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Yellow Perch Maturity and Fecundity as a Function of Age and Growth

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Fisheries Research Report No. 1915
October 30, 1984

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION

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[1] Contribution from Dingell-Johnson Study F-35-R, Michigan

Abstract

The fecundity and rate of maturity of yellow perch (<u>Perca flavescens</u>) were examined in relation to age and size. Samples were obtained from native and experimental populations in small lakes and ponds in lower Michigan. Fecundity was more strongly related to parental weight or length than to age. Attainment of sexual maturity was a function of sex, length, and age, with the older and larger individuals more likely to be mature. For males, which mature sooner than females, the smallest mature specimen was 61 mm and the largest immature fish was 106 mm. Males matured after one growing season unless growth was unusually poor. For females, the smallest mature specimen was 86 mm and the largest immature fish was 180 mm. Females rarely matured after one growing season but most had matured after four. The study populations matured sooner and were less fecund than yellow perch populations cited in the literature (mostly in the Great Lakes) but were similar to some populations of European perch.

Introduction

The yellow perch (Perca flavescens) is abundant in cool lakes and rivers of North America and is often important to sport and commercial fisheries. However, in small lakes it has a tendency to overpopulate, resulting in a preponderance of slow-growing, small-sized fish which have little value. This problem stimulated a series of studies on the dynamics of yellow perch (Schneider 1972, 1973, 1979, 1983). This report summarizes data on the fecundity and the rate of maturity of yellow perch in ponds and small lakes in southern Michigan, and considers how fecundity and maturity respond to changes in growth. As used in this report, fecundity means the number of ripe eggs in the ovaries prior to spawning, and rate of maturity refers to the probability of being sexually mature at a given size or age.

Although often the topic of life history observations, published data on the fecundity and rate of maturity of yellow perch are surprisingly sparse. The most thorough reports are from populations in the Great Lakes (Sheri and Power 1969; Brazo et al. 1975; Sztramko and Teleki 1977; Hartman et al. 1980; Wells and Jorgenson 1983) and Maryland estuaries (Muncy 1962; Tsai and Gibson 1971). Reports from small lakes, which form the bulk of the species habitat, have been fragmentary (Pearse 1925; Herman et al. 1959; Vessel and Eddy 1941; and unpublished citations by Thorpe 1977). By comparison, information on the reproductive potential of the similar European perch (Perca fluviatilis) is much more extensive (Thorpe 1977).

Study Sites

Yellow perch, with growth patterns ranging from very slow to very fast, were collected from natural and experimental populations in small lakes and ponds in lower Michigan. These types of waters typically support mixtures of warmwater and coolwater species, principally bluegill (Lepomis macrochirus), largemouth bass (Micropterus salmoides), yellow perch, and pumpkinseed (Lepomis gibbosus).

Sugarloaf Lake (Washtenaw County), Cassidy Lake (Washtenaw County), and Jewett Lake (Ogemaw County) were sampled most intensively. They are small (5-73 ha) and shallow (maximum depth 3.4-5.8 m) with alkalinities of 34-130 ppm $CaC0_3$. The population in Sugarloaf Lake was natural with moderate growth rates (age-III perch averaged 165 mm total length). The population in Cassidy Lake was natural and fast growing in 1964 (age-III perch averaged 190 mm total length); then it was eliminated and an experimental perch-only population was established by stocking perch from nearby Sugarloaf Lake. This experimental population experienced very slow growth in 1967-69 (age-III perch averaged 112 mm total length). Later other species were added to the lake and moderate perch growth was established. Jewett Lake was also an experimental lake; there perch growth varied from very slow to very fast. Sample sites of lesser importance were Mill Lake (Washtenaw County), Vandercook Lake (Jackson County), Marble and Gilead lakes (Branch County), and Devoe, Grebe, and Lodge lakes (Ogemaw County). These hard-water lakes range from 7 to 316 ha in area and from 5 to 18 m in maximum depth. Some experimental perch were reared in 0.2-ha ponds at Saline Fisheries Research Station of the Michigan Department of Natural Resources (Washtenaw County).

Methods

Fecundity

A total of 86 mature female yellow perch, 96 to 297 mm total length, were collected from Sugarloaf and Cassidy lakes in late winter to early spring, 1964 to 1969. Ovaries were removed and preserved in 10% formalin.

