.–We used an aerial-roving design for the summer survey (Lockwood 2000b). Fishing boats were counted by aircraft and two clerks working from boats collected angler interview data. Survey period was from May 4 through October 31, 2002. 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 summer creel period were Memorial Day (May 27, 2002), Fourth of July, and Labor Day (September 2, 2002). 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.

One of two shifts was selected each sample day for interviewing (Table 4). Interview starting location (a section within the reservoir) and order were randomized daily. On days when the clerks interviewed in all sections prior to completion of the shift, they continued interviewing at the beginning of the specified order and proceeded to the appropriate scheduled sections. In this situation, interview forms were updated for any anglers encountered for a second time (i.e., anglers that had been interviewed earlier during the day). If the clerks knew that a party had been interviewed earlier that day but could not identify their interview form, the party was not reinterviewed. That is, no angling party had a second set of interview forms filled out for them on the same day.

Aerial counts progressed from marker 1 to marker 19 or from marker 19 to marker 1 (Figure 4). This sequence was randomized. The pilot flew one of the two randomly selected predetermined routes using GPS coordinates (Table 5). Each flight was made at 500–700 ft elevation and took approximately 16 min to complete with air speed of about 100 mph. Counting was done by the contracted pilot and only fishing boats were counted (i.e., watercraft involved in alternate activities, such as water skiing, were not counted). Time of count was randomized to cover daylight times within the sample period. Count information for each count was recorded on a lake map.

Winter.–We used a progressive-roving design for winter surveys (Lockwood 2000b). Two clerks working from snowmobiles collected count and interview data. Survey period was from December 7, 2002 through February 23, 2002. No interview or count data were collected on holidays. Holidays during the winter creel period were New Years Eve (December 31, 2002), New Years Day (January 1, 2003), Martin Luther King Day (January 13, 2003), and President's Day (February 17, 2003). Both weekend days and three randomly selected weekdays were selected for sampling during each week of the survey season. The clerks followed a randomized count and interview schedule. One of two shifts was selected each sample day (Table 4). Starting location (section) and direction of travel were randomized for both counting and interviewing.

Progressive (instantaneous) counts of open-ice anglers and occupied shanties were made once per day. No anglers were interviewed while counting (Wade et al. 1991).

Estimation methods.–Catch and effort estimates were made by section using a multiple-day method (Lockwood et al. 1999). Expansion values ("F" in Lockwood et al. 1999) are given in Table 4. These values are the number of hours within sample days. Effort is the product of mean counts by grid for a given period day type, days within the period, and the expansion value for that period. Thus, the angling effort and catch reported here are for those periods sampled, no expansions were made to include periods not sampled (e.g., 0100 to 0400 hours). Lakewide estimates were the sum of section estimates for each given time period and day type. While both summer and winter surveys were designed to collect roving interviews, the clerk was instructed to also collect access interviews from any angling parties observed completing their trip. Similar to roving interviews, all anglers within a party were interviewed. When 80% or more of interviews (80:20 ratio) within a time period (weekday or weekend day within a multiple-day period) were of an interview type, the appropriate catch-rate estimator for that interview type was used on all interviews. When less than 80% were of a single interview type, a weighted average R_w was used:

$$R_w = \frac{\left(\hat{R} \cdot n_1\right) + \left(\overline{R} \cdot n\ \right)}{\left(n_1 + n_2\right)}, \qquad (1)$$

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:

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

where $s_{\hat{R}}^2$ is the estimated variance of $\hat{R}$ and $s_{\overline{R}}^2$ is the estimated variance of $\overline{R}$. (See Lockwood et al. 1999 for appropriate catch rate and variance equations.)

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: Chapter 6). 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 two standard errors (SE). Error bounds (2 SE) provided statistical significance, assuming normal distribution shape and *N* greater than or equal to 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-unmarked fish for Petersen population estimates.

Results[1]

Fish Community

We collected 19 species of fish with fyke nets and electrofishing gear Cisco Lake Chain (Table 6). Total sampling effort was 445 fyke-net lifts and 16 electrofishing runs. We captured 11,010 walleyes, 3,979 northern pike, and 49 muskellunge. Other game fish species collected in order of abundance were yellow perch, bluegill, black crappie, rock bass, pumpkinseed, largemouth bass, smallmouth bass, and tiger muskellunge. We collected two lake herring with electrofishing gear.

Size Structure

Although, largemouth bass and smallmouth bass were collected in roughly equal numbers, the size structures of the two populations differed substantially. Fifty percent of the largemouth bass were larger than legal size (14 in), but only 12% of the smallmouth bass were larger than 14 in. Mean lengths for panfish species were as follows: 7.7 in for yellow perch, 7.0 in for bluegill, 9.4 in for black crappie, 7.1 in for rock bass, and 6.2 in for pumpkinseed. The percent composition of harvestable-sized fish ranged from 65% for pumpkinseeds to 91% for black crappies.

Overall, the population of spawning walleyes in the entire Cisco Lake Chain was dominated by 11- to 15-in walleyes, but had a considerable number of walleyes up to 30 in (Table 7). The percentage of walleyes greater than 15 in was 29 for the entire Cisco Lake Chain. The percentage of walleyes greater than 15 in was 64 and 25 for the north and south lake groups, respectively.

The mean length of walleyes captured in the entire Cisco Lake Chain was 14.4 in. The mean lengths of walleyes in the north and south lake groups were 16.9 in and 14.0 in, respectively. The difference in walleye mean lengths between the north and south lake groups was statistically significant ($t = 23.984$, $P = 0.0001$). Walleye length-frequency distributions also differed significantly

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

(Kolmogorov-Smirnov asymptotic test statistic = 12.953; P = 0.0001) between the north and south lake groups, and the shape of the distributions differed (Kolmogorov-Smirnov asymptotic test statistic = 5.852; P = 0.0001) when the distributions were centered for length.

The portion of northern pike in the Cisco Lake Chain that were larger than the statewide minimum length of 24 in was 6%. If we classify all northern pike greater than or equal to 18 in as harvestable (as discussed above), then the portion of harvestable fish was 51%. Overall, most northern pike (82%) were from 13 to 22 in (Table 7). Of the muskellunge (northern and tiger) collected, 16% were greater than 42 in, and two of these fish were larger than 50 in.

Walleyes, Northern Pike, and Muskellunge

Sex composition.–Males outnumbered females for both walleyes and northern pike in our survey, which is typical for spawning populations of these species (Carlander 1997; Priegel and Krohn 1975; Bregazzi and Kennedy 1980). Of all walleyes captured in the Cisco Lake Chain, 79.7% were male, 19.7% were female, and 0.6% were unknown sex. This corresponds to a sex ratio (M : F) of 4:1. Of legal-sized walleyes captured, 50.8% were male, 49.0% were female, and 0.1% were unknown sex; which corresponds to a sex ratio of about 1:1. In the north walleye lake group, 63.2% of all walleyes were male, 35.8% were female, and 1.0% were of unknown sex. In the south walleye lake group, 81.2% of all walleyes were male, 18.2% were female, and 0.6% were of unknown sex. Of all northern pike captured, 50.8% were male, 46.1% were female, and 3.1% were unknown sex. The corresponding sex ratio is 1.1:1. For northern pike greater than or equal to 18 in, 47.6% were males, 51.4% were females, and 1.0% were unknown. Finally, of legal-sized (≥24 in) northern pike captured, 17.1% were male, 81.5% were female, and 1.4% were unknown sex. Of all muskellunge captured, 33.3% were male, 29.2% were female, and 37.5 were unknown sex. The corresponding sex ratio is 1.1:1. Of legal-sized muskellunge captured, none were male, 100% were female, and none were unknown sex.

Abundance.–We tagged 2,832 legal-sized walleyes (1,356 reward and 1,476 nonreward tags) and clipped fins of 6,881 sublegal walleyes. Five recaptured walleyes were observed to have lost their tags during the spring netting/electrofishing survey, so the effective number tagged was 2,827. This initial 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. Creel clerks observed a total of 364 walleyes, of which 61 marked (had a fin clip, or a tag) in the entire Cisco Lake Chain. We reduced the number of unmarked walleyes in the single-census calculation by 99 fish to adjust for sublegal fish that grew over the minimum size limit during the fishing season. The creel clerk observed one fish that had a fin clip, no tag, and was determined to have been legal size at the time of tagging. Based on the sample of 61 recaptured fish, the estimate of tag loss is 1.6%, with a standard error of 0.1%. In the north lake group, creel clerks observed a total of 52 walleyes, of which eight were marked (had a fin clip, or a tag), and we reduced the number of unmarked walleyes in this sample by eight fish to adjust for sublegal fish that grew over the minimum size limit during the fishing season. In the south lake group, creel clerks observed a total of 315 walleyes, of which 54 were marked (had a fin clip, or a tag), and we reduced the number of unmarked walleyes in this sample by 83 fish to adjust for sublegal fish that grew over the minimum size limit during the fishing season.

We estimated 7,236 legal-size walleyes (CV=0.06) were present in the entire Cisco Lake Chain using the multiple-census method, with 1,517 in the north lake group and 5,719 in the south lake group (Table 8). Using the single-census method, we estimated 12,558 legal-size walleyes (CV=0.12) were present in the entire Cisco Lake Chain, with 3,755 in the north lake group and 8,803 in the south lake group (Table 8).

We estimated 40,239 adult walleyes (CV=0.07) were present in the entire Cisco Lake Chain using the multiple-census method, with 3,557 adult walleyes in the north lake group and 36,683 in the south lake group (Table 8). Using the single-census method, we estimated 40,823 adult walleyes (CV=0.11) were present in the entire Cisco Lake Chain, with 5,761 in the north lake group and 35,062 in the south lake group.

We tagged a total of 961 northern pike (≥18 in) in the entire Cisco Lake Chain, 532 were reward tags and 429 were nonreward tags. Four recaptured fish were observed to have lost their tags during the spring netting/electrofishing survey, so the effective number tagged was 957. We also clipped fins of 1,667 northern pike (<18 in). The creel clerk observed 107 northern pike, of which seven were tagged. We reduced the number of unmarked northern pike in the single-census calculation by 43 fish to adjust for sublegal fish that grew over the minimum acceptable size during the fishing season. The creel clerk observed two of seven recaptured fish that had lost tags.

The estimated number of 18 in northern pike was 7,784 (CV=0.31) using the single-census method (Table 9). The multiple-census-estimates of adult northern pike were 7,083 (CV=0.19) and 4,321 (CV=0.17), respectively in the northern and southern halves for a total of 11,404 (CV=13). The single-census estimate was 14,904 (CV=0.31) adult northern pike.

We tagged eight (all nonreward) legal-sized muskellunge in the Cisco Lake Chain, and clipped fins of 40 sublegal muskellunge. The minimum number of recaptures was not attained for the multiple-census method. Also, the creel clerk did not observe any muskellunge in the possession of anglers, so no single-census abundance estimate was made.

Mean lengths at age.–For walleyes, there was 38.7% agreement between the first two ageing technicians. For fish that were aged by a third reader, agreement was with first reader 82.3% of the time and with second reader 17.7% of the time; thus, there appeared to be bias among readers. This bias was apparently due to identification of the first annulus. At least two readers agreed 85.9% of the time, and 6.4% of samples were discarded due to poor agreement. For the remaining 7.7% of samples we used an average age from the three readers. Our reader agreement (first two reads) for walleye spines was somewhat lower than other studies. Isermann et al. (2003) achieved 55% reader agreement and Kocovsky and Carline (2000) achieved 62%. Reader agreement (first two reads) in five Michigan large lakes surveyed to date has ranged from 40.8 to 67.6% with an average of 56.1%. Similar to us, Miller (2001) found that at least two of three readers agreed 94.2% of the time.

Female walleyes had higher mean lengths at age than males for the entire Chain and for north and south lake groups separately (Tables 10, 11, and 12). This is typical for walleye populations in general (Colby et al. 1979; Carlander 1997; Kocovsky and Carline 2000).

The analysis of variance indicated a significant difference in walleye mean length at age between the north and south walleye lake groups (F = 62.158, P = 0.0001). There was no significant lake×age interaction (F = 0.953, P = 0.340). On average, walleyes in the north lake group were 3.0 in larger than in the south (Tables 11 and 12).

We calculated mean growth indices for walleyes of -0.6 and -3.2 for the northern and southern halves of the Cisco Lake Chain, respectively. Thus, walleye mean lengths at age in the north appeared to be only slightly lower than the state average, while those in the south were substantially lower. We note that state average mean lengths were estimated by scale ageing, 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.

We fit mean length at age data for male, female, and all walleyes to a von Bertalanffy growth curve. In the north lake group, male, female, and all walleyes had L_∞ values of 21.1 in, 29.9 in, and

31.2 in, respectively. In the south lake group, male, female, and all walleyes had L_∞ values of 19.1 in, 29.9 in, and 34.6 in, respectively.

For northern pike, there was 80.6% agreement between the first two ageing technicians. For fish that were aged by a third reader, agreement was with first reader 88.3% of the time and with second reader 11.7% of the time; thus, there appeared to be some bias among readers. Again, this bias was apparently due to identification of the first annulus. At least two readers agreed 97.8% of the time, and 2.2% of samples were discarded due to poor agreement. We did not use an average age for any samples. Reader agreement (first two reads) in four Michigan large lakes surveyed to date has ranged from 59.0 to 80.5% with an average of 68.0%.

Female northern pike generally had higher mean lengths at age than males (Table 13). 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 6, and females were 3.4 in longer than males at age 6 (Table 13).

We calculated a mean growth index for northern pike of -4.0, thus the mean lengths at age for northern pike are low relative to the state average. As with walleyes, the Large Lakes Program will eventually age enough northern pike with fin rays to recalculate state averages for future comparisons.

We fit mean length at age data for male, female, and all northern pike to a von Bertalanffy growth curve. Male, female, and all northern pike had L_∞ values of 25.4, 25.4, and 25.6 in, respectively.

For muskellunge, there was 75.6% agreement between the first two ageing technicians. For fish that were aged by a third reader, agreement was with first reader 83.3% of the time and with second reader 16.7% of the time; thus, there appeared to be some bias among readers. Again, this bias was apparently due to identification of the first annulus. At least two readers agreed 90.2% of the time, and 2.4% of samples were discarded due to poor agreement. For the remaining 7.3% of samples we used an average age from the three readers.

We were not able to identify the sex of most of the muskellunge so computations of mean lengths at age are for all sexes combined (Table 14).

We calculated a mean growth index for muskellunge of -3.4, which means that fish in our sample from the Cisco Lake Chain appeared to grow substantially slower than the state average. However, the state averages we used were calculated for the middle of the growing season, and the geographic distribution of the lakes used to derive these state averages are unknown.

Mortality.–For walleyes in the entire Cisco Lake Chain, we estimated catch at age for 7,617 males, 1,886 females, and 9,731 total walleye (including unknown-sex fish). For use in the catch-curve analyses, we selected the minimum age where the mean length was greater than legal size, and fish younger than that minimum age were represented in proportion to their true abundance, suggesting that fish are fully mature at the selected age. These criteria resulted in minimum ages of 7, 5, and 6 for males, females, and all walleyes, respectively. We did not include age-17 and -19 fish because the mortality estimates appeared more indicative of the general trend in declining catch with age when they were not included. For walleyes in the entire Cisco Lake Chain, the catch-curve regressions for male, female and all walleyes were significant ($P<0.050$), and produced total instantaneous mortality rates for legal-sized fish of 0.569 for males, 0.286 for females, and 0.359 for all fish combined (Figure 5). These instantaneous rates corresponded to annual mortality rates of 43% for males, 25% for females, and 30% for all walleyes combined.

For walleyes in the north lake group, we estimated catch at age for 746 males, 421 females, and 1,183 total walleye (including unknown-sex fish) (Table 15). We used ages 5 and older in the catch-curve analysis to represent the legal-sized population (Figure 6). We chose age 5 as the youngest age because: 1) average length of walleyes at age 4 was 16.1 in for males and 17.3 in for females

(Table 11), so a high proportion of age-5 fish were of legal size at the beginning of the fishing season; and 2) relative abundance of females younger than age 5 do not appear to be represented in proportion to their true abundance (Figure 6), suggesting that they are not fully mature at age 4. For walleyes in the north lake group, the catch-curve regressions for male, female and all walleyes were significant ($P < 0.050$), and produced total instantaneous mortality rates for legal-sized fish of 0.621 for males, 0.292 for females, and 0.363 for all fish combined (Figure 6). These instantaneous rates corresponded to annual percent mortality rates of 46% for males, 25% for females, and 30% for all walleyes combined.

For walleyes in the south lake group, we estimated catch at age for 6,873 males, 1,460 females, and 8,542 total walleye (including unknown-sex fish). For use in the catch-curve analyses, we selected the minimum age where the mean length was greater than legal size, and fish younger than that minimum age were represented in proportion to their true abundance, suggesting that fish are fully mature at the selected age. These criteria resulted in minimum ages of 7, 5, and 7 for males, females, and all walleyes, respectively. For walleyes in the south lake group, the catch-curve regressions for male, female and all walleyes were significant ($P < 0.050$), and produced total instantaneous mortality rates for legal-sized fish of 0.578 for males, 0.277 for females, and 0.391 for all fish combined (Figure 7). These instantaneous rates corresponded to annual percent mortality rates of 44% for males, 24% for females, and 32% for all walleyes combined.

The catch curve regressions for walleyes differed between northern and southern portions of the chain ($F = 43.522$, $P < 0.001$), though this difference was due to higher catch in the south. The lake×age interaction term was not significant ($F = 0.775$, $P = 0.392$); thus, the slopes (mortality rates) were not different between the northern and southern groups.

Anglers returned a total of 440 walleye tags (227 reward and 213 nonreward tags) in the year following tagging from the Cisco Lake Chain (Table 16; Figure 8). One tagged fish was also observed in the possession of an angler that was not subsequently reported to the central office by the angler. The estimated angling exploitation rate for walleyes was 17.3% based on return of reward tags, adjusted for tag loss. The angler exploitation was higher for walleyes tagged in the south lake group than in the north lake group (18.5% versus 13.6%, respectively). Overall, anglers reported reward tags at a slightly higher rate than nonreward tags (17.0% versus 14.7%), but they likely did not fully report either one. Based on all tagged walleyes (legal fish) known to be caught, the reported release rate was 0.5%.

In the entire Cisco Lake Chain, the estimated exploitation rate for walleyes was 30.7% based on dividing harvest by the multiple-census abundance estimate, and 17.7% based on dividing harvest by the single-census abundance estimate (Table 8). The harvest estimate used here was first adjusted for nonsurveyed months (using tag returns), and second for the proportion of harvested fish that were not of legal size at the time of tagging. In the north lake group, the estimated exploitation rate for walleyes was 54.5% based on dividing harvest by the multiple-census abundance estimate, and 22.0% based on dividing harvest by the single-census abundance estimate. In the south lake group, the estimated exploitation rate for walleyes was 26.8% based on dividing harvest by the multiple-census abundance estimate, and 17.4% based on dividing harvest by the single-census abundance estimate.

