

**Yellow Perch Length-Fecundity and Length-Egg Size Relationships in Indiana
Waters of Lake Michigan**

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Abstract. – This study was undertaken to quantify the length-fecundity and length-egg size relationships for yellow perch *Perca flavescens* in the Indiana waters of Lake Michigan. Data were pooled from gill net collections made in 1985-86 and 1999, resulting in a wide length range of mature female yellow perch (172-332 mm TL). The length - fecundity relationship was: $\log_{10}F = -3.220 + 3.223 \log_{10}TL$ ($r^2 = 0.89$), where F = fecundity and TL = total length in mm. The mean preserved egg volume increased with yellow perch TL and was represented by the equation: $\log_{10}V = -2.06 + 1.10 \log_{10}TL$ ($r^2 = 0.48$), where V = preserved egg volume (mL), and TL = total length. These results reveal that larger females produced both more and larger eggs than smaller females. Therefore, intense harvest targeting large yellow perch (primarily females) in the 1980s and 1990s may have had an effect on the quantity and quality of eggs spawned by the population, possibly resulting in reduced recruitment.

Fecundity may be defined as the spawning potential of fish for a particular season or alternatively, the number of ripening eggs in a female prior to the next spawning period (Bagenal 1978). Although fecundity does not always equate to reproductive success (fertility), it can provide an objective measure of reproductive effort (Moyle and Cech 2000). Expanding this latter concept to include all mature females in a population enumerates the potential egg deposition in a specific location, or population fecundity. However, fecundity or reproductive effort may vary annually (Nikolskii 1969) based on differences in food supply (Treasurer 1981), environmental conditions, including variations in temperature and stress, density-dependent mechanisms (Sztramko and Teleki 1977), and fish size (Tsai and Gibson 1971; Bagenal 1978). Larger fish with a greater visceral space for egg development have larger ovaries, and thus more eggs than smaller fish. It is also generally accepted that egg size also increases with body length (Hislop 1988; Wright and Shoesmith 1988; Zivkov and Petrova 1993; Moyle and Cech 2000) although variation occurs among years in response to environmental conditions (Bagenal and Braum 1978; Mitton and Lewis 1989). Fecundity values are often used to calculate egg and fry survival, and ultimately, recruitment rates (Shoesmith 1990). Thus, fecundity data are important to theoretical and empirical studies of early life-history strategies (Heins and Baker 1993) and are essential for management policies directed toward fish stocks (Sheri and Power 1969).

Yellow perch *Perca flavescens* in the Great Lakes have long been valued by both sport and commercial interests, but management of the fisheries has been complicated (Francis et al. 1996). The Lake Michigan yellow perch population has historically exhibited wide fluctuations in abundance (Wells 1977). The population has been

depressed since the mid 1990s following a rapid decline from the highs of the 1980s, (Francis et al. 1996; Shroyer and McComish 1998; Allen et al. 2003) despite a multistate management strategy that consisted of restricting the recreational and commercial fisheries in 1995, and eventual closing the commercial component in 1997. The decline in Lake Michigan yellow perch abundance has been attributed to consecutive year-class failures associated with a plethora of hypothesis including alewife interaction (Shroyer and McComish 2000), food availability (Dettmers et al. 2003), and other biotic and abiotic factors (Clapp and Dettmers 2004) that may impact the population at the critical larval stage.

The relationship between fish length and fecundity for yellow perch in Lake Michigan is difficult to establish when comparing historical studies on the subject. As an example, fecundity varied from 60,000 to 102,000 eggs for fish ranging from 300-319 mm total length (TL) and was likely the result of small sample size ($n = 4$) for that length class (Wells and Jorgenson 1983). In addition, Heyer et al. (2001) found a range of 11,000 to 36,700 eggs for fish 216-287 mm TL, but again, the number of spawning individuals sampled was limited. Brazo et al. (1975) reported a fecundity range of 10,654 to 157,594 for females 190 mm to 354 mm TL. However, current trends in maturing females in southern Lake Michigan have shown females maturing (> 50%) by 170 mm TL (Allen et al. 2003) suggesting an expanded range of females could be included to create a larger and more robust data set. Furthermore, yellow perch in Indiana waters of Lake Michigan appear to form a localized population in the extreme southern end of the lake based on movement (Marsden et al. 1993), genetics (Miller 2003), and abundance (Francis et al. 1996), but no comprehensive fecundity data are