Later the egg complement of each ovary was either counted entirely or estimated by subsampling, depending on its size. Usually I counted all the eggs in small ovaries (less than 5 g), 3- to 5-g samples of medium-sized ovaries (5-25 g), and about 5% of the large ovaries (greater than 25 g). This procedure usually produced a fecundity estimate with a standard error of ±10%. Ovaries were subsampled by weighing them, cutting them into several pieces, and then randomly selecting three pieces to be weighed and counted. The number of eggs per gram was then computed for each ovary and prorated to obtain an estimate of the total number of eggs. It was observed that the number of eggs per gram of ovary was highly variable, depending on proximity to spawning, size of ovary (and fish), and unknown variables as well.

Maturity

Samples were selected from a wide variety of situations to fully define the relationship of maturity to age and growth. Sampled were 1,486 perch, 35 to 300 mm total length, which had completed 1 to 8 growing seasons. Many of the fish were of known age; the ages of others were estimated from their scales. Some size groups and age groups were sampled more intensively than others to obtain better stratified estimates of the ratio of mature to immature females. Samples were collected by electrofishing and angling, and to a much lesser extent by gill netting and pond draining, from late September to mid-May, 1965 to 1984. Maturity ratios derived from comparable electrofishing and angling collections did not differ significantly (95% confidence level); consequently samples collected by all four methods were pooled.

Fish were dissected, or in the case of ripe fish stripped, to determine sex and maturity. Gonads which would ripen by spring could easily be recognized the preceding fall. In males, the pair of thread-like testes would enlarge and turn from translucent to white. In females the fused ovaries would greatly expand and change from translucent to granular.

Large collections (146-632 fish) were made at Cassidy Lake, Jewett Lake, Saline ponds, and Sugarloaf Lake; small collections (15-37 fish) were made at Mill, Vandercook, Marble, and Gilead lakes. The first three sites were experimental situations for which brood stock had been obtained from Sugarloaf, Mill, Devoe, Grebe, or Lodge lakes, or from southern Lake Michigan. As no differences in rate of maturity could be detected among these various sources, the data were pooled.

Results

Fecundity

The number of eggs produced by yellow perch was an exponential function of length. Log_{10} transformation, followed by a least squares fit, produced good linear regressions for all pooled data (Fig. 1) and for individual data sets (Fig. 2 and Table 1). Second degree polynomials were also fit to these data, but they were generally not as satisfactory as log-log fits.

Regressions for Cassidy Lake samples in 1967, 1968, and 1969 had overlapping confidence limits and were not statistically different; consequently these data were pooled for most analyses. Thus there were four basic data sets: a fast-growing population in Cassidy Lake (1964), a very slow-growing population in Cassidy Lake (1967-69), a slow-growing population in Sugarloaf Lake (1965), and the same Sugarloaf Lake population in a different year (1966). These data were analyzed further to determine the effects of age and growth, and to determine if there were important differences among years or populations.

Age effects.--Age had no effect, independent of length, on the number of eggs produced by mature yellow perch. In a multiple regression of fecundity versus length and age using all the pooled data, the partial correlation coefficients were 0.959 for length and -0.137 for age. Deletion of age from the regression resulted in an insignificant decline in the coefficient of determination (R^2) from 0.953 to 0.952.

The same conclusion was reached by comparing fecundity-length regressions for the 1965 year class of Cassidy Lake perch at successive ages (Fig. 3). This cohort was sampled in 1967, 1968, and 1969 at ages II, III, and IV, respectively. Due to poor growth (average lengths of 125, 144, and 138 mm for these respective samples) the length ranges of all three samples were quite similar. Figure 3 shows that the elevations of the regression lines are not related to age and that the confidence belts broadly overlap, indicating no effect of age on fecundity. Tsai and Gibson (1971) likewise found no age effect for the Patuxent River yellow perch population.

Condition effects.--Both lengths and weights were obtained for perch sampled in 1967 and 1968. Analyses of these data indicated that perch in good condition (heavier at a given length than average) tended to produce more eggs. That is, deviations in fecundity from the norm (predicted on basis of length) were positively correlated with deviations in weight from the norm ($r = 0.67$ for 1967 and 0.52 for 1968). Multiple regressions confirmed that fecundity was more strongly correlated with weight than length, but only slightly so. Sztramko and Teleki (1977) and Sheri and Power (1969) reached the same conclusion for the yellow perch populations they studied. However, length alone was a very adequate predictor, accounting for 97 to 98% of the variation in number of eggs in the 1967 and 1968 samples. The R^2's were improved to 98-99% if both weight and length were included in the regression analysis.