Tribal fishers (Chippewa Indians) harvested and reported 44 walleyes with jaw tags in their spring spear fishery for walleyes on the Cisco Lake Chain (Jennifer Krueger, Great Lakes Indian Fish and Wildlife Commission, personal communication). This represents a spearing exploitation of about 1.6% based on the total number of walleye tagged over the course of our entire spring survey. This exploitation is for walleye 15-in and larger, and does not include smaller adult walleye.

The total tribal spear fishery harvest of walleyes of all sizes was 485 in the entire Cisco Lake Chain (Jennifer Krueger, Great Lakes Indian Fish and Wildlife Commission, personal communication). If we divide this reported harvest by our estimates of adult walleye abundance (Table 8), we can estimate the spearing exploitation of adult walleye. Based on both the multiple-census and single-census estimates of abundance, the spearing exploitation of adult walleye in the Cisco Lake Chain in 2002 was 1.2%.

We estimated catch at age for 1,726 males, 1,562 females, and 3,378 total northern pike (including unknown-sex fish; Table 17). We used ages 4 through 9 in all catch-curve regressions to represent the northern pike population (Figure 9). We chose age 4 as the youngest age because mean length at age 4 was >18.0 in for all sexes (Table 13), so a high proportion of age-4 fish were of a size acceptable to anglers (there is no size limit for northern pike in the Cisco Lake Chain) at the beginning of fishing season.

The catch-curve regressions for male, female, and all northern pike were significant ($P < 0.050$), and produced total instantaneous mortality rates of 1.2836 for males, 0.8948 for females, and 1.0116 for all fish combined (Figure 9). These instantaneous rates corresponded to total annual mortality rates of 72% for males, 59% for females, and 64% for all sexes combined.

Anglers returned a total of 131 northern pike tags (88 reward and 43 nonreward tags) in the year following tagging (Table 18). The angler survey clerk did not observe any tagged fish in the possession of anglers that were not subsequently reported to the central office by the anglers. However, two of seven recaptured fish had lost their tag, for an estimated tag loss of 28.6%. The estimated exploitation rate for northern pike was 23.2% based on return of reward tags, adjusted for tag loss (Table 9). Overall, anglers reported reward tags at a higher rate than nonreward tags (16.6% versus 10.1%; unadjusted for tag loss), but they likely did not fully report either one. The estimated exploitation rate for northern pike was 44.1% based on dividing harvest by the multiple-census abundance estimate, and 19.7% based on dividing harvest by the single-census creel survey abundance estimate (Table 9). The harvest estimate used here was first adjusted for nonsurveyed months (using tag returns), and second for the proportion of harvested fish that were not of legal size at the time of tagging.

For muskellunge, we estimated catch at age without identifying sex for 46 fish (Table 17). We did not have enough samples for a valid catch curve analysis. The regression of ages 5 through 15 was insignificant ($F = 0.3839$, $P = 0.5527$).

Anglers returned one muskellunge tag (nonreward) in the year following tagging from the Cisco Lake Chain. This 53 in fish was released; thus, we can only assume that muskellunge exploitation is minimal. Given that we tagged eight legal-size muskellunge, the resulting exploitation rate if a single tagged fish was harvested would be 12.5%. We could not estimate exploitation for muskellunge by dividing harvest by abundance, because: 1) there was no estimate of harvest, 2) the only multiple-census abundance estimate we made was for muskellunge of all sizes, and 3) there was no single-census estimate of abundance.

Recruitment.–Recruitment variability for walleyes in the Cisco Lake Chain is represented by the amount of variation explained by the age variable ($R^2 = 0.88$) in the catch curve regression. There did not appear to be any consistent difference in year-class strength variation between the north and south lake groups. The catch curves are indicative of average recruitment stability for a walleye population.

We found one weak relationship between a climatological variable and walleye year-class strength in the Cisco Lake Chain. Standardized residuals from the walleye catch curve were positively correlated with average June air temperature ($r = 0.632$, $P = 0.050$, $df = 9$). Although this relationship is weak, and does not imply causation, it is at least in agreement with the findings of other studies on recruitment relationships, which we detail in the Discussion section.

Variability in northern pike year-class strength was low in the Cisco Lake Chain, as seen in the statistics of the catch-curve regression. The residual values were relatively 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 ($R^2 = 0.98$).

We found two significant climatological variables that were related to northern pike year-class strength. Standardized residuals from the catch curve were positively correlated with the average daily maximum air temperature in April (r = 0.898, P = 0.039, df = 4), and the average of mean daily air temperature in April (r = 0.919, P = 0.027, df =4). Although these relationships are weak, and do not imply causation, they are reasonable explanations for recruitment variability, which we detail in the Discussion section.

We felt it would not be prudent to assess the variability in muskellunge year-class strength in the Cisco Lake Chain based on a sample of 40 fish aged. Additionally, we only collected eight fish over legal size.

Movement.–Based on recaptures during the spring survey, there was movement of walleyes among lakes in the Cisco Lake Chain (Table 19). A total of 462 walleyes tagged in the Chain were recaptured during the spring netting survey. The weighted average of walleye that were recaptured in their lake of origin was 86.8%.

Based on voluntary tag returns from anglers, there was considerable movement of walleyes among lakes in the Cisco Lake Chain (Table 20). While there was movement in multiple directions throughout the Chain, 50.5% (weighted average) of recaptured walleyes were caught in the lake where they were tagged. When we divided the Chain into north and south lake groups using the narrows between Lindsley and Morley as the dividing line, 92.6% of returned walleyes tagged in the north were recaptured there, and 86.1% of returned walleyes tagged in the south were recaptured there.

During the year following tagging, one walleye was recaptured in Helen Lake, which is connected to Mamie Lake via approximately 1.5 miles of narrow creek. Also, one walleye was recaptured in Spring Lake, which is connected to Mamie Lake by a 1.5 mi section of Spring Creek. Including all tag returns to present, eight walleyes have been returned from Spring Lake. We did not tag any walleye in either Helen or Spring lakes.

Based on recaptures during the spring survey, there was movement of northern pike among lakes in the Cisco Lake Chain (Table 21). A total of 193 northern pike tagged in the Chain were recaptured during the spring netting survey. The weighted average of northern pike that were recaptured in their native lake was 53.9%.

Based on voluntary tag returns, there was considerable movement of northern pike among lakes in the Cisco Lake Chain (Table 22). While there was movement in multiple directions throughout the Chain, 49.6% (weighted average) of northern pike were recaptured within the lake where they were tagged.

During the year following tagging, two northern pike were recaptured in Clearwater Lake, which is connected to Little Africa Lake by a small creek. We did not tag any northern pike in Clearwater Lake.

We did not recapture any legal-sized muskellunge during our spring survey. Additionally, we had a single muskellunge tag return. This fish was tagged in Record Lake and recaptured in Thousand Island Lake.

Angler Survey

Summer.–The clerk interviewed 5,336 boating anglers during the summer 2002 survey on the Cisco Lake Chain. Most interviews (96%) were roving (incomplete-fishing trip). Anglers fished an estimated 171,310 angler hours and made 41,087 angler trips (Table 23).

The total harvest from the Cisco Lake Chain was 113,135 fish, which consisted of thirteen different species (Table 23). Yellow perch were most numerous with an estimated harvest of 58,769, and 64,626 reported releases. Bluegill were second with a harvest of 37,906, and 104,323 releases. Anglers harvested 2,737 walleyes and 2,318 northern pike, and reported releasing 16,346 walleyes (86% of total catch) and 11,936 (84% of total catch) northern pike. Anglers harvested 1,660 smallmouth bass and released 17,741 (91% of total catch). Anglers harvested 942 walleyes in the north lake group and 1,795 in the south lake group. We do not know what proportions of the released fish of each species were of legal size. In future surveys, we recommend distinguishing between sublegal- and legal-sized fish released.

Winter.–The clerk interviewed 456 open ice anglers and 175 shanty anglers on the Cisco Lake Chain. While this survey was designed to collect roving interviews, 43% of open ice and 23% of shanty interviews were access type (completed trip). Open ice and shanty anglers fished 8,952 angler hours and made 1,792 trips on the Cisco Lake Chain (Table 24). We were not able to estimate a variance for each site in the winter survey. Thus, the totals by species reported in Table 24 contain only the variance from those sites for which it was calculated and should be considered minimum values.

A total of 7,281 fish were harvested, composed of seven species. Anglers harvested 211 walleyes, and reported releasing 267 (56% of total catch). All of the walleyes harvested were from the south lake group. Anglers harvested 229 northern pike, and released 418 (65% of total catch). Anglers also harvested 3,470 yellow perch, and 3,319 bluegill. An estimated 12 muskellunge were caught and released.

Annual totals for summer through winter.–In the annual period from May 4, 2002 through February 26, 2003, anglers fished 180,262 hours and made 42,879 trips to the Cisco Lake Chain. Of the total annual fishing effort, 95% occurred in the open-water summer period and 5% occurred during ice-cover winter period.

The total annual harvest was 120,416 fish. The estimated total annual harvest of walleyes was 2,948, making up only 2% of the total harvest. Anglers harvested 942 walleyes in the north lake group and 2,006 in the south lake group. Yellow perch were the most commonly harvested species at 62,239, making up 52% of the total harvest. Bluegill were the second highest in harvest, at 41,225 (34% of total). Panfish species (yellow perch, bluegill, black crappie, pumpkinseed, and rock bass) accounted for 93% of the total number harvested. Harvest of northern pike was relatively low, with an estimated 2,547 taken.

Bluegill were the predominant species caught (harvested + released) at 147,160, followed closely by yellow perch (128,088). Resulting catch rates (catch per h) for bluegill and yellow perch were 0.816 and 0.711, respectively. Total catch of walleye was 19,561, with a corresponding catch rate of 0.109 per hour. Anglers reported releasing 85% of all walleyes caught. Total catch of walleye peaked in May, and steadily declined throughout the summer and fall. Estimated total annual catch of northern pike was 14,901, with a resulting catch rate of 0.083. Anglers released 83% of northern pike caught. Estimated total annual catch of smallmouth bass was 19,401, with a resulting catch rate of 0.108. Smallmouth bass catch peaked in July, with none reported caught during winter months even incidentally (harvest of smallmouth and largemouth bass would have been illegal January–March). Anglers released 91% of smallmouth bass. Although we did not estimate any harvest of muskellunge, 316 fish were caught and released throughout the year.

It should be noted that catch rates are calculated with general effort, not targeted effort, and are therefore not necessarily indicative of the rate that an angler targeting one species may experience.

Eight species that we captured during spring netting operations did not appear in the angler harvest – black bullhead, brown bullhead, central mudminnow, creek chub, golden shiner, mottled sculpin, tiger muskellunge, and white sucker.

Discussion

Fish Community

The seasonal and gear biases associated with our survey complicate comparisons of population and community indices with data from previous surveys on the Cisco Lake Chain. Most previous fisheries surveys on the Chain were conducted during the summer. Because the 2002 survey was conducted during the spring, we would expect the catch to be biased toward spring spawners (e.g. walleye, northern pike, and yellow perch). However, the relative abundance of these species was similar in 2002 to past surveys. For example, Deephouse (1993a) reported fyke-net catch-per-unit effort values of 4.2 and 1.4 for walleyes, and 1.2 and 0.6 for northern pike collected from Thousand Island Lake during surveys in late May of 1990 and June of 1992, respectively. These values are similar to what we observed for walleyes (4.9) and slightly lower than what we observed for northern pike (4.1) in Thousand Island Lake. Deephouse (1993b) reported catches per fyke-net lift of 2.7 and 2.2 for walleyes and northern pike, respectively in a June survey of Cisco Lake. Our walleye catch per fyke-net lift in Cisco Lake was similar (1.3), while our northern pike catch per effort (6.9) was over three times higher. Conversely, panfish species (especially bluegill and pumpkinseed) were underrepresented in the 2002 catch, relative to surveys that have occurred later in the spring. Deephouse (1993b) reported catches per effort of 43.8 for bluegill and 36.8 for pumpkinseeds in a June survey of Cisco Lake, compared to 2.1 and 2.0 for bluegills and pumpkinseeds, respectively in 2002. Additionally, Deephouse (1993a) reported catches per effort of 32.8 for bluegill and 4.2 for pumpkinseeds in a June survey of Thousand Island Lake, compared to 2.2 and 1.2 for bluegills and pumpkinseeds, respectively in 2002. Sunfish typically do not move into shallow water until late May or early June, so spring fyke net sampling is not an effective technique for capturing these species. As noted in previous surveys, largemouth bass, smallmouth bass, and muskellunge comprised only a small percentage of the total catch.

Small fish could easily swim through the mesh used during this survey, so these fish were not 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 the Cisco Lake Chain (e.g. shiners, sculpins, and darters).

Because sampling protocol has been similar for all large lake surveys, we compared the Cisco Lake Chain data to data from four other Michigan lakes: Houghton Lake, Burt Lake, Michigamme Reservoir, and Crooked and Pickerel Lakes. The species composition in the Cisco Lake Chain was similar to the other lakes with one notable exception. Yellow perch were much more abundant in the Cisco Lake Chain than in the other systems. This species comprised 64.6% of the catch (by number) in the Cisco Lake Chain, compared to 0.4–5.7% in the other large lakes.

No lake herring were collected during the netting survey, but fyke nets in the spring are not an efficient gear for capturing this open-water species. Gill-net sampling is usually more effective in determining the status of lake herring populations in lakes. Five species that appeared in the angler harvest were not captured during spring netting operations – brook trout, lake herring, lake whitefish, round whitefish, and common carp. This was the first evidence of lake whitefish and round whitefish in the Cisco Lake Chain, which suggests the possibility that these species were misidentified by anglers.

Size Structure

The size structure of walleyes in our spring survey was below average relative to other large lakes in Michigan. In eight lakes surveyed thus far in the Large Lakes Program, the percentage of legal walleyes averaged 64, compared to 29 for the Cisco Lake Chain. However, these comparisons are not totally valid since some surveys used trap and fyke nets with larger mesh (1.5-in) than used on the survey of the Cisco Lake Chain (½ to ¾-in mesh). In fact, compared to other walleye populations in the western Upper Peninsula the walleyes in the Cisco Lake Chain have average to above average length frequency. The differences we found in mean length and length distributions between the north and south lake groups were notable, and are likely a result of density-dependent growth. Walleyes were much more abundant in the south lake group where growth was slowest.

Historic length frequency evaluations of northern pike in the Cisco Lake Chain indicate that the population has been dominated by small fish for many years, and minimum size limits for northern pike have been liberal (e.g. 14 in) or nonexistent since the mid 1960s. Currently, the size structure of northern pike in the Cisco Lake Chain is below average. In seven lakes surveyed thus far in the Large Lakes Program, the percentage of legal (≥24 in) northern pike averaged 16.5, compared to 6.2 for the Cisco Lake Chain, though the same potential mesh-size biases exist as mentioned for walleyes. While we did collect some large (≥30 in) northern pike, the population is dominated by fish too small to be attractive to most anglers. Northern pike in the Cisco Lake Chain are unlikely to attain lengths much greater than 24 in, though there is the potential to reach around 34 in.

The size structure of muskellunge in the Cisco Lake Chain was impressive. Although we did not have a large sample size, many (60%) of the captured individuals were large (≥30 in) fish, and some legal-sized fish were collected. Both the length-frequency data and the history of Master Angler entries for this system indicate that muskellunge in the Cisco Lake Chain have the potential to reach trophy size.

Walleyes, Northern Pike, and Muskellunge

Sex composition.–Male walleyes outnumbered females in our survey when all sizes were considered. Our results are comparable to those found in previous surveys of Big Lake in 1991 and 1999, and Mamie Lake in 1999, where the sex ratios of adult fish were 31:1, 5.9:1, and 4.9:1, respectively (Gilbert 2002).

In contrast, the male : female ratio of legal size fish was 1:1. This is the lowest ratio of males to females that we have found in eight large lakes surveyed to date. The average for the seven previous surveys was 3.3:1.

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 the Cisco Lake Chain both when all sizes, and when greater than or equal to 18 in fish were considered. However, females greatly outnumbered males when only fish great than or equal to 24 in were considered. This disparity between sex composition of all sizes and fish of legal size is likely due to faster growth in females. Higher mortality of males as reported by Craig (1996) would also contribute to this disparity. We estimated an annual mortality rate of 72% for males and 59% for females, so mortality could contribute towards the skewed sex ratio. Clark et al. (2004) and Hanchin et al. (2005a) 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.

Our small sample size of muskellunge precludes us from drawing any conclusions about the existing sex ratio. Muskellunge rarely have flowing gametes at the time of the year our survey occurred, so we could not determine the sex for many of the fish we collected.

Abundance.–WDNR has made previous mark-and-recapture estimates of walleye abundance for some of the lakes in the Cisco Lake Chain. In 1991 and 1999, they estimated 11,428 (14.8 per acre) and 4,480 (5.8 per acre) adult walleye, respectively in Big Lake. In 1999, WDNR also estimated 1,591 (4.0 per acre) adult walleyes in Mamie Lake. Our estimates of adult walleye density in the entire Chain ranged from 10.1 to 10.2 per acre.

We used different methods than these previous abundance estimates and were successful in obtaining both multiple- and single-census estimates (Table 8). For the multiple-census estimate, the minimum number of recaptures was obtained; however, we may have violated some conditions for an unbiased estimate that are discussed later. For the single-census estimate, we had sufficient numbers of both marked fish and number of fish observed for marks. Assuming that the legal walleye population was approximately 10,000 fish, and based on tagging around 3,000 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 200 fish (Robson and Regier 1964). Our corrected recapture sample of 265 exceeded this recommendation, but was short of the recommendation (800) for research ($\alpha = 0.05$, $P = 0.10$).

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 estimate for walleyes was considerably lower than the single-census estimate for legal-size fish, but not for adult fish (Table 8). The 95% confidence limits between the two types of estimates did not overlap for legal fish; thus, estimates between methods are likely significantly different at the 95% confidence level. The precision of multiple-census estimates was better than single-census estimates (Table 8). Confidence limits were within 13–15% for the two multiple-census estimates, and within 24–6% of the single-census estimates.

Our single-census estimate appeared more accurate than the multiple-census estimate when judged in relation to the independently-derived harvest estimate. For example, our exploitation estimates made by dividing harvest by abundance were 30.7% using the multiple-census estimate and 17.7% using the single-census estimate. The estimate using the single-census abundance estimate is only slightly higher than our exploitation estimate based on tag returns, which we know is a minimum estimate. In contrast, the exploitation estimate made by dividing harvest by the multiple-census abundance estimate is 77% higher than the estimate based on tag returns. Also, the exploitation calculated with the multiple-census abundance estimate is equal to the total mortality estimate, suggesting that the estimated exploitation is biased high.

Our estimates of adult walleye abundance were not similar to the Wisconsin regression estimate of 14,041 (Table 8). This is different from the findings of Clark et al. (2004), Hanchin et al. (2005a), and Hanchin et al. (2005b) who found that estimates from the Wisconsin regression for walleyes were reasonably close to either the single-census, or multiple-census estimate. Similar to the Wisconsin model, we have developed a regression model to predict walleye abundance from lake area, based on data from Michigan lakes (Hanchin et al. 2007). The current Michigan model predicted an even lower abundance of adult walleyes (8,121; Table 8) than the Wisconsin model.

