Yellow Perch Fecundity in Indiana Waters of Lake Michigan, 1985-1986

An Honors Thesis (ID 499)

by

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ABSTRACT

Fecundity of yellow perch (Perca flavescens Mitchill) was evaluated for fish from Lake Michigan near Michigan City, Indiana in 1985 and 1986. Pre-spawning gillnet-captured fish (n = 83) used for fecundity models ranged from 172 to 290 mm maximum total length and age 3 to 6. Fecundity estimations were completed using both volumetric and gravimetric methods.

Comparison of estimated fecundities to total counts of eggs from three fish (202, 227, and 242 mm) revealed volumetric estimates more closely approximated the actual (mean error -3.4% SD 8.2%) than did gravimetric estimates (mean error +8.8% SD 6.5%). Equations describing fecundity (F) as a function of total length (L) were developed as least squares linear regression models. All models utilized means for fish in 10 mm intervals transformed to base 10 logarithms. The 1985 and 1986 data were combined by method of fecundity estimation since no difference in models was found between years ($P > 0.05$). The 1985-86 model based on volumetric estimates was $\log F = -4.0396 + (3.5834) \log L$ ($r = 0.982$) while the 1985-86 model based on gravimetric estimates was $\log F = -3.8258 + (3.5097) \log L$ ($r = 0.986$). The volumetric model was used to predict fecundity based on length and age.

The fecundity of yellow perch has previously been reported for fish collected from Lake Michigan near Ludington, Michigan in 1972 (Brazo et al. 1975), and

Saugatuck, Michigan in 1972 and 1979 (Wells and Jorgenson 1983). The regression models relating log F as a function of log L in these studies fall within the 95% confidence interval of the 1985-86 volumetric model. This confirms that over the length range compared, fecundity as a function of length in the present study does not significantly differ from that reported previously for Lake Michigan yellow perch.

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INTRODUCTION

The yellow perch, Perca flavescens (Mitchill), has for many years been highly valued by man. It is popular with sportfishermen, among other reasons because it feeds actively throughout the year and thus can be caught through the ice as well as in open water. It is a popular food fish, and is taken commercially from Ohio to Alberta (Scott and Crossman 1973). The yellow perch is clearly a fish which is worthy, in a practical sense, of intensive study.

According to Wells (1977), yellow perch occur throughout Lake Michigan wherever suitable depths are found, but have generally been most abundant in Green Bay and the southern part of the lake. Wells also states that Lake Michigan yellow perch have been important commercially since the 1880s and as a sport fish at least since the 1920s. Historically, the annual commercial catch has generally ranged from 0.5 to 1.5 million kg, and the annual angler harvest may often have numbered in the millions of fish (Wells 1977).

In Indiana waters, the population density is currently high. Growth rates and length-weight relationships are considerably lower than in previous years, apparently due to density-dependent factors (Gallinat 1987). It therefore appears that the fish may be in a somewhat stressed condition, with potential effects on fecundity. A comparison of current fecundity with that of previous years

might shed light on some theoretical questions about variations in fish fecundity.

Effective management of a fish population relies on knowing as much as possible about its biology. A fecundity study not only provides information on a basic aspect of natural history, but also may be useful in association with studies of population dynamics, stock-recruitment problems, production, and racial characteristics (Bagenal 1978). In addition, fecundity models can be useful in regulating the numbers and size of fish harvested to insure that an adequate brood stock is preserved (Newton and Kilambi 1973).

ACKNOWLEDGEMENTS

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LITERATURE REVIEW

GENERAL ECOLOGY AND LIFE HISTORY

Environmental Preferences and Habitat Selection

The yellow perch (*Perca flavescens*, Mitchill) can adapt to a wide variety of habitats, but lakes, backwaters, and sloughs with modest amounts of vegetation and moderately fertile water are most favorable (Becker 1983). It is classified as a temperate mesothermal fish (Collette et al. 1977); adults seem to prefer temperatures of 20-21 C (Ney 1978). According to Wells (1977), juveniles and adults in Lake Michigan are mainly demersal, but some may occur in midwater in summer. Fish older than one year "are mainly at depths of 9-27 m in winter and early spring; less than 27 m in late summer; and 18-37 m in fall." During midsummer, "perch are often concentrated in a relatively small interval within the depth ranges given, and the depth of greatest abundance may shift rapidly as bottom temperatures fluctuate."

Behavior

Adults and young commonly form loose aggregations of 50-200 individuals, segregated by size. Yellow perch are strictly diurnal fish, resting on the bottom at night (Scott and Crossman 1973). Adults have been observed to make daily migrations, moving offshore at dawn and onshore at dusk (Ney 1978).

Food Habits

Yellow perch are classified as daytime benthic carnivores (Emery 1973). They are important ecologically in converting invertebrate foods into a form which may be utilized by terminal fish predators (Thorpe 1977). Adults are usually considered to feed primarily on benthic insect larvae, particularly chironomids and mayflies. Other invertebrates such as planktonic crustaceans, amphipods, mysids, leeches, and crayfish regularly enter the diet. At a certain length threshold, fish may enter the diet as an important component (Collette et al. 1977; Ney 1978). In southern Lake Michigan in 1984, perch longer than 120 mm total length fed primarily on rainbow smelt and young-of-the-year perch (Gallinat 1987). Perch also commonly prey on the eggs of various fish species (Scott and Crossman 1973). Eggs of the alewife (*Alosa pseudoharengus*) are frequently consumed in southern Lake Michigan (Gallinat 1987).

