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Assessment of Walleye Spawning Runs in Tributaries to the Upper Great Lakes and Factors Potentially Influencing the Magnitude of Spawning Runs

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Abstract

Walleye (*Sander vitreus*) are a highly-prized and important top predator in the Great Lakes region, including Green Bay, Lake Michigan. Walleye populations in northern Green Bay have been assessed for decades but relatively little information is available to characterize the river-spawning component of the larger Green Bay population. In addition, the ability to rehabilitate and manage Walleye populations in Great Lakes tributaries is hampered by a lack of understanding of relationships between factors thought to influence Walleye reproductive success and the size of spawning stocks. To help address these knowledge gaps, I characterized Walleye spawning runs on eight rivers in the Upper Peninsula by conducting electrofishing surveys using multi-pass mark-recapture open population estimate methods. Over 25,600 Walleyes were handled during population estimate surveys, excluding recaptured fish. Estimates of spawning run size ranged from 56,710 Walleyes in the Whitefish River to 422 fish in the Manistique River. Multiple age classes were represented in each river, indicating natural reproduction during years when stocking did not occur. To identify aspects of habitat potentially associated with Walleye spawning run magnitude I examined correlations between estimates of Walleye spawning run size for eleven Michigan rivers (including the eight surveyed in this project) and 27 GIS-based parameters describing spawning and nursery habitats associated with downstream river reaches. None of the parameters describing river and estuary habitats were significantly correlated with size of Walleye spawning runs, though larger spawning runs appeared to be associated with larger rivers having intermediate channel gradients. This study provided an opportunity to adapt existing field techniques to learn more about Walleye spawning populations in individual rivers and their contribution to the larger population of northern Green Bay. The estimates and analyses here will contribute to future efforts to better understand factors influencing Walleye stocks in Green Bay, the Great Lakes region, and beyond.

INTRODUCTION

Walleye are a highly-prized and important top predator in the Great Lakes region, including Green Bay, Lake Michigan. The productive fishery during recent decades has made the region popular for Walleye anglers and tournaments. This was not always the case. Habitat destruction, pollution, interactions with non-native species, and over-exploitation pushed stocks to very low levels in the mid-1960s, and by 1973, only the Menominee River on the Michigan–Wisconsin border supported a self-sustaining stock (Schneider et al. 1991). In northern Green Bay, which includes Little Bay de Noc (LBDN) and Big Bay de Noc (BBDN), improved habitat conditions and extensive stocking helped to restore naturally reproducing populations, but trophic changes associated with dreissenid mussel colonization and other factors, such as illegal harvest, are thought to have contributed to recent population declines. Natural reproduction is important to northern Green Bay populations, with naturally reproduced fish making up an estimated 76% and 61% of Walleye year classes in LBDN and BBDN during 2004–2009 (Zorn 2015).

While Walleye populations in northern Green Bay have been assessed for decades, relatively little information is available to distinguish the river-spawning and reef-spawning components of the larger Green Bay population. Looking at recaptures of spawning fish, Zorn and Schneeberger (2011) showed 96% fidelity of Walleyes to widely-separated spawning areas in northern Green Bay, while Dembkowski et al. (2018) noted 83% fidelity of tagged Walleyes to individual spawning rivers in relatively close proximity to each other in southern Green Bay. It is thought that spawning reefs contribute to Walleye stocks, but quantitative estimates of river or reef spawning stocks are unavailable. Estimates of the size of Walleye spawning runs in rivers in combination with statistical catch-at-age based model estimates can be used to gain insight on the relative contributions of river- and reef-spawning stocks to the northern Green Bay Walleye population.

Extensive effort is expended annually by the Michigan Department of Natural Resources (MDNR) Fisheries Division to rear and stock Walleyes, often with the goal of restoring self-sustaining inland and Great Lakes populations. Recruitment is often thought to be the factor limiting Walleye populations, with our ability to rehabilitate stocks in Great Lakes tributaries being hampered by a lack of understanding of relationships between factors thought to influence Walleye reproductive success and the size of Walleye spawning stocks. These include: the relative contribution of tributary and nearshore spawning areas to recruitment, both historically and currently; the extent and significance of changes to key habitats (e.g., dams on spawning tributaries); and biophysical nursery habitat for Walleye larvae and juveniles. A better understanding of which factors are important to Walleye recruitment, and ultimately spawning population size, would enable more effective rehabilitation and management of Great Lakes Walleye populations and protection and rehabilitation of key habitats. These are regional issues, so information would ideally be collected from many areas and lead to development of a broadly applicable model for understanding linkages between river and nearshore habitats and adfluvial Walleye populations in the Great Lakes.

The primary objectives of this study were: 1) to characterize Walleye spawning runs in tributaries to northern Green Bay, and other Upper Peninsula rivers, specifically focusing on run size, age composition, and other attributes of each stock, such as length-at-age, occurrence of external cysts (e.g. lymphocystis) and lamprey wounds; 2) to estimate river and reef-based contributions to the overall LBDN Walleye population by comparing Statistical Catch-At-Age (SCAA)-based estimates of adult Walleye population size to estimates of spawning adults in key tributaries; and 3) to explore relationships among Walleye spawning run size and potential recruitment-related parameters for study rivers and others in Michigan where estimates of Walleye spawning run magnitude occur.

METHODS

Study areas

This study focused primarily on tributaries to Green Bay in Michigan's Upper Peninsula, a subset of the many Michigan rivers hosting spawning runs of Walleyes. These Green Bay tributaries drain a glaciated landscape, with glacial deposits ranging in texture from clay lakeplains to medium or coarse-textured end and ground moraines (Farrand and Bell 1982). Field work for Walleye spawning run estimation occurred on the lowermost Great Lakes accessible reaches of third-order or larger streams that could be sampled with boat electrofishing in spring. Walleye spawning typically occurred in relatively high gradient reaches and rapids dominated by coarse gravel and cobble. Walleye spawning runs were estimated in eight Upper Peninsula streams and previously published estimates from three streams were also obtained for comparison (Figure 1; Table 1). Of the Upper Peninsula streams, six are tributaries to Green Bay (Menominee, Cedar, Ford, Escanaba, Rapid, and Whitefish rivers), the Manistique River drains into Lake Michigan, and the Tahquamenon River flows into Lake Superior. Additional sampling occurred in the Manistique (2007); Ford (2008, 2010); Ontonagon (2012); and Ogontz (2015) rivers during the years in parentheses but these surveys missed much of the run or caught too few fish to produce population estimates due to timing of surveys or river conditions and these data were excluded from further analysis.

Field methods

Multiple-pass, mark-recapture electrofishing was used to estimate size of Walleye spawning runs. All surveys were conducted during daytime using pulsed DC current with a Smith Root boat electrofishing unit. Spring warming patterns were synchronous in rivers across the region (Figure 2) so one river was typically surveyed per year, with the survey spanning the bulk of the spawning period for Walleyes in the river. A Hobo electronic temperature logger was typically deployed in the river at the beginning of the survey period to record hourly water temperatures throughout the duration of the survey. Surveys began once substantial numbers of Walleyes were present in the spawning area and generally continued daily (weather permitting, except for weekends) until it was determined that a large majority of Walleye spawning had occurred. The progress of the spawning run was assessed by examining daily patterns in the ratio of male to female fish in the spawning area and the reproductive status of females. For data analysis purposes I considered the spawning period to have largely concluded when the male to female ratio returned to mostly males and the proportion of spent females was relatively high. These criteria are consistent with previous efforts on other Michigan rivers (Thomas 1995; Leonardi and Thomas 2000). It typically took 2–3 weeks of field sampling to conduct a spawning run estimate survey.

Sampling crews applied a day-specific fin clip to each Walleye encountered rather than marking every fish with a uniquely numbered tag as often occurs in such surveys (Hanchin 2017). Since thousands of Walleyes were handled on some rivers, this approach provided us with individual capture history for estimating spawning run size using open-population formulas, yet kept us from becoming involved in a large multi-water, multi-year tag return processing operation as typically occurs when fish are uniquely marked with external tags (Pine et al. 2003). From each Walleye captured, we recorded: total length, sex, reproductive status of females (gravid, ripe, partially spent, or spent), the presence of unidentified external cysts (e.g., lymphocystis), external deformities or injuries (e.g., lamprey wounds), and noted any existing clips. The 3–5 anterior-most dorsal spines were removed from 20 Walleyes per inch group per sex for aging purposes. Fin clips for future genetic analysis were also removed from all 21 and 26 inch-long Walleyes from which aging structures were taken. Each fish was given the clip assigned for that day (the "Clip du jour") prior to being released. The same sequence of day-specific fin clips was used in each river where spawning run surveys occurred (Table 2). Biological data and capture history information for every Walleye encountered were entered into a MS Access database. For each spawning run survey that led to a population estimate I wrote an overview summary of the survey shortly after the field season ended and distributed it to local fishery managers and interested individuals (Appendix A).

Population estimation

Multi-pass, open population estimation methods (i.e., Jolly-Seber model, Seber 1982) were used to estimate the size of each Walleye spawning run because we had capture histories for individual fish. It is appropriate to use open population analysis methods for spawning Walleyes since fish moved freely into and out of the spawning habitats over the course of the entire spawning period. The Jolly-Seber model assumes that: 1) every fish present in the population has an equal probability of capture during each sampling event; 2) survival from one sampling equal to the next is equal for fin clipped and unclipped fish; 3) fin clips are not overlooked or lost; and 4) all fish are released immediately after the sample and all sample periods have a short duration (i.e., instantaneous) (Seber 1982).

I used the Arnason and Schwarz (1999) formulation of the Jolly-Seber model, POPAN in Program MARK (White and Burnham 1999), which is appropriate for situations where individuals from a larger population enter or depart from the sample area between sampling events. This was consistent with behavioral movements of individual Walleyes into and out of the spawning reaches sampled over the course of each spawning period. This formulation helped to address potential violation of assumption 1, the only assumption of major concern given our methods.

Male and female Walleyes showed distinct movement patterns during the spawning period, with males often spending considerable time (one week or more) on the spawning habitats and females typically moving into spawning habitats a few days before spawning and emigrating (i.e., not being caught in surveys) shortly after spawning. Given their different spawning migration patterns and our ability to readily distinguish sex of fish during the spawning run, I developed separate estimates for males and females spawning in each river. Sex-specific data files showing numbers of Walleyes exhibiting each unique capture history were developed for each river. For population estimation purposes only, I assigned a sex to the small number of fish where sex determination was not obvious, basing sex assignments on river-specific data showing which sex was most common for each inch group of Walleyes. The number of fish showing each unique capture history was tallied, with the resulting lists providing input files for the POPAN module in Program MARK (Appendix B).

Within POPAN, I entered the numbers of sampling intervals (electrofishing days), the number of days between sampling events, and labelled groups (Male or Female) for each river. When running estimates, I specified "parameter specific" link function, using the mlogit link function for parameters that must sum to one (e.g., male or female), and the log link ("log") function for positively constrained values, such as population size (N) or change (lambda). Saturated and reduced models were compared for each river, and in every case but one (Manistique River) the saturated model produced the best fit. For the Manistique River, the constant P model performed better than the saturated model, but survey catches on the river were much lower than other rivers and differences between model estimates were minor (61 fish for males and 26 fish for females). So, for consistency I reported estimates from the saturated model for all rivers.

River and estuary characterization

I compiled data on 27 parameters to assess their potential relation to the magnitude of Walleye spawning runs (Table 3). In addition to the eight rivers we conducted population estimates on, I obtained estimates of spawning run size that were available for other Michigan rivers with Great Lakes access, using the most recent estimate available. The estimates were as follows; Huron River 5,810 Walleyes (Leonardi and Thomas 2000); Clinton River 7,406 (Thomas 1995); and Muskegon River 46,479 Walleyes (O'Neal 1998). Total numbers of Walleyes stocked in the river or in receiving waters near the river mouth 4 to 6 years prior to the population estimate were obtained from Michigan DNR Fisheries Division's online Fish Stocking Database (Table 1) to assess their association with river spawning run estimates (Zorn 2015).

GIS-based data were obtained on attributes of the lower portions of rivers that were accessible for spawning Walleyes, specifically the length of the reach accessible to Walleyes, average gradient of the highest order confluence-to-confluence reach of the stream, and catchment size and estimated dissolved load and yield of total phosphorus for the lowermost confluence-to-confluence reach of the stream (Table 3).

Several attributes of estuary areas were quantified using GIS-based habitat data layers, typically by querying conditions within 1-km and 5-km buffers from the river mouth into the Great Lakes receiving waters to the 5-m depth contour. The 5-km buffer was also tested because a 1-km buffer was not always large enough to intersect the GIS habitat layer for some variables and river estuaries. Habitat variables examined included spring degree day accumulation, chlorophyll a, water circulation, spring warming rate, area of riverine or lacustrine wetlands, and amounts of submerged aquatic vegetation (Table 3). Relationships between Walleye run magnitude and environmental variables were explored visually with plots and using Pearson correlation analyses.

RESULTS

Walleye spawning run attributes

Spawning run estimates were made from surveys conducted between 2005 and 2011 (Table 4). The earliest survey began on March 29 (Manistique River) and the latest surveys concluded on April 28 in the Rapid and Whitefish rivers (Table 5). The typical chronology of the spawning run involved males moving into and establishing residency in spawning areas for much of the spawning run, with females appearing to enter spawning areas shortly before spawning and leaving soon after spawning. These contrasting behaviors were evident in our recapture data, with males making up 79% of the fish recaptured two or more times, and 90% of Walleyes recaptured three or more times (Table 6). Higher capture and recapture rates for male Walleyes relative to those of females were consistent across all rivers surveyed (Table 5; Table 6), and likely explains why relative standard error values (standard error divided by estimate) were higher for females in all rivers (Table 7).

I concluded surveys when most or all of the following were apparent: declining total daily catches (Figure 3); reduced proportions of females in the daily catch (Figure 3); and increased percentages of ripe, partially spent, and spent females in the daily catch (Figure 4). Collectively these indicators were useful in guiding our decisions but they were highly variable, being influenced by current weather, water temperature (Figure 4), streamflow conditions, and other factors that could influence gonad maturation processes in female Walleyes and fish movements into and out of study reaches.

Over the course of conducting the Walleye spawning run estimate surveys, crews handled over 25,600 individual Walleyes, excluding recaptured fish. Crews handled the most Walleyes (9,494 fish) on the Menominee River, the numbers buoyed by 15 to 17 inch males, most from an exceptional 2003 year class of Walleyes (Table 8; Figure 5). The next largest number of Walleyes captured was 6,928 fish on the Whitefish River, the mainstay of the LBDN Walleye population. Not surprisingly, the Menominee and Whitefish rivers had the highest population estimates, with 55,735 and 56,710 Walleyes respectfully (Table 7). The Escanaba, Ford, and Rapid rivers each supported sizable Walleye spawning runs with estimated run sizes for these rivers of 10,791, 10,689, and 4,222 fish (Table 7). The estimates were reasonably precise, with the standard error for most estimates of total run size being within 10–20% of the estimate (Table 7). A more detailed account of each year's spawning run survey is in Appendix A.

Age and growth data from the study rivers provided insight into Walleye recruitment and growth rates of fish in different areas. Multiple age classes were represented in each river, indicating natural reproduction during years when stocking did not occur (Table 9; Table 10). For males and females, size at age up to age 10 appeared to be greater for populations spawning in the Cedar, Menominee, and Manistique rivers (Figure 6). I compared mean length at age 8 among Walleyes in the eight rivers because differences were quite apparent and sample sizes relatively large, but no significant differences were apparent when 95% confidence intervals were included (Figure 7).

There were some similarities among rivers in terms of prevalence of lamprey wounds and occurrence of unidentified external cysts. The occurrence of external cysts among Walleyes averaged 12.7 percent, showing no consistent differences between sexes in study rivers (Table 11). The Menominee River fish had the lowest prevalence of external cysts, while the Rapid, Whitefish, Escanaba, and Cedar rivers had above average levels of occurrence (Table 11). Similarly, Menominee River Walleyes had the lowest prevalence of sea lamprey wounds (Table 11), though part of this may be due to some crews not recording this parameter since it was not specifically listed on the data sheet. The highest prevalence of lamprey wounds occurred for the Cedar and Manistique rivers, both of which discharge into deeper water environments (potentially better suited to lamprey) than other rivers (e.g., Menominee, Escanaba, Rapid, Whitefish) which drain into shallower, warmer bays.

Run size vs. river and estuary characteristics

Walleye run size in the eight study rivers and three additional Michigan rivers with spawning run estimates was compared to numbers of Walleyes stocked four to six years prior to the estimate and 26 river and estuary habitat-based parameters potentially related to survival and growth of larval Walleyes and Walleye reproductive success in general (Table 3). No variables were significantly correlated at the 5% significance level (Table 12). The drainage area at the river mouth was positively associated with size of Walleye spawning runs and nearly significant ($P = 0.06$). While the linear correlation was not significant, highest runs were noted in rivers having intermediate average gradient values (0.0006 to 0.0012), providing spawning habitats with coarse substrate (Figure 8). Collectively, this suggests that larger spawning runs might be expected in larger rivers that provide riffles and rapids with coarse substrates for spawning. Examination of correlations and plots of these data (Figure 8) suggest few other obvious associations between size of Walleye spawning runs and the parameters examined.

DISCUSSION

The surveys provided a large amount of information chronicling Walleye spawning runs in several rivers. This information demonstrated the dynamic or fluid nature of Walleye spawning runs and how attributes of the run varied over time and with river conditions, such as temperature. Overall, walleye behavior patterns were consistent with the life history literature (Becker 1983). For example, males consistently established temporary residency in the vicinity of spawning areas during much of the spawning period, while females mostly moved into spawning areas when ready to reproduce and genderally did not linger in spawning areas. The biological data also enabled us to characterize important attributes of Walleye stocks, including growth rates, lymphocystis infection and sea lamprey wounding rates.

The spawning run estimates provide additional perspective on contributions of individual river spawning stocks to the larger Green Bay population. For example, the combined estimate for the four LBDN tributaries studied (Whitefish, Rapid, Escanaba, and Ford rivers) amounted to slightly over

88,000 adult Walleyes. The number of age 4 and older Walleyes in LBDN in 2009 (approximate mid-point of river spawning run estimates) was approximately 168,000 fish, based on the most recent SCAA model estimate (Zorn, unpublished data). This suggests that the Walleye runs in these rivers made up about 52% of the LBDN population. The remaining 48% of the LBDN population could be produced by other LBDN locations (rivers, reefs, unsampled reaches of study rivers, etc.), fish spawning in study rivers before or after we sampled, stocked fish (Zorn 2015), or migrants from other areas. Errors associated with estimates of Walleye run size in rivers and the overall LBDN population also complicate accounting for sources of adult Walleyes in the LBDN population.

My ability to estimate the size of Walleye runs in study rivers was limited by several factors. First, we often did not sample the entire period of the spawning run for a river though our sampling likely covered 80–90% of the run, focusing on several weeks bounding the peak spawning period. Spawning runs can be quite protracted, especially towards the end, and expending considerable effort to document the beginning and end of the run is costly and inefficient, given the minor amount of additional information obtained. So, our Walleye run estimates often excluded very early or late spawning fish, particularly females. Second, our sampling covered a considerable length of river, targeting the best spawning habitat, but sometimes did not include the entire reach available to Walleyes. This was especially the case on long, unfragmented rivers (e.g., Cedar, Ford, Whitefish) or rivers such as the Tahquamenon which had many miles of free-flowing habitat downstream of the first barrier. Preliminary sampling on the Cedar suggested that over 95% of spawning likely occurred at or downstream of the most downstream rapids (Zorn, unpublished data), so our estimate likely captured most of the run. On the other hand, we sampled at several rapids on the lower Whitefish River and saw no obvious downstream–upstream diminution of Walleye catches in the rapids we sampled. I suspect considerable spawning further upstream in the Whitefish River, which would be consistent with anecdotal reports of spawning Walleyes many miles upriver. Thus, logistic limits to the temporal or spatial coverage of our field sampling likely resulted in underestimation of Walleye run size in some rivers.

The lack of missing age classes (i.e., presence of reasonable sample sizes) for Walleyes 10 years of age and younger in Green Bay tributaries (Table 9) for numerous years when stocking did not occur (Table 10) suggests fairly consistent natural reproduction of Walleye in study rivers draining into northern Green Bay. This is consistent with the finding that 76% of Walleyes from the 2004–2009 year classes in LBDN were from natural reproduction (Zorn 2015). The closest stocking event in the Tahquamenon River prior to our 2008 survey was in 1992, and no Walleyes had been stocked into the Great Lakes accessible reach of the Manistique River prior to our 2010 survey (MDNR Fisheries Division Fish Stocking Database). The presence of multiple year classes Walleyes in the Tahquamenon River is indicative of natural reproduction, while lower numbers in the Manistique may result from limited natural reproduction or some downstream movement of Walleyes stocked above the dam in Manistique. I did not estimate relative abundance of non-stocked vs. stocked year classes for populations spawning in northern Green Bay tributaries because alternate-year stocking of Walleyes often occurred in receiving waters (Table 10), and with over- or under-estimation of Walleye age by one year when using dorsal spines being somewhat common (Erickson 1983; Carpenter et al. 2017), fish aged one year above or below the actual age could readily be misassigned to stocked or wild year classes. Nevertheless, evidence of consistent natural reproduction of Walleyes in many study rivers and lack of significant contribution of stocked fish to subsequent Walleye spawning runs (Table 12) suggest that the contribution of stocked Walleyes to spawning runs may be questionable for some systems.

Comparisons of spawning population size between rivers should take into consideration potential effects of exceptionally strong year classes on estimates of overall population size because Walleye are notorious for having strong or weak year classes. For example, the exceptionally strong 2003 year class in the Menominee River caused the population estimate of Walleyes for that river to be much higher than what it would have been if the survey had occurred a couple years earlier, prior to these fish reaching sexual maturity.

Previous work by Jones et al. (2006) suggests that Walleye reproductive success (and ultimately abundance of Walleye stocks) is influenced by conditions in spawning rivers (Mion et al. 1998) and reefs (Roseman et al. 2001) and nursery habitats. I found no significant correlations and few apparent relationships between size of Walleye spawning runs and the river and estuary parameters examined. Length of the reach accessible for spawning and the amount of spawning habitat available were thought to relate to potential Walleye reproduction in other studies (Jones et al. 2003; Cheng et al. 2006), but aside from river size, none of the river habitat variables I looked at were related to Walleye spawning run abundance. Similarly, previous studies (Koonce et al. 1977; Jones et al. 2006) suggest that water temperature may relate to year class strength and ultimately stock size, but the temperature metrics I examined were not correlated to Walleye run size. This may be due to limited range of variation in thermal metric values (e.g., spring warming rates) among the systems I studied or other factors. In addition, measuring correlations based on period means in temperature conditions or other factors and use of overall stock size estimates tend to downplay influences of individual year conditions on Walleye year class strength, hindering detection of factors potentially important to walley recruitment.

Other factors may also have influenced the lack of significant correlations between habitat conditions and spawning run abundance. The breadth in geographic location, habitat conditions, and populations of the systems studied may have been too limited to show significant correlations between habitat variables and Walleye spawning run size (Levin 1992). In addition, uncertainty associated with our estimates of Walleye spawning stock size (Pritt et al. 2013) or influences of exceptional year classes on estimates (e.g., 2003 year class in the Menominee River run) may also have obscured detection of general relationships between river or estuary habitat and Walleye spawning run abundance. A small sample size (i.e., few estimates) also prevented more detailed analyses, such as looking at combined effects of multiple variables or effects of variables through time on Walleye abundance (Jones et al. 2006). The ability to pair habitat conditions for any individual habitat variable to Walleye year class strength for individual years would undoubtedly have resulted in more meaningful comparisons, but such data were unavailable. The approach taken here had not been used before, so was deemed worth exploring. Nevertheless, the estimates and analyses from this study contribute to the body of knowledge for future efforts to better understand factors influencing Walleye stocks in Green Bay, the Great Lakes region, and beyond.