available for this stock. Therefore, the objective of this study was to model the length-fecundity and length-egg size (expressed as volume in this study) relationships for yellow perch collected from Indiana waters of Lake Michigan. These findings will further the understanding of yellow perch recruitment and reproduction in Lake Michigan, as well as, complement existing knowledge of yellow perch fecundity in the other Great Lakes and elsewhere.

Methods

Yellow perch were collected for fecundity and egg volume analysis from southern Lake Michigan using gill nets in May or early June 1985, 1986, and 1999 at a site approximately 1.6 km NE of the Michigan City, Indiana, harbor. Nets were comprised of nine panels of 15.2 m each, repeating three mesh sizes (51, 64, 76 mm stretch) and were set overnight along both 10 m and 15 m depth contours following the methods of Shroyer and McComish (1998). Total lengths (mm) and weights (g) of each fish were recorded. From the 1985-86 catch, a total of 83 fish was collected, ranging in TL from 172 to 290 mm. The 1999 sampling objective was to collect data from large fish (>250 mm TL) that were rare or absent in 1985-86 so as to expand the size range of study specimens. Thus, an additional 32 fish were collected in 1999, ranging from 254 to 332 mm TL and used in the analysis. Up to 12 fish were selected from each 10 mm size class that spanned the range of ripe females collected (172 to 332 mm TL). Only four size classes (171-180, 181-190, 201-210 and 211-220) had 12 or more fish, and selection to these classes was random.

Ovaries were removed, weighed, and placed into Gilson's fluid as soon as practicable following collection, but always within 2 hr, following methodology outlined

by Bagenal and Braum (1978). Eggs were allowed to soak for 7 to 17 months in the fluid to facilitate the breakdown of the connective tissue present between the eggs. Prior to initiating the enumeration and measuring procedures, any remaining connective tissue was manually removed, and eggs were thoroughly rinsed.

Fecundity was estimated using a volumetric approach (Bagenal and Braum 1978). Analysis began by pipetting eggs into a 15 mL centrifuge tube graduated in 0.1 mL increments. They were allowed to settle for about 15-30 s and the centrifuge tube was then tilted and lightly tapped several times to level the top of the column of eggs. The top edge of the egg mass was then measured to the nearest 0.05 mL by interpolation. If the ovary volume exceeded 15 mL, this procedure was repeated and values were summed until the total volume of eggs in the ovary was measured. A small tube for measuring subsamples of eggs was made by cutting the end off a disposable plastic micropipette tip (100-1000 μ L capacity), leaving some taper, but increasing the minimum diameter to approximately 4 mm so that eggs would not jam in the bottom. The cut end was heat-sealed, precisely 1 mL of distilled water was added to the tube with a Hamilton 705-N μ L syringe, and a fine mark was made to the tube at the meniscus. Three, 0.1 mL subsamples of eggs were collected from each ovary and were transferred to a glass petri dish where they were enumerated manually with the aid of a digital counter. Means and statistical variability of egg sub-samples could not be calculated as the sub-samples do not meet the independence assumption. Fecundity for each female was calculated as:

$$F = nV_0 / 0.3$$

where: F = total fecundity.