Other variation.--The fecundity of Cassidy Lake perch in 1964, Cassidy Lake perch in 1967-69, and Sugarloaf Lake perch in 1965 were all similar, as indicated by over-lapping confidence limits (Fig. 2). However, perch obtained from

Sugarloaf Lake in 1966 were significantly less fecund over most sizes. The reason for this is unknown. Genetically, the samples should have been similar, considering the origin of the stocks and proximity of these populations. Limnologically, the lakes are similar. Growth and age effects were shown above to be of minor importance. Unexplained year-to-year variations in yellow perch fecundity have also been observed by Sztramko and Teleki (1977). For trout, Bagenal (1969) concluded that food supply during the period when eggs are developing can influence fecundity directly, independent of its effect on parental length or weight.

Comparisons.--The fecundity of yellow perch in this study was less, at a given length, than for most yellow perch populations cited in the literature (Fig. 4). For a 250-mm perch, egg estimates were 23,600 in this study and 20,000 to 50,000 in other studies. Fecundity was lowest in the Severn River Estuary and highest in the Bay of Quinte, Lake Ontario. Data from Lake Michigan (2 sites), western Lake Erie, Patuxent River Estuary, and Long Point Bay (3 years) were quite similar, falling within the shaded central area of the graph. The differences among lines are considerable, but are not obviously keyed to growth or habitat.

Other fecundity reports in the literature are 9,046 eggs for 160-mm perch in Lake Medota (Pearse 1925), which falls in the shaded area of Figure 4, and a set of preliminary estimates by Vessel and Eddy (1941) for Minnesota waters which are much higher than any other figures. Additional data for European and yellow perch cited by Thorpe (1977) fall within the graph lines.

Maturity

The attainment of sexual maturity was a function of sex, length, and age (Table 2). Males matured at a smaller size and younger age than females. Within each sex, the older and larger individuals had a higher probability of being mature than younger and smaller fish. Alm (1959) reached the same conclusion for European perch and other species.

For males, the smallest mature specimen was 61 mm and the largest immature fish was 106 mm. Nearly all males over 80 mm long were mature (Table 2). Maturity was reached at age I unless growth was unusually poor. Among the slow growers, 50-79 mm, 55% were mature at age I and 92% were mature at age II.

For females, the smallest mature specimen was 86 mm and the largest immature one was 180 mm. Females did not mature at age I unless growth was exceptionally good. Percentages of mature 1-year olds progressively increased from 0% for females less than 80 mm to 85% for females 170-199 mm (Table 2). For any given size, there was a greater probability of being mature as age increased. Generally, nearly all females age IV and older, or 160 mm and larger, were mature.

Perch in Michigan inland lakes matured at an unusually small size compared to other yellow perch populations reported in the literature (Table 3). All of these reports are from populations in estuaries (Muncy 1962; Tsai and Gibson 1971) or the Great Lakes (Jobes 1952; El-Zarka 1959; Sheri and Power 1969; Brazo et al. 1975; Sztramko and Teleki 1977; Hartman et al. 1980; Wells and Jorgenson 1983). In the small lakes which I studied, most males and a few fast-growing females were mature at age I. Typically, males mature at age II and females at age III-IV by most accounts. The literature on European perch shows more diversity, including data similar to that in this study (Thorpe 1977).

Discussion

Results from this study and others indicate that perch fecundity is overwhelmingly a function of body weight or length, and that rate of maturation is a function of both size and age. As a result, a fast-growing perch has a higher probability of being mature and will produce more eggs than a slow-growing perch. However, this does not necessarily mean that a perch population comprised of fast growers will produce more eggs in total than a population of slow growers because total egg production is also a function of the total number of females and their survival rate.

The general pattern for perch seems to be that as population density decreases (as due to a weak year class) competition for food is reduced, individual growth increases, maturity is advanced, and the number of eggs produced per female increases; but survival of yearling and older perch decreases or remains constant (Buck and Thoits 1970; Forney 1971; Schneider 1971, 1972, 1973; Craig and Kipling 1983). Opposite trends occur when population density increases. Thus growth, maturity, and fecundity are fairly sensitive to density and respond in a compensatory manner, directing the population back towards a normal, equilibrium, level. On the other hand, mortality of fingerling and adult perch tends to be either insensitive to density or depensatory. The net result is that egg production is often higher for large, slow-growing year classes than for small, fast-growing ones.