Reproduction

Yellow perch have an extended annual period of gonadal maturation prior to spawning. Maturation of the gonads occurs in fall and winter at temperatures below 12 C (Collette et al. 1977). Active growth of ova and vitellogenesis occupy about 220 days, but ovulation and spawning last for only a few days (Hokanson 1977).

Spawning generally takes place soon after ice-out in spring at water temperatures of 7.2-11.1 C (Becker 1983). Becker notes that spawners do not build nests, and there is no evidence of guarding the eggs and young in the wild. The eggs are simply extruded in long strands which are draped over vegetation or submerged brush in water depths of 0.6-3 m.

The time required for the eggs to hatch depends on the water temperature and the rate of spring warming (Ney 1978). Reported incubation times have ranged from 8-27 days (Becker 1983). Hatching occurs in about 6 days at 20 C and 50 days at 5-6 C. At normal spring water temperatures of 8-15 C, the incubation period is 2-3 weeks. A rising thermal regimen (0.5-1.0 C/day) shortens hatching times and reduces abnormalities (Ney 1978).

According to Becker (1983), the larvae are less than 5 mm long at hatching. They swim up to the surface, and for 3 or 4 weeks are pelagic in the upper 0.9-1.2 m of water. He notes that the larvae feed on zooplankton after depletion of the yolk-sac at 3-5 days after hatching. Becker also notes that in Lake Winnebago, they are reported to become demersal when about 25 mm long. According to Wells (1977), "in southeastern Lake Michigan, postlarval young-of-the-year...live mostly in depths less than 5 m until fall; in October and November they are most numerous at 13-22 m but have been found as deep as 31 m."

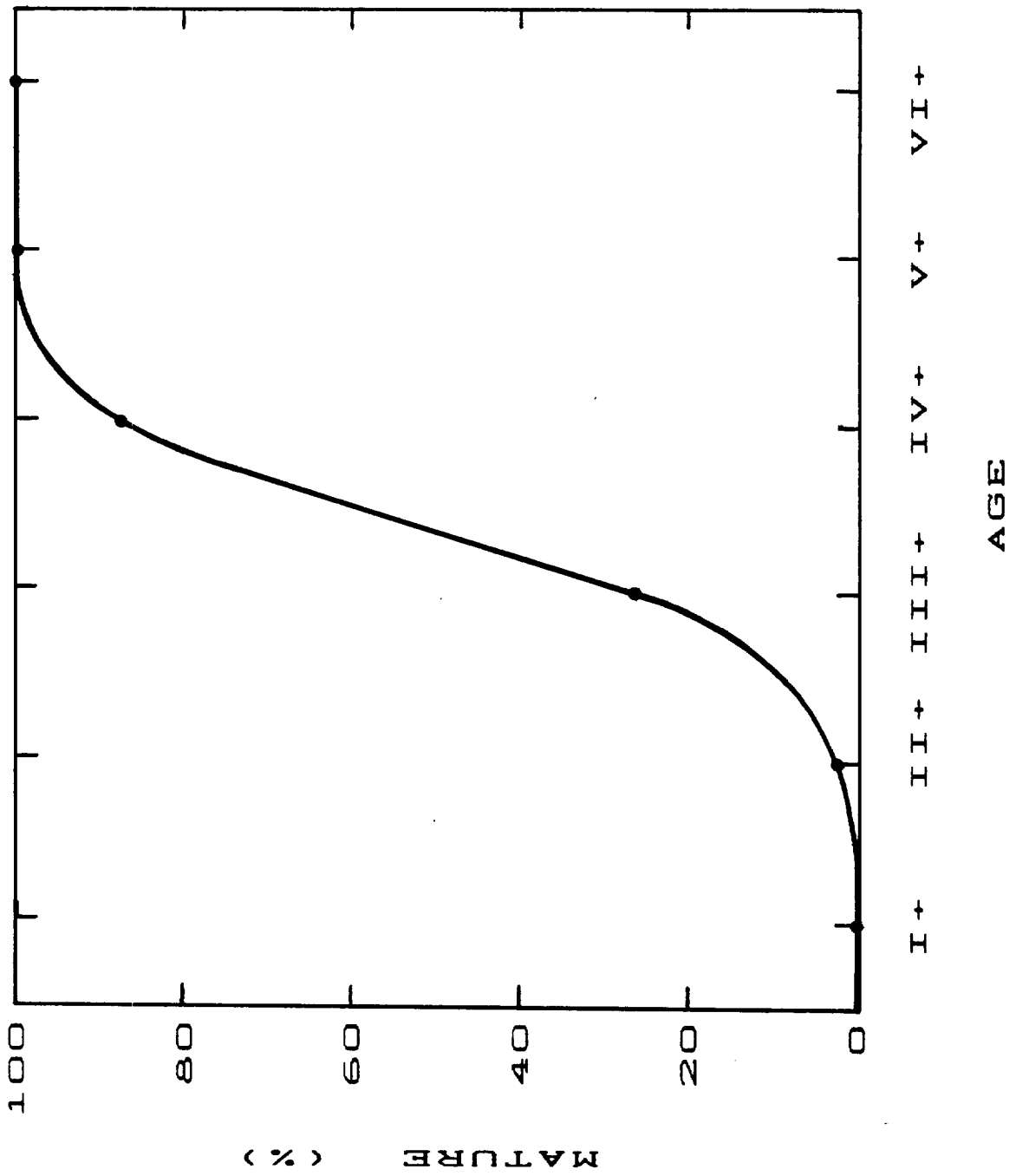
MATURITY OF FEMALES

Age at Maturity

The age at which sexual maturity is attained varies in different waters. According to Thorpe (1977), female yellow perch generally become mature in their third year. Brazo et al. (1975) reported that in Lake Michigan (near Ludington, Michigan) during the early 1970s, almost all fish older than age I were mature. In contrast, Gallinat (1987) found that in Lake Michigan (near Michigan City, Indiana) during 1985-86, the period of the present study, only 27% of the females were mature at age III, but 86% were mature at age IV and 100% at age V (Figure 1).

