STATE OF MICHIGAN
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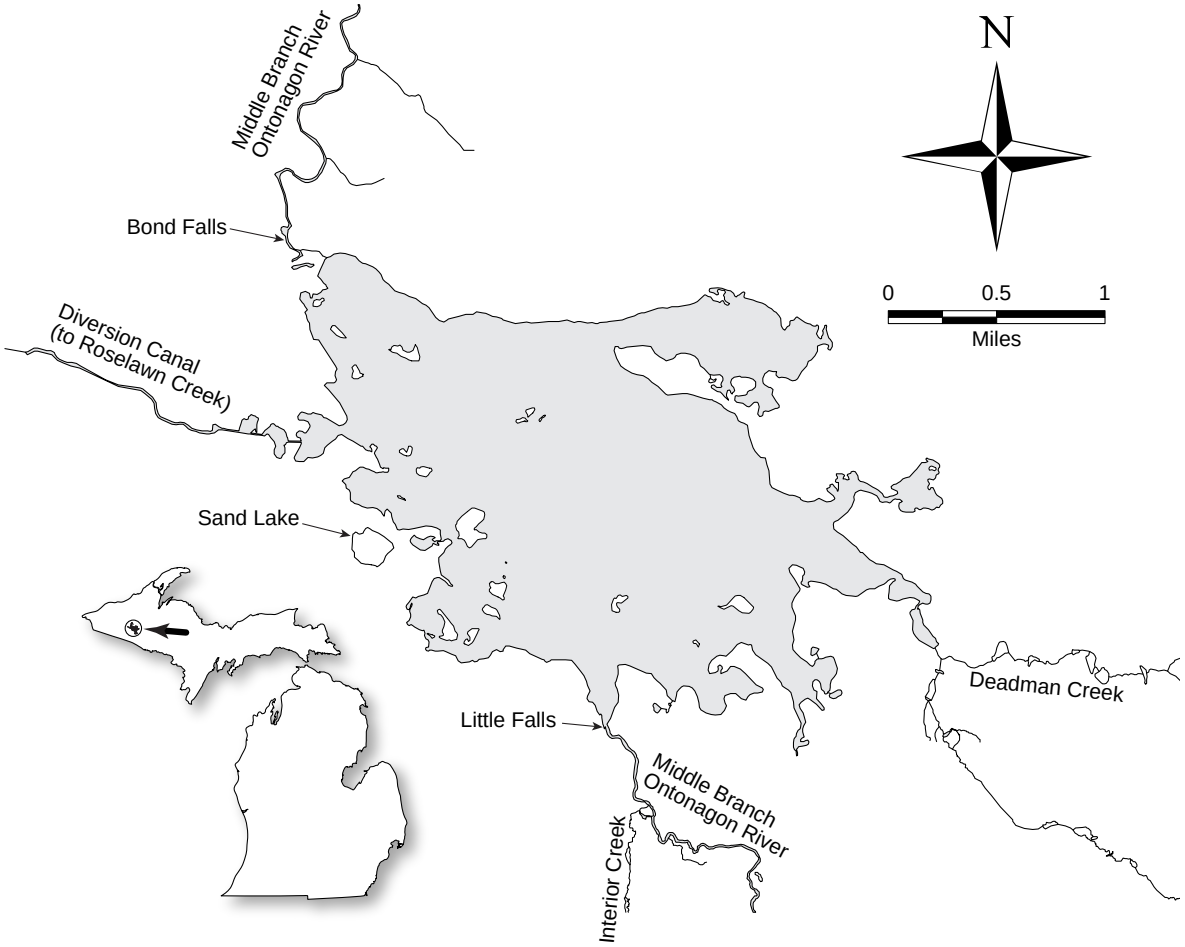
The Fish Community and Fishery of Bond Falls Flowage, Ontonagon County, Michigan in 2003 with Emphasis on Walleye and Northern Pike

Patrick A. Hanchin



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FISHERIES DIVISION
SPECIAL REPORT 50

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FISHERIES DIVISION

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Michigan Department of Natural Resources
Fisheries Special Report 50, 2009

The fish community and fishery of Bond Falls Flowage, Ontonagon County, Michigan in 2003 with emphasis on walleye and northern pike

Patrick A. Hanchin

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

Introduction

The Michigan Department of Natural Resources (MDNR), Fisheries Division surveyed fish populations and angler catch and effort on Bond Falls Flowage, Ontonagon County, Michigan from April 2003 through October 2003. This work was part of the Large Lake Program, which is designed to improve assessment and monitoring of fish communities and fisheries in Michigan's largest inland lakes (Clark et al. 2004).

The Large Lake Program has three primary objectives. The first objective is to produce consistent indices of abundance and estimates of annual harvest and fishing effort for walleye, northern pike, smallmouth bass, and muskellunge. These species were selected since they are susceptible to trap or fyke nets and are readily harvested by anglers. The intent is to produce statistics for important fishes to help detect major changes in their populations over time. The second objective is to produce abundance estimates and sufficient growth and mortality statistics to be able to evaluate effects of fishing on those species which support valuable fisheries. This usually involves targeting species with nets or other gears to collect, sample, and mark sufficient numbers. I selected walleyes *Sander vitreus* and northern pike *Esox lucius* as target species in this survey of Bond Falls Flowage. The final objective is to evaluate the suitability of various statistical estimators for use in large lakes. For example, in the current survey I applied and compared two types of abundance and three types of exploitation rate estimators.

I will refer to fishes by common name in the text. Common and scientific names of fish species are listed in the Appendix.

Study Area

Bond Falls Flowage is located on the Middle Branch Ontonagon River, and has a surface area of approximately 2,100 acres. According to the Michigan Digital Water Atlas (Breck 2004), the area of Bond Falls Flowage is 2,127 surface acres, while the Upper Peninsula Power Company (UPPCo) 1987 license application reported 2,160 acres at maximum operating level (UPPCo 1987). In this report, I used the modern acreage of 2,127 for calculating fish density estimates. The Upper Peninsula Power Company (2006) reported 1,836 and 1,574 acres of usable surface area, when 100-ft and 200-ft buffers were considered. Usable surface area is the total surface area of the impoundment at full pool, minus the area considered unacceptable for boating purposes. The shoreline length is approximately 20.2 miles, not including islands (UPPCo 2006). The maximum depth is 40 ft, which occurs where the reservoir inundated natural lakes such as Calderwood and Jesse James. Although bathymetric data about the reservoir is lacking, UPPCo (1985) reported area-capacity curves based on data they received when they assumed ownership of the facilities. The gross storage capacity of the reservoir is

42,000 acre-feet (UPPCo 1987). In general, the majority of the Flowage is eight to ten feet deep (MUCC 1982). The summer thermocline develops between 20 and 30 ft (MUCC 1982).

Michigan Department of Environmental Quality (MDEQ) characterizes Bond Falls Flowage as mesotrophic, based on intermediate nutrient concentrations and water clarity. Dissolved oxygen generally ranges from six to nine ppm in the upper 20 ft of the water column, and two to six ppm in the thermocline, but some deep areas are nearly anoxic (MUCC 1982; USGS 2007). In 2004, total alkalinity was 47 mg/l CaCO3, specific conductivity ranged from 106 to 129 μS/cm, and pH ranged from 6.7 to 8.0 (USGS 2007) for various sites throughout the Flowage.

Bond Falls Flowage has two major feeder tributaries, the Middle Branch of the Ontonagon River and Deadman Creek (Figure 1). The Little Falls are located where the Middle Branch empties into the reservoir, and they create a barrier to upstream fish passage. The Bond Falls Project consists of two dams; one located on the outlet of the Middle Branch Ontonagon River (45-ft-high, 900-ft-long main dam with spillway), and a second (25-ft-high, 850-ft-long control dam) located at the diversion canal. Bond Falls Flowage provides seasonal reservoir storage and diversion of river flow to the Victoria hydroelectric facility via the 7,500-ft canal to Roselawn Creek and eventually the South Branch Ontonagon River. There is no hydroelectric facility at Bond Falls. The maximum operating level of the reservoir is 1,475.9 ft elevation, and the minimum operating level is 1,467.9 ft. The gross storage capacity of the Flowage is estimated at 42,000 acre-ft (UPPCo 1987). Historically, the winter drawdown was as much as 20 ft, which decreased the surface area of the reservoir to around 1,400 acres. Conditions of the 2003 FERC license for Bond Falls Flowage allow for a maximum drawdown of 8 ft, with a maximum of 6-ft from May 1 through January 31. In the absence of detailed bathymetric data the impacts of the drawdown on surface area and volume are unknown. The 2003 re-licensing also set forth minimum flow requirements for the Middle Branch Ontonagon River and the diversion canal.

Bond Falls Flowage has extensive open-water area, many coves, and more than 20 islands. The shoreline irregularity index is 3.86. Nearshore substrate generally consists of coarse sands, though several large cobble fields, a couple of boulder fields, submerged coarse woody debris, and beds of submerged aquatic vegetation are also present (UPPCo 2006). Thick organic material is found in coves, wetlands, and beds of submerged aquatic vegetation. Submerged aquatic vegetation is generally found to depths of seven feet or less, and is composed of *Vallisneria, Potamogeton, Polygonum, Najas, Ceratophyllum, Utricularia, Elodea,* and *Myriophyllum.*

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

Although UPPCo controls the land immediately surrounding the Bond Falls Flowage, most of the property in this region is included in the Ottawa National Forest. Small tracts of private land exist on the northeast end of the impoundment, but there is virtually no residential development around the remainder of the Flowage. Bond Falls Flowage has two public access boat launches, including sites at the diversion canal, and off the United States Forest Service road 5350. There are also numerous rustic campsites and day-use areas around the Flowage. UPPCo recently sold a large portion of their land holdings to Naterra Land, and vacation home development surrounding the Flowage is expected to increase exponentially in the next decade. The land sold to Naterra is not adjacent to the

impoundment, as UPPCo has retained a riparian belt that extends from less than 100 feet to more than 1,000 feet from the shoreline.

The current fish community of Bond Falls Flowage is typical of mesotrophic reservoirs in the western Upper Peninsula. Coolwater fishes present include, but are not limited to, walleyes, northern pike, minnows, suckers, sunfishes, yellow perch, bullheads, and muskellunge. In recent history, the lake was stocked with yellow perch and walleyes between 1984 and 2001 (Table 1). There have been eight State of Michigan Master Angler awards taken from Bond Falls Flowage from 1993–2006, including four rock bass, one northern pike, one muskellunge, one brook trout, and one black crappie.

Methods

Fish populations in Bond Falls Flowage were sampled with fyke nets and electrofishing gear from April 28 to May 6, 2003. We used three boats daily, each with a three-person crew, for 2 weeks. Each net-boat crew tended 10–15 nets, and electrofishing was used at night as an additional collection method for walleyes. Fyke nets were 6 ft x 4 ft with 2-in stretch mesh and 90- to 98-ft leads. Duration of net sets ranged from 1–2 nights, but most were 1 night. We used a Smith-Root® boat equipped with boom-mounted electrodes (DC) for electrofishing. Latitude and longitude were recorded for all net locations and electrofishing runs using GPS. In 2003, we also conducted a standardized survey using multiple gears (P. A. Hanchin, personal communication) from June 23–27.

Fish Community

The overall fish community was described in terms of species present, catch per unit effort, percent by number, and length frequencies. Total lengths of all walleyes and northern pike were measured to the nearest 0.1 in. For other fish, lengths were measured to the nearest 0.1 in for subsamples of up to 200 fish per work crew. Crews ensured that lengths were taken over the course of the survey to account for any temporal trends in the size structure of fish collected. Size-structure data for target species (walleye and northern pike) only included fish on their initial capture occasion. Walleyes and northern pike with flowing gametes were identified as male or female; fish with no flowing gametes were identified as unknown sex.

I used Microsoft Access© to store and retrieve data collected during the tagging operation. I calculated mean catch per unit effort (CPUE) in fyke nets as an indicator of relative abundance, utilizing the number of fish per net night (including recaptures) for all net lifts that were determined to have fished effectively (i.e., without wave-induced rolling or human disturbance).

Schneider et al. (2000) cautioned that trap net and fyke net collections provide “snapshots” of fish community composition in lakes. Yet, with proper consideration of gear biases and sampling time frames, some indices of species composition might provide useful insight into fish community dynamics. I calculated the percents by number of fish collected in each of three feeding guilds: 1) species that are primarily piscivores; 2) species that are primarily pelagic planktivores and/or insectivores; and 3) species that are primarily benthivores. These indices will be used to compare fish communities among lakes or within the same lake over time, especially in the future when more large lake surveys using similar methods are available for comparison. Of the species collected, I classified walleye, northern pike, and smallmouth bass as piscivores; rock bass, bluegill, pumpkinseed, yellow perch, black crappie, and common shiners as pelagic planktivores-insectivores; and white suckers and brown bullheads as benthivores.

Walleye and Northern Pike

Abundance.–I estimated the abundance of legal-sized walleyes and northern pike using mark-and-recapture methods. Walleyes (≥15 in) and northern pike (≥24 in) were fitted with monel-metal jaw tags. To assess tag loss, tagged fish were double-marked by clipping the left pelvic fin. An approximate 1:1 ratio of $10-reward : nonreward tags was maintained. Large tags (size 16) that were used on large northern pike (≥36 in) were all nonreward. Fish recaptured with nets or electrofishing gear were recorded as either tagged (numbers recorded) or fin-clipped.

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 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. There was harvest of fish during the marking period by Tribal fishers, though I did not have information on daily removals of marked fish. Thus, I was not able to adjust the number of marked fish at large by sample period (day).

I 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, I used the Schumacher-Eschmeyer formula for daily recaptures during the tagging operation. I used the following formula from Ricker (1975):

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

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

The variance formula was,

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

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

Variance of $1/N_1$ is:

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

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

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

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

Because we clipped fins and recorded recaptures of all walleyes (legal and sublegal), I was also able (for comparison) to make a direct multiple-census estimate of adult walleyes on the spawning grounds using the Schumacher-Eschmeyer formula and including the mature sublegal fish that were marked and recaptured.