A numerical example is provided by comparing the 1976 and 1977 year classes of yellow perch in Jewett Lake (Schneider 1983). The 1976 year class was significantly stronger (four times more numerous) and significantly slower growing (9-31 mm shorter at a given age) but survived at the same rate (0.100 versus 0.106--annual average for ages 0-III). Lifetime egg production estimates, calculated with the aid of maturity and fecundity data just presented, were 2.20 million for the 1976 year class and 0.39 million for the 1977 year class. Similarly, Craig and Kipling (1983) concluded that egg production is depensatory for European perch in Lake Windermere.

Because compensatory changes in maturity and fecundity typically are not adequate to restore a perch population to its equilibrium level, additional population regulation must be affected through a compensatory change in survival of progeny. This occurs before the progeny reach their first fall of life, mainly in the first few months after hatching. At the extreme, this is demonstrated by complete recruitment failure for several to many years following the establishment of an extremely large, slow-growing , year class (Alm 1952; Eschmeyer 1938; Schneider 1972). In more normal circumstances the importance of this feedback mechanism is obscured by the stochastic effects of weather on hatching and fry survival. Consequently, a correlation between adult density or egg production and subsequent recruitment is rarely observed within well established populations (Le Cren 1965; El-Zarka 1959). However, Craig and Kipling (1983) were able to correlate ($r = 0.934$) recruitment of Lake Windermere perch with biomass of adults, temperature in the year of hatching (degree days over 14 C), and the ratio of perch cohort strength to northern pike cohort strength.

What, then, is the practical significance of the response of maturity and fecundity to growth if it is not important for maintaining population density in a steady state? Apparently, it is a mechanism which enables the species to be more opportunistic, to quickly expand into new or unstable environments. Because perch are more tolerant of low levels of dissolved oxygen than many competing fishes, such opportunities occur frequently. Thus a growth increase signals that food supply is good and that fry survival and recruitment might possibly improve. The existing perch respond by producing more eggs per fish.

Fecundity and rate of maturation vary considerably among yellow perch populations and fecundity also varies from year to year within populations. Presumably these variations are adaptations to different types of habitats and responses to subtle environmental changes but a comprehensive explanation is not yet evident. Data from this study and from the Great Lakes hint that some populations develop low fecundity and early maturation and others high fecundity and late maturation. But Severn River perch did not hold to this pattern. They seemed to have both low fecundity and late maturity (the smallest mature female was 173 mm). For European perch, considerable differences have been found among subpopulations within the same lake (Thorpe 1977). These differences have been tentatively attributed to food supply or to the severity of environmental conditions in the spawning areas.

Acknowledgments

I am grateful to the staff of the Institute for Fisheries Research for assistance in the field and laboratory and to W. C. Latta and R. D. Clark, Jr., for editorial suggestions.