Size at Maturity

The size at maturity also varies. Jobes (1952) found that in Lake Erie, 48.4% of the females were mature or maturing at 203 to 216 mm. Furthermore, at 216 to 229 mm 86.1% of females were mature and 97% were mature at 229 to 241 mm, while all were mature at 241 mm and over. In Lake Huron, El-Zarka (1959) found that no females were mature at 127 to 137 mm, and only 44% were mature at 140 to 150 mm. The majority of females he examined above 150 mm were mature; at 178 to 188 mm the proportion was 80%, reaching 95% at 203 to 213 mm. He found that all females longer than 229 mm were mature. Gallinat (1987) has determined the percent maturity by length class for yellow perch collected from Indiana waters of Lake Michigan in 1984 and 1986. In


MATURE (%)
100
80
60
40
20
0
I+
II+
III+
IV+
V+
VI+
AGE

1984, 10% of the females were mature at 170-179 mm, 50% at 200-209 mm, 80% at 210-219 mm, and 100% at 230-239 mm. In 1986, maturity estimated for the same length intervals was 20%, 70-80%, 90%, and 100%.

FECUNDITY

Introduction

Fecundity is most commonly defined as "the number of ripening eggs found in the female just prior to spawning." Some authors refer to this definition as "specific fecundity." In contrast, the "population fecundity" is "the sum of the absolute fecundities of all the breeding females." A third measure of fecundity, the "relative fecundity," expresses fecundity as the number of eggs per unit weight of fish; however, the utility of reporting relative fecundity has come under serious doubt (Bagenal 1978). Throughout this paper, the word "fecundity" refers to the specific fecundity unless otherwise specified.

The level of fecundity of a species is an adaptation to varying conditions, especially mortality. The fecundity is generally directly related to the degree of mortality through predation and to other causes of mortality not associated with aging. Species which typically suffer high mortality tend to be relatively fecund (Nikolskii 1969).

Three classes of eggs are generally found in ripening ovaries. The most numerous are small, white, and opaque, and are sometimes referred to as the "recruitment stock."

"Maturing eggs" develop from the recruitment stock. The maturing eggs are relatively large, yolk-laden, and often colored yellow, orange, or green. "Atretic eggs" are maturing eggs which are destined to die and be resorbed (Bagenal 1978).

Collecting and Handling Eggs

Bagenal and Braum (1978) discuss sampling of fish for fecundity analysis. It is very important when collecting fish for fecundity analysis that the sample obtained is representative of the population with respect to length, weight, and age as well as fecundity. Bias may be introduced by selective sampling gear or by other factors. A potential source of non-gear bias is the time of sampling. For example, in some species different age groups spawn at somewhat different times, so that a sample taken at one particular time might over-represent a certain segment of the population.

Although fresh eggs have been used to estimate fecundity, it is generally more satisfactory to work with preserved eggs. Eggs may be preserved directly in 4-5% formalin; boiled, then placed in formalin; or boiled, then dried; but preservation in modified Gilson's fluid[1] is generally recommended (Bagenal and Braum 1978). Bagenal and Braum (1978) give detailed instructions for

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1. Gilson's fluid formulation: 100 mL 60% alcohol, 880 mL water, 15 mL 80% nitric acid, 18 mL glacial acetic acid, 20 g mercuric chloride (Bagenal and Braum 1978).

preserving and handling ovaries for use in fecundity analysis.

The following procedure applies to ovaries which are to be preserved in Gilson's fluid (Bagenal and Braum 1978). After the ovaries are removed from the fish, they should be split lengthwise and turned inside out to facilitate penetration of the preservative. Large ovaries should be cut into smaller pieces. The ovaries are then placed in labeled jars and preserved. The jars should be shaken vigorously and left for at least 24 h to allow the Gilson's fluid to fix and harden the eggs. The ovaries can remain in the preservative for up to several months without adverse effects. Repeated shaking during storage helps to separate the eggs from the ovarian tissue.

Methods of Estimating Fecundity

Introduction

In some cases fecundity may be determined by total egg counts, but this method is impractical with fish which produce large numbers of eggs, such as the yellow perch (Bagenal and Braum 1978). Automatic fish egg counters exist, but Bagenal and Braum (1978) have found them unsatisfactory for use with perch eggs. The most commonly used methods of determining fecundity are based on taking replicate subsamples of eggs from an ovary and using the information obtained from the subsamples to estimate the total number of eggs in the ovary.

Gravimetric Subsampling

Estimating fecundity by gravimetric subsampling involves weighing all the eggs in the ovary and in multiple subsamples, determining the number of eggs per unit weight of subsample, and then estimating the number of eggs in the entire ovary based on the number of eggs per unit weight. Total fecundity equals the weight of all the eggs in the ovary times the mean number of eggs in the subsamples, divided by the mean weight of the eggs in the subsamples (Treasurer 1981).

