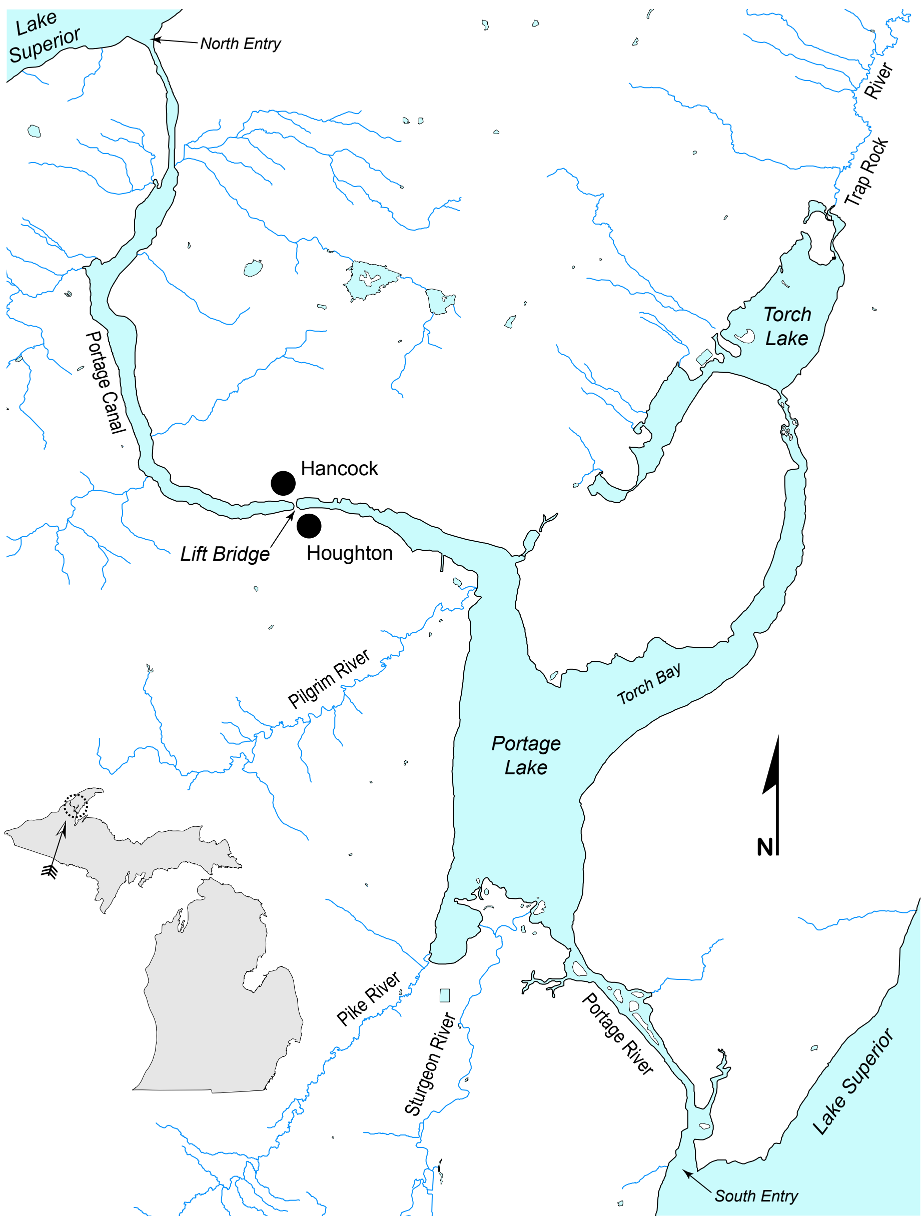
STATE OF MICHIGAN
DEPARTMENT OF NATURAL RESOURCES

FR13 June 2016

The Fish Community and Fishery of the Portage-Torch Lake System, Houghton County, Michigan in 2007-08

Patrick A. Hanchin



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FISHERIES DIVISION
FISHERIES REPORT 13

Suggested Citation Format

Hanchin, P. A. 2016. The fish community and fishery of the Portage-Torch lake system, Houghton County, Michigan in 2007-08. Michigan Department of Natural Resources, Fisheries Report 13, Lansing.

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Michigan Department of Natural Resources
Fisheries Report 13, 2016

The Fish Community and Fishery of the Portage-Torch Lake System, Houghton County, Michigan in 2007-08.

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Introduction

The Michigan Department of Natural Resources (DNR), Fisheries Division surveyed fish populations and angler catch and effort in Portage and Torch Lakes [henceforth referred to as the Portage-Torch lake system (PTLS)], Houghton County, Michigan from April 2007 through February 2008. This work was part of the Large Lakes Program, which is the assessment and monitoring program for fish communities and fisheries in Michigan's largest inland lakes (Clark et al. 2004). The Large Lakes Program has three primary objectives. The first objective is to produce indices of abundance and estimates of annual harvest and fishing effort for walleye *Sander vitreus*, northern pike *Esox lucius*, smallmouth bass *Micropterus dolomieui*, and muskellunge *Esox masquinongy*. The second objective is to produce growth and mortality statistics to evaluate the effects of fishing on these species. The third objective is to evaluate the suitability of various statistical estimators for use in large lakes. For example, comparisons were made among three types of abundance and three types of exploitation rate estimators in this survey of the PTLS. The Large Lakes Program maintains consistent sampling methods over lakes and time, which allows the evaluation of differences in fish population and harvest statistics among lakes or changes within a lake over time. The PTLS was the nineteenth waterbody surveyed under the protocols of the program. However, since twenty waterbodies had been surveyed at the time the report was written, statistics from all surveyed waterbodies were used for comparison. The sample size for these types of comparisons varies throughout the report since some statistics could not be estimated for a waterbody and/or species.

Study Area

The PTLS, also known as the Keweenaw Waterway, is a system of lakes and channels with a watershed of approximately 350 square miles. The Portage River watershed makes up approximately 80% and the Torch Lake watershed makes up 20% of the total watershed (Anonymous 1987). The watershed is within the Western Upper Peninsula ecoregion (Eagle et al. 2005). This ecoregion is primarily forest (81%) and wetland (11%), with some agriculture (2%) and urban (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; however the soil types in the vicinity of the PTLS are largely sandy loam, loam, and silt. The number of growing degree days (area-weighted average) for Portage and Torch lakes are 1,619 and 1,671, respectively (Breck 2004).

The PTLS has a surface area of approximately 13,208 acres (Breck 2004), with Portage Lake and the Portage Canal (not including the Portage River and South Entry) comprising approximately 10,808 acres and Torch Lake approximately 2,400 acres. The main tributaries to the PTLS are the Pilgrim, Pike, Sturgeon, and Trap Rock rivers, and numerous smaller creeks (Figure 1). A few of the tributaries have resident salmonid populations and many support steelhead, Coho salmon, smelt, and sucker runs. The Pike, Sturgeon, and Snake rivers have modest spawning migrations of walleyes, and significant spawning migrations of northern pike. The outlets of the PTLS are the Portage Canal at the north entry and the Portage River at the south entry. The lake level of the PTLS is equal to that of Lake Superior, and the direction of flow depends on wind direction and seiches (Churchill et al. 2004). Although Portage Lake thermally stratifies in the summer, the wind-driven seiches make it susceptible to repeated turnover (Churchill and Kerfoot 2007). The PTLS is connected to Otter and Prickett lakes via the Sturgeon River. Fish have access to Otter Lake via a fish ladder associated with the lake-level control structure, but there is no upstream fish passage over the Prickett Lake Dam. Mean and maximum depths are 56 and 115 ft, respectively in Torch Lake, and the maximum depth is 54 ft in Portage Lake.

The PTLS has undergone significant anthropogenic alterations over the last 150 years. In the mid-19^{th} century the Portage River was dredged to allow shipping access to the towns of Houghton and Hancock from Keweenaw Bay. In 1874, a 22-mile canal was completed between the northwest end of Portage Lake and Lake Superior that allowed ships to bypass the trip around the Keweenaw Peninsula and provided a harbor of refuge. In the mid-1870s, a channel was dredged between Portage and Torch Lakes in order to allow ships to reach the mines and communities along Torch Lake. Finally, the Portage Canal was widened from 100 ft to 500 ft in 1935.

Copper mining in the vicinity of the PTLS began around 1860 and continued until 1968. The most significant consequence of one hundred years of mining was the deposition of stamp sands leftover from the processing of ore in the stamp mills. This massive deposition of sediment in the PTLS drastically altered the natural shoreline and substrate within the lakes. In Torch Lake alone approximately 200 million tons of stamp sand and mine tailings were deposited, which displaced 20% of the original lake volume (Anonymous 1987). Furthermore, stamp sands and tailings deposited in the PTLS were largely re-processed to remove additional copper, and were again deposited into the waterway. Concerned about the rampant environmental damage in the PTLS, Juetten (1971) made several recommendations about zoning ordinances, dredging, and sediment deposition. Eventually, zoning ordinances were instituted regarding development, and sediments from periodic dredging of the waterway are now deposited on terrestrial sites away from the PTLS.

The water quality of the PTLS has been in question for over thirty years (Kraft 1979, Kraft and Sypniewski 1981) largely because of the trace amounts of harmful heavy metals contained in the stamp sands, the other industrial pollution, and the sewage discharged into the PTLS. Initial concerns over pollution in the PTLS began when Tomljanovich (1974) reported a prevalence of tumors in the sauger population and were reinforced when Black et al. (1982) published an article in the Journal of the National Cancer Institute. In 1983, the Michigan Department of Public Health issued a consumption advisory for walleyes and saugers from Torch Lake as a precautionary measure until the cause of the tumors could be determined. A year later Torch Lake was designated as both a 307 site under the Michigan Environmental Response Act and a Superfund site by the United States Environmental Protection Agency. Based on these declarations, the International Joint Commission designated Torch Lake as a Great Lakes Area of Concern (AOC) in 1985. In response to the designation as an AOC, remedial action plans (Anonymous 1987; Anonymous 2001) summarized existing information in the PTLS, identified problems, and proposed restoration actions. The 1987 Remedial Action Plan (Anonymous 1987) details results from several studies examining the histology of resident fishes. Numerous studies attempted to link the prevalence of tumors in walleye and sauger to the pollution related to the mining waste, though concrete evidence on the cause was never determined. Since tumor-inducing agents were not found in Torch Lake, there was no basis for the fish consumption advisory and it was lifted in 1989. Once the fish consumption advisory was lifted, the designation as an AOC was also eliminated. Recently, the Michigan Department of Environmental Quality reported PCB levels in Torch Lake that were significantly higher than other areas in the PTLS and Lake Superior (Anonymous 2006); thus, there are apparently still some concerns about water quality in the PTLS. As of the time this report was written, the Michigan Department of Community Health advised against eating Torch Lake walleyes greater than 22 inches and advised that walleye greater than 22 inches from Portage Lake should only be eaten once per week.

Water quality in Torch Lake was described extensively in the 1987 Remedial Action Plan (Anonymous 1987). Copper concentrations in Torch Lake were found to be significantly higher than in nearby reference lakes, which also resulted in higher copper concentrations in yellow perch gonads (Baumann et al. 1990). While the water quality of the PTLS has been greatly affected by mining and industrial waste, it has improved over the years. Chlorides and conductivity have changed drastically since mining has ceased. Chloride levels in Torch Lake dropped from 210 mg/L in 1967 to 13 mg/L in 1979, while conductivity dropped from 700 to 136 µmhos/cm over the same period. Water clarity also increased substantially following the cessation of mining. Torch Lake is considered mesotrophic based on an average total phosphorous level of 0.02 mg/L (Wright et al. 1973) and summer dissolved oxygen is adequate from the surface to the hypolimnion. Water chemistry can change quite rapidly in the PTLS as seiches occurring on Lake Superior can "flush" the system in either direction.

The PTLS has approximately 90 miles of shoreline, which is moderately developed with private residences and commercial buildings. There are five major urban areas (Houghton/Hancock, Chassel, Dollar Bay, Hubbell, and Lake Linden), though they are relatively small towns. Most shoal area has sandy substrate or stamp sands, though rock and gravel are also present. Organic sediments are more common in deeper areas. A few locations are also inundated with slab wood and old timbers from sawmill operations that existed on the lake. Aquatic vegetation is sparse, especially in the vicinity of stamps sands. One of the major rehabilitation strategies resulting from the Superfund process was the capping and re-vegetation of mine tailings around shoreline areas of the PTLS. While significant progress has been made in this remediation, no action was recommended for the polluted lake sediments in Torch Lake due to the vast amount of tailings and expense associated with removal/remediation.

The fish community of the PTLS is diverse, which is largely due to its connectivity with Lake Superior. Families of fish known to currently exist include, but are not limited to, *Catostomidae, Centrarchidae, Clupeidae, Cottidae, Cyprinidae, Esocidae, Gadidae, Ictaluridae, Osmeridae, Percidae, Percopsidae, Petromyzontidae, Salmonidae (including sub-family Coregoninae), and Umbridae*. The history of fisheries management on the PTLS has largely consisted of fish stocking with a few statewide regulation changes over the years. Laarman (1976) provided a list of early (1904 to 1943) fish stocking in Portage Lake, which included 1.63 million walleye fry and 200 yearling rainbow trout. Since then, mainly walleyes and Coho salmon have been stocked (Table 1), with a few brook trout and rainbow trout. Saugers were only stocked on one occasion (58,000 fry in 1988). The PTLS produces large fish of numerous species and there have been ninety-seven State of Michigan Master Angler awards reported from 1990-2009, including 35 walleyes, 32 northern pike, 10 smallmouth bass, 7 rock bass, 5 black crappie, 1 white sucker, 1 smelt, 1 pumpkinseed, 1 muskellunge, 1 sturgeon, 1 burbot, 1 yellow perch, and 1 common carp.

Methods

Fish populations in the PTLS were sampled with trap nets, fyke nets, and an electrofishing boat from March 28 - May 8, 2007. The survey was spread over such a long duration since there were early attempts to collect spawning northern pike in tributary systems (prior to ice-out on the lakes) and there was a late effort to collect spawning smallmouth bass; however, the majority of the survey effort took place from April 17 to 27. Trap nets were 8 ft x 6 ft x 3 ft with 2-in stretch mesh and 70- to 100-ft leads, and fyke nets were 6 ft x 4 ft with 3/4-in stretch mesh and 70- to 100-ft leads. A Smith-Root® boat equipped with boom-mounted electrodes (DC) was used for electrofishing. Nets were located to target walleyes and northern pike (nonrandomly), though efforts were also made to cover the entire lake. Duration of net sets ranged from 1–3 nights, but most were 1 night. Latitude and longitude were recorded for all net locations using hand-held global positioning systems (GPS). In addition to the spring survey a standardized survey (Wehrly et al. 2015) was conducted from June 4-7, and July 27 using fyke nets, trap nets, 125-ft experimental gill nets (25-ft panels of 1.5-, 2.0-, 2.5-, 3.0, and 4.0-in mesh), seines, and electrofishing.

Fish Community

The status of the overall fish community was described in terms of species present, catch per unit effort (CPUE), percentages by number, and length frequencies. Mean CPUE in trap and fyke nets was calculated as an indicator of relative abundance, using the number of fish per net night (including recaptures) for all net lifts that were determined to have fished effectively (i.e., without wave-induced rolling or human disturbance). Fish collected were categorized into three feeding guilds, and percentages in each were calculated:

1. Primarily piscivores (walleye, northern pike, smallmouth bass, largemouth bass, burbot, sea lamprey, and silver lamprey)
2. Primarily pelagic planktivores and/or insectivores (rainbow smelt, rock bass, yellow perch, rainbow trout, bluegill, golden shiner, spottail shiner, common shiner, pumpkinseed, ruffe, black crappie, central madminnow, alewife, brook trout, cisco, bluntnose minnow, and brown trout)
3. Primarily benthivores (white sucker, brown and black bullhead, trout perch, common carp, mottled sculpin, creek chub, round whitefish, shorthead redhorse, silver redhorse, longnose sucker, and lake sturgeon)

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

Abundance–The abundance of legal-size walleyes, northern pike, and smallmouth bass was estimated using mark-and-recapture methods. Walleyes (≥15 in), northern pike (≥24 in), and smallmouth bass (≥14 in) were fitted with monel-metal jaw tags. No specific tagging goal was set for walleyes, northern pike or smallmouth bass, but rather crews tagged as many as possible until the walleye spawning season was nearing completion. To assess tag loss, tagged fish were double-marked by clipping the anterior 3 spines/fin rays of the dorsal fin. Reward ($10) and nonreward tags were applied in an approximate 1:1 ratio. Large tags (size 16) used on large northern pike (≥36 in) were all nonreward.

Initial tag loss was assessed during the marking period as the proportion of recaptured fish of legal size without tags. This tag loss was largely caused by entanglement with nets, and thus was not used to adjust estimates of abundance or exploitation. Newman and Hoff (1998) reported similar netting-induced tag loss. All fish that lost tags during netting recapture were re-tagged, and were accounted for in the total number of marked fish at large.

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

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

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

C_d = total number of fish caught during day d;

R_d = number of recaptures during day d;

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

d = day (ranging from d_1 to d_n).

The variance formula 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 $1/N_1$).

The multiple-census method was used to estimate the abundance of both legal-size and adult walleyes and northern pike. Adult fish were defined as those greater than legal size, or less than legal size, but of identifiable sex by the discharge of gametes. In order to account for unequal effort in different parts of the PTLS (Ricker 1975), multiple-census estimates were made by location (Portage Lake, Torch Lake, and Sturgeon River system), where possible, which were then summed.

For the single-census estimates, all locations within the PTLS were pooled for a single estimate due to the fact that the recapture sample consisted of fish observed in the companion angler survey, and extensive movement occurred among locations during the angling season. The minimum number of recaptures necessary for an unbiased estimate was set a priori at three, and the Chapman modification of the Petersen method was used to generate population estimates (with variance) using the following formulas from Ricker (1975):

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

N_2 = single-census population estimate (numbers of legal-size fish);

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

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

R = number of recaptures in second sample.