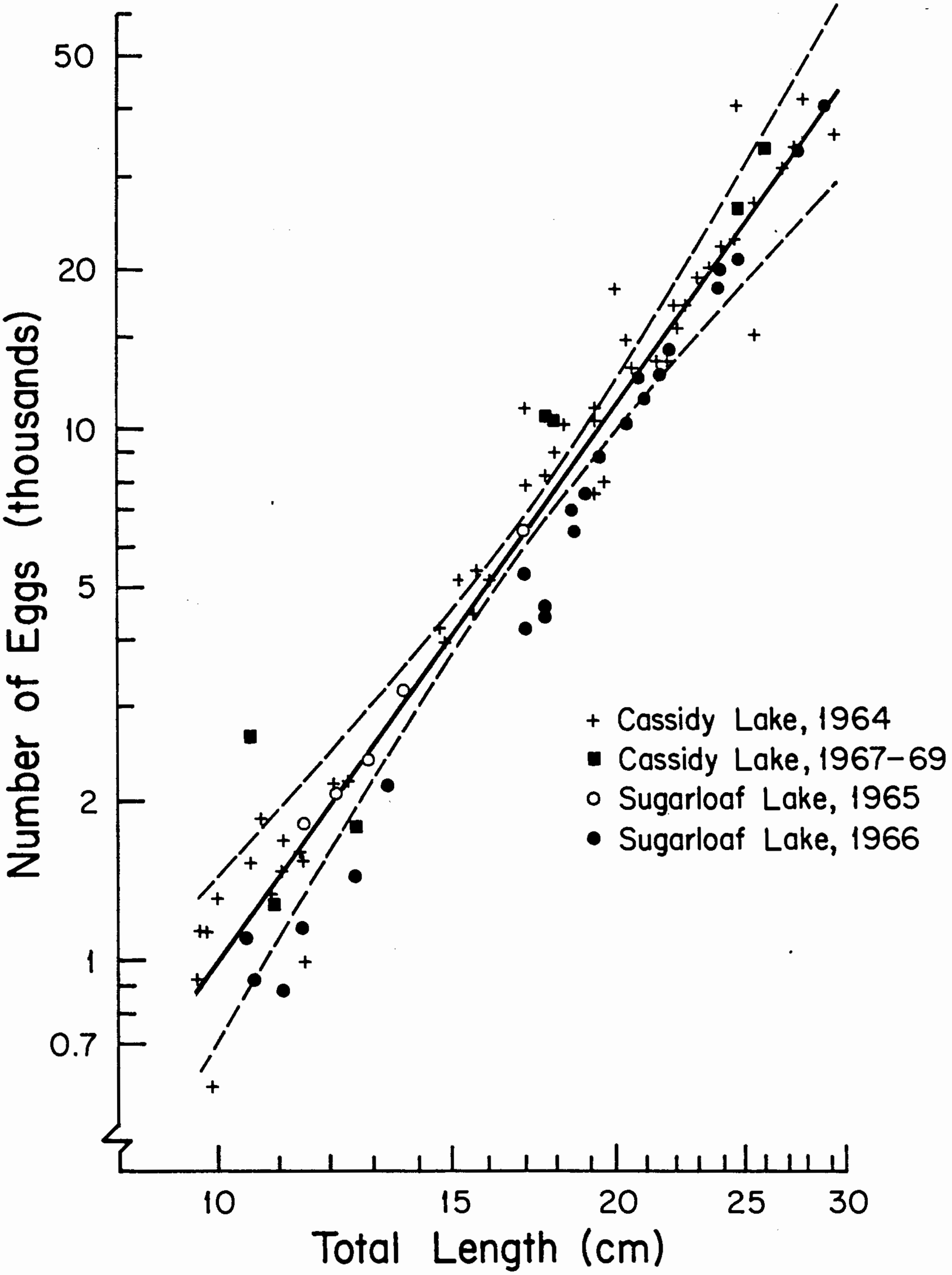

Figure 1. Regression (log scale) of fecundity on total length, with 95% confidence belt, for 86 yellow perch from four pooled collections.