Eggs may be subsampled gravimetrically either wet or dry. The wet method has the advantage that after the subsamples have been weighed and preserved, the rest of the ovary may be discarded. This is desirable if one is working with fish that have large ovaries, and storage of the whole preserved ovaries is a problem. The dry method, however, has the advantage that the eggs are easier to store, and may give more consistent and accurate results than the wet method (Bagenal and Braum 1978). If storage of the whole ovaries does not present a problem, the dry method is probably the better choice.

Bagenal and Braum (1978) describe a dry method which is often referred to as Simpson's method. The preserved and washed eggs are poured into a filter paper in a funnel. When the liquid has drained off, the filter paper and eggs are spread on blotting paper to remove excess liquid. After remaining on the blotting paper about 20 minutes, the eggs

are spread on a tray consisting of filter paper sheets with their edges turned up. As the eggs air dry, they are periodically moved about to prevent clumps from forming. When the eggs are dry enough to be moved without raising the surface of the filter paper, they may be stored in specimen tubes. The fecundity estimate is based on the mean number of eggs per unit weight of two or more random subsamples and the total dry weight of the eggs in the ovary.

Bagenal and Braum (1978) emphasize that certain procedures must be followed to insure the accuracy of the method just described. When working with small eggs, a balance weighing to 0.1 mg is necessary. The moisture content of the eggs must be equilibrated with the air of the room where the counting and weighing is done. The subsamples should contain 200 to 500 eggs, and the eggs should be randomly mixed before subsampling.

Volumetric Subsampling

Another subsampling technique is the volumetric method (Bagenal and Braum 1978). It entails measuring the total volume of eggs in the ovary, then taking multiple subsamples. The estimate of the total number of eggs in the ovary is based on counts of the eggs in the subsamples. The average number of eggs per unit volume of subsample is multiplied by the total volume of the ovary to yield an estimate of the total number of eggs in the ovary. Wet eggs are usually used in volumetric subsampling.

Bagenal and Braum (1978) report that a Stempel pipette, originally designed for subsampling marine plankton, has been used to take volumetric subsamples of fish eggs, but has been found to be ineffective. An alternative method involves thoroughly mixing the eggs with water in a suitable container, then quickly taking an aliquot subsample.

Yet another method of volumetric subsampling has been used. The cleaned eggs are poured into a tall measuring cylinder of water, allowed to settle, and the total volume of the ovary is noted. In order to obtain representative subsamples, care must be taken that the eggs do not stratify according to size and sinking rates. Therefore, after the total volume of eggs is noted, all but a small quantity of the water is removed and the eggs are shaken and stirred. A specific volume of eggs is then removed and counted (Bagenal and Braum 1978).

Sphere Volume Method

Gravimetric and volumetric subsampling techniques are the ones most often used for determining fish fecundity. However, Kucera and Kennedy (1977) have devised a third subsampling technique in which the fecundity estimate is based on the mean volume of individual eggs. This technique requires the assumption that the eggs are approximately spherical.

Each ovary is weighed fresh to $\pm$ 1 mg. Then ten egg diameters per ovary are measured to the nearest 0.1 mm with an ocular micrometer. The mean egg volume is

calculated from the mean egg diameter by the equation

$$V = (4\pi r^3)/3$$

where r equals the mean egg radius and V equals the mean egg volume. Fecundity is determined by dividing the total ovary weight by the mean egg volume. This requires the assumptions that the eggs have a specific gravity of 1.0, and that the eggs are of uniform size throughout the ovary.

The main advantage of the sphere volume method over the gravimetric and volumetric methods is the rapidity of data collection, which allows fecundity estimates to be based on larger samples of fish than possible with other methods. The sphere volume method is reported to take less than 10 percent of the time required for the gravimetric method, which is the next fastest (Kucera and Kennedy 1977).

Counting Eggs In Subsamples

All the methods of determining fecundity which have been described require counting individual eggs in subsamples. This process is usually completed manually. Dodgshun (1980) outlines a method of counting eggs which would seem to improve the ease and accuracy of the counting. He counted eggs with an electrically operated mechanical-digital microbiological colony counter. Each time a fine-tipped marking pen in a microswitch holder was pressed to a solid surface, a number was displayed sequentially on a digital display unit.

The eggs in each subsample were embedded in liquid agar in a petri dish. After the agar solidified, the eggs were

counted by being "marked off" on the undersurface of the petri dish with the microswitch pen.

Dodgshun claims two main advantages of this technique over simple manual counting. One is that it is easy to keep track of which eggs have been counted, since all are "marked off" as counting progresses. The other is that petri dishes of embedded eggs may be prepared and then stored under refrigeration for several weeks until time permits their counting.

Relative Accuracies of the Subsampling Techniques

Although all three of the major subsampling techniques just reviewed have their merits, their respective accuracies seem to vary. Unfortunately, few workers have compared the relative accuracies of the different methods.

Wolfert (1969) compared volumetric (displacement) and wet gravimetric estimates on the basis of the results of analysis of five walleye ovaries. Error of the estimates was determined by comparing the estimates to total counts of the same ovaries. The gravimetric method was by far the most accurate. The mean error was +0.9%, with a range of -1.3% to +2.8%. In contrast, the error of the volumetric estimates ranged from -15.0 to +4.7%. Ovary samples used in the estimates ranged from 2.5% to 11.8% (mean 4.6%) of the total ovary weight.