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

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

N_a = estimated number of adult walleyes or northern pike

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

N_{leg} = number of legal-size fish caught

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

For the single-census estimates, fish that recruited to legal size during the angler survey were accounted for based on the estimated weighted average monthly growth for fish of slightly sublegal size. This was done because estimates were for the abundance of legal-size fish at time of marking (spring) and growth of fish occurred during the recapture period. It was necessary to reduce the number of unmarked fish used in the formula by the estimated number that recruited to legal size during the recapture period. For example, to make this adjustment for walleye the annual growth of slightly sublegal fish (i.e., 14.0–14.9 inch fish) was determined from mean length-at-age data. This value was then divided by the length of the growing season in months (6) and rounded to the nearest 0.1 inch. This average monthly growth was used as the criteria to remove unmarked fish that were observed in the angler survey. The largest size of a sublegal walleye at tagging was 14.9 inches; thus, an average monthly growth of 0.2 inches would result in all unmarked fish ≤ 15.1 inches caught during the first full month (June) after tagging to be subtracted from the total number of fish caught in second sample (C). 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) as the standard deviation divided by the point estimate 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 because they provided a good combination of ease of collection in the field and accuracy and precision of age estimates. Ease of collection was considered important because crews worked in cold, windy conditions, dealt with large numbers of fish, and tagged fish in addition to measuring and collecting structures. Although 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), collecting these structures would have required killing the fish, which would greatly reduce the number of marked fish at large. Additionally, since there is not consensus on the accuracy and precision of spines versus scales (Belanger and Hogler 1982; Campbell and Babaluk 1979; Erickson 1983; Kocovsky and Carline 2000; Isermann et al. 2003), spines were chosen since they likely provide more accurate ages for the oldest fish in the populations. Accurate ages for older fish were important since one goal was to estimate annual mortality. Studies have demonstrated that fin rays are a valid aging structure for a number of species (Skidmore and Glass 1953; Ambrose 1983), including northern pike (Casselman 1996), but no comparisons have been made to statistically compare accuracy and precision of fin rays to other aging structures for northern pike. Sample size goals were 20 male and 20 female fish per inch group for walleyes and northern pike and 20 smallmouth bass per inch group.

Dorsal spines and fin rays were prepared by sectioning samples using a table-mounted high-speed rotary cutting tool. Sections approximately 0.02-in thick were cut as close to the proximal end of the spine or ray as possible. Sections were examined at 40x-80x magnification with transmitted light and were photographed with a digital camera. The digital image was archived for multiple readers. Two technicians independently aged samples, and ages were considered final when independent estimates were in agreement. Samples in dispute were aged by a third technician. Disputed ages were considered final when the third technician agreed with one of the first two. Samples were discarded if three technicians disagreed on age, though occasionally an average age was used when ages assigned to older fish (≥ age 10) were within ±10% of each other.

After a final age was identified for all samples, age-length keys (Devries and Frie 1996) were constructed and weighted mean lengths-at-age were calculated. Mean growth indices were calculated by comparing the data to Michigan state averages derived using scales (Schneider et al. 2000) and spines/fin rays (DNR Fisheries Division – unpublished data). The mean growth index is the average of deviations (by age group) between the observed mean lengths and statewide seasonal average lengths.

Angler Survey

Fishing harvest seasons during this survey were May 15, 2007–February 29, 2008 for walleyes and northern pike, and May 26 through December 31, 2007 for smallmouth and largemouth bass. Minimum size limits were 15 inches for walleyes, 24 inches for northern pike, 14 inches for smallmouth and largemouth bass, and 42 inches for muskellunge. Daily bag limit was five fish in any combination of walleyes, northern pike, smallmouth bass, or largemouth bass, and one for muskellunge. Harvest was permitted all year for other species present and no minimum size limits were imposed. The daily bag limit for yellow perch was 50. The daily bag limit for “sunfish”, including black crappie, bluegill, pumpkinseed, and rock bass was 25 in any combination. The daily bag limit for lake whitefish and lake herring was 12 in combination.

Field methods–Direct contact angler surveys were conducted during the open-water period – May 15 to October 31, 2007, and the ice-cover period – January 3 through February 29, 2008. A roving-roving and aerial-roving design was used for both the open-water period and the ice-cover period (Lockwood 2000a). Two clerks working from a boat or snowmobile conducted angler interviews and made boat counts. Both aerial and ground progressive counts of fishing boats were made once per day in the summer survey, and ground progressive counts of open-ice anglers and occupied shanties were made once per day in the winter survey. Both weekend days and three randomly-determined weekdays were selected for counting and interviewing–no holidays were sampled. One of two shifts was selected each sample day. The PTLS was divided into three sections: West Portage Lake, East Portage Lake, and Torch Lake (Figure 2). Each section was sampled once per day. Starting location within a section and direction of travel were randomized for both counting and interviewing. Four possible count orders were used: marker 1 to marker 18; marker 18 to marker 1; marker 13 clockwise to marker 1, then marker 18 to marker 13; or marker 10 counter-clockwise to marker 18, then marker 1 to marker 10 (Figure 2, Table 2). Minimum fishing time prior to interviewing (incomplete-trip interview) was 1 h (Lockwood 2004; Clark et al. 2004). All roving interview data were collected by individual angler to avoid party size bias (Lockwood 1997), though the number of anglers in each party was recorded on one interview form for each party. While this survey was designed to collect roving interviews, completed-trip interviews were noted. Interview information collected included: date, fishing mode, start time of fishing trip, interview time, species targeted, bait used, number of fish harvested by species, number of fish caught and released by species, length of harvested walleyes, northern pike, and smallmouth bass, and applicable tag numbers.

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

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

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

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

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

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

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

All estimates are given with ± 2 SE, which provided statistical significance of 75 to 95% assuming a normal distribution and $N \geq 10$ (Dixon and Massey 1957). All count samples exceeded minimum sample size (10) and effort estimates approximated 95% confidence limits. Most error bounds for catch and release, and harvest estimates also approximated 95% confidence limits. However, coverage for rarely caught species is more appropriately described as 75% confidence limits due to severe departure from normality of catch rates. For walleyes, northern pike, and smallmouth bass the initial harvest estimates were expanded by adjusting for the nonsurveyed period based on the percentage of tag returns from the nonsurveyed period. Additionally, and for proper comparison with the abundance estimate, the harvest for these species was further adjusted for the percentage of sublegal fish that grew over the minimum size limit during the fishing season.

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

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

Using the first method, exploitation rate was estimated as the fraction of available reward tags returned by anglers, adjusted for tag loss. The tag loss adjustment was made by reducing the number of available reward tags by the percentage of tags lost over the course of the creel survey. Tagging mortality was assumed to be negligible as was a high (near 100%) reporting rate for reward tags on fish caught by anglers. Although actual nonreporting was not assessed (for all tags, reward and nonreward), the actual number of tag returns was compared to the expected number (X) based on the ratio:

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

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

Additionally, individual tags observed by the creel clerks were verified 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 clerks, and further reporting to the DNR was unnecessary. Tags observed by the creel clerks that were not voluntarily reported by the angler were added to the voluntary tag returns for exploitation estimates.

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

In the second and third methods, exploitation was calculated as the adjusted harvest estimate from the angler survey (H_a from above) divided by the multiple- and single-census abundance estimates for legal-size fish. The estimated annual harvest was adjusted for the nonsurveyed period based on the fraction of tag returns from the nonsurveyed period. Also, for proper comparison with the abundance estimates of legal fish as existed in the spring, the harvest estimate was reduced to account for fish that grew to legal size over the course of the creel survey. The reduction of harvest was based on the percentage of fish observed in the creel survey that were determined to have been sublegal at the time of the spring survey (See *Abundance* sub-section of the *Methods* section). Confidence limits (95%) were calculated for these exploitation estimates assuming a normal distribution, and summing the variances of the abundance and harvest estimates.

Recruitment–Since population data for fish in the PTLS were only obtained during one year, year-class strength could not be rigorously evaluated. However, I considered relative year-class strength as an index of recruitment, and used the residuals from the catch-curve regressions as indices of year-class strength (Maceina 2003). Similarly, Isermann et al. (2002) used the coefficient of determination from catch curve regressions as a quantitative index of the recruitment variability in crappie populations.

Movement–Fish movement during the spring survey was evaluated by comparing the distance between points of capture and recapture. Due to the large sample sizes and the complexity of irregular shorelines, distances between capture locations were calculated as a straight line using the haversine formula (Sinnott 1984). Fish movements were also assessed in a descriptive manner by examining the location of angling capture versus the location of initial capture at tagging. Analysis of variance was used to determine differences in minimum distance moved between sexes and among sizes at initial capture. Deviation in latitude between capture locations was used to determine north-south movement.

Results[1]

Fish Community

A total of 37,813 fish comprised of 37 species were collected in the spring survey (Table 3). Total sampling effort was 46 trap-net lifts, 443 fyke-net lifts, 4 electrofishing runs, and one ¼-arc seine haul made with a trap-net lead. The total catch included 5,699 walleyes, 1,965 northern pike, and 115 smallmouth bass, which made up approximately 15%, 5%, and 0.3% of the total catch, respectively. Other abundant fish species collected in order of abundance of total catch were: brown bullhead, white sucker, redhorse sucker species, and smelt. The overall fish community composition was 66% benthivores, 21% piscivores, and 13% pelagic planktivores-insectivores (Table 3).

Size Structure and Sex Ratio

The percentages of legal-size walleyes, northern pike, and smallmouth bass were 97, 43, and 88, respectively (Table 4). The population of spawning walleyes exhibited a rather normal length distribution, with a peak around 21 inches. The largest walleye collected was 30.7 inches and 8% of all walleyes were greater than 25 inches (memorable size; Gabelhouse 1984). The population of spawning northern pike was dominated by 20- to 25-inch fish, with the peak of the distribution occurring at 22 inches. Memorable-size northern pike (≥ 34 in) were relatively abundant, making up 6% of the total catch. Few smallmouth bass were caught, but the distribution ranged from 12 to 21 inches, with a peak at 15 inches. The male:female ratio was 3.4:1 for legal-size walleyes and was 3.5:1 for adult walleyes. Three percent of all walleyes were of unknown sex. Male northern pike outnumbered females by a ratio of 1.4:1 when all sizes were considered and by a ratio of 1.3:1 when fish of legal size were considered. Six percent of all northern pike were of unknown sex.

Abundance

Crews placed a total of 4,777 tags on legal-size walleyes (2,685 reward and 2,092 nonreward tags) and in total marked (with jaw tag or fin clip) 4,840 adult walleyes. One recaptured walleye died, and fifteen lost their tag during the spring netting survey; thus, the effective number tagged (M) was 4,761. The angler survey clerk observed a total of 1,075 walleyes, of which 102 were marked (R; had a fin clip, or a tag). The initial C was reduced by 172 (16%) to adjust for sublegal fish that grew over the minimum size limit during the fishing season (final C = 903). For walleyes, multiple-census population estimates were made for Portage Lake and Torch Lake, which were then summed. An individual estimate for the Sturgeon River system was not possible due to the low number of walleyes marked there so these fish were included in the estimate for Portage Lake. The estimated number of legal-size walleyes was 16,911 by the multiple-census method and 41,795 by the single-census method (Table 5). The estimated number of adult walleyes was 17,147 by the multiple-census method, and 42,231 by the single-census method. The coefficient of variation was 0.06 for both of the multiple-census estimates, and was 0.09 for both of the single-census estimates.

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

Crews placed a total of 738 tags on legal-size northern pike in the PTLS (285 reward and 453 nonreward tags) and in total marked 1,638 adult northern pike. Twenty-four recaptured northern pike lost their tag during the spring netting; thus, the effective number tagged (*M*) was 714. The creel clerk observed 164 northern pike, of which 11 were marked (*R*; had a fin clip, or a tag). The initial *C* was reduced by 43 (26%) to adjust for sublegal fish that grew over the minimum size limit during the fishing season (final *C* = 121). For northern pike, multiple-census population estimates were made for: 1) the Sturgeon River system, and 2) Portage and Torch lakes combined, which were then summed. An individual estimate for Torch Lake was not possible due to the low number of recaptures there. The estimated number of legal-size northern pike was 2,740 (CV = 0.23) by the multiple-census method, and was 7,269 (CV = 0.26) by the single-census method. The estimated number of adult northern pike was 7,370 (CV = 0.24) by the multiple-census method and 16,006 (CV = 0.26) by the single-census method (Table 5).

Crews tagged 96 (*M*) legal-size smallmouth bass in the PTLS (66 reward and 30 nonreward tags). No recaptured smallmouth bass died or lost their tag during the spring netting. The creel clerk observed 116 smallmouth bass, of which none were marked (*R*; had a fin clip, or a tag). The initial *C* was reduced by 6 (5%) to adjust for sublegal fish that grew over the minimum size limit during the fishing season (final *C* = 110). The minimum number of recaptures was not obtained during the spring netting (R = 1) to make a multiple-census estimate, nor during the angler survey for a single-census estimate.

Growth–Technicians aged 460 walleyes (Table 6), 597 northern pike (Table 7), and 88 smallmouth bass (Table 8). The overall mean growth index for walleyes was +1.9 when compared to the statewide average derived using dorsal spines. Walleye mean lengths-at-age were higher than the statewide averages for all ages, with the deviations increasing from age 2 to age 5, and then leveling out or decreasing from ages 6 to 10 (Table 9). Females had higher mean lengths-at-age than males across all ages. For northern pike, the overall mean growth index was +1.2 when compared to the statewide average derived using dorsal fin rays. Mean lengths-at-age were higher than the statewide average for all ages except age 1 and 8 (Table 10), and female northern pike had higher mean lengths-at-age than males. Smallmouth bass had higher mean lengths-at-age than the statewide average for all ages except age 9, and the mean growth index was +0.7.

Angler Survey

Open-water period–Clerks interviewed 2,085 anglers during the open-water period on the PTLS with most (88%) interviews consisting of incomplete fishing trips. Although the open-water fishery on the PTLS was diverse, it was clearly directed at major predator species. Anglers fished an estimated 31,206 hours during the open-water period and caught a total of 16,380 fish, comprising 15 species (Table 11). Walleyes were the most numerous, making up 29% of the catch by number. Anglers released 27% of all walleyes caught. Smallmouth bass were the second most frequently caught species, making up 28% of the catch by number. Contrary to walleyes, most (90%) smallmouth bass caught were released. Yellow perch and northern pike followed in catch by number, making up 17% and 13%, respectively. Anglers reported releasing 72% of yellow perch and 85% of northern pike. Overall, open-water harvest was dominated by walleyes, yellow perch, and smallmouth bass, which accounted for 84% of the total harvest. Lake sturgeon were detected in the angler catch, with an estimated 5 being caught and released in May and June.

Walleyes were the most sought after species during the open-water period. Of those anglers who reported targeting a species other than "anything", 78% were targeting walleyes, 13% were targeting northern pike, and 6% were targeting bass. Open-water walleye catch rates averaged 0.154 fish per hour (range = 0.005 to 0.190). Walleye catch rates were relatively consistent from June through August, ranging from 0.170 to 0.190 fish per hour while catch rates in September (0.046) and October

(0.005) were much lower. Catch rates for northern pike were lower than for walleyes, averaging 0.068 fish per hour during the open-water period, but smallmouth bass catch rates were similar to those for walleyes, averaging 0.145 fish per hour. Catch rates for smallmouth bass were rather consistent throughout the open-water period, with the exception of October which was more than twice that of the next highest catch rate (Table 11).

Ice-cover period–The fishery during the ice-cover period on the PTLS was not as diverse as the open-water period, though it was still dominated by predator species. Clerks interviewed 747 anglers during the ice-cover period, most (90%) of which had not completed their fishing trips. Anglers fished 11,518 hours (Table 11) and caught a total of 1,501 fish, comprising nine species. Angler catch was dominated by walleyes and northern pike, which accounted for 86% by number. Northern pike were the most sought after species during this period. Of those anglers that reported targeting a species other than "anything", 57% targeted northern pike, 42% targeted walleyes, and 1% targeted panfish species. Both the catch and harvest rates for walleyes were about 1/3 of those observed during the open-water period. For northern pike, the overall catch rate was similar between the ice-cover and open-water periods, but the harvest rate was almost three times higher during the ice-cover period. The catch rate for smallmouth bass was 300 times higher during the open-water period. Anglers released 9% of all walleyes and 63% of all northern pike caught. Lake sturgeon were again detected in the angler catch, with an estimated 38 being caught and released.

Annual period–For both open-water and ice-cover periods (May 15 to October 31, 2007 and January 3 to February 29, 2008), anglers fished 42,724 hours on the PTLS. Angler effort peaked in August and varied substantially throughout the year. Of the total annual fishing effort, 73% occurred during the open-water period and 27% occurred during the ice-cover period. Daily fishing effort was slightly higher for ice-cover than for open-water period (199 versus 184 h/d). Walleyes were the predominant species caught (harvested + released), followed by smallmouth bass, northern pike, and yellow perch. Catch rates for walleyes, smallmouth bass, and northern pike were 0.124, 0.106, and 0.068 fish per hour, respectively. Catch rates were calculated with general effort, not targeted effort, and are therefore not necessarily indicative of the rate that an angler targeting one species may have experienced. Anglers released 25% of all walleyes, 79% of northern pike, and 90% of smallmouth bass caught.

The total annual harvest was 6,339 fish, which was predominantly walleyes (62%), yellow perch (12%), and northern pike (10%). There was no angler survey during November and December, because it was thought that relatively little fishing occurred during that time of year, and ice conditions were unsafe. However, 1.6% of walleye and 4.8% of northern pike tag returns were reported as being caught during this nonsurveyed period so the actual harvests for walleyes and northern pike could have been about 1.6% (4,007) and 4.8% (644) higher than what we estimated, respectively. No smallmouth bass were reported as being harvested during the nonsurveyed period. After being further adjusted for the percentage of sublegal fish that grew over the minimum size limit during the fishing season (see *Abundance* section), the total expanded harvest (H_a) for walleye, northern pike, and smallmouth bass was 3,336, 475, and 419 fish, respectively.