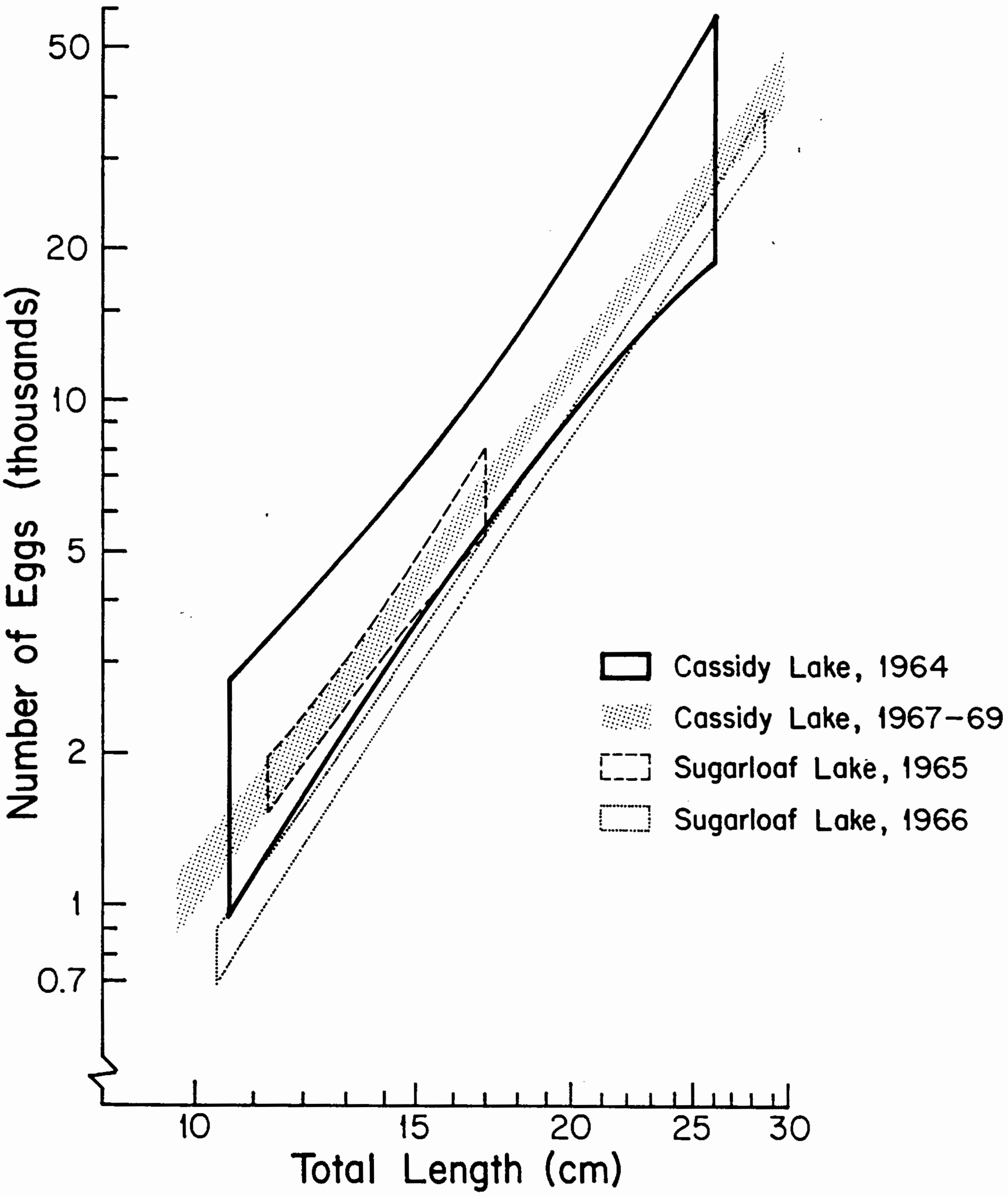

Figure 2. Confidence belts (95% level) of fecundity-length regressions for yellow perch from four collections.