V_0 = total volume of eggs in mL

n = total volume of eggs in the three sub-samples

0.3 = total volume of the three sub-samples in mL

Mean individual preserved egg volume was also estimated for each ovary, using the formula:

$$V_L = 0.3/n$$

where: V_L = mean individual preserved egg volume in mL

n = total number of eggs in the three sub-samples combined

0.3 = total volume of the three sub-samples in mL

Simple linear regression was used to estimate the length-fecundity and the length-egg volume relationships. We \log_{10} -transformed both TL and number of eggs because this linearizes $F = aTL^b$, the theoretical fecundity equation according to Bagenal (1978), where:

F = fecundity

a = constant

TL = total length (mm)

b = exponent

A \log_{10} - \log_{10} transformation was also used for the relationship between TL and egg size. The relationship was modeled as $\log_{10}V = a + b\log_{10}TL$, where:

V = mean individual preserved egg volume (mL)

a = intercept

b = constant

TL = total length (mm)

A homogeneity of slopes test and an analysis of covariance (ANCOVA) were used to compare the regression equations of the 1985-86 and 1999 samples to determine whether the individual data sets could be combined, thus forming a single length-fecundity relationship (Zar 1999). A similar comparison was made for the 1985-86 and 1999 length-egg size relationship. We also compared our length-fecundity relationship with previously published reports to establish degree of similarity. We plotted the 95% confidence limits around our regression line and compared this area with the regression lines from other studies for overlap. Although this comparison was limited because the original raw data for all studies was not available, it did provide some measure of similarity and comparison.

Results

Relationships between fecundity and yellow perch total length did not differ significantly between 1985-86 and 1999 (homogeneity of slopes test: $F = 1.39$, $df = 114$, $P = 0.24$; ANCOVA homogeneity of Y intercept test: $F = 2.01$, $df = 114$, $P = 0.16$). Therefore, pooled data from all years was used to establish the fecundity linear regression model ($F = 919.7$, $df = 114$, $P < 0.001$, $r^2 = 0.89$, Figure 1):

$$\log_{10}F = -3.220 + 3.223 \log_{10}TL$$

where:

F = fecundity

TL = total length (mm)

Fecundity predicted by the linear regression model over the observed length range was from 9663 eggs for a 172 mm fish to 80,469 eggs for a 332 mm fish.

The egg volume – total length relationship was also not significantly different between 1985-86 and 1999 (homogeneity of slopes test: $F = 0.53$, $df = 114$, $P = 0.82$; homogeneity of Y intercept test: $F = 1.64$, $df = 114$, $P = 0.21$). Thus, the data from both periods were pooled and were used to form a single linear regression). We found a positive linear relationship model ($F = 106$, $df = 114$, $P < 0.001$, $r^2 = 0.48$, Figure 2) between fish length and preserved egg volume described by the equation:

$$\log_{10}V = -2.06 + 1.10 \log_{10}TL$$

where:

V = preserved egg volume (mL)

TL = total length (mm)

Mean egg size predicted from this linear regression model ranged from 2.58×10^{-6} mL for a 172 mm fish to 5.36×10^{-6} mL for a 332 mm fish.

Egg production in our study was similar to the Lake Michigan study near Saugatuck (Wells and Jorgenson 1983) as the regression lines for the studies overlapped (Figure 3). The Brazo et al. (1975) findings near Ludington were not similar to our study as the regression line did not fall within the 95% confidence limits detailed by our statistics for fish in the same size ranges. However, if Brazo et al. (1975) had extended the lower range of their study to include fish less than 190 mm, their regression line would have likely crossed the 95% confidence interval. Furthermore, yellow perch studies outside Lake Michigan were not within the 95% confidence limits. Formal statistical comparisons could not be made contrasting our data with others because not all original data sets were available, and these findings should be viewed as only suggestive.