Treasurer (1981) found that in his estimates of the fecundity of Eurasian perch (Perca fluviatilis), the volumetric method seemed to underestimate the number of

eggs. This is consistent with the large error toward the negative side reported by Wolfert for his volumetric method. The particular volumetric technique Treasurer used incorporated a Stempel pipette and apparently involved mixing the eggs with water, then taking a subsample. Treasurer believed the underestimates were due to unrepresentative subsamples resulting from rapid sinking of the eggs. The method in which the eggs are allowed to settle before subsamples are taken avoids the problem of rapid sinking of the eggs. According to Bagenal and Braum (1978), it has been reported that in trials of this method with three different species, "the mean deviation from the average number of eggs in 20 replicates varied from 3.8 to 4.5 percent."

Kucera and Kennedy (1977) compared mean fecundities determined by gravimetric and sphere volume methods. In an analysis of variance, they found no significant differences between the two techniques.

Statistical Analysis of Fecundity Data

According to Bagenal and Braum (1978), the statistical analysis of fecundity data should be carried out on a linear regression model because the linear relationship allows standard statistical techniques to be used and also stabilizes the variance related to fish size. Linear models do have a disadvantage, however: the antilogarithm of a fecundity estimate derived from a logarithmic equation will always tend to give an underestimate. Correction factors

have been used to compensate for this fact (Bagenal and Braum 1978).

Regression Models of Fecundity

Previously reported regression models of yellow perch fecundity have most commonly related fecundity to length, body weight, and age. Of the three predictors of fecundity, Brazo et al. (1975) found age to be the least reliable. Variation in fecundity within age classes is large, and much overlap in fecundity occurs among different age classes (Sheri and Power 1969; Brazo et al. 1975). Any potential effects of age on fecundity may be masked by the large degree of variability. Although the relationship of fecundity to age may be required in the preparation of life tables, it is unnecessary to obtain this directly. Instead, the mean fecundity for each age may be calculated from the mean length for each age group and the fecundity-length relation (Bagenal 1978).

According to Bagenal (1978), a large number of workers have concluded that the relationship between fecundity and length is of the form:

$$F = aL^b$$

where: F = fecundity, L = length, and a and b are a constant and an exponent derived from the data. A linear model may be produced from the original equation by a logarithmic transformation. This model has the form:

$$\log F = \log a + b \log L$$

where the coefficients are the same as those defined for the

original equation.

Bagenal (1978) also discusses the correlation of fecundity to body weight. He states that correlations of fecundity to weight have shown very little advantage over fecundity-length correlations when adequately analyzed. He also brings out two inherent problems with correlating fecundity and weight. For one, the somatic weight commonly changes significantly as spawning approaches. Secondly, if the total body weight (somatic weight + gonad weight) is used, this may introduce a misleading high correlation since a more fecund fish will naturally have a greater gonad weight than one which is less fecund.

From the discussion of the disadvantages of attempting to correlate fecundity with weight and age, it is apparent that the relationship of fecundity to length is generally the most useful.

When comparing regression models of fecundity among different samples of fish, it is extremely important to limit the comparisons to those which are generated from fish of the same size. Regression equations may be distinctly influenced by variations in size composition (Sztramko and Teleki 1977).

Reported Yellow Perch Fecundity Estimates

The fecundity of yellow perch ranges from about 3,000 to 160,000 eggs (Table 1). Since the fecundity of fish is generally roughly proportional to the cube of the body length (Bagenal 1978), small increases in length typically

Table 1. Reported yellow perch fecundity estimates from various localities and years. TL = total length, FL = fork length.

Locality	Body Length (mm)	Body Weight (g)	Fecundity	Authority
Minnesota lakes	--	--	10,000-46,000	1
Severn R., Md.	170-360 (TL)	--	4,600-109,000	2
Lake Ontario	135-257 (FL)	27-308	3,035-61,465	3
Patuxent R., Md.	174-290 (FL)	65-411	5,266-75,715	4
Lake Michigan	190-354 (TL)	82-678	10,654-157,594	5
Lake Erie	156-353 (FL)	96-866	12,641-135,848	6
Lake Michigan	174-355 (TL)	78-760	9,300-136,000	7

1. Eddy and Surber 1960
2. Muncy 1962
3. Sheri and Power 1969
4. Tsai and Gibson 1971
5. Brazo et al. 1975
6. Sztramko and Teleki 1977
7. Wells and Jorgenson 1983

yield a large increase in fecundity. In other words, fecundity is highly influenced by the size (= length) of the fish.

Fecundity estimates have been obtained for Lake Michigan yellow perch in two separate studies. Brazo et al. (1975), for fish collected near Saugatuck, Michigan in 1972, reported a range of 10,654 eggs for an age II fish (190 mm total length; 82 g) to 157,594 for an age VI fish (354 mm total length; 678 g). Wells and Jorgenson (1983), for fish collected in a number of locations in southern Lake Michigan in 1972 and 1979, found a range from 9,300 eggs for a fish 174 mm total length (weight 78 g) to 136,000 eggs for a 355 mm fish (weight 760 g).

Factors Influencing Fecundity

Specific fecundity and population fecundity may vary from year to year, within certain limits (Nikolskii 1969). Two examples illustrate this point. Bagenal (1978) has found "considerable and statistically highly significant annual changes in absolute, relative, and population fecundity" of various European freshwater and saltwater fishes. Healey (1978) has demonstrated significant annual variations in fecundity of exploited versus unexploited populations of whitefish (*Coregonus clupeaformis*) and lake trout (*Salvelinus namaycush*). Of course, it is also possible for fecundity to remain stable from year to year.