Population density of walleyes in the Cisco Lake Chain was above average compared to other lakes in Michigan and elsewhere. Our single-census estimate for 15 in and larger walleyes was 12,133 or 3.0 per acre (Table 8). Density of legal-size walleyes estimated recently for nine large lakes in Michigan averaged 2.2 per acre (range 0.4 to 4.6).

Population densities of adult walleyes from our multiple- and single-census estimates were 10.1 and 10.2 per acre, respectively. Similar to legal-size walleyes, density of adult walleyes is relatively high in the Cisco Lake Chain. Adult walleye abundance has averaged 3.1 per acre in nine large lakes surveyed thus far in Michigan. In nearby Lake Gogebic, Miller (2001) estimated 62,497 male spawning walleyes (approximately 13 in and greater), or 4.8 adult males per acre. Norcross (1986) similarly estimated 63,000 male walleyes in Lake Gogebic, though after adjusting for undersampled females he arrived at an estimate of around 125,000 legal (≥13 in) walleyes, or 9.5 per acre. Nate et al. (2000) reported an average density of 2.2 adult walleyes per acre for 131 Wisconsin lakes having natural reproduction.

We were successful in obtaining abundance estimates for northern pike (Table 9); however, it is difficult to determine which estimation method was best. For the multiple-census estimate of 18-in-and-larger fish, the minimum number of recaptures was obtained, and the coefficients of variation were relatively low. For the single-census estimate, we did not examine enough fish for marks in the creel survey sample. Using our estimate of approximately 8,000 18 in and larger northern pike, and knowing that we tagged around 1,000 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 $1\text{-}\alpha$ the level of precision) is approximately 500 fish (Robson and Regier 1964). Our corrected recapture sample of 64 fish was well short of this recommendation.

The confidence interval for the single-census abundance estimate of northern pike was broad, and it overlapped with the confidence interval for the multiple-census estimate. Precision was better for the multiple-census estimate than for the single-census estimate. Confidence limits were within 25% of the multiple-census estimate and within 62% of the single-census estimate.

Despite the lack of precision, our single-census estimate for northern pike appeared reasonable when judged in relation to the independently-derived harvest estimate. The annual exploitation estimate made from dividing harvest by the single-census abundance was only 3.5 percentage points less than the estimate from tag returns (Table 9). Although the exploitation estimate derived using the single-census abundance is close to the exploitation estimate based on tag returns, it is lower than the estimate based on tag returns, which we believe is a minimum. Considering both sample size and measures of precision, we consider the multiple-census estimate to be the most reliable, though as Pierce (1997) found, it is likely biased low. Our estimates converted to densities for the entire lake are 0.9 per acre for the multiple-census method and 2.0 per acre for the single-census method.

Our estimates of adult northern pike abundance were much higher than those for 18-in-and-larger fish. Estimates were more similar between methods (Table 9), but the multiple-census estimate was still lower than the single-census estimate. The estimates for the Cisco Lake Chain convert to densities of 2.9 and 3.7 adult pike per acre from multiple-census and single-census estimates, respectively. Adult northern pike abundance averaged 0.9 per acre (range 0.1–2.0) in six large lakes surveyed thus far in Michigan, so density is above average in the Cisco Lake Chain. Craig (1996) gives a table of abundance estimates (converted to density) for northern pike from various investigators across North America and Europe including one from Michigan (Beyerle 1971). The sizes and ages of fish included in these estimates vary, but considering only estimates done for age 1 and older fish, the range in density was 1 to 29 fish per acre. Also, Pierce et al. (1995) estimated abundance and density of northern pike in seven small (<300 ha) Minnesota lakes. Their estimates of density ranged from 4.5 to 22.3 per acre for fish age 2 and older.

While we were able to make an estimate of muskellunge abundance, the coefficient of variation was high, and we did not consider it reliable. The estimate converts to a density of 0.3 muskellunge (all sizes) per acre. In comparison, Cornelius and Margenau (1999) reported an average density of 0.65 adult muskellunge per acre for 5 years of study in Bone Lake, Wisconsin and 0.9 per acre in Deer Lake. Margenau and AveLallemant (2000) reported adult muskellunge densities ranging from 0.05 to 0.99 per acre (average = 0.4) for 15 Wisconsin lakes.

There are several potential sources of error in our multiple-census estimates of abundance. 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, and we possibly did not sample all spawning congregations in this large chain of lakes. 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 mix completely with unmarked fish. Additionally, it does not matter if all spawning congregations were sampled in the initial tagging operation.

Pierce (1997) found that multiple-census methods severely 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. Our multiple-census estimates were 40% lower for legal walleyes, 1% lower for adult walleyes, 55% lower for 18 in northern pike, and 23% lower for adult northern pike. Pierce concluded that gear size selectivity and unequal vulnerability of fish to near shore netting make multiple-census estimates consistently low. He also concluded that recapturing fish at a later time with a second gear type resulted in estimates that were more valid. Clark et al. (2004) and Hanchin et al. (2005a) also found similar patterns between abundance estimation methods for walleyes and northern pike in Michigan lakes.

While single-census estimates using two gear types are probably better than multiple-census estimates, they are not without problems. Mark-and-recapture estimates assume tags are not lost; so if tag loss increased with time, and fin clips regenerated, it would have affected the single-census method more than the multiple-census method. Higher tag loss that could not be identified by the presence of a double mark would lead to an overestimate of abundance, and our single-census estimates were higher than our multiple-census estimates. Although we detected some tag loss during the angler survey, we believe that our creel clerks were able to identify all marked fish by either jaw tags or fin clips.

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 Cisco Lake Chain is only about one-fifth the size of Houghton Lake.

Based on our experience in this study, we believe it would be possible, but costly, to improve precision of walleye abundance estimates for the Cisco Lake Chain or other lakes of comparable size. Obtaining more precise estimates would require: 1) marking more fish, 2) recapturing more marked fish, or 3) both. Confidence limits on our single-census estimate of 12,133 legal-sized walleyes were plus or minus 22% of the estimate (Table 8), which is about what would be predicted from Figure 7 in Clark et al. (2004) given 2,832 fish or 23% of the population was marked. We collected and marked 2,488 walleyes with three 10-to-15 net, three-person work crews, and collected 344 walleyes with an electrofishing crew. Therefore, the average number of fish marked per three-person crew was about 708 over the course of the two-week survey. In order to achieve precision of ±15%, it would be necessary to mark about 4,853 walleyes [40% of the population – Figure 7 in Clark et al. (2004)]. Assuming that the number of fish marked per crew did not diminish with increasing number of crews, this would have taken seven netting crews with 21 people working together on the lake during the two weeks after ice-out. This amount of necessary effort would almost double the effort used on the survey; however, it pales in comparison to the sixfold increase in effort needed on Houghton Lake (Clark et al. 2004) in order to achieve precision of about plus or minus 20%.

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 a twofold increase in the number of fish observed for marks to improve precision to about plus or minus 15%. This would require a minimum of one additional angler survey clerk or a substantial netting and/or electrofishing effort.

Mean lengths at age.–For walleyes, mean lengths at age for the north lake group in our survey were higher than those recorded in the individual surveys of Cisco and Thousand Island lakes in 1990 (Table 25). Cisco and Thousand Island lakes are the largest lakes in the north lake group. Mean lengths at age for walleyes captured in the south lake group, by contrast, were considerably lower than those observed during the surveys in 1990.

The greater mean lengths of walleyes in the north lake group versus the south lake group are probably due to a lower walleye density (Table 8) and a higher relative abundance of prey species, especially yellow perch. In fact, the catches per fyke-net lift in the north lake group were 3.5 for yellow perch and 5.1 for walleyes, resulting in a yellow perch-to-walleye ratio of 0.7. In the south lake group, the catches per fyke-net lift were 7.6 for yellow perch and 51.4 for walleyes, resulting in a ratio of 0.1. Thus, based on the ratio of prey relative abundance to predator relative abundance, there is more forage available in the north lake group. Additionally, there is considerably more walleye spawning habitat in the south lake group, so it is not surprising that walleye abundance was greater in those lakes.

Walleye mean lengths at age for both north and south lake groups were lower than the state average for ages 3–10 (Table 25). While slow growth is consistent with past surveys on the Cisco Lake Chain, it should be noted that all state averages to this point have been calculated using scales. Thus, comparisons to mean lengths at age from spine ageing are not necessarily informative. Past studies comparing spine ageing to scale ageing suggest that biases of these techniques generally lead to scale-aged fish having greater mean lengths (Miller 2001; Clark et al. 2004).

The mean lengths at age and growth index for south Cisco Lake Chain walleyes were similar to those of other waters in the region, such as Lake Gogebic and Michigamme Reservoir (Table 25). In fact, negative mean growth indices are normal for western Upper Peninsula walleye populations. Although lack of forage, perhaps related to high density of walleyes, appears to be affecting growth of walleyes in the south lake group of the Cisco Lake Chain, walleye growth throughout the chain might also be constrained by regional environmental factors, (e.g. short growing season, cool temperatures, and low nutrient levels).

For northern pike, slow growth has been considered a problem in the Cisco Lake Chain for many years, but historic length-at-age data is lacking. Mean lengths at age for northern pike captured during this survey were well below the state averages (Table 26). Northern pike from the Cisco Lake Chain do not attain a total length of 24 inches until age 6 or 7, whereas the statewide average age for northern pike reaching legal size is 4 or 5. As with walleyes, state averages for northern pike were based entirely on scale ageing, which probably overestimates mean lengths for older ages. Mean lengths at age for Cisco Lake Chain northern pike were also lower than those for pike from other area lakes (e.g. Bond Falls Flowage and Michigamme Reservoir).

Several factors probably contribute to the poor growth of northern pike in the Cisco Lake Chain. As noted for walleyes, short growing seasons and low nutrient levels might negatively affect growth of northern pike in the western Upper Peninsula. Availability of suitable forage also may be an issue in the Cisco Lake Chain. Northern pike typically prefer soft-rayed fishes, especially white suckers. Few white suckers were collected during the 2002 survey, so the Cisco Lake Chain pike may be forced to prey on less desirable spiny-rayed fishes such as yellow perch and bluegills.

Length at age data for Michigan muskellunge populations is limited, so it is difficult to draw many conclusions from the muskellunge growth data. The length distribution of captured muskellunge, coupled with the large number of Master Angler entries from this system, suggest that Cisco Lake Chain muskellunge are growing fast enough to provide an attractive trophy fishery.

Mortality.–To our knowledge, this was the first attempt to estimate total mortality of walleyes from the Cisco Lake Chain. The total mortality of walleyes we found was generally low, with 18 year classes (age 1–17, 19) represented. In both north and south lake groups, and the entire Chain, males had significantly higher (almost double) annual mortality rates than females. The statistical difference in catch at age that we found between the north and south lake groups was largely due to differences in catch, since the annual mortality rates were similar between lakes.

Compared to total mortality estimates for walleyes from other lakes in Michigan and elsewhere, our estimate of 30% was relatively low. In nine large lake walleye populations surveyed to date, annual mortality has averaged 37.2% (range 24–51%). 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%.

Our three estimates of annual exploitation rate of walleyes were somewhat different; 17.3% from tag returns, 30.7% using harvest divided by the multiple-census abundance estimate, and 17.7% using harvest divided by the single-census abundance estimate. We consider the tag return estimate to be a minimum because we did not adjust for tagging mortality or nonreporting, and if these problems occurred to any degree, we would have underestimated exploitation (Miranda et al. 2002). We did not estimate tagging mortality, and we used an estimated tag loss rate of 1.6%. We did not make a true estimate of nonreporting, but one of 61 tags observed by the creel clerk was not subsequently reported by anglers. This indicates that nonreporting may have occurred to some degree, but was probably minimal. Also, nonreporting appeared to be low due to the fact that the number of tags voluntarily returned by anglers (440) was near the predicted number of returns (512) based on the ratio described previously in the **Methods** section.

We attempted to get some measure of nonreporting of tags by offering a $10 reward on about half of the tags and comparing return rates of reward to nonreward tags. We found that reporting rate for reward tags (17.0%) was slightly higher than for nonreward tags (14.7%), which might be expected given that our reward amount was relatively low compared to those used by other authors (Miranda et al. 2002). Clark et al. (2004) used the same tags and reward amount in Houghton Lake and did not observe much difference in return rates of reward and nonreward tags. However, in Michigamme Reservoir, there was a large difference in reporting rates, and the authors believed that anglers must have returned nearly 100% of reward tags (Hanchin et al. 2005a).

Although we did not have a formal question on the tag return forms, some anglers reported releasing fish. The low release rate (0.5%) we observed for walleye of legal size is about what we would expect. We believe this estimate is a minimum, given that anglers releasing fish are less likely to remove tags, or record the tag number information. Additionally, we did not have the question on the tag return forms that were available from clerks and MDNR offices.

Since we believe the estimate from tag returns is a minimum, the single-census estimate of abundance resulted in a more reasonable estimate of exploitation compared to the multiple-census estimate. The estimate based on the multiple-census abundance (30.7%) is larger than our estimate of total mortality (30.2%), indicating that it is biased high. Given that, the true annual angling exploitation rate of walleye in the Cisco Lake Chain is likely about 20%.

Compared to exploitation rates for walleyes from other lakes in Michigan and elsewhere, our estimate for the Cisco Lake Chain is about average. The average exploitation rate for walleye from nine large lakes surveyed to date was 15.8% with a range of 3.5 to 31.8%. Comparable to our estimate, Serns and Kempinger (1981) reported average exploitation rates of 24.6% and 27.3% for male and female walleyes respectively in Escanaba Lake, Wisconsin during 1958–1979. In general, the range of exploitation for walleye across its range is large. For example, Schneider (1978) gave a range of 5 to 50% for lakes in Midwestern North America, and Carlander (1997) gave a range of 5 to 59% for a sample of lakes throughout North America. Additionally, exploitation can vary over time for a single water body; in western Lake Erie estimates ranged from 7.5 to 38.8% from 1989 through 1998 (Thomas and Haas 2000).

The spear fishing harvest of walleye in the Cisco Lake Chain in 2002 was low relative to the angling harvest. Spearing exploitation of 15-in walleye was about 1.6%, or about one tenth that of the angling harvest. The combined angling and spearing exploitation in 2002 was reasonable and sustainable.

This was the first attempt to estimate total mortality of northern pike from the Cisco Lake Chain. Male northern pike had higher mortality than females, which is expected. Our estimate of total annual mortality (64%) was near the higher end of the range for northern pike in Michigan and elsewhere, though it is no cause for concern. In six northern pike populations surveyed in large lakes to date, annual mortality has averaged 54% (range 36–69%). Perhaps the lower size limit for northern pike in the Cisco Lake Chain is a cause for the higher mortality. Additionally, the slow growth of northern pike in this system makes them vulnerable to predation/cannibalism for a relatively long period.

Pierce et al. (1995) estimated total mortality for northern pike in seven small (<300 acres) lakes in Minnesota to be 36–65%. They 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%. Diana (1983) estimated total annual mortality for two other lakes in Michigan, Murray Lake at 24.4% and Lac Vieux Desert at 36.2%.

Our three estimates of the annual exploitation rate of northern pike varied from 19.7 to 44.1%. Just as for walleye, we consider the estimate of 23.2% from tag returns to be a minimum. We did not make a true estimate of nonreporting, but the number of tags voluntarily returned by anglers (131) was close to the predicted number (168) of returns based on the ratio described previously in the **Methods** section. Thus, we consider the true exploitation rate to be at least greater than 23%. The estimate of 44.1% using the multiple-census abundance estimate is probably too high because, as discussed earlier, the multiple-census abundance estimate is generally too low. The estimate of 19.7% using the single-census abundance estimate is probably the least biased estimate, but it has a high coefficient of variation. None-the-less, the upper 95% confidence limit of 33.9% for this latter estimate is probably the close to the maximum level for the true exploitation rate. Thus, we believe the true annual exploitation rate for northern pike in the Cisco Lake Chain is between 23% and 34%.

Compared to exploitation rates for northern pike from other lakes in Michigan and elsewhere, our estimate of 23–34% for the Cisco Lake Chain appears to be average. 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, in four other northern pike populations surveyed to date in our Large Lake Program, annual exploitation estimated with these methods has averaged 23.5% (range 7.8 to 44.7%).

Although we were unable to produce a valid catch curve regression, total mortality of adult muskellunge in the Cisco Lake Chain is likely relatively low. We say this primarily because our estimate of the annual exploitation rate for muskellunge was zero. No tagged fish were reported as harvested and the estimated harvest from the angler survey was zero. Also, the majority of anglers who seriously target and regularly catch muskellunge are known to practice catch and release. Additionally, a large proportion (40%) of fish we collected were relatively old (≥ age 10), and one fish was aged as 15. Casselman (1999) reported modal ages of 8 and 11 for males and females, respectively from muskellunge taken in the Cleithrum Project. The Cleithrum Project analyzed age data taken largely from angler-caught "trophy" muskellunge. Casselman (1996) also estimated 20% and 16% total annual mortality of male and female muskellunge, respectively.

Recruitment.–Walleyes in the Cisco Lake Chain were represented by 18 year classes (ages 1 through 17, and age 19) in our samples (Figure 5). Variability in year-class strength, as represented by the R^2 of 0.88 for the catch-curve regression, was average relative to other Michigan populations. In nine other Michigan walleye populations surveyed as part of the Large Lakes Program to date, the R^2 has ranged from 0.67 to 0.98, with an average of 0.82. Substantial natural reproduction occurred every year from 1986 through 1998, and likely occurred from 1999 through 2001, though these fish were not fully recruited to our sampling gear and survey timing. Thus, we conclude that natural reproduction of walleyes is currently very good, certainly sufficient to maintain the current population.

We find it interesting to note that the 1992 and 1993 year classes (age-9 and -10 walleye) corresponded with negative residuals in the Cisco Lake Chain. Many lakes in the Midwest had poor walleye year classes in 1992 and 1993, possibly due to the eruption of Mount Pinatubo and subsequent cooling (Shupp 2002). Additionally, the relationships we found between walleye year-class strength and June temperatures are consistent with the findings of Shupp (2002) for Minnesota lakes.

For northern pike, 9 year classes (ages 1 through 9) were represented in our samples (Figure 9, Table 17). Recruitment of northern pike was very consistent ($R^2 = 0.98$ in Figure 9), and based on the above average adult density, recruitment was also high. In five other Michigan northern pike populations surveyed as part of the Large Lakes Program, the R^2 for northern pike catch-curve regressions has ranged from 0.80 to 1.00, with an average of 0.91.

The relationships we found between year-class strength and April temperatures are somewhat consistent with the findings of others. Casselman and Lewis (1996) reported a positive relationship between year-class strength and the average July–August water temperature. Fortin et al. (1982) reported that June air temperature was related to year-class strength. Finally, Kipling (1983) reported a similar relationship with the temperature index of the first summer in Lake Windermere, England.

As previously stated, we did not assess the variability in muskellunge year-class strength in the Cisco Lake Chain due to low sample size.