For the single-census estimate, I used numbers of marked and unmarked fish observed by creel clerks in the companion angler survey as the "recapture-run" sample. I used the Chapman modification of the Petersen method (Ricker 1975) to generate population estimates and the minimum number of recaptures necessary for an unbiased estimate was set a priori at three (Ricker 1975). I used the following formula from Ricker (1975):

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

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

I calculated the variance as:

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

Asymmetrical 95% confidence limits were calculated using the Poisson distribution for the 95% confidence limits on the number of recaptured fish (R), which were substituted into the equation for N_2 above (Ricker 1975). I estimated numbers of adult walleyes from the single-census estimate by dividing the estimate of walleyes greater than or equal to 15 in by the proportion of walleyes greater than or equal to 15 in on the spawning grounds, using the formula:

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

where N_a =estimated number of adult walleyes; N_{sub} = number of sublegal and mature fish (< 15 inches) caught; N_{leg} = number of legal fish caught.

I calculated the variance as:

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

Similar to walleye, I defined adult northern pike as those ≥24 in or <24 in, but of identifiable sex. I estimated adult northern pike abundance using the multiple-census and adjusted single-census methods as was done for walleyes.

For walleye, I used a regression equation developed for Wisconsin lakes (Hansen 1989) to provide an a priori estimate of abundance. This regression predicts adult (walleyes ≥15 in, or <15 in, but of identifiable sex) walleye abundance, based on lake size, in lakes with natural reproduction as the recruitment source. Parameters for this equation are re-calculated every year by Wisconsin Department of Natural Resources (WDNR). I used the same parameters used by WDNR in 2003 (Joe Hennessy, WDNR, personal communication):

$$\ln(N) = 1.6251 + 0.9441 \times \ln(A),$$

where N is the estimated number of walleyes and A is the surface area of the lake in acres. This equation was derived from 185 abundance estimates from lakes in northern Wisconsin. The equation gave an estimate of 7,041 walleyes, with a 95% confidence interval of 2,315 to 21,418, for Bond Falls Flowage. The 'confidence interval' here is, more precisely, a prediction interval with 95% confidence (Zar 1999).

I also used two regression equations developed for Michigan lakes to provide additional a priori estimates of walleye abundance (MDNR unpublished data). These regressions predict legal (≥ 15 in) and adult (≥ 15 in, or < 15 in, but of identifiable sex during spring surveys) walleye abundance based on lake size, and were derived from historic abundance estimates made in Michigan over the past 20 years. The following equation for adult walleyes was based on 35 abundance estimates:

$$\ln(N) = 0.1087 + 1.0727 \times \ln(A),$$

where N is the estimated number of adult walleyes and A is the surface area of the lake in acres. For Bond Falls Flowage, the equation gave an estimate of 4,139 adult walleyes, with a 95% prediction interval (Zar 1999) of 991 to 17,289. The equation for legal walleyes was based on 21 estimates:

$$\ln(N) = 0.3323 + 1.0118 \times \ln(A),$$

which gave an estimate of 3,246 legal walleyes, with a 95% prediction interval of 697 to 15,106.

For the single-census estimate, I accounted for fish that recruited to legal size during the angler survey based on the estimated weighted average monthly growth for fish of slightly sublegal size. That is, because I was estimating the abundance of legal-sized walleyes (≥15 in) and northern pike (≥24 in) at time of marking (spring) and growth of fish occurred during the recapture period, it was necessary to reduce the number of unmarked fish by the estimated number that recruited to legal size during the recapture period. For example, to make this adjustment for walleyes I determined the annual growth of slightly sublegal fish (i.e., 14.0–14.9-in fish) from mean length-at-age data. I then divided it by the length of the growing season in months (6) and rounded to the nearest 0.1 in. This average monthly growth was then used as the criteria to remove unmarked fish that were observed in the creel. The largest size of a sublegal fish at tagging was 14.9 in; thus, an average monthly growth of 0.2 in would result in all unmarked fish less than or equal to15.1 in caught during the first full month (June) after tagging to be removed from analysis. Adjustments were made for each month of the creel survey resulting in a final ratio of marked to unmarked fish. This final ratio was used to make the single-census population estimate.

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

Growth.–Dorsal spines were used to age walleyes and dorsal fin rays were used to age northern pike. These structures provided the best combination of ease of collection in the field and accuracy and precision of age estimates. I considered ease of collection important because staff worked in cold, windy conditions, dealt with large numbers of fish, and tagged fish in addition to measuring and collecting structures. Otoliths have been shown to be the most accurate and precise ageing structure for older walleyes (Heidinger and Clodfelter 1987; Kocovsky and Carline 2000; Isermann et al. 2003) and otoliths or cleithra for northern pike (Casselman 1974; Harrison and Hadley 1979), but collecting these structures requires killing the fish and in this study, fish were tagged and released for later recapture. Results from several studies comparing ageing structures for walleyes agreed that spines were quicker to remove than scales, but they do not agree that spines are more accurate than scales (Campbell and Babaluk 1979; Kocovsky and Carline 2000; Isermann et al. 2003). Errors in ages from spines were often related to misidentifying the first annulus in older fish (Ambrose 1983; Isermann et al. 2003). There is also considerable disagreement as to whether spines or scales were more precise for walleyes age estimation. Erickson (1983) and Campbell and Babaluk (1979) found that spines were more precise, Belanger and Hogler (1982) found spines and scales were equally precise, and Kocovsky and Carline (2000) found scales were more precise. Since northern pike older than 6 years are notoriously difficult to age with scales (Carlander 1969), field technicians and biologists in MDNR have used dorsal fin rays instead. They are as quick and easy to remove in the field as spines for walleyes. Studies have demonstrated that fin rays are a valid ageing structure for a number of species (Skidmore and Glass 1953; Ambrose 1983), including northern pike (Casselman 1996), but no comparisons have been made to statistically compare accuracy and precision of fin rays to other ageing structures for northern pike.

The study goal was to collect 15 male and 15 female fish per inch group, for each species. Samples were sectioned using a table-mounted high-speed rotary cutting tool. Sections approximately 0.5-mm thick were cut as close to the proximal end of the spine or ray as possible. Sections were examined at 40x–80x with transmitted light and were photographed with a digital camera. The digital image was archived for multiple reads. Two technicians independently aged samples, and ages were considered final when independent estimates were in agreement. Samples in dispute were aged by a third technician. Disputed ages were considered final when the third technician agreed with one of the first two. Samples were discarded if three technicians disagreed on age, though occasionally an average age was used when ages assigned to older fish (≥ age 10) were within plus or minus 10% of each other.

After a final age was identified for all samples, I calculated weighted mean lengths-at-age and age-length keys (Devries and Frie 1996) for male, female and all (males, females, and fish of unknown sex) walleyes and northern pike. Mean lengths-at-age were compared to those from previous surveys of Bond Falls Flowage and to other large lakes. I also computed a mean growth index to compare the data to Michigan state averages, as described by Schneider et al. (2000). The mean growth index is the average of deviations (by age group) between the observed mean lengths and statewide seasonal average lengths. In addition, I fit mean length-at-age data to a von Bertalanffy growth equation using nonlinear regression, and calculated the total length at infinity (L_∞) for use as an index of growth potential. All growth curves were forced through the origin.

Mortality.–I calculated catch-at-age for males, females, and all fish (including males, female, and those of unknown sex), and estimated instantaneous total mortality rates using catch-curve analyses with assumptions described by Ricker (1975). My goal was to estimate total mortality for fish of legal size for comparison with fishing mortality, which was only estimated for fish of legal size. When choosing age groups to be included in the analyses, I considered several potential problems. First, an assumption of catch-curve analysis is that the mortality rate is uniform with age over the full range of age groups in analysis. Fish were collected with gears different from those used in the fishery and the size (age) of recruitment in the fishery was controlled by minimum-size-limit regulations. For fish

smaller than the minimum size limit, mortality is M+H; for fish larger, mortality is M+H+F, where M, H, and F are natural, hooking (from catch and release), and fishing mortality, respectively. Thus, from the standpoint of uniformity in mortality, age groups used in a single catch curve should contain fish that are either all smaller than, or all larger than the minimum size limit in the fishery. Second, walleye and northern pike exhibit sexual dimorphism (Carlander 1969 and 1997), which could lead to differences in mortality between sexes. Thus, when sufficient data were available, I computed separate catch curves for males and females to determine if total mortality differed with sex. A catch curve was also computed for all fish that included males, females, and fish of unknown sex. Third, walleyes and northern pike were collected in the act of spawning, so I needed to be sure that fish in each age group were sexually mature and represented on the spawning grounds in proportion to their true abundance in the population. Thus, I included in the analyses only age groups with fish that I judged to be mostly mature. I based this judgment on a combination of information, including relative abundance and mean size by age and percent maturity by size.

I 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. I 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. I made the assumption that mortality was negligible and that near 100% of reward tags on fish caught by anglers would be returned. Although I did not truly assess nonreporting, I did compare the actual number of tag returns to the expected number (X) based on the ratio:

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

where N_t = Number of tags observed in creel, N_c = Number of fish observed in creel, H = Total expanded harvest of species.

Additionally, I checked individual tags observed by the creel clerk to see if they were subsequently reported by 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 50% of the tags. Tag return forms were made available at boater access sites, at MDNR offices, and from creel clerks. Additionally, tag return information could be submitted on-line at the MDNR website. All tag return data were entered into the database so that it could be efficiently linked to and verified against data collected during the tagging operation. I developed linked documents in Microsoft Word® so that payment vouchers and letters to anglers were automatically produced with relevant information from the database. Letters (for both reward and nonreward tags) sent to anglers described information regarding the length and sex of the tagged fish, and the location and date of tagging. Return rates were calculated separately for reward and nonreward tags.

In the second and third methods, I calculated exploitation as the estimated annual harvest from the angler survey divided by the multiple- and single-census 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 based on the percentage of fish observed in the creel survey that were determined to have been sublegal at the time of the spring survey (See *Abundance* subsection of the **Methods** section).

Recruitment.–I considered relative year-class strength as an index of recruitment. As Maceina (2003), I assumed the residuals of the catch-curve regressions were indices of year-class strength. I explored relationships among year-class strength and various environmental variables by using correlation analyses. Historic weather data were obtained from the National Weather Service observation station in Watersmeet, MI (National Climate Data Center station 208680). Relationships with water quality were not explored, because I did not have any historic water quality data specific to the lake itself. Variables that I 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 average monthly precipitation. Statistical significance was set at $\alpha = 0.05$.

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

Angler Survey

Fishing harvest seasons for walleyes, northern pike, and muskellunge during this survey were May 15, 2003–February 28, 2004. Minimum size limits were 15 in for walleyes, 24 in for northern pike, and 42 in for muskellunge. Daily bag limit was five fish in any combination of walleyes, northern pike, smallmouth bass, largemouth bass, or flathead catfish, with no more than two northern pike. Fishing harvest seasons for smallmouth bass and largemouth bass were May 24 through December 31, 2003. 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 8 in 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 yellow perch was 50 per day. Bag limit for “sunfishes”, including black crappie, bluegill, pumpkinseed, and rock bass was 25 per day in any combination. Bag limit for lake herring was 12 in combination with lake whitefish.

Direct contact angler creel surveys were conducted during the open-water period - May 8 to October 15, 2003. For sampling purposes, Bond Falls Flowage was split into three sections (Figure 2). All count and interview data were collected and recorded by section. Similarly, effort and catch estimates were made by section and summed for lake-wide estimates. Scanner-ready interview and count forms were used.

The survey was designed for the collection of 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. All roving interview data were collected by individual angler to avoid party size bias (Lockwood 1997). While the survey was designed to collect roving interviews, the clerk occasionally encountered anglers as they completed their fishing trips. The clerk was instructed to interview these anglers and record the same information as for roving interviews – noting that the interview was from a completed trip. Similar to roving interviews, all access interview data were collected by individual angler.

Count information collected included: section, date, count time, and number of fishing boats counted. Interview information collected included: date, section, 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 tag number (when applicable). 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.

A progressive-roving design was used for the survey (Lockwood 2000b). Fishing boats were counted by one clerk working from a boat, who also collected angler interview data. Both weekend days and three randomly selected weekdays were selected for counting and interviewing during each week of the survey season; counting and interviewing were done on the same days, and one instantaneous count of fishing boats was made per day. No count or interview data were collected on holidays. Holidays during the period were Memorial Day (May 26, 2003), Independence Day (July 4, 2003), and Labor Day (September 1, 2003).

One of two shifts was selected each sample day for interviewing (Table 2). Interview starting location and direction (clockwise or counter-clockwise) were selected at random for each day. On days when the clerk interviewed in all sections prior to completion of the shift, they continued interviewing at the beginning of the specified section. 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 clerk knew that a party had been interviewed earlier that day but could not identify their interview form, the party was not re-interviewed. That is, no angling party had a second set of interview forms filled out for them on the same day.

Time of count was randomized to cover daylight times within the selected sample shift. Only fishing boats were counted (i.e., watercraft involved in alternate activities, such as water skiing, were not counted).

Estimation methods.–Catch and effort estimates were made by section using a multiple-day method (Lockwood et al. 1999). Effort is the product of mean counts by section for a given period day type, days within the period, and the expansion value (Table 2) for that period. Thus, the angling effort and catch reported here are for those periods sampled; no expansions were made to include periods not sampled (e.g., 0100 to 0400 hours). Lake-wide estimates were the sum of section estimates for each given time period and day type. When 80% or more of interviews within a time period (weekday or weekend day within a multiple-day period) were of a single interview type (roving or access), 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:

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

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

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

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

From the angler creel data collected, catch and harvest by species were estimated, and angling effort was estimated as both angler hours and angler trips. An angler trip is defined as the period an angler is at a lake (fishing site) and actively fishing. When an angler leaves the lake or stops fishing for a significant period of time (e.g., an angler leaving the lake to eat lunch), the trip has ended. Movement between fishing spots, for example, was considered part of the fishing trip. Mail or telephone surveys typically report angling effort as angler days (Pollock et al. 1994). Angler trips

differ from angler days, because multiple trips can be made within a day. Based on historical Michigan creel data, anglers make an average of 1.2 trips per angler day (MDNR Fisheries Division unpublished data).