Mortality–Ages 4 and older fish were used in the catch-curve analyses to represent the legal-size male walleye population, and ages 6 and older were used for legal-size females and all legal-size walleyes (Figure 3; Table 12). The catch-curve regressions were all significant ($P < 0.05$) and produced total annual mortality rates of 25%, 21%, and 29% for males, females, and all walleyes, respectively. Anglers returned a total of 485 tags (306 reward and 179 nonreward) from harvested walleyes, and 18 tags (11 reward and 7 nonreward) from released walleyes in the year following tagging (Tables 5 and 13). Additionally, 19 (7 reward and 12 nonreward) tagged walleyes in the possession of anglers were observed during the creel survey that were not subsequently reported. The creel clerks did not observe any recaptured walleyes that had lost tags during the angler survey; thus, a tag loss rate of 5% was applied based on previous Large Lake Program surveys. The reward tag return estimate of annual exploitation of walleyes was 12.3% after adjusting for tag loss (Table 5). Anglers reported reward tags at a higher rate (11.9% versus 8.9%), but the number of tags from harvested fish voluntarily returned by anglers (485) was higher than the expected number of returns (380) based on the ratio described previously in the Methods section. Based on all tagged walleyes caught, the reported release rate was 3.4%. The estimated exploitation rate for walleyes was 19.9% based on dividing harvest by the multiple-census abundance estimate, and 8.1% based on dividing harvest by the single-census abundance estimate (Table 5).

Ages 4 and older fish were used in the catch-curve analyses to represent the legal-size northern pike population (Figure 4). The catch-curve regressions were all significant ($P < 0.05$) and produced total annual mortality rates of 44%, 39%, and 43% for males, females, and all northern pike, respectively. Anglers returned a total of 70 tags (30 reward and 40 nonreward) from harvested northern pike, and 12 tags (6 reward and 6 nonreward) from released northern pike in the PTLS in the year following tagging. Additionally, 3 (nonreward) tagged northern pike in the possession of anglers were observed during the creel survey that were not subsequently reported. The creel clerks observed three recaptured northern pike that had lost tags during the angler survey; thus, annual tag loss was 27%. The reward tag return estimate of annual exploitation of northern pike was 15.2% after adjusting for tag loss (Table 5). Anglers reported reward tags at a higher rate (13.2% versus 10.4%), but the number of tags voluntarily returned by anglers (70) was higher than the expected number of returns (43) based on the ratio described previously in the Methods section. Based on all tagged northern pike caught, the reported release rate was 14.1%. The estimated exploitation rate for northern pike was 17.3% based on dividing harvest by the multiple-census abundance estimate, and 6.5% based on dividing harvest by the single-census abundance estimate (Table 5).

Ages 4 and older fish were used in the catch-curve analyses to represent the legal-size smallmouth bass population (Figure 5). The catch-curve regression was significant ($P < 0.05$) and resulted in a total annual mortality rate of 23%. Anglers returned a total of 14 tags (12 reward and 2 nonreward) from harvested smallmouth bass, and 2 tags (reward) from released smallmouth bass in the PTLS in the year following tagging. The creel clerks did not observe any recaptured smallmouth bass that had lost tags during the angler survey; thus, an annual tag loss rate of 5% was applied based on previous Large Lake Program surveys. The reward tag return estimate of annual exploitation of smallmouth bass was 19.1% after adjusting for tag loss (Table 5). Anglers reported reward tags at a higher rate (21.2% versus 6.7%). An expected number of tag returns could not be calculated since there were no recaptured smallmouth bass observed in the creel survey. Based on all tagged smallmouth bass caught, the release rate was 12.5%. Exploitation rates based on dividing harvest by the abundance estimates could not be made since the abundance estimates were not valid.

Recruitment–Walleyes in the PTLS exhibited variable year-class strength, while northern pike and smallmouth bass had more consistent recruitment. Walleyes were represented by 18 year classes (ages 2 – 18, and 20), with an r^2 value from the catch curve regression of 0.64 (Figure 3). Thus, annual mortality alone only explained 64% of the variation in the abundance of individual year classes. Much of the apparent recruitment variability was due to the 1997-2000 walleye year classes, which were poor. While the number of walleyes stocked in the PTLS was not significantly related to the residuals from the catch curve regression ($F = 0.52$, $P = 0.48$, $df = 14$), three of the five poor year classes occurred in years when few or no walleyes were stocked. Northern pike were represented by 12 year classes (ages 1 -12) with an r^2 of 0.90, and smallmouth bass were represented by fourteen year classes (ages 3 through 16) with an r^2 of 0.90.

Movement–Based on recaptures during the spring survey, the majority of walleyes and northern pike were recaptured in the same general location where they were tagged (Tables 14 and 15). There appeared to be a trend for movement to the Portage Canal since approximately 11% of walleyes and

45% of northern pike tagged in Portage Lake were subsequently recaptured in the Portage Canal. However, 20% of walleyes and 27% of northern pike moved in the opposite direction from the Portage Canal to Portage Lake. Of all the walleyes recaptured during the spring survey, the distance between points of initial capture and recapture averaged 1.3 miles (median = 0.4) with a maximum of 24.6 miles. Movement did not strongly follow either latitudinal direction, with 54% of recaptures taking place north of their initial capture location and 46% being south. Longitudinal movement also did not favor either direction, with 45% of recaptures taking place west of their capture location and 55% being east. Distance between capture locations for northern pike averaged 1.4 miles (median = 0.5 miles) with a maximum of 24.2 miles. Similar to walleyes, northern pike movement did not follow any strong latitudinal direction, with 53% of recaptures taking place north of their initial capture location and 47% being south. Longitudinal movement also followed no trend, with 51% of recaptures taking place west of their capture location and 49% being east. Overall, movement detected during the spring survey did not reveal anything particularly notable about the walleye and northern pike populations in the PTLS.

Based on angler tag returns received through the time this report was written the majority of walleyes tagged in Portage Lake remained there, while the majority of walleyes tagged in Torch Lake moved into Portage Lake. Of walleyes tagged in Portage Lake, 88% were captured in there, with 10% of them caught from elsewhere in the PTLS, and the remaining caught from Lake Superior and its tributaries (Figure 7, Table 16). In contrast, the majority (57%) of Torch Lake walleyes were recaptured in Portage Lake, with only 40% being captured in their native lake. Overall, only 3% of tag returns were from Lake Superior and connecting waters outside of the PTLS. Walleyes that moved outside of the PTLS were recaptured in Keweenaw Bay, L'Anse Bay, four different tributaries to Lake Superior (Brule, Ontonagon, and Montreal rivers, and Lac La Belle), and in the Apostle Islands of Wisconsin (Figure 7). One walleye tagged in the Portage Canal was caught by an angler in the Snake River, a tributary to the Portage River. Of all the walleyes recaptured by anglers, the distance between points of initial capture and recapture averaged 5.0 miles (median = 3.7) with a maximum of 100 miles (straight line). Movement did not strongly follow either latitudinal direction, with 44% of recaptures taking place north of their initial capture location and 56% being south. Longitudinal movement favored a westerly direction, with 76% of recaptures taking place west of their capture location and 24% being east. The distance between initial capture and recapture locations for walleyes differed by sex (Z = 3.195, P = 0.001, df = 623), but the minimum distance moved per day did not (Z = 1.447, P = 0.148, df = 623). Furthermore, the minimum distance moved was not related to length at tagging (r = 0.033, P = 0.407, N = 624).

The only obvious trend in movement for northern pike was from the Sturgeon and Portage rivers into Portage Lake (Table 17). Most (86%) northern pike tagged in Portage Lake were recaptured there, with the remaining returns spread out through the PTLS and Lake Superior. Overall, only 6% of tag returns were from Lake Superior and connecting waters outside of the PTLS. The farthest movement of a northern pike tagged in the PTLS was to Agate Harbor in Lake Superior (south-west of Copper Harbor), a distance of at least 45 miles in the most direct route for travel. There were 22 tag returns from smallmouth bass tagged in Portage Lake and returns came from Portage Lake (55%), the Sturgeon River System (32%), Torch Lake (9%), and the Portage River (4%).

Discussion

Fish Community

Numerous surveys have been conducted on the PTLS utilizing various gears at different times of the year. Although this lack of standardization makes comparisons difficult, changes related to the sauger and walleye populations are apparent. Saugers were historically one of the dominant predators in the PTLS and were collected in good numbers in the 1950's, 1960's, and early 1970's. In 1960 biologists believed the population was experiencing a low point due to several poor year classes, and they established a possession limit of 20, when there was previously none. This apparent decline in recruitment was most likely the beginning of the demise of the sauger population. In 1968, harvest regulations for saugers were further restricted with a 13-inch minimum size limit and a possession limit of five. As late as the early 1970's adult saugers were still relatively abundant, and many collected in a 1971 survey exceeded the state record. However, gill-net catch per unit effort of saugers between 1971 and 1979 declined 6-fold and age frequencies from 1971, 1974, and 1979 indicated little recruitment since around 1970. The last time saugers were collected in the PTLS was in 1980, and a few years later no saugers were caught in surveys of the PTLS. The disappearance of saugers was thought to be a result of contaminants, degraded spawning substrate, and poor recruitment due to lower turbidity from the cessation of mining operations. It is not clear how saugers would decline as the turbidity associated with mining was alleviated since presumably they were present prior to mining. The last effort to re-establish the sauger population was made in 1988 by stocking fry, though it was unsuccessful.

Although the demise of saugers in the PTLS was undesirable, the walleye population most likely benefited and filled the niche left open by saugers. Initial attempts at stocking walleye fry had taken place in the PTLS from 1904-06, in 1935, and in 1942, while yearling walleyes were stocked in 1943 (Laarman 1976). The success of these initial stocking efforts was not evaluated, but gill-net catch per unit effort of walleyes was relatively constant from 1955-1970 (Laarman 1976). While there was a 6-fold decrease in the relative abundance of saugers from 1971 to 1979, the relative abundance of walleyes increased 3 times over the same period. Still, the walleye population did not appear to have consistent recruitment and stocking resumed in 1987. In the early 1990's fall surveys demonstrated successful stocking; thus, stocking continued through 2005 when it was terminated due to concerns over viral hemorrhagic septicemia in the Great Lakes.

Besides the changes with saugers and walleyes, the overall fish community in the PTLS today is similar to that described by Laarman (1976) for Portage Lake. Some minnow species that had been collected in the past have not been collected recently (Appendix), though recent surveys using small-mesh seines have not been extensive. Also, muskellunge (N = 17) were collected in the spring of 1954 and again in 1973, though we did not collect any in 2007 even with the large amount of effort. One addition to the PTLS fish community recently has been the invasion by the nonnative ruffe which was first detected in 2002, and was again collected in 2004 and 2007. It should be noted that although brown bullheads are still abundant in the PTLS, their relative abundance was likely overestimated in 2007. The majority of brown bullheads were collected in Dollar Bay, with some nets having well over 1,000 bullheads. Since the bullheads were released into Dollar Bay, which is segregated from Portage Lake by a narrow canal, we likely re-captured the same fish multiple times. This would have also biased the proportion of benthivores calculated from the total catch. Overall, the 2007 survey showed a diverse and well-balanced fish community in the PTLS.

Size structure and growth–There have been few surveys conducted on the PTLS during the walleye spawning season to use for comparisons of size structure. A few gill-net surveys collected ample number of walleyes, but the issue of gear selectivity precludes proper comparison. However, from comparisons to other walleye populations in large lakes, it is apparent that the walleye population of the PTLS has relatively high size structure. The current size structure of walleyes in the PTLS (97% legal size) was well above the median (71%) and mean (71%) of legal-size walleyes in spring surveys for 20 populations surveyed under the Large Lakes program. Similar walleye size structure was also observed in other large lakes connected to the Great Lakes (Hanchin 2011, Hanchin et al. 2007). The high size structure is likely a result of the abundant prey species in both the PTLS and Lake Superior. Abundant prey fishes similarly contribute towards the high size structure of northern pike, though given the abundance of small northern pike collected in the Sturgeon River system, the percentage of legal-size fish does not accurately reflect the abundance of large northern pike in the PTLS. A better metric for assessing the size structure of northern pike is proportional size structure (PSS_Q; Guy et al. 2006), for which northern pike had a measure of 70. While Anderson and Weithman (1978) recommended a range of 30-60 for a balanced northern pike population, this recommendation is not necessarily suitable for the PTLS since it is connected to the relatively productive waters of the Great Lakes. In other words, the high size structure of the northern pike population is a result of abundant prey in Lake Superior, and is not necessarily due to density-dependent factors.

The high size structure of walleyes and northern pike on the PTLS is a direct reflection of the growth exhibited by these species. Mean lengths-at-age for both walleyes and northern pike were well above the statewide average and were similar to previous surveys on the PTLS (Tables 9 and 10). Although the mean lengths-at-age for walleyes appear to have changed over the years, it would not be prudent to interpret this as true change given the low sample sizes of some age groups and years. The superior growth of walleyes and northern pike in the PTLS results from the abundant prey base in both the PTLS and the nearshore waters of Lake Superior. The PTLS has abundant populations of bullhead, trout perch, suckers, and at times alewives and smelt. Similar walleye growth was observed for Lake Charlevoix (Hanchin, 2015) and Muskegon Lake (Hanchin et al. 2007), which are both open to Lake Michigan.

Abundance–One of the initial goals of the Large Lakes Program was to compare different methods for estimating the abundance of walleyes and northern pike. The results from the PTLS were consistent with the trend that has been observed in previous surveys (Clark et al. 2004; Hanchin et al. 2005a, b, c; Hanchin and Kramer 2007). That is, the multiple-census estimates for both walleyes and northern pike were much lower than the single-census estimates for both legal-size fish and adult fish. Multiple-census estimates made during the onshore spawning migration of species such as walleyes and northern pike are likely biased low due to size selectivity and unequal vulnerability of fish to near-shore netting (Pierce 1997). Additionally, they have the potential problem of incomplete mixing, which is not a problem with the single-census method since it allows sufficient time for marked fish to fully mix with unmarked fish. In comparing surveys conducted similarly to ours, Pierce (1997) concluded that recapturing fish at a later time with a second gear type resulted in estimates that were more valid. And while the single-census estimate did not necessarily compare better to the independently-derived exploitation estimate as was the case with most previous surveys, this was likely due to differences in the actual areas surveyed. That is, the exploitation estimate from tag returns incorporated tagged fish caught from anywhere in the PTLS and connected waters, while the creel survey only incorporated harvest in Portage and Torch Lakes proper (did not include the majority of the Portage canal, Portage River, or Sturgeon River). Thus, based on comparisons with the independently-derived creel estimates, and the more rigorous evaluation by Pierce (1997), the single-census estimates are considered more accurate than the multiple-census ones for the PTLS.

The single-census estimates for walleyes were also compared to the predicted abundance from four regression equations--two developed from Wisconsin lakes (Hansen and Hennessy 2006), and two from Michigan lakes (DNR Fisheries Division -- unpublished data). These equations predict legal size or adult walleye abundance based on lake size and were derived from historic abundance estimates made in each state over the past 20-25 years. The following equation for adult walleyes in Michigan was based on 31 abundance estimates:

$$\ln(N) = 0.2979 + 1.0554 \times \ln(A),$$

$$r^2 = 0.80, \qquad P < 0.0001,$$

where N is the estimated number of adult walleyes and A is the surface area of the lake in acres. For the PTLS, the equation gives an estimate of 30,108 adult walleyes, with a 95% prediction interval

(Zar 1999) of 5,507 to 164,607. The equation for adult walleyes in 1842-Treaty-ceded territory of Wisconsin lakes (in 2006) in which natural reproduction is the primary recruitment source was based on 193 estimates:

$$\ln(N) = 01.5086 + 0.9572 \times \ln(A),$$

$$r^2 = 0.77, \qquad P < 0.0001.$$

The equation gives an estimate of 39,786 walleyes, with a 95% prediction interval of 12,659 to 125,044 for the PTLS. The equation for adult walleyes in 1842-Treaty-ceded territory of Wisconsin lakes in which stocking is the primary recruitment source was based on 135 estimates:

$$\ln(N) = 01.0987 + 0.8831 \times \ln(A),$$

$$r^2 = 0.61, \qquad P < 0.0001.$$

The equation gives an estimate of 13,066 walleyes, with a 95% prediction interval of 2,910 to 58,659 for the PTLS. The equation for legal walleyes in Michigan was based on 32 estimates:

$$\ln(N) = 0.5423 + 0.9794 \times \ln(A),$$

$$r^2 = 0.74, \qquad P < 0.0001.$$

The equation gives an estimate of 18,692 legal walleyes, with a 95% confidence interval of 3,899 to 89,597 for the PTLS.

The single-census estimate of legal walleye abundance was much higher than the estimate from the Michigan regression equation, indicating that the walleye population in the PTLS is rather different than the populations used to derive the equation. The primary reason for the difference is that the PTLS is a Great Lakes population, while most of the populations used in the regression equation were from inland lakes. A secondary reason for the disparity is that the area of the western upper peninsula around the PTLS has a surficial geology that results in abundant walleye spawning habitat in many lakes. In contrast, many of the populations used in the Michigan regression equation were from the lower peninsula, where walleye spawning substrate is often more limited. The equation that had the best agreement with the empirical abundance estimate for the PTLS was the Wisconsin equation for lakes with natural reproduction (Table 5). The prediction from this equation was only 6% lower than the empirical estimate for adult walleyes. Thus, the Wisconsin equation would be an appropriate surrogate for a current empirical estimate as long as the stocking and/or recruitment patterns in the PTLS do not change to any large degree.

The current population density of walleyes in the PTLS was at or above average compared to other walleye lakes in Michigan. The single-census estimate for 15-in-and-larger walleyes in the PTLS was 3.2 per acre. Density of legal-size walleyes estimated recently for twenty large lakes in Michigan has averaged 2.0 fish per acre (range = 0.4 to 4.6 fish/acre), though the median (1.8 fish/acre) is a better measure of central tendency for these data (DNR unpublished data). Population density of adult walleyes (3.2 fish/acre) was equal to the average (3.2 fish per acre) though higher than the median (2.4 fish/acre) from 20 populations surveyed in the Large Lakes Program. Density was also higher than the average (2.2 adult walleyes/acre) for 131 northern Wisconsin lakes having natural reproduction (Nate et al. 2000). It is worth noting that the single-census estimate of adult walleye abundance was not a true mark-recapture estimate since it was essentially an estimate for legal-size walleyes that was adjusted to account for sub-legal mature walleyes that were on the spawning grounds. It is uncertain how this would compare to a true mark-recapture estimate of adults, but if the catchability (in nets and by angling) of sub-legal adult walleyes was similar to legal-size walleyes, the estimate should be relatively unbiased as compared to a true mark-recapture estimate of adult walleyes.

