in reduction of the sample size from 154 to 83 fish, providing the needed reduction in time needed for processing.

Treatment of Data

Models for the relationship of fecundity to total length were obtained by least squares linear regression using the Minitab (TM) computer software package. The models utilized mean lengths and estimated fecundities for fish in 10 mm length intervals (170-179, 180-189, etc.), transformed to base 10 logarithms. This procedure minimized bias due to unequal numbers in some intervals and provided more uniform weighting of data over the total length range. Confidence intervals were calculated at the 95% level for the slopes, intercepts, and predicted means of the various models.

Age Determination

Plastic impressions of scales were made using an Ann Arbor roller press. Scale images were projected by a tri-simplex microprojector with 40X magnification, and ages were determined using standard methods.

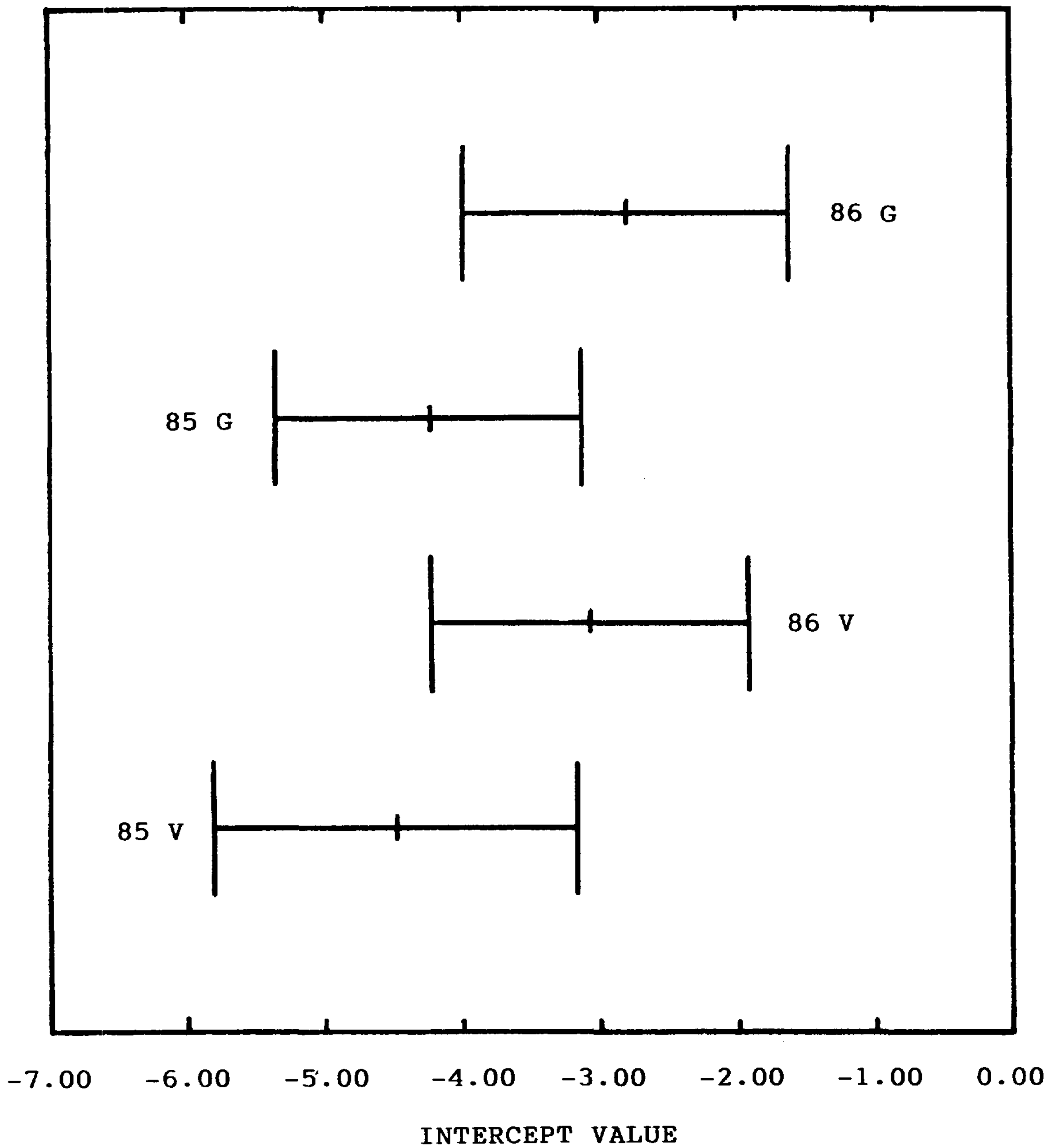
RESULTS AND DISCUSSION

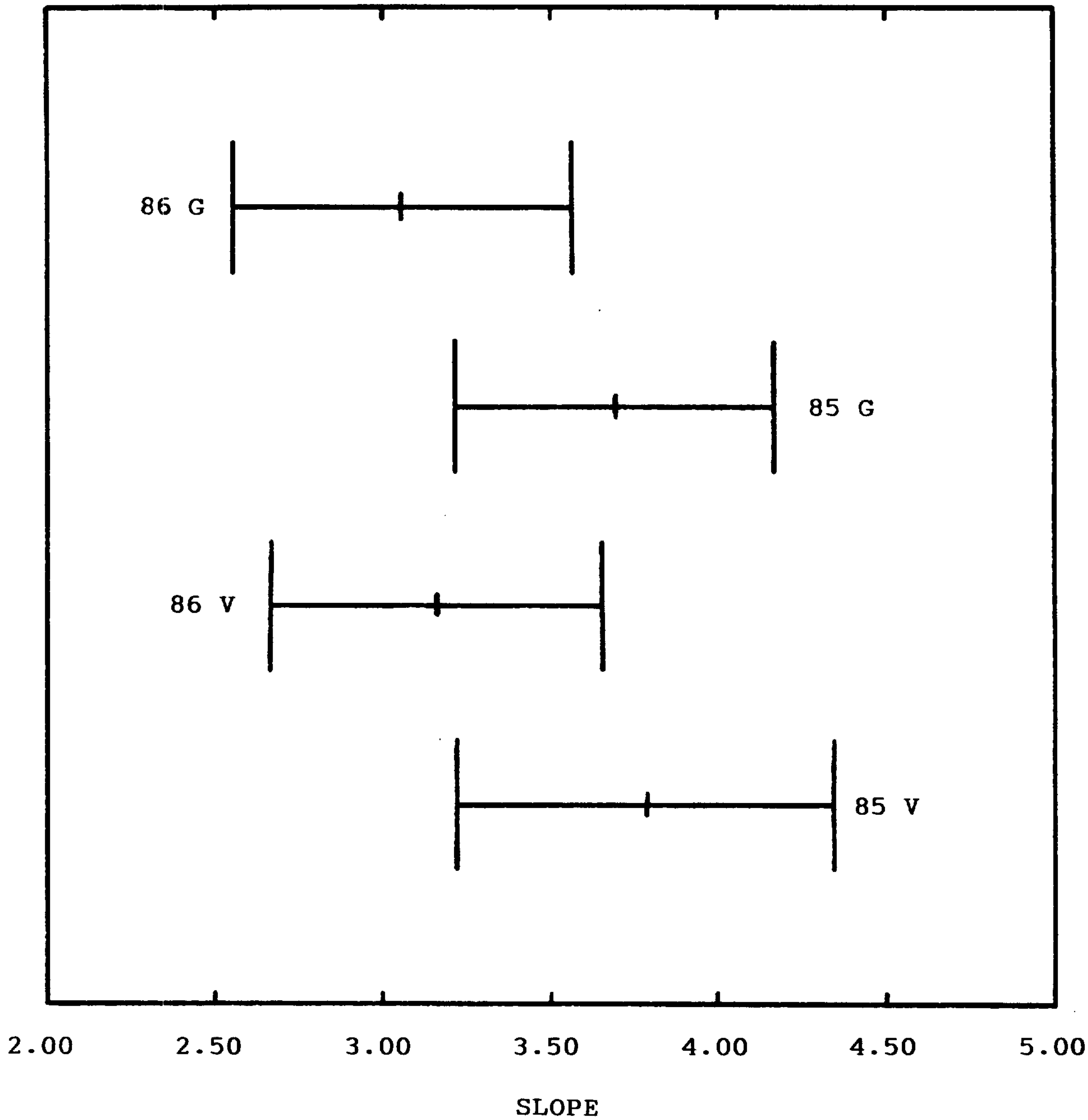
Regression models were individually developed for 1985 volumetric estimates, 1985 gravimetric estimates, 1986 volumetric estimates, and 1986 gravimetric estimates. Comparisons of the 95% confidence intervals of the slopes and intercepts of the four regression equations revealed overlap among all intercepts and slopes, respectively (Figures 3 and 4). The overlap was interpreted as evidence of no significant differences; there were no significant differences among the compared slopes or intercepts, allowing the conclusion that regression models were statistically similar.

Since there were no significant differences among the models within or between years, the 1985 and 1986 data were pooled for each method of estimation, and a regression model was formulated for each method. From this point on, all discussion of results refers to the combined 1985-86 data.