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

Fish Community

We collected 11 species of fish in Bond Falls Flowage (Table 3). Total sampling effort was 195 fyke-net lifts, and 13 electrofishing runs. We captured 5,618 walleyes and 967 northern pike; other species collected are listed in order of abundance in Table 4. Walleyes were the most abundant species in the catch in Bond Falls Flowage, comprising 75% of the catch, by number; northern pike were the next most abundant species, comprising 13% of the catch. Rock bass and white suckers made up 7% and 3% of the catch by number, respectively; seven additional species made up the remaining 2% of the total catch. The feeding guild classifications gave an overall fish community composition in Bond Falls Flowage of 88% piscivores, 9% pelagic planktivores-insectivores, and 3% benthivores (Table 3).

The percentage of walleyes and northern pike that were legal size was 34 and 14, respectively (Table 4). Most walleyes (90%) were from 11 to 16 in, and few fish were greater than 20 in. Most northern pike (90%) were from 16 to 25 in, and few fish (7%) were of legal size. Rock bass were dominated by the 7-inch group, and 44% of all rock bass were greater than eight inches. We did not collect large enough sample sizes of most other species to assess their size structure.

Male walleyes outnumbered females in the samples from Bond Falls Flowage. Of all walleyes captured, 81% were male, 18% were female, and 1% were unknown sex. This corresponds to a sex ratio (M : F) of 4.4:1.0. Of legal-sized walleyes captured, 66% were male, 33% were female, and 1% were unknown sex, for a sex ratio of 2.0:1.0. Of all northern pike captured in Bond Falls Flowage, 60% were male, 33% were female, and 7% were unknown sex (sex ratio = 1.8:1.0). Of legal-sized northern pike captured, 35% were male, 53% were female, and 12% were unknown sex (sex ratio = 0.7:1.0).

Walleye and Northern Pike

Abundance.–We placed 2,307 tags on legal-sized walleyes (1,019 reward and 1,288 nonreward tags) and clipped fins of 1,967 sublegal walleyes (Table 5). Eight recaptured walleyes lost their tags during the spring netting/electrofishing survey, so the effective number tagged was 2,299. The angler survey clerk observed a total of 154 walleyes on Bond Falls Flowage, of which 39 were tagged. I reduced the number of unmarked walleyes in the single-census calculation by 33 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 39 re-captured fish, the estimate of tag loss is 2.6% (SE = 0.07%).

The estimated number of legal-sized walleyes in Bond Falls Flowage was 4,631 using the multiple-census method and 7,015 using the single-census method (Table 5). The estimated number of adult walleyes was 12,501 using the multiple-census method, and 12,906 using the single-census method. The coefficient of variation (CV = standard deviation/estimate) was 0.09 for the multiple-census estimate of legal walleyes, 0.08 for the multiple-census estimate of adult walleyes, and 0.13 for both of the single-census estimates (legal-size and adult).

We placed 107 tags on legal-sized northern pike (56 reward and 51 nonreward tags) and clipped fins of 710 sublegal northern pike (Table 5). One recaptured northern pike lost its tag during the spring netting/electrofishing survey, so the effective number tagged was 106. The creel clerk observed a total of 17 northern pike on Bond Falls Flowage, of which 1 was tagged; thus the minimum number of recaptures was not obtained for an unbiased single-census estimate.

The estimated numbers of legal-sized and adult northern pike in Bond Falls Flowage were 164 and 5,538, respectively, using the multiple-census method (Table 5). The CV was 0.21 for the multiple-census estimate of legal northern pike, and 0.15 for the multiple-census estimate of adult northern pike.

Growth.–For walleyes, there was 48% agreement between the first two ageing technicians. For fish that were aged by a third reader, agreement was with first reader 33% of the time and with second reader 67% of the time. This bias among readers was apparently due to differences in identification of the first annulus. At least two readers agreed 94% of the time, and 4% of samples were discarded due to lack of agreement. For the remaining 2% of samples, I used an average age from the three readers.

Walleyes in Bond Falls Flowage ranged in age from two to sixteen years (Table 6), and had a mean growth index of -3.3. Females generally had higher mean lengths-at-age than males when samples were sufficient for comparison. Mean length-at-age data for male, female, and all walleyes were fit to a von Bertalanffy growth curve. In Bond Falls Flowage, male, female, and all walleyes had L_∞ values of 19.0, 23.7, and 20.1 in, respectively.

For northern pike, there was 79% agreement between the first two ageing technicians. For fish that were aged by a third reader, agreement was with first reader 29% of the time and with second reader 71% of the time. At least two readers agreed 99% of the time. One sample (0.3%) was discarded due to lack of agreement, and an average age was used for one sample.

Female northern pike generally had higher mean lengths-at-age than males (Table 7), though this was more apparent at older ages. As with walleyes, this is typical for northern pike populations (Carlander 1969; Craig 1996). I calculated a mean growth index of -0.6 for northern pike in Bond Falls Flowage. Mean length-at-age data for male, female, and all northern pike were also fit to a von Bertalanffy growth curve. Male, female, and all northern pike had L_∞ values of 28.1, 48.9, and 43.9 in, respectively.

Mortality.–I estimated catch-at-age for 3,448 males, 784 females, and 4,279 total walleyes (including unknown-sex fish) in Bond Falls Flowage (Figure 3, Table 8). Walleye ages 5 and older in the catch-curve analysis were used to represent the legal-size population (Figure 3). I chose age 5 as the youngest age because: 1) average length of walleyes at age 5 was 14.8 in for males and 16.8 in for females (Table 6), so a high proportion of age-5 fish were of legal size at the beginning of fishing season; and 2) relative abundance of fish younger than age 5 do not appear to be representative of their true abundance (Figure 3), suggesting that age-4 fish (males and females) are not all mature. Ages 13 and 14 were excluded in the catch curve regressions, since these appeared to be missing year

classes (1989, 1990) whose relative abundance in 2003 is not necessarily indicative of the population mortality rate experienced over the time period.

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 0.676 for males, 0.498 for females, and 0.603 for all fish combined (Figure 3). These instantaneous rates correspond to total annual mortality rates of 49% for males, 39% for females, and 45% for all walleyes combined (Table 5).

Anglers returned 682 tags (361 reward and 321 nonreward tags) from harvested walleyes and 16 tags (7 reward and 9 nonreward) from released walleyes in the year following tagging on Bond Falls Flowage (Table 9). Annual tag loss was 2.6%, and seven tagged fish observed in the possession of anglers were not subsequently reported to the central office by the anglers. The estimated exploitation rate for walleyes was 36.8% based on return of reward tags (Table 5), adjusted for tag loss. Anglers reported reward tags at a higher rate than nonreward tags (36.1% versus 25.6%); the reporting rate of nonreward tags relative to reward tags (λ in Pollock et al. 1991) was 70%. Based on all tagged walleyes known to be caught, the reported release rate was 2.3%. The estimated exploitation rate for walleyes was 16.4% (CV = 0.18) based on dividing harvest by the multiple-census abundance estimate, and 10.9% (CV = 0.20) based on dividing harvest by the single-census abundance estimate (Table 5).

For northern pike, I estimated catch-at-age for 494 males, 274 females, and 832 total northern pike (including unknown-sex fish; Table 8). The only age groups of males where the mean length was greater than legal size (> 24 in) were ages 8 and 10; thus, I estimated mortality from a catch curve of only adult males. I used ages 3 through 10 in the catch-curve regression to represent the adult male northern pike population, and ages 5 through 9 in the catch-curve analysis for female northern pike (Figure 4). I chose age 5 as the youngest age group for female northern pike because mean length-at-age 5 was 24.3 in (Table 7), so a high proportion of age-5 fish were legal-sized at the beginning of fishing season. For all northern pike, I used ages 7 through 10 in the catch curve analysis. I chose age 7 as the youngest age because it was the first age for which the mean length was greater than legal size for both sexes (Table 7), so a high proportion of age-7 fish were legal-sized at the beginning of fishing season.

The catch-curve regression for adult male northern pike was significant ($P < 0.050$) and resulted in a total instantaneous mortality rate of 0.862 (Figure 4). The regression for female northern pike was not significant ($P = 0.070$), which was likely a result of limiting the analysis to fish of legal size, rather than the adult population. The regression for all northern pike was significant ($P < 0.050$), resulting in an estimated total instantaneous mortality rate of 0.845. These instantaneous rates corresponded to total annual mortality rates of 58% for adult males, and 57% for legal-sized fish of all sexes combined (Table 5).

Anglers returned 28 tags (14 reward and 12 nonreward tags) from harvested northern pike, and two tags (nonreward) from released northern pike in the year following tagging on Bond Falls Flowage (Table 9). The creel clerk did not observe any marked fish that had lost their tag, but I used an average tag loss rate of 5%, based on nine surveys to date. No tagged fish were observed in the possession of anglers that were not subsequently reported to the central office. The estimated exploitation rate for northern pike was 26.8% based on return of reward tags (Table 5), adjusted for tag loss. Anglers reported reward and nonreward tags at a similar rate (25.0% versus 27.5%). Based on all tagged northern pike known to be caught, the reported release rate was 7.1%. The estimated exploitation rate for northern pike was 62.9% (CV = 0.38) based on dividing harvest by the multiple-census abundance estimate (Table 5). An estimate based on dividing harvest by the single-census abundance estimate was not made.

Recruitment.–Variability in year-class strength can be inferred from the statistics of the catch-curve regression. For walleyes, the amount of variation explained by the age variable was 0.79

(Figure 3). I did not find any significant relationships between climatological variables and walleye year-class strength in Bond Falls Flowage. Additionally, there was no significant relationship between year-class strength and the number of walleyes stocked.

For northern pike, the amount of variation explained by the age variable was 0.97 (Figure 4). The catch curve for northern pike was based on legal-size fish, and thus was only based on four year classes. For evaluating recruitment, it is not necessary for the fish to be legal size, only that they are vulnerable to the sampling gear. Thus, I made a second regression for northern pike utilizing the natural log of catch for ages 4 through 10. With the addition of these ages the amount of variation explained by the age variable was similar ($R^2 = 0.94$). The residuals from a regression of adult northern pike catch by age were positively correlated with the average daily minimum air temperature in May ($r = 0.919$, $P = 0.010$, $df = 5$) and the average daily air temperature in May ($r = 0.893$, $P = 0.016$, $df = 5$).

Movement.–Based on voluntary tag returns, there was no movement observed of walleyes, or northern pike out of Bond Falls Flowage.

Angler Survey

Our clerk interviewed 1,319 boating anglers during the 2003 survey. Most interviews (94%) were roving (incomplete-fishing trip). Anglers fished an estimated 21,182 angler hours and made 6,749 trips (Table 10).

Estimated total harvest was 3,193 fish, which consisted of 11 different species (Table 10). Walleyes were most numerous, with an estimated harvest of 965. Anglers also harvested 803 rock bass, 116 northern pike, 563 yellow perch and 463 smallmouth bass. Three species that we captured during spring netting operations did not appear in the angler catch – brown bullhead, common shiner, and white sucker. Anglers reported releasing 2,187 walleyes (69% of total walleye catch), 1,600 northern pike (93% of total catch), and 1,172 smallmouth bass (72% of total catch). I do not know the proportion of the released fish that were of legal size; however, I assume that a large proportion of the released walleyes and northern pike were sublegal. For both walleyes and northern pike, the assumption that the high release rate was due to catching many sublegal fish is corroborated by the size structure of this species, which contained high proportions of sublegal-sized fish (Table 4). In future surveys, I recommend distinguishing between sublegal- and legal-size fish released.

Walleyes were the predominant species caught (harvested + released) at 3,152. Resulting catch rate (catch per h) for walleyes was 0.149. Total catch and catch rate of walleyes peaked in September, but they were caught regularly throughout the season. Estimated total annual catch of northern pike was 1,716, with a resulting catch rate of 0.081. Total catch and catch rate of northern pike peaked in May. Estimated total annual catch of smallmouth bass was 1,635, with a resulting catch rate of 0.077. Smallmouth bass catch and catch rate peaked in June. Reported catch rates were calculated based on overall fishing effort, not targeted effort, and are therefore not necessarily indicative of the rate that an angler targeting one species may experience.

We did not survey from October 15 through the winter, because relatively little fishing occurs on Bond Falls Flowage during that time of year. Three walleye tag returns were reported from this nonsurveyed period; thus, the total annual walleye harvest was actually about 0.4% higher than the direct survey estimate, or 969 walleyes. No northern pike tag returns were reported during nonsurveyed months.

Discussion

Fish Community

The current survey of Bond Falls Flowage differed from past surveys in the season surveyed, and in the amount and type of survey effort used. Previous surveys took place in the summer and fall. Because of the seasonal bias, more large, mature fish of several species were observed than would normally be caught in surveys that have historically been conducted later in spring or summer. This would include spring-spawning species such as walleyes, northern pike, white sucker, yellow perch, and smallmouth bass.

The seasonal and gear biases associated with the survey preclude comparisons of population and community indices to most other surveys of Michigan lakes. Because of the mesh-size bias, smaller fish would not be represented in the 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 Bond Falls Flowage (e.g., various species of shiners, darters, minnows).

The fish assemblage in Bond Falls Flowage was dominated by piscivores; however, our method of fish collection directly biased this result. When collecting fish with electrofishing gear we netted only target species, and thus biased the species composition of fish collected in the survey. Since electrofishing was the most effective gear for collecting walleyes in this survey, the bias is especially prominent. Therefore, comparing the relative proportion of feeding guilds to other spring surveys where the effort was dominated by netting is not appropriate.