Finally, this study provided an opportunity to adapt existing field survey techniques to learn more about Walleye spawning populations, providing insights on the overall population of northern Green Bay. The innovative date-specific fin clipping approach enabled efficient multiple mark-recapture population estimation using open population methods appropriate for the adfluvial populations studied. Estimates had reasonably tight error bounds (i.e., standard errors 10–20% of the size of the total population estimate), being suitable for management use (Table 7). The fin-clipping approach also saved us from having to uniquely tag or mark thousands of Walleyes and subsequently becoming involved in a costly, long-term tag recapture processing operation for multiple water bodies. This study provided a valuable proof of concept for this innovative approach to estimating Walleye spawning runs in rivers.

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REFERENCES

Albert, D. A., D. A. Wilcox, J. W. Ingram, and T. A. Thompson. 2005. Hydrogeomorphic classification for Great Lakes coastal wetlands. Journal of Great Lakes Research 31 (Supplement 1):129–146.

Arnason, A. N., and C. J. Schwarz. 1999. Using POPAN–5 to analyse banding data. Bird Study 46 (Supplement 1), S157–S168.

Becker, G. C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison.

Carpenter, K., T. Zorn, D. Isermann, C. Isermann, and D. Dembkowski. 2017. Precision of otolith and dorsal spine age estimates for Walleye Sander vitreus in northern Lake Michigan. Michigan Chapter American Fisheries Society Annual Meeting, Mackinaw City. Poster.

Cheng, F., U. Zika, K. Banachowski, D. Gillenwater, and T. Granata. 2006. Modelling the effects of dam removal on migratory Walleye (*Sander vitreus*) early life-history stages. River Research and Applications 22:837–851.

Dembkowski, D. J., D. A. Isermann, S. R. Hogler, W. A. Larson, and K. N. Turnquist. 2018. Stock structure, dynamics, demographics, and movements of Walleyes spawning in four tributaries to Green Bay. Journal of Great Lakes Research 44:970–978.

Erickson, C. M. 1983. Age determination of Manitoban Walleyes using otoliths, dorsal spines, and scales. North American Journal of Fisheries Management 3:176–181.

Farrand, W. R., and D. L. Bell. 1982. Quaternary geology of Michigan. Lansing, Michigan: Michigan Department of Natural Resources, Geological Survey Division. 2 sheets. Scale 1:500,000.

Hanchin, P. A. 2017. A summary and analysis of the Large Lakes Survey Program in Michigan 2001–2010. Michigan Department of Natural Resources Fisheries Report 25. Lansing.

Jones, M. L., J. K. Netto, J. D. Stockwell, and J. B. Mion. 2003. Does the value of newly accessible spawning habitat for Walleye (Stizostedion vitreum) depend on its location relative to nursery habitats? Canadian Journal of Fisheries and Aquatic Sciences 60:1527–1538.

Jones, M. L., B. J. Shuter, Y. Zhao, and J. D. Stockwell. 2006. Forecasting effects of climate change on Great Lakes fisheries: models that link habitat supply to population dynamics can help. Canadian Journal of Fisheries and Aquatic Sciences 63:457–468.

Koonce, J. F., T. B. Bagenal, R. F. Carline, K. E. F. Hokanson, and M. Nagieć. 1977. Factors influencing year-class strength of percids: a summary and a model of temperature effects. Journal of the Fisheries Research Board of Canada 34:1900–1909.

Leonardi, J. M. and M. V. Thomas. 2000. An assessment of the Huron River Walleye population. Michigan Department of Natural Resources, Fisheries Technical Report Number 97–2. Ann Arbor.

Levin, S. A. 1992. The problem of pattern and scale in ecology. Ecology 73:1943–1967.

Mion, J. B., R. A. Stein, and E. A. Marschall. 1998. River discharge drives survival of larval Walleye. Ecological Applications 8:88–103.

Pine, W. E., K. H. Pollock, J. E. Hightower, T. J. Kwak, and J. A. Rice. 2003. A review of tagging methods for estimating fish population size and components of mortality. Fisheries 28:10–23.

Pritt, J. J., M. R. DuFour, C. M. Mayer, P. M. Kocovsky, J. T. Tyson, E. J. Weimer, and C. S. Vandergoot. 2013. Including independent estimates and uncertainty to quantify total abundance of fish migrating in a large river system: Walleye (*Sander vitreus*) in the Maumee River, Ohio. Canadian Journal of Fisheries and Aquatic Sciences 70:803–814.

O'Neal, R. P. 1998. Muskegon River Walleye survey, 1998. Michigan Department of Natural Resources, Fisheries Division, Fish Information Collection System, Lansing.

Roseman, E. F., W. W. Taylor, D. B. Hayes, R. L. Knight, and R. C. Haas. 2001. Removal of Walleye eggs from reefs in western Lake Erie by a catastrophic storm. Transactions of the American Fisheries Society 130: 341–346.

Schneider, J. C., T. J. Lychwick, E. J. Trimberger, J. H. Peterson, R. O'Neal, and P. J. Schneeberger. 1991. Walleye rehabilitation in Lake Michigan, 1969–1989. Pages 23–62 *in* P. J. Colby, C. A. Lewis, and R. L. Eshenroder, editors. Status of Walleye in the Great Lakes: case studies prepared for the 1989 workshop. Great Lakes Fishery Commission, Special Publication 91–1, Ann Arbor.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters, 2nd edition. Macmillan, New York.

Thomas, M. V. 1995. An assessment of the Clinton River Walleye population. Michigan Department of Natural Resources, Fisheries Technical Report Number 95–2, Ann Arbor.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 (Supplement 1):S120–S139.

Zorn, T. G. 2015. Contribution of stocked Walleyes to populations in northern Green Bay, Lake Michigan. North American Journal of Aquaculture 77:409–422.

Zorn, T. G., and P. J. Schneeberger. 2011. Habitat and fish community changes in the Michigan waters of Green Bay 1988–2005. Michigan Department of Natural Resources, Fisheries Research Report 2096, Ann Arbor.

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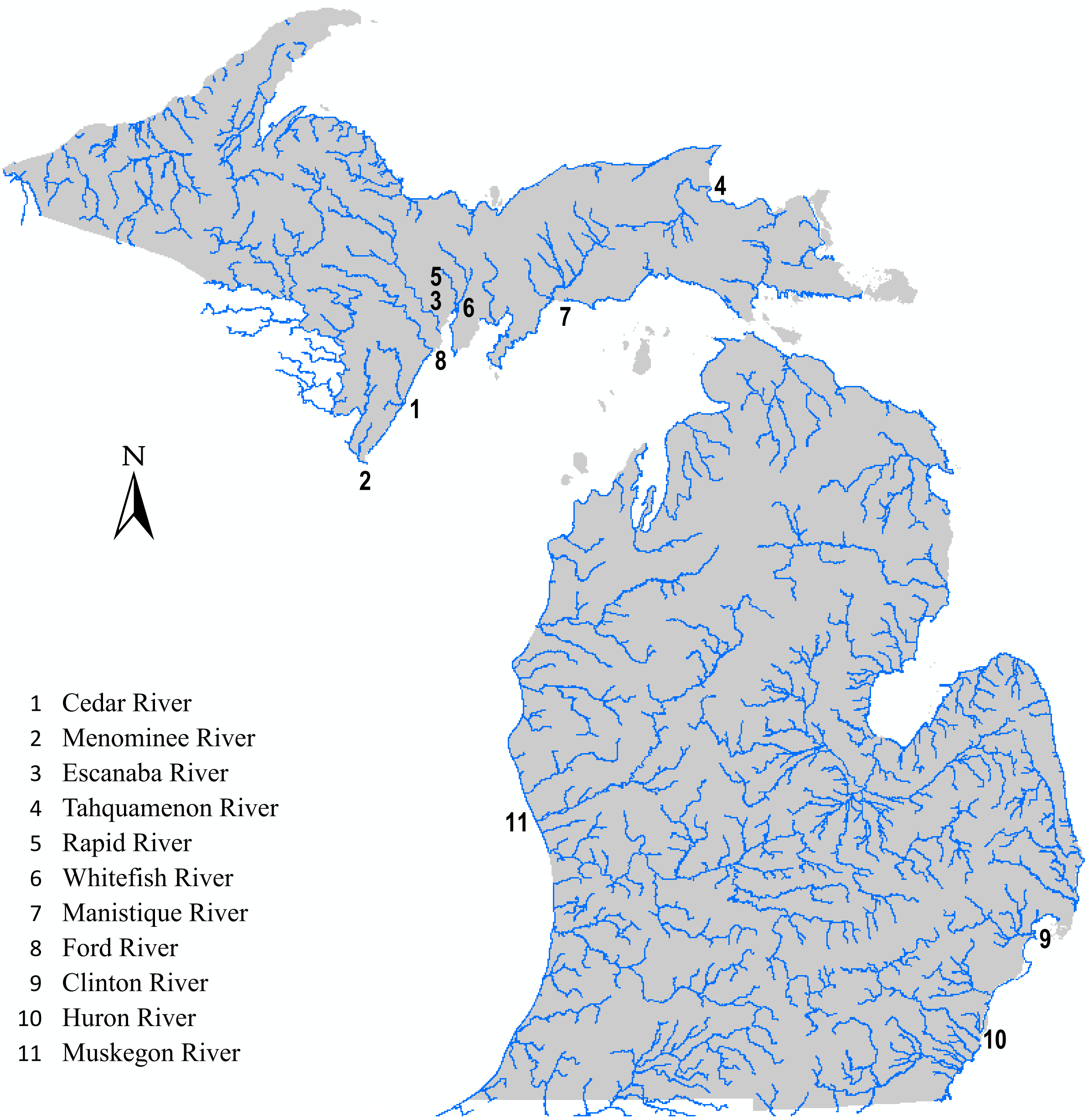


FIGURE 1. Map showing locations in Michigan where walleye spawning run estimates were conducted in this study (rivers 1–8). Previous estimates occurred for rivers 9–11.

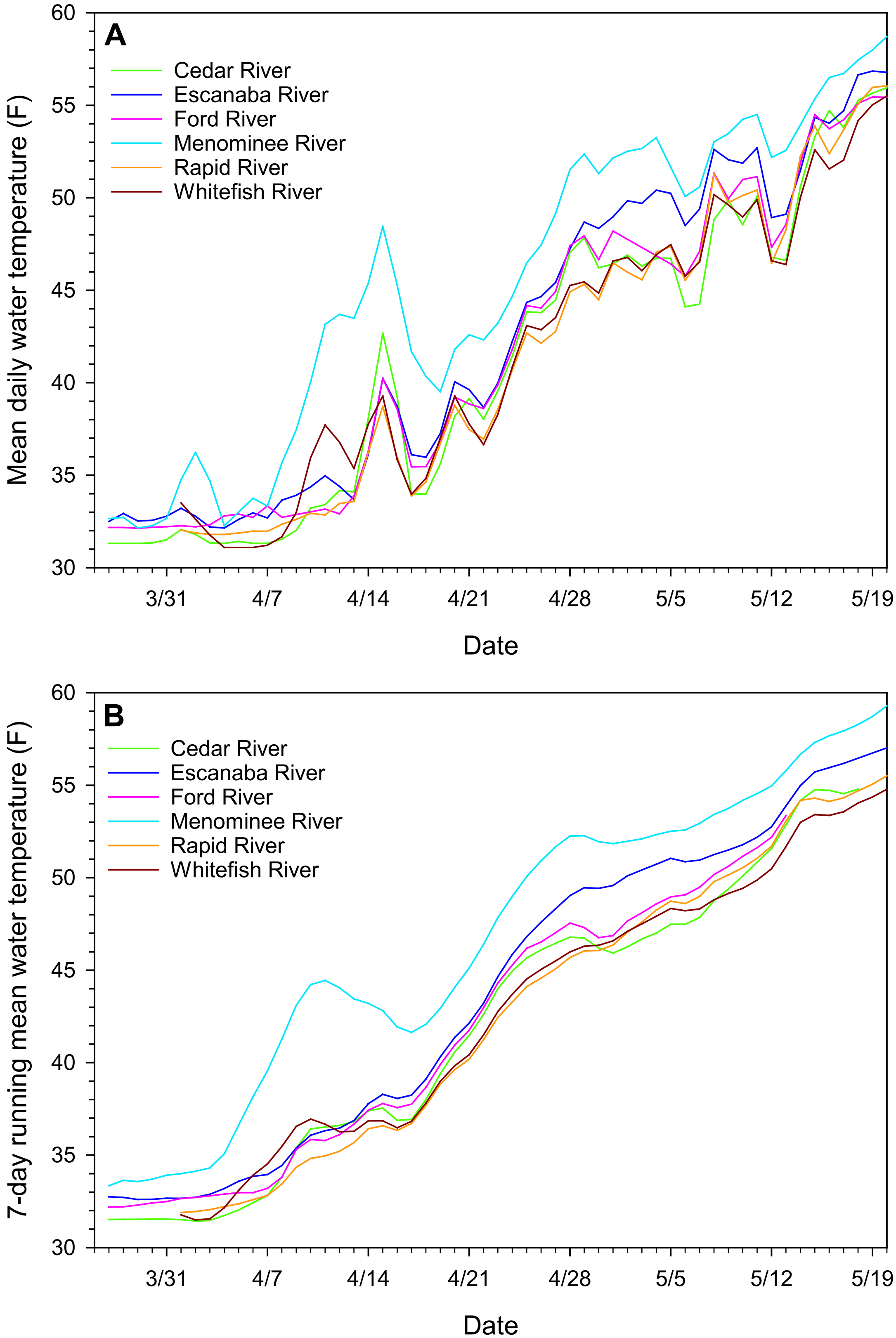


FIGURE 2. A) Mean daily water temperature and B) 7-day running mean water temperature in Upper Peninsula tributaries to Lake Michigan during spring 2003. Sampling occurred at road crossings for US–2 (Escanaba, Rapid, Whitefish), M–35 (Ford), US–41 (Menominee), and at the Cedar River State Forest Campground.

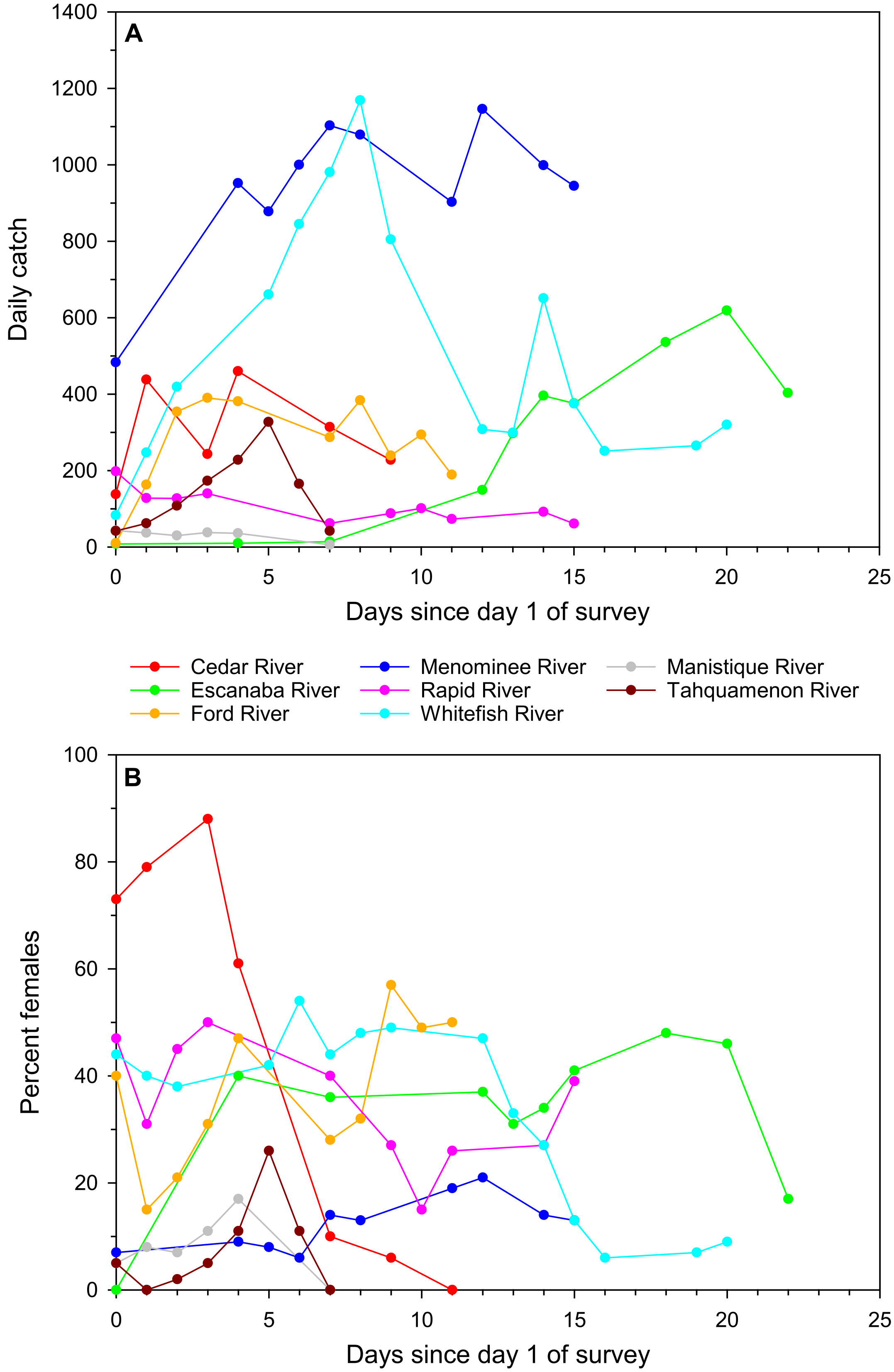


FIGURE 3. Progressive changes in A) daily catch of walleyes and B) percentage of the daily catch that consisted of females.

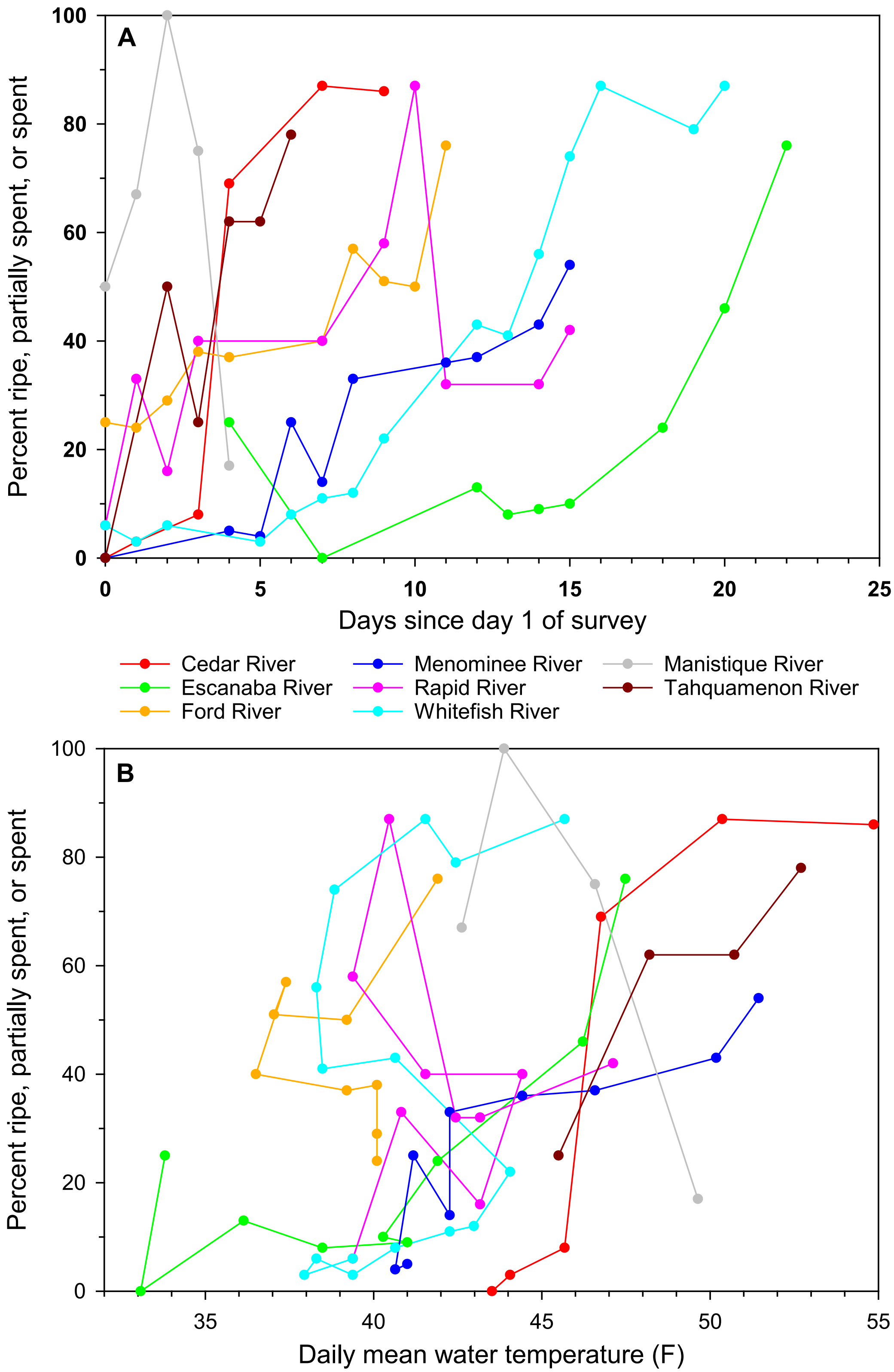


FIGURE 4. A) Percentage of females that were ripe, partially spent, or spent as walleye run sampling progressed. B) Daily mean water temperature and the percent of female walleyes that were ripe, partially spent, or spent walleyes during spawning run surveys. The line traces values at the start of the survey (typically with low temperatures and low percentages; lower left end of line), progressing to warmer temperatures and higher percentages (upper right end of the line).

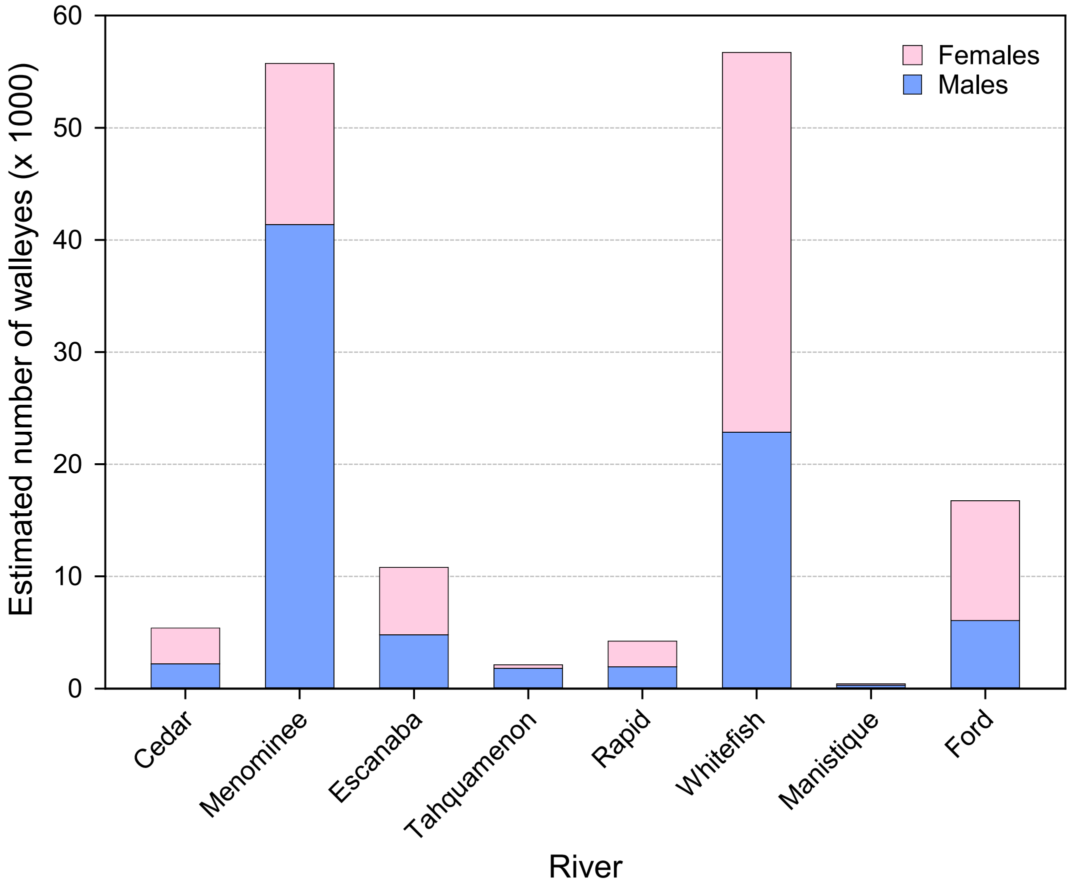


FIGURE 5. Estimated size of walleye run by sex for eight Upper Peninsula rivers.