Bagenal (1978) found that above average fecundity appeared to be associated with low population density and vice versa, suggesting a density-dependent regulating mechanism. In addition to density, fluctuations in fecundity have been related to temperature, food supply, stress, and various combinations of stimuli (Sztramko and Teleki 1977). Volodin (1979) goes so far as to consider fecundity an index of environmental quality. Variations in fecundity have also been granted considerable significance by Nikolskii (1969), who states that variation in fecundity is "one of the basic means of adjusting the rate of reproduction to changing conditions."

According to Nikolskii (1969), two distinct periods clearly influence fecundity. The first is when the general level of fecundity of the individual is determined as the germinal epithelium is laid down during the first year of life. The second is the growing season preceding spawning when the food supply, and presumably other environmental factors, have a pronounced effect. Nikolskii states:

> The control during the second period is exerted via the formation of new oocytes and by delay or (for good food supply) acceleration of the transition from the phase of little growth to that of vacuolization and accumulation of yolk.

In addition, fecundity may be decreased by atrophy of the oocytes at all developmental stages (i.e., an increase in the proportion of atretic eggs). The degeneration of eggs is intensified by insufficient food and has been documented

both experimentally and under natural conditions (Nikolskii 1969).

Fecundity and Year-Class Strength

Annual variations in year-class strength are of considerable interest to fisheries managers. Although knowledge of fecundity may be valuable for a number of reasons discussed earlier, fecundity studies are not likely to provide any particular insight to this topic because variations in fecundity are probably much less important than other factors in determining year-class strength. To cite just one example, the first-year mortality of yellow perch is so high (Ney 1978) that variations in fecundity, within reasonable limits, appear insignificant. It is generally agreed there is little correlation between the number of eggs laid and the number of offspring reaching maturity (Muncy 1962; Nikolskii 1969).

DESCRIPTION OF STUDY AREA

Yellow perch were collected from extreme southeastern Lake Michigan near Michigan City, Indiana (Figure 2). The study area was in the same general region as the study areas described in detail by McComish (1981), Gallinat (1987), and McKeag (1987), among others.

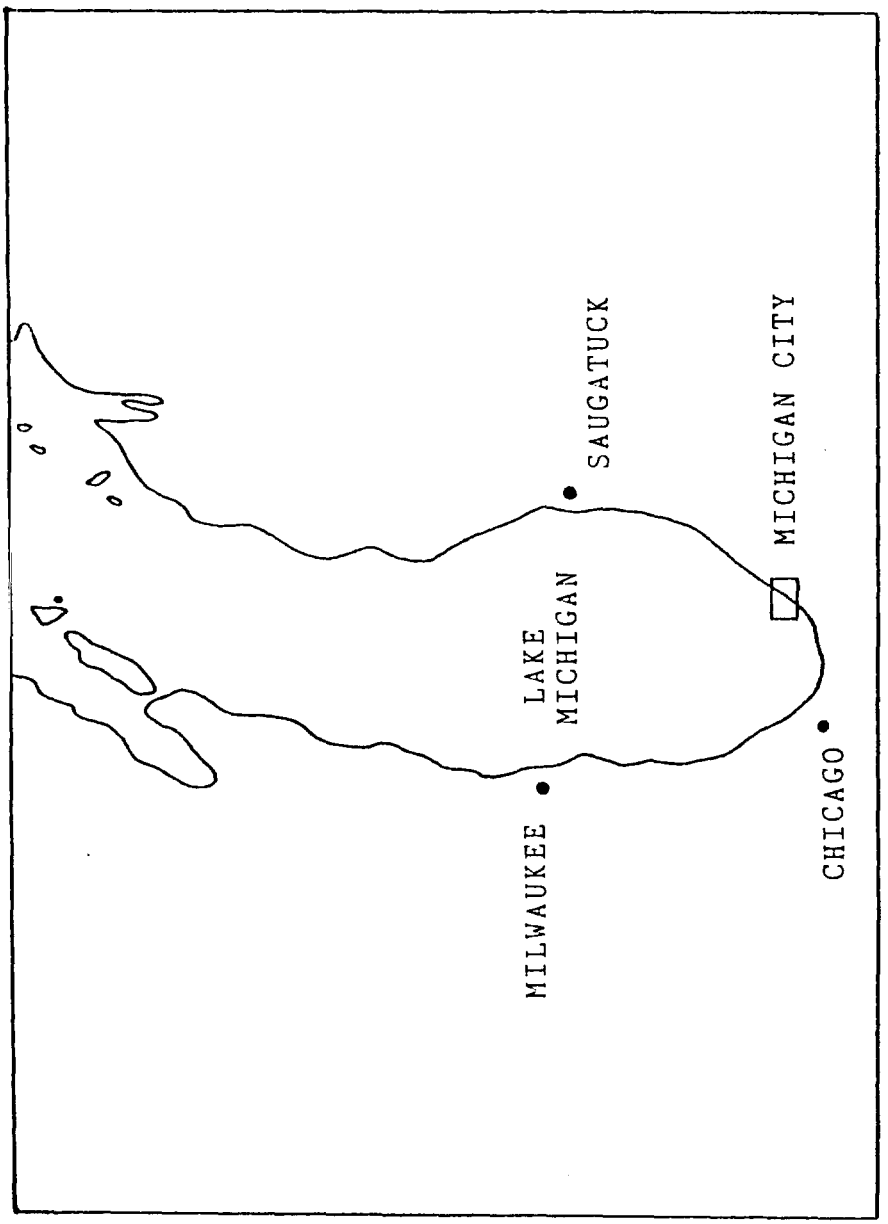
METHODS AND MATERIALS

Collection and Initial Processing

A total of 154 pre-spawning female yellow perch were obtained on May 8, 1985 and on May 8, May 27, and June 4, 1986, from gillnets set by personnel of the Indiana Department of Natural Resources (Appendices 1 and 2). At the beginning of processing and data collection for fecundity analysis, the fish were very fresh and in many cases still alive.