The size structure of walleyes from the spring survey of Bond Falls Flowage was below average when compared to other large lakes. In eleven lakes surveyed in the Large Lake Program to date, the average percentage of walleyes over legal size was 71, compared to 34 for Bond Falls Flowage. In general, the majority of walleyes in Bond Falls Flowage are unlikely to attain lengths much greater than 20 in, though there is a small potential to reach 26 in. The size structure of northern pike was also below average. In ten northern pike populations surveyed in the Large Lake Program to date, the average percentage of northern pike over legal size was 27, compared to 14 for Bond Falls Flowage. Most northern pike in Bond Falls Flowage are unlikely to attain lengths much greater than 25 in, though, a small portion have the potential to reach 40 in.

Male walleyes outnumbered females in the survey, both when all sizes and fish of legal size were considered. I was unable to find any previous information concerning sex composition from Bond Falls Flowage for comparison. In other Michigan lakes and elsewhere, males consistently dominate sex composition in samples taken during spawning (Carlander 1997; 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 Bond Falls Flowage when all sizes were considered. However, females outnumbered males when only legal-size fish were considered. This disparity between sex composition of all fish of legal-size fish is likely due to faster growth in females. Higher mortality of males as reported by Craig (1996) would also contribute to this disparity, though the estimates of mortality for male northern pike were only slightly higher than for females. In other large lakes, the same disparity in sex ratio between all northern pike and northern pike of legal size was found (Clark et al. 2004, Hanchin et al. 2005a, Hanchin et al. 2005b).

Based on studies from other lakes, male northern pike 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, and found that sex ratios during the February and March spawning period ranged from 6:1 to 8:1 (male : female), but the overall sex ratio for an entire year of sampling was not significantly different from 1:1.

Walleye and Northern Pike

Abundance.–These were the first estimates of adult walleye abundance for Bond Falls Flowage. I was successful in obtaining both multiple-census and single-census estimates. For the single-census estimate, there were sufficient numbers of fish marked, and observed for marks in the recapture sample. Assuming that the legal walleye population was approximately 7,000 fish, and based on tagging 2,307 fish, the recommended recapture sample to observe for marks in management studies (α = 0.05, P = 0.25; where P denotes the level of accuracy, and 1-α the level of precision) is approximately 140 fish (Robson and Regier 1964). The corrected recapture sample of 121 fish in the angler survey was slightly less than this recommendation, but was sufficient to produce a reliable single-census estimate. The CV's were 0.09 and 0.13 for the multiple-census and single-census estimates, respectively. Thus, based on this measure of precision alone, I considered both the multiple-census and single-census estimates to be reliable.

The multiple-census estimate for walleyes was lower than the single-census estimate for legal-size fish, but was similar for adult fish. The 95% confidence limits for the two types of estimates overlapped. Precision was similar between the multiple-census and single-census estimates. Confidence limits were within 22% of the multiple-census estimates, and within 25% of the single-census estimates.

The estimates of walleye abundance were not different than the a priori Michigan and Wisconsin model estimates. The single-census estimate of adult walleye abundance was 83% higher than the Wisconsin model estimate and 212% higher than the Michigan model estimate. Apparently, the higher density in Bond Falls Flowage results in the walleye population being an outlier in these predictive regressions.

Population density of walleyes in Bond Falls Flowage was above average compared to other lakes in Michigan. Using the modern acreage of 2,127, the single-census estimate for 15-in-and-larger walleyes in Bond Falls Flowage was 3.3 per acre. Density of legal-size walleyes estimated recently for eleven lakes surveyed under the Large Lake Program in Michigan averaged 2.2, and ranged from 0.4 to 4.6 per acre. Density in the nearby Cisco Lake Chain was estimated at 3.0 per acre in 2002 (Hanchin et al. 2008).

Population density of adult walleyes from the single-census estimate was 6.1 per acre. Adult walleye abundance has averaged 3.5 per acre in eleven lakes surveyed thus far as part of the Large Lake Program. Adult walleye density in the nearby Cisco Lake Chain was estimated at 10.2 per acre in 2002 (Hanchin et al. 2008). Nate et al. (2000) reported an average density of 2.2 adult walleyes per acre for 131 Wisconsin lakes having natural reproduction.

I had less success in obtaining abundance estimates for northern pike. I was successful in obtaining multiple-census estimates, but did not obtain the minimum number of recaptures for the single-census method. This likely occurred because we did not tag many northern pike, or examine enough fish for marks in the creel survey sample.

Although the multiple-census estimate of legal northern pike was considered reliable based on the CV, it does not compare well with the independently-derived exploitation estimate based on harvest. The exploitation rate derived by dividing the harvest estimate by the multiple-census abundance estimate is 62.9%, which is much higher than the exploitation estimate based on reward tag returns. Thus, it appears that I either underestimated the abundance of legal-size northern pike, or overestimated the harvest of northern pike. Though both biases may have occurred to some degree, it seems more likely that I underestimated abundance using the multiple-census estimate. Despite the lack of reliable estimates, the population density of legal-size northern pike in Bond Falls Flowage is probably about average relative to other lakes in Michigan and elsewhere. The multiple-census abundance estimate converts to a density of 0.08 per acre, and I believe the true density is higher than

that. The density of legal-size northern pike estimated recently for nine lakes surveyed under the Large Lake Program in Michigan averaged 0.14, and ranged from 0.01 to 0.53 per acre.

The multiple-census estimate of adult northern pike converts to a density of 2.6 per acre. Compared to other large lakes sampled in Michigan, population density for adult northern pike in Bond Falls Flowage is above average. Adult northern pike abundance averaged 0.95 per acre (range 0.1–2.9) in ten lakes surveyed as part of the Large Lake Program thus far in Michigan.

Compared to other lakes worldwide, population density in Bond Falls Flowage is low. 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 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, comparable to the ages used in the Bond Falls Flowage estimates.

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. 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. While single-census estimates using two gear types are probably better than multiple-census estimates, they are not without problems. I tried to obtain single-census estimates through the angler survey, but failed to get sufficient recaptures. Clark et al. (2004) illustrated 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.

Growth.–Our reader agreement (first two reads) for walleye spines was somewhat lower than observed in other studies. Isermann et al. (2003) achieved 55% reader agreement and Kocovsky and Carline (2000) achieved 62% agreement. Reader agreement (first two reads) in surveys of 18 lakes surveyed under the Large Lake Program to date has ranged from 39 to 84% with an average of 54%. Similar to results from the current study, Miller (2001) found that at least two of three readers agreed 94% of the time. Reader agreement for northern pike was also similar to other studies. Reader agreement (first two reads) in ten lakes surveyed under the Large Lake Program to date ranged from 59 to 88% with an average of 73%.

Walleye mean lengths-at-age for Bond Falls Flowage were considerably lower than the State average, indicating poor growth. However, these deviations from the state average were likely due, at least in part, to biases between ageing methods. State average mean lengths were estimated by scale ageing, and past studies comparing spine ageing to scale ageing suggest that biases of these techniques generally lead to estimated mean lengths-at-age of scale-aged fish to be larger than spine-aged fish (Kocovsky and Carline 2000, Miller 2001, Clark et al. 2004). Females had higher mean lengths-at-age than males when samples were sufficient for comparison; this is typical for walleye populations (Colby et al. 1979, Carlander 1997, Kocovsky and Carline 2000).

Walleye growth was assessed in Bond Falls Flowage by DNR Fisheries Division in 1999 (Table 11), and it appears that the growth rate has declined since then. The mean growth index decreased from -2.6 to -3.3 from 1999 to 2003. Although there is no trend evident from two data points, the possibility of declining growth could be a result of increasing walleye density that is disproportionate to the resource capacity (prey base). While the mean lengths-at-age are low relative

to the State average, they are similar to those observed in other water bodies in the western Upper Peninsula such as Lake Gogebic and the Cisco Lake Chain (Table 11).

The mean lengths-at-age for northern pike were average compared to other lakes in Michigan, and they were within 1.0 inch of the scale-aged State average mean lengths. In the 1999 survey of Bond Falls Flowage, the mean lengths-at-age were lower, on average, than in 2003. Additionally, the mean lengths-at-age for northern pike in Bond Falls Flowage are better than most other similar water bodies in the western Upper Peninsula such as the Cisco Lake Chain, Michigamme Reservoir, and Lac Vieux Desert (Table 12). Length-at-infinity ($L\infty$) values of male (28.1 in) and female (48.9 in) northern pike suggest that growth potential is above average in Bond Falls Flowage. Female pike typically attain legal size (24 in) at age 5, while males attain this size at age 7.

Mortality.–This was the first attempt to estimate total mortality of walleye from Bond Falls Flowage. Age groups 2 through 12, and 15 to 16 were represented in the samples. Total mortality of walleye (45%) was above the average (37%) for eleven walleye populations surveyed previously as part of the Large Lake Program, though it is within the range (24 to 51%) observed for those populations. Schneider (1978) summarized available estimates of total annual mortality for adult walleye in Michigan. They ranged from 20% in Lake Gogebic to 65% in the bays de Noc, Lake Michigan. Schneider (1978) also presented estimates from lakes throughout midwestern North America, other than Michigan. These estimates ranged from 31% in Escanaba Lake, Wisconsin to 70% in Red Lakes, Minnesota. Colby et al. (1979) also summarized total mortality rates for walleye from a number of lakes across North America. Estimates presented ranged from 13 to 84% for fish age 2 and older, with estimates for the majority of populations between 35% and 65%.

The three estimates of annual exploitation rate of walleye were rather different; 36.8% from tag returns, 16.4% using harvest divided by the multiple-census abundance estimate, and 10.9% using harvest divided by the single-census abundance estimate. I consider the tag return estimate to be a minimum because I did not adjust for tagging mortality or nonreporting; if these problems occurred to any degree, I would have underestimated exploitation (Miranda et al. 2002).

I did not make a true estimate of nonreporting, but attempted to get some measure of nonreporting of tags by offering a $10 reward on approximately half of the tags and comparing return rates of reward to nonreward tags. The reporting rate of nonreward tags relative to reward tags (λ) of 70.4% was below the average (80%) observed in ten walleye populations surveyed in the Large Lake Program to date. The magnitude of nonreporting of reward tags is unknown. I found that three of the seventeen reward tags (18%) observed by the creel clerk were not subsequently reported by the angler. This indicates that nonreporting of reward tags occurred to some degree, but the small number of tagged fish observed by the creel clerk was not a large enough sample from which to draw convincing conclusions. Additionally, I believe that some anglers did not return the tags since they believed the MDNR had already retrieved all necessary information during the angler interview. Finally, I found evidence against nonreporting in that the number of tags voluntarily returned by anglers was 284% of the expected number of returns. The underestimation of the number of expected returns also suggests that the harvest was underestimated. 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).

Since I believe the exploitation estimate from tag returns (36.8%) is a minimum, neither of the estimates derived from harvest divided by abundance appear reasonable. The major problem with estimating exploitation by using harvest as a fraction of abundance is that the error associated with two individual estimates is compounded. For example, if the harvest estimate is biased low, and the abundance estimate is biased high, the exploitation estimate would include the error from both individual estimates (numerator too low and denominator too high), resulting in a gross inaccuracy. I

believe this error occurred to some degree with both exploitation estimates, since there was some evidence of underestimated walleye harvest. Since I trust the tag-return estimate the most, the true annual exploitation rate of walleyes in Bond Falls Flowage was likely in the 35–40% range. If this exploitation rate were sustained, nearly all of the tagged walleyes would be harvested within three years of tagging. In fact, the decline in tag returns in the three years following tagging was severe (Figure 5), though we still received three tag returns from the spring of 2007.

The exploitation rate observed in Bond Falls Flowage in 2003 was not only a result of angling - tribal spearing also occurred on the Flowage during the spring of 2003. However, since I was not able to differentiate tag returns from the two sources, I could not make a separate estimate of spearing exploitation based on tag returns. I did receive information from the Great Lakes Indian Fish and Wildlife Commission (Krueger 2003) on the total spearing harvest of walleyes by one tribe (Lac Vieux Desert) in Bond Falls Flowage; thus, I was able to estimate spearing exploitation as the harvest divided by abundance. In 2003, 433 adult walleyes were harvested, and 258 (60%) of the walleyes were greater than 15 in. This results in an estimated spearing exploitation of 3.7 to 5.6% when the harvest is divided by the single- and multiple-census abundance estimates, respectively. I was not aware of any other tribes that harvested walleyes in Bond Falls Flowage by spearing in 2003.

Compared to exploitation rates for walleyes from other lakes in Michigan and elsewhere, the estimate for Bond Falls Flowage (35–40%) is above average. The average exploitation rate for eleven walleye population surveyed in the Large Lake Program to date was 14.8%, with a range of 3.5 to 29.3%. Thus, Bond Falls represents the highest exploitation observed thus far in the Large Lake Program. Comparable to my estimate, Serns and Kempinger (1981) reported average exploitation rates of 24.6% and 27.3% for male and female walleyes respectively in Escanaba Lake, WI during 1958–1979. In general, the range of exploitation for walleyes across their 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 waterbody; in western Lake Erie estimates ranged from 7.5 to 38.8% from 1989 through 1998 (Thomas and Haas 2000).

In 2003, a question was added to the tag return form asking anglers if they released the tagged fish. The low reported release rate (2.6%) for walleyes of legal size was expected. I believe this estimate is a minimum, given that anglers releasing fish are less likely to remove tags, or record the tag number information. The reported release rate for walleyes of legal size in South Manistique Lake was 0.8% in 2003 (Hanchin and Kramer 2008).