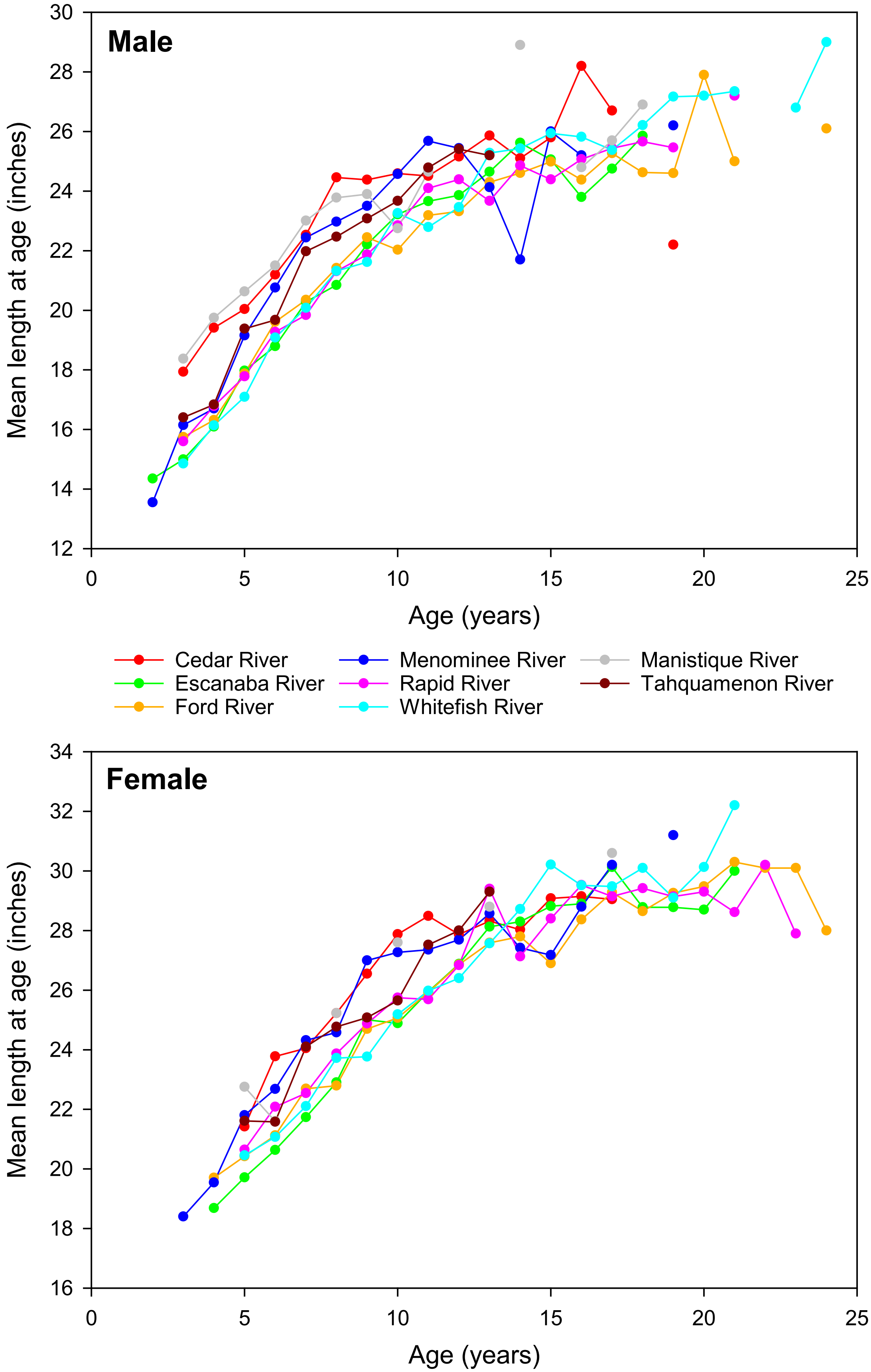


FIGURE 6. Mean length at age of male and female walleyes in spawning populations from eight Upper Peninsula rivers.

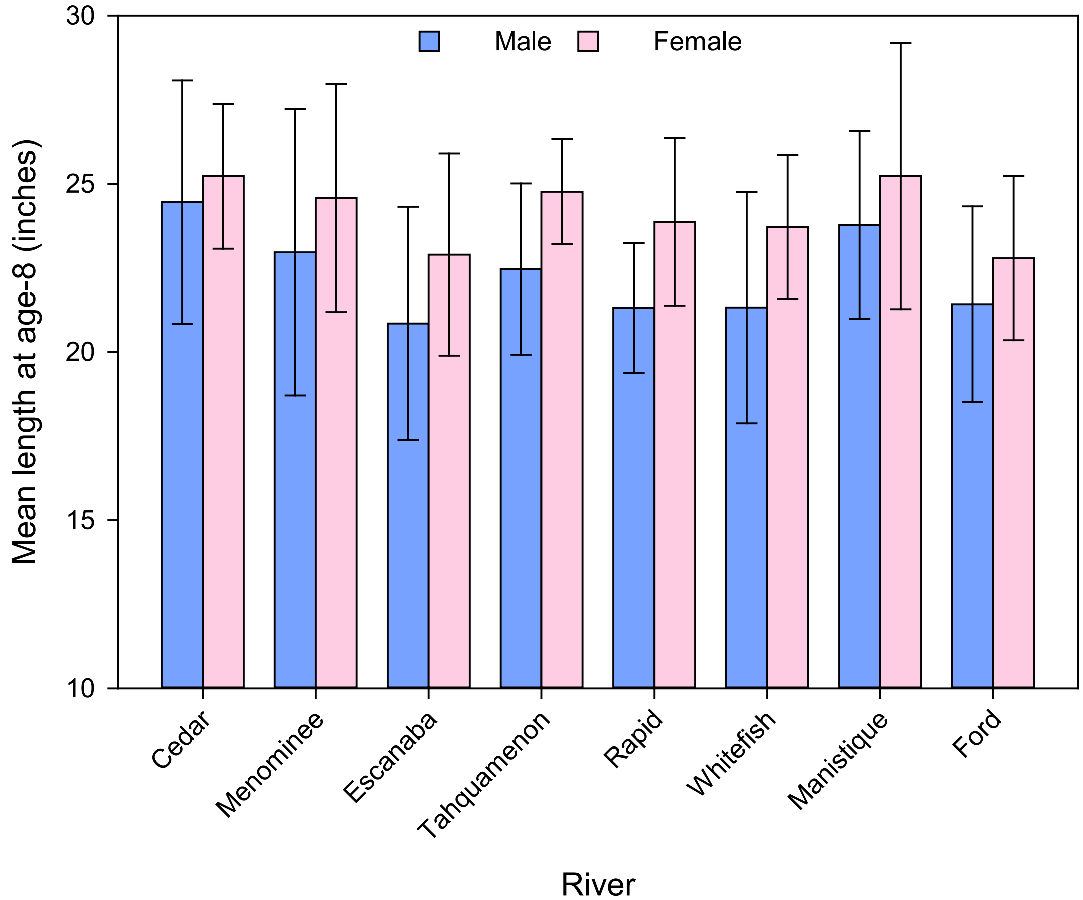


FIGURE 7. Comparison of mean length at age 8 for walleyes from spawning runs in eight Upper Peninsula rivers. Error bars depict 95% confidence intervals around means.

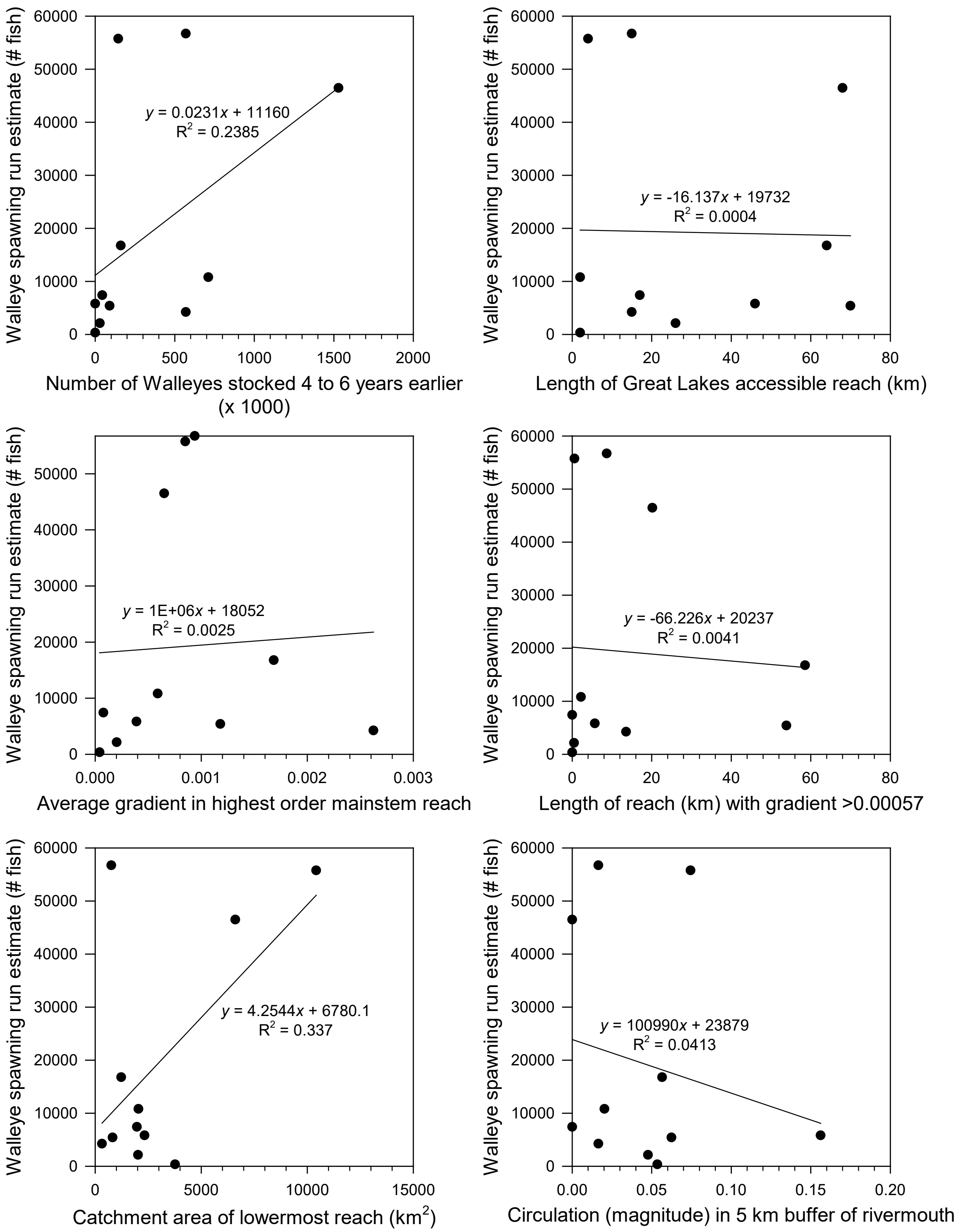


FIGURE 8. Plots of select parameters against Walleye spawning run size in 11 Michigan rivers with Great Lakes access. The lines are fitted linear regression lines and coefficents.

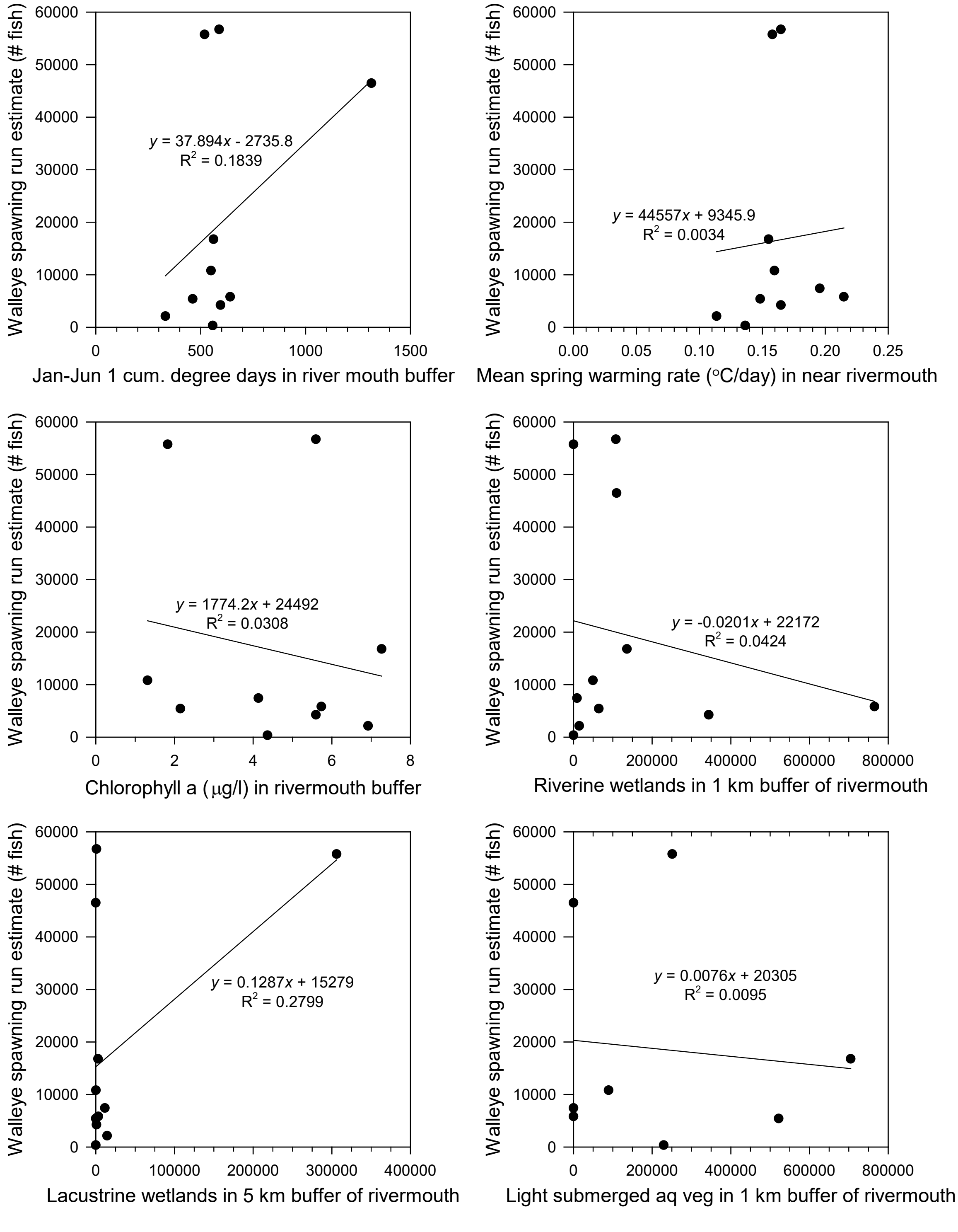


FIGURE 8. Continued.

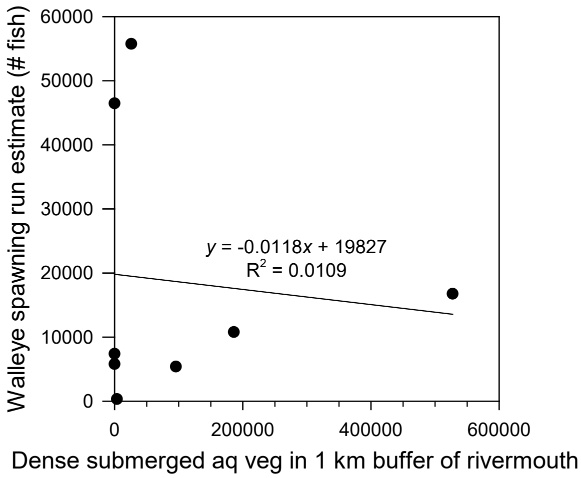


FIGURE 8. Continued.

TABLE 1. Study rivers showing the year of the walleye run estimate, estimated run size, and numbers of walleyes larger than fry which were stocked four to six years prior to the estimate year. Stocking values shown for the Rapid, Whitefish, Ford, and Escanaba rivers were numbers of walleyes stocked into Little Bay de Noc, the receiving water for these and other tributaries. Detailed maps of reaches electrofished for population estimates occur in Appendix A.

ID	River	Estimate year	Run size	Prior stocking
1	Cedar	2005	5,390	90,554
2	Menominee	2006	55,735	144,076
3	Escanaba	2008	10,791	710,508
4	Tahquamenon	2008	2,123	28,885
5	Rapid	2009	4,222	569,225
6	Whitefish	2009	56,710	569,225
7	Manistique	2010	334	0
8	Ford	2011	16,748	160,749
9	Clinton	1991	7,406	44,218
10	Huron	1994	5,810	0
11	Muskegon	1998	46,479	1,529,220

TABLE 2. Sequence of day-specific fin clips used on rivers where multiple-pass mark-recapture population estimates were made. Fin clips usually involved removing a 20–30 mm wide piece of tissue. Note that the caudal notch clips were used only in 2009 and were applied so that other caudal clips remained visible.

Day	Code	Fin clip
1	LP	Left pectoral
2	LV	Left pelvic
3	RP	Right pectoral
4	RV	Right pelvic
5	BC	Bottom of caudal
6	TC	Top of caudal
7	BA	Bottom of anal
8	TA	Top of anal
9	ASD	Anterior part of soft dorsal
10	PSD	Posterior part of soft dorsal
11	PSP	Posterior part of spiny dorsal (clip 3 or more spines)
12	BCN	Bottom caudal notch
13	TCN	Top caudal notch

TABLE 3. Data used in characterizing river and estuary habitats for study rivers including the source. For many GIS-based buffer layers only the name for 1 km buffers is shown because difference in variable names between 1 km and 5 km buffers is the number preceding "k" (e.g., CDD_1k5m_WAVG and CDD_5k5m_WAVG).

Variable name	Description	Source
num_stock_4–6yrs_earlier	Number of walleyes stocked 4–6 years earlier	MDNR Fisheries Division
SumLengthKM	Length of Great Lakes accessible reach	1:100,000 NHD+ Version 1
AveGrad	Average channel gradient (as a proportion) for highest order accessible reach of the mainstem	1:100,000 NHD+ Version 1
KM>00057	Length (km) of accessible reaches with gradient > 0.057%	1:100,000 NHD+ Version 1
DAmaxKM2	Catchment area (km^2) of lowermost accessible reach	1:100,000 NHD+ Version 1
TotP-DlvAccLoad, TotP-DlvAccYld	Total dissolved phosphorus load (kg) and yield (kg/km^2) estimates for 2002	EPA SPARROW Mapper MRB3
CDD_1k5m_WAVG	Average cumulative degree days (°C) from January 1 to June 1 for 2006–2011, in buffers 1 or 5 km from river mouth to 5 m depth contour	NOAA Great Lakes Operational Forecast System
CHLA_1k5m_WAVG	Chlorophyll A (microgram/L) from January 1 to June 1, in buffers 1 or 5 km from river mouth to 5 m depth contour	Michigan Tech Research Institute
CIR_1k5m_WAVG	Magnitude of water circulation in buffers 1 or 5 km from river mouth to 5 m depth contour	NOAA Great Lakes Coastal Forecasting System
SRW_1k5m_WAVG	Avg daily spring warming rate (°C/day) from 2006–2011, in buffers 1 or 5 km from river mouth to 5 m depth contour	NOAA Great Lakes CoastWatch satellite imagery
RivWet_CWI1k5m	Area (m^2) of riverine wetlands (code values 6 to 10 in Albert et al. 2005), in buffers 1 or 5 km from river mouth to 5 m depth contour	Coastal Wetlands Inventory, Albert et al. 2005
LacWet_CWI_1k5m	Area (m^2) of lacustrine wetlands (code values 3 to 5 in Albert et al. 2005), in buffers 1 or 5 km from river mouth to 5 m depth contour	Coastal Wetlands Inventory, Albert et al. 2005

TABLE 3. Continued.

Variable name	Description	Source
LtSAV1_1k5m	Area (m^2) of light submerged aquatic vegetation (code value 1) in buffers 1 or 5 km from river mouth to 5 m depth contour from May to September 2008–2011 satellite photos of Great Lakes	Michigan Tech Research Institute
NoSAV3_1k5m	Area (m^2) of sand or uncolonized substrate (code value 3) in buffers 1 or 5 km from river mouth to 5 m depth contour from May to September 2008–2011 satellite photos of Great Lakes	Michigan Tech Research Institute
DnSAV7_1k5m	Area (m^2) of dense submerged aquatic vegetation (code value 7) in buffers 1 or 5 km from river mouth to 5 m depth contour from May to September 2008–2011 satellite photos of Great Lakes	Michigan Tech Research Institute
TrbSAV9_1k5m	Area (m^2) unclassified due to turbidity (code value 9) in buffers 1 or 5 km from river mouth to 5 m depth contour from May to September 2008–2011 satellite photos of Great Lakes	Michigan Tech Research Institute

TABLE 4. Total numbers of walleye caught, numbers of recaptured fish, and percentage of the daily catch made up of recaptures for each survey.

Date	River	Days since day 1	Daily mean temp. (F)	Total catch	Recaptures	Percent recaptures
04/11/2005	Cedar	0	43.5	138	0	
04/12/2005	Cedar	1	44.1	438	12	3
04/14/2005	Cedar	3	45.7	243	42	17
04/15/2005	Cedar	4	46.8	460	65	14
04/18/2005	Cedar	7	50.4	314	39	12
04/20/2005	Cedar	9	54.9	228	42	18
04/22/2005	Cedar	11	50.0			
03/30/2006	Menominee	0		483	0	
04/03/2006	Menominee	4	41.0	952	11	1
04/04/2006	Menominee	5	40.6	878	30	3
04/05/2006	Menominee	6	41.2	1000	37	4
04/06/2006	Menominee	7	42.3	1103	47	4
04/07/2006	Menominee	8	42.3	1079	88	8
04/10/2006	Menominee	11	44.4	903	95	11
04/11/2006	Menominee	12	46.6	1146	145	13
04/13/2006	Menominee	14	50.2	999	150	15
04/14/2006	Menominee	15	51.4	945	137	14
04/03/2008	Escanaba	0		8	0	
04/07/2008	Escanaba	4	33.8	10	0	0
04/10/2008	Escanaba	7	33.1	14	0	0
04/15/2008	Escanaba	12	36.1	149	2	1
04/16/2008	Escanaba	13	38.5	297	6	2
04/17/2008	Escanaba	14	41.0	396	27	7
04/18/2008	Escanaba	15	40.3	376	48	13
04/21/2008	Escanaba	18	41.9	536	73	14
04/23/2008	Escanaba	20	46.2	619	97	16
04/25/2008	Escanaba	22	47.5	403	114	28
04/18/2008	Tahquamenon	0		42	0	
04/19/2008	Tahquamenon	1		62	1	2
04/20/2008	Tahquamenon	2		108	3	3
04/21/2008	Tahquamenon	3	45.5	173	24	14
04/22/2008	Tahquamenon	4	48.2	228	38	17
04/23/2008	Tahquamenon	5	50.7	327	75	23
04/24/2008	Tahquamenon	6	52.7	165	62	38
04/25/2008	Tahquamenon	7	53.8	42	18	43
04/08/2009	Whitefish	0	39.4	83	0	
04/09/2009	Whitefish	1	37.9	247	0	0

TABLE 4. Continued.