Abundance estimates for northern pike were successful, and for the same reasons explained for walleyes the single-census estimates are considered more accurate than the multiple-census ones. The single-census estimate for legal-size northern pike converts to a density of 0.6 per acre, which is well above the average (0.2) and median (0.1) estimated recently in the Large Lakes Program. Similarly, the density of adult northern pike (1.2 fish/acre) was also above the average (0.9) and median (0.6) estimated recently in the Large Lakes Program. The higher northern pike density observed in the PTLS is primarily a result of the abundant spawning habitat and abundant prey.

Angler Survey

Summary–The fishery of the PTLS is dominated by walleyes, northern pike, and smallmouth bass, though there is some diversity resulting from the connection to Lake Superior. A fishery exists for panfish species, though the effort directed towards panfish is not nearly as high as that directed towards predator species. Harvested walleyes greatly outnumbered released walleyes, which is a result of the relatively high size structure, and harvest mentality of most walleye anglers. Although no differentiation was made between sub-legal and legal-size released fish, it was assumed that a large proportion of the released walleyes were sub-legal. Although a much higher proportion of the northern pike caught were subsequently released, it is not a straightforward assumption that the most released northern pike were sub-legal, since a relatively high percentage of legal-size northern pike were released (based on tag returns). Walleyes were overwhelmingly the target species during the open-water period, though northern pike were targeted slightly more during the ice-cover period. Overall, the open-water period accounted for the majority (73%) of the annual effort, though daily effort was actually higher during the ice-cover period.

Historical comparisons–There have not been any other comprehensive creel surveys conducted on the PTLS, though conservation officers occasionally interviewed anglers in the 1950's and 1960's, and a mail survey was conducted in the early 1970's estimating angler effort. Total annual angling effort on Portage and Torch lakes estimated with mail surveys in 1971 and 1973 was 10,990 and 29,700 angler days. To compare these estimates with that observed in 2007-08, the current average number of trips per day (1.2 trip/day; DNR Fisheries Division – unpublished data) and the average length of a completed trip (3.9 h/trip for the annual period) from the 2006-07 angler survey were multiplied to estimate the average length of an angler day (1.2 * 3.9 = 4.7 angler hours). Thus, the 1970 and 1973 estimates are 51,653 and 139,590 hours of fishing effort, respectively. These estimates indicate that the fishing effort during 1970's was much higher than the 2006-07 estimate (42,724 total angler hours) or the two two estimation methods are not directly comparable.

In addition to possible changes in angler effort, changes in the species composition are noticeable, which reflect the changes in the fish community. Laarman (1976) reported results from generalized creel surveys conducted by conservation officers on Portage Lake from 1951 to 1964; however, the surveys were only designed to measure the success of those interviewed. During this broad range of years anglers caught mostly yellow perch and sauger, which comprised from 59-69%, and 10-27% of the total harvest, respectively. The general creel survey on the PTLS was similar between the periods from 1951-57 and 1958-64, with the exception being sauger, which made up less than ½ of the composition in the latter half of this period. Walleyes made up less than 3% of the total harvest during these creel survey periods, while they made up 62% of the harvest in 2007-08. Thus, the trends observed in the angler catch appear to mirror the trends observed in netting surveys. That is, as the sauger population declined, the walleye population increased. It is not clear why yellow perch made up such a large portion of the angler harvest from 1957-1964. Perhaps more anglers targeted yellow perch, or yellow perch were simply more abundant during a time when saugers were decreasing in abundance.

Comparison to other large lakes–In addition to the historic angler survey data for the PTLS, comparisons with angler surveys from other large lakes are useful. An estimated 42,724 angler hours occurred on the PTLS during the angler survey, which corresponds to 3.2 hours per acre. This is well below the mean and median values for other lakes surveyed under the Large Lakes Program (Table 18), but perhaps expected given the lower population density around the PTLS and its distance from major cities. The harvest per acre (0.5) of all fish species in the PTLS was also well below the mean and median values for other large lakes, though this is largely due to the fact that angler effort was directed primarily at walleyes, northern pike, and smallmouth bass. Michigan lakes with a high harvest per acre generally have popular bluegill/sunfish fisheries that bolster the total harvest.

Overall, the walleye fishery in the PTLS is impressive, offering anglers the opportunity to experience high catch rates and large walleyes. The estimated annual harvest from the PTLS was 0.3 walleyes per acre, which is below the average (0.5 per acre) and median (0.4 per acre) for twenty populations surveyed as part of the Large Lakes Program. The average harvest of six other large Michigan Lakes (>1,000 acres) reported by Lockwood (2000a) was 0.63 walleyes per acre, ranging from 0.09 for Brevoort Lake to 1.68 for Chicagon Lake. These Michigan lakes were subject to similar gears and fishing regulations, including a 15-in-minimum size limit. The lower harvest per acre of walleyes in the PTLS is a result of the lower angler effort, the large size of the lake, and the migratory nature of the population since density and catch rates were above average. The harvest per hour (0.09) for walleyes was more than twice the average (0.04) and median (0.04) values, and the catch rate of all walleyes (0.12 per hour) was also higher than the average (0.11 fish/hour) and median (0.09 fish/hour) values from other populations surveyed under the Large Lakes Program.

The fishery for northern pike in the PTLS was also above-average in most categories. The estimated annual harvest was 0.05 fish per acre, which was between the average (0.08) and median (0.03) values from populations (having a 24-in minimum size limit) sampled in the Large Lakes Program. The average harvest of seven other large Michigan lakes (>1,000 acres) was 0.15 northern pike per acre, ranging from 0.002 per acre in Bond Falls Flowage to 0.65 per acre in Fletcher Pond (Lockwood 2000b). These lakes were also subject to similar gears and fishing regulations, including a 24-in minimum size limit. Elsewhere, Pierce et al. (1995) estimated harvests from 0.7 to 3.6 per acre in seven smaller Minnesota lakes, which ranged from 136 to 628 acres in size and had no minimum size limit for northern pike. Although the harvest per acre of northern pike in the PTLS was average, given the relatively high density of legal-size northern pike, harvest per acre would likely have been much higher if the angler effort was higher. Although harvest per acre was average, the harvest per hour (0.014) for northern pike was at least twice the average (0.007) and median (0.005) values from other large lake populations. Similarly, the catch rate of all northern pike (0.07 fish/hour) was also higher than the average (0.05 fish/hour) and median (0.04 fish/hour) values from other populations surveyed under the Large Lakes Program.

Although a valid estimate of smallmouth bass abundance was not made, if the catch rate is any indication of abundance, the population is above average. The average open-water catch rate for smallmouth bass from 18 lakes sampled in the Large Lakes Program was 0.08 per hour (median = 0.06 fish/hour); thus, a rate of 0.15 per hour for the PTLS is about twice the average catch rate. Since these catch rates are calculated with general effort, the value for each lake may be biased low if smallmouth bass are not highly targeted. That could be the case with the PTLS where only 6% of open-water anglers were targeting smallmouth bass. The estimated annual harvest of smallmouth bass was 0.03 fish per acre, which was below the average (0.10) and median (0.07) from lakes sampled in the Large Lakes Program. The average harvest of eight large (>1,000 acres) Michigan lakes was 0.08 smallmouth bass per acre, ranging from 0.03 in Brevoort Lake to 0.15 in Elk Lake (Lockwood 2000b). These lakes were all subject to similar gears and fishing regulations, but the surveys did not always include the entire open-water period. As was the case for walleyes and northern pike, the relatively low harvest per acre of smallmouth bass is mainly due to the overall lower angler effort, but the fact that few anglers target smallmouth bass is also a cause.

Mortality–Total annual mortality for walleyes in the PTLS was low compared to the average (40%) and median (41%) values for populations surveyed in the Large Lakes Program. Additionally, it was lower than the total annual mortality of mature walleyes (42%) in the St. Louis River, a nearby tributary to Lake Superior (Schram et al. 1992). However, the regression was highly affected by several weak year classes, making it difficult to be confident in the mortality estimate. In fact, mortality may have actually differed across age groups. When a separate catch curve regression was conducted on ages 14-20, the resulting annual mortality was 52%, or almost double the number calculated for all age groups of legal size. The age-14 through -20 walleyes are generally 26 in and larger. To see if fishing mortality was actually higher for older age groups, I calculated exploitation by inch group and found that exploitation on walleyes 26 inches or larger was noticeably higher than that for walleyes from 21 to 25 inches (Figure 8). Thus it appears that the higher total mortality observed on older walleyes could be due to higher fishing mortality. A similar trend was observed by Hanchin (2011) for walleyes in Lake Gogebic, though the higher exploitation was observed on walleyes 22 inches and larger. If total annual mortality in the PTLS is actually closer to 52%, it would exceed the recommended mortality cap of 45% in the rehabilitation plan for Lake Superior walleye populations (Hoff 2002) even though the PTLS was not considered a population that required rehabilitation. Although there appeared to be relatively higher exploitation on older walleyes in the PTLS, the overall exploitation of walleyes (12.3%) was similar to median value (11.8%) from other populations sampled in the Large Lakes Program.

Total mortality of northern pike in the PTLS (43%) was below the average (50%) and median (48%) values from northern pike populations surveyed as part of the Large Lakes Program, but was within the range (35% to 65%) for the majority of North American lakes summarized by Pierce at al. (1995). Additionally, angler exploitation was not excessive and accounted for less than one-half of the total mortality. The mean and median exploitation rates for northern pike from Large Lake Program surveys to date are 16.7% and 15.2%, respectively. Interestingly, the variation among the three estimates of northern pike exploitation for the PTLS elucidated some potential biases in the harvest estimate for northern pike. First, the method of estimating exploitation by dividing harvest by abundance is not necessarily valid when the area surveyed for the abundance estimates differs from the area surveyed to estimate harvest. This was the case for the PTLS since the abundance estimates incorporated fish in the entire PTLS, while the creel survey did not include the majority of the Portage Canal, Portage River, or Sturgeon River. Thus, the exploitation estimates derived using this method would undoubtedly be biased low. This is obvious with the exploitation estimate derived by dividing harvest by the single-census abundance estimate, but it is not as obvious with the multiple-census estimate. As previously mentioned multiple-census methods underestimate the abundance of spawning northern pike (Pierce 1997). This underestimation of abundance using multiple-census methods has resulted in exploitation estimates that were on average 250% higher than tag-return estimate in other Large Lake Program surveys. In the PTLS the estimate derived using the multiple-census abundance estimate was only 14% higher. Thus, the similarity between the tag-return estimate and the estimate derived from dividing harvest by the multiple-census abundance likely resulted from the low bias of the abundance estimate being countered by the low bias of the harvest estimate for northern pike.

Smallmouth bass in the PTLS were not sampled in great abundance since the timing of the survey was too early for their onshore migration; however, a sufficient number were collected to estimate total mortality and angler exploitation. The estimate of total mortality for smallmouth bass in the PTLS (23%) appears to be on the low side of the range for waters reported in the literature. Forney (1961) reported estimates of 52%, 58%, and 18% total mortality for smallmouth bass in Oneida Lake, New York, while Paragamian and Coble (1975) reported 55% mortality for smallmouth bass in the Red Cedar River, Wisconsin. Clady (1975) reported total mortality estimates of 33% for smallmouth bass in a Michigan lake with no fishing, and 41% - 65% in a lake subject to simulated exploitation of 13% - 16%, while Bryant and Smith (1988) reported 58% total mortality of adult smallmouth bass from Anchor Bay of Lake St. Clair. Finally, total mortality of smallmouth bass in ten populations surveyed in the Large Lakes Program has averaged 33%, with a median value of 34%, and a range of 22-45%.

While total mortality of smallmouth bass was relatively low, angler exploitation (19%) was about average or slightly above. Exploitation of smallmouth bass in ten populations surveyed in the Large Lakes Program has averaged 13%, with a range of 4 to 21%. Latta (1975) reported a range of 9% to 33% exploitation, with an average of 19%, for a sample of smallmouth bass populations throughout the Great Lakes region and the northeastern United States. In Oneida Lake, Forney (1972) reported 20% exploitation of adult smallmouth bass, while Paragamian and Coble (1975) reported 29% exploitation in the Red Cedar River of Wisconsin. In Michigan, Latta (1963) reported 22% exploitation of smallmouth bass near Waugoshance Point in Lake Michigan, and Bryant and Smith (1988) reported a rate of 13% for smallmouth bass in Lake St. Clair. Although exploitation was not excessively high, it is of some concern that it makes up such a large portion of the annual mortality, and it may imply that the population is extremely vulnerable to angling. I examined tag returns to see if the majority were caught while smallmouth bass were on their spawning beds (usually late May to early June at this latitude), but this was not the case; tag returns were spread rather evenly throughout the summer and fall. Interestingly, the only population surveyed in the Large Lakes Program with lower total mortality was nearby Lake Gogebic at 22%. Similar to the PTLS, exploitation of smallmouth bass in Lake Gogebic (19%) also made up a large portion of annual mortality. However, given the relatively low number of smallmouth bass aged/tagged in Lake Gogebic (N = 60) and the PTLS (N = 90), interpretations should be made cautiously. Additionally, even though angler exploitation made up a large portion of total mortality, it was likely compensated for by lower natural mortality in the population.

Recruitment–Walleye recruitment in the PTLS is comprised of stocking and natural reproduction, though the relative proportion of each remains unknown. As the sauger population in the PTLS was decreasing during the 1970's, the walleye population was increasing entirely via natural reproduction. Although managers did not assess recruitment during this time, stocking was initiated in an attempt to jump-start the growing walleye population. While the walleye stocking efforts of the 1980's through 2000's were likely successful in increasing abundance, it is uncertain what the actual contribution was towards annual reproduction. There is some evidence that stocking has recently played a part in adult abundance since three of the five years with apparently weak year classes (1996-2000) had little or no walleyes stocked. If stocking is the main source of recruitment in the PTLS, its effect should be realized by lower adult abundance in the coming years since walleyes were not stocked from 2006 through 2010. Regardless of the source, walleye recruitment in the PTLS appears to be erratic, as evidenced by the catch curve regression. The r^2 value from the catch curve (0.64) was well below the average (0.78) and median (0.87) from other Michigan walleye populations surveyed as part of the Large Lakes program to date; thus, recruitment is highly variable. Contrary to walleyes, northern pike and smallmouth bass in the PTLS have rather consistent recruitment. Most of the variation in northern pike ($r^2 = 0.90$; Figure 4) and smallmouth bass ($r^2 = 0.90$; Figure 5) catch by age class was explained by annual mortality. Also, these indices of variability were above the averages for northern pike (0.87) and smallmouth bass (0.77) from other Michigan populations surveyed as part of the Large Lakes program. The consistency of recruitment for northern pike is expected given the abundance of flooded vegetation that exists in the Sturgeon River "sloughs" area, and the consistency for smallmouth bass would suggest that preferred spawning habitat is at least available and that environmental conditions have been favorable for both species in recent years.

Movement–Given the large size of the PTLS and its connection to Lake Superior, fish have the capability of moving large distances. Although considerable movement to Lake Superior was not documented, the fishery in the near-shore areas around the PTLS is directed primarily at lake trout and lake whitefish, which generally occupy deeper water than walleyes. Additionally, since tag returns from Lake Superior and connected waters were not adjusted for effort, it is possible that greater than 3% of walleyes spawning in the PTLS move to Lake Superior following spawning. In the Muskegon River population (Hanchin et al. 2007) 50% of walleye tag returns were from Lake Michigan and connecting waters (outside of the Muskegon River and Lake), and in Lake Charlevoix (Hanchin, 2015) 12% were from Lake Michigan. Most Lake Superior walleye tag returns were from short distances in Keweenaw Bay, though the movement to the Brule River in Minnesota represented a distance of at least 100 miles. An interesting documentation of walleye movement made during this study came from the recapture of a walleye that was tagged in the mouth of the Nipigon River in 2002 by the Ontario Ministry of Natural Resources. This walleye, a 23-inch male, moved a minimum of 150 miles, though likely more than four times that if it followed the Lake Superior shoreline rather than traversing the open water of Lake Superior. It was surprising that tag returns were not reported from Huron Bay of Lake Superior, which is known to at least contain a substantial congregation of walleyes in the spring. It would be interesting to know if there is mixing between these spawning populations, or if there is a tendency for movement to occur in one direction. Similar to walleyes, most northern pike remained in the PTLS, though as for the same reasons movement to Lake Superior could have been underestimated due to the lower fishing effort in the near-shore areas of Lake Superior.

Summary and Management Recommendations

The Portage-Torch lake system supports above-average density walleye and northern pike populations with high size structure and excellent growth potential. The favorable size structure and growth result from abundant prey, which is largely made available by the connection to Lake Superior. Saugers are most likely extirpated from the system as none were collected in the largest netting effort on the PTLS, nor were any detected in the angler harvest. The walleye population persists based on a combination of natural recruitment and stocking, though the contribution of each source remains unknown. Recruitment to the adult population appears to be erratic, though it is unknown if that is due to natural fluctuations or stocking success. Future stocking efforts should include chemical marking of fingerlings so that the relative contribution of stocking can be determined. Also, fall electrofishing surveys should be conducted in nonstocked years to document the extent of natural reproduction in Portage Lake. There are several possible factors affecting walleye recruitment such as predation by the substantial smelt population, or early mortality syndrome resulting from a diet high in thiaminase-rich fish such as alewives.

The creel survey showed that the number of walleyes and northern pike harvested per acre was below average, while both catch and harvest rates were above average. This provides indication that angler success is relatively high, even though angler effort is relatively low. Given the angler success and the opportunity to catch large fish, the popularity of the walleye and northern pike fisheries in the PTLS appears to be gaining in recent years. In fact, several national walleye fishing tournaments have been held on the PTLS over the past decade. Although angler exploitation is currently about average, the fishery should be occasionally monitored as its reputation for high catch rates and trophy walleyes will undoubtedly attract interest.