This was also the first attempt to estimate total mortality of northern pike in Bond Falls Flowage. My estimate of 57% was above average compared to estimates from other lakes. Total mortality rates from ten populations surveyed as part of the Large Lake Program in Michigan have ranged from 31 to 69%, with an average of 51%. Pierce et al. (1995) estimated total mortality for northern pike in seven small (< 300 acres) lakes in Minnesota to be 36 to 65%. They also summarized total mortality for adult northern pike from a number of lakes across North America; these estimates ranged from a low of 19% (Mosindy et al. 1987) to a high of 91% (Kempinger and Carline 1978), with the majority of lakes between 35% and 65%. Clark et al. (2004) estimated total annual mortality for northern pike in Houghton Lake, Michigan to be 51%, and Diana (1983) estimated total annual mortality for northern pike in two other lakes in Michigan, Murray Lake (24.4%) and Lac Vieux Desert (36.2%).

Our two estimates of annual exploitation rate of northern pike were rather different; 26.8% from tag returns and 62.9% using harvest divided by the multiple-census abundance estimate. Again, I consider the tag return estimate to be a minimum. I found that reporting rate for reward tags (25.5%) was essentially equal to that for nonreward tags (27.5%). There was likely nonreporting of both tag types, but since only one tagged northern pike was observed by the creel clerk, I was not able to estimate nonreporting of reward tags.

Since I believe the exploitation estimate from tag returns is a minimum, the estimate derived from harvest divided by the multiple-census abundance resulted in a possible estimate of exploitation (i.e., was higher than the tag return estimate). However, the exploitation estimate based on the multiple-census abundance exceeded the catch-curve estimate of total annual mortality by 31%. As with walleye, the exploitation rate determined by dividing the harvest estimate by the multiple-census estimate of abundance was probably too high because multiple-census estimates are biased low. If I adjust the multiple-census abundance estimate by Pierce's (1997) average bias of 39%, I get an exploitation rate for northern pike of 38.3%. Thus, considering the results and biases of both methods, the true exploitation rate of northern pike in Bond Falls Flowage is likely between 30% and 40%. Based on this range, and the estimate of total mortality, it appears that fishing mortality contributes more to total mortality of northern pike than natural sources in Bond Falls Flowage.

Compared to exploitation rates for northern pike from other lakes in Michigan and elsewhere, the tag return estimate of 26.8% for Bond Falls Flowage is above average. The average exploitation rate for northern pike from nine lakes surveyed under the Large Lake Program to date was 19.4%, with a range of 7.8 to 31.4%. Latta (1972) reported northern pike exploitation in two Michigan lakes, Grebe Lake (12–23%) and Fletcher Pond (38%). Pierce et al. (1995) reported rates of 8 to 46% for fish over 20 in from seven lakes in Minnesota. Carlander (1969) gave a range of 14 to 41% for a sample of lakes throughout North America.

Recruitment.–Year-class strength of walleyes is often highly variable, and factors influencing year-class strength have been related to density-dependent factors such as size of parent stock (Chevalier 1973; Forney 1976) and prey abundance (Madenjian et al. 1996, Hansen et al. 1998), and density-independent factors, such as variability of spring water temperatures (Busch et al. 1975, Hansen et al. 1998). In addition, stocking can affect walleye year-class strength (Li et al. 1996b), but stocking success has also been highly variable, depending on the size and number of fish stocked (Fielder 1992), level of natural reproduction occurring (Li et al. 1996a), and primary recruitment source (Laarman 1978; Nate et al. 2000).

We obtained population data only a single year, and so could not rigorously evaluate year-class strength. However, I attempted to gain insight about the relative variability of recruitment by examining the properties of the catch-curve regressions. Maceina (2003) used catch-curve residuals as a quantitative index of the relative year-class strength of black crappie and white crappie in Alabama reservoirs, and showed that residuals were related to various hydrological variables in the reservoirs.

Walleyes in Bond Falls Flowage were represented by 13 year classes (ages 2 through 12, 15 and 16) in the samples. Variability in year-class strength was average for walleye populations in large Michigan lakes (R^2=0.79 in Figure 3). In eleven other Michigan walleye populations surveyed as part of the Large Lake Program to date, the R^2 ranged from 0.50 to 0.94, with an average of 0.82. Given that we sampled some large year classes that coincided with years when few or no walleyes were stocked (1994–1999), natural reproduction of walleyes appears to be excellent in Bond Falls Flowage. Substantial natural reproduction probably occurred, at least beginning in 1994, though it could have been earlier. The lack of a statistically significant relationship between walleye year-class strength and stocking levels is also evidence that natural reproduction is substantial.

Northern pike in Bond Falls Flowage were represented by 10 year classes (ages 1 through 10) in the samples, suggesting consistent natural reproduction. Variability in year-class strength was relatively low (R^2 = 0.97 in Figure 4), though I only included four age classes in the regression. In ten other Michigan northern pike populations surveyed as part of the Large Lake Program to date, the R^2 ranged from 0.78 to 1.00, with an average of 0.86. Although I found a positive correlation between year-class strength and one environmental variable (average daily minimum air temperature in May), the correlation would not have been significant if I had made Bonferroni corrections of alpha, as suggested in Zar (1999). Additionally, similar measures of air temperature (mean daily, maximum daily) were not significant, suggesting that the one correlation was likely spurious.

Movement.–I did not document any movement of walleyes or northern pike out of Bond Falls Flowage. However, movement out of Bond Falls is possible via the Middle Branch of the Ontonagon River, and the South Branch of the Ontonagon via a series of small creeks.

Angler Survey

The fishery of Bond Falls Flowage is dominated by walleye, northern pike, and smallmouth bass, which combined comprise 73% of the total catch. Walleyes made up 30% of the total annual harvest, and 35% of the total catch. Walleye harvest was highest in May and August, though the highest catch rate (all sizes) was in September. The high catch rate was a result of many released fish, which were most likely sublegal. Catch rate for walleye was highest in September (0.520/hour), followed by August (0.157/hour), and May (0.136/hour). Northern pike were harvested in low numbers throughout the year, but were caught and released often. Catch peaked in May (catch rate = 0.134 per hour). Smallmouth bass provide significant angling opportunity in Bond Falls Flowage, and are caught (harvest + release) most readily in June (catch rate = 0.204 per hour).

Panfish species make up a significant portion of the harvest (51%) and total catch (27%) on Bond Falls Flowage. Rock bass make up the highest proportion of panfish catch, and are caught throughout the year. Yellow perch harvest was highest in August, though they are also caught throughout the year.

Muskellunge appear to provide some angling opportunity at certain times of the year. Muskellunge were reported as harvested in September and caught and released in July. The muskellunge population in Bond Falls Flowage is likely of low abundance.

Historical comparisons.–The only previous harvest and effort estimates for Bond Falls Flowage were reported by Lockwood (2000a). A creel survey was conducted from May 15 through September 6, 1994, and although the 2003 survey was one month longer, the data are still relatively comparable. Total angler effort in 1994 was 7,812 h, compared to 21,182 h in the 2003 survey, but a multitude of factors affecting angler effort (i.e. weather conditions, fishing success, etc.) makes interpretation difficult. Although we surveyed one additional month in 2003, that month alone does not account for the large difference in angler effort. The species composition of the harvest was similar between years; however, the most commonly harvested species in 1994 was rock bass, compared to walleye in 2003. The number of walleyes harvested in 1994 (282) was significantly lower than in 2003 (965). This may be a result of the walleye population building since the early 1990's as natural reproduction increased. The harvest per hour of walleyes in 1994 was 0.036, which is lower than the 2003 harvest rate of 0.046. While the harvest rate for walleyes increased between survey periods, the harvest rate for yellow perch and rock bass decreased by 24% and 57%, respectively. The 1994 survey did not estimate released fish.

Comparison to other large lakes.–In general, creel surveys conducted in Michigan in the past 10 years used the same methods used on Bond Falls Flowage, but most of them differ from this survey in seasonality. For comparison, I used recent angler survey results for Michigan's large inland lakes from 1993 through 1999 as compiled by Lockwood (2000a), and results from other lakes surveyed under the Large Lake Program.

I estimated 21,182 angler hours occurred on Bond Falls Flowage during the year from May 8 through October 15, 2003. This corresponds to 10.0 hours per acre, which is about average compared to other large lakes in Michigan (Table 13). The harvest per acre of all fish for Bond Falls Flowage was 1.5 per acre, which is low relative to other large lakes, though it does not have a popular panfish fishery like some of the other lakes to boost the total harvest. Also, the release rate of gamefish was relatively high in Bond Falls Flowage. For example, the percentages of the total walleye and northern

pike catches that were released were 69 and 93, respectively, while the averages for eleven lakes previously surveyed under the Large Lake Program were 44% and 76%, respectively.

For walleye, the estimated annual harvest from Bond Falls Flowage was 0.45 fish per acre. This harvest is below the average relative to other waters in Michigan. The average harvest from eleven large Michigan lakes surveyed thus far in the Large Lake Program was 0.71 walleyes per acre, ranging from 0.20 for North Manistique Lake (Hanchin and Kramer 2008a) to 1.47 for the south basin of Lake Leelanau (Hanchin et al. 2007). The average harvest from six other large Michigan Lakes (> 1,000 acres) reported by Lockwood (2000a) was 0.63 walleyes per acre, ranging from 0.09 for Brevoort Lake to 1.68 for Chicagon Lake. Although the harvest per acre was lower than average, the catch rate in Bond Falls Flowage was higher than average. Although this metric (catch rate) is affected by the problems previously mentioned for lack of targeted effort, the catch per hour of all walleyes (0.149) was 26% higher than the average from eleven other lakes (0.118) surveyed under the Large Lake Program. These Michigan lakes all were subject to similar gears and fishing regulations, including a 15-in minimum size limit.

For northern pike, the estimated annual harvest from Bond Falls Flowage was 0.06 fish per acre. This harvest was below average compared to other waters in Michigan and elsewhere. The average harvest from nine other lakes sampled in the Large Lake Program was 0.112 northern pike per acre, ranging from 0.004 in Crooked-Pickerel lakes (Hanchin et al. 2005b) to 0.464 in Houghton Lake (Clark et al. 2004). The average harvest from seven other large Michigan lakes (> 1,000 acres) reported by Lockwood (2000a) was 0.151 northern pike per acre, ranging from 0.002 per acre in Bond Falls Flowage, Gogebic County to 0.654 per acre in Fletcher Pond, Alpena County. These Michigan lakes all were subject to similar gears and fishing regulations, including a 24-in minimum size limit. Elsewhere, Pierce et al. (1995) estimated harvests from 0.7 to 3.6 per acre in seven, smaller Minnesota lakes. These lakes ranged from 136 to 628 acres in size and had no minimum size limits for northern pike.

For smallmouth bass, the total catch (harvest + release) in Bond Falls Flowage was 1,635. This exceeded the total annual catch of smallmouth bass in Crooked and Pickerel lakes (1,300; Hanchin et al 2005b), and Burt Lake (796; Hanchin et al. 2005c). The annual harvest of smallmouth bass in Bond Falls Flowage was 0.218 per acre, which is above average compared to other waters in Michigan. The average harvest in nine other lakes sampled in the Large Lake Program was 0.083 smallmouth bass per acre, ranging from 0.007 in Burt Lake (Hanchin et al. 2005c) to 0.416 in the Cisco Lake Chain (Hanchin et al. 2008). The average harvest of seven other large Michigan lakes (> 1,000 acres) reported by Lockwood (2000a) was 0.088 smallmouth bass per acre, ranging from 0.026 per acre in Brevoort Lake, Mackinac County to 0.146 per acre in Elk Lake, Antrim and Grand Traverse counties.

Summary

The walleye fishery in Bond Falls Flowage is one of the better fisheries in Michigan. In 2003, the flowage contained at least 6.1 adult walleyes per acre and anglers harvested 0.45 per acre at a rate of 0.046 walleyes per hour fished. Bond Falls Flowage experienced the highest exploitation (36.8%) of walleyes thus far in the Large Lake Program. It remains to be seen if the fishery is sustainable at this high level, though the preponderance of sublegal walleyes is promising. Available data suggest that this walleye population may have been building since the early 1990's. Given the apparent increase in walleye abundance in recent years, I assume that current fishing regulations are adequately protecting the walleye stock. Although historic data on walleyes in Bond Falls Flowage is lacking, the most recent surveys suggest that natural reproduction is substantial, and growth may be decreasing, which could be a result of increasing walleye density.

The walleye population in Bond Falls Flowage is high-density with below-average growth. The high walleye density likely has a density-dependent effect on growth. Most walleyes in Bond Falls

Flowage do not reach legal size until age 5. Additionally, size structure was below average, with only 54% of the spring spawning stock above the 15-in minimum size limit. This is similar to Michigamme Reservoir, in which 53% of the spring spawning stock was above 15 in (Hanchin et al. 2005a).

The northern pike fishery in Bond Falls Flowage is below average. Only 0.06 northern pike per acre were harvested, at a rate of 0.005 fish per hour. Both these figures are low compared to those observed in other lakes. Although the population density of legal northern pike is low, the density of adult northern pike is much higher than observed in other large lakes. Total mortality and growth rates are in acceptable ranges, and natural reproduction is consistent from year to year. The northern pike population in Bond Falls Flowage is similar to those in Michigamme Reservoir and the Cisco Lake Chain (Hanchin et al. 2005a, Hanchin et al. 2008).

The smallmouth bass fishery in Bond Falls Flowage is about average for lakes in the western Upper Peninsula. Anglers harvested 0.22 smallmouth bass per acre, at a rate of 0.022 fish per hour; these rates are similar to those observed in the nearby Cisco Lake Chain. Harvest per acre of smallmouth bass is much higher than the average from other lakes surveyed under the Large Lake Program in Michigan, but the majority of the lakes surveyed are in the northern Lower Peninsula or eastern Upper Peninsula. The higher harvest per acre observed in the western Upper Peninsula is due, in part, to higher density populations, and potentially more harvest-oriented anglers.

In Bond Falls Flowage, the total number of fish harvested per acre was below average compared to other large lakes in Michigan, but this is probably a result of fishing effort directed at large predators, rather than panfish. Bond Falls Flowage is primarily a walleye and smallmouth bass fishery, with a less than average northern pike fishery.