Date	River	Days since day 1	Daily mean temp. (F)	Total catch	Recaptures	Percent recaptures
04/10/2009	Whitefish	2	38.3	419	18	4
04/13/2009	Whitefish	5	39.4	661	11	2
04/14/2009	Whitefish	6	40.6	845	22	3
04/15/2009	Whitefish	7	42.3	981	69	7
04/16/2009	Whitefish	8	43.0	1169	122	10
04/17/2009	Whitefish	9	44.1	805	95	12
04/20/2009	Whitefish	12	40.6	308	41	13
04/21/2009	Whitefish	13	38.5	299	45	15
04/22/2009	Whitefish	14	38.3	651	97	15
04/23/2009	Whitefish	15	38.8	375	64	17
04/24/2009	Whitefish	16	41.5	251	38	15
04/27/2009	Whitefish	19	42.4	265	59	22
04/28/2009	Whitefish	20	45.7	320	67	21
04/13/2009	Rapid	0	39.4	198	0	
04/14/2009	Rapid	1	40.8	128	8	6
04/15/2009	Rapid	2	43.2	127	9	7
04/16/2009	Rapid	3	44.4	140	12	9
04/20/2009	Rapid	7	41.5	62	8	13
04/22/2009	Rapid	9	39.4	88	14	16
04/23/2009	Rapid	10	40.5	101	21	21
04/24/2009	Rapid	11	42.4	73	15	21
04/27/2009	Rapid	14	43.2	92	24	26
04/28/2009	Rapid	15	47.1	61	12	20
03/29/2010	Manistique	0		43	0	
03/30/2010	Manistique	1	42.6	37	4	11
03/31/2010	Manistique	2	43.9	30	8	27
04/01/2010	Manistique	3	46.6	38	10	26
04/02/2010	Manistique	4	49.6	36	14	39
04/05/2010	Manistique	7	50.9	6	4	67
04/11/2011	Ford	0		10	0	
04/12/2011	Ford	1	40.1	163	0	0
04/13/2011	Ford	2	40.1	354	9	3
04/14/2011	Ford	3	40.1	390	23	6
04/15/2011	Ford	4	39.2	381	42	11
04/18/2011	Ford	7	36.5	287	38	13
04/19/2011	Ford	8	37.4	384	67	17
04/20/2011	Ford	9	37.0	239	53	22
04/21/2011	Ford	10	39.2	294	46	16
04/22/2011	Ford	11	41.9	189	50	26

TABLE 5. Sex composition of walleyes captured on each day, percentage of the total daily catch as females, and the reproductive status of females.

Date	River	Daily mean temp. (F)	Male	Female	Sex unknown	Percent females	Gravid	Ripe	Partially spent	Spent	Percent ripe, spent, or partially spent
04/11/2005	Cedar	43.5	35	94	9	73	93				0
04/12/2005	Cedar	44.1	88	332	18	79	322	8	2		3
04/14/2005	Cedar	45.7	28	214	1	88	196	8	1	9	8
04/15/2005	Cedar	46.8	177	277	6	61	85	52	12	128	69
04/18/2005	Cedar	50.4	276	31	7	10	4	12	1	14	87
04/20/2005	Cedar	54.9	211	14	3	6	2	3	1	8	86
04/22/2005	Cedar	50.0	10		5	0					
03/30/2006	Menominee		449	34		7	33				0
04/03/2006	Menominee	41.0	865	81	6	9	76	2		2	5
04/04/2006	Menominee	40.6	801	68	9	8	65	2		1	4
04/05/2006	Menominee	41.2	931	56	13	6	41	12	2		25
04/06/2006	Menominee	42.3	948	151	9	14	130	17	1	3	14
04/07/2006	Menominee	42.3	942	136	1	13	91	29	4	11	33
04/10/2006	Menominee	44.4	724	168	11	19	108	21	2	37	36
04/11/2006	Menominee	46.6	898	236	12	21	147	37	7	44	37
04/13/2006	Menominee	50.2	840	139	20	14	78	26	2	31	43
04/14/2006	Menominee	51.4	801	120	25	13	55	18	6	40	54
04/03/2008	Escanaba		8			0					
04/07/2008	Escanaba	33.8	6	4		40	3		1		25
04/10/2008	Escanaba	33.1	9	5		36	5				0
04/15/2008	Escanaba	36.1	94	55		37	47	1	1	5	13
04/16/2008	Escanaba	38.5	205	91	1	31	84	4	1	2	8

TABLE 5. Continued.

Date	River	Daily mean temp. (F)	Male	Female	Sex unknown	Percent females	Gravid	Ripe	Partially spent	Spent	Percent ripe, spent, or partially spent
04/17/2008	Escanaba	41.0	259	136	1	34	124	6	1	5	9
04/18/2008	Escanaba	40.3	220	156		41	141	10		5	10
04/21/2008	Escanaba	41.9	279	254	3	48	194	21	7	32	24
04/23/2008	Escanaba	46.2	328	279	12	46	152	26	8	93	46
04/25/2008	Escanaba	47.5	328	67	8	17	16	6	2	43	76
04/18/2008	Tahquamenon		40	2		5	2				0
04/19/2008	Tahquamenon		62			0					
04/20/2008	Tahquamenon		106	2		2	1	1			50
04/21/2008	Tahquamenon	45.5	165	8		5	6	2			25
04/22/2008	Tahquamenon	48.2	202	26		11	10	13	3		62
04/23/2008	Tahquamenon	50.7	241	86		26	32	29	6	18	62
04/24/2008	Tahquamenon	52.7	147	18		11	4	9		5	78
04/25/2008	Tahquamenon	53.8	42			0					
04/08/2009	Whitefish	39.4	46	36	1	44	34			2	6
04/09/2009	Whitefish	37.9	147	99	1	40	91		2	1	3
04/10/2009	Whitefish	38.3	261	158		38	148	4	1	4	6
04/13/2009	Whitefish	39.4	383	273	5	42	264	4	1	4	3
04/14/2009	Whitefish	40.6	381	450	13	54	415	17	5	13	8
04/15/2009	Whitefish	42.3	547	430	2	44	383	27	2	17	11
04/16/2009	Whitefish	43.0	608	560	1	48	492	29	2	37	12
04/17/2009	Whitefish	44.1	407	395	3	49	305	33	1	51	22
04/20/2009	Whitefish	40.6	163	145		47	83	7	1	54	43
04/21/2009	Whitefish	38.5	201	98		33	58	16	3	21	41

TABLE 5. Continued.

Date	River	Daily mean temp. (F)	Male	Female	Sex unknown	Percent females	Gravid	Ripe	Partially spent	Spent	Percent ripe, spent, or partially spent
04/22/2009	Whitefish	38.3	478	173		27	76	27	5	65	56
04/23/2009	Whitefish	38.8	325	50		13	13	12	3	22	74
04/24/2009	Whitefish	41.5	233	15	1	6	2	4	7	2	87
04/27/2009	Whitefish	42.4	245	19		7	4	1		14	79
04/28/2009	Whitefish	45.7	290	30		9	4	2	2	22	87
04/13/2009	Rapid	39.4	104	94		47	88	5		1	6
04/14/2009	Rapid	40.8	88	40		31	27	11	1	1	33
04/15/2009	Rapid	43.2	70	57		45	48	7	1	1	16
04/16/2009	Rapid	44.4	70	70		50	42	21		7	40
04/20/2009	Rapid	41.5	37	25		40	15	2	2	6	40
04/22/2009	Rapid	39.4	64	24		27	10	13		1	58
04/23/2009	Rapid	40.5	85	15		15	2	6	4	3	87
04/24/2009	Rapid	42.4	54	19		26	13		4	2	32
04/27/2009	Rapid	43.2	67	25		27	17	1	1	6	32
04/28/2009	Rapid	47.1	37	24		39	14	5		5	42
03/29/2010	Manistique		41	2		5	1	1			50
03/30/2010	Manistique	42.6	34	3		8	1	2			67
03/31/2010	Manistique	43.9	28	2		7		2			100
04/01/2010	Manistique	46.6	34	4		11	1	2		1	75
04/02/2010	Manistique	49.6	30	6		17	5	1			17
04/05/2010	Manistique	50.9	6			0					
04/11/2011	Ford		6	4		40	3	1			25
04/12/2011	Ford	40.1	138	25		15	19	5		1	24

Table 5. Continued.

Date	River	Daily mean temp. (F)	Male	Female	Sex unknown	Percent females	Gravid	Ripe	Partially spent	Spent	Percent ripe, spent, or partially spent
04/13/2011	Ford	40.1	281	73		21	52	15	3	3	29
04/14/2011	Ford	40.1	270	119	1	31	74	39		6	38
04/15/2011	Ford	39.2	200	179	2	47	111	52	4	10	37
04/18/2011	Ford	36.5	207	79	1	28	47	17	6	8	40
04/19/2011	Ford	37.4	261	122	1	32	52	30	8	32	57
04/20/2011	Ford	37.0	69	92		57	45	14	3	30	51
04/21/2011	Ford	39.2	150	142	2	49	71	38	5	28	50
04/22/2011	Ford	41.9	95	94		50	23	16		55	76

TABLE 6. Number of times individual male (M) and female (F) walleyes were encountered during multi-pass mark-recapture electrofishing surveys in study rivers.

		Number of encounters					
River	Sex	1	2	3	4	5	>1
Cedar	M	612	95	10	1		106
	F	810	84	8	0		92
Escanaba	M	1223	200	41	3		244
	F	900	72	2	0		74
Ford	M	1230	206	24	9	2	241
	F	850	42	0	0	0	42
Manistique	M	102	27	3	2		32
	F	15	1	0	0		1
Menominee	M	6932	611	36			647
	F	1115	51	3			54
Rapid	M	510	71	8			79
	F	334	27	2			29
Tahquamenon	M	598	161	26	3		190
	F	134	4	0	0		4
Whitefish	M	3659	464	50	1	1	516
	F	2584	160	9	0	0	169
Totals	M	14866	1835	198	19	3	2055
	F	6742	441	24	0	0	465

TABLE 7. Number of walleyes observed (n observed), population estimate (Estimate), standard error of the estimate (SE), and lower and upper 95% confidence interval (95% Conf. Int.) estimates for male (M), female (F), and total walleyes in each spawning run. When making total walleye estimates the unknown sex (U) fish were assigned a sex using river-specific percent female by body length relationships described in Methods.

						95% Conf. Int.	
Year	River	Sex	n observed	Estimate	SE	Lower	Upper
2005	Cedar	M	825	2,202	196	1,864	2,638
		F	962	3,188	1,114	1,827	6,551
		U	49				
		Total	1,836	5,390	1,310	3,691	9,189
2006	Menominee	M	8,199	41,367	2,539	36,746	46,719
		F	1,189	14,368	2,437	10,388	20,066
		U	106				
		Total	9,494	55,735	4,976	47,134	66,785
2008	Escanaba	M	1,736	4,797	353	4,173	5,564
		F	1,047	5,994	1,083	4,280	8,598
		U	25				
		Total	2,808	10,791	1,436	8,453	14,162
2008	Tahquamenon	M	1,005	1,806	133	1,577	2,101
		F	142	317	189	171	1,116
		Total	1,147	2,123	322	1,748	3,217
2009	Rapid	M	584	1,944	228	1,566	2,468
		F	362	2,278	637	1,378	3,976
		Total	946	4,222	865	2,944	6,444
2009	Whitefish	M	4,148	22,864	1,546	20,071	26,147
		F	2,753	33,846	10,403	19,174	61,628
		U	27				
		Total	6,928	56,710	11,949	39,245	87,775
2010	Manistique	M	134	235	34	187	323
		F	16	99	92	30	496
		Total	150	334	126	217	819
2011	Ford	M	1,416	6,059	985	4,497	8,426
		F	888	10,689	3,206	6,135	19,199
		U	7				
		Total	2,311	16,748	4,191	10,632	27,625

TABLE 8. Percent occurrence by inch group of male (M) and female (F) spawning walleyes in eight Upper Peninsula rivers, and numbers of fish observed by sex.

Males n:	825		8,199		1,736		1,005	
Females n:	961		1,189		1,047		142	
Unknown n:	46		106		25		0	
River	Cedar		Menominee		Escanaba		Tahquamenon	
Length (in)	M	F	M	F	M	F	M	F
12			0.02		0.12			
13			0.33		0.17			
14			4.21		1.79		0.30	
15			21.82	0.08	7.03		0.90	
16	0.12		33.09		10.71		4.68	
17	0.36		18.04	0.17	11.98	0.19	4.48	0.70
18	1.21		4.13	0.34	10.02	1.15	2.09	
19	1.45	0.10	1.65	1.18	9.16	3.34	11.44	1.41
20	4.00	0.21	1.76	2.27	10.66	4.11	19.70	2.82
21	12.36	0.42	2.23	7.32	10.71	4.11	26.47	12.68
22	21.33	1.87	2.74	6.64	10.08	8.31	18.01	16.90
23	22.91	6.87	3.43	7.91	7.26	8.40	5.77	16.20
24	17.82	8.84	3.44	11.69	5.41	9.46	3.58	18.31
25	10.30	16.44	2.02	15.64	3.17	12.99	1.89	14.08
26	6.18	16.96	0.88	14.89	1.27	14.42	0.40	7.04
27	0.97	20.81	0.20	14.89	0.40	12.51	0.10	2.82
28	0.97	16.55	0.01	10.77	0.06	9.84		2.82
29		8.22		4.88		7.93	0.20	2.82
30		2.29		1.26		2.77		1.41
31		0.42		0.08		0.38		
32						0.10		
33								

TABLE 8. Continued.

	Rapid		Whitefish		Manistique		Ford	
Males n:	584		4,148		134		1,416	
Females n:	362		2,753		16		888	
Unknown n:	0		27		0		7	
River	Rapid		Whitefish		Manistique		Ford	
Length (in)	M	F	M	F	M	F	M	F
12								
13	0.68		0.07					
14	0.86		0.63				0.64	
15	2.40		2.46				4.66	
16	9.59		5.86		1.49		11.65	
17	10.27		7.47		2.24		12.71	
18	7.19		5.74	0.15	4.48		5.93	
19	4.62	1.38	5.09	0.47	5.97		4.66	1.24
20	9.59	2.21	7.57	1.82	9.70		9.46	1.58
21	13.70	1.66	11.91	2.54	20.90	6.25	13.14	5.41
22	11.13	3.59	11.98	4.43	13.43	25.00	14.12	9.12
23	9.76	4.97	12.32	7.95	12.69	12.50	11.37	11.71
24	8.90	10.22	10.70	7.77	13.43	6.25	6.92	13.63
25	5.31	6.91	9.47	9.66	7.46	6.25	3.60	15.32
26	4.62	12.71	5.38	10.35	5.97	18.75	0.71	14.75
27	1.20	15.75	2.56	14.09	0.75	6.25	0.42	12.16
28		15.75	0.72	16.75	1.49	12.50		7.88
29	0.17	13.81	0.07	13.08				4.84
30		9.12		8.35		6.25		2.25
31		1.66		2.32				0.11
32		0.28		0.22				
33				0.04				

TABLE 9a. Mean length at age in inches, standard deviation, and sample size for male Walleye from spawning runs in eight Upper Peninsula rivers.

Males – Mean length

Age	Cedar	Menominee	Escanaba	Tahquamenon	Rapid	Whitefish	Manistique	Ford
2		13.55	14.35					
3	17.93	16.14	14.99	16.40	15.60	14.85	18.37	15.74
4	19.41	16.70	16.09	16.83	16.78	16.13	19.75	16.31
5	20.04	19.15	17.97	19.38	17.78	17.09	20.63	17.87
6	21.20	20.76	18.79	19.67	19.27	19.08	21.50	19.61
7	22.53	22.44	20.28	21.98	19.84	20.08	23.01	20.35
8	24.46	22.97	20.85	22.47	21.31	21.32	23.78	21.42
9	24.38	23.50	22.21	23.08	21.87	21.62	23.90	22.45
10	24.59	24.57	23.22	23.67	22.85	23.26	22.75	22.03
11	24.51	25.68	23.66	24.79	24.10	22.79	24.65	23.19
12	25.16	25.44	23.86	25.41	24.39	23.46		23.32
13	25.86	24.13	24.65	25.20	23.67	25.28		24.30
14	25.10	21.70	25.62		24.86	25.43	28.90	24.61
15	25.80	26.00	25.06		24.39	25.94		24.99
16	28.20	25.20	23.80		25.07	25.82	24.80	24.38
17	26.70		24.75		25.44	25.38	25.70	25.27
18			25.85		25.66	26.21	26.90	24.63
19	22.20	26.20			25.46	27.17		24.60
20						27.20		27.90
21					27.20	27.35		25.00
22								
23						26.80		
24						29.00		26.10

Males – Standard deviation

Age	Cedar	Menominee	Escanaba	Tahquamenon	Rapid	Whitefish	Manistique	Ford
2		0.91	0.21					
3	0.90	1.43	0.58	0.87	0.42	0.07	2.73	0.92
4	0.87	2.29	1.37	0.97	1.65	1.13	1.72	1.29
5	1.09	1.48	1.74	1.03	1.77	1.59	1.36	1.19
6	1.16	0.78	1.47	1.25	1.95	1.60	1.91	0.85
7	1.61	1.62	1.43	1.57	1.82	1.56	1.94	0.99
8	1.85	2.17	1.77	1.30	0.99	1.76	1.43	1.49
9	1.96	1.56	1.79	0.76	1.58	1.46	1.01	1.42
10	1.79	1.39	1.66	1.70	1.98	1.49	0.78	1.34
11	1.44	1.36	1.28	1.22	1.88	1.70	3.75	1.53
12	1.35	1.84	1.52	1.22	1.25	1.87		1.37

TABLE 9a. Continued.

Males – Standard deviation cont.

Age	Cedar	Menominee	Escanaba	Tahquamenon	Rapid	Whitefish	Manistique	Ford
13	1.66	1.59	2.08	0.28	1.93	1.73		1.66
14	0.90		1.66		2.23	1.85		1.64
15	0.57		1.09		2.82	1.65		1.00
16			0.85		1.56	1.34		0.52
17			1.77		1.37	1.91		1.90
18			0.21		1.85	1.86		1.26
19					1.81	0.96		
20								
21						0.07		2.69
22								
23								
24								

Males – Number aged

Age	Cedar	Menominee	Escanaba	Tahquamenon	Rapid	Whitefish	Manistique	Ford
2		4	2					
3	4	111	17	33	4	2	3	5
4	8	15	53	14	43	60	6	53
5	9	23	25	43	28	15	40	35
6	31	20	12	11	24	26	9	17
7	23	23	30	42	20	20	12	16
8	9	18	24	21	15	31	23	10
9	23	25	12	6	11	10	4	6
10	20	31	15	7	17	13	2	14
11	7	23	14	10	21	15	2	14
12	11	8	21	20	12	5		17
13	14	4	17	2	7	5		12
14	6	1	6		8	12	1	12
15	2	1	7		7	14		8
16	1	1	2		7	18	1	6
17	1		2		10	16	1	3
18			2		9	13	1	6
19	1	1			7	3		1
20						1		1
21					1	2		2
22								
23						1		
24						1		1

TABLE 9b. Mean length at age in inches, standard deviation, and sample size for female walleyes from spawning runs in eight Upper Peninsula rivers.

Females – Mean length

Age	Cedar	Menominee	Escanaba	Tahquamenon	Rapid	Whitefish	Manistique	Ford
2								
3		18.40						
4		19.54	18.68					19.70
5	21.42	21.80	19.71	21.61	20.64	20.45	22.75	20.42
6	23.78	22.68	20.63	21.58	22.08	21.07	21.60	21.12
7	24.05	24.32	21.73	24.10	22.54	22.10		22.69
8	25.23	24.58	22.90	24.77	23.87	23.72	25.23	22.79
9	26.55	27.00	25.01	25.08	24.88	23.77		24.70
10	27.88	27.27	24.89	25.65	25.75	25.19	27.60	25.07
11	28.49	27.36	25.95	27.52	25.69	25.98		25.93
12	27.87	27.69	26.88	28.00	26.84	26.40		26.86
13	28.32	28.57	28.13	29.30	29.40	27.57	28.80	27.59
14	28.03	27.42	28.30		27.13	28.72		27.80
15	29.08	27.18	28.82		28.40	30.21		26.90
16	29.15	28.80	28.90		29.53	29.52		28.37
17	29.05	30.20	30.13		29.15	29.48	30.60	29.28
18			28.78		29.42	30.10		28.65
19		31.20	28.78		29.14	29.10		29.26
20			28.70		29.30	30.13		29.48
21			30.00		28.62	32.20		30.30
22					30.20			30.10
23					27.90			30.10
24								28.00

Females – Standard deviation

Age	Cedar	Menominee	Escanaba	Tahquamenon	Rapid	Whitefish	Manistique	Ford
2								
3								
4		0.96	0.59					0.28
5	1.16	1.19	1.06	0.94	1.33	1.10	0.57	0.74
6	0.87	1.65	1.17	1.44	1.32	1.45		1.25
7	1.22	1.38	1.51	1.07	1.86	1.24		1.12
8	1.10	1.73	1.53	0.80	1.27	1.09	2.02	1.24
9	1.11	2.52	1.55	1.41	1.92	1.46		0.86
10	2.34	1.80	1.13	0.92	1.08	1.63		1.15
11	1.75	1.83	2.57	1.47	1.33	1.65		1.47
12	1.17	1.40	1.77	1.39	2.00	2.09		1.82

TABLE 9b. Continued.

Females – Standard deviation cont.								
Age	Cedar	Menominee	Escanaba	Tahquamenon	Rapid	Whitefish	Manistique	Ford
13	1.35	1.57	1.77	0.14		1.33		1.38
14	1.20	2.16	1.78		1.72	1.55		1.64
15	1.59	2.51	1.53		1.73	0.96		2.78
16	0.79	0.50	0.99		1.28	1.75		1.92
17	1.91		1.03		1.42	1.61		1.74
18			1.62		1.52	1.53		1.27
19			1.31		1.04	1.83		1.07
20					0.90	0.55		0.75
21					1.02			
22								
23								0.71
24								

Females – Number aged								
Age	Cedar	Menominee	Escanaba	Tahquamenon	Rapid	Whitefish	Manistique	Ford
2								
3		1						
4		8	4					2
5	6	46	27	30	8	10	4	12
6	11	10	20	12	10	15	1	21
7	37	12	15	45	11	18		28
8	12	30	35	15	11	25	7	22
9	15	10	20	4	12	13		10
10	16	22	20	2	13	11	1	9
11	15	25	11	9	18	30		23
12	10	17	15	8	17	17		22
13	20	10	25	2	1	7	1	20
14	14	5	22		8	10		7
15	11	4	12		8	15		3
16	4	3	9		14	21		9
17	4	1	7		15	16	1	8
18			4		17	23		8
19		1	5		7	4		8
20			1		3	3		5
21			1		5	1		1
22					1			1
23					1			2
24								1

TABLE 10. Walleye stocked in Michigan waters of Green Bay during 1984–2009 which may have contributed to spawning runs in study tributaries. Note that the Menominee stockings occurred at Stony Point, about 8 miles north of the Menominee River mouth. Data source is the MDNR Fish Stocking Database.