Smallmouth bass in the PTLS likely have a lower density than walleyes and northern pike, though the abundance estimate was not valid in our survey. Surprisingly, the exploitation rate for smallmouth bass was higher than for walleyes and northern pike. Also, anglers experienced higher catch rates for smallmouth bass than walleyes and northern pike. Similar to walleyes and northern pike, the harvest per acre of smallmouth bass was below average relative to other large lakes in Michigan, but the catch rate for all size of smallmouth bass was almost twice the average. Overall mortality of smallmouth bass was low, though angling mortality accounted for a considerable portion. Given the apparent vulnerability of the smallmouth bass in the PTLS, it would be prudent to survey the population again in the near future, and to do so in May when they are more vulnerable to survey gears.

Acknowledgements

I thank the many Michigan Department of Natural Resources employees who collected the data for this study. I especially thank Joseph “Ed” Pearce, William Wellenkamp, Brian Gunderman, and Valerie Miller from the Baraga office who made the tagging operation a success. I thank Rueben Peterson and Wayne Laitala, for many hours on the water and ice interviewing anglers. I thank Nathan Skop and Cathy Sullivan for data entry and tag return processing, Alan Sutton, Ann Arbor for assisting in preparation of angler survey estimates and figures, and Zhenming Su, Ann Arbor for designing the angler survey. I thank Mike Thomas for reviewing the manuscript, and I thank anglers that provided assistance by returning tags and responding to creel clerks. This work was funded by the Federal Aid to Sport Fish Restoration Project F-81-R-6, Study 230725 (75%) and the Game and Fish Fund of the State of Michigan (25%).

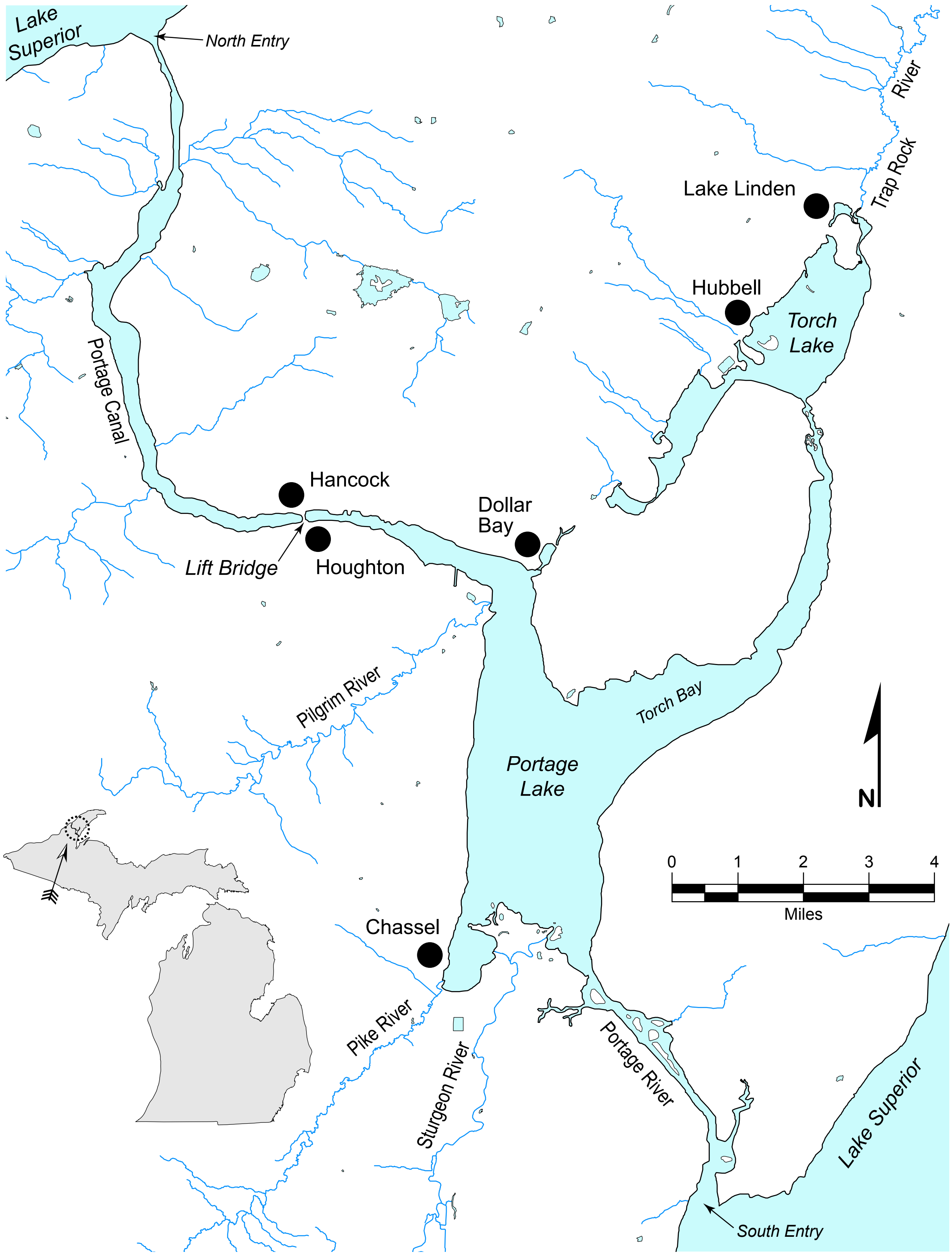

Figure 1.–Map of the Portage-Torch lake system, Houghton County, Michigan, including tributary streams.

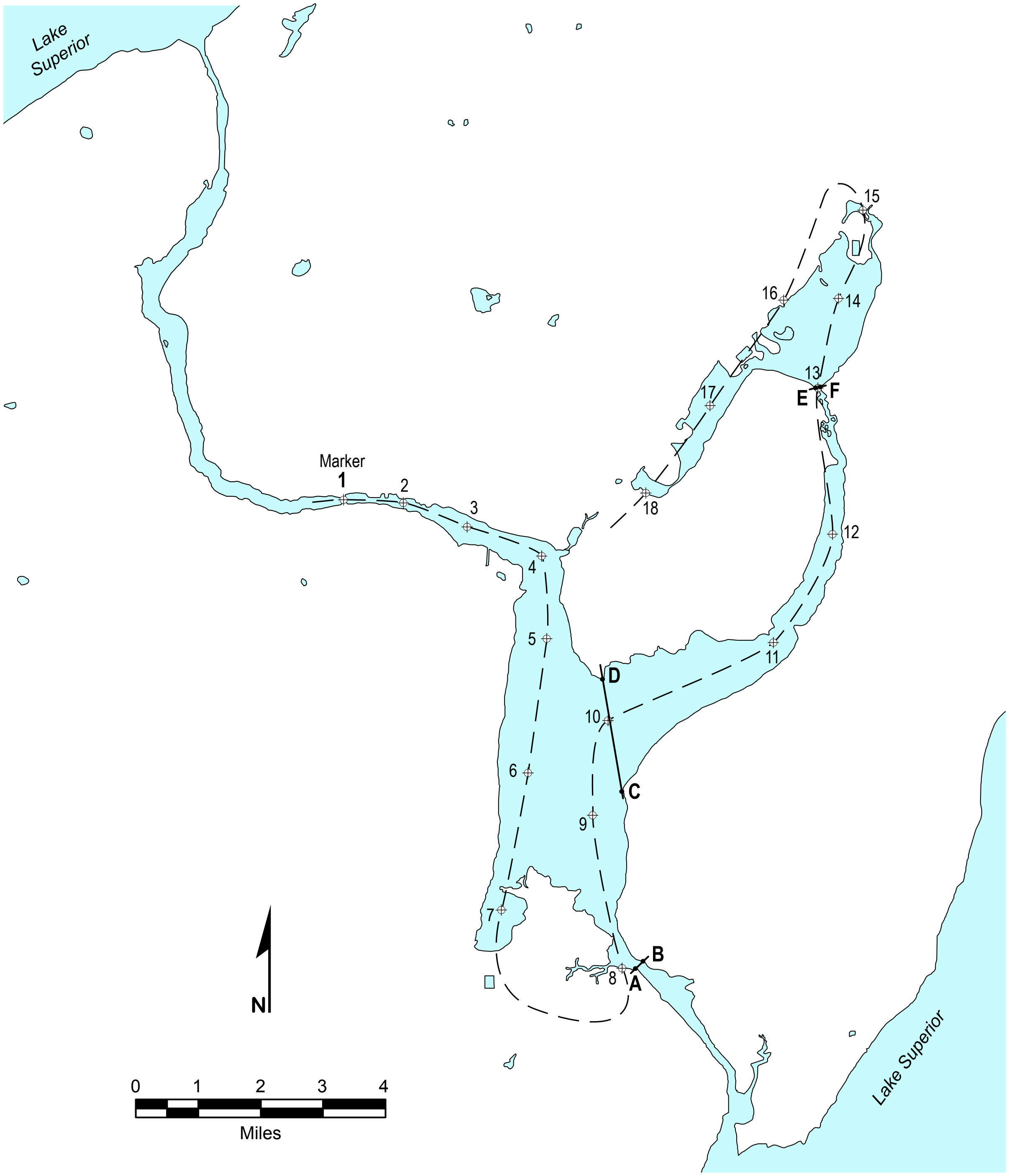

Figure 2.–Counting path and associated count path way points for the angler survey of Portage and Torch lakes. Dashed line indicates flight path and solid lines indicate separate sections.

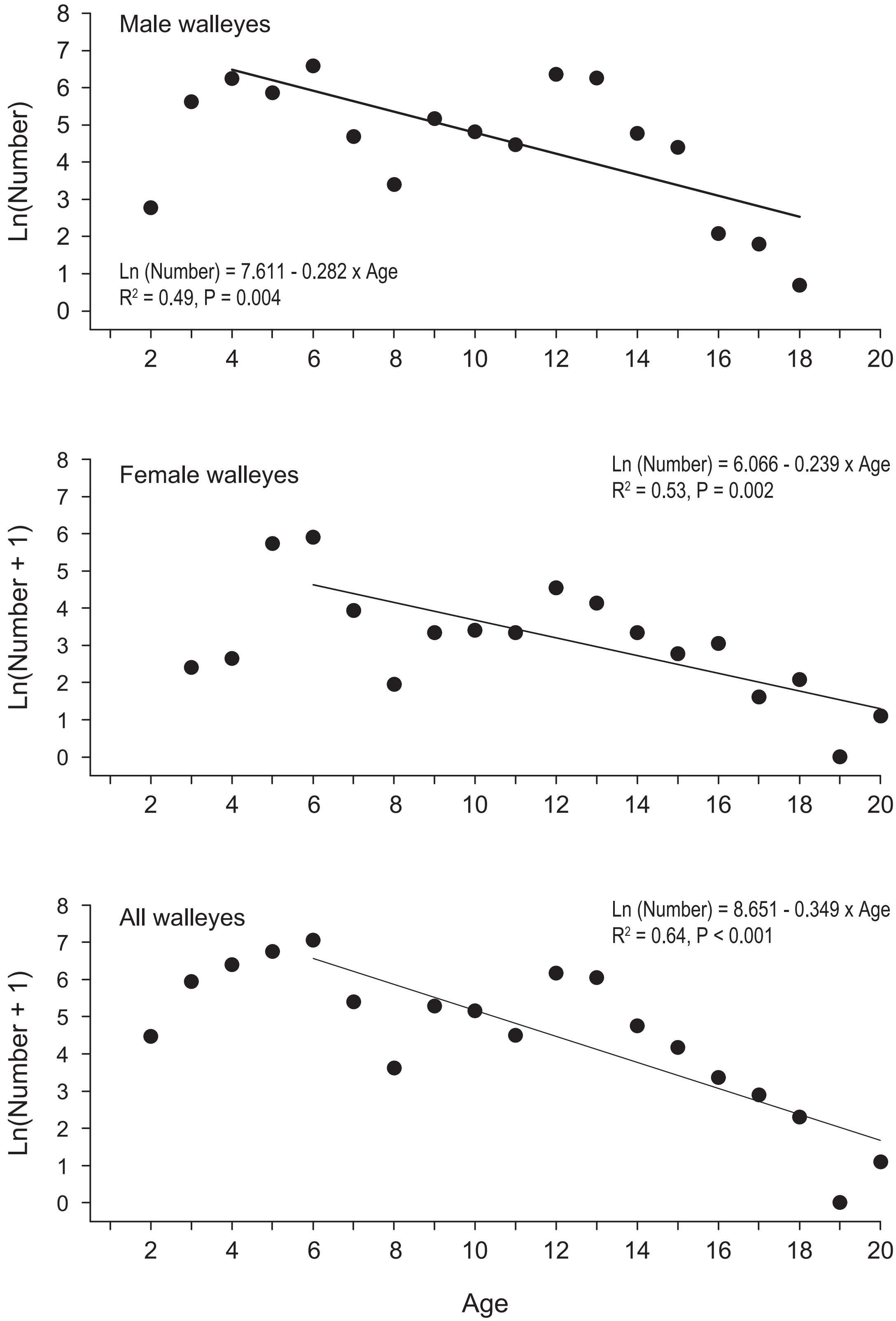

Figure 3.–Plots of observed ln(number) versus age for legal-size male, female, and all (including males, females, and unknown sex) walleyes in the Portage-Torch lake system. Lines are plots of regression equations given beside each graph, where significant.

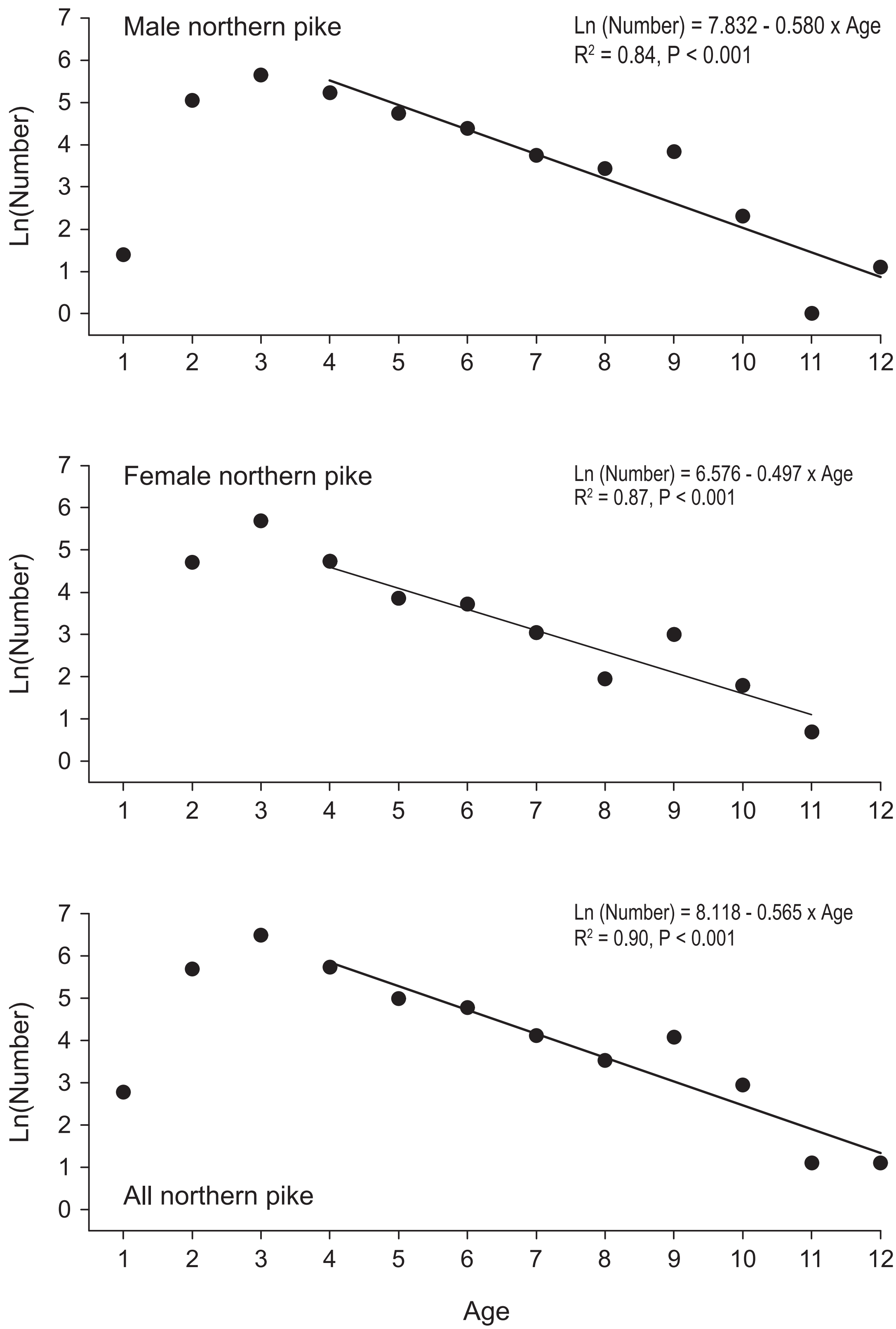

Figure 4.–Plots of observed ln(number) versus age for males, females, and all (including males, females, and unknown sex) legal-size northern pike in the Portage-Torch lake system. Lines are plots of regression equations given beside each graph, where applicable.