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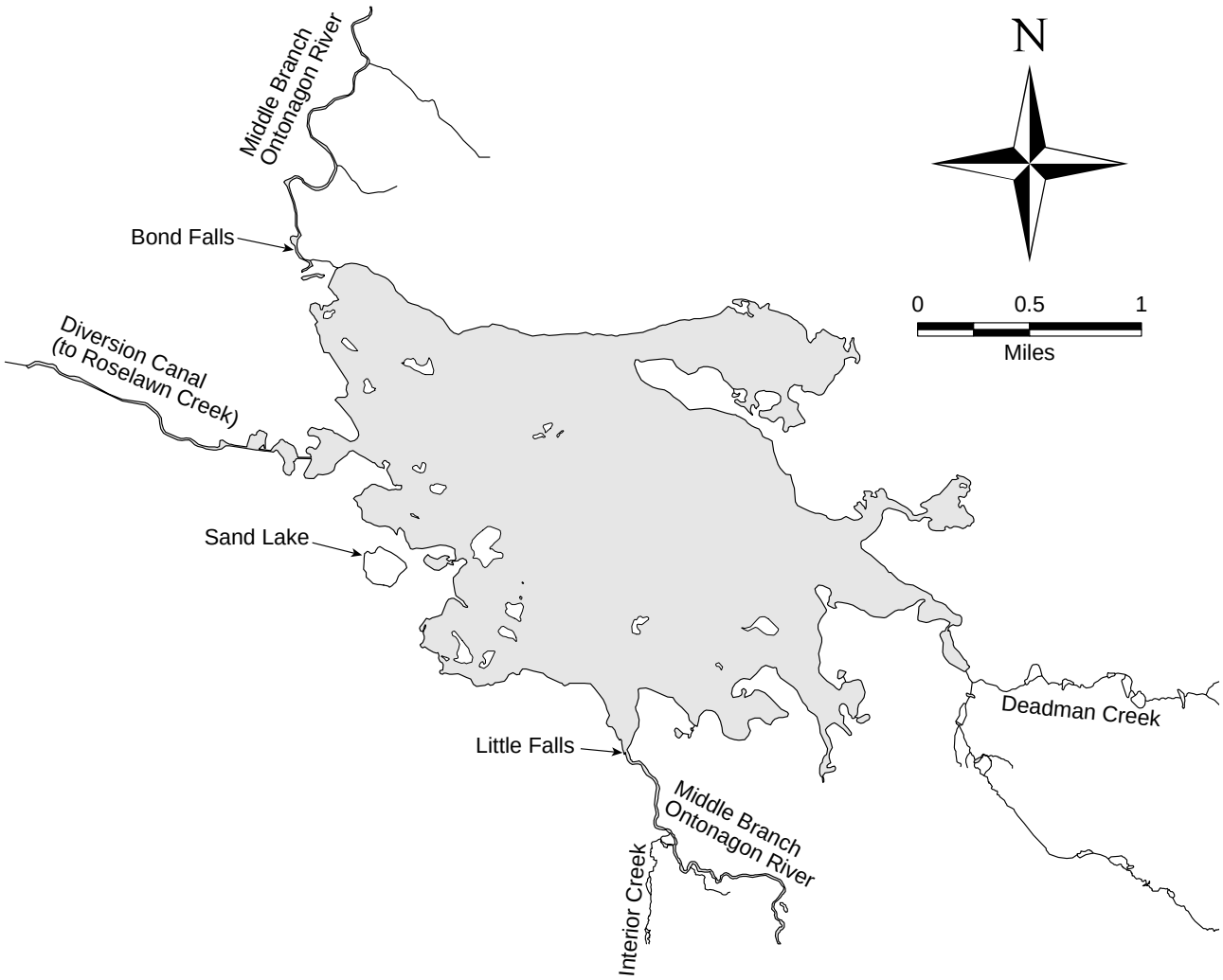

Figure 1.–Bond Falls Flowage, Ontonagon County, Michigan.

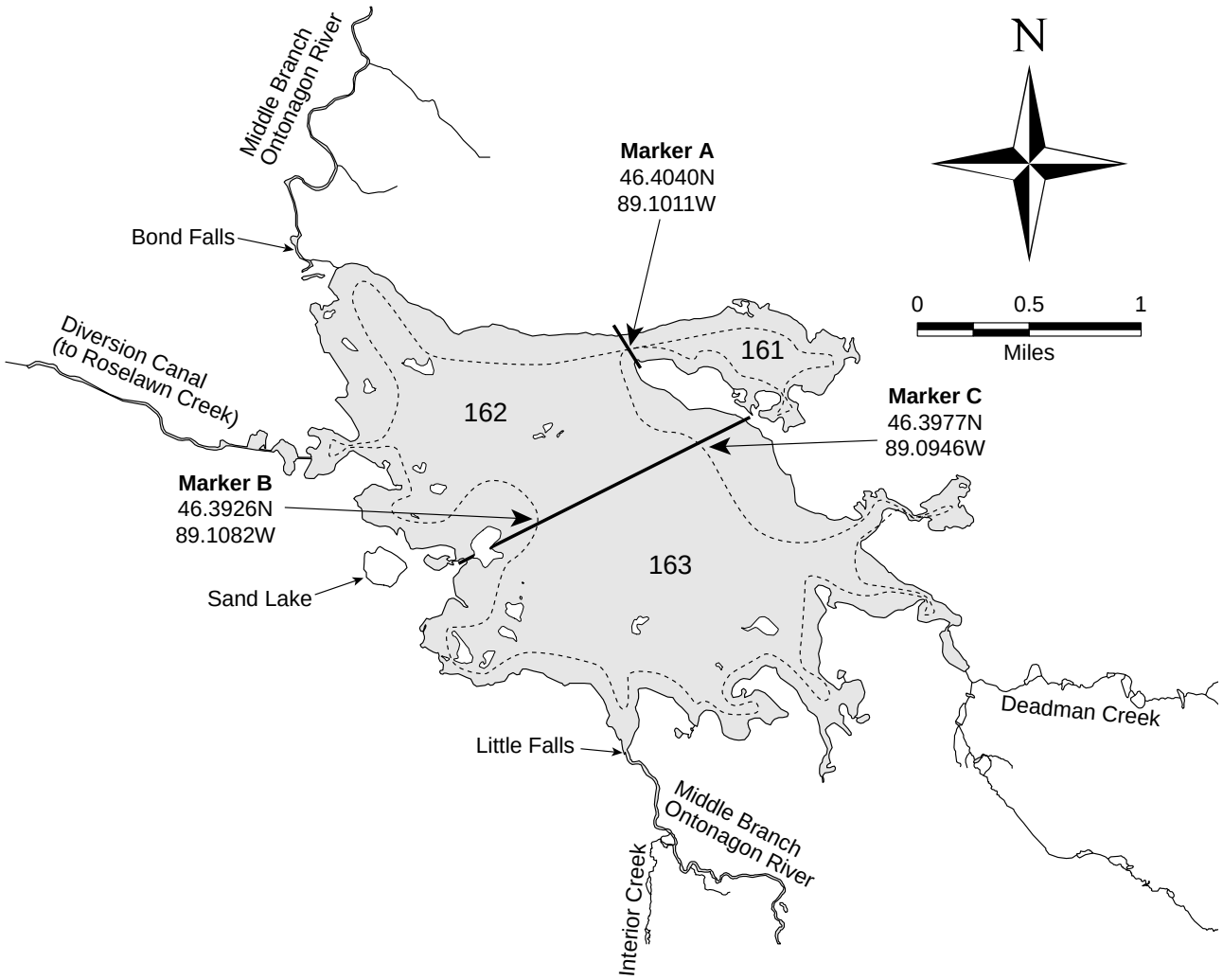

Figure 2.–Counting path, associated count path way points (Markers A-C), and interview sections (sites 161, 162, 163) for the Bond Falls Flowage 2003 angler survey.

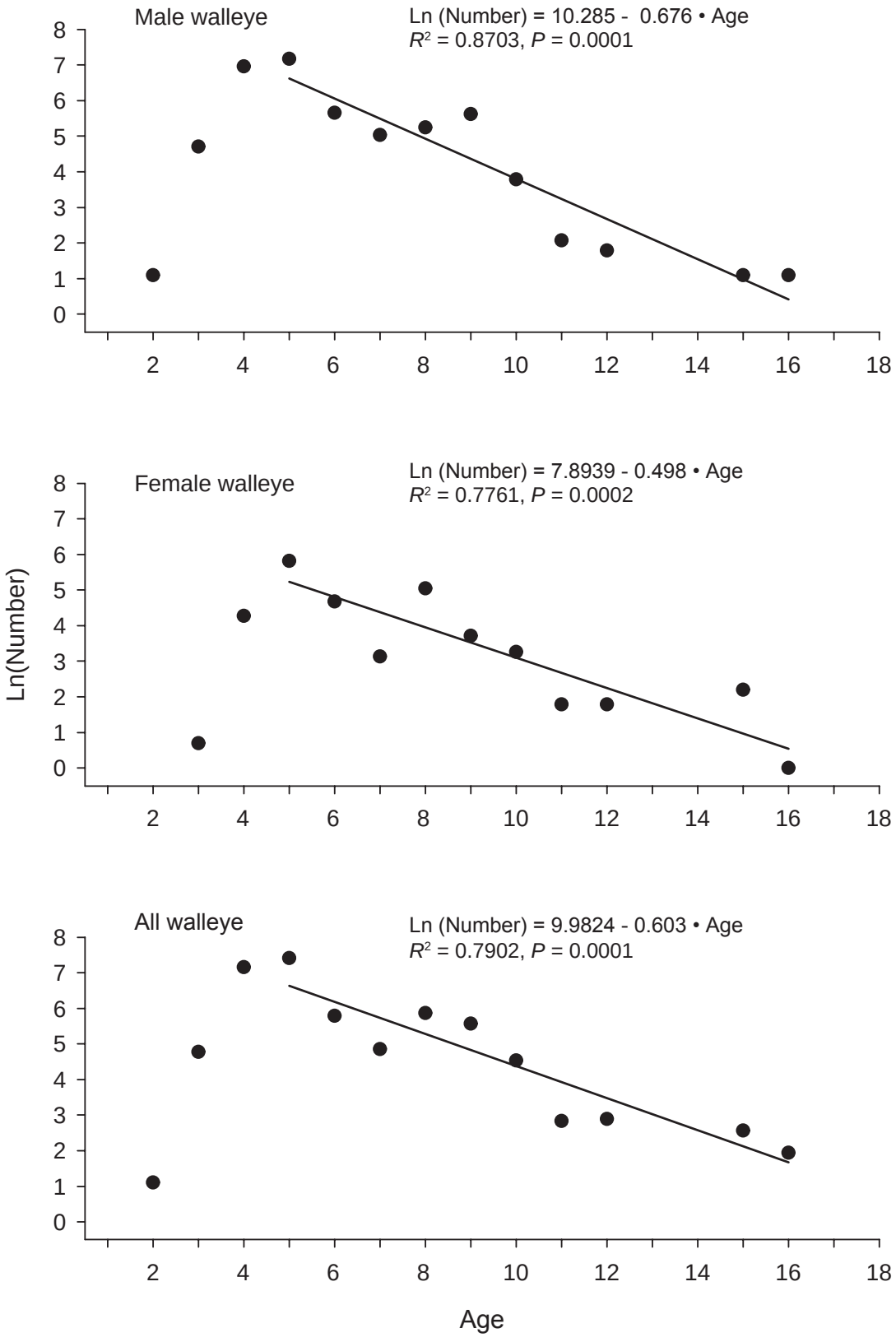

Figure 3.–Plots of observed ln(number) versus age for male, female, and all (including males, females, and unknown sex) walleyes in Bond Falls Flowage. Lines are plots of regression equations shown.

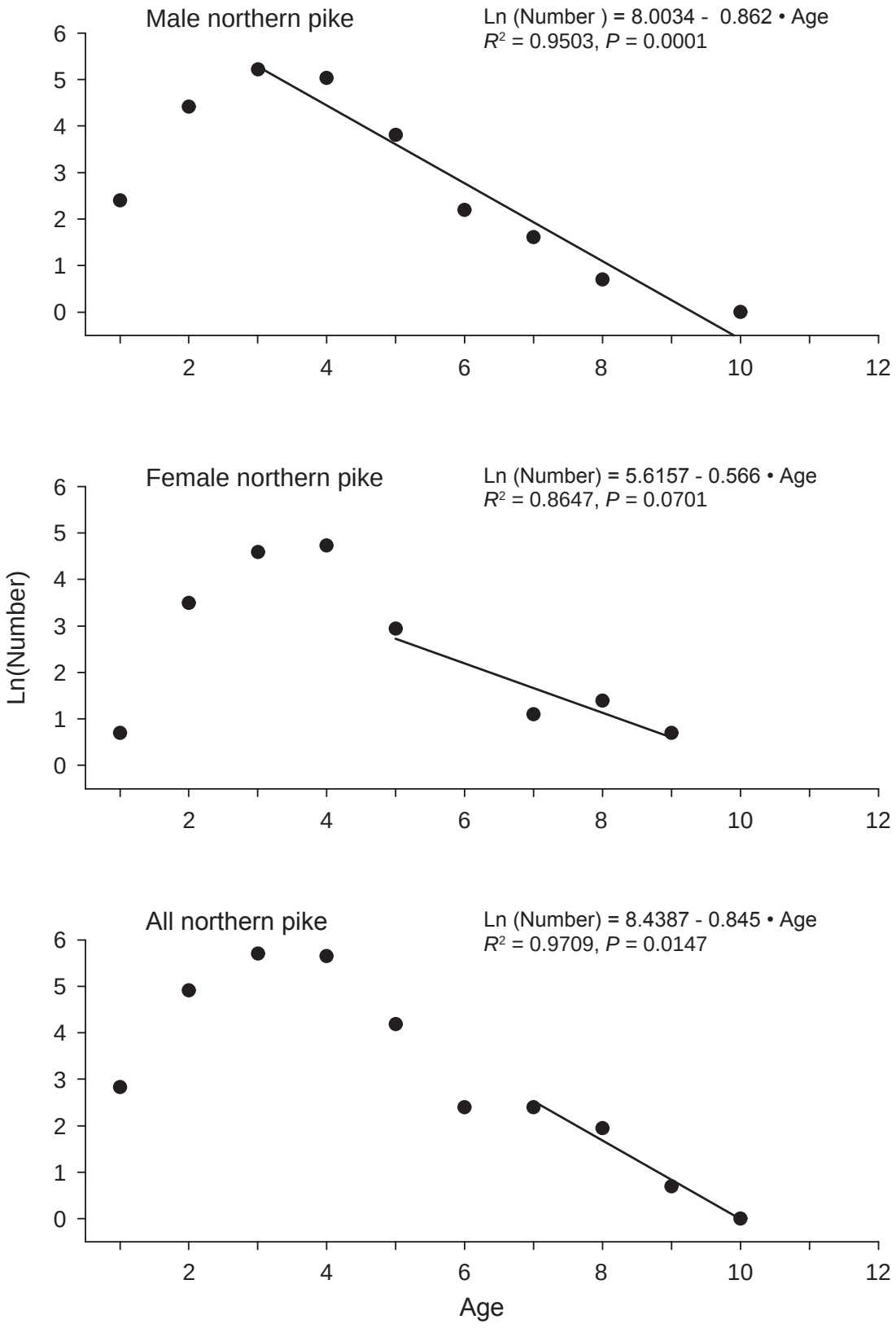

Figure 4.–Plots of observed ln(number) versus age for sublegal male, legal-size female, and legal-size all (including males, females, and unknown sex) northern pike in Bond Falls Flowage. Lines are plots of regression equations shown.