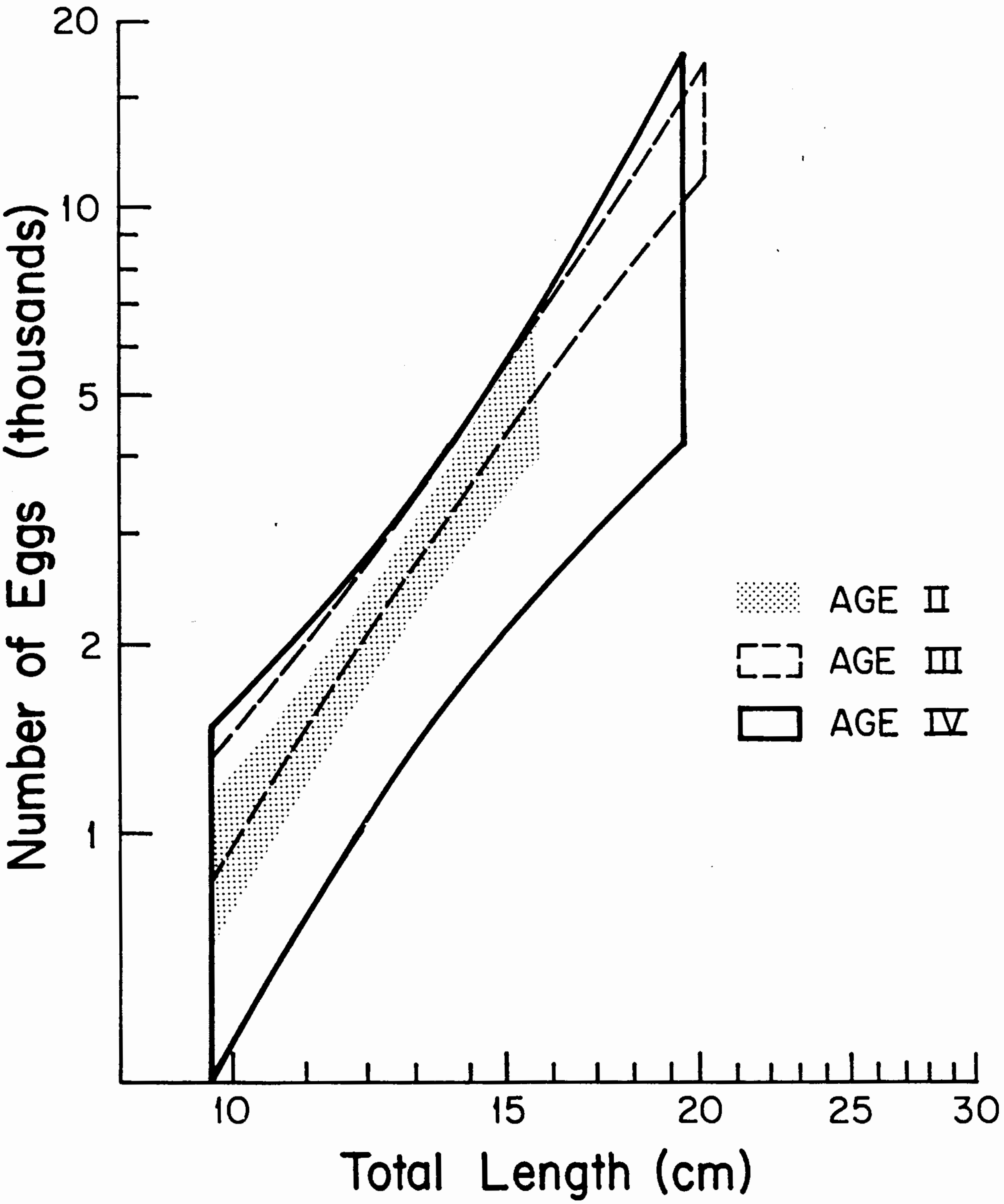

Figure 3. Confidence belts (95% level) of fecundity-length regressions for the 1965 year class of Cassidy Lake perch at ages II, III, and IV.