Movement.–We documented extensive movement of walleyes within and outside of the Cisco Lake Chain. First, we documented the movement of walleyes during the spawning period when they are moving to, or departing the spawning grounds. The majority (86.8%) of these recaptures were caught in or near the lake where they were originally tagged (Table 19). Of course, the maximum time between tagging and recapturing fish during spring netting was only about 2 weeks. Second, we documented movement via angling recaptures throughout the year following tagging. Almost half of the fish (49.5%) were recaptured in lakes other than the ones in which they were tagged, and their movements were more widespread over this longer time span (Table 20). Finally, we documented upstream movement of several walleyes to small lakes outside the Cisco Lake Chain.

There was a relatively high level of segregation of walleyes between various lakes in the Cisco Lake Chain. We identified north and south lake groups, with the dividing line between Lindsley and Morley lakes (Table 2, Figure 1), in which there appeared to be two distinct walleye populations. There was little movement of walleyes between these two lake groups, with 93% of the walleyes tagged in the north group recaptured in the north group, and 86% of the walleyes tagged in the south group recaptured in the south group. Walleye populations within the north and south lake groups also had significant differences in abundance (Table 8) and mean lengths at age (Tables 11 and 12).

Though the movement between north and south lake groups is relatively small, it does appear to be beneficial for the walleyes participating from the standpoint of spawning habitat and foraging potential. If we apportion the apparent movement between lake groups by walleye abundance, there is a net movement of walleyes from the south to the north lake group following spawning. Walleye spawning habitat is more prevalent in the southern lakes, and forage appears to be more abundant in the northern lakes. Based on our single-census estimates of abundance in each half of the chain, approximately 263 legal walleye moved from the north to the south, and 1,232 moved from the south to the north following spawning. The observed net movement north following spawning may in fact be a result of a net movement south just prior to the spawn.

While it would be interesting to know the seasonal movement patterns of walleyes within the Cisco Lake Chain, movements associated with spawning are the most important. Walleyes spawn throughout the Cisco Lake Chain, but we do not know if they demonstrate 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.

Similar to walleye, we documented extensive movement of northern pike within and outside of the Cisco Lake Chain. We documented the movement of northern pike during the spawning period when they are moving to, or departing the spawning grounds. A small majority (53.9%) of these recaptures were caught in or near the lake where they were originally tagged. Second, we documented movement through angling recaptures throughout the year following tagging. The percentage of these recaptures found in their native lake (49.6%) was similar to that for the spring netting recaptures. Additionally, when we separated the Chain into northern and southern sections, the recapture rates for the respective sections were high (67–95%). Apparently, there is some segregation of northern pike within the Chain, which is also likely due to the narrow, shallow channels that connect the various lakes. As for walleyes, we documented movement of northern pike to lakes that are connected by small creeks, and are not considered part of the Chain.

Little can be said about muskellunge movement in the Cisco Lake Chain since we only had a single tag return.

Angler Survey

The Cisco Lake Chain is primarily a summer fishery, because the area is popular for summer vacations and has relatively few permanent residents. The fishery is diverse; however, panfish species account for the majority of the angler harvest, and likely targeted effort as well. The walleye and northern pike fisheries have good catch rates, but also high release rates, possibly due to the relatively high proportion of smaller fish of these species. Although we did not differentiate between sublegal and legal released fish, we assume that a large proportion of the released walleye and northern pike were sublegal (or smaller than 18 in for northern pike).

We did not survey during November, or the first week of December because we thought that relatively little fishing occurred during that time of year; however, sixteen walleye tag returns were reported as being caught during that time. Thus, the total annual walleye harvest was actually about 3.7% higher than our direct survey estimate, or 3,054 walleyes. Similarly one northern pike tag return was reported as caught during the nonsurveyed period (Table 18), resulting in an adjusted harvest of about 2,566 northern pike.

Historical comparisons.–Previous harvest and effort estimates within the Cisco Lake Chain were available for Big Lake from WDNR files, and for Cisco and Thousand Island lakes (Ryckman and Lockwood 1985). Cisco Lake was surveyed during the summers of 1977 and 1978. Methods used were similar to those used in the current summer survey, except that Ryckman and Lockwood (1985) estimated total catch by species, which presumably only included harvest. Thus, our comparisons include fish harvested, but not released. Total angler hours were similar for Cisco Lake among years, with 27,085, 28,171, and 30,400 hours in 1977, 1978, and 2002, respectively. In both historic angler surveys, the total catch was dominated by yellow perch (12,641 fish, 47% of total catch – 1977; 7,275 fish, 30% of total catch – 1978). These estimates are much lower than the 22,269 (53% of total catch) yellow perch harvested in 2002, though their percentage of the total catch was similar among years. Yellow perch harvest rates from Cisco Lake also increased from 0.47 and 0.26 per hour in 1977 and 1978, to 0.73 per hour in 2002. Overall harvest of panfish species was lower in 1977 (23,498 fish) and 1978 (21,337 fish) than in 2002 (40,509 fish). Interestingly, no black crappie were detected in the 1977 and 1978 surveys, though 2,529 fish were harvested in 2002. Harvest of northern pike varied among years, with 362, 84, and 730 fish harvested in 1977, 1978, and 2002, respectively. Northern pike harvest rates also varied among years, with 0.09, 0.08, and 0.02 fish harvested per hour in 1977, 1978, and 2002, respectively. The number of walleyes harvested also varied among years. In 1977 and 1978 the total harvest of walleye was 372 (1% of total catch) and 595 (2% of total catch), respectively, compared to 42 (< 1% of total catch) in 2002. The lower harvest of walleyes observed in 2002 may be due, in part, to a more restrictive size limit. The size limit for walleyes was 13 inches in 1978, compared to 15 in currently. Other differences from the 1977 and 1978 surveys were the presence of lake herring, brook trout, largemouth bass, muskellunge, and carp in the 2002 angler catch.

Thousand Island Lake was also surveyed during the summers of 1977 and 1978 (Ryckman and Lockwood 1985). Total angler hours were similar among years, with 30,301, 37,599, and 37,505 hours in 1977, 1978, and 2002, respectively. In both historic angler surveys, the total catch was dominated by yellow perch (13,946 fish, 53% of total catch – 1977; 7,668 fish, 37% of total catch – 1978). These estimates are lower than the 26,553 (24% of total catch) yellow perch caught in 2002, though their percentage of the total catch was similar among years. Yellow perch catch rates also increased from 0.40 and 0.20 per hour in 1977 and 1978, to 0.71 per hour in 2002. Overall catch of panfish species was much lower in 1977 (22,758 fish) and 1978 (16,758 fish) than in 2002 (90,890 fish). Similar to Cisco Lake, no black crappie were detected in the 1977 and 1978 surveys, though 1,060 fish were harvested in 2002. Catch of northern pike varied among years, with 2,132, 1,784, and 4,129 fish caught in 1977, 1978, and 2002, respectively. Northern pike catch rates also varied among years, with 0.06, 0.05, and 0.11 fish caught per hour in 1977, 1978, and 2002, respectively. The number of walleyes caught varied among years, but not considerably. In 1977 and 1978 the total catches of walleye were 497 (2% of total catch) and 1,228 (6% of total catch), respectively, compared to 1,476 (1% of total catch) in 2002. Other differences from the 1977 and 1978 surveys were the presence of lake herring and round whitefish in the 2002 angler catch.

The methods used in the Wisconsin surveys of Big Lake may differ slightly, but in general, we consider their estimates as comparable to ours. Total annual angler hours (summer + winter) on Big Lake were 33,727 in 1990–91, and 26,940 in 1991–92. These estimates were similar to our estimate of 29,364 angler hours for Big Lake in 2002–03. In contrast to angler effort, the harvest was rather different among the surveys. Total harvest of all species was 2,577 in 1990-91, 20,167 in 1991-92, and 10,295 fish in 2002–03. The differences were mainly due to the extent of yellow perch harvest among years.

Total catch and harvest of walleyes in Big Lake was quite variable among the survey periods. Total catch and harvest of walleyes was 3,727 and 390 in 1990–91, 11,551 and 437 in 1991–92, and 6,938 and 883 in 2002–03, respectively. Harvest per hour was also slightly different among the surveys. Harvest per hour (general effort) of walleye was higher in 2001–02 (0.030) than in 1990–91 (0.012) and 1991–92 (0.016).

Total catch and harvest of northern pike in Big Lake was generally low in all survey periods. Total catch and harvest of northern pike was 31 and 0 in 1990–91, 873 and 247 in 1991–92, and 502 and 78 in 2002–03, respectively. The total catch of muskellunge was surprisingly different among surveys. The WDNR estimated unexpectedly high catches of 740 in 1990–91 and 166 in 1991–92, while we estimated that only 90 muskellunge were caught in 2002–03. The harvest of most other species was similar among the three angler surveys.

Comparison to other large lakes.–In general, surveys conducted in Michigan during the past 10 years used the same methods we used on the Cisco Lake Chain of lakes, but most of them still differ from our survey in seasonality. For example, few other surveys were conducted in consecutive summer and winter periods. Thus, these differences need to be considered when comparing our data with 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 (Rakoczy and Wesander-Russell 2002). Additionally, we were able to compare the Cisco Lake Chain data to previous surveys conducted as part of the Large Lakes Program.

We estimated that 180,262 angler hours occurred on the Cisco Lake Chain during the period from May 4 through October 31, 2002 and December 7 through February 26, 2003. This represents the second largest total effort and the highest hours fished per acre (45.2) we have observed thus far in the Large Lakes Program (Table 27). Obviously, these lakes are a popular destination for summer vacationers, and local anglers. In addition to effort per acre, the number of fish harvested per acre (30.2) was also high. In fact, it was the second highest observed thus far in the Large Lakes Program. This reflects not only the popular panfish fishery of the Cisco Lake Chain, but also the diverse fishery in general.

For walleyes, our estimated annual harvest from the Cisco Lake Chain was 0.80 fish per acre, which is about the average (0.83) for nine lakes surveyed under the Large Lakes Program thus far. The catch per hour (0.11) for all sizes of walleye was also near the average (0.14) for the nine lakes surveyed thus far. These Michigan lakes all were subject to similar gears and fishing regulations, including a 15-in minimum size limit.

For northern pike, our estimated annual harvest from the Cisco Lake Chain was 0.64 fish per acre. This harvest was above average compared to other waters in Michigan. The average for eight lakes surveyed as part of the Large Lakes Program thus far was 0.19. 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 less than 0.1 per acre in Bond Falls Flowage, Gogebic County to 0.7 per acre in Fletcher Pond, Alpena County. These Michigan lakes reported for comparison all were subject to a 24-in minimum size limit, while the Cisco Lake Chain had no 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. Thus, the harvest per acre on the Cisco Lake Chain is near the low end of the range Pierce reported for Minnesota lakes with no size limit on northern pike.

The total catch (harvest + release) of black bass (smallmouth bass plus largemouth bass) in the Cisco Lake Chain was 25,728. This exceeded the combined total annual catch (13,110) of black bass in Houghton, Burt, Crooked-Pickerel, and Lake Leelanau (Clark et al. 2004; Hanchin et al 2005b; Hanchin et al. 2005c; Hanchin et al. 2007). Harvest of smallmouth bass on a per acre basis was the highest (0.42) estimated thus far in the Large Lakes Program, where the average of five lakes was 0.12. Even with the high angling effort, the catch per hour of all sizes of smallmouth bass (0.11) was also the highest of these same five large lakes (average = 0.06).

Management Implications

The Cisco Lake Chain has slow-growing walleyes when compared to state averages, but they are not much below average for Michigan's western Upper Peninsula. Most walleyes do not reach legal size (15 in) until age 6 in the Cisco Lake Chain, which is the same as nearby Michigamme Reservoir, but higher than that of Houghton Lake (age 5). Walleyes up to age 19 were represented in our sample, with many fish up to age 15, indicating that natural reproduction is consistent, and that overall mortality is low. Our estimates of mortality confirmed that it is relatively low.

The current walleye density is average to above average when compared to other lakes in Michigan and elsewhere. However, walleye density in the Cisco Lake Chain is not homogenous, and based on our multiple-census abundance estimates, the southern portion of the Chain has a much higher density of walleyes than the northern portion. The abundance of legal and adult walleyes was 3.8 and 10.3 times higher, respectively, in the south lake group than in the north lake group.

Based on the mean lengths at age we observed and a size structure with 71% of the spring spawning stock below the 15-in minimum size limit, the walleyes in the Cisco Lake Chain exhibit relatively slow growth compared to walleye populations in other parts of Michigan. By comparison, in Michigamme Reservoir and Houghton Lake, Michigan, only 47% and 27% of the spring spawning stock were below 15 in, respectively. Due to the high density, relatively slow growth, and consistent natural reproduction of walleye in the Cisco Lake Chain, there is little to gain by stocking walleye. In fact, stocking walleye on top of a high-density population may even have a negative effect on growth.

Our estimate of exploitation for Cisco Lake Chain walleyes was about average for Michigan lakes. The annual harvest was 0.8 walleye per acre and catch per hour for walleye of all sizes was 0.108. Compared to other walleye fisheries in Michigan and elsewhere, these estimates were about average. Given the current harvest, Michigan-Wisconsin sportfishing regulations for walleye in the Cisco Lake Chain adequately protect the walleye population.

The overall fishery in the Cisco Lake Chain is impressive. The number of fish harvested per acre (30.2) was the second highest of any large lake surveyed under similar methods. Surprisingly, the number of hours fished per acre (45.2) was the highest of any large lake surveyed to date. The Cisco Lake Chain has considerable angling opportunity for walleye, northern pike, and panfish, and a diversity of other species in lower abundance.

Our estimates of adult walleye abundance were much higher than the estimates made a priori with the Wisconsin and Michigan regression equations. However, in the short term, it seems reasonable to apply the Wisconsin regression to estimate walleye abundance in western Upper Peninsula lakes when abundance estimates are needed for management purposes. The Wisconsin model was closer to our individual estimates than the Michigan model. This was expected given the larger sample size of lakes used to develop the Wisconsin model and the physical similarities between northern Wisconsin and western Upper Peninsula lakes. In the long term, MDNR should continue to work towards developing an improved regression by conducting abundance estimates in other Michigan lakes.

Our estimate of adult northern pike density in the Cisco Lake Chain was higher than any other large lake we have surveyed to date. Adult density was almost twice that of the Houghton Lake walleye population (Clark et al. 2004), which was classified as a low-density, fast-growing population. In contrast, the northern pike population in the Cisco Lake Chain should be classified as high-density and slow-growing. With a density approximately two-thirds that of the Cisco Lake Chain, the northern pike population in nearby Michigamme Reservoir was classified as a low-density, slow-growing population.

The Cisco Lake Chain currently has no size limit for northern pike. This regulation is consistent with the results of this study in that recruitment was sufficient, and the population had a large proportion of small fish. Although this special regulation has not noticeably improved the size structure of the northern pike population in the Chain, it does provide additional harvest opportunities in a system where few fish reach the statewide minimum length of 24 inches.

Acknowledgements

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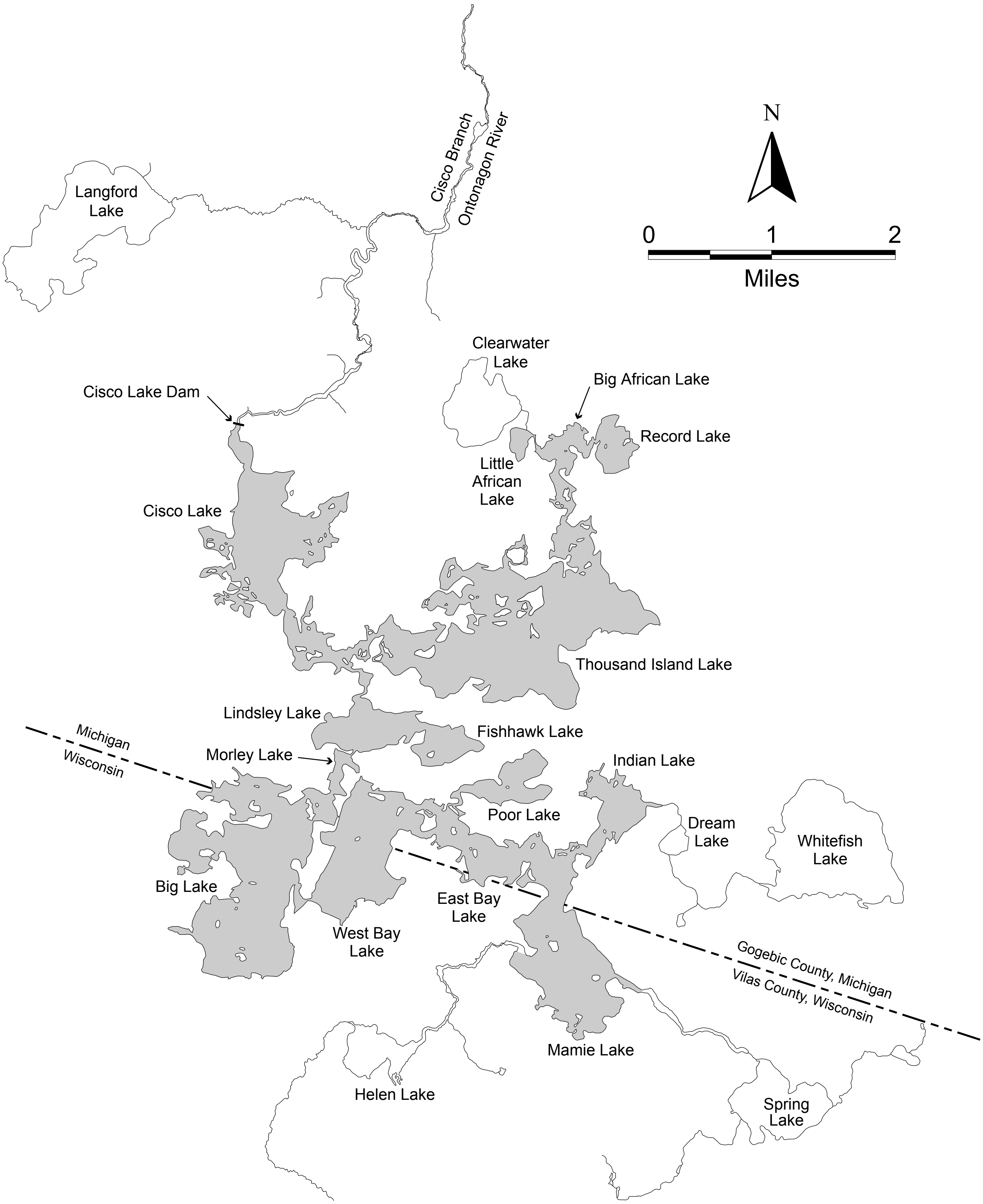

Figure 1.–Map of the Cisco Lake Chain, Gogebic County, Michigan and Vilas County, Wisconsin. Lakes shaded in gray were considered part of the Cisco Lake Chain for purposes of the netting survey and creel survey.