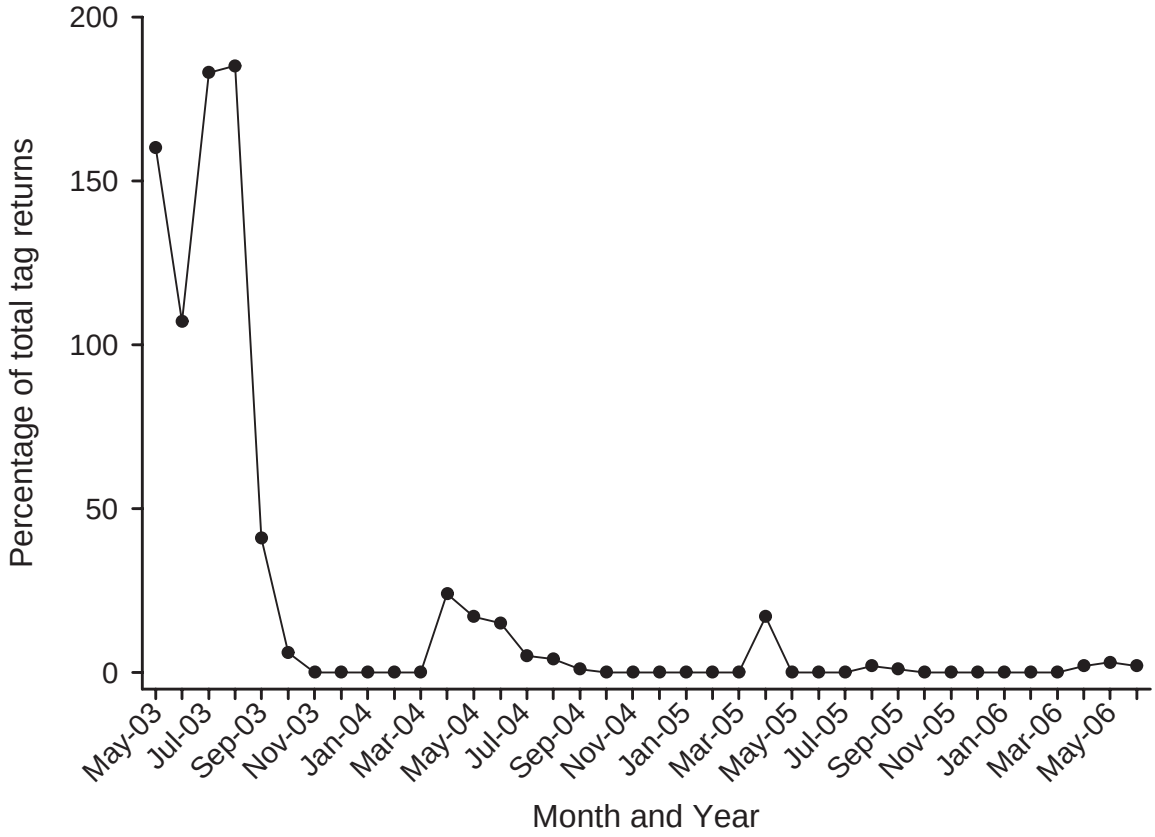

Figure 5.–Walleye tag returns (reward and nonreward) by month and year for walleye harvested from Bond Falls Flowage from May 2003 to June 2006.

Table 1.–Number and size of fish stocked in Bond Falls Flowage 1984 through 2003. Fish were not stocked in unlisted years.

Year	Species (strain)	Number	Average size (in)
1984	Yellow perch	3,078	4.2
1987	Walleye (Gogebic)	4,000	1.5
1988	Walleye (Bay de Noc)	10,538	1.1
	Yellow perch	7,458	4.8
1989	Walleye (Bay de Noc)	30,000	1.7
1990	Walleye (Bay de Noc)	10,195	1.7
	Yellow perch	4,376	1.4
1991	Walleye (Bay de Noc)	15,040	1.6
	Yellow perch	7,613	5.4
1992	Walleye (unknown)	90,000	0.8
1993	Walleye (Bay de Noc)	3,686	2.8
1995	Yellow perch	44,855	5.0
1998	Walleye (Bay de Noc)	6,900	3.4
2000	Walleye (Bay de Noc)	11,076	1.6
2001	Walleye (Bay de Noc)	28,269	1.8

Table 2.-Survey periods, sampling shifts, and expansion value "F" (number of fishing hours within a sample day; Lockwood et al 1999) for the Bond Falls Flowage angler survey, May–October, 2003.

Survey period	Sample shifts (h)		F
May 8–31	0600–1430	1330–2200	17
June	0600–1430	1330–2200	17
July	0600–1430	1300–2130	17
August	0630–1500	1230–2100	16
September	0630–1500	1200–2030	15
October 1–15	0630–1500	1030–1900	14

Table 3.–Fish collected from Bond Falls Flowage using a total sampling effort of 195 fyke-net lifts and 13 electrofishing runs from April 28 to May 6, 2003.

Species	Total catch[a]	Percent by number	Mean fyke-net CPUE[a,b]	Length range (in)	Average length (in)[c]	Number measured[c]
Walleye	5,618	75.0	15.9	4.3–26.8	15.4	4,285
Northern pike	967	12.9	3.9	10.1–41.8	20.8	821
Rock bass	511	6.8	1.9	4.3–11.0	7.8	510
White sucker	218	2.9	0.1	10.4–23.1	17.5	18
Black crappie	101	1.3	0.4	5.9–13.8	10.8	101
Smallmouth bass	36	0.5	<0.1	8.6–18.3	14.1	36
Yellow perch	20	0.3	<0.1	4.3–13.6	8.4	20
Pumpkinseed	14	0.2	<0.1	4.5–7.7	6.4	13
Bluegill	3	<0.1	<0.1	6.8–9.6	7.7	3
Brown bullhead	1	<0.1	<0.1	5.0	5.0	1
Common shiner	1	<0.1	<0.1	–	–	0

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

Table 4.–Number of fish per inch group caught and measured in spring netting and electrofishing operations on Bond Falls Flowage, April 28 to May 6, 2003.

Inch group	Species									
	Walleye	Northern pike	Rock bass	White sucker	Black crappie	Smallmouth bass	Yellow perch	Pumpkinseed	Bluegill	Brown bullhead
3	–	–	–	–	–	–	–	–	–	–
4	1	–	2	–	–	–	1	1	–	–
5	–	–	22	–	1	–	5	2	–	1
6	1	–	88	–	–	–	–	9	2	–
7	4	–	172	–	–	–	5	1	–	–
8	1	–	130	–	3	1	1	–	–	–
9	4	–	68	–	21	–	1	–	1	–
10	65	3	27	1	27	–	3	–	–	–
11	303	6	1	1	35	–	1	–	–	–
12	681	5	–	–	8	5	1	–	–	–
13	907	12	–	–	6	13	2	–	–	–
14	852	12	–	–	–	8	–	–	–	–
15	648	17	–	3	–	5	–	–	–	–
16	376	37	–	1	–	2	–	–	–	–
17	188	42	–	3	–	1	–	–	–	–
18	129	71	–	4	–	1	–	–	–	–
19	68	113	–	2	–	–	–	–	–	–
20	35	116	–	1	–	–	–	–	–	–
21	13	107	–	1	–	–	–	–	–	–
22	1	85	–	–	–	–	–	–	–	–
23	2	84	–	1	–	–	–	–	–	–
24	4	53	–	–	–	–	–	–	–	–
25	2	31	–	–	–	–	–	–	–	–
26	1	8	–	–	–	–	–	–	–	–
27	–	5	–	–	–	–	–	–	–	–
28	–	3	–	–	–	–	–	–	–	–
29	–	3	–	–	–	–	–	–	–	–
30	–	–	–	–	–	–	–	–	–	–
31	–	–	–	–	–	–	–	–	–	–
32	–	1	–	–	–	–	–	–	–	–
33	–	–	–	–	–	–	–	–	–	–
34	–	1	–	–	–	–	–	–	–	–
35	–	1	–	–	–	–	–	–	–	–
36	–	–	–	–	–	–	–	–	–	–
37	–	–	–	–	–	–	–	–	–	–
38	–	–	–	–	–	–	–	–	–	–
39	–	1	–	–	–	–	–	–	–	–
40	–	2	–	–	–	–	–	–	–	–
41	–	2	–	–	–	–	–	–	–	–
Total	4,285	821	510	18	101	36	20	13	3	1

Table 5.–Estimates of abundance, angler exploitation rates, and instantaneous fishing mortality rates for Bond Falls Flowage walleyes and northern pike. Estimation methods are described in the text. Asymmetrical 95% confidence intervals for estimates are given in parentheses, where applicable.

Parameter	Walleyes	Northern pike
Number tagged	2,307	107
Total tag returns	698	28
Number of legal-size[a] fish		
Multiple-census estimate	4,631 (3,785 – 5,964)	164 (109 – 330)
Single-census estimate	7,015 (5,196 – 9,676)	–
Michigan model prediction[b]	3,246 (697 – 15,106)	–
Number of adult[c] fish		
Multiple-census method	12,501 (10,532 – 15,376)	5,538 (4,041 – 8,800)
Single-census estimate	12,906 (9,560 – 17,802)	–
Michigan model prediction[d]	4,139 (991 – 17,289)	–
Wisconsin model prediction[e]	7,041 (2,315 – 21,418)	–
Annual exploitation rates		
Based on reward tag returns	36.8%	26.8%
Based on harvest/abundance[f]	16.4% (10.5% – 22.4%)	62.9% (14.6% – 100%)
Based on harvest/abundance[g]	10.9% (6.5% – 15.2%)	–
Total annual mortality rates	45%	57%

[a] Walleyes ≥ 15 in and northern pike ≥ 24 in.
[b] Michigan model prediction of legal-size walleye abundance based on lake area, N = 21.
[c] Fish of legal size and sexually mature fish of sublegal size on spawning grounds.
[d] Michigan model prediction of adult walleye abundance based on lake area, N = 35.
[e] Wisconsin model prediction of adult walleye abundance for natural reproduction, N = 185
[f] Multiple-census estimate of legal-size walleye abundance.
[g] Single-census estimate of legal-size walleye abundance.

Table 6.–Weighted mean lengths (in) and sample sizes by age and sex for walleyes collected from Bond Falls Flowage, April 28 to May 6, 2003. Standard deviation is in parentheses.

	Mean length			Number aged		
Age	Males	Females	All fish[a]	Males	Females	All fish[a]
2	10.7 (0.0)	—	10.7 (0.0)	3	—	3
3	12.1 (0.4)	11.2 (0.0)	12.0 (0.5)	7	3	10
4	13.5 (0.7)	15.9 (1.0)	13.9 (1.1)	23	11	34
5	14.8 (0.8)	16.8 (0.9)	15.4 (1.2)	21	30	51
6	16.1 (0.3)	17.5 (1.4)	16.6 (1.0)	6	10	16
7	16.0 (0.7)	20.1 (0.8)	16.7 (1.7)	4	5	9
8	17.3 (1.0)	18.9 (1.7)	17.8 (1.7)	12	26	38
9	17.3 (1.1)	20.5 (1.3)	18.0 (1.5)	18	12	30
10	17.0 (0.6)	19.6 (3.1)	17.3 (2.2)	2	9	11
11	20.1 (0.0)	23.6 (2.2)	21.3 (2.1)	2	4	6
12	19.4 (0.0)	20.9 (—)	19.9 (0.7)	2	1	3
13	—	—	—	—	—	—
14	—	—	—	—	—	—
15	19.2 (—)	20.7 (2.3)	20.1 (2.0)	1	2	3
16	19.1 (—)	26.7 (—)	20.2 (2.9)	1	1	2

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

Table 7.–Weighted mean lengths (in) and sample sizes by age and sex for northern pike collected from Bond Falls Flowage, April 28 to May 6, 2003. Standard deviation is in parentheses.