	Little Bay de Noc		Big Bay de Noc		Cedar River area	Menominee
Year	Fingerlings	Fry	Fingerlings	Fry	Fingerlings	Fingerlings
1984	230,090	2,000,000				
1985	319,660	1,900,000				
1986	255,291	2,000,000	205,722	2,954,500		
1987	318,200	3,598,270	175,600			
1988	84,777		73,322		72,068	7,400
1989	278,076		217,507	2,775,000	96,727	
1990	505,941				157,757	92,797
1991	164		694,059		206,207	99,986
1992	426,471				32,770	166,563
1993			325,201		44,070	46,982
1994	263,508				217,162	307,145
1995			383,519		190,354	189,474
1996	560,558				96,161	123,569
1997			263,994		161,064	59,239
1998	652,288		169,212		100,767	128,471
1999			544,378	5,300,000		
2000	510,406			2,400,000	90,554	118,303
2001			463,052			
2002	141,283					25,773
2003			607,231			
2004	569,225				105,542	22,391
2005			749,427			
2006	160,749					
2007						
2008	93,604					
2009			268,102			

TABLE 11. Percent occurrence of unidentified external cysts of male and female walleyes, and sea lamprey wounds on spawning walleyes in study rivers. Numbers of fish examined is indicated by “n”.

		Unidentified external cysts %				Lamprey wounds %	
Year	River	n	Males	Females	Combined	n	Occurrence
2005	Cedar	1835	14.1	15.4	14.7	1836	1.96
2006	Menominee	9494	2.9	8.8	3.7	9494	0.09
2008	Escanaba	2808	14.2	15.6	14.7	2808	0.57
2008	Tahquamenon	1147	11.9	10.6	11.8		
2009	Rapid	946	20.2	17.4	19.1	1070	0.65
2009	Whitefish	6928	15.9	13.6	15.0	7679	1.07
2010	Manistique	150	10.4	18.7	11.3	190	1.58
2011	Ford	2311	11.5	11.4	11.5	2613	1.22
	Total	25619				25690	
	Average		12.6	13.9	12.7		0.72

TABLE 12. Pearson correlations between size of walleye spawning runs in rivers, prior walleye stocking levels (num stock 4–6yrs earlier), and variables describing spawning rivers and receiving estuaries. See Table 3 for variable descriptions. Significance level (P) and sample size (N) are shown.

Variable	Correlation	P	N
num_stock_4–6yrs_earlier	0.488	0.13	11
SumLengthKM	–0.020	0.95	11
AveGrad	0.050	0.89	11
KM>00057	–0.064	0.85	11
DAmaxKM2	0.581	0.06	11
TotP-DlvAccLoad	0.270	0.42	11
TotP-DlvAccYld	–0.237	0.48	11
CDD_1k5m_WAVG	0.429	0.22	10
CDD_5k5m_WAVG	0.438	0.21	10
CHLA_1k5m_WAVG	–0.176	0.63	10
CHLA_5k5m_WAVG	–0.018	0.96	10
CIR_1k5m_WAVG	–0.140	0.68	11
CIR_5k5m_WAVG	–0.203	0.55	11
SRW_1k5m_WAVG	0.059	0.87	10
SRW_5k5m_WAVG	0.057	0.88	10
LacWet_CWI_1k5m	–0.126	0.71	11
LacWet_CWI5k5m	0.529	0.09	11
RivWet_CWI1k5m	–0.206	0.54	11
RivWet_CWI5k5m	–0.027	0.94	11
DnSAV7_1k5m	–0.104	0.81	8
DnSAV7_5k5m	–0.028	0.93	11
LtSAV1_1k5m	–0.097	0.82	8
LtSAV1_5k5m	0.082	0.81	11
NoSAV3_1k5m	–0.030	0.94	8
NoSAV3_5k5m	0.169	0.62	11
TrbSAV9_1k5m	–0.249	0.55	8
TrbSAV9_5k5m	–0.203	0.60	9

APPENDICES

APPENDIX A. Detailed summaries of walleye run assessments for individual rivers that were written shortly after the conclusion of each field season. Data tables and summaries here were preliminary only and may not match final values elsewhere in this report.

Notes from Cedar River Walleye Run Estimation 2005

Troy Zorn
Marquette Fisheries Research Station
May 10, 2005

Introduction and Methods

From April 11 to April 22 2005, Marquette Fisheries Research Station staff conducted a multiple pass, mark –recap survey of the Cedar River to estimate the size of the walleye run. In addition to characterizing the walleye run, we also documented spatial use of the lower river by spawning walleye in relation to a proposed sea lamprey barrier site. The early part of the spring, during which our sampling occurred, was characterized by a long, continuous spell of warm, dry weather which presumably resulted in relatively low flow conditions and a narrower window for walleye spawning in the river.

It was my intent to sample walleye during the run in an 8.8 –mile portion of the river extending from state forest campground downstream to the public access site (PAS) at the river mouth (Figure 1). We divided the 8.8 mile stretch into three reaches for sampling and data entry/summary purposes: 1) Upper River – old state forest campground downstream to the hairpin bend above the most downstream (First) Rapids, which the included the proposed sea lamprey barrier site and six major rapids all of whose locations I noted with GPS; 2) First Rapids area – bounded upstream by hairpin bend and downstream by a big bend in the river, and; 3) Lower River – First Rapids (beginning at the big bend) downstream to the PAS. These subsections allowed us to better quantify catch upstream and downstream of the proposed sea lamprey barrier site.

We could not motor our boomshocker through the First Rapids, which is located about 1.5 miles upstream of the PAS, and for sample days 1 –3 were limited to collecting walleye from immediately downstream of the First Rapids to the PAS. During time we discovered that the state forest campground had been relocated and the old campground was located behind a locked gate (luckily, we had the key for it) one mile downstream of the site of the current state forest campground. On sample day 4, with assistance from the MDNR Fish Division's Crystal Falls crew, we simultaneously sampled the Lower River up to the First rapids and the Upper River down to the end of the First rapids. Sex composition of the catch varied considerably between these stretches, with considerably more male walleye occurring in and upstream of the First Rapids, proper. To more fully "capture" the run, the Marquette crew sampled from the old state forest campground downstream to the PAS on days 5 –7.

Results and discussion

Over the course of sampling we captured 2031 walleye, 206 of which had been previously marked. These totals may differ slightly from those computed from daily catch summaries (Table 1), because tallies are from field sheets and all data are not yet fully entered and proofed. Our findings showed that the vast majority of walleye observed were in the First Rapids reach of the river. Of the 19 walleye collected from the Upper River reach on April 15, 14 were upstream of the proposed sea lamprey barrier site. Of the 2031 total walleye observed, 36 (1.7%) were in the Upper River reach. These data suggested that, at least in 2005, few walleye would likely be spawning upstream of the proposed sea lamprey barrier site. I was hoping that we would be able to sample in the reach of the Cedar River between the Jam Dam and County Road 551 bridges (about 10 miles upstream of the old state forest campground), where Conservation Officer Jason Niemi (personal communication) had reported observing walleye in past years. However, our catch observations from this survey, our need for data in the First Rapids area for run size estimation, and knowledge that the run would soon conclude kept us from venturing into this reach of river. Given the low numbers of walleye we saw in the Upper River reach during the 2005 survey, it seemed unlikely that a large proportion of the walleye population might also be spawning even further upstream in the Jam Dam County Road 551 reach. It is possible however, that walleye may migrate into and spawn in these areas during years when streamflows are high during the spawning period (Bill Ziegler, personal communication). If this were to occur, concerns would exist in regards to passage of walleye at the proposed lamprey barrier.

I have made a very preliminary estimate of the size of the walleye run based upon tallies from our field sheets. Following the approach used by Thomas (1995) to estimate walleye runs in southeastern Michigan rivers, I used the Shumacher –Eschmeyer equation which assumes a closed population (i.e. no immigration or emigration). I computed the estimate based upon data collected for sample days to the period of peak spawning (when movement is assumed to be minimal), defined here as when the male:female ratio changes to mostly males and the proportion of spent females starts to increase substantially. The estimated size of the 2005 Cedar River walleye run based upon data from April 11 –20 was about 8600 fish, with 95% confidence limits roughly 50% higher and lower than this value. To enable estimation using open population methods (e.g., Cormack Jolly Seber), I gave Cedar River walleye fin clips unique to each day. This estimate will be made once all the data have been entered and proofed.

Our sampling concluded before adfluvial runs of many other species began. However, towards the end of our sampling period the river saw heavy use of longnose sucker, and to a lesser degree, white sucker. These species were evenly distributed throughout the Upper River and First Rapids reaches. I anecdotally estimate that the sucker run could easily be ten times larger than the walleye run. Thus, many suckers and their offspring would need to be passed at the sea lamprey barrier site. Steelhead were the only other Great Lakes species observed in the river upstream of the barrier. Other Great Lakes fishes migrating into the river toward the end of our sampling included smallmouth bass, shorthead redhorse, carp, and gizzard shad. River resident or migrant northern pike and northern hog sucker were also observed in the river. State –threatened lake sturgeon spawn well after walleye and may also use the river.

Ideally, design of a lamprey barrier and associated fish passage structure should allow for passage of very large numbers of downstream migrating fish. I observed that walleye catch dropped off dramatically between April 20 and 22 as the spawning period concluded. Assuming that there was relatively little emigration prior to the end of the spawning period (probably true for nearly all male and most female walleyes in the Cedar River in 2005 since the bulk of walleye spawning happened in just a few days), as many as 8,000 walleye would have out –migrated in two days. If suckers exhibit similar post –spawn behavior, the sucker out –migration may be quite spectacular. Thus, consideration should be given in the lamprey barrier design phase to enabling downstream passage en masse of sizeable numbers (e.g., 10,000 –100,000) of post –spawn fish.

Table 1. Preliminary total numbers of walleye collected (includes recaptured fish) in three sections of the Cedar River by sample day and location. Areas not sampled are indicated by “ –“.

Day	Date	Upper River	First Rapids area	Lower River
1	4/11/2005	–	84	54
2	4/12/2005	–	346	93
3	4/14/2005	–	221	22
4	4/15/2005	19	417	17
5	4/18/2005	13	301	–
6	4/20/2005	–	182	46
7	4/22/2005	4	6	5

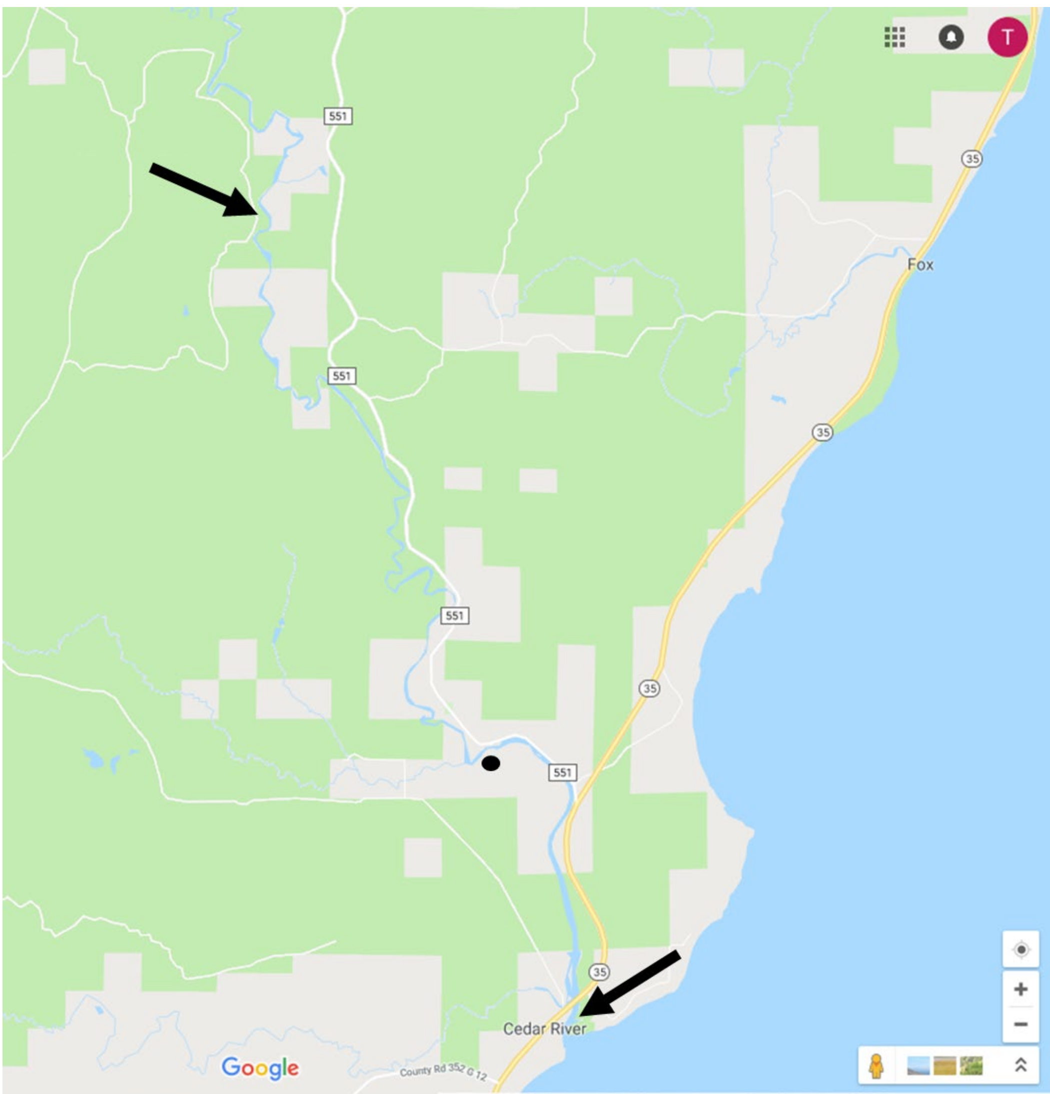


Figure 1. Sample reach of the Cedar River showing upstream and downstream ends of reach (black arrows) and the First Rapids (black dot).

Summary of Menominee River Walleye Run Estimation 2006

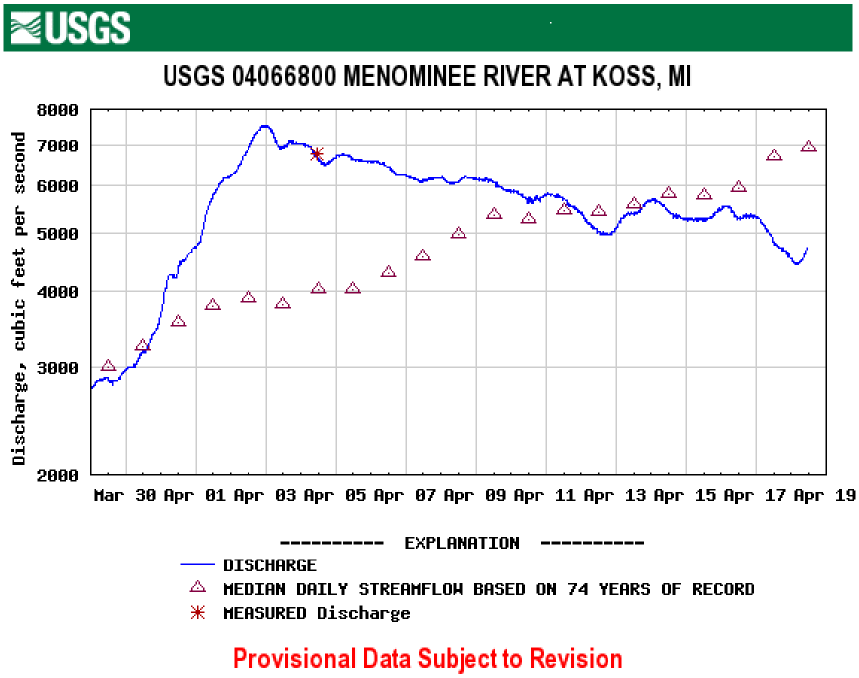
Troy Zorn
Michigan DNR Fisheries Division
Marquette Fisheries Research Station
June 2008

Intro and methods

From March 30 to April 14, 2006 Wisconsin DNR Fisheries and Marquette Fisheries Research Station staff conducted a multiple pass, mark –recap survey of the Menominee River to estimate the size of the walleye run in the river below the most downstream dam. The primary objective was to assess the size, age, and sex composition of the run.

The Menominee River was sampled from the Mystery Ship Marina in Menominee upstream to the dam (white arrows indicate upstream and downstream extent of survey). Fish were sampled with two boomshocking units by Michigan and Wisconsin DNR personnel. Unique marks were given each day, enabling the spawning run to be estimated using both closed and open population methods. Spines were also collected from 20 fish per sex and inch group for aging. Tissue samples were also collected from a subset of fish for potential genetic analyses in the future.

Spring conditions in the river were somewhat different when compared to typical values. The “spring thaw” occurred relatively early due to unusually warm weather in late March. River flows on March 30 were at long –term median levels, but quickly climbed due to meltwater, peaking on April 2. Then, flows declined gradually through the remainder of the sampling period. Typically the river’s discharge gradually increases through the first few weeks of April. These conditions did not appear to obviously disrupt the walleye run or effect sampling efficiency.

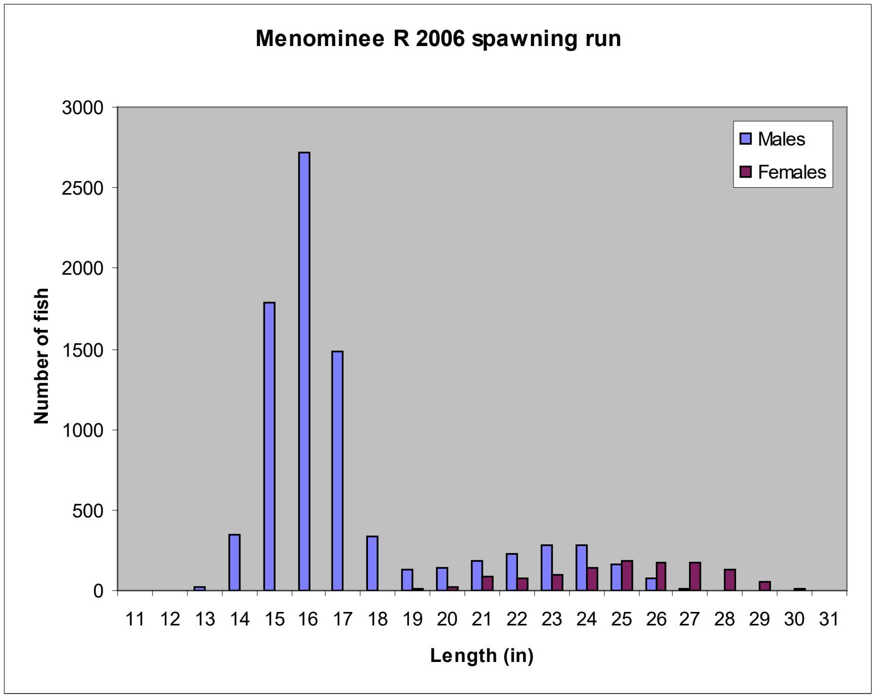


Results

Total number of fish captured and numbers of marked fish observed each day occur below.

Date	Day	Total catch	Recaps
03/30/2006	1	483	0
04/03/2006	2	952	11
04/04/2006	3	878	30
04/05/2006	4	1000	37
04/06/2006	5	1103	47
04/07/2006	6	1079	88
04/10/2006	7	903	95
04/11/2006	8	1146	145
04/13/2006	9	999	150
04/14/2006	10	945	137
sum		9488	740

The sample was heavily skewed to small males, with 72% of the walleyes examined being males less than 20” long. These males may represent the 2003 year class, which was strong in Little Bay de Noc and elsewhere in the Great Lakes, and was expected to be strong in the Menominee River area. A large run of females from this year class can be expected within the next couple years as they mature to spawning size. Spine ages (when available) will be used to assess the age composition of the run.



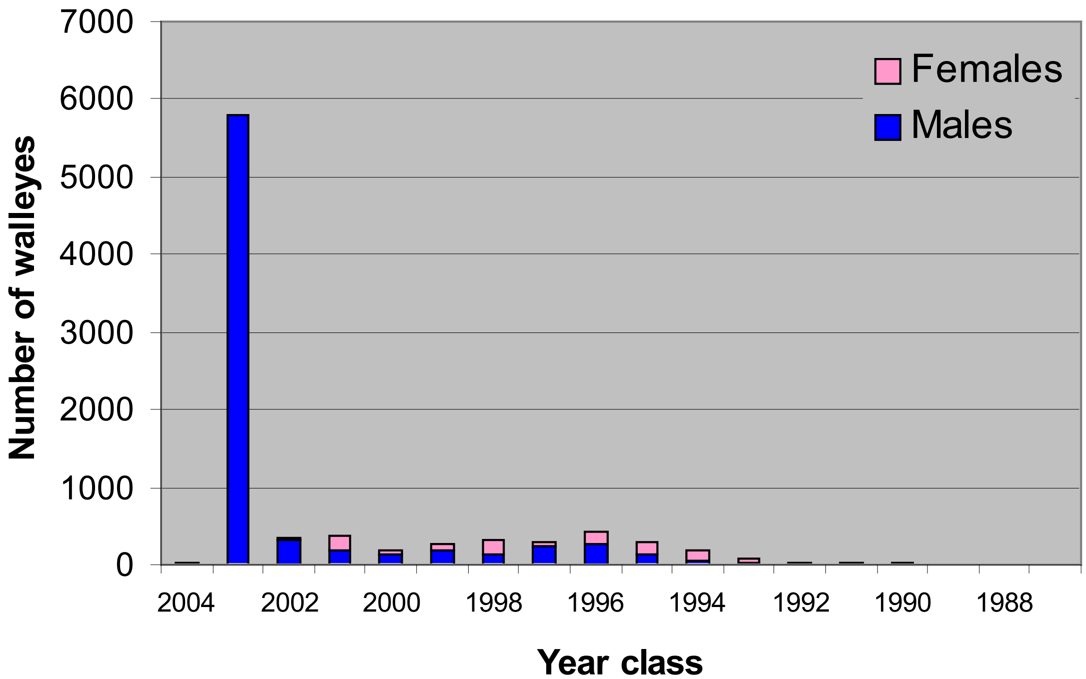
The preliminarily estimate for the 2006 spawning run was 58,382 walleyes (95% confidence interval of 15,044) using the Shumacher –Eschmeyer (SE) estimation. The estimate of the run by sex was 45,221 males and 13,161 females. Data from days 8 –10 were excluded from this estimate due to the increased proportion of spent females observed (and likely emigration of spent fish) which would violate the assumption of a closed population. Cormack –Jolly –Seber (CJS) estimation assumes an open population, but confidence limits are not reported (at least not in the spreadsheet I have). The CJS estimate for the population using data up to day 7 produces very similar estimates for each sex (45,861 males and 11,559 females). Generally, the greatest agreement between population estimates occurs when population data up to day 7 are used. Inclusion of data from days 8 –10 results in a CJS estimate that is roughly 4,000 fish higher, but a SE estimate that is about 5,400 fish lower.

Availability of age data for the run will enable description of run composition by year class, as well as some assessment of the contribution of wild vs. hatchery –reared fish to the current spawning run.