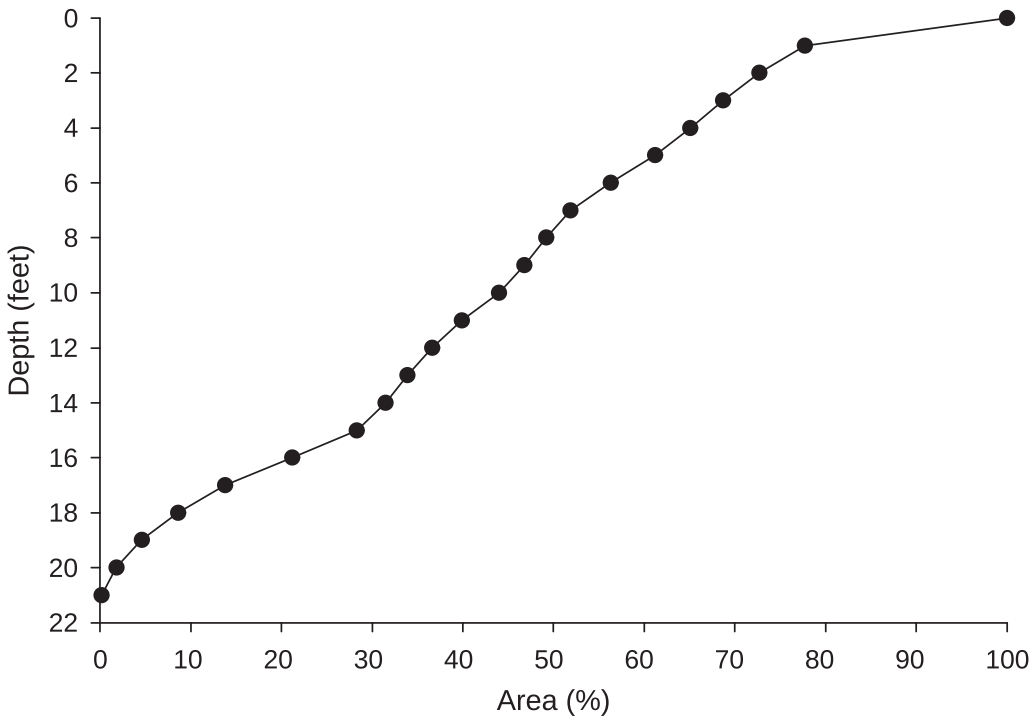

Figure 2.–Percent of area equal to or greater than a given depth for Cisco Lake, within the Cisco Lake Chain, Michigan and Wisconsin. Data taken from MDNR Digital Water Atlas.

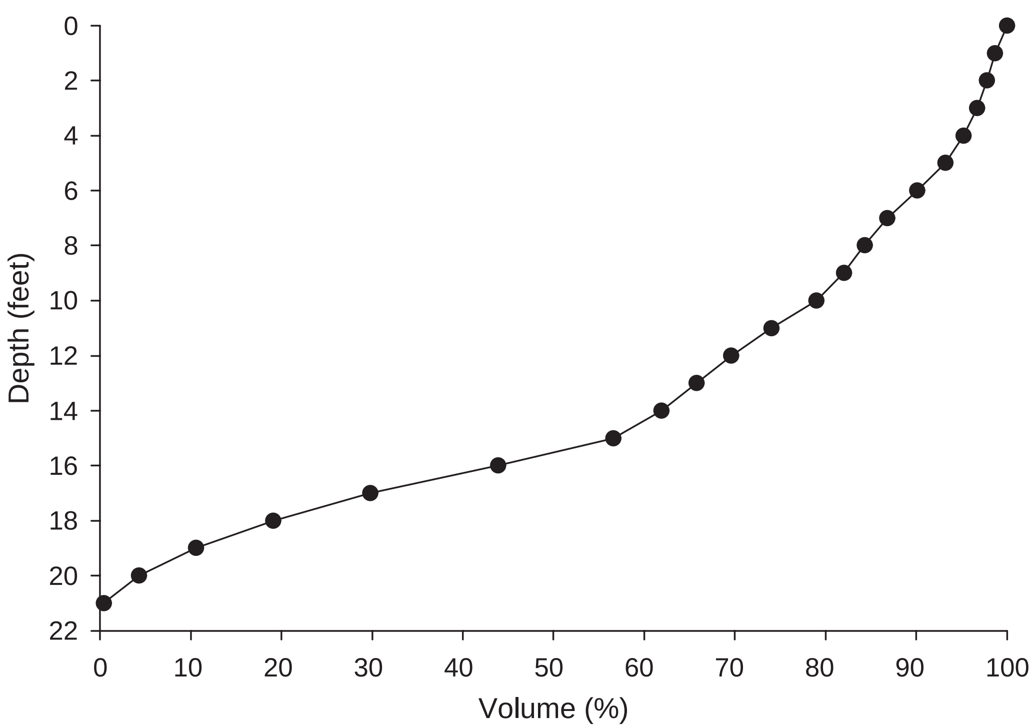

Figure 3.–Percent of volume equal to or greater than a given depth for Cisco Lake, within the Cisco Lake Chain, Michigan and Wisconsin. Data taken from MDNR Digital Water Atlas.

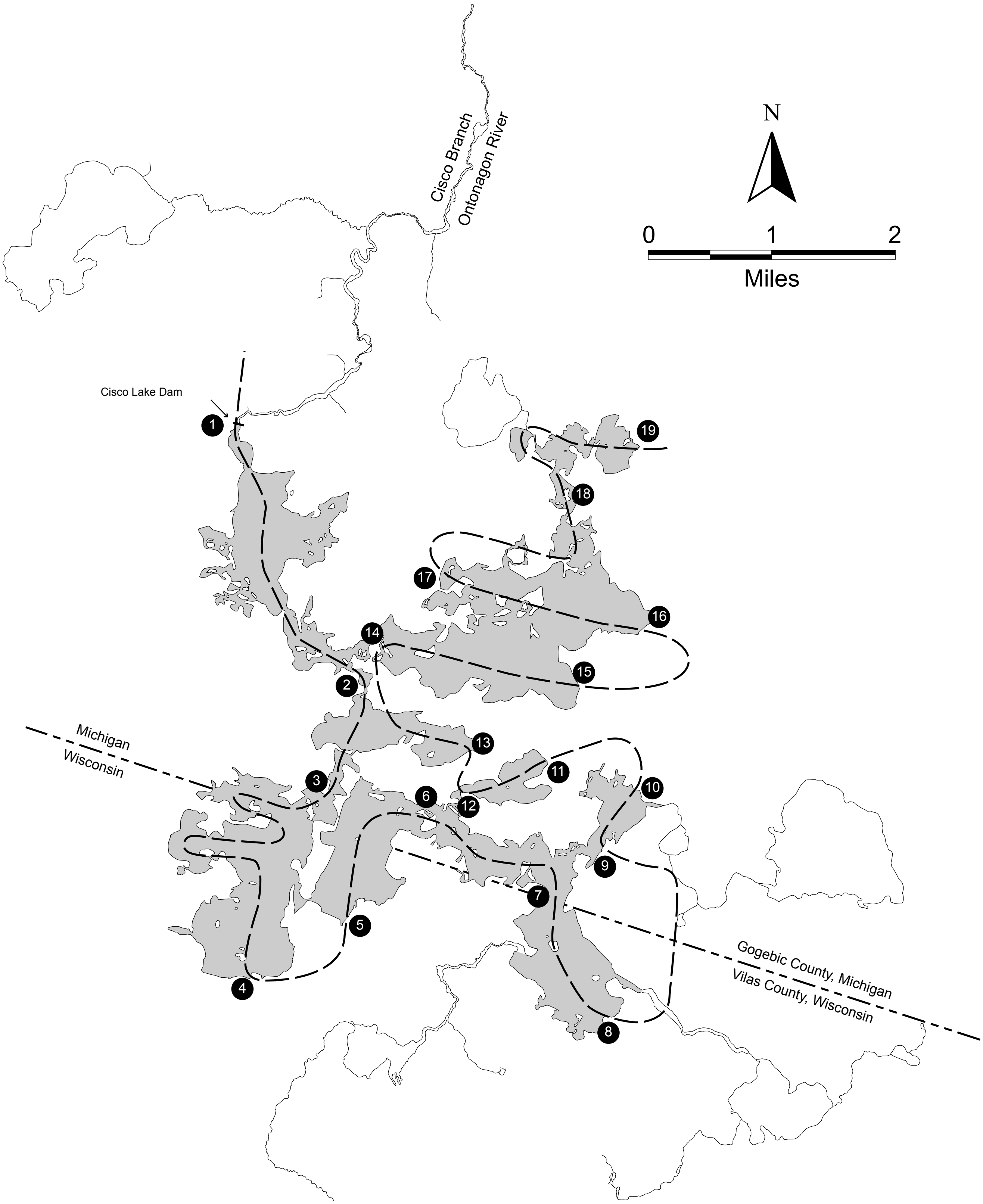

Figure 4.–Counting path, and associated way points for the Cisco Lake Chain, summer 2002. Latitude and longitude for points 1–19 are given in Table 5.

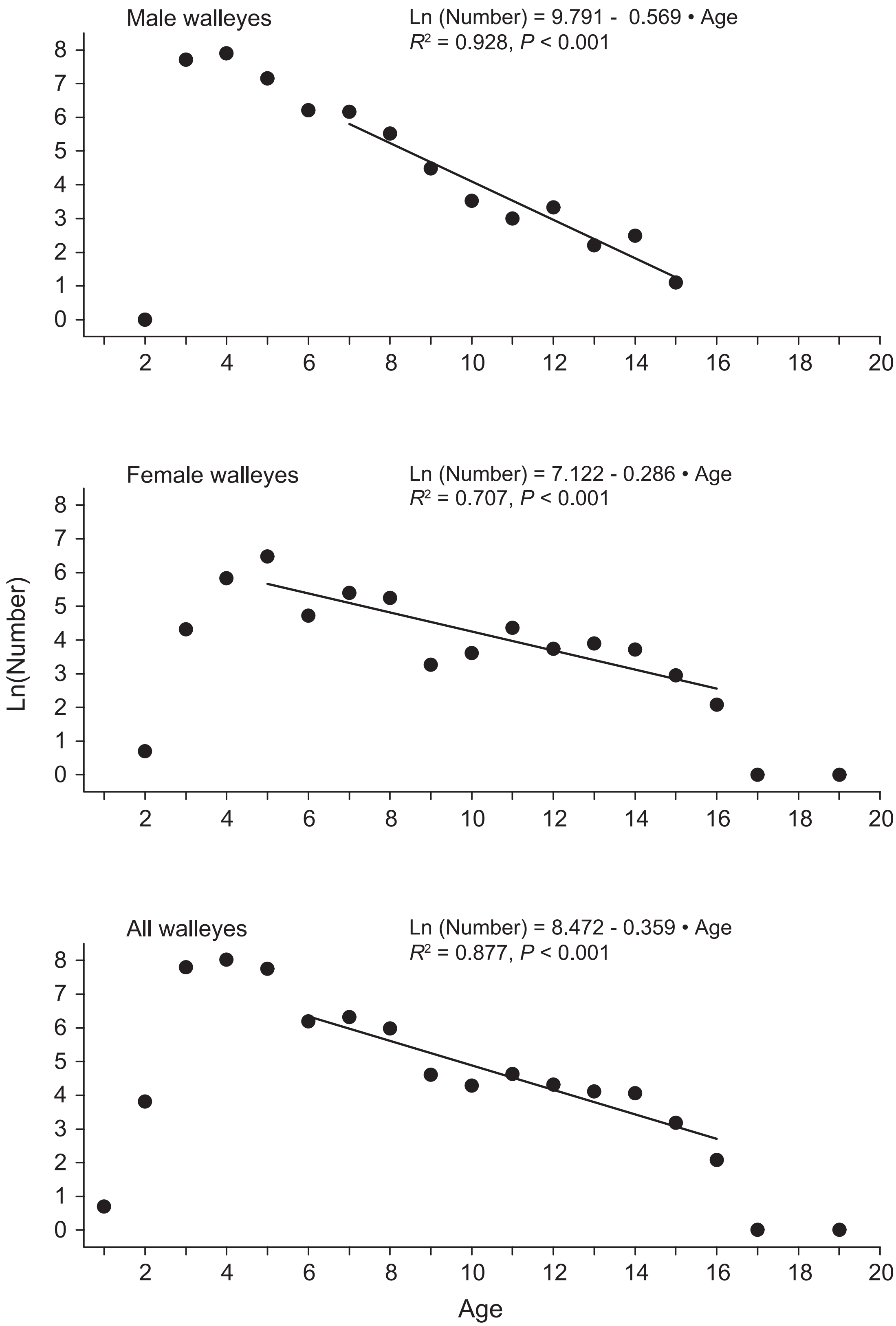

Figure 5.–Plots of observed ln(number) versus age for male, female, and all (including males, females, and unknown sex) walleye in the entire Cisco Lake Chain. Lines are plots of regression equations given beside each graph.

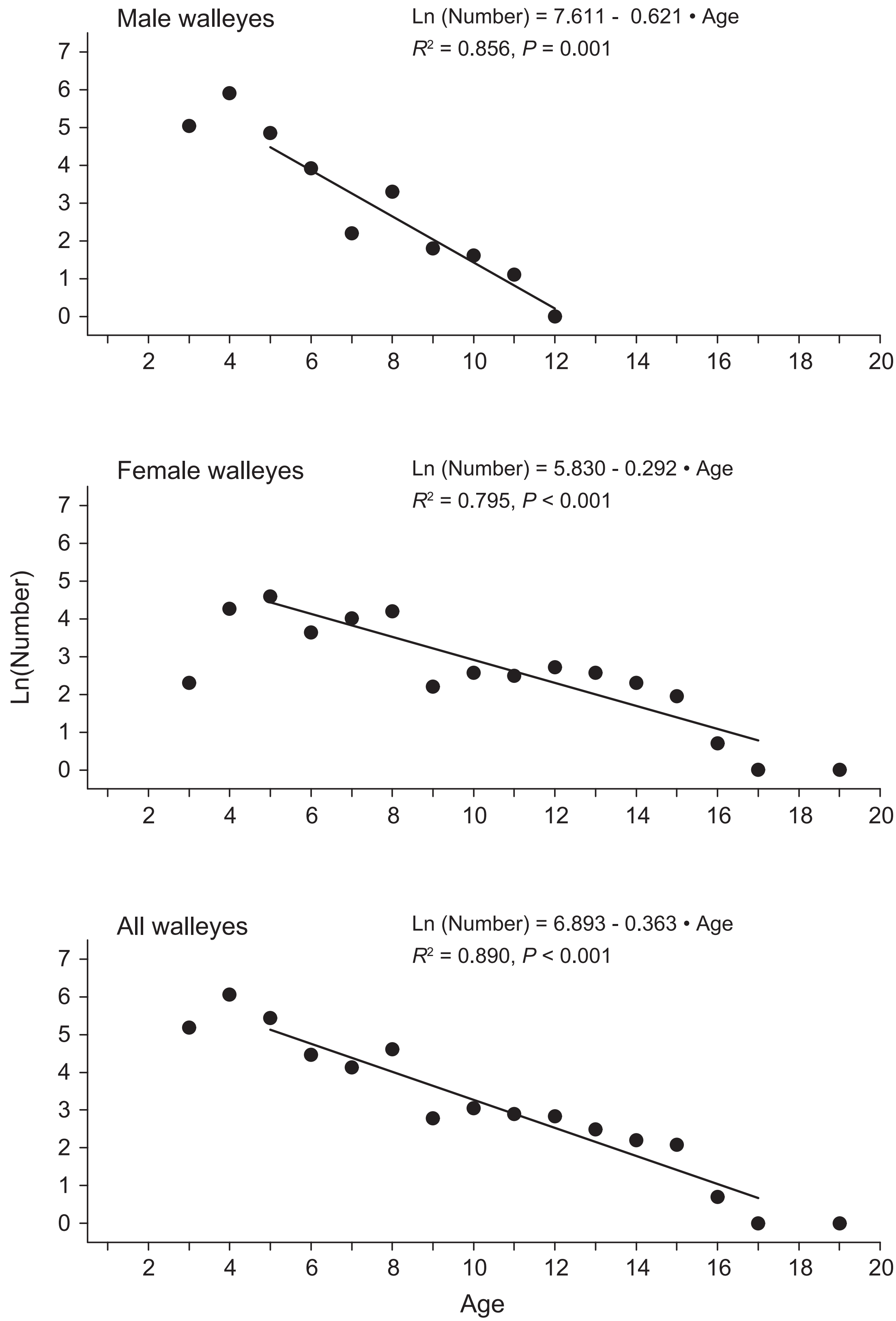

Figure 6.–Plots of observed ln(number) versus age for male, female, and all (including males, females, and unknown sex) walleye in the north lake group of the Cisco Lake Chain. Lines are plots of regression equations given beside each graph.

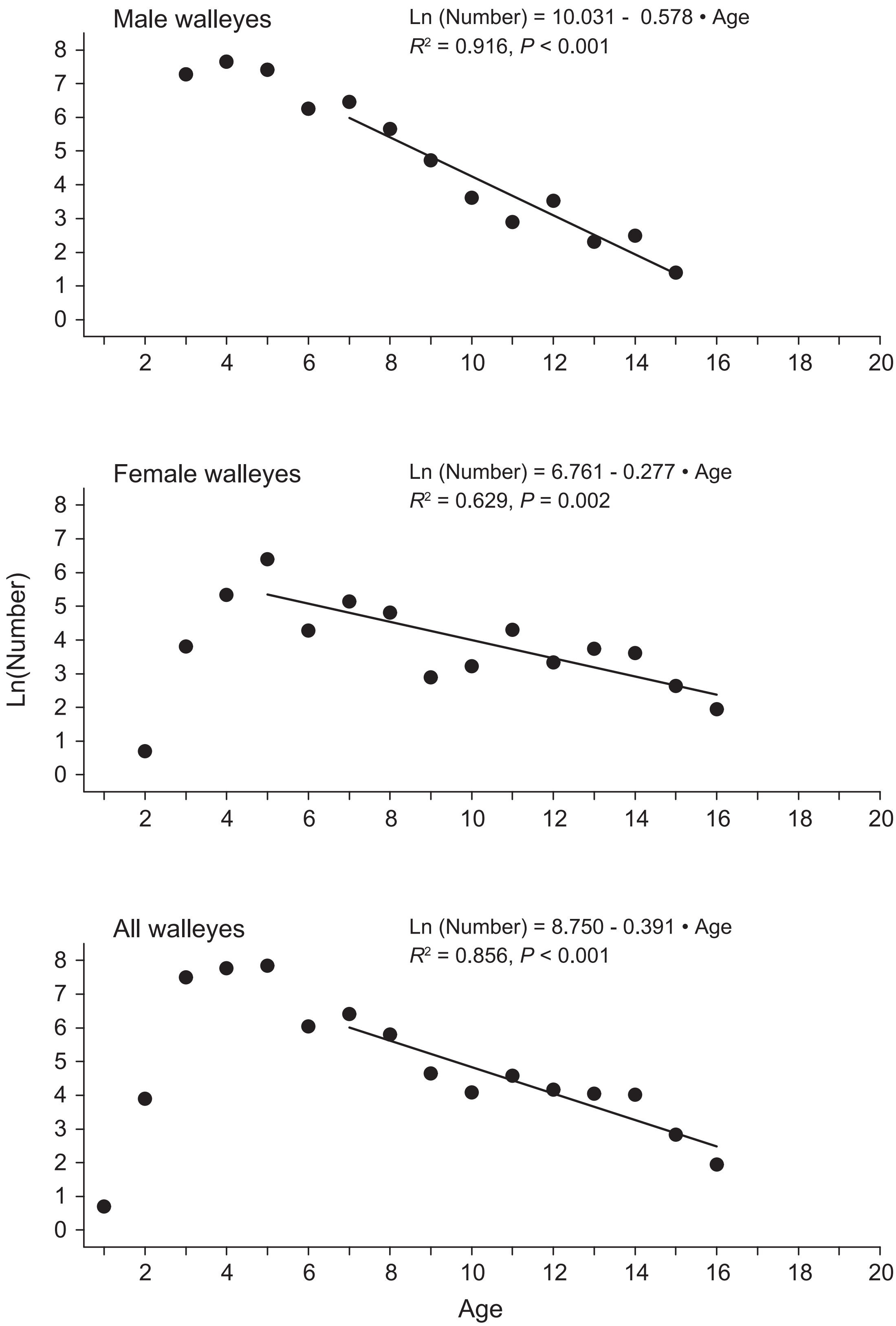

Figure 7.–Plots of observed ln(number) versus age for male, female, and all (including males, females, and unknown sex) walleye in the south lake group of the Cisco Lake Chain. Lines are plots of regression equations given beside each graph.