	Mean length			Number aged		
Age	Males	Females	All fish[a]	Males	Females	All fish[a]
1	12.6 (1.0)	10.3 (0.0)	12.2 (1.3)	8	2	11
2	17.2 (2.4)	17.9 (1.9)	17.4 (2.2)	32	20	52
3	19.8 (1.7)	20.6 (2.0)	20.1 (1.9)	38	35	73
4	21.6 (2.1)	22.9 (2.1)	22.3 (2.3)	38	40	79
5	21.4 (2.6)	24.3 (0.9)	22.8 (2.5)	13	7	20
6	23.6 (0.7)	— (—)	23.7 (0.7)	3	0	3
7	23.8 (1.2)	32.9 (7.0)	27.3 (5.4)	3	2	5
8	29.2 (4.1)	37.4 (6.5)	33.6 (6.7)	2	4	6
9	—	37.3 (4.4)	37.3 (4.4)	—	3	3
10	35.1 (—)	—	35.1 (—)	1	—	1

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

Table 8.–Catch-at-age estimates (apportioned by age-length key), by sex, for walleyes and northern pike from Bond Falls Flowage, April 28 to May 6, 2003.

Age	Year class	Walleyes			Northern pike		
		Males	Females	All fish[a]	Males	Females	All fish[a]
1	2002	—	—	—	11	2	17
2	2001	3	—	3	83	33	135
3	2000	111	2	119	184	98	299
4	1999	1,056	72	1,284	154	113	283
5	1998	1,306	336	1,657	45	19	66
6	1997	287	107	326	9	—	11
7	1996	153	23	128	5	3	11
8	1995	191	155	353	2	4	7
9	1994	277	41	261	—	2	2
10	1993	44	26	93	1	—	1
11	1992	8	6	17	—	—	—
12	1991	6	6	18	—	—	—
13	1990	—	—	—	—	—	—
14	1989	—	—	—	—	—	—
15	1988	3	9	13	—	—	—
16	1987	3	1	7	—	—	—
Total		3,448	784	4,279	494	274	832

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

Table 9.–Voluntary angler tag returns from walleyes (reward and nonreward, harvested and released combined), by month, for the year following tagging in Bond Falls Flowage. Percentage of total is in parentheses.

Month	Species	
	Walleyes	Northern pike
4	0 (0.0)	1 (3.6)
5	160 (22.9)	10 (35.7)
6	107 (15.3)	9 (32.1)
7	184 (26.4)	5 (17.9)
8	200 (28.7)	1 (3.6)
9	41 (5.9)	2 (7.1)
10	6 (0.9)	0 (0.0)
11	0 (0.0)	0 (0.0)
12	0 (0.0)	0 (0.0)
1	0 (0.0)	0 (0.0)
2	0 (0.0)	0 (0.0)
3	0 (0.0)	0 (0.0)
Total	698	28

Table 10.–Angler survey estimates for summer and fall 2003 from Bond Falls Flowage. Survey period was from May 8 through October 15, 2003. Two standard errors are given in parentheses.

Species	Catch per hour	Month						
		May	June	July	August	September	October	Season
		Number harvested						
Smallmouth bass	0.022 (0.012)	22 (29)	267 (227)	48 (40)	77 (63)	49 (68)	0 (0)	463 (251)
Walleyes	0.046 (0.015)	310 (194)	31 (34)	164 (94)	373 (174)	86 (75)	0 (0)	965 (289)
Yellow perch	0.027 (0.014)	3 (5)	95 (119)	128 (100)	315 (235)	22 (44)	0 (0)	563 (285)
Northern pike	0.006 (0.004)	77 (66)	7 (10)	5 (8)	25 (28)	2 (4)	0 (0)	116 (73)
Muskellunge	<0.001 (0.001)	0 (0)	0 (0)	0 (0)	0 (0)	10 (21)	0 (0)	10 (21)
Black crappie	0.009 (0.008)	0 (0)	25 (49)	157 (158)	5 (11)	4 (8)	0 (0)	191 (166)
Bluegill	0.002 (0.003)	0 (0)	0 (0)	17 (22)	31 (63)	0 (0)	0 (0)	48 (66)
Largemouth bass	0.001 (0.002)	0 (0)	18 (36)	0 (0)	0 (0)	0 (0)	0 (0)	18 (36)
Pumpkinseed	<0.001 (0.001)	0 (0)	0 (0)	0 (0)	7 (14)	0 (0)	0 (0)	7 (14)
Rock bass	0.038 (0.025)	15 (30)	386 (344)	239 (299)	163 (221)	0 (0)	0 (0)	803 (507)
Green sunfish	<0.001 (0.001)	0 (0)	9 (19)	0 (0)	0 (0)	0 (0)	0 (0)	9 (19)
Total harvested	0.151 (0.041)	426 (210)	838 (436)	758 (368)	997 (378)	174 (113)	0 (0)	3,193 (724)
		Number released						
Smallmouth bass	0.055 (0.028)	87 (94)	779 (536)	74 (52)	129 (113)	103 (84)	0 (0)	1,172 (565)
Walleye	0.103 (0.068)	394 (425)	145 (139)	293 (200)	445 (276)	910 (1,288)	0 (0)	2,187 (1,405)
Northern pike	0.076 (0.028)	620 (384)	350 (252)	306 (198)	226 (176)	99 (80)	0 (0)	1,600 (536)
Muskellunge	<0.001 (<0.001)	0 (0)	0 (0)	2 (3)	0 (0)	0 (0)	0 (0)	2 (3)
Rock bass	0.017 (0.009)	41 (44)	162 (147)	62 (59)	48 (56)	35 (47)	0 (0)	349 (180)
Bluegill	<0.001 (<0.001)	0 (0)	0 (0)	4 (8)	0 (0)	2 (3)	0 (0)	6 (9)
Yellow perch	0.019 (0.018)	0 (0)	6 (12)	115 (153)	266 (340)	10 (21)	0 (0)	397 (374)
Total released	0.270 (0.089)	1,142 (582)	1,441 (626)	856 (330)	1,113 (488)	1,159 (1,294)	0 (0)	5,713 (1,659)
Total (harvested + released)	0.420 (0.107)	1,568 (619)	2,280 (763)	1,615 (494)	2,110 (618)	1,333 (1,299)	0 (0)	8,905 (1,810)
		Fishing effort						
Angler hours		5,185 (2,104)	5,118 (1,318)	3,492 (1,185)	5,203 (1,511)	1,915 (800)	268 (443)	21,182 (3,270)
Angler trips		1,511 (666)	1,937 (658)	980 (349)	1,555 (559)	686 (323)	81 (135)	6,749 (1,198)

Table 11.–Mean lengths (in) of walleyes from the 2003 survey of Bond Falls Flowage compared to other surveys of comparable waters. Number of walleyes aged in parentheses.

		Lake							
Age	State average[a]	Bond Falls Flowage 2003[b]	Bond Falls Flowage 1999[c]	Southern Cisco Lake Chain 2002[b]	Lake Gogebic 1999[b]	Lac Vieux Desert 1998[b]	South Manistique Lake 2003[b]	Michigamme Reservoir 2001[b]	Lake Michigamme 2002[c]
2	10.4	10.7 (3)	8.5 (1)	10.7 (5)		9.1 (3)	11.4 (2)	12.6 (20)	8.3 (2)
3	13.9	12.0 (10)		11.6 (52)	11.4 (1)	11.2 (3)	13.5 (21)	15.2 (20)	10.4 (4)
4	15.8	13.9 (34)	14.5 (3)	13.3 (48)	13.0 (1)	15.0 (5)	15.9 (51)	16.8 (19)	11.9 (1)
5	17.6	15.4 (51)	15.4 (11)	14.3 (68)	13.8 (34)	16.1 (2)	17.1 (33)	18.0 (8)	12.7 (5)
6	19.2	16.6 (16)		15.0 (19)	16.4 (2)	16.6 (1)	19.7 (10)	19.3 (6)	15.1 (2)
7	20.6	16.7 (9)	18.7 (1)	16.4 (53)	16.7 (1)	18.6 (10)	19.4 (8)	21.0 (8)	14.5 (1)
8	21.6	17.8 (38)		17.6 (48)	17.1 (10)		19.8 (17)	21.8 (4)	16.7 (1)
9	22.4	18.0 (30)	22.0 (1)	16.8 (11)	17.0 (3)	20.8 (2)	19.9 (17)	23.0 (3)	
10	23.1	17.3 (11)		20.4 (13)	17.8 (7)	21.0 (1)	18.8 (2)	27.9 (1)	21.4 (1)
11		21.3 (6)		23.0 (31)	17.3 (2)		21.0 (19)		
12		19.9 (3)		21.5 (18)		26.0 (1)	22.1 (16)		18.4 (1)
13				24.1 (22)	20.1 (3)		23.6 (8)		
14				23.6 (19)			22.6 (4)		
15		20.1 (3)		24.6 (5)			26.0 (5)		
16		20.2 (2)		28.3 (4)					22.3 (1)
17									
Mean growth index[d]		-3.3	-2.6	-3.2	-3.3	-1.5	-0.8	-3.2	-5.3

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

Table 12.–Mean lengths (in) of northern pike from the 2003 survey of Bond Falls Flowage compared to other surveys. Number of northern pike aged in parentheses.

		Lake						
Age	State average[a]	Bond Falls Flowage 2003[b]	Bond Falls Flowage 1999[c]	South Manistique 2003[b]	Michigamme Reservoir 2001[b]	Lake Michigamme 2002	Lac Vieux Desert 1998[b]	Cisco Lake Chain 2002[b]
1		12.2 (11)		13.3 (2)				11.1 (57)
2	17.7	17.4 (52)	17.0 (5)	16.7 (41)	16.0 (94)	17.2 (8)	14.5 (3)	15.8 (167)
3	20.8	20.1 (73)	19.6 (7)	20.2 (46)	18.8 (118)	19.5 (17)	16.2 (17)	17.8 (177)
4	23.4	22.3 (79)	21.5 (9)	23.6 (26)	20.6 (64)	23.8 (6)	18.8 (10)	19.2 (274)
5	25.5	22.8 (20)	23.7 (4)	22.5 (5)	21.3 (51)	22.9 (5)	24.5 (1)	21.6 (111)
6	27.3	23.7 (3)	31.7 (1)	23.9 (6)	25.3 (35)	28.6 (10)	19.2 (2)	22.5 (37)
7	29.3	27.3 (5)		24.8 (4)	25.6 (21)	34.6 (8)		25.5 (24)
8	31.2	33.6 (6)			27.5 (3)	31.5 (1)		21.6 (7)
9		37.3 (3)		28.6 (1)	36.3 (4)	32.1 (1)		28.6 (5)
10		35.1 (1)		29.1 (1)				
11					34.0 (1)			
Mean growth index[d]		-0.6	-2.4	-1.6	-2.7	+0.1	-4.6	-4.0

[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 June and aged using fin rays.
[d] The mean deviation from the Statewide quarterly average. Only age groups where N≥5 were used.

Table 13.–Comparison of recreational fishing effort and total harvest on Long Lake to those of other Michigan lakes surveyed as part of the Large Lakes Program. Lakes are listed from highest to lowest total fishing effort. Lake size was from Laarman (1976).

Lake	County	Size (acres)	Survey period	Fishing effort (hours)	Fish harvested (number)	Fish harvested per hour	Hours fished per acre	Fish harvested per acre
Houghton	Roscommon	20,075	Apr 2001 – Mar 2002	499,048	386,287	0.77	24.9	19.2
Cisco Chain	Gogebic, Vilas	3,987	May 2002 – Feb 2003	180,262	120,412	0.67	45.2	30.2
Muskegon	Muskegon	4,232	Apr 2002 – Mar 2003	180,064	184,161	1.02	42.5	43.5
Fletcher Pond	Alpena, Montmorency	8,970	May – Sep 1997	171,521	118,101	0.69	19.1	13.2
Burt	Cheboygan	17,120	Apr 2001 – Mar 2002	134,205	68,473	0.51	7.8	4.0
South Manistique	Mackinac	4,133	May 2003 – Mar 2004	142,686	43,654	0.31	34.5	10.6
Gogebic	Ontonagon, Gogebic	13,380	May 1998 – Apr 1999	121,525	26,622	0.22	9.1	2.0
Lake Leelanau	Leelanau	8,607	Apr 2002 – Mar 2003	112,112	15,464	0.14	13.0	1.8
Big Manistique	Luce, Mackinac	10,346	May 2003 – Mar 2004	88,373	71,652	0.81	8.5	6.9
Crooked and Pickerel	Emmet	3,434	Apr 2001 – Mar 2002	55,894	13,665	0.24	16.3	4.0
Michigamme Reservoir	Iron	6,400	May 2001 – Feb 2002	52,686	10,899	0.21	8.2	1.7
Bond Falls Flowage	Ontonagon	2,127	May – Oct 2003	21,182	3,193	0.15	10.0	1.5
North Manistique	Luce	1,709	May 2003 – Mar 2004	10,614	7,603	0.72	6.2	4.4
Average				136,167	82,322	0.50	18.9	11.0
Median				121,525	43,654	0.51	13.0	4.4

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David F. Clapp, Editor
Troy Zorn, Reviewer
Deborah L. MacConnell, Desktop Publisher
Alan D. Sutton, Graphics

Approved by Tammy J. Newcomb

Appendix

Appendix–Fish species captured in Bond Falls Flowage in 2003 using various gear types.

Common name	Scientific name
Species collected in spring 2003 with fyke nets and electrofishing gear	
Bluegill	*Lepomis macrochirus*
Black crappie	*Pomoxis nigromaculatus*
Brown bullhead	*Ameiurus nebulosus*
Common shiner	*Notropis cornutus*
Northern pike	*Esox lucius*
Pumpkinseed	*Lepomis gibbosus*
Rock bass	*Ambloplites rupestris*
Smallmouth bass	*Micropterus dolomieu*
Walleye	*Sander vitreus*
White sucker	*Catostomus commersonii*
Yellow perch	*Perca flavescens*
Additional species collected in summer 2003 with fyke nets, gill nets, seines, and electrofishing gear	
Creek chub	*Semotilus atromaculatus*
Golden shiner	*Notemigonus crysoleucas*
Largemouth bass	*Micropterus salmoides*