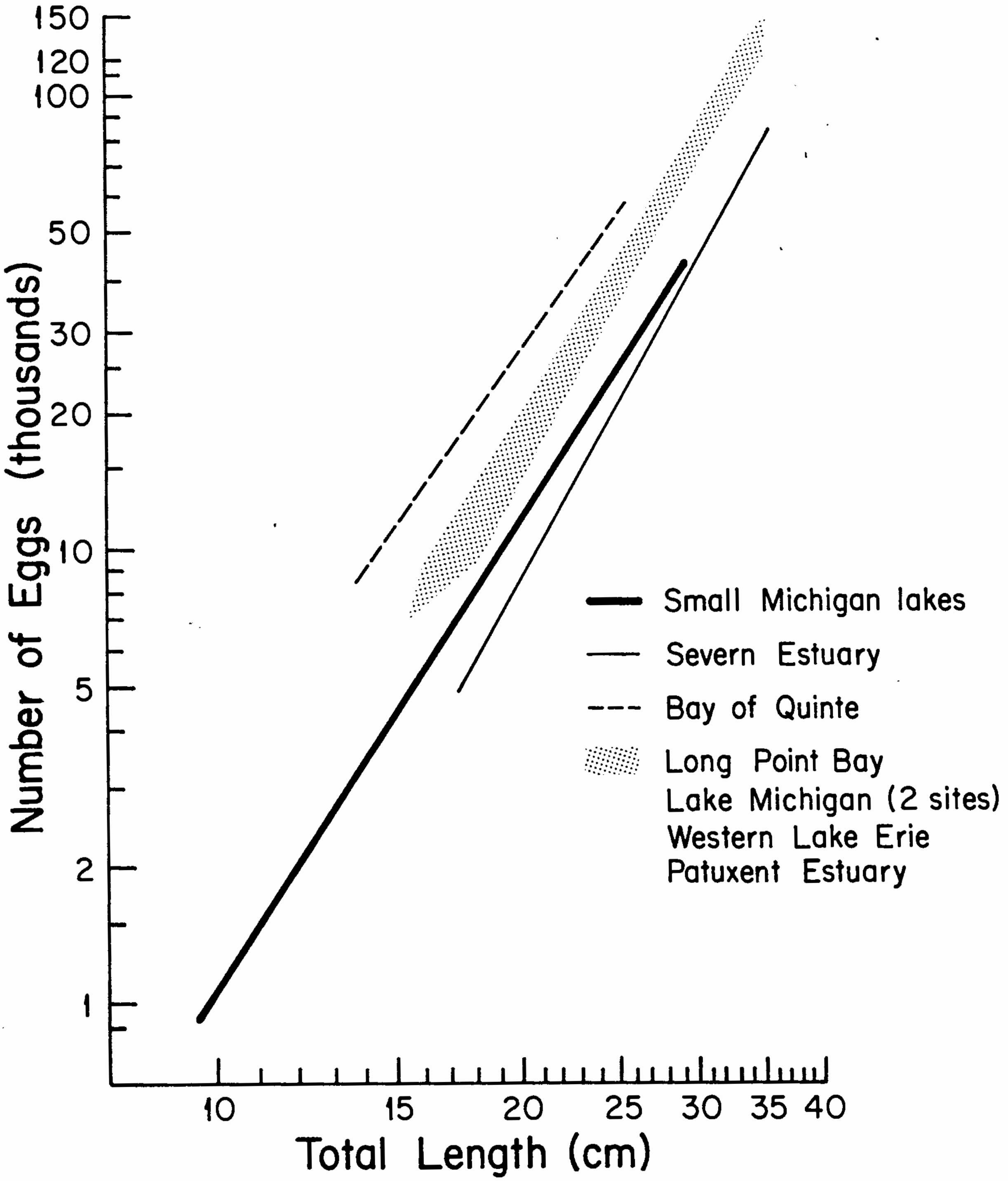

Figure 4. Fecundity-length regressions for yellow perch populations in small Michigan lakes (this study); the Severn River Estuary (Muncy 1962); Lake Ontario's Bay of Quinte (Sheri and Power 1979); and in the shaded area, for Lake Erie's Long Point Bay (Sztramko and Teleki 1977), Lake Michigan (Brazo et al. 1980, and Wells and Jorgenson 1983), western Lake Erie (Hartmann et al 1980), and the Patuxent River Estuary (Tsai and Gibson 1971). Fork lengths were converted to total lengths, as necessary, with a factor of 1.044.

Table 1. Yellow perch collections used for studies of fecundity and the coefficients determined for least-squares regressions: $\log_{10}$ (eggs) = $\log_{10}$ (a) + b $\log_{10}$ (length).

Collection				Regression coefficients		
Year	Lake	Number of fish	Size range (mm)	$\log_{10}a$	b	R^2
1964	Cassidy	7	107-261	-3.7276	3.4147	0.940
1967-69	Cassidy	50	97-297	-3.8301	3.4303	0.962
1965	Sugarloaf	5	114-170	-3.7067	3.3702	0.989
1966	Sugarloaf	24	104-287	-4.7204	3.7742	0.985
All	Both	86	97-297	-3.9131	3.4556	0.952

Table 2. Percent of yellow perch sexually mature in relation to length and age. (Number of perch examined in parentheses.)

Sex and length group (mm)	Age				
	1	2	3	4	5-8
Male					
20-49	0 (16)	--- ---	--- ---	--- ---	--- ---
50-79	55 (71)	92 (13)	--- ---	--- ---	--- ---
80-109	99 (93)	100 (71)	100 (65)	100 (1)	--- ---
110-139	100 (108)	100 (27)	100 (21)	100 (2)	--- ---
140-287	100 (14)	100 (51)	100 (89)	100 (26)	100 (47)
Female					
20-49	0 (17)	--- ---	--- ---	--- ---	--- ---
50-79	0 (66)	0 (16)	--- ---	--- ---	--- ---
80-109	1 (91)	36 (78)	38 (52)	--- ---	--- ---
110-139	9 (44)	39 (75)	76 (29)	100 (1)	--- ---
140-169	67 (3)	61 (31)	83 (60)	100 (2)	--- ---
170-199	85 (13)	100 (13)	100 (51)	94 (16)	100 (10)
200-229	---	100 (16)	100 (13)	100 (11)	100 (8)
230-300	--- ---	100 (19)	100 (10)	100 (10)	100 (16)

Table 3. Lengths (mm) of smallest mature and largest immature yellow perch in small Michigan lakes (this study) compared to the range in the literature.

	This study	Literature range
<u>Males</u>		
Smallest mature	61	105-160
Largest immature	106	135-220
<u>Females</u>		
Smallest mature	86	140-190
Largest immature	180	210-235

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Report approved by W. C. Latta

Typed by G. M. Zurek