Discussion

Mean fecundity for a given length yellow perch in our study was higher when compared to fish from Chesapeake Bay, and Keowee Reservoir, South Carolina (Muncy 1962; Clugston et al. 1978), and lower when compared to Lake Ontario and Lake Erie (Sheri and Power 1969; Sztramko and Teleki 1977) (Figure 3). Although fecundity in some parts of southern Lake Michigan was similar to our study (Wells and Jorgenson 1983), Heyer et al. (2001) found lower fecundity for Lake Michigan fish collected off Milwaukee although his size range of fish (216 to 287 mm TL) and number ($n = 10$) of females evaluated were limited. Declines in egg production have been demonstrated for yellow perch populations that are suffering from poor conditions, particularly deficient food supply and limited growth the previous summer (Newsome and Leduc 1975). Similarly, fecundity in several percid populations can be affected by growth rates and food supply (Baccante and Reid 1988; Diana and Salz 1990; Hayes and Taylor 1994,) as gonad production is energy intensive (Craig 1987). Parasitic infection can also influence yellow perch fecundity (Johnson and Dick 2001), a factor that is not always considered when evaluating gonadal productivity. Zivkov and Petrova (1993) indicated fecundity of pikeperch *Sander lucioperca* in different bodies of water is determined by differences in maturation period, lengths of life cycle, and types of female age structure. Because fish in the southern portion of Lake Michigan may represent a single population (Marsden et al. 1993; Francis et al. 1996; Miller 2003), it is plausible they would exhibit fecundity traits similar to each other. Several factors could be influencing the fecundity – length relationship for yellow perch that exists among divergent bodies of water; however

geographical proximity does not appear to be a principal contributing factor in southern Lake Michigan.

Our positive egg size – total length relationship was supported by Heyer et al. (2001), who also showed increased energy reserves (yolk) available to offspring of larger females, as measured by dry weight and total DNA content. Egg size from the ovaries of yellow perch just prior to spawning have been found to have a mean diameter from 0.94 mm to 1.62 mm over a fish length range from 170-320 mm TL (Treasurer 1981). In the closely related European perch *Perca fluviatilis*, egg size has been found to increase with total length and may be a compensating mechanism for populations that are highly variable or experiencing fluctuating mortality (Volodin 1979). Larvae from larger females (producing larger eggs) therefore may better resist starvation, feed on larger food items, swim faster to avoid predation, disperse farther, and are subject to lower overall mortality (Braum 1978; Wright and Shoesmith 1988; Duarte and Alcaraz 1989, Moodie et al. 1989).

Changes in egg size and number based on fish length could affect recruitment in fish stocks, especially in exploited fisheries where larger fish tend to be harvested, leaving smaller fish as the main component of reproductive potential (Coates 1988). This has important implications for the yellow perch population in southern Lake Michigan where intense exploitation during the mid 1980s through 1997 truncated the adult size distribution, prior to and during a decline in recruitment (Allen et al. 2003; Marsden and Robillard 2004). The selective removal of larger yellow perch, resulting in a predominance of smaller females in the population, would have led to fewer and smaller egg production based on our findings. This may not be a problem during years when

large numbers of eggs are laid, as the quantity and quality of larvae produced may not be limiting. However, Marsden and Robillard (2004) suggested that the suppressed female broodstock in the Illinois waters of Lake Michigan contributed to the decline in yellow perch abundance in 1994 through 1997. Thus, the remaining mature females, if less in total length, would have produced fewer eggs and eggs of lower quality resulting in larvae more susceptible to the factors affecting yellow perch recruitment (Clapp and Dettmers 2004). Furthermore, Marsden and Robillard (2004) concluded that the most judicious management decision to conserve yellow perch in southern Lake Michigan was to curtail or abandon harvest in an effort to protect the broodstock and increase spawning potential. Had excessive exploitation not truncated the length frequencies of spawning size yellow perch in southern Lake Michigan during the mid 1980's to the mid 1990's (Allen et al. 2003; Marsden and Robillard 2004), the recent reduction in recruitment might not have been as acute or as enduring.

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Figure 1. Relationship between total length and fecundity of yellow perch in Indiana waters of Lake Michigan based on the collection from two time periods.

Figure 2. Relationship between total length and preserved egg volume of yellow perch in Indiana waters of Lake Michigan based on collection from two time periods.

Figure 3. Length – fecundity relationship for yellow perch in the Indiana waters of Lake Michigan (this study - solid line along with 95% confidence intervals). Six other studies are shown for comparison, with regression lines plotted from published slope and intercept values. All regression equations were transformed using $\log_{10} - \log_{10}$ transformations except (a), where length was not transformed. In addition, the length range of each regression line approximated (within 5 mm) the data range used to generate the equation.