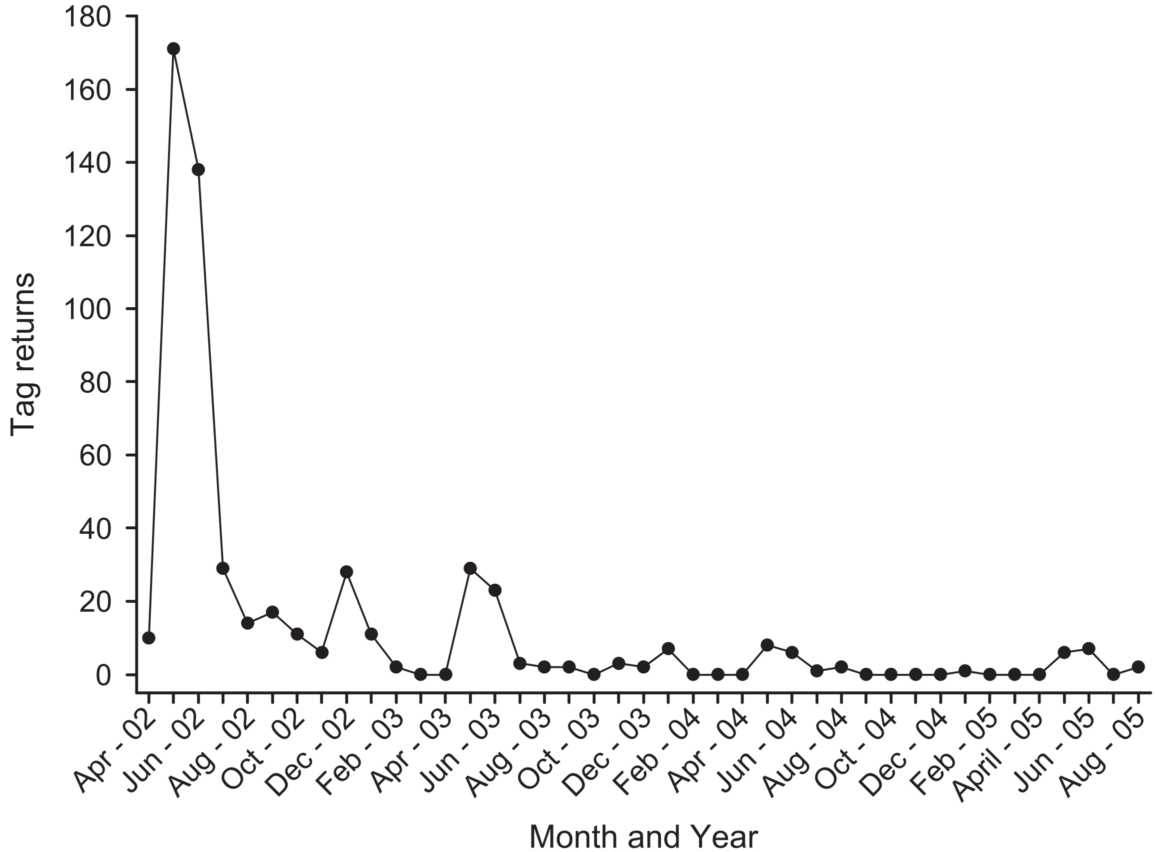

Figure 8.–Walleye tag returns (reward and nonreward) by month and year for walleye tagged during the spawning run (April 21 to May 3, 2002) in the Cisco Lake Chain. Based on returns received as of October 28, 2005.

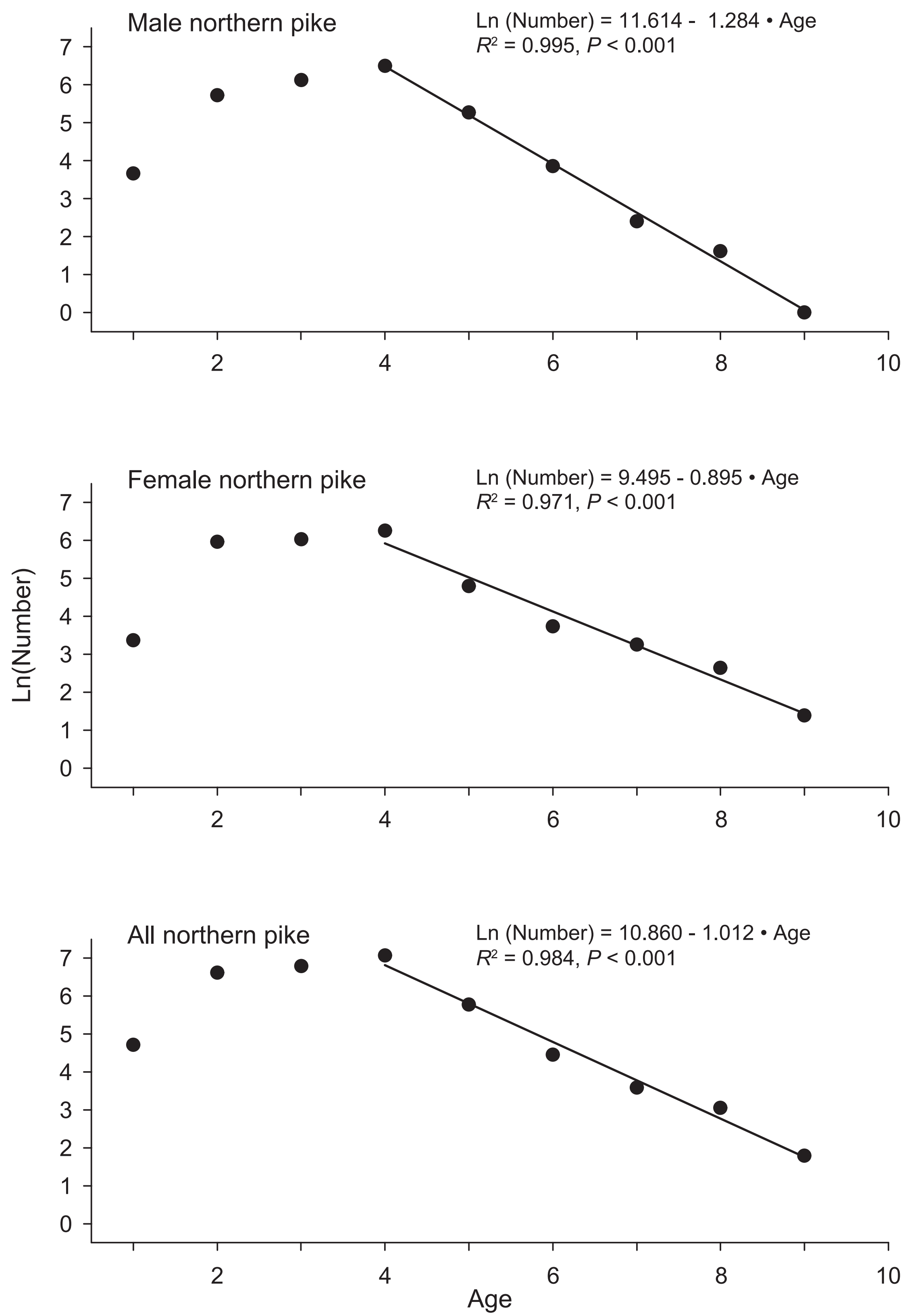

Figure 9.–Plots of observed ln(number) versus age for male, female, and all (including males, females, and unknown sex) northern pike in the entire Cisco Lake Chain. Lines are plots of regression equations given beside each graph.

Table 1.–Number and size of fish stocked in the Cisco Lake Chain from 1979 through 2003.

Year	Lake	Species (Strain)	Number	Avg. length (in)
1979	Thousand Island	Lake trout	1,750	11.88
1979	Lindsley	Tiger muskellunge	800	5.56
1979	Cisco	Tiger muskellunge	2,000	5.44
1981	Cisco	Muskellunge (Northern)	400	7.76
1983	Cisco	Walleye (Gogebic)	5,000	–[a]
1983	Cisco	Walleye[b]	4,000	–
1984	Cisco	Walleye (Gogebic)	8,360	1.52
1984	Cisco	Walleye[b]	3,800	5.08
1985	Cisco	Walleye (Gogebic)	200,000	0.40
1985	Cisco	Walleye[b]	9,700	2.00
1985	Cisco	Walleye[b]	6,500	3.04
1985	Cisco	Walleye[b]	3,589	6.08
1985	Mamie	Muskellunge[c]	700	11.00
1985	West Bay	Muskellunge[c]	700	11.00
1986	Cisco	Walleye (Manistique)	100,000	0.20
1986	Thousand Island	Walleye (Manistique)	5,000	1.64
1986	Cisco	Walleye[b]	1,000	2.52
1987	Cisco	Walleye[b]	5,000	6.80
1988	Cisco	Walleye[b]	5,160	6.00
1989	Cisco	Walleye[b]	8,500	5.80
1991	Thousand Island	Walleye (Bay de Noc)	15,416	1.68
1992	Cisco	Walleye	3,000	1.68
1992	Cisco	Walleye	25,000	1.76
1993	Cisco	Walleye (Bay de Noc)	15,000	1.88
1993	Thousand Island	Walleye (Bay de Noc)	24,178	3.00
1994	Cisco	Walleye[b]	2,000	9.16
1995	Thousand Island	Walleye (Bay de Noc)	25,023	1.44
1996	Cisco	Walleye[b]	4,200	7.24
1997	Thousand Island	Walleye[b]	5,300	7.12
1998	Cisco	Walleye (Bay de Noc)	13,703	1.56
1998	Thousand Island	Walleye[b]	8,000	3.40
1999	Cisco	Walleye (Bay de Noc)	10,237	1.60
2000	Cisco	Walleye (Bay de Noc)	5,565	2.12
2003	Thousand Island	Walleye (Bay de Noc)	9,516	1.04

[a] Average length unknown, but fish were probably spring fingerlings (around 1.5–2.2 inches)
[b] Private stocking event (under permit)
[c] Wisconsin Department of Natural Resources stocking event

Table 2.–The names, surface areas, and sampling effort for lakes we considered as part of the whole Cisco Lake Chain. The north and south groups of lakes listed below appeared to have fairly distinct walleye populations, so we calculated walleye population statistics separately for these groups of lakes, as well as, the Cisco Lake Chain as a whole. Surface area for lakes is from Michigan Digital Water Atlas (Breck 2004).

		Number	
Walleye group, Lake name	Surface area (acres)	Fyke-net lifts	Electrofishing runs
North			
Cisco Lake	567	108	2
Thousand Island Lake	1,009	86	4
Little African Lake	21	1	1
Big African Lake	86	7	1
Record Lake	68	16	1
Lindsley Lake	156	46	1
Fishhawk Lake	77	8	1
Total north	1,984	272	11
South			
Poor Lake	106	12	1
Indian Lake	129	16	0
Morley Lake	59	6	1
East Bay Lake	277	25	0
Big Lake	733	53	1
West Bay Lake	362	33	1
Mamie Lake	337	28	1
Total south	2,003	173	5
Grand total	3,987	445	16

Table 3.–Latitude and longitude coordinates for section boundaries used in angler survey of the Cisco Lake Chain.

Lake boundary	Latitude	Longitude
Cisco – Lindsley, Fishhawk	46°13.33′	89°25.76′
Lindsley, Fishhawk – Big	46°12.93′	89°25.89′
West Bay – East Bay	46°12.55′	89°25.15′
East Bay – Mamie	46°11.95′	89°23.70′
Cisco – Thousand Island	46°13.76′	89°25.61′
Thousand Island – Little African, Big African, Record	46°14.62′	89°23.78′

Table 4.–Survey periods, sampling shifts, and expansion value "F" (number of fishing hours within a sample day) for the Cisco Lake Chain angler survey, spring 2002 through winter 2003.

Survey period	Sample shifts (h)		F
May 4–31	0600–1430	1330–2200	16
June	0600–1430	1330–2200	16
July	0600–1430	1330–2130	16
August	0630–1500	1230–2100	15
September	0630–1500	1200–2030	14
October	0630–1500	1030–1900	13
December 7–December 31	0700–1530	1100–1930	13
January	0700–1530	1100–1930	14
February 1–26	0700–1530	1100–1930	14

Table 5.–GPS coordinates for the Cisco Lake Chain angler survey, 2002. See Figure 4 for general flight path and numbered locations.

Marker	Latitude	Longitude
1	46°15.13′	89°27.14′
2	46°13.33′	89°25.76′
3	46°12.93′	89°25.89′
4	46°11.33′	89°26.74′
5	46°11.85′	89°25.74′
6	46°12.55′	89°25.15′
7	46°11.95′	89°23.70′
8	46°11.05′	89°23.17′
9	46°12.41′	89°23.20′
10	46°12.77′	89°23.16′
11	46°12.95′	89°23.91′
12	46°12.71′	89°24.72′
13	46°12.98′	89°24.52′
14	46°13.76′	89°25.61′
15	46°13.55′	89°23.65′
16	46°13.94′	89°22.76′
17	46°14.19′	89°25.02′
18	46°14.62′	89°23.78′
19	46°15.14′	89°23.05′

Table 6.–Fish collected from the Cisco Lake Chain of lakes using a total sampling effort of 445 fyke-net lifts and 16 electrofishing runs from April 21 to May 3, 2002.

Species	Total catch[a]	Percent by number	Mean fyke-net CPUE[a,b]	Length range (in)	Average length (in)[c]	Number measured[c]
Yellow perch	41,800	64.6	63.9	3.2–12.6	7.7	2,117
Walleyes	11,010	17.0	11.4	4.8–29.8	14.4	9,744
Northern pike	3,979	6.2	5.0	6.4–34.7	18.2	3,392
Bluegill	3,311	5.1	5.3	1.7–11.8	7.0	1,713
Black crappie	1,414	2.2	2.1	2.0–14.0	9.4	1,061
Rock bass	1,035	1.6	1.6	3.0–10.4	7.1	881
Pumpkinseed	894	1.4	1.4	2.9–11.9	6.2	588
Brown bullhead	801	1.2	1.5	2.3–13.6	9.1	369
Largemouth bass	115	0.2	0.2	3.1–19.7	13.4	115
Smallmouth bass	97	0.1	0.1	2.7–17.4	12.5	97
Golden shiner	89	0.1	<0.1	3.0–6.5	4.8	81
White sucker	58	<0.1	<0.1	3.3–22.7	16.7	58
Muskellunge	49	<0.1	<0.1	8.5–53.0	31.1	49
Tiger Muskellunge	5	<0.1	<0.1	8.2–34.3	19.8	5
Creek chub	4	<0.1	<0.1	8.4–8.6	8.5	3
Mottled sculpin	4	<0.1	<0.1	3.0–4.4	3.6	3
Black bullhead	2	<0.1	<0.1	6.5–8.4	7.4	2
Central mudminnow	2	<0.1	<0.1	3.04.1	3.6	2
Lake herring	2	<0.1	–	–	–	–

[a] Includes recaptures
[b] Number per fyke-net night
[c] Does not include recaptures for northern pike and walleyes

Table 7.–Number of fish per inch group caught and measured in spring netting and electrofishing operations on the Cisco Lake Chain, April 21 to May 3, 2002.

Inch group	Species																	
	Walleyes	Northern pike	Yellow perch	Bluegill	Black crappie	Rock bass	Pumpkinseed	Brown bullhead	Largemouth bass	Smallmouth bass	Golden shiner	White sucker	Muskellunge	Tiger muskellunge	Creek chub	Mottled sculpin	Black bullhead	Central mudminnow
1	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	8	4	–	1	2	–	1	–	–	–	–	–	–	–	–
3	–	–	6	37	3	6	14	3	1	–	10	1	–	–	–	2	–	1
4	1	–	75	96	24	45	28	2	2	–	37	3	–	–	–	1	–	1
5	2	–	195	176	18	132	163	5	2	–	27	1	–	–	–	–	–	–
6	2	1	348	363	49	171	273	17	2	–	7	–	–	–	–	–	1	–
7	1	8	545	693	109	298	108	49	2	1	–	1	–	–	–	–	–	–
8	7	6	469	282	179	189	–	94	2	–	–	–	1	1	3	–	1	–
9	24	27	315	52	250	38	–	81	6	–	–	–	–	–	–	–	–	–
10	445	25	124	3	189	2	–	63	5	8	–	–	1	–	–	–	–	–
11	1,180	40	31	2	132	–	1	41	5	20	–	–	2	–	–	–	–	–
12	1,619	70	9	–	84	–	–	10	18	32	–	–	1	–	–	–	–	–
13	2,030	118	–	–	19	–	–	2	12	23	–	–	–	1	–	–	–	–
14	1,586	202	–	–	1	–	–	–	15	6	–	1	1	–	–	–	–	–
15	1,048	320	–	–	–	–	–	–	14	3	–	8	1	–	–	–	–	–
16	531	411	–	–	–	–	–	–	15	1	–	9	1	–	–	–	–	–
17	311	439	–	–	–	–	–	–	10	2	–	8	–	–	–	–	–	–
18	168	394	–	–	–	–	–	–	3	–	–	6	5	1	–	–	–	–
19	135	353	–	–	–	–	–	–	1	–	–	11	1	–	–	–	–	–
20	123	323	–	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–
21	111	213	–	–	–	–	–	–	–	–	–	3	1	–	–	–	–	–
22	87	142	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–
23	64	89	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
24	71	69	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–
25	70	54	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
26	62	29	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–

Table 7.–Continued.