Each fish was first lightly damp dried with paper towels, then weighed to the nearest 0.1 g on a Mettler P1200 balance. The maximum total length (Nielsen and Johnson 1983) was measured to the nearest millimeter on a standard measuring board, and a scale sample was taken for use in age determination.

The point of a sharp scissors was inserted into the body cavity ventrally just posterior to the pelvic fins and an incision was made posteriorly to the vent while keeping the inside point of the scissors angled outward to avoid damaging the ovary. From the most anterior part of the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MILWAUKEE
SAUGATUCK
MICHIGAN CITY
CHICAGO

ventral incision, another incision was made up the left side of the fish to the dorsal extremity of the body cavity. The resulting flap was then bent back and the ovary carefully lifted and cut free from the fish. Each ovary was then weighed to the nearest 0.1 g on the Mettler P1200.

After weighing, the ovarian wall was carefully slit longitudinally with the scissors (taking care not to damage the eggs) and the ovary was turned "inside out," then preserved in modified Gilson's fluid in a labeled museum jar (either 90 mL or 120 mL capacity). This procedure is outlined and recommended by Bagenal and Braum (1978).

Preparation of Ovaries for Analysis

The ovaries were preserved in Gilson's fluid for 7 to 17 months before further analysis. The ovarian wall was removed from the ovaries collected in 1985 about 2-3 months after collection. This was done by carefully scraping the main mass of eggs away from the ovarian wall with a scalpel, then removing the few remaining eggs with forceps. The eggs were then placed back in the preservative. It was later decided that removal of the ovarian wall at this stage was unnecessary, and so it was not carried out on the ovaries collected in 1986. All ovaries were periodically shaken in their jars during storage to help separate the eggs from each other and the ovarian tissue and to aid in penetration of the preservative.

By the time it became possible to begin preparing for the actual fecundity estimates, the Gilson's fluid and

periodic shaking had almost completely broken down the tissue holding the eggs together. The following steps were taken to separate the eggs from tissue fragments:

1. The jar containing the ovary was shaken a final time to break up any remaining clumps of eggs.

2. The Gilson's fluid was carefully decanted off into a 250 mL beaker.

3. The cloudy liquid was poured from the beaker into a large glass petri dish, a little at a time, and checked for eggs. Any eggs which had been accidentally decanted off were removed with an eyedropper and placed back with the rest of the eggs. The Gilson's fluid was then discarded.

4. The eggs were rinsed in their jar with distilled water as follows. The water was vigorously poured into the jar until it was nearly full, causing a swirling of the eggs and tissue fragments. The eggs were allowed to just settle to the bottom of the jar. The rinse water containing fragments of ovarian tissue was then quickly decanted off into a 250 mL beaker and checked for eggs as in Step 3, then discarded. This process was repeated until the rinse water was clear and contained only a trace of tissue fragments. Once the decanted liquid became clear enough for stray eggs to be spotted easily (usually after the second rinse), it was decanted into the petri dish all at once to be checked for stray eggs. An average-sized ovary usually required rinsing with about 1000-1500 mL of water, corresponding to 20-30 minutes of effort. Large ovaries required much more water and time. No satisfactory method was found to speed up the process.

5. If the eggs were not to be used immediately in fecundity analysis, they were placed back in Gilson's fluid.

Total Counts

Total egg counts for use in error analysis were conducted on ovaries from three fish of lengths 202, 227, and 242 mm (I.D. numbers 85-39, 85-17, 85-2; Appendix 1). These fish were chosen both to represent a length range and because they had approximately representative fresh ovary weights for their lengths. Fresh ovary weight was used as

the major criterion for selection because it was assumed to be correlated with fecundity, although fecundity is clearly related both to the size of the ovary and the size of the eggs (Nikolskii 1969). Typical ovary weights were determined from a regression model for ovary weight as a function of length, derived from the pooled 1985 and 1986 data. Mean lengths and ovary weights for 10 mm length classes were used in calculating the regression equation. Only 1985 fish were selected for total counts because at that time the 1986 ovaries had not yet been rinsed.

Eggs were counted, approximately 200-500 at a time, in a gridded petri dish. A hand-operated digital counter was used to help prevent losing the count. The number of eggs was recorded for each batch; after all batches were counted, the numbers of eggs in the individual batches were summed to give the total fecundity. The eggs were then placed back in their original storage jar with Gilson's fluid, to await further analysis.

Fecundity Estimation

In general, both a volumetric and a gravimetric method of fecundity estimation were carried out on each ovary, including the ovaries for which total counts were obtained. There were four exceptions to this rule. For fish 86-38, 86-46, 86-94, and 86-101 (Appendix 2), fecundity was estimated volumetrically, but not gravimetrically, due to accidental loss of the samples during the gravimetric analysis. The sample size for gravimetric estimates was thus

smaller by four fish than that for volumetric estimates.

A small volumetric measuring tube to be used in subsampling was made as follows. The end was cut off a disposable plastic micropipette tip (100-1000 µL 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 then heat-sealed. Known volumes of distilled water were transferred to the tube with a Hamilton 705-N microliter syringe, and a fine permanent calibration mark was made on the tube at the meniscus when precisely 0.1 mL had been added. The mark fell within the tapered region of the tube.