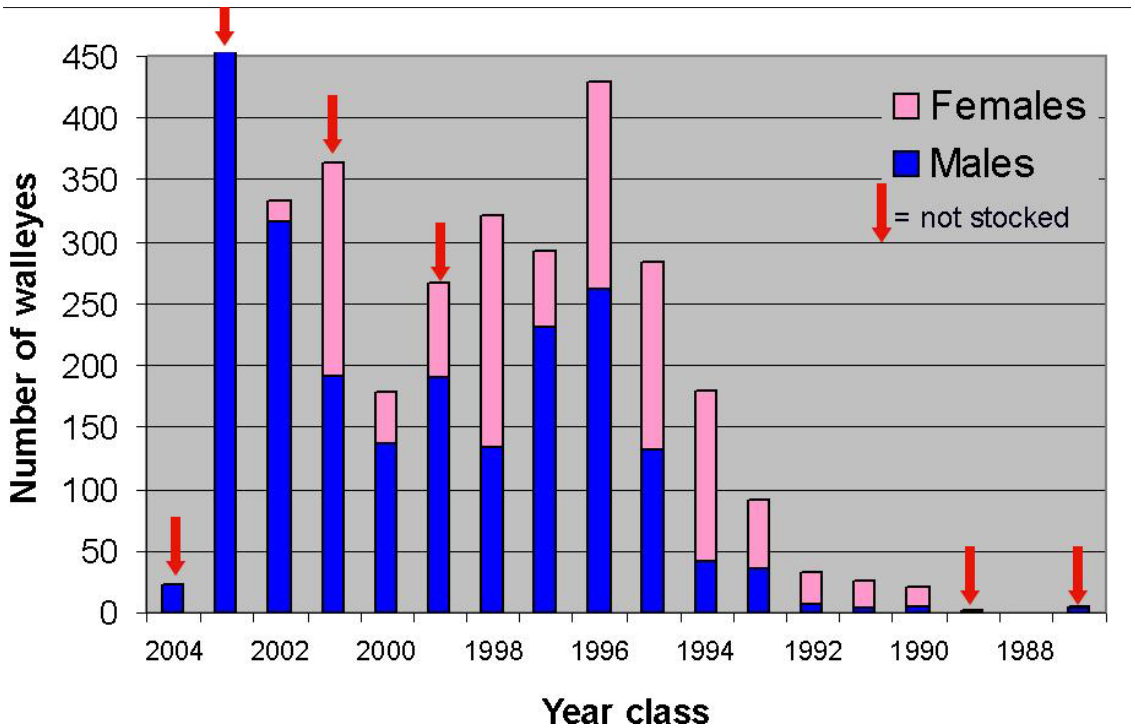
Age structure of the spawning run and evidence of natural reproduction of Menominee River walleyes (added June 2008)

Completion of aging of samples from walleye in previous tagging surveys and the population estimate survey of 2006 allowed us to assign year classes to the fish collected and to estimate the contribution of naturally –reproduced year classes to the Menominee River population. Ages of tagged fish collected during early tagging studies suggested that nine naturally –produced year classes were present in the river before MDNR stocking was initiated in 1988. Year classes present were 1977 –78, 1981 –87, and 1989.

Ages of fish collected in the 2006 survey suggested that natural reproduction occurred in 6 years when stocking did not occur.



Naturally reproduced year classes included the massive 2003 year class (in figure above), along with strong year classes in 2001 and 1999 (indicated by red arrows in figure below). Fall sampling of young walleyes in the Menominee River to assess natural reproduction and look for oxytetracycline (OTC) marked fish from the hatchery also indicated the presence of naturally –reproduced fish in 2005 –07.



Other species observed during spring 2006 walleye survey of Menominee River, and their relative abundance in the river during the time of the survey are listed below:

Abundant – longnose sucker, white sucker
Common – rainbow trout, brown trout, redhorse spp. (mostly shorthead redhorse), northern pike, smallmouth bass
Scarce – splake, lake sturgeon, muskellunge, round whitefish, northern hogsucker, gizzard shad, carp, yellow perch, largemouth bass

Summary of Walleye Run Estimation
Escanaba, Ford, and Tahquamenon rivers – 2008

Troy Zorn
Marquette Fisheries Research Station
January 2009

Intro and methods

In spring 2008, personnel from the MDNR's Marquette Fisheries Research Station and Northern Lake Michigan and Eastern Lake Superior management units evaluate the size and age composition of spawning runs of walleyes in the Escanaba, Ford, and Tahquamenon rivers. Estimates were made using multiple mark –recapture techniques and fish were collected using boat electrofishing units. Unique fin clips were given to fish each day which resulted in a capture history for each individual encountered. This enabled spawning runs to be estimated using both closed and open population estimation methods. Spines were also collected from 20 fish per sex and inch group for aging. Tissue samples were also collected from a subset of fish for potential genetic analyses in the future. The upstream extent of the sample reach on the Escanaba was the dam and that on the Tahquamenon was Lower Tahquamenon Falls (Figure 1).

Spring weather and streamflow conditions were characterized by unusually late spring warming, which kept waters cold and flows relatively low until well into mid –April when the thaw began (Figure 3). Flows in all three rivers were well above long –term median levels, peaking within a day of April 22, and gradually declining thereafter (Figure 4). Weather conditions pushed Little Bay de Noc (Whitefish River) walleye spawning and egg take activities back to April 24, about 10 days later than normal, and suggested that the runs we estimated were also occurring later than is typical. The relatively late movement of fish into rivers may also have compressed spawning run periods rivers, such as Ford, though this is speculation.

Results

Escanaba River – During 10 days of sampling we handled 2,808 walleyes (including 367 recaptures). The walleye run peaked around April 21 when the male:female ratio was lowest and before the percentage of spent females increased dramatically. The preliminarily estimate for the 2008 spawning run was 8,413 walleyes (95% confidence interval of 2,889) using the Shumacher – Eschmeyer (SE) estimation. The estimate of the run by sex was 3,873 males and 4,540 females. Data from April 23 and 25 were excluded from the estimate due to the increased proportion of spent females and likelihood that significant emigration of females from the river had occurred. The CJS estimate (an open population estimation method) as of April 21 was 6,140 walleyes.

Ford River – The walleye run here was sampled primarily by the NLMMU as they could fit it in around other surveys related to walleye egg –take and tagging activities in Little Bay de Noc. However, the five surveys that occurred during April 17 –23 indicated a substantial spawning run of walleyes, with 1,448 fish being sampled. The walleye run here likely peaked around April 21 since a large proportion of spent females were observed on April 22 –23. Both estimation methods suggested that the spawning run may include about 5,000 males (95% confidence interval of ~1,200). Only four of the 667 females observed were recaptured fish, which precluded an estimate of females using either estimator. A more complete survey should occur here in future years to better quantify the size of the run.

Tahquamenon River – The walleye run here was sampled by ELSMU on eight days from April 18 – 25. During this time staff sampled 1147 walleyes, 221 of which were recaptured fish. The walleye run seemed to peak around April 23, as the proportion of spent females increased and catches notably declined thereafter. Female walleyes were vulnerable to gear for only a very brief time, even though sampling seemed to cover the spawning period fairly well. Of the 142 females observed, only four were recaptures. While this precluded a CJS estimate for females, a Schumacher –Eschmeyer estimate was possible and its value (1,414 females) seemed to corroborate estimates of the males (1,716 fish). The 95% confidence interval for the male estimate was 188 fish, indicating fair accuracy. Thus, the combined estimate for the run was 3,130 walleyes.

Size structure of walleye runs was distinct among the rivers studied (Figure 5). There was a fairly large separation by size among male and female walleyes in the Escanaba River, with mean lengths of the sexes at 19.8 and 25.4 inches. Considerably more overlap in size structure occurred among Ford River walleyes, where mean lengths of male and female fish were 21.6 and 24.3 inches. Average sizes of male and female walleyes in the Tahquamenon River spawning run (20.9 and 24.0 inches) was slightly smaller than those of walleyes in the Ford River.

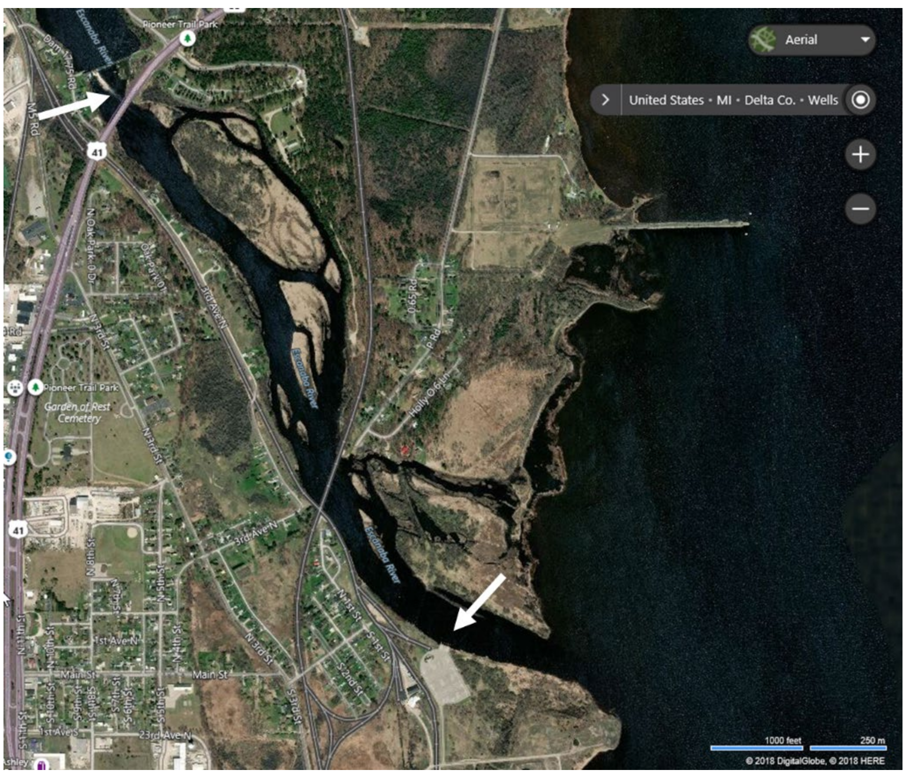


Figure 1. Sample reaches on the Tahquamenon (above) and Escanaba (below), with arrows indicating upstream and downstream ends of sample reaches. Downstream end of reach on the Tahquamenon is approximate.

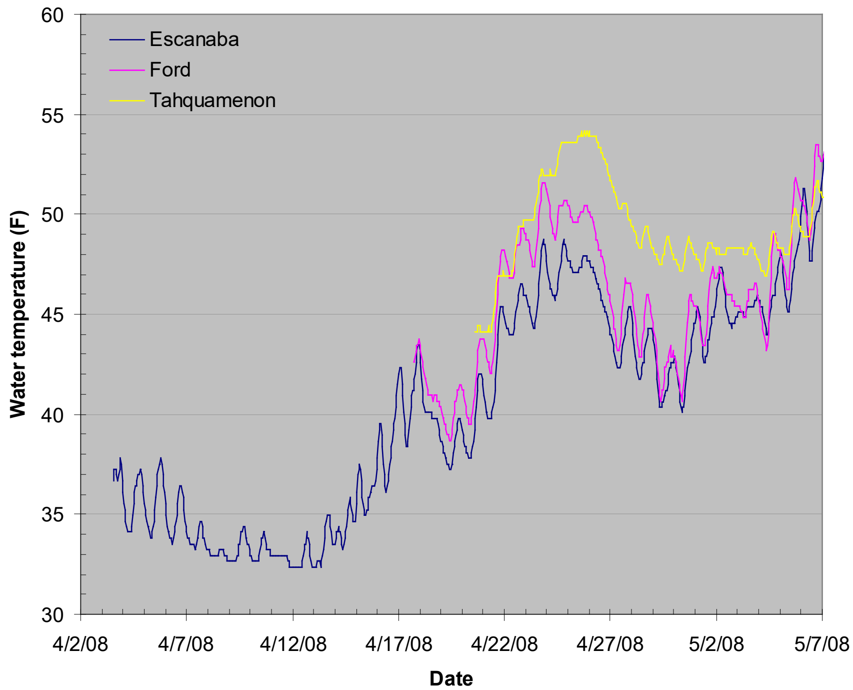


Figure 3. Water temperature conditions in study rivers during spring 2008.

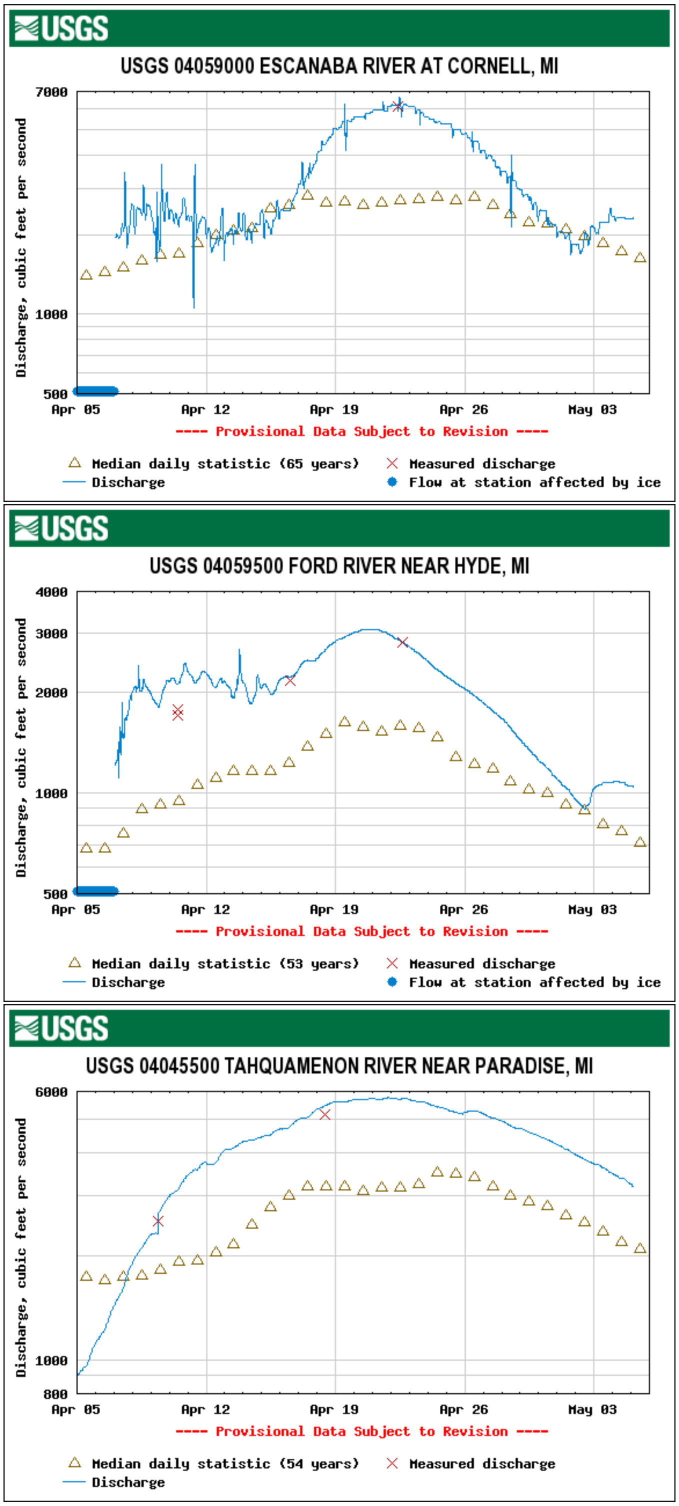


Figure 4. Flow conditions in three study rivers in spring 2008.

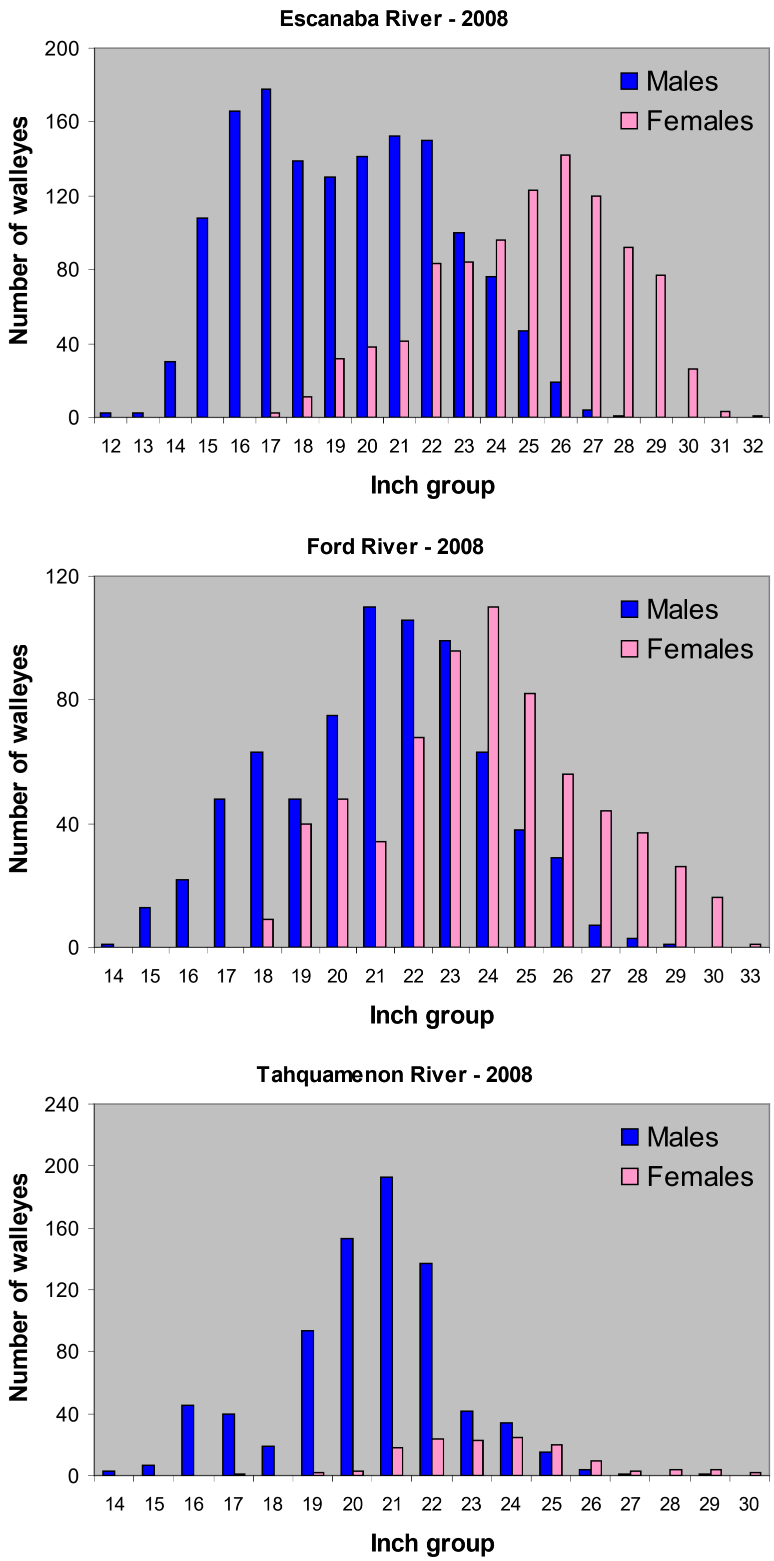


Figure 5. Size structure of walleye spawning populations in study rivers, Spring 2008.

Table 1. Daily walleye catch showing recaptures of fish during spawning run assessments in three study rivers in spring 2008.

Date	Day	Daily Mean Temp (C)	Total catch	Recaptures	M:F ratio	Gravid	Ripe	Counts P Spent	Spent	Total
Escanaba										
3-Apr	1		8	0		0	0	0	0	0
7-Apr	2	1.0	10	0	1.5	3	0	1	0	4
10-Apr	3	0.6	14	0	1.8	5	0	0	0	5
15-Apr	4	2.3	149	2	1.7	47	1	1	5	54
16-Apr	5	3.6	297	6	2.3	84	4	1	2	91
17-Apr	6	5.0	396	27	1.9	124	6	1	5	136
18-Apr	7	4.6	376	48	1.4	141	10	0	5	156
21-Apr	8	5.5	536	73	1.1	194	21	7	32	254
23-Apr	9	7.9	619	97	1.2	152	26	8	93	279
25-Apr	10	8.6	403	114	4.9	16	6	2	43	67
Total:			2808	367						
Ford										
17-Apr	1		135	0	4.2	24	1	0	1	26
18-Apr	2	5.3	239	3	4.1	36	10	0	1	47
20-Apr	3	5.2	142	4	1.0	40	26	0	5	71
22-Apr	4	8.9	477	12	0.6	124	32	17	118	291
23-Apr	5	9.6	455	29	0.9	30	39	0	166	235
Total:			1448	48						
Tahquamenon										
18-Apr	1		42	0	20.0	2	0	0	0	2
19-Apr	2		62	1		0	0	0	0	0
20-Apr	3		108	3	53.0	1	1	0	0	2
21-Apr	4	7.5	173	24	20.6	6	2	0	0	8
22-Apr	5	9.0	228	38	7.8	10	13	3	0	26
23-Apr	6	10.4	327	75	2.8	32	29	6	18	85
24-Apr	7	11.5	165	62	8.2	4	9	0	5	18
25-Apr	8	12.1	42	18		0	0	0	0	0
Total:			1147	221						

Summary of Walleye Run Estimation
Whitefish and Rapid rivers – 2009

Troy Zorn
Marquette Fisheries Research Station

Intro and methods

In spring 2009, personnel from the MDNR's Marquette Fisheries Research Station and Northern Lake Michigan Management Unit and the U.S. Forest Service evaluate the size and age composition of spawning runs of walleyes in the Whitefish and Rapid rivers. Estimates were made using multiple mark –recapture techniques and fish were collected using three boat electrofishing units. Sampling occurred on the Rapid River from the mouth up to the rapids at the railroad crossing, approximately 0.75 miles upriver, and was usually accomplished with one or two passes of the boomshocker on each sampling day (Figure 1). On the Whitefish River, sampling encompassed the lower 4.8 miles of river including 4 major rapids complexes. The Whitefish was split up into zones, with one boat typically working the most lower river up to and including the most downstream rapids (in addition to the Rapid River), another boat working the long middle reach and the second rapids, and the third boat sampling the uppermost reach, including the 3rd and 4th rapids upstream. Access for teams working the upper two reaches was obtained via Clyde's camp at the end of county road I29 on the west bank of the river. Unique fin clips were given to fish each day which resulted in a capture history for each individual encountered. This enabled spawning runs to be estimated using both closed and open population estimation methods. Spines were also collected from 20 fish per sex and inch group for aging. Tissue samples were also collected from a subset of fish for potential genetic analyses in the future. We also jaw –tagged walleyes sampled during this time.

Spring 2009 came a bit late, though April showed a fairly steady warming, except for an April 18 –22 cold spell from that interrupted the warming trend (Figure 3). Temperature effects were also likely reflected in river flow conditions. No flow gauge occurs on either river, though flow conditions are approximated by measurements at the nearby Escanaba River USGS gauging station. The later colder spring resulted in delayed snowmelt runoff to rivers, resulting in flows being below long –term median levels early in April and above median values later in the month (Figure 4). These conditions made for excellent sampling, with adequate water levels for boomshocking and fairly steady upstream migrations of spawning walleyes.

Results

Whitefish River – During 15 days of sampling we handled 7,679 walleyes (including 748 recaptures). The walleye run peaked around April 16 when catches of both males and females were high, the male:female ratio was low, and before the percentage of spent females increased dramatically. We think our sampling was likely effective at documenting almost the entire spawning run, because of the low catches of female walleyes during the early and late stages of the sampling period, as well as changes in the maturity status (particularly percentages of pre – vs. post –ripe states) of females over the course of the run. The preliminarily estimate for the 2009 spawning run was roughly 46,700 walleyes (95% confidence interval of 5,600) using open population estimation methods (POPAN from Program MARK). The actual number is likely larger than this since many miles of free – flowing river occurred upstream of our sample reach.

Rapid River – The walleye run here was sampled primarily by MFRS and NLMMU, as a task secondary to walleye egg –take and tagging activities in Little Bay de Noc and walleye run sampling in the Whitefish River. Due to this, and the impassable lowermost rapids, a smaller portion of the river and its walleye run were likely sampled. Nevertheless, we collected substantial numbers of walleyes, with 1070 walleyes being caught (including 123 recaptured fish) over the course of 10 sampling days. Despite the smaller daily samples of walleye and the limited area sampled, I think the state of ripeness of female walleyes suggest that our samples were close to the beginning of the run. However, the large portion of gravid females caught toward the end of the sampling period suggests a sizeable number of pre –spawn females were still entering the river when our survey concluded (due to other tasks).

Our estimate of the size of the walleye run in the Rapid River (4,200 fish with a 1,700 fish 95% confidence interval) is likely quite conservative since such a small portion of the river was sampled and because most females captured over the course of the survey, even on the last days, were still gravid. The relatively high portion of gravid females towards the end of the run may be partly related to the short survey reach post –spawn females could quickly emigrate from. In summary, the Rapid River hosts a very substantial spawning run of walleyes.