Inch group	Species: Walleyes	Northern pike	Yellow perch	Bluegill	Black crappie	Rock bass	Pumpkinseed	Brown bullhead	Largemouth bass	Smallmouth bass	Golden shiner	White sucker	Muskellunge	Tiger muskellunge	Creek chub	Mottled sculpin	Black bullhead	Central mudminnow
27	29	22	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
28	28	9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
29	9	9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
30	–	13	–	–	–	–	–	–	–	–	–	–	3	–	–	–	–	–
31	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
32	–	1	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–
33	–	2	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–
34	–	2	–	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–
35	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–
36	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–	–	–
37	–	–	–	–	–	–	–	–	–	–	–	–	4	–	–	–	–	–
38	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–
39	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
40	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–	–	–
41	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–
42	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–	–	–
44	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
45	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
48	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
50	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
53	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
Total	9,744	3,392	2,117	1,713	1,061	881	588	369	115	97	81	58	45	5	3	3	2	2

Table 8.–Estimates of abundance, angler exploitation rates, and total annual mortality rates for spawning walleye in the Cisco Lake Chain using the different methods described in text. Symmetrical 95% confidence intervals for estimates are given in parentheses.

Parameter	Entire Cisco Lake Chain	North lake group	South lake group
Total tag returns	440	94	346
Number of legal-size[a] fish			
Multiple-census method	7,236 (6,264–8,209)	1,517 (1,277–1,757)	5,719 (4,776–6,663)
Single-census method	12,558 (9,264–15,852)	3,755 (1,613–5,897)	8,803 (6,777–10,829)
Michigan model prediction[b]	5,783 (1,247–26,823)	2,919 (633–13,473)	2,947 (638–13,599)
Number of adult[c] fish			
Multiple-census method	40,239 (34,260–46,219)	3,557 (3,004–4,109)	36,683 (30,728–42,638)
Single-census method	40,823 (31,003–50,643)	5,761 (2,475–9,047)	35,062 (26,993–43,130)
Wisconsin model prediction[d]	12,883 (4,220–39,326)	6,651 (1,988–19,250)	6,712 (2,005–19,417)
Michigan model prediction[e]	8,469 (1,605–44,692)	4,081 (777–21,426)	4,122 (785–21,641)
Annual exploitation rates			
Based on reward tag returns	17.3%	13.6%	18.5%
Based on harvest/abundance[f]	30.7% (22.4%–39.0)	54.5% (27.4%–81.7%)	26.8% (21.1%–32.4%)
Based on harvest/abundance[g]	17.7% (11.7%–23.7%)	22.0% (5.7%–38.3%)	17.4% (12.6%–22.2%)
Total annual mortality rates	30%	30%	32%

[a] ≥15 in.
[b] Michigan model prediction of legal walleye abundance based on lake area, N=2.
[c] Estimated numbers of fish, both legal-size and sexually mature sublegal size, on spawning grounds in spring 2002.
[d] Wisconsin model prediction of adult walleye abundance based lake area and natural reproduction, N=79.
[e] Michigan model prediction of adult walleye abundance based on lake area, N=35.
[f] Multiple-census estimate of legal-size walleye abundance.
[g] Single-census estimate of legal-size walleye abundance from creel survey.

Table 9.–Estimates of abundance, angler exploitation rates, and total annual mortality rates for Cisco Lake Chain spawning northern pike using the different methods described in text. Symmetrical 95% confidence intervals for estimates are given in parentheses, along with coefficient of variation (CV) where applicable.

Parameter	Estimate
Number tagged	962
Total tag returns	131
Number of 18-in fish[a]	
Multiple-census method	3,478 (2,625–4,332)
Single-census method	7,784 (2,928–12,639)
Number of adult[b] **fish**	
Multiple-census method	11,404 (8,066–14,743)
Single-census method	14,904 (5,607–24,201)
Annual exploitation rates	
Based on reward tag returns	23.2%
Based on harvest/abundance[c]	44.1% (25.6%–62.7)
Based on harvest/abundance[d]	19.7% (5.5%–33.9%)
Annual mortality rate	64%

[a] There is no size limit for northern pike on the Cisco Lake Chain; thus we used 18 in as the minimum size acceptable to anglers.

[b] Estimated numbers of fish, both legal-size (24 in) and sexually mature sublegal size, on spawning grounds in April 2002. For valid comparison with previous estimates, we used 24 in as the legal size for northern pike.

[c] Multiple-census estimate of legal-size (18 in) walleye abundance.

[d] Single-census estimate of legal-size walleye abundance from creel survey.

Table 10.–Weighted mean lengths and sample sizes (number aged) by age and sex for walleyes collected from the entire Cisco Lake Chain, April 21 to May 3, 2002. Standard deviation is in parentheses.

	Mean length (SE)			Number aged		
Age	Males	Females	All fish[a]	Males	Females	All fish[a]
1	––	––	8.4 (–)	–	–	1
2	8.1 (–)	11.1 (–)	10.6 (0.9)	1	1	5
3	12.0 (1.0)	12.6 (1.5)	11.9 (1.0)	51	23	78
4	13.6 (1.3)	15.1 (1.6)	13.8 (1.4)	58	42	101
5	14.0 (1.3)	15.7 (1.7)	14.6 (1.4)	34	76	110
6	14.7 (1.3)	18.6 (2.1)	15.6 (2.2)	19	24	43
7	15.4 (1.1)	19.8 (2.1)	17.1 (2.6)	24	56	80
8	16.2 (1.9)	21.8 (1.9)	19.1 (3.2)	35	62	97
9	15.4 (1.9)	23.5 (1.3)	18.0 (3.9)	9	10	19
10	17.9 (1.4)	24.7 (1.7)	21.5 (3.6)	9	15	24
11	20.4 (2.3)	24.1 (2.1)	23.1 (2.7)	10	31	41
12	18.1 (2.2)	25.6 (1.4)	22.6 (3.8)	9	19	28
13	19.7 (0.9)	26.3 (1.9)	24.8 (3.2)	5	26	31
14	19.6 (2.6)	26.1 (2.3)	24.4 (3.6)	5	21	26
15	18.6 (0)	26.7 (0.9)	25.8 (2.9)	2	9	11
16	––	28.5 (0.5	28.5 (0.5)	–	6	6
17	––	28.4 (–)	28.4 (–)	–	1	1
18	––	––	––	–	–	–
19	––	29.8 (–)	29.8 (–)	–	1	1

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

Table 11.–Weighted mean lengths and sample sizes (number aged) by age and sex for walleyes collected from the north walleye lake group of the Cisco Lake Chain, April 21 to May 3, 2002. Standard deviation is in parentheses.

	Mean length (SE)			Number aged		
Age	Males	Females	All fish[a]	Males	Females	All fish[a]
3	12.9 (1.2)	13.8 (1.1)	12.9 (1.2)	22	3	26
4	14.8 (1.1)	16.5 (1.4)	15.1 (1.3)	32	20	53
5	16.1 (0.9)	17.3 (2.1)	16.5 (1.6)	15	27	42
6	15.9 (1.7)	20.0 (1.8)	17.8 (2.6)	10	14	24
7	18.4 (1.3)	20.8 (1.9)	20.6 (2.1)	3	24	27
8	19.1 (1.3)	22.6 (1.8)	21.5 (2.3)	14	35	49
9	19.7 (0.4)	23.9 (1.2)	22.0 (2.3)	3	5	8
10	19.3 (0.0)	25.3 (1.1)	23.3 (3.0)	3	8	11
11	20.1 (1.1)	24.7 (1.6)	23.8 (2.3)	2	8	10
12	21.2 (–)	25.7 (1.6)	25.1 (2.1)	1	9	10
13	– –	27.4 (1.0)	27.3 (1.0)	–	9	9
14	– –	27.8 (0.4)	27.7 (0.4)	–	7	7
15	– –	27.1 (1.4)	27.2 (1.3)	–	5	6
16	– –	29.2 (0.8)	29.2 (0.8)	–	2	2
17	– –	28.4 (–)	28.4 (–)	–	1	1
18	– –	– –	– –	–	–	–
19	– –	29.8 (–)	29.8 (–)	–	1	1

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

Table 12.–Weighted mean lengths and sample sizes (number aged) by age and sex for walleyes collected from the south walleye lake group of the Cisco Lake Chain, April 21 to May 3, 2002. Standard deviation is in parentheses.

	Mean length (SE)			Number aged		
Age	Males	Females	All fish[a]	Males	Females	All fish[a]
1	——	——	8.4 (—)			1
2	8.1 (—)	11.1 (—)	10.7 (0.9)	1	1	5
3	11.6 (0.9)	11.5 (0.6)	11.6 (0.8)	29	20	52
4	13.0 (1.2)	14.2 (1.1)	13.3 (1.1)	26	22	48
5	13.6 (0.8)	15.4 (1.3)	14.3 (1.2)	19	49	68
6	14.4 (1.1)	17.2 (1.4)	15.0 (1.5)	9	10	19
7	15.3 (0.9)	19.1 (1.8)	16.4 (2.0)	21	32	53
8	15.7 (1.5)	21.0 (1.7)	17.6 (2.9)	21	27	48
9	15.0 (1.5)	22.9 (0.6)	16.8 (3.3)	6	5	11
10	17.5 (1.2)	24.0 (1.9)	20.4 (3.4)	6	7	13
11	19.6 (1.8)	23.9 (2.2)	23.0 (2.7)	8	23	31
12	17.6 (1.4)	25.6 (1.4)	21.5 (4.0)	8	10	18
13	19.6 (0.9)	25.8 (2.0)	24.1 (3.2)	5	17	22
14	18.9 (1.7)	25.4 (2.4)	23.6 (3.5)	5	14	19
15	18.6 (—)	26.4 (0.3)	24.6 (3.5)	1	4	5
16	——	28.3 (—)	28.3 (—)	—	4	4

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

Table 13.–Weighted mean lengths and sample sizes (number aged) by age and sex for northern pike collected from the entire Cisco Lake Chain, April 21 to May 3, 2002. Standard deviation is in parentheses.

	Mean length (SE)			Number aged		
Age	Males	Females	All fish[a]	Males	Females	All fish[a]
1	11.3 (1.2)	12.4 (1.2)	11.1 (1.7)	27	22	57
2	15.6 (1.9)	16.0 (1.8)	15.8 (1.9)	68	98	167
3	17.3 (2.4)	18.3 (2.6)	17.8 (2.5)	84	93	177
4	18.4 (2.4)	20.3 (3.0)	19.2 (2.8)	125	149	274
5	20.6 (2.2)	23.2 (3.5)	21.6 (3.0)	56	55	111
6	20.9 (2.1)	24.3 (2.5)	22.5 (2.8)	15	22	37
7	24.1 (3.4)	26.4 (3.9)	25.5 (3.8)	7	17	24
8	20.0 (–)	22.4 (2.7)	21.6 (2.5)	1	6	7
9	30.4 (–)	26.7 (2.9)	28.6 (4.0)	2	3	5

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

Table 14.–Weighted mean lengths and sample sizes (number aged) for muskellunge collected from the entire Cisco Lake Chain, April 21 to May 3, 2002. Standard deviation is in parentheses.

Age	Mean length (SE)	Number aged
1	11.9 (—)	1
2	18.6 (0.3)	5
3	16.0 (—)	1
4	29.4 (3.2)	4
5	33.5 (1.7)	6
6	36.0 (—)	1
7	— —	0
8	35.4 (5.0)	3
9	39.7 (3.3)	3
10	37.0 (—)	1
11	39.6 (3.6)	6
12	45.6 (4.7)	3
13	40.6 (0.6)	2
14	43.2 (4.6)	3
15	53.0 (—)	1

Table 15.–Catch at age estimates (apportioned by age-length key) by sex for walleyes collected from the Cisco Lake Chain, April 21 to May 3, 2002.

	Year	Entire chain			North lake group			South lake group		
Age	class	Males	Females	All fish[a]	Males	Females	All fish[a]	Males	Females	All fish[a]
1	2001	–	–	2	–	–	–	–	–	2
2	2000	1	2	45	–	–	–	1	2	49
3	1999	2,230	75	2,419	153	10	177	1,446	45	1,787
4	1998	2,684	340	3,013	365	71	424	2,101	207	2,361
5	1997	1,283	646	2,313	127	98	229	1,661	597	2,527
6	1996	499	112	488	50	38	86	516	72	420
7	1995	476	220	552	9	55	62	635	170	606
8	1994	250	189	397	27	66	100	286	122	331
9	1993	88	26	100	6	9	16	112	18	103
10	1992	34	37	72	5	13	21	37	25	59
11	1991	20	78	102	3	12	18	18	74	97
12	1990	28	42	75	1	15	17	34	28	64
13	1989	9	49	61	–	13	12	10	42	57
14	1988	12	41	58	–	10	9	12	37	55
15	1987	3	19	24	–	7	8	4	14	17
16	1986	–	8	8	–	2	2	–	7	7
17	1985	–	1	1	–	1	1	–	–	–
18	1984	–	–	–	–	–	–	–	–	–
19	1983	–	1	1	–	1	1	–	–	–
Total		7,617	1,886	9,731	746	421	1,183	6,873	1,460	8,542

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

Table 16.–Angler tag returns from walleyes (reward and nonreward) by month for the year following tagging in the Cisco Lake Chain.

Month	Number of tag returns	Percentage of total
Apr 02	10	2.3
May 02	172	39.1
Jun 02	140	31.8
Jul 02	29	6.6
Aug 02	14	3.2
Sep 02	17	3.9
Oct 02	11	2.5
Nov 02	6	1.4
Dec 02	28	6.4
Jan 03	11	2.5
Feb 03	2	0.5
Mar 03	0	0.0
Total	440	

Table 17.–Catch at age estimates (apportioned by age-length key) by sex for northern pike and muskellunge collected from the Cisco Lake Chain, April 21 to May 3, 2002

		Northern pike			Muskellunge
Age	class	Males	Females	All fish[a]	All fish[a]
1	2001	39	29	111	2
2	2000	306	387	742	7
3	1999	458	416	885	1
4	1998	665	523	1,172	3
5	1997	194	121	319	6
6	1996	47	42	86	2
7	1995	11	26	36	–
8	1994	5	14	21	4
9	1993	1	4	6	4
10	1992	–	–	–	1
11	1991	–	–	–	7
12	1990	–	–	–	3
13	1989	–	–	–	2
14	1988	–	–	–	3
15	1987	–	–	–	1
Total		1,726	1,562	3,378	46

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

Table 18.–Angler tag returns from northern pike (reward and nonreward) by month for the year following tagging in the Cisco Lake Chain.

Month	Number of tag returns	Percentage of total
Apr 02	0	0.0
May 02	40	30.5
Jun 02	49	37.4
Jul 02	14	10.7
Aug 02	15	11.5
Sep 02	3	2.3
Oct 02	4	3.1
Nov 02	1	0.8
Dec 02	4	3.1
Jan 03	1	0.8
Feb 03	0	0.0
Mar 03	0	0.0
Total	131	

Table 19.–Spring movement of walleye tagged and recaptured during the spawning run (April 21 to May 3, 2002) in the Cisco Lake Chain. Each cell represents the percentage of recaptured fish from each lake for a given tagging location. N = total recaptures from those fish tagged in a given lake.

	Recapture location														
Tagging location	Cisco	Little Africa	Big Africa	Record	Thousand Island	Lindsley	Fishhawk	Morley	Big	West Bay	Poor	East Bay	Indian	Mamie	**N**
Cisco	86.7	0	0	0	0	0	0	0	13.3	0	0	0	0	0	15
Little Africa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Big Africa	0	0	0	0	100	0	0	0	0	0	0	0	0	0	1
Record	0	0	50	50	0	0	0	0	0	0	0	0	0	0	2
Thousand Island	0.9	0	0	0	99.1	0	0	0	0	0	0	0	0	0	108
Lindsley	15.8	0	0	0	0	84.2	0	0	0	0	0	0	0	0	19
Fishhawk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Morley	0	0	0	0	0	22.2	0	44.4	33.3	0	0	0	0	0	9
Big	1.3	0	1.3	0	0	0	0	3.8	79.7	13.9	0	0	0	0	79
West Bay	0	0	0	0	0	0	0	1	3.8	94.3	0	1	0	0	105
Poor	0	0	0	0	0	0	0	0	0	0	80	20	0	0	5
East Bay	0	0	0	0	0	0	0	3.6	3.6	50	0	32.1	0	10.7	28
Indian	0	0	0	0	0	0	0	0	0	0	0	0	100	0	3
Mamie	0	0	0	0	0	0	0	0	0	2.3	0	4.5	0	93.2	88

Table 20.–Walleye movement depicted from tag returns (reward and nonreward) from walleye tagged during the spawning run (April 21 to May 3, 2002) in the Cisco Lake Chain for the year following tagging. Each cell represents the percentage of tag returns from each lake for a given tagging location. N = total tag returns from those fish tagged in a given lake. The "Cisco Chain" column represents fish where exact recapture location was unknown.

Tagging location	Recapture location																	
	Cisco	Little Africa	Big Africa	Record	Thousand Island	Lindsley	Fishhawk	Morley	Big	West Bay	Poor	East Bay	Indian	Mamie	Cisco Chain	Helen	Spring	N
Cisco	77.8	0	0	0	16.7	0	0	0	0	0	0	0	0	5.6	0	0	0	18
Little Africa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Big Africa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Record	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Thousand Island	5.7	1.9	0	5.7	84.9	0	0	0	0	0	0	0	0	1.9	0	0	0	53
Lindsley	27.3	0	0	0	27.3	18.2	4.5	0	9.1	4.5	0	4.5	0	0	4.5	0	0	22
Fishhawk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Morley	9.5	0	0	0	9.5	4.8	9.5	0	28.6	19.0	4.8	9.5	0	0	4.8	0	0	21
Big	5.6	0	0	0	3.7	2.8	0.9	3.7	50.5	8.4	0.9	12.1	0	7.5	3.7	0	0	107
West Bay	6.6	0	0	0	2.6	1.3	1.3	1.3	9.2	31.6	5.3	30.3	1.3	7.9	0	1.3	0	76
Poor	0	0	0	0	0	0	0	0	0	0	100.0	0	0	0	0	0	0	5
East Bay	7.0	0	0	0	4.7	0	0	2.3	0	16.3	0	34.9	4.7	27.9	2.3	0	0	43
Indian	20.0	0	0	0	0	0	0	0	0	20.0	0	0	60.0	0	0	0	0	5
Mamie	4.6	0	0	0	2.3	0	1.1	0	4.6	5.7	0	10.3	4.6	64.4	1.1	0	1.1	87

Table 21.–Spring movement of northern pike tagged and recaptured during the spawning run (April 21 to May 3, 2002) in the Cisco Lake Chain. Each cell represents the percentage of recaptured fish from each lake for a given tagging location. N = total recaptures from those fish tagged in a given lake.