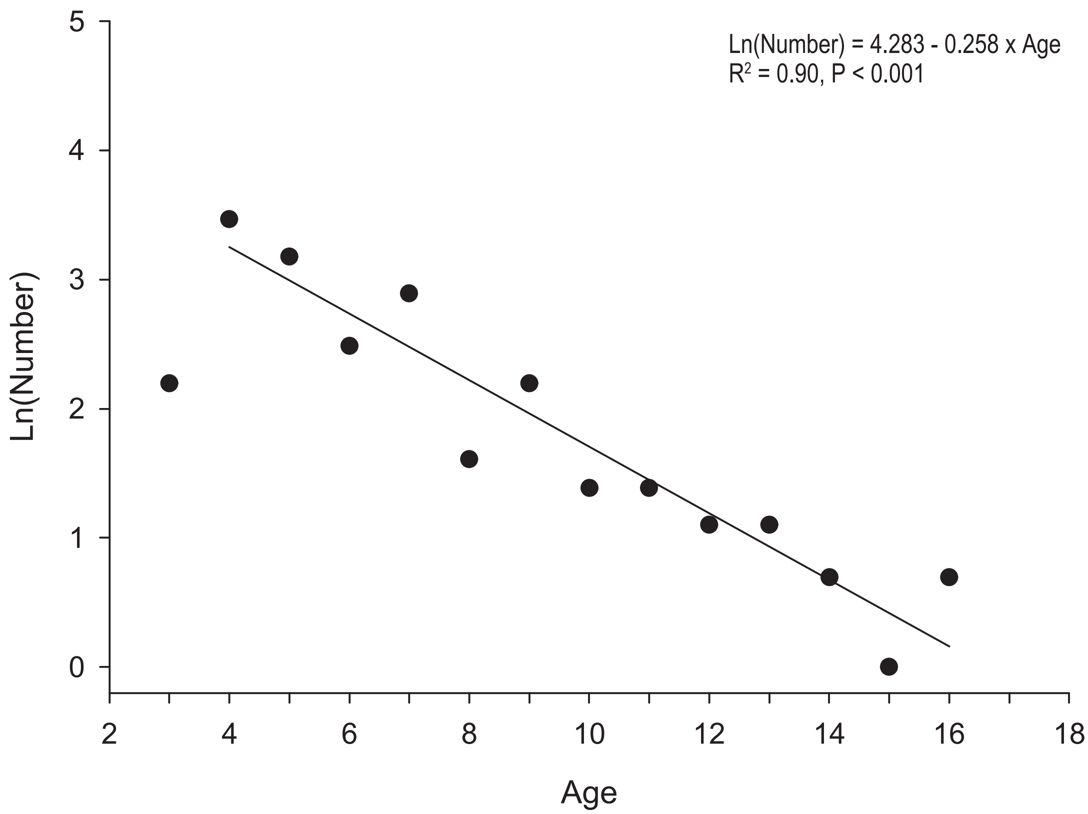

Figure 5.–Plots of observed ln(number) versus age for age-4 and older smallmouth bass in the Portage-Torch lake system. Line is plot of regression equation given beside graph.

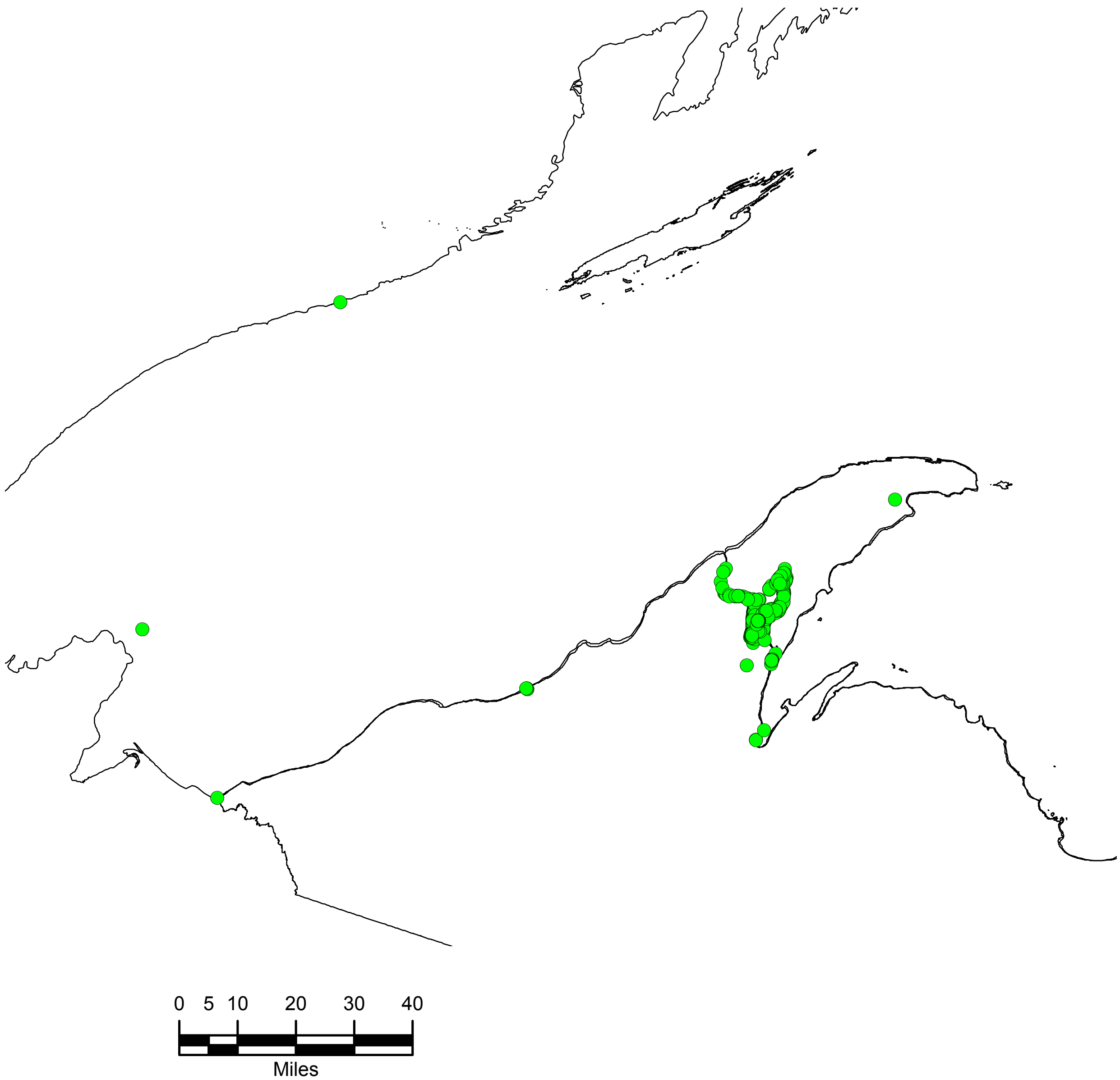

Figure 6.–Walleye tag returns through October of 2009 from the spring 2007 tagging event in the Portage-Torch lake system.

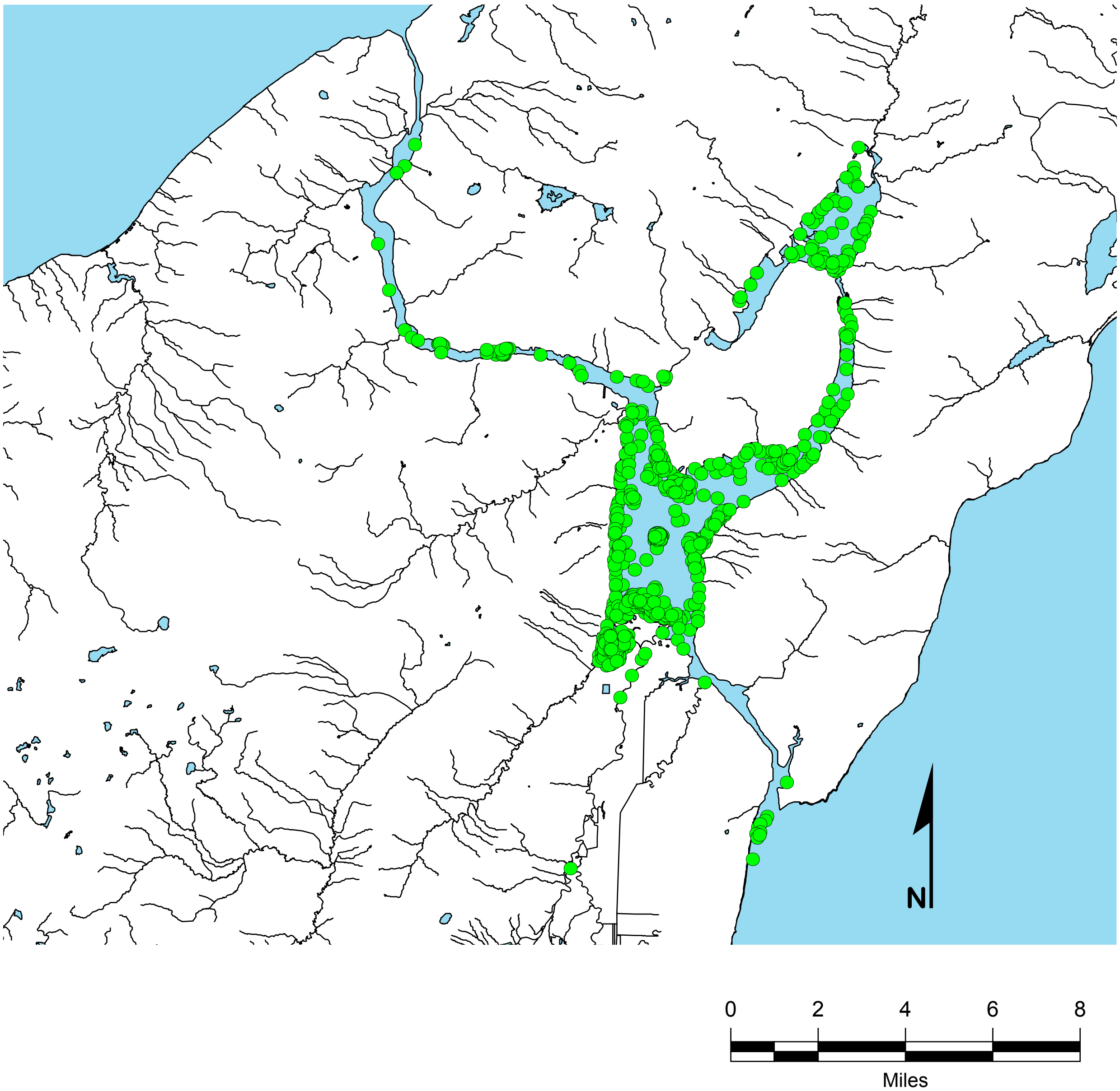

Figure 7.–Walleye tag returns within the Portage-Torch lake system through October of 2009 from the spring 2007 tagging event in the Portage-Torch lake system.

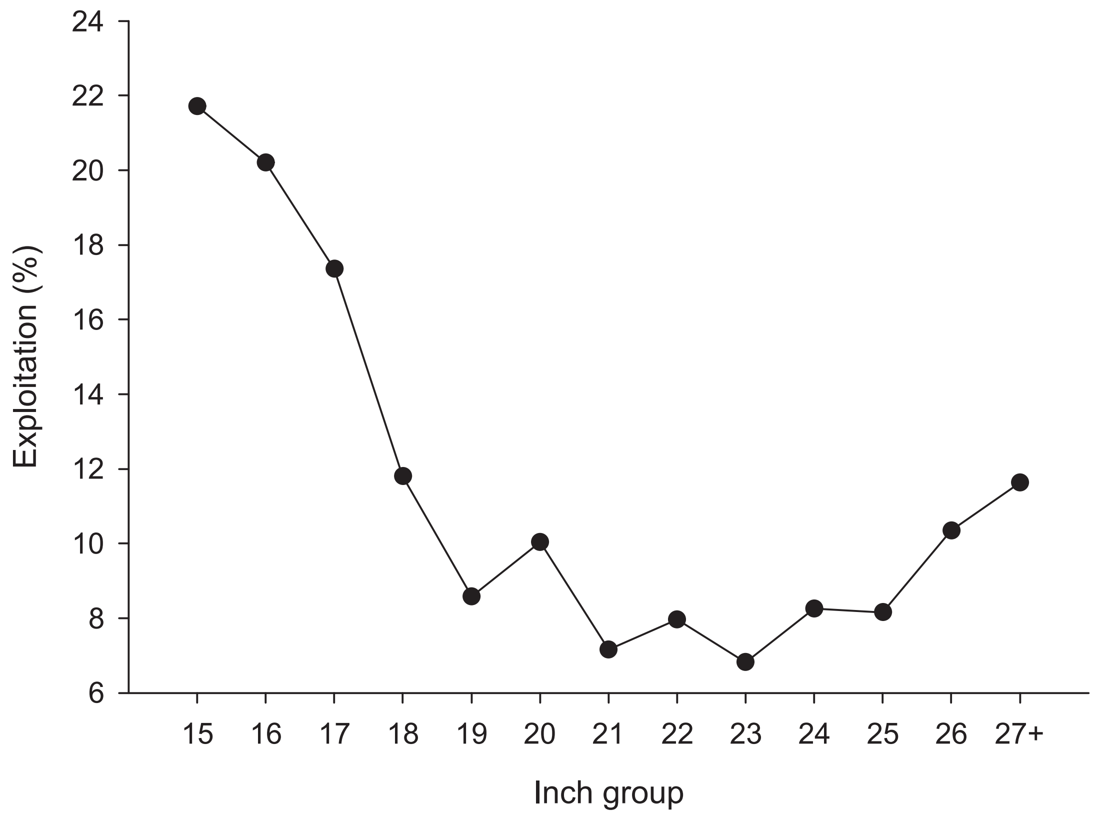

Figure 8.–Exploitation by inch group, based on walleye tag returns from the Portage-Torch lake system in the year following tagging.

Table 1.–Number and size of fish stocked in the Portage-Torch lake system 1985 through 2007.

Year	Species	Number	Average size (in)
1985	Coho salmon	51,755	5.1
1986	Coho salmon	44,998	5.5
	Brook trout	125	11.2
	Rainbow trout	125	17.2
1987	Coho salmon	36,100	5.7
	Walleye	8,000	1.5
1988	Coho salmon	50,005	5.4
	Sauger	58,000	0.3
1989	Coho salmon	50,012	5.7
	Walleye	176,589	1.6
1990	Coho salmon	50,094	5.2
	Walleye	41,699	1.6
1991	Coho salmon	40,169	5.3
	Walleye	75,642	1.6
1992	Coho salmon	40,001	5.9
	Walleye	71,160	1.7
1993	Coho salmon	50,000	5.9
	Walleye	79,800	1.9
1994	Walleye	106,029	1.7
1997	Walleye	1,880	3.6
1998	Walleye	133,537	1.6
1999	Walleye	37,536	1.6
2000	Walleye	125,664	1.5
2001	Walleye	107,970	1.8
2002	Walleye	61,821	2.0
2003	Walleye	110,627	1.6
	Walleye	1,500,000	0.3
2004	Walleye	144,413	1.4
	Walleye	2,050,000	0.3
2005	Walleye	49,970	2.0
		4,500,000	0.3

Table 2.–Coordinates (degrees and minutes) for the flight path markers and markers that delineate the three survey grids on Portage and Torch lakes.

Marker	Latitude	Longitude
A	47° 01.03' N	-88° 28.14' W
B	47° 01.13' N	-88° 27.99' W
C	47° 03.48' N	-88° 28.54' W
D	47° 05.04' N	-88° 28.99' W
E	47° 09.18' N	-88° 24.83' W
F	47° 09.20' N	-88° 24.74' W
1	47° 07.42' N	-88° 34.39' W
2	47° 07.41' N	-88° 33.17' W
3	47° 07.10' N	-88° 31.85' W
4	47° 06.73' N	-88° 30.32' W
5	47° 05.59' N	-88° 30.16' W
6	47° 03.71' N	-88° 30.46' W
7	47° 01.79' N	-88° 30.91' W
8	47° 01.03' N	-88° 28.42' W
9	47° 03.14' N	-88° 29.12' W
10	47° 04.48' N	-88° 28.86' W
11	47° 05.63' N	-88° 25.54' W
12	47° 07.16' N	-88° 24.40' W
13	47° 09.19' N	-88° 24.79' W
14	47° 10.45' N	-88° 24.43' W
15	47° 11.68' N	-88° 23.98' W
16	47° 10.40' N	-88° 25.54' W
17	47° 08.90' N	-88° 26.98' W
18	47° 07.66' N	-88° 28.23' W

Table 3.–Fish collected from the Portage-Torch lake system using a total sampling effort of 46 trap-net lifts, 443 fyke-net lifts, 4 electrofishing runs, and one ¼-arc seine haul from March 28 to May 8, 2007.

Species	Total catch [a]	Percent by number	Mean CPUE [a, b]		Length (in)		Number measured [c]
			trap net	fyke net	range	average [c]	
Brown bullhead	15,402	40.8	30.4	29.8	1.8–12.5	7.8	638
Walleye	5,699	15.1	26.6	8.9	9.5–30.7	20.9	4,925
White sucker	5,297	14.0	17.7	9.5	3.0–22.2	16.3	1054
Northern pike	1,965	5.2	5.4	3.6	8.2–44.1	23.7	1,723
Redhorse spp.	1,958	5.2	2.6	3.8	13.4–25.6	20.5	245
Silver redhorse	1,229	3.3	8.1	1.9	12.8–25.0	20.5	92
Rainbow smelt	1,220	3.2	12.0	1.5	3.0–10.5	5.1	392
Yellow perch	944	2.5	0.2	2.0	3.1–11.7	6.2	292
Pumpkinseed	900	2.4	0.4	1.8	2.0–8.7	4.4	453
Trout perch	762	2.0	0.0	1.7	2.0–4.2	3.4	85
Rock bass	650	1.7	0.7	1.3	1.8–11.2	6.3	292
Black crappie	521	1.4	1.5	0.9	2.8–13.3	10.1	449
Golden shiner	469	1.2	0.0	1.0	2.9–6.0	3.9	230
Shorthead redhorse	143	0.4	0.4	0.2	7.4–24.3	19.2	82
Smallmouth bass	115	0.2	0.6	0.1	2.5–21.1	16.0	112
Ruffe	103	0.3	0.1	0.2	3.0–9.1	4.6	72
Longnose sucker	80	0.2	0.7	0.1	12.0–20.0	15.8	61
Common shiner	51	0.1	0.0	0.1	3.0–5.7	3.9	42
Round whitefish	46	0.1	0.5	<0.1	7.0–15.6	12.2	46
Burbot	42	0.1	0.1	0.1	8.7–38.5	17.7	42
Rainbow trout	37	0.1	0.2	0.1	5.5–28.0	12.9	37
Bluegill	35	0.1	<0.1	0.1	3.1–10.9	5.4	12
Spottail shiner	23	0.1	0	<0.1	3.2–4.8	3.7	20
Sea lamprey	18	<0.1	0	<0.1	8.0–20.5	15.3	8
Mottled sculpin	16	<0.1	0	<0.1	2.6–4.4	3.5	13
Central mudminnow	15	<0.1	0	<0.1	3.4–4.5	4.1	5
Creek chub	13	<0.1	0	<0.1	–	4.0	1
Alewife	9	<0.1	0.1	<0.1	3.2–4.8	4.1	9
Cisco	8	<0.1	0	<0.1	10.8–13.7	12.7	8
Black bullhead	8	<0.1	0	<0.1	9.0–11.5	10.5	8
Brook trout	8	<0.1	<0.1	<0.1	4.3–10.5	7.6	8
Largemouth bass	9	<0.1	0	<0.1	9.7–16.1	11.9	9
Common carp	6	<0.1	0	<0.1	5.0–33.0	24.7	6
Coho salmon	4	<0.1	<0.1	<0.1	4.1–20.8	10.6	4
Brown trout	3	<0.1	<0.1	<0.1	6.8–30.8	15.0	3
Lake sturgeon	3	<0.1	<0.1	<0.1	24.0–47.8	32.4	3
Bluntnose minnow	1	<0.1	0	<0.1	–	3.5	1
Silver lamprey	1	<0.1	0	<0.1	–	–	0

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

Table 4.–Number of fish per inch group collected from the Portage-Torch lake system, March 28 to May 8, 2007.