The walleye spawning runs from both rivers were notable for the large numbers of walleyes over 30 inches in length (Figure 4). Size structure of walleye runs was similar between both rivers, likely reflecting a common growth habitat (Little Bay de Noc) for fish in the remainder of the year (Figure 4). Findings on growth of walleyes in each spawning population will be discussed in a future report.

Other species of fish observed in the two rivers over the study included northern pike, white sucker, steelhead, common carp, northern hog sucker, and sea lamprey.

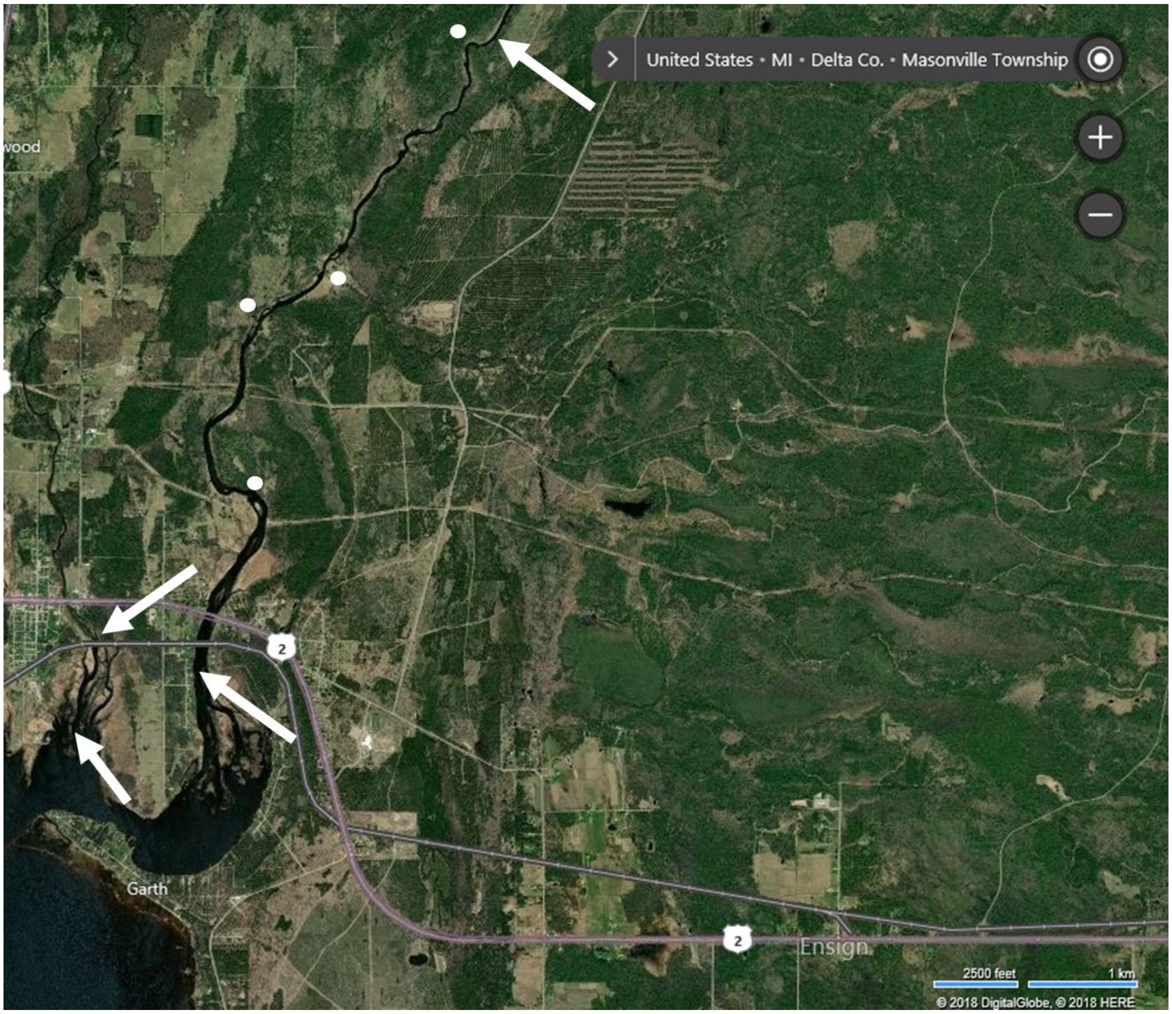


Figure 1. Sampling reaches of the Rapid (left) and Whitefish (right) rivers with the upstream and downstream ends of reaches indicated by white arrows. Major rapids on the Whitefish River are indicated by white dots.

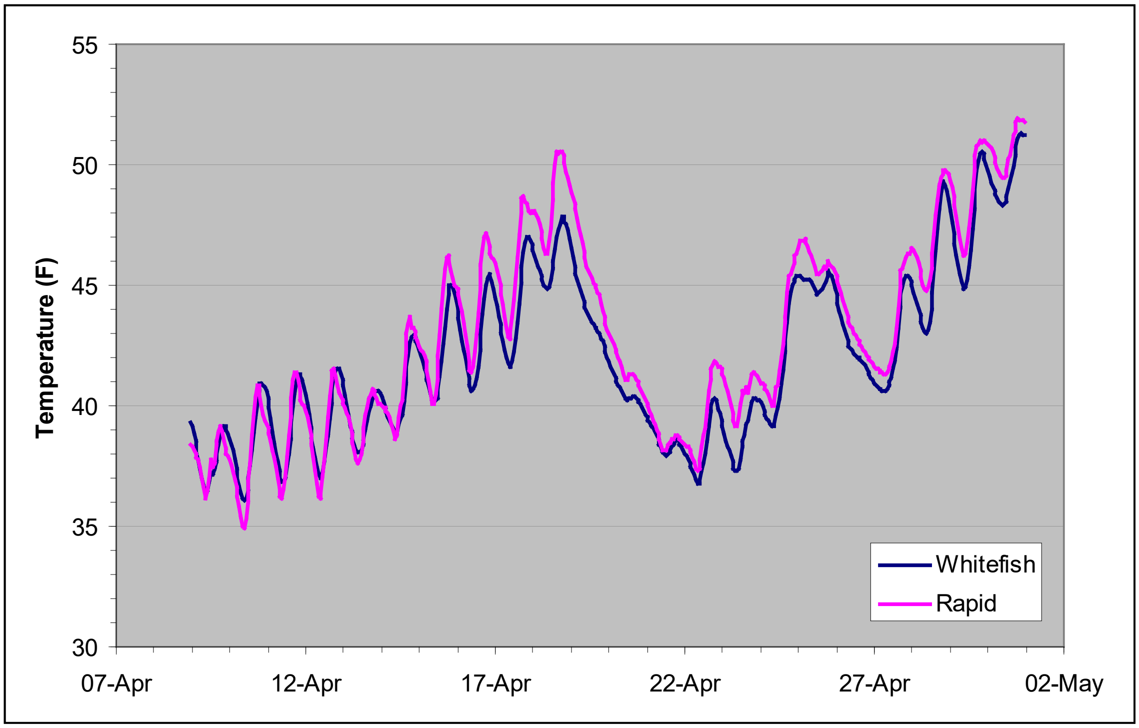


Figure 3. Water temperature conditions in Whitefish and Rapid rivers during spring 2009.

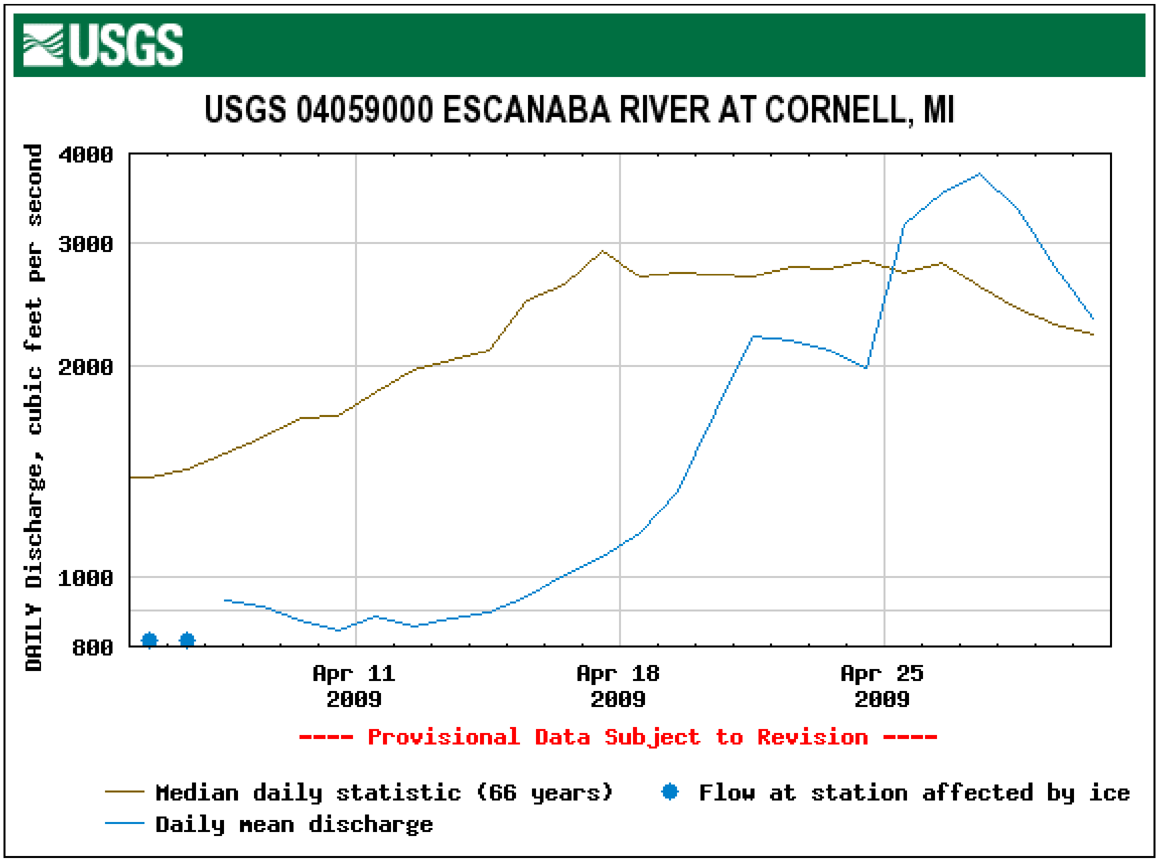
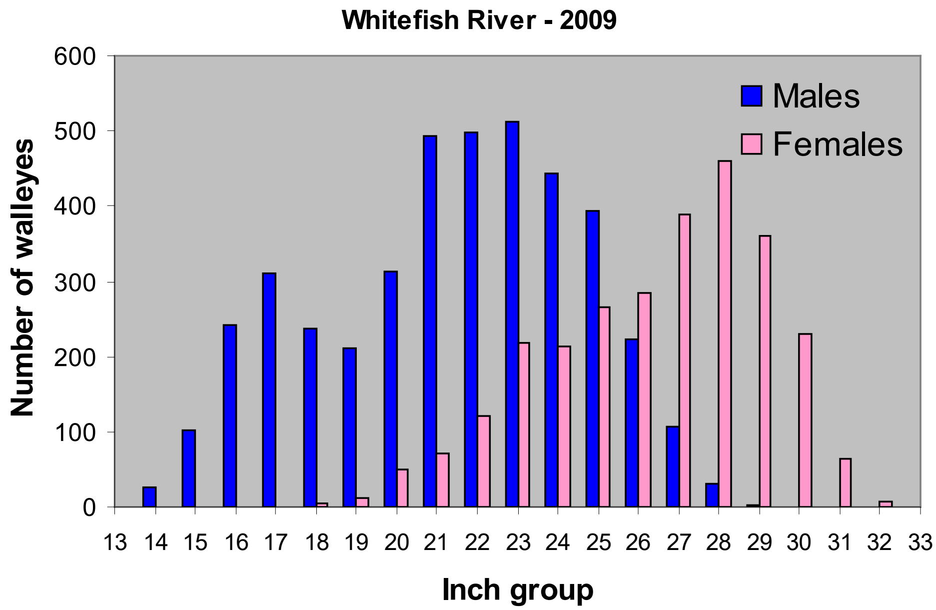


Figure 3. Flow conditions at the nearby Escanaba River in spring 2009.



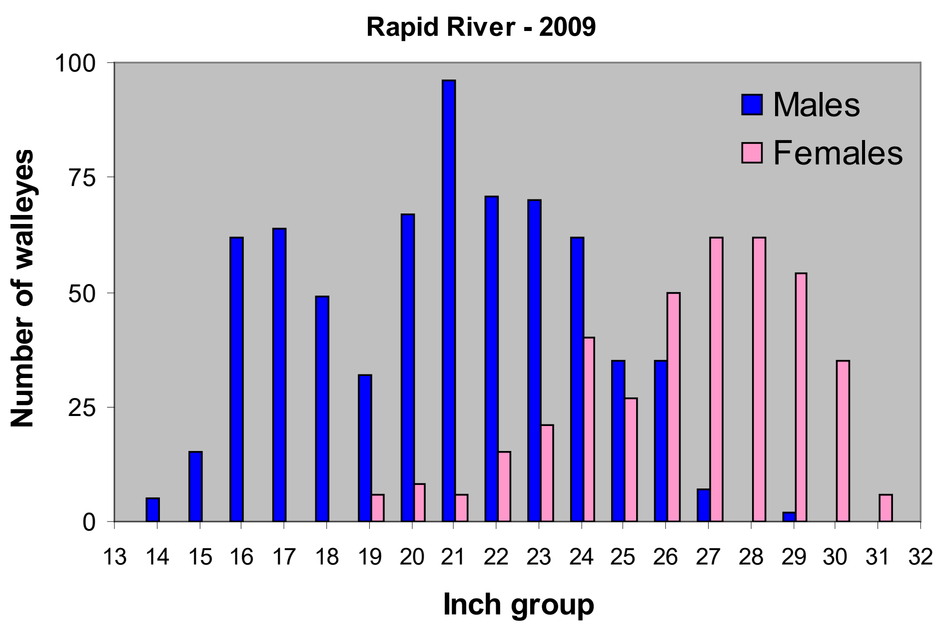


Figure 4. Size structure of walleye spawning populations in study rivers, Spring 2009.

Table 1. Daily walleye catch showing recaptures of fish during spawning run assessments of the Whitefish and Rapid rivers in spring 2009.

Date	Day	Daily Mean Temp (C)	Total catch	Recaptures	% recaps	M:F ratio	Gravid	Ripe	Counts P Spent	Spent	Total
Whitefish											
8-Apr	1	39.3	83	0	0%	1.3	34	0	0	2	36
9-Apr	2	37.9	247	0	0%	1.5	91	0	2	1	94
10-Apr	3	38.4	419	18	4%	1.7	148	4	1	4	157
13-Apr	4	39.5	661	11	2%	1.4	264	4	1	4	273
14-Apr	5	40.6	845	22	3%	0.8	415	17	5	13	450
15-Apr	6	42.3	981	69	7%	1.3	383	27	2	17	429
16-Apr	7	43.0	1169	122	10%	1.1	492	29	2	37	560
17-Apr	8	44.0	805	95	12%	1.0	305	33	1	51	390
20-Apr	9	40.6	308	41	13%	1.1	83	7	1	54	145
21-Apr	10	38.5	299	45	15%	2.1	58	16	3	21	98
22-Apr	11	38.4	651	97	15%	2.8	76	27	5	65	173
23-Apr	12	38.8	375	64	17%	6.5	13	12	3	22	50
24-Apr	13	41.5	251	38	15%	15.5	2	4	7	2	15
27-Apr	14	42.4	265	59	22%	12.9	4	1	0	14	19
28-Apr	15	45.7	320	67	21%	9.7	4	2	2	22	30
Totals			7679	748	10%						
Rapid											
13-Apr	1	39.4	198	0	0%	1.1	88	5	0	1	94
14-Apr	2	40.9	128	8	6%	2.2	27	11	1	1	40
15-Apr	3	43.1	127	9	7%	1.2	48	7	1	1	57
16-Apr	4	44.4	140	12	9%	1.0	42	21	0	7	70
20-Apr	5	41.5	62	8	13%	1.5	15	2	2	6	25
22-Apr	6	39.4	88	14	16%	2.7	10	13	0	1	24
23-Apr	7	40.5	101	21	21%	5.7	2	6	4	3	15
24-Apr	8	42.5	73	15	21%	2.8	13	0	4	2	19
27-Apr	9	43.2	92	24	26%	2.7	17	1	1	6	25
28-Apr	10	47.1	61	12	20%	1.5	14	5	0	5	24
Totals			1070	123	11%						

Summary of Walleye Run Estimation
Manistique River – 2010

Troy Zorn
Marquette Fisheries Research Station
April 2010

Intro and methods

In spring 2010, personnel from the MDNR's Marquette Fisheries Research Station evaluated the size and age composition of the spawning run of walleyes in the Manistique River. Fish were collected using a boat electrofishing unit, and multiple pass mark –recapture estimation techniques were used. The primary area of sampling was the base of the rapids near the Manistique Paper Mill plant (Figure 1). Deeper habitats between the islands downstream of the rapids to US –2 were also sampled during the first couple trips, but they failed to produce any walleyes and were abandoned with effort focusing on the rapids area. Unique fin clips were given to fish each day which resulted in a capture history for each individual encountered. This enabled spawning runs to be estimated using both closed and open population estimation methods. Spines were also collected from 20 fish per sex and inch group for aging. Tissue samples were also collected from a subset of fish for potential genetic analyses in the future. We also jaw –tagged walleyes sampled during this time.

The weather in during March and April 2010 was quite unusual and appeared to affect the way the spawning run progressed on the river. A prolonged warm, dry spell throughout March resulted in loss of nearly all snowmelt to spring runoff before April (Figure 3). By April, the flow of the Manistique, like that of most U.P. rivers, had declined to baseflow levels, rather than the more typical surging discharges that result from snowmelt in April. Once temperatures began to climb in April, rivers warmed quickly and walleye spawning activities ensued. A temperature logger was deployed in the river, and will be recovered in late summer. We began sampling on March 29, and by April 5, the walleye run appeared to be over in the Manistique. Walleye tagging and egg take activities also occurred about 2 weeks earlier than typical. By comparison, our 2009 sampling of walleye runs in the Whitefish and Rapid rivers showed gravid females continuing to enter the rivers as late as April 28, when sampling stopped.

Results

During 6 days of sampling we handled 190 walleyes (including 40 recaptures). It is difficult to determine when peak spawning occurred because very few females (< 7) were collected on any day, but I suspect the peak of the run happened around April 2 when the highest numbers of female walleyes were caught, or during the weekend which followed. On April 5, we only caught six walleyes in the Manistique, and much lower catches also occurred in Little Bay de Noc where egg take and tagging activities were occurring.

The preliminarily estimate for the 2010 spawning run was roughly 350 walleyes (95% confidence interval of about 140) using open population estimation methods (POPAN from Program MARK). The actual size of the run is likely somewhat larger than this since we could not sample a roughly 1000 foot long, upstream rapids area due to low water depths. However, our sampling area covered the major staging pools at the base of these rapids, and we were highly effective at capturing fish in these areas. Also, since the spawning and staging areas were small compared to other tributaries we have sampled, it is not likely that we would have missed large congregations of fish. The estimate for female walleyes may be somewhat low since gravid and ripe female walleyes were caught on both ends of our survey; some fish may have spawned before or after our sampling. Nevertheless, our estimate provides a reasonable picture of the general number of walleyes spawning in the river.

Length distribution data for walleyes in the Manistique River spawning run revealed some interesting information. Despite the population's small size, walleyes of all size (and presumably age) classes are well –represented, suggesting fairly consistent, albeit limited, natural reproduction for a river reach that has no record of walleye stocking (Figure 4). Limited numbers of walleyes have been stocked in the river upstream of the dam, but no stocking has occurred anywhere in the river since 2002, suggesting a sizeable portion of the spawning run is from natural reproduction. The extent of natural reproduction will be better understood once aging samples have been processed.

Other species of fish observed in the Manistique River while sampling included northern pike, white sucker, longnose sucker, steelhead, and many sea lamprey.

Walleye tagging summary
On April 1, 5, and 6, we tagged 502 walleyes in conjunction with egg –take operations at Little Bay de Noc. Information gained from reports of tagged walleyes will used to assess exploitation and survival of walleye stocks.

Figure 1. The lower Manistique River, with the upstream and downstream extent of the sample reach indicated by white arrows.

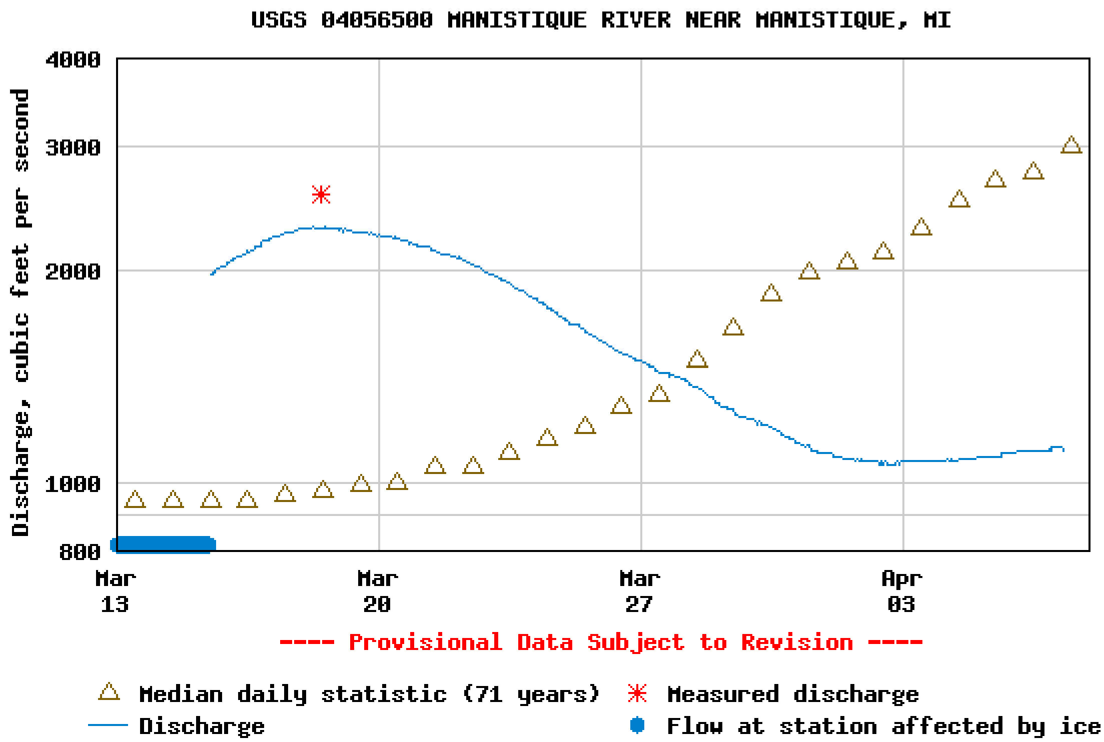


Figure 3. Flow conditions in the Manistique River in spring 2010.