Tagging location	Recapture location														
	Cisco	Little Africa	Big Africa	Record	Thousand Island	Lindsley	Fishhawk	Morley	Big	West Bay	Poor	East Bay	Indian	Mamie	N
Cisco	96.2	0	0	0	0	0	0	0	3.8	0	0	0	0	0	26
Little Africa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Big Africa	0	50	50	0	0	0	0	0	0	0	0	0	0	0	2
Record	0	0	0	100	0	0	0	0	0	0	0	0	0	0	2
Thousand Island	0	0	0	0	75	0	0	0	12.5	0	0	12.5	0	0	8
Lindsley	0	0	0	0	37.5	37.5	0	12.5	0	0	0	12.5	0	0	8
Fishhawk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Morley	0	0	0	0	0	0	0	6	20	20	0	0	0	0	5
Big	2	0	0	0	0	2	0	7.8	51	15.7	2	11.8	5.9	2	51
West Bay	0	0	0	0	0	0	0	10	15	35	5	25	5	5	20
Poor	0	0	0	0	0	0	0	0	0	0	100	0	0	0	13
East Bay	0	0	0	0	0	5	0	5	15	0	25	25	5	20	20
Indian	0	0	0	0	0	0	0	0	9.1	9.1	0	18.2	45.5	18.2	11
Mamie	0	0	0	0	0	0	0	7.4	7.4	11.1	3.7	18.5	22.2	29.6	27

Table 22.–Northern pike movement depicted from tag returns (reward and nonreward) from northern pike tagged during the spawning run (April 21 to May 3, 2002) in the Cisco Lake Chain for the year following tagging. Each cell represents the percentage of tag returns from each lake for a given tagging location. N = total tag returns from those fish tagged in a given lake. The "Cisco Chain" column represents fish where exact recapture location was unknown.

Tagging location	Recapture location																N
	Cisco	Little Africa	Big Africa	Record	Thousand Island	Lindsley	Fishhawk	Morley	Big	West Bay	Poor	East Bay	Indian	Mamie	Cisco Chain	Clearwater	
Cisco	86.4	0	0	0	4.5	2.3	0	2.3	0	0	0	0	0	2.3	2.3	0	44
Little Africa	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	1
Big Africa	0	33.3	16.7	0	16.7	0	0	0	0	0	0	0	0	0	0	33.3	6
Record	0	25.0	0	50.0	25.0	0	0	0	0	0	0	0	0	0	0	0.0	8
Thousand Island	15.4	0	15.4	7.7	53.8	0	0	0	0	0	0	0	0	0	7.7	0	13
Lindsley	50.0	0	25.0	0	0	25.0	0	0	0	0	0	0	0	0	0	0	4
Fishhawk	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	1
Morley	25.0	0	0	0	0	0	0	0	0	0	0	25.0	0	50.0	0	0	4
Big	37.5	0	0	0	6.3	6.3	6.3	0	43.8	0	0	0	0	0	0	0	16
West Bay	16.7	0	0	0	0	0	0	0	0	0	0	33.3	0	33.3	16.7	0	6
Poor	20.0	0	0	0	0	20.0	0	0	0	0	40.0	0	0	20.0	0	0	5
East Bay	15.4	0	0	0	0	0	7.7	0	15.4	0	7.7	30.8	0	15.4	7.7	0	13
Indian	0	0	0	0	0	0	0	0	0	0	0	100.0	0	0	0	0	3
Mamie	14.3	0	0	0	0	0	0	0	28.6	0	14.3	28.6	0	14.3	0	0	7

Table 23.–Angler survey estimates for summer (May 4–October 31, 2002) from the Cisco Lake Chain. Two standard errors are given in parentheses.

Species	Catch/hour	May	June	July	August	September	October	Season
		Number harvested						
Brook trout	0.0002 (0.0004)	0 (0)	0 (0)	34 (67)	0 (0)	0 (0)	0 (0)	34 (67)
Lake herring	0.0008 (0.0010)	0 (0)	0 (0)	38 (76)	97 (148)	10 (19)	0 (0)	145 (167)
Lake whitefish	<0.0001 (0.0001)	0 (0)	0 (0)	0 (0)	7 (10)	0 (0)	0 (0)	7 (10)
Smallmouth bass	0.0097 (0.0043)	11 (22)	283 (257)	644 (567)	469 (318)	253 (205)	0 (0)	1,660 (729)
Largemouth bass	0.0048 (0.0024)	0 (0)	167 (171)	579 (372)	62 (77)	13 (18)	0 (0)	821 (417)
Walleyes	0.0160 (0.0042)	1,024 (480)	767 (350)	532 (329)	197 (150)	150 (95)	67 (44)	2,737 (704)
Yellow perch	0.3431 (0.0487)	11,358 (4,381)	11,270 (2,714)	12,674 (3,673)	9,496 (2,636)	11,189 (3,135)	2,781 (1,186)	58,769 (7,631)
Northern pike	0.0135 (0.0047)	213 (204)	746 (473)	507 (269)	115 (124)	692 (517)	46 (63)	2,318 (790)
Black crappie	0.0286 (0.0115)	560 (626)	2,297 (1,437)	1,523 (1,102)	104 (85)	413 (325)	5 (9)	4,901 (1,945)
Bluegill	0.2213 (0.0439)	124 (182)	5,493 (2,450)	16,898 (5,445)	8,711 (3,064)	6,070 (2,428)	609 (978)	37,906 (7,206)
Pumpkinseed	0.0103 (0.0056)	0 (0)	529 (686)	789 (595)	190 (144)	256 (243)	0 (0)	1,763 (951)
Rock bass	0.0117 (0.0060)	0 (0)	1,205 (817)	716 (592)	49 (65)	29 (59)	0 (0)	2,000 (1,013)
Round whitefish	0.0004 (0.0006)	0 (0)	0 (0)	0 (0)	62 (105)	0 (0)	0 (0)	62 (105)
Total harvested	0.6604 (0.0738)	13,290(4,460)	22,756 (4,125)	34,933 (6,761)	19,573 (4,068)	19,075 (4,026)	3,507 (1,539)	113,135 (10,851)
		Number released						
Lake herring	<0.0001 (0.0001)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	7 (13)	7 (13)
Lake whitefish	0.0103 (0.0121)	0 (0)	0 (0)	1,771 (2,073)	0 (0)	0 (0)	0 (0)	1,771 (2,073)
Smallmouth bass	0.1036 (0.0202)	691 (652)	3,259 (1,087)	6,402 (2,247)	5,283 (1,981)	1,902 (792)	204 (172)	17,741 (3,307)
Largemouth bass	0.0320 (0.0077)	525 (348)	1,086 (546)	2,263 (870)	907 (540)	657 (399)	38 (65)	5,476 (1,278)
Walleye	0.0954 (0.0159)	4,335 (1,527)	3,675 (1,387)	2,842 (914)	2,217 (743)	2,271 (687)	1,006 (623)	16,346 (2,550)
Yellow perch	0.3772 (0.0715)	8,132 (6,113)	6,241 (2,089)	21,278 (7,913)	15,138 (4,269)	12,800 (3,659)	1,038 (530)	64,626 (11,672)
Northern pike	0.0697 (0.0150)	2,464 (1,460)	3,149 (1,073)	2,389 (1,110)	1,980 (858)	1,701 (920)	253 (192)	11,936 (2,477)
Bluegill	0.6090 (0.0998)	425 (445)	12,973 (4,766)	37,590 (9,230)	33,354 (9,706)	18,826 (6,994)	1,155 (2,238)	104,323 (16,007)
Pumpkinseed	0.0547 (0.0380)	63 (80)	665 (674)	6,501 (6,294)	1,686 (1,324)	461 (527)	0 (0)	9,376 (6,489)
Rock bass	0.0350 (0.0102)	534 (401)	1,801 (832)	3,080 (1,393)	462 (355)	87 (64)	25 (27)	5,990 (1,710)
Muskellunge	0.0018 (0.0009)	67 (105)	43 (46)	70 (59)	58 (45)	4 (6)	62 (72)	304 (155)
Carp	0.0001 (0.0001)	0 (0)	0 (0)	11 (22)	0 (0)	0 (0)	0 (0)	11 (22)
Total released	1.3887 (0.1493)	17,236 (6,516)	32,891 (5,726)	84,196 (14,196)	61,085 (10,946)	38,709 (8,043)	3,789 (2,399)	237,905 (21,611)
Total (harvested + released)	2.0492 (0.1838)	30,527 (7,896)	55,647 (7,057)	119,129 (15,724)	80,658 (11,678)	57,783 (8,995)	7,296 (2,850)	351,040 (24,182)
		Fishing effort						
Angler hours		26,393 (4,534)	38,124 (4,375)	41,049 (4,891)	30,835 (3,456)	26,570 (4,080)	8,339 (2,155)	171,310 (9,841)
Angler trips		6,224 (1,773)	9,542 (3,334)	9,365 (2,910)	7,681 (2,049)	6,52 (1,716)	1,755 (596)	41,087 (5,498)

Table 24.–Angler survey estimates for winter 2002-03 from the Cisco Lake Chain. Survey period was from Dec 7, 2002 through February 26, 2003. Two standard errors are given in parentheses[a].

Species	Catch/hour	December	January	February	Season
		Number harvested			
Yellow perch	0.3876 (0.0591)	146 (93)	3,098 (3,760)	226 (183)	3,470 (3,766)
Northern pike	0.0256 (0.0002)	41 (82)	181 (228)	7 (4)	229 (242)
Black crappie	0.0012 (0.0000)	0 (0)	11 (23)	0 (0)	11 (23)
Bluegill	0.3708 (0.0352)	40 (79)	3,022 (2,609)	257 (344)	3,319 (2,633)
Pumpkinseed	0.0032 (0.0000)	0 (0)	29 (57)	0 (0)	29 (57)
Walleye	0.0236 (0.0001)	66 (–)	106 (86)	39 (24)	211 (89)
Rock bass	0.0013 (0.0000)	0 (0)	0 (0)	12 (16)	12 (16)
Total harvested	0.8133 (0.1315)	293 (147)	6,447 (4,583)	541 (391)	7,281 (4,602)
		Number released			
Largemouth bass	0.0034 (0.0000)	0 (0)	30 (34)	0 (0)	30 (34)
Walleyes	0.0298 (0.0001)	62 (14)	108 (73)	97 (43)	267 (86)
Yellow perch	0.1366 (0.0070)	136 (226)	1,015 (1,264)	72 (104)	1,223 (1,288)
Northern pike	0.0467 (0.0003)	44 (29)	276 (201)	98 (27)	418 (205)
Bluegill	0.1801 (0.0116)	0 (0)	1,540 (1,636)	72 (92)	1,612 (1,639)
Muskellunge	0.0013 (0.0000)	0 (0)	2 (3)	10 (10)	12 (10)
Total released	0.3979 (0.0294)	242 (228)	2,971 (2,079)	349 (148)	3,562 (2,097)
Total (harvested + released)	1.2112 (0.2248)	535 (271)	9,418 (5,033)	890 (418)	10,843 (5,057)
		Fishing effort			
Angler hours		1,093 (753)	6,337 (5,544)	1,522 (631)	8,952 (5,630)
Angler trips		181 (102)	1,290 (1,503)	321 (171)	1,792 (1,516)

[a] We were not able to calculate variance for every species at each site; thus, the two standard errors represent a minimum error.

Table 25.–Mean lengths of walleyes from the 2002 survey of the Cisco Lake Chain compared to other surveys. For all surveys, walleyes were collected during the spring. Unless otherwise noted, ages were determined from dorsal spine samples. Number aged in parentheses.

		Lake							
Age	State average[a]	North Cisco Lake Chain 2002	South Cisco Lake Chain 2002	Cisco Lake 1990[b]	Thousand Island 1990[c]	Gogebic 1999	Michigamme Res. 2001[d]	Burt 2001[e]	Crooked & Pickerel 2001[g]
2	10.4		10.7 (5)	9.0 (7)	10.3 (4)		8.3 (9)	11.0 (14)	12.1 (2)
3	13.9	12.9 (26)	11.6 (52)	12.1 (8)	13.7 (5)	11.4 (1)	12.5 (76)	14.1 (64)	12.5 (23)
4	15.8	15.1 (53)	13.3 (48)	13.7 (8)	15.1 (8)	13.0 (1)	14.0 (90)	16.1 (34)	13.7 (61)
5	17.6	16.5 (42)	14.3 (68)	14.9 (9)	15.1 (1)	13.8 (34)	14.8 (41)	17.3 (22)	14.9 (92)
6	19.2	17.8 (24)	15.0 (19)	17.6 (2)	16.8 (4)	16.4 (2)	15.5 (91)	17.8 (65)	15.8 (58)
7	20.6	20.6 (27)	16.4 (53)	19.0 (5)	18.6 (7)	16.7 (1)	16.2 (64)	19.0 (44)	16.4 (76)
8	21.6	21.5 (49)	17.6 (48)	17.9 (4)	20.5 (1)	17.1 (10)	16.8 (20)	19.4 (14)	17.3 (50)
9	22.4	22.0 (8)	16.8 (11)	20.0 (1)	18.2 (1)	17.0 (3)	18.7 (15)	20.7 (13)	17.1 (14)
10	23.1	23.3 (11)	20.4 (13)	24.0 (2)	22.5 (1)	17.8 (7)	19.4 (15)	21.8 (12)	18.4 (7)
11		23.8 (10)	23.0 (31)			17.3 (2)	20.3 (12)	20.3 (7)	18.8 (5)
12		25.1 (10)	21.5 (18)				18.7 (19)	21.5 (7)	18.8 (3)
13		27.3 (9)	24.1 (22)			20.1 (3)	19.9 (9)	21.9 (7)	
14		27.7 (7)	23.6 (19)	26.5 (2)			19.3 (11)	22.1 (2)	
15		27.2 (6)	24.6 (5)				20.2 (3)	23.0 (4)	19.7 (1)
16		29.2 (2)	28.3 (4)				19.5 (3)	21.3 (1)	
17		28.4 (1)					20.5 (1)	22.4 (1)	
Mean growth index[g]		-0.6	-3.2	-1.9	-1.1	-3.3	-3.2	-0.8	-3.1

[a] Jan–May averages from Schneider et al (2000), aged using scales.
[b] From Deephouse (1993b).
[c] From Deephouse (1993a).
[d] From Hanchin et al. (2005c).
[e] From Hanchin et al. (2005a).
[f] From Hanchin et al. (2005b).
[g] The mean deviation from the statewide quarterly average. Only age groups where N ≥ 5 were used.

Table 26.–Mean lengths of northern pike from the 2002 survey of the Cisco Lake Chain compared to other surveys. Number aged in parentheses.

		Lake						
Age	State average[a]	Cisco Lake Chain 2002[b]	Thousand Island 1997[c]	Bond Falls 1999[d]	Michigamme Res. 2001[b,e]	Burt 2001[b,f]	Houghton 2001[b,g]	Pickerel & Crooked 2001[b,h]
1	11.7	11.1 (57)						10.9 (7)
2	17.7	15.8 (167)	17.9 (2)	17.5 (5)	16.0 (94)	17.4 (4)	19.3 (60)	16.1 (48)
3	20.8	17.8 (177)	21.0 (5)	19.6 (7)	18.8 (118)	21.6 (43)	21.6 (169)	19.2 (93)
4	23.4	19.2 (274)	24.5 (1)	21.5 (9)	20.6 (64)	23.5 (20)	23.5 (89)	20.3 (38)
5	25.5	21.6 (111)		23.7 (4)	21.3 (51)	24.2 (14)	24.9 (49)	22.1 (15)
6	27.3	22.5 (37)		31.7 (1)	25.3 (35)	28.6 (10)	28.5 (34)	22.8 (5)
7	29.3	25.5 (24)			25.6 (21)	28.8 (7)	31.2 (18)	25.7 (5)
8	31.2	21.6 (7)			27.5 (3)	29.6 (9)	32.2 (9)	30.8 (3)
9		28.6 (5)			36.3 (4)	37.0 (2)	38.8 (2)	
10							40.0 (2)	
11					34.0 (1)			
12								
Mean growth index[i]		-4.0		-2.1	-2.7	-0.2	0.8	-2.7

[a] Jan–May averages from Schneider et al. (2000), aged using scales.
[b] Fish collected in the spring and aged using fin rays.
[c] Fish collected in the summer and aged using scales.
[d] Fish collected in the summer and aged using sin rays.
[e] From Hanchin et al. (2005c).
[f] From Hanchin et al. (2005a).
[g] From Clark et al. (2004).
[h] From Hanchin et al. (2005b).
[i] The mean deviation from the statewide quarterly average. Only age groups where N ≥ 5 were used.

Table 27.–Comparison of recreational fishing effort and total harvest on the Cisco Lake Chain to those of other selected Michigan lakes. Lakes are listed from highest to lowest total fishing effort. Lake size was from Laarman (1976).

Lake County	Size (acres)	Survey period	Fishing effort (h) total	 per acre	Fish harvested total	 per h	 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 (all year)	20,075	Apr 2001–Mar 2002	499,048	24.9	386,287	0.77	19.2
Erie[a] Wayne/Monroe	–	Apr–Oct, 2001	490,807	–	378,700	0.77	–
Superior[a] many	–	Apr–Oct, 2001	180,428	–	60,947	0.34	–
Cisco Chain Gogebic/Vilas	3,987	May 2002–Feb 2003	180,262	45.2	120,412	0.67	30.2
Muskegon Muskegon	4,232	Apr 2002–Mar 2003	180,064	42.5	187,161	1.02	43.5
Fletcher Pond Alpena/Montmorency	8,970	May–Sep, 1997	171,521	19.1	118,101	0.69	13.2
Burt Cheboygan	17,120	Apr 2001–Mar 2002	134,205	7.8	68,473	0.51	4.0
Gogebic Ontonagon/Gogebic	13,380	May 1998–Apr 1999	121,525	9.1	26,622	0.22	2.0
Leelanau Leelanau	8,607	Apr 2002-Mar 2003	112,112	13.0	15,464	0.14	1.8
Mullett Cheboygan	16,630	May–Aug, 1998	87,520	5.3	18,727	0.21	1.1
Crooked and Pickerel Emmet	3,434	Apr 2001–Mar 2002	55,894	16.3	13,665	0.24	4.0
Michigamme Reservoir Iron	6,400	May 2001–Feb 2002	52,686	8.2	10,899	0.21	1.7

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

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Appendix–Fish species captured in the Cisco Lake Chain from 1938 through 2002 using various gear types.

Common name	Scientific name
Species collected during 2002 large lake survey	
Black crappie	*Pomoxis nigromaculatus*
Black bullhead	*Ameiurus melas*
Bluegill	*Lepomis macrochirus*
Brown bullhead	*Ameiurus nebulosus*
Central mudminnow	*Umbra limi*
Creek chub	*Semotilus atromaculatus*
Golden shiner	*Notemigonus crysoleucas*
Largemouth bass	*Micropterus salmoides*
Mottled sculpin	*Cottus bairdii*
Muskellunge	*Esox masquinongy*
Northern pike	*Esox lucius*
Pumpkinseed	*Lepomis gibbosus*
Rock bass	*Ambloplites rupestris*
Smallmouth bass	*Micropterus dolomieu*
Tiger muskellunge	*Esox lucius X E. masquinongy*
Walleye	*Sander vitreus*
White sucker	*Catostomus commersonii*
Yellow perch	*Perca flavescens*
Additional species collected during previous surveys (1938–97)	
Bluntnose minnow	*Pimephales notatus*
Common shiner	*Luxilus cornutus*
Iowa darter	*Etheostoma exile*
Lake herring[1]	*Coregonus artedi*
Lake trout[2]	*Salvelinus namaycush*
Long-eared sunfish[3]	*Lepomis megalotis*
Yellow bullhead	*Ameiurus natalis*

[1] Status unknown; last specimen collected in 1975
[2] Status unknown
[3] Only recorded in 1938; identification questionable