	Species																
Inch group	Brown bullhead	Walleyes	White sucker	Northern pike	Redhorse sucker	Silver redhorse	Rainbow smelt	Yellow perch	Pumpkinseed	Trout perch	Rock bass	Black crappie	Golden shiner	Shorthead redhorse	Smallmouth bass	Ruffe	Longnose sucker
1	1	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–
2	29	–	–	–	–	–	–	–	32	1	7	1	1	–	1	–	–
3	38	–	10	–	–	–	2	9	178	68	42	–	138	–	–	9	–
4	42	–	9	–	–	–	159	73	130	16	25	2	76	–	–	45	–
5	47	–	4	–	–	–	187	56	40	–	35	5	14	–	–	16	–
6	41	–	3	–	–	–	36	69	39	–	62	11	1	–	–	1	–
7	49	–	5	–	–	–	4	41	29	–	54	4	–	1	–	–	–
8	84	–	1	2	–	–	1	21	5	–	42	42	–	–	–	–	–
9	159	2	1	2	–	–	2	12	–	–	17	93	–	–	–	1	–
10	119	6	3	1	–	–	1	7	–	–	5	175	–	1	–	–	–
11	24	12	5	3	–	–	–	4	–	–	1	103	–	1	–	–	–
12	5	32	6	6	–	1	–	–	–	–	–	10	–	–	5	–	1
13	–	31	51	17	2	–	–	–	–	–	–	3	–	1	9	–	3
14	–	53	124	21	2	–	–	–	–	–	–	–	–	2	19	–	13
15	–	200	166	39	3	–	–	–	–	–	–	–	–	4	25	–	17
16	–	198	192	63	4	–	–	–	–	–	–	–	–	8	13	–	17
17	–	288	173	71	13	9	–	–	–	–	–	–	–	6	21	–	6
18	–	290	153	81	23	9	–	–	–	–	–	–	–	8	8	–	3
19	–	571	105	95	33	16	–	–	–	–	–	–	–	12	6	–	–
20	–	688	33	135	48	21	–	–	–	–	–	–	–	11	4	–	1
21	–	730	8	140	45	13	–	–	–	–	–	–	–	13	1	–	–
22	–	628	2	153	49	13	–	–	–	–	–	–	–	8	–	–	–
23	–	498	–	150	15	5	–	–	–	–	–	–	–	5	–	–	–
24	–	306	–	149	7	4	–	–	–	–	–	–	–	1	–	–	–
25	–	147	–	111	1	1	–	–	–	–	–	–	–	–	–	–	–
26	–	116	–	83	–	–	–	–	–	–	–	–	–	–	–	–	–
27	–	60	–	65	–	–	–	–	–	–	–	–	–	–	–	–	–
28	–	48	–	67	–	–	–	–	–	–	–	–	–	–	–	–	–
29	–	16	–	50	–	–	–	–	–	–	–	–	–	–	–	–	–
30	–	5	–	48	–	–	–	–	–	–	–	–	–	–	–	–	–
31	–	–	–	29	–	–	–	–	–	–	–	–	–	–	–	–	–
32	–	–	–	26	–	–	–	–	–	–	–	–	–	–	–	–	–
33	–	–	–	21	–	–	–	–	–	–	–	–	–	–	–	–	–
34	–	–	–	22	–	–	–	–	–	–	–	–	–	–	–	–	–
35	–	–	–	27	–	–	–	–	–	–	–	–	–	–	–	–	–
36	–	–	–	16	–	–	–	–	–	–	–	–	–	–	–	–	–
37	–	–	–	6	–	–	–	–	–	–	–	–	–	–	–	–	–
38	–	–	–	8	–	–	–	–	–	–	–	–	–	–	–	–	–
39	–	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–
40	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–
41	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–
42	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–
43	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–
44	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–
45	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
46	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
47	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total	638	4,925	1,054	1,723	245	92	392	292	453	85	292	449	230	82	112	72	61

Table 4.–Extended.

Inch group	Species																			
	Common shiner	Round whitefish	Burbot	Rainbow trout	Bluegill	Spottail shiner	Sea lamprey	Mottled sculpin	Central mudminnow	Creek chub	Alewife	Cisco	Black bullhead	Brook trout	Largemouth bass	Common carp	Coho salmon	Brown trout	Lake sturgeon	Bluntnose minnow
1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–
3	23	–	–	–	3	15	–	9	2	–	2	–	–	–	–	–	–	–	–	1
4	18	–	–	–	5	5	–	2	3	1	7	–	–	1	–	–	2	–	–	–
5	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–
6	–	–	–	12	1	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–
7	–	2	–	4	1	–	–	–	–	–	–	–	–	5	–	–	–	1	–	–
8	–	2	2	5	3	–	2	–	–	–	–	–	–	1	–	–	–	–	–	–
9	–	–	2	1	–	–	–	–	–	–	–	–	1	–	1	–	–	–	–	–
10	–	7	1	–	1	–	3	–	–	–	–	1	4	1	5	–	–	–	–	–
11	–	10	–	–	–	–	–	–	–	–	–	1	3	–	–	–	–	–	–	–
12	–	5	1	1	–	–	–	–	–	–	–	2	–	–	–	–	1	–	–	–
13	–	11	5	–	–	–	–	–	–	–	–	4	–	–	–	–	–	–	–	–
14	–	8	5	1	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
15	–	1	3	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
16	–	–	1	1	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
17	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
18	–	–	3	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–
19	–	–	4	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
20	–	–	2	–	–	–	2	–	–	–	–	–	–	–	–	–	1	–	–	–
21	–	–	3	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
22	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
23	–	–	5	1	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–
24	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–
25	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–
26	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–
27	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
28	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1	–	–
30	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
31	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–
32	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–
34	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
36	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
37	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
38	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
39	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
41	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
42	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
43	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
44	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
45	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
46	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
47	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–
Total	42	46	42	37	12	20	8	13	5	1	9	8	8	8	9	6	4	3	3	1

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

Parameter	Walleyes	Northern pike	Smallmouth bass
Number tagged	4,777	738	96
Total tag returns	522	85	16
Number of legal-size[a] fish			
Multiple-census estimate	16,911 (14,878 – 19,588)	2,740 (1,880 – 5,046)	–
Single-census estimate	41,795 (34,488 – 51,145)	7,269 (4,218 – 13,438)	–
Michigan model[b]	18,692 (3,899 – 89,597)	–	–
Number of adult[c] fish			
Multiple-census estimate	17,147 (15,125 – 19,792)	7,370 (4,855 – 15,292)	–
Single-census estimate	42,231 (34,848 – 51,680)	16,006 (9,287 – 29,590)	–
Michigan model[d]	30,108 (5,507 – 164,607)	–	–
Wisconsin NR model[e]	39,786 (12,659 – 125,044)	–	–
Wisconsin ST model[f]	13,066 (2,910 – 58,659)	–	–
Annual exploitation rates			
Based on reward tag returns	12.3%	15.2%	19.1%
Based on harvest/abundance[g]	19.9% (5.1% – 34.7%)	17.3% (9.5% – 25.2%)	–
Based on harvest/abundance[h]	8.1% (5.9% – 10.2%)	6.5% (2.6% – 10.5%)	–
Total annual mortality rates	52%	43%	23%

[a] Walleyes ≥ 15 inches, northern pike ≥ 24 inches, and smallmouth bass ≥ 14 inches.
[b] Michigan model prediction of legal walleye abundance based on lake area, N = 32.
[c] Fish of legal-size and sexually mature fish of sublegal size on spawning grounds.
[d] Michigan model of adult walleye abundance based on lake area, N = 31.
[e] Wisconsin model of adult walleye abundance (natural recruitment) based on lake area, N = 193.
[f] Wisconsin model of adult walleye abundance (stocking) based on lake area, N = 135.
[g] Multiple-census estimate of legal-size walleye abundance.
[h] Single-census estimate of legal-size walleye abundance.

Table 6.–Weighted mean total lengths (inches) and sample sizes by age and gender for walleyes collected from the Portage-Torch lake system, March 28 to May 8, 2007. Standard deviation is in parentheses.

Age	Mean length						Number aged		
	Males		Females		All fish [a]		Males	Females	All fish [a]
1	–		–		–		–	–	–
2	14.0	(1.0)	–		12.7	(1.2)	9	–	67
3	15.8	(0.8)	17.1	(1.5)	16.0	(1.2)	33	5	55
4	17.3	(0.8)	19.2	(0.4)	17.7	(1.1)	32	6	39
5	19.2	(0.6)	21.1	(0.7)	20.3	(1.1)	12	26	38
6	20.0	(0.7)	21.9	(0.8)	21.1	(1.3)	20	32	53
7	19.9	(1.0)	22.8	(0.7)	22.2	(1.6)	3	9	12
8	22.3	(–)	25.1	(0.5)	23.4	(1.3)	1	2	3
9	21.5	(0.9)	24.5	(1.0)	22.5	(1.5)	5	8	13
10	22.5	(0.7)	24.7	(1.3)	23.4	(1.3)	5	8	13
11	23.4	(1.1)	26.5	(1.0)	24.3	(1.8)	5	8	13
12	22.4	(1.4)	26.2	(0.9)	23.0	(2.0)	23	23	47
13	23.4	(1.2)	26.6	(1.5)	23.9	(1.7)	31	18	50
14	23.6	(1.3)	27.2	(1.3)	24.8	(2.0)	12	9	21
15	24.3	(1.0)	27.9	(0.9)	25.5	(1.9)	7	6	13
16	25.6	(0.8)	28.2	(0.4)	27.4	(1.2)	3	7	10
17	26.3	(0.0)	30.1	(0.7)	27.2	(1.7)	4	3	7
18	28.7	(–)	28.7	(0.2)	28.7	(0.1)	1	3	4
19	–		–		–		–	–	–
20	–		29.3	(0.0)	29.3	(0.0)	–	2	2

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

Table 7.–Weighted mean total lengths (inches) and sample sizes by age and gender for northern pike collected from the Portage-Torch lake system, March 28 to May 8, 2007. Standard deviation is in parentheses.

	Mean length			Number aged		
Age	Males	Females	All fish [a]	Males	Females	All fish [a]
1	12.0 (1.1)	–	11.4 (1.8)	4	–	15
2	17.8 (2.1)	20.2 (2.4)	18.8 (2.6)	51	41	101
3	20.6 (2.9)	22.5 (2.9)	21.8 (3.1)	69	97	171
4	23.4 (2.8)	25.6 (3.6)	24.4 (3.3)	38	48	86
5	26.1 (2.7)	30.7 (3.4)	27.6 (3.8)	28	30	59
6	27.9 (2.3)	31.7 (3.9)	29.4 (3.7)	26	29	59
7	26.3 (2.8)	33.6 (3.2)	28.8 (4.5)	11	15	27
8	30.2 (2.9)	35.7 (2.5)	31.3 (3.5)	13	6	20
9	30.1 (3.7)	36.2 (6.6)	32.3 (5.7)	20	19	39
10	35.3 (1.4)	40.6 (2.0)	36.4 (3.7)	7	6	15
11	34.3 (–)	40.8 (0.4)	38.6 (3.8)	1	2	3
12	34.6 (1.4)	–	34.6 (1.4)	2	–	2

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

Table 8.–Weighted mean total lengths (inches) and sample sizes for smallmouth bass (males and females combined) collected from the Portage-Torch lake system (PTLS), March 28 to May 8, 2007. Standard deviation is in parentheses.

Age	State average	PTLS Mean length	Number aged
3	11.6	13.0 (0.7)	8
4	13.5	14.5 (0.6)	23
5	15.1	15.5 (0.7)	16
6	15.7	16.8 (0.8)	9
7	16.5	17.3 (0.4)	12
8	17.1	18.3 (0.6)	3
9	18.4	17.9 (1.1)	6
10	18.8	19.6 (0.0)	3
11		20.3 (0.9	3
12		19.9 (0.5	2
13		18.2 (–)	1
14		17.8 (–)	1
15		–	–
16		20.2 (–)	1

Table 9.–Mean total lengths (inches) of walleyes (males and females combined) from the 2007 survey of the Portage-Torch lake system compared to previous surveys. Number aged in parentheses.

		Survey year/lake						
	State	2007[b]	2000[b]		1994[c]		1988[c]	
Age	average[a]	Portage Lake	Portage Lake	Torch Lake	Portage Lake	Torch Lake	Portage Lake	Torch Lake
1	8.3				7.2 (1)	7.7 (1)	10.7 (2)	
2	12.2	12.7 (67)			11.8 (2)		13.8 (4)	14.6 (5)
3	14.4	16.0 (55)	13.1 (1)	13.5 (6)	14.7 (10)	14.9 (2)	16.9 (9)	17.5 (3)
4	15.8	17.7 (39)	16.6 (6)	18.1 (1)	17.1 (3)	16.4 (20)	21.3 (3)	19.5 (1)
5	17.2	20.3 (38)	18.2 (8)	17.5 (7)	19.1 (6)	20.1 (6)		
6	18.7	21.1 (53)	19.9 (26)	19.0 (26)		19.5 (4)		
7	19.6	22.2 (12)	20.7 (10)	21.1 (7)				
8	20.3	23.4 (3)	22.4 (1)	21.7 (10)		22.4 (1)		
9	21.2	22.5 (13)		22.5 (5)	24.3 (1)			
10	21.8	23.4 (13)	24.0 (2)	23.1 (11)			24.5 (1)	
11		24.3 (13)	22.8 (1)	22.8 (5)			30.0 (1)	
12		23.0 (47)		23.3 (2)				
13		23.9 (50)	27.5 (1)					
14		24.8 (21)				29.6 (1)		
15		25.5 (13)						
16		27.4 (10)						
17		27.2 (7)				29.0 (1)		
18		28.7 (4)						
19								
20		29.3 (2)						
Mean growth index[d]		+1.9	+1.0	+0.7	+1.1	+1.8	+2.5	+2.4

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

Table 10.–Mean total lengths (inches) of northern pike (males and females combined) from the 2007 survey of the Portage-Torch lake system compared to previous surveys. Number aged in parentheses.

		Survey year/lake					
	State	2007		2000 [b]			
Age	average [a]	Portage Lake		Portage Lake		Torch Lake	
1	11.8	11.4	(15)	13.8	(4)		
2	17.1	18.8	(101)	20.7	(10)		
3	20.5	21.8	(171)	23.5	(3)	21.6	(31)
4	22.8	24.4	(86)	25.3	(14)	25.5	(28)
5	24.9	27.6	(59)	31.8	(7)	25.3	(2)
6	26.6	29.4	(59)	35.1	(1)	25.1	(2)
7	28.5	28.8	(27)	33.5	(1)	26.1	(1)
8	31.9	31.3	(20)	27.7	(1)	32.0	(1)
9		32.3	(39)	36.8	(2)	32.1	(2)
10		36.4	(15)				
11		38.6	(3)			32.8	(1)
12		34.6	(2)				
Mean growth index [c]		+1.2		+4.3		+1.9	

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

Table 11.–Angler survey estimates for the Portage-Torch lake system. Survey period was from May 15 to October 31, 2007 and January 3 to February 29, 2008. Catch per hour (C/H) is harvest and release rate, respectively (fish per hour). Two standard errors are given in parentheses.