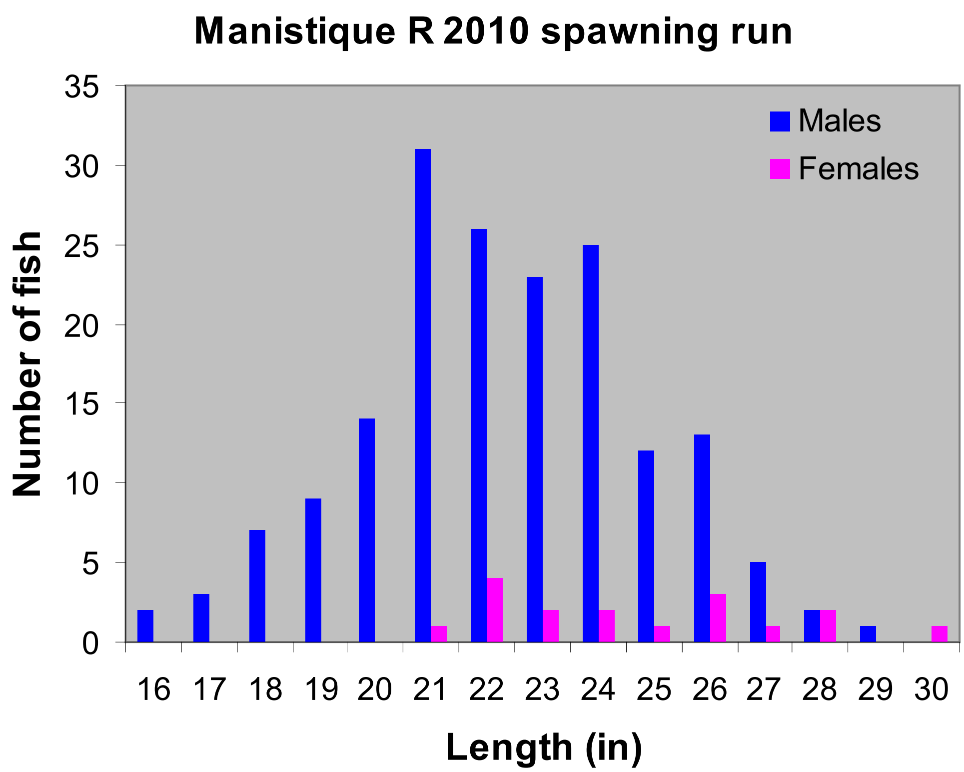


Figure 4. Size structure of walleye spawning population in the Manistique River, Spring 2010.

Table 1. Daily walleye catch showing recaptures of fish during spawning run assessments of the Whitefish and Rapid rivers in spring 2009.

Date	Day	Daily Mean Temp (C)	Total catch	Recaptures	% recaps	% Females	Gravid	Ripe	Counts P Spent	Spent	Total
29-Mar	1	-	43	0	0%	4.7%	1	1	0	0	2
30-Mar	2	-	37	4	11%	8.1%	1	2	0	0	3
31-Mar	3	-	30	8	27%	6.7%	0	2	0	0	2
1-Apr	4	-	38	10	26%	10.5%	1	2	0	1	4
2-Apr	5	-	36	14	39%	16.7%	5	1	0	0	6
5-Apr	6	-	6	4	67%	0.0%	0	0	0	0	0
Totals			190	40							

Summary of Walleye Run Estimation
Ford River – 2011

Troy Zorn
Marquette Fisheries Research Station
October

Intro and methods

In spring 2011, personnel from the MDNR's Marquette Fisheries Research Station evaluated the size and age composition of the spawning run of walleyes in the Ford River. Fish were collected using a boat electrofishing unit, and multiple pass mark –recapture estimation techniques were used. The primary area of sampling was from the mouth to the upstream end of the first major rapids on the river (Figure 1). We also sampled the three channels that formed the river's mouth and ventured out about 50 yards or so into Lake Michigan proper. Unique fin clips were given to fish each day which resulted in a capture history for each individual encountered. This enabled spawning runs to be estimated using both closed and open population estimation methods. Spines were also collected from 20 fish per sex and inch group for aging. Tissue samples were also collected from a subset of fish (21 and 26 inch groups) for potential genetic analyses in the future. We also jaw –tagged walleyes sampled during this time.

Timing was exquisite from weather and personnel perspectives. The river was quite low following an exceptionally dry late February and March. However, a soaking rainstorm occurred around April 9th, which increased the river's discharge to the point where we could sample with the boomshocker. The river then gradually fell over the entire sampling period, but provided adequate flows for us to sample most all of the walleye run. Catches had declined considerably by April 22 and the run seemed pretty much over when our sampling had to conclude due to other demands on personnel. A temperature logger was deployed in the river and was be recovered in late summer.

Results

Preliminary data summary not available.

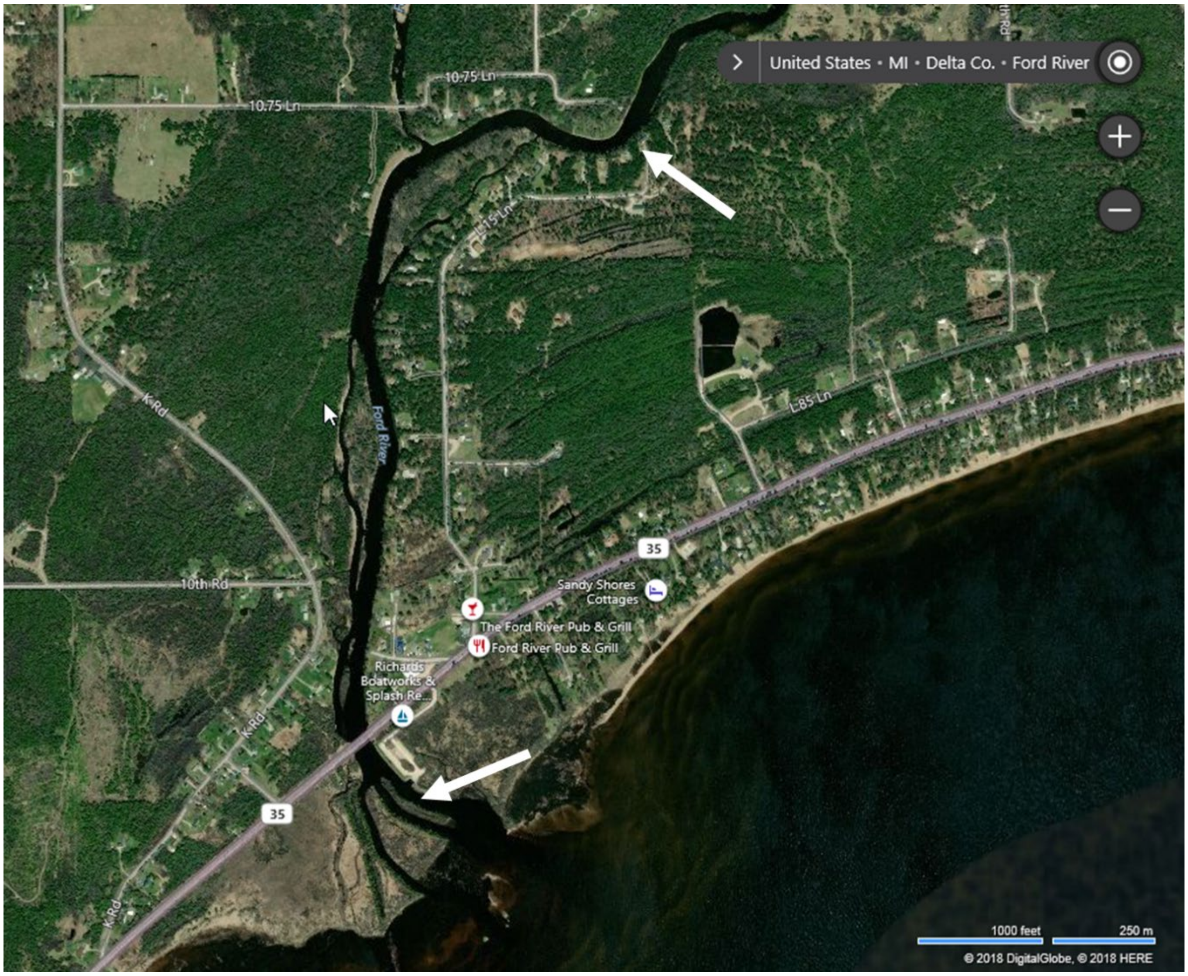


Figure 1. The lower Ford River, with upstream and downstream ends of sample reach bounded by white arrows.

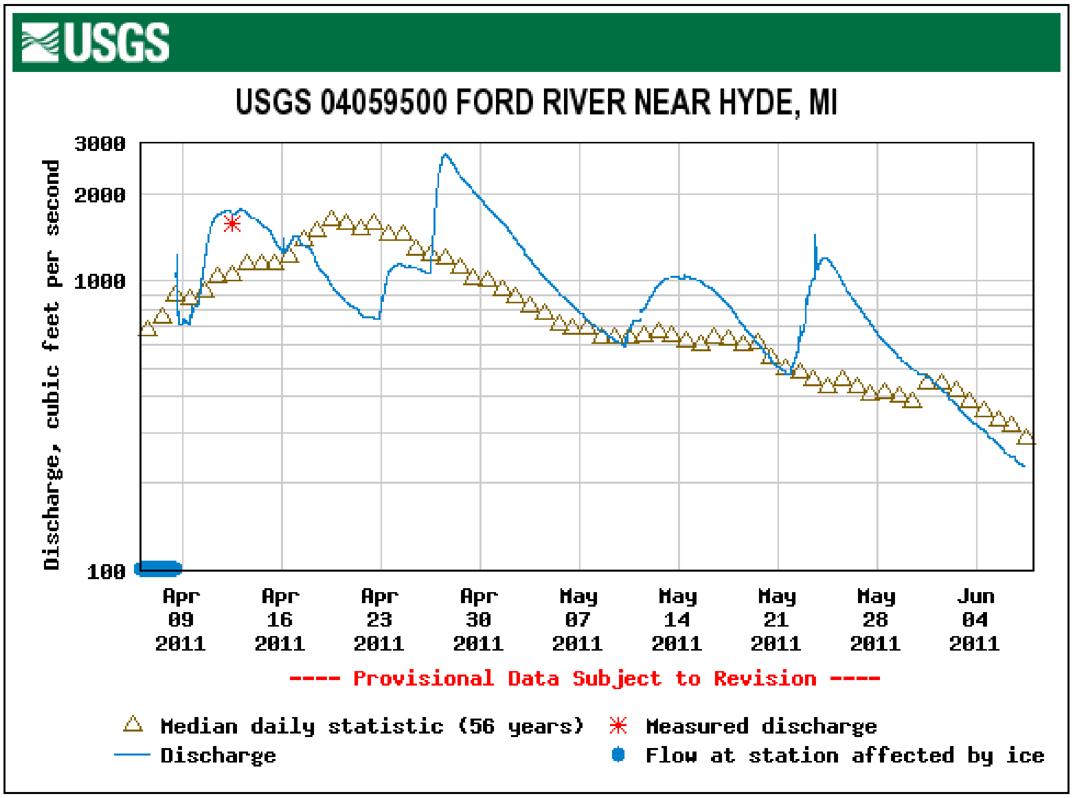


Figure 3. Flow conditions in the Ford River in spring 2011.

APPENDIX B. Capture histories for walleyes in study rivers used as input files in Program MARK. For each line of data, the first sequence of numbers (e.g., 0001001) identifies the unique capture history and the second and third numbers identify the numbers of male and female walleyes exhibiting that capture history.

```
/* 2005 Cedar R wae frequency of occurrence by capture history for M & F, respectively */
0000001     5     4;
0000010     157   17;
0000011     2     0;
0000100     220   32;
0000110     23    0;
0001000     122   228;
0001001     3     0;
0001010     18    0;
0001100     16    3;
0001101     1     0;
0001110     4     0;
0010000     10    160;
0010010     2     0;
0010100     1     2;
0011000     5     19;
0011010     1     0;
0011100     1     0;
0100000     69    290;
0100010     1     0;
0100100     4     0;
0101000     7     20;
0101010     1     0;
0101100     0     1;
0101110     1     0;
0110000     6     20;
0111000     1     5;
1000000     29    79;
1000100     5     0;
1001000     0     5;
1010000     0     7;
1010010     1     0;
1100000     2     8;
1110000     0     2;

/* 2006 Menominee R wae frequency of occurrence by capture history for M & F, respectively */
0000000001  695   113;
0000000010  712   132;
0000000011  0     5;
0000000100  758   221;
0000000101  10    2;
0000000110  6     4;
0000001000  607   159;
0000001001  10    1;
0000001010  10    1;
```

0000001100	17	3;
0000010000	772	124;
0000010001	19	2;
0000010010	25	1;
0000010011	1	0;
0000010100	18	3;
0000010101	2	0;
0000011000	22	1;
0000011100	1	0;
0000100000	814	142;
0000100001	18	2;
0000100010	14	3;
0000100100	25	2;
0000100101	1	0;
0000101000	15	1;
0000101010	1	0;
0000101100	1	0;
0000110000	13	2;
0000110100	1	0;
0000111000	1	0;
0001000000	800	55;
0001000001	20	1;
0001000010	18	0;
0001000100	26	0;
0001001000	11	0;
0001001100	1	0;
0001010000	18	0;
0001010010	1	0;
0001100000	9	1;
0001100010	1	0;
0001100100	1	0;
0010000000	674	60;
0010000001	13	0;
0010000010	19	2;
0010000100	12	1;
0010001000	16	1;
0010010000	16	2;
0010010010	2	0;
0010100000	8	1;
0010100001	2	1;
0010110001	0	0;
0011000000	11	1;
0011000010	1	1;
0011000100	3	0;
0011100000	1	0;
0100000000	716	78;
0100000001	16	1;
0100000010	26	1;
0100000100	21	0;
0100000110	1	0;
0100001000	12	1;

0100010000	18	1;
0100010001	2	0;
0100010010	2	0;
0100010100	1	0;
0100100000	10	0;
0100100001	1	0;
0101000000	8	1;
0101001000	1	0;
0110000000	17	0;
0110000001	1	0;
0110000010	0	1;
0110000100	1	0;
0110010000	1	0;
0111000000	2	0;
1000000000	384	31;
1000000001	6	0;
1000000010	7	0;
1000000100	2	1;
1000001000	8	1;
1000010000	6	0;
1000010010	1	0;
1000100000	11	0;
1001000000	7	0;
1010000000	6	1;
1100000000	11	0;

/* 2008 Escanaba R wae frequency of occurrence by capture history for M & F, respectively */

00000001	229	60;
00000010	236	253;
00000011	29	4;
00000100	186	220;
00000101	18	3;
00000110	16	10;
00000111	10	0;
00001000	144	131;
00001001	13	0;
00001010	12	5;
00001011	3	1;
00001100	8	9;
00001101	2	0;
00010000	198	111;
00010001	11	1;
00010010	5	2;
00010011	3	0;
00010100	8	7;
00010101	1	0;
00010110	3	0;
00010111	1	0;
00011000	5	4;
00011010	5	0;
00011011	1	0;

00011100	3	0;
00100000	149	74;
00100001	5	0;
00100010	1	3;
00100011	2	0;
00100100	13	2;
00100110	2	0;
00101000	14	4;
00101010	1	0;
00101100	1	0;
00110000	13	6;
00110101	1	0;
01000000	65	45;
01000001	3	0;
01000010	5	1;
01000100	5	2;
01000110	2	0;
01001000	7	1;
01001010	1	0;
01010000	1	4;
01100000	3	1;
01100100	0	1;
10000000	16	6;
10000001	2	0;
10000010	0	1;
10000100	2	0;
10001000	0	1;
10010000	0	1;
10010010	1	0;
11000000	1	0;
11100000	1	0;

/* 2008 Tahquamenon R wae frequency of occurrence by capture history for M & F, respectively */

00000001	24	0;
00000010	86	17;
00000100	148	83;
00000101	4	0;
00000110	15	1;
00000111	1	0;
00001000	125	25;
00001001	5	0;
00001010	12	0;
00001100	20	0;
00001110	3	0;
00010000	90	7;
00010001	3	0;
00010010	11	0;
00010100	16	0;
00010110	3	0;
00011000	12	1;
00011010	1	0;

00011100	5	0;
00100000	70	0;
00100001	1	0;
00100010	3	0;
00100100	11	2;
00100110	1	0;
00101000	5	0;
00101001	1	0;
00101010	1	0;
00101100	1	0;
00110000	8	0;
00111100	1	0;
01000000	34	0;
01000001	2	0;
01000010	2	0;
01000100	4	0;
01000110	2	0;
01001000	6	0;
01010000	5	0;
01010010	1	0;
01010100	1	0;
01011000	1	0;
01011100	1	0;
01100000	1	0;
01100100	1	0;
10000000	21	2;
10000001	1	0;
10000010	2	0;
10000100	1	0;
10000110	1	0;
10001000	2	0;
10010000	8	0;
10100010	1	0;
10100110	1	0;
10101000	1	0;
11000000	1	0;

/* 2009 Rapid R capture history for M & F walleyes, respectively */

0000000001	26	23;
0000000010	47	23;
0000000011	2	0;
0000000100	40	14;
0000000101	0	1;
0000000110	2	1;
0000001000	64	13;
0000001001	1	0;
0000001010	1	0;
0000001100	2	0;
0000010000	45	18;
0000010001	1	0;
0000010010	1	0;

0000010100	2	1;
0000010110	2	0;
0000011000	2	2;
0000100000	28	23;
0000100010	1	0;
0000101000	2	0;
0001000000	55	62;
0001000001	1	0;
0001000010	0	1;
0001000100	1	1;
0001001000	2	0;
0001001001	1	0;
0001010000	3	0;
0001100000	1	0;
0010000000	49	49;
0010000001	1	0;
0010000010	2	0;
0010000100	3	0;
0010001000	4	0;
0010010000	2	1;
0010100000	2	0;
0010110000	0	1;
0011000000	1	3;
0100000000	66	31;
0100000001	3	0;
0100000010	6	0;
0100001000	3	0;
0100100000	2	0;
0101000000	3	0;
0101100000	1	0;
0110000000	4	1;
1000000000	90	78;
1000000010	1	0;
1000000011	1	0;
1000000100	1	0;
1000001000	2	0;
1000010000	4	0;
1000010010	1	0;
1000010100	1	1;
1000100000	0	2;
1001000000	1	3;
1010000000	1	2;
1010001000	1	0;
1100000000	0	8;

/* 2009 Whitefish R capture history for M & F walleyes, respectively */

00000000000001	225	28;
00000000000010	183	18;
00000000000011	5	0;
00000000000100	185	14;
00000000000101	8	0;

00000000000110	5	0;
00000000001000	256	46;
00000000001001	3	0;
00000000001010	3	0;
00000000001100	3	0;
00000000010000	384	154;
00000000010001	9	1;
00000000010010	2	0;
00000000010100	2	0;
00000000010110	1	0;
00000000011000	1	0;
00000000100000	144	82;
00000000100001	6	0;
00000000100010	4	0;
00000000101000	8	1;
00000000110000	5	3;
00000000110010	1	0;
00000001000000	105	128;
00000001000001	2	0;
00000001000010	5	0;
00000001000011	1	0;
00000001000110	1	0;
00000001001000	7	1;
00000001010000	8	1;
00000001010010	1	0;
00000001100000	4	3;
00000010000000	329	345;
00000010000001	4	0;
00000010000010	2	0;
00000010000100	5	0;
00000010001000	1	1;
00000010010000	5	2;
00000010100000	6	1;
00000011000000	5	4;
00000100000000	456	497;
00000100000001	4	0;
00000100000010	8	0;
00000100000100	7	1;
00000100001000	12	0;
00000100010000	14	6;
00000100100000	5	2;
00000100110000	1	0;
00000101000000	7	3;
00000110000000	16	8;
00001000000000	412	366;
00001000000001	4	0;
00001000000010	9	1;
00001000000100	4	0;
00001000001000	13	1;
00001000010000	12	3;
00001000100000	2	2;

00001001000000	9	3;
00001001010000	1	0;
00001010000000	13	14;
00001010000100	1	0;
00001010001000	1	0;
00001010100000	1	0;
00001100000000	22	12;
00001100001000	1	0;
00001100010000	1	1;
00001110000000	1	1;
00010000000000	314	405;
00010000000001	5	1;
00010000000010	3	0;
00010000000100	3	0;
00010000000101	1	0;
00010000001000	5	0;
00010000010000	5	0;
00010000100000	2	1;
00010001000000	1	2;
00010001000010	1	0;
00010001100000	2	0;
00010010000000	4	3;
00010100000000	17	11;
00010100001000	1	0;
00010100010000	1	0;
00010110000000	2	2;
00011000000000	10	16;
00011010000000	1	1;
00011100000000	2	0;
00100000000000	304	244;
00100000000001	4	0;
00100000000010	4	0;
00100000000100	4	0;
00100000001000	3	0;
00100000010000	11	1;
00100000010001	1	0;
00100000100000	3	2;
00100001000001	1	0;
00100001100000	1	0;
00100010000000	7	3;
00100010100000	0	1;
00100100000000	11	9;
00100100000010	1	0;
00100100000100	2	0;
00100100001000	1	0;
00100110000000	1	0;
00101000000000	10	4;
00101000000001	1	0;
00101000001000	1	0;
00110000000000	7	6;
00110000000001	1	0;

00110100000000	0	1;
01000000000000	209	137;
01000000000001	3	0;
01000000000010	2	0;
01000000001000	3	0;
01000000010000	3	0;
01000000110000	1	0;
01000001000000	1	0;
01000010000000	3	6;
01000100000000	4	3;
01000100010000	1	0;
01000101000000	1	0;
01001000000000	10	3;
01001100000000	1	0;
01010000010000	1	0;
01010000100000	1	0;
01010010000000	1	0;
01011000000000	1	0;
01100000000000	3	1;
01100000000010	1	0;
01100100000000	0	1;
10000000000000	153	120;
10000000000001	2	0;
10000000000010	1	0;
10000000000100	2	0;
10000000001000	1	0;
10000000001010	1	0;
10000000010000	4	1;
10000000100000	3	0;
10000001000000	1	0;
10000010000000	1	3;
10000100000000	5	1;
10001000000000	2	2;
10001100000000	1	0;
10010000000000	1	0;
10010000010000	1	0;
10010100000000	0	1;
10011100000000	1	0;
10100000000000	3	0;
10100000100000	1	0;
10101000000000	1	0;
11000000000000	8	7;
11000000010000	1	0;
11001100000100	1	0;

/* 2010 Manistique R wae frequency of occurrence by capture history for M & F, respectively */

000001	2	0;
000010	17	5;
000100	22	4;
000110	2	0;
001000	17	2;

```
001010 2        0;
001100 1        0;
010000 17       3;
010001 1        0;
010010 3        0;
010011 1        0;
010100 4        0;
011000 2        0;
011100 0        0;
011101 1        0;
011110 1        0;
100000 27       1;
100001 1        0;
100010 3        1;
100100 2        0;
101000 3        0;
101010 1        0;
110000 3        0;
110100 1        0;

/* 2011 Ford R capture history for M & F walleyes, respectively */
000000001       55      84;
000000010       103     130;
000000011       11      4;
000000100       88      91;
000000101       2       0;
000000110       4       0;
000000111       1       0;
000001000       165     108;
000001001       6       3;
000001010       8       4;
000001100       20      3;
000010000       132     73;
000010001       3       1;
000010010       7       1;
000010011       1       0;
000010100       7       0;
000011000       19      2;
000011010       2       0;
000011100       1       0;
000100000       142     163;
000100001       2       2;
000100010       0       2;
000100100       2       1;
000100101       1       0;
000101000       8       2;
000101001       1       0;
000101010       1       0;
000110000       8       1;
000110011       1       0;
000110100       1       0;
```

000111000	1	0;
001000000	201	111;
001000001	2	0;
001000010	7	0;
001000100	5	1;
001000101	1	0;
001001000	9	0;
001001010	2	0;
001001100	1	0;
001010000	5	1;
001010110	1	0;
001011000	2	0;
001100000	11	3;
001100001	1	0;
001110000	1	0;
001110100	1	0;
001111000	0	0;
001111001	1	0;
010000000	229	63;
010000001	4	0;
010000010	3	1;
010000100	3	1;
010001000	9	0;
010010000	5	0;
010100000	7	4;
010100100	1	0;
010101000	1	0;
010110000	1	0;
010111000	1	0;
011000000	5	3;
011010000	0	0;
011010100	1	0;
011100000	0	0;
011110000	2	0;
011111000	1	0;
100000000	115	27;
100000001	1	0;
100001000	1	0;
100010000	2	0;
100011000	1	0;
100100000	3	1;
100100010	0	0;
100100011	1	0;
100101000	0	0;
100101100	1	0;
101000000	10	0;
101000100	1	0;
110000000	7	1;
110010000	1	0;