After some initial experimentation, the following procedure was carried out for volumetric and gravimetric data collection on each ovary (Appendices 3 and 4). As much Gilson's fluid as possible was decanted off the eggs. They were then rinsed with about 250 mL of distilled water, and transferred (by means of a wide-mouthed eyedropper) to a calibrated Autoclear 15 mL, 16.8 X 119.1 mm conical polycarbonate centrifuge tube having 0.1 mL graduations. Sufficient water was transferred with eggs so they remained submerged. The eggs were allowed to settle for a short time after all were transferred. The tube was then tilted and lightly tapped with the fingers, as necessary, to level off the top of the column of eggs, which formed a smooth boundary analogous to a meniscus. The "egg meniscus" was

then estimated to the nearest 0.05 mL to provide a quantitative approximation of the total volume of eggs.[1] Since the preserved eggs were less than 1 mm in diameter and packed tightly, it is felt this was a reasonable approximation. Eight of the ovaries were too large to fit in the tube all at once, so the volume was measured in two separate portions.

Three 0.1 mL subsamples were then taken from each ovary as follows. Eggs were removed from the top of the column in the centrifuge tube with an eyedropper and added to the micropipet-tip subsampling tube up to the 0.1 mL mark. The top surface of the eggs was leveled off to facilitate the volume reading by gentle tilting and tapping of the tube with the fingers. The eggs were then transferred to a gridded petri dish and counted. After counting, the subsample was placed in an individually labeled Fisher brand 2" X 2" hexagonal plastic weighing dish which had previously been dried in an oven to constant weight. The eggs in the centrifuge tube were then thoroughly mixed by a strong stream of water from a washbottle, and another subsample was removed, counted, and placed in its own weighing dish. The same procedure (including mixing) was followed for a third subsample. Each subsample generally contained 200-400 eggs. After the three subsamples were taken, the remainder of the eggs were placed in a labeled Fisher brand 3" X 3" X 1" square plastic weighing dish which had previously been

1. The volumes in Appendix 3 are not always reported in 0.05 mL increments: correction factors have been added in some cases.

oven-dried and weighed for constant weight.

The weighing dishes containing the eggs then were dried in a Thelco Model 18 drying oven for 5 days at 60 C. At the end of this time, they were cooled in a dessicator with $CaSO_4$ dessicant for several hours, then weighed to the nearest 0.0001 g on a Mettler H10T analytical balance.

Estimated fecundities were calculated as follows. In each case, an individual estimate was calculated from each subsample, and the mean of the three estimates was then calculated and used in subsequent analyses (Appendices 5 and 6). Minitab (TM), a statistical software package in the Ball State University VAX computer system, was utilized in the calculations.

For the volumetric method:

$$n/(0.1\ mL) = F/V$$

where: n = the number of eggs in a particular subsample, F = fecundity, V = the total volume of the ovary, and 0.1 mL is the volume of each subsample. Thus:

$$F = nV/(0.1\ mL).$$

Calculation of fecundity by the gravimetric method was more complex. The total dry weight of each ovary was first obtained from the equation

$$W_t = (W_1 + W_2 + W_3 + W_4) - (W_5 + W_6 + W_7 + W_8)$$

Where W_t = the total dry weight of all the eggs in the ovary and $W_{(1-8)}$ are the following dry weights:

W_1 = the large plastic weighing dish and its contents (i.e., the eggs not included in the subsamples)

W_2 = the first subsample and its weighing dish

W_3 = the second subsample and its weighing dish

W_4 = the third subsample and its weighing dish

W_5 = the weight of the large plastic weighing dish alone

W_6 = the weight of the first subsample's weighing dish alone

W_7 = the weight of the second subsample's weighing dish alone

W_8 = the weight of the third subsample's weighing dish alone

The weight of each subsample was obtained by subtracting the weight of its weighing dish from the combined weight of the subsample and its dish. Each fecundity estimate was then obtained from the equation

$$n/w = F/W$$

or

$$F = nW/w$$

where n = the number of eggs in the subsample, w = the weight of the eggs in the subsample, F = fecundity, and W = the total weight of all the eggs in the ovary.

Reduction of the Sample Size

The procedures described above were so time-consuming it soon became apparent that available time would not permit fecundity estimates to be carried out for the entire sample of fish. Therefore, a subsample of fish with representative fresh ovary weights for their lengths was chosen for analysis.

The following steps were used in selecting the subsample. The procedure was carried out separately for the 1985 and 1986 samples.

1. All the fish were divided into 5 mm length classes (170-174, 175-179, etc.).
2. When three or fewer fish were available per length class, they were selected.
3. When four or more fish were available per length class, three fish with fresh ovary weights representing the range of the length class were selected: one at the low end, one near the midpoint, and one at the high end.

Two fish were rejected from the potential data base because their fresh ovary weights were far below those in adjacent length classes. One additional fish (301 mm; I. D. number 86-57) was rejected because eggs in the very large ovary were not adequately preserved in the small storage jar used.

The goal while following the above procedure was to have each 5 mm length class represented by exactly six fish, three from the 1985 sample and three from 1986. If a length class in one year's sample contained fewer than three fish, more fish were selected from that length class in the other year's sample in order to bring the total number of fish in the class up to six. In some cases, however, fewer than six fish were available in a length class for both years combined, so not all length classes of the fish selected for analysis contained six fish. The attempt to keep the total number of fish in each length class equal was motivated by the possibility of combining the 1985 and 1986 data for the fecundity model formulation. The selection process resulted