	Month								Open-water		Ice-cover		Annual	
Species	May	Jun	Jul	Aug	Sep	Oct	Jan	Feb	total	C/H	total	C/H	total	C/H
Number harvested														
Walleyes	116	466	1,089	1,670	154	1	318	128	3,496	0.112	446	0.039	3,942	0.092
	(117)	(177)	(277)	(648)	(131)	(1)	(187)	(105)	(747)	(0.029)	(214)	(0.012)	(777)	(0.023)
Northern pike	35	50	100	117	13	0	215	84	315	0.010	299	0.026	614	0.014
	(35)	(43)	(51)	(83)	(19)	(0)	(112)	(75)	(113)	(0.004)	(135)	(0.006)	(176)	(0.005)
Smallmouth bass	4	67	233	117	15	6	0	0	442	0.014	0	0.000	442	0.010
	(8)	(51)	(113)	(88)	(27)	(11)	(0)	(0)	(155)	(0.005)	(0)	(0)	(155)	(0.004)
Yellow perch	0	47	312	353	38	0	2	0	750	0.024	2	<0.001	752	0.018
	(0)	(67)	(167)	(213)	(77)	(0)	(4)	(0)	(289)	(0.010)	(4)	(<0.001)	(289)	(0.007)
Bluegill	0	0	22	0	0	0	0	0	22	0.001	0	0	22	0.001
	(0)	(0)	(27)	(0)	(0)	(0)	(0)	(0)	(27)	(0.001)	(0)	(0)	(27)	(0.001)
Pumpkinseed	0	12	0	23	6	0	15	0	41	0.001	15	0.001	56	0.001
	(0)	(25)	(0)	(36)	(12)	(0)	(29)	(0)	(45)	(0.002)	(29)	(0.003)	(54)	(0.001)
Rock bass	0	0	0	334	0	0	0	0	334	0.011	0	0	334	0.008
	(0)	(0)	(0)	(484)	(0)	(0)	(0)	(0)	(484)	(0.016)	(0)	(0)	(484)	(0.011)
Black crappie	0	10	62	48	11	0	19	0	131	0.004	19	0.002	150	0.004
	(0)	(13)	(60)	(43)	(19)	(0)	(31)	(0)	(77)	(0.003)	(31)	(0.003)	(83)	(0.002)
Rainbow trout	0	0	2	0	0	0	0	0	2	<0.001	0	0	2	<0.001
	(0)	(0)	(5)	(0)	(0)	(0)	(0)	(0)	(5)	(0.001)	(0)	(0)	(5)	(<0.001)
White sucker	0	0	0	0	0	0	0	2	0	0	2	<0.001	2	<0.001
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(4)	(0)	(0)	(4)	(<0.001)	(4)	(<0.001)
Brown bullhead	0	0	0	23	0	0	0	0	23	0.001	0	0	23	0.001
	(0)	(0)	(0)	(46)	(0)	(0)	(0)	(0)	(46)	(0.002)	(0)	(0)	(46)	(0.001)
Total harvest	155	652	1,820	2,685	237	7	569	214	5,556	0.178	783	0.068	6,339	0.148
	(122)	(202)	(352)	(848)	(157)	(12)	(222)	(129)	(961)	(0.040)	(257)	(0.037)	(995)	(0.033)

Table 11.–Continued.

Species	Month								Open-water		Ice-cover		Annual	
	May	Jun	Jul	Aug	Sep	Oct	Jan	Feb	total	C/H	total	C/H	total	C/H
Number released														
Walleyes	0	181	552	549	18	0	15	29	1,300	0.042	44	0.004	1,344	0.031
	(0)	(107)	(195)	(258)	(25)	(0)	(26)	(45)	(341)	(0.012)	(52)	(0.004)	(345)	(0.009)
Northern pike	57	197	778	565	198	0	367	133	1,795	0.058	500	0.043	2,295	0.054
	(54)	(106)	(252)	(291)	(138)	(0)	(167)	(107)	(426)	(0.016)	(198)	(0.005)	(470)	(0.014)
Largemouth bass	0	0	12	73	0	0	0	0	85	0.003	0	0	85	0.002
	(0)	(0)	(18)	(143)	(0)	(0)	(0)	(0)	(144)	(0.005)	(0)	(0)	(144)	(0.003)
Smallmouth bass	187	534	1,476	1,342	462	68	0	5	4,069	0.130	5	<0.001	4,074	0.095
	(132)	(257)	(632)	(566)	(378)	(98)	(0)	(10)	(977)	(0.036)	(10)	(0.001)	(978)	(0.027)
Yellow perch	135	366	1,122	321	9	0	102	0	1,953	0.063	102	0.009	2,055	0.048
	(167)	(199)	(646)	(294)	(18)	(0)	(118)	(0)	(756)	(0.026)	(118)	(0.010)	(765)	(0.019)
Bluegill	0	8	31	0	9	0	0	0	48	0.002	0	0	498	0.001
	(0)	(17)	(41)	(0)	(15)	(0)	(0)	(0)	(46)	(0.002)	(0)	(0)	(46)	(0.001)
Pumpkinseed	0	14	140	192	39	0	0	0	385	0.012	0	0	385	0.009
	(0)	(20)	(138)	(182)	(51)	(0)	(0)	(0)	(235)	(0.008)	(0)	(0)	(235)	(0.006)
Rock bass	0	81	41	15	23	0	18	0	160	0.005	18	0.002	178	0.004
	(0)	(87)	(39)	(23)	(32)	(0)	(36)	(0)	(103)	(0.003)	(36)	(0.003)	(109)	(0.003)
Black crappie	7	11	4	47	4	0	11	0	73	0.002	11	0.001	84	0.002
	(14)	(13)	(9)	(77)	(8)	(0)	(22)	(0)	(81)	(0.003)	(22)	(0.002)	(84)	(0.002)
White sucker	0	2	5	0	18	12	0	0	37	0.001	0	0	37	0.001
	(0)	(4)	(10)	(0)	(31)	(23)	(0)	(0)	(40)	(0.001)	(0)	(0)	(40)	(0.001)
Redhorse	0	0	0	9	0	0	0	0	9	<0.001	0	0	9	<0.001
	(0)	(0)	(0)	(18)	(0)	(0)	(0)	(0)	(18)	(0.001)	(0)	(0)	(18)	(<0.001)
Brown bullhead	137	234	191	336	0	6	0	0	904	0.029	0	0	904	0.021
	(208)	(157)	(111)	(478)	(0)	(11)	(0)	(0)	(556)	(0.018)	(0)	(0)	(556)	(0.013)
Coho salmon	0	1	0	0	0	0	0	0	1	<0.001	0	0	1	<0.001
	(0)	(3)	(0)	(0)	(0)	(0)	(0)	(0)	(3)	(<0.001)	(0)	(0)	(3)	(<0.001)
Lake sturgeon	4	1	0	0	0	0	31	7	5	<0.001	38	0.003	43	0.001
	(7)	(3)	(0)	(0)	(0)	(0)	(31)	(14)	(8)	(<0.001)	(34)	(0.003)	(35)	(0.001)
Total released	527	1,630	4,352	3,449	780	86	544	174	10,824	0.347	718	0.062	11,542	0.270
	(303)	(402)	(976)	(920)	(409)	(102)	(213)	(117)	(1,494)	(0.068)	(243)	(0.034)	(1,513)	(0.055)
Total catch	682	2,282	6,172	6,134	1,017	93	1,113	388	16,380	0.525	1,501	0.130	17,881	0.419
(harvested + released)	(326)	(450)	(1,038)	(1,252)	(439)	(102)	(308)	(174)	(1,776)	(0.093)	(353)	(0.064)	(1,811)	(0.077)
Angler hours	1,122	3,408	9,640	13,087	3,745	204	6,262	5,256	31,207		11,518		42,725	
	(567)	(779)	(1,316)	(3,616)	(1,832)	(186)	(1,786)	(4,585)	(4,374)		(4,920)		(6,583)	

Table 12.–Catch at age estimates (apportioned by age-length key) by gender for walleyes, northern pike, and smallmouth bass from the Portage-Torch lake system, March 28 to May 8, 2007.

Age	Year class	Walleyes			Northern pike			Smallmouth bass
		Males	Females	All fish [a]	Males	Females	All fish [a]	All fish [a]
1	2006	–	–	–	4	–	16	–
2	2005	16	–	86	156	110	295	–
3	2004	276	10	381	282	295	658	8
4	2003	516	13	601	186	113	309	31
5	2002	349	306	848	114	47	147	23
6	2001	723	364	1155	80	41	119	11
7	2000	108	50	220	42	21	61	17
8	1999	30	6	36	31	7	34	4
9	1998	176	27	196	46	20	59	8
10	1997	123	29	172	10	6	19	3
11	1996	87	27	89	1	2	3	3
12	1995	575	93	475	3	–	3	2
13	1994	522	61	422	–	–	–	2
14	1993	118	27	114	–	–	–	1
15	1992	81	15	64	–	–	–	0
16	1991	8	20	28	–	–	–	1
17	1990	6	4	17	–	–	–	–
18	1989	2	7	9	–	–	–	–
19	1988	–	–	–	–	–	–	–
20	1987	–	2	2	–	–	–	–
Total		3,716	1,061	4,915	955	662	1,723	114

[a] Catch at age for “All fish” includes males, females, and fish of unknown gender.

Table 13.–Voluntary angler tag returns (reward and nonreward, harvested and released combined) from walleyes by month for the angling season following tagging in the Portage-Torch lake system. Tags observed by creel clerk, but not reported by angler are also included. Percentage of total is in parentheses.

Month	Species		
	Walleyes	Northern pike	Smallmouth bass
4	0 (0)	0 (0)	0 (0.0)
5	86 (16.5)	33 (38.8)	1 (6.3)
6	221 (42.3)	23 (27.1)	5 (31.3)
7	108 (20.7)	13 (15.3)	2 (12.5)
8	72 (13.8)	6 (7.1)	6 (37.5)
9	7 (1.3)	3 (3.5)	2 (12.5)
10	2 (0.4)	1 (1.2)	0 (0.0)
11	3 (0.6)	0 (0)	0 (0.0)
12	5 (1.0)	3 (3.5)	0 (0.0)
1	12 (2.3)	1 (1.2)	0 (0.0)
2	6 (1.1)	2 (2.4)	0 (0.0)
3	0 (0)	0 (0)	0 (0.0)
Total	522	85	16

Table 14.–Recapture locations of walleyes tagged in the Portage-Torch lake system based on recaptures during the spring netting survey. Percent of total recaptured fish is in parentheses.

Tagging location	Recapture location				
	Portage Lake	Torch Lake	Portage Canal	Portage River	Sturgeon River
Portage Lake	526 (88.1)	3 (0.5)	68 (11.4)	0 (0)	0 (0)
Torch Lake	0 (0)	88 (100)	0 (0)	0 (0)	0 (0)
Portage Canal	11 (19.6)	0 (0)	45 (80.4)	0 (0)	0 (0)
Portage River	5 (71.4)	1 (14.3)	1 (14.3)	0 (0)	0 (0)
Sturgeon River	1 (100)	0 (0)	0 (0)	0 (0)	0 (0)

Table 15.–Recapture locations of northern pike tagged in the Portage-Torch lake system based on recaptures during the spring netting survey. Percent of total recaptured fish is in parentheses.

Tagging location	Recapture location				
	Portage Lake	Torch Lake	Portage Canal	Portage River	Sturgeon River
Portage Lake	22 (52.4)	1 (2.4)	19 (45.2)	0 (0)	0 (0)
Torch Lake	0 (0)	1 (100)	0 (0)	0 (0)	0 (0)
Portage Canal	2 (27.3)	0 (0)	8 (72.7)	0 (0)	0 (0)
Portage River	3 (8.3)	0 (0)	0 (0)	17 (70.8)	5 (20.8)
Sturgeon River	2 (9.4)	0 (0)	0 (0)	10 (31.3)	19 (59.4)

Table 16.–Recapture locations of walleyes tagged in the Portage-Torch lake system based on voluntary angler tag returns (reward and nonreward, harvested and released) received through the time of report writing (June 2010). Percent of total recaptured fish is in parentheses.

	Recapture location						
Tagging Location	Portage Lake	Torch Lake	Portage Canal	Portage River	Sturgeon River	Keweenaw Bay	Other Lake Superior
Portage Lake	447 (88.2)	27 (5.3)	17 (3.4)	1 (0.2)	4 (0.8)	7 (1.4)	4 (0.8)
Torch Lake	54 (57.4)	38 (40.4)	1 (1.1)	0 (0)	0 (0)	1 (1.1)	0 (0)
Portage Canal	38 (65.5)	4 (6.9)	11 (19.0)	1 (1.7)	2 (3.4)	0 (0)	2 (3.4)
Portage River	10 (71.4)	0 (0)	1 (7.1)	0 ()	0 (0)	1 (7.1)	2 (14.3)
Sturgeon River	1 (33.3)	1 (33.3)	0 (0)	0 ()	0 (0)	1 (33.3)	0 (0)

Table 17.–Recapture locations of northern pike tagged in the Portage-Torch lake system based on voluntary angler tag returns (reward and nonreward, harvested and released) received through the time of report writing (June 2010). Percent of total recaptured fish is in parentheses.

	Recapture location						
Tagging Location	Portage Lake	Torch Lake	Portage Canal	Portage River	Sturgeon River	Keweenaw Bay	Other Lake Superior
Portage Lake	30 (85.7)	0 (0)	2 (5.7)	1 (2.9)	1 (2.9)	1 (2.9)	0 (0)
Torch Lake	1 (33.3)	2 (66.7)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Portage Canal	5 (45.5)	1 (9.1)	4 (36.4)	0 (0)	0 (3.4)	0 (0)	1 (9.1)
Portage River	20 (71.4)	1 (3.6)	0 (0)	4 (14.3)	0 (0)	3 (10.7)	0 (0)
Sturgeon River	24 (82.8)	1 (3.4)	0 (0)	2 (6.9)	1 (0)	1 (3.4)	0 (0)

Table 18.–Comparison of recreational fishing effort and total harvest on the Portage-Torch lake system to estimates from other selected Michigan lakes. Lakes are listed from highest to lowest total fishing effort.

Lake County	Size (acres)	Survey period	Fishing effort (hours)	Fish harvested (number)	Fish harvested per hour	Hours fished per acre	Fish harvested per acre
Houghton Roscommon	20,075	Apr 2001–Mar 2002	499,048	386,287	0.77	24.9	19.2
Cisco Chain Gogebic, Vilas	3,987	May 2002–Feb 2003	180,262	120,412	0.67	45.2	30.2
Muskegon Muskegon	4,232	Apr 2002–Mar 2003	180,064	184,161	1.02	42.5	43.5
Burt Cheboygan	17,395	Apr 2001–Mar 2002	134,205	68,473	0.51	7.7	3.9
South Manistique Mackinac	4,133	May 2003–Mar 2004	142,686	43,654	0.31	34.5	10.6
Leelanau Leelanau	8,607	Apr 2002–Mar 2003	112,112	15,464	0.14	13.0	1.8
Gogebic Gogebic, Ontonagon	13,127	May 2005–Mar 2006	101,372	15,689	0.15	7.7	1.2
Big Manistique Luce, Mackinac	10,346	May 2003–Mar 2004	88,373	71,652	0.81	8.5	6.9
Mullett Cheboygan	16,704	May 2009–Mar 2010	71,240	63,136	0.89	4.3	3.8
Black Cheboygan, Presque Isle	10,113	Apr 2005 Mar 2006	59,874	18,762	0.31	5.9	1.9
Charlevoix Charlevoix	17,268	Apr 2006 Mar 2007	57,126	19,671	0.34	3.3	1.1
Crooked and Pickerel Emmet	3,434	Apr 2001–Mar 2002	55,894	13,665	0.24	16.3	4.0
Michigamme Reservoir Iron	6,400	May 2001–Feb 2002	52,686	10,899	0.21	8.2	1.7

Table 18.–Continued.

Lake County	Size (acres)	Survey period	Fishing effort (hours)	Fish harvested (number)	Fish harvested per hour	Hours fished per acre	Fish harvested per acre
Portage and Torch Houghton	13,208	May 2007–Feb 2008	42,724	6,339	0.15	3.2	0.5
Long Presque Isle, Alpena	5,342	Apr 2004–Mar 2005	34,894	7,004	0.20	6.5	1.3
Grand Presque Isle	5,822	Apr 2004–Mar 2005	33,037	10,623	0.32	5.7	1.8
Michigamme Baraga, Marquette	4,292	May–Sep 2006	26,574	4,307	0.16	6.2	1.0
Peavy Pond Iron	2,794	May 2004–Feb 2005	26,447	6,299	0.24	9.5	2.3
Bond Falls Flowage Ontonagon	2,127	May–Oct 2003	21,182	3,193	0.15	10.0	1.5
North Manistique Luce	1,709	May 2003–Mar 2004	10,614	7,603	0.72	6.2	4.4
Average			96,521	53,865	0.42	13.5	7.1
Median			58,500	15,577	0.31	8.0	2.1

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Ellen S. Grove, Desktop Publisher

Approved by Gary E. Whelan

Appendix–Fish species collected in the Portage-Torch lake system from 1953 through 2007.

Common name	Scientific name
Species collected in spring 2007 with trap nets, fyke nets, and electrofishing gear	
Alewife	*Alosa pseudoharengus*
Black bullhead	*Ameiurus melas*
Black crappie	*Pomoxis nigromaculatus*
Bluegill	*Lepomis macrochirus*
Bluntnose minnow	*Pimephales notatus*
Brook trout	*Salvelinus fontinalis*
Brown bullhead	*Ameiurus nebulosus*
Brown trout	*Salmo trutta*
Burbot	*Lota lota*
Central mudminnow	*Umbra limi*
Cisco	*Coregonus artedi*
Coho salmon	*Oncorhynchus kisutch*
Common carp	*Cyprinus carpio*
Common shiner	*Luxilus cornutus*
Creek chub	*Semotilus atromaculatus*
Golden shiner	*Notemigonus crysoleucas*
Lake sturgeon	*Acipenser fulvescens*
Largemouth bass	*Micropterus salmoides*
Longnose sucker	*Catostomus catostomus*
Mottled sculpin	*Cottus bairdi*
Northern pike	*Esox lucius*
Pumpkinseed	*Lepomis gibbosus*
Rainbow smelt	*Osmerus mordax*
Rainbow trout	*Oncorhynchus mykiss*
Rock bass	*Ambloplites rupestris*
Round whitefish	*Prospium cylindraceum*
Ruffe	*Gymnocephalus cernuus*
Sea lamprey	*Petromyzon marinus*
Shorthead redhorse	*Moxostoma macrolepidotum*
Silver lamprey	*Ichthyomyzon unicuspis*
Silver redhorse	*Moxostoma anisurum*
Smallmouth bass	*Micropterus dolomieu*
Spottail shiner	*Notropis hudsonius*
Trout perch	*Percopsis omiscomaycus*
Walleye	*Sander vitreus*
White sucker	*Catostomus commersonii*
Yellow perch	*Perca flavescens*

Appendix–Continued.

Common name	Scientific name
Additional species collected in summer 1994 with bottom trawl	
Spoonhead sculpin	*Cottus ricei*
Johnny darter	*Etheostoma nigrum*
Additional species collected in fall 1993 with bottom trawl	
Logperch	*Percina caprodes*
Additional species collected in summer 1973 with gill nets	
Muskellunge	*Esox masquinongy*
Additional species collected in fall 1970 with bottom trawl	
Silver shiner	*Notropis photogenis*
Additional species collected in summer 1953 with trawls	
Ninespine stickleback	*Pungitius pungitius*