The length-frequency distribution of the 83 fish used in fecundity analysis shows that the distribution is skewed toward the smaller sizes (170-229 mm) (Figure 5). This illustrates why means of each 10 mm length class were used in fecundity analysis to achieve more equal weighting of data over the length range from 170 to 299 mm (see Methods).

A comparison was made between the mean lengths by age in the current study and the mean back-calculated lengths at annulus for a larger sample of the perch population in 1985 and 1986 (Gallinat 1987) (Table 2). Since the fish in the


86 G
85 G
86 V
85 V
-7.00
-6.00
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
INTERCEPT VALUE


86 G
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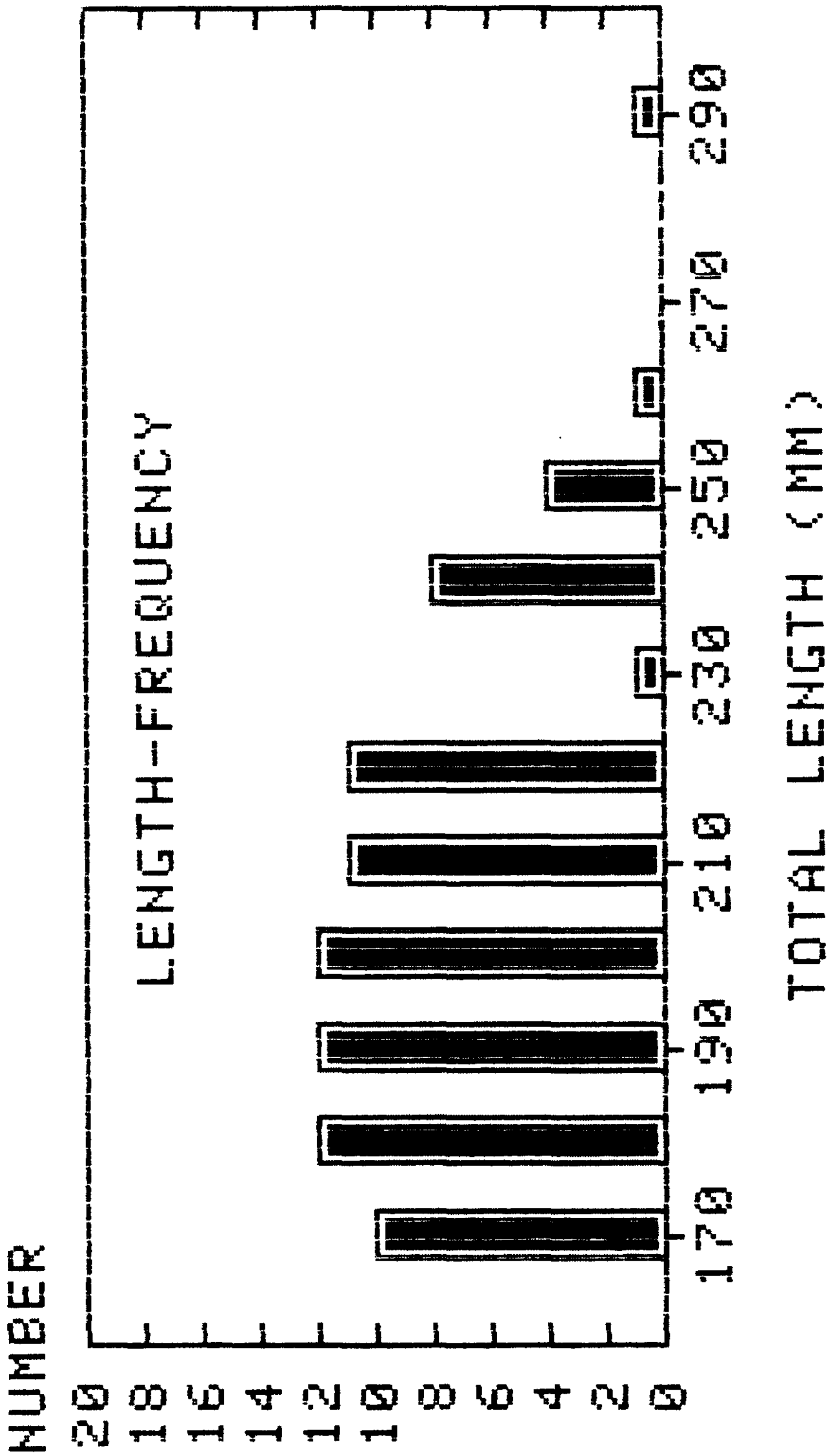
86 V
85 V
2.00
2.50
3.00
3.50
4.00
4.50
5.00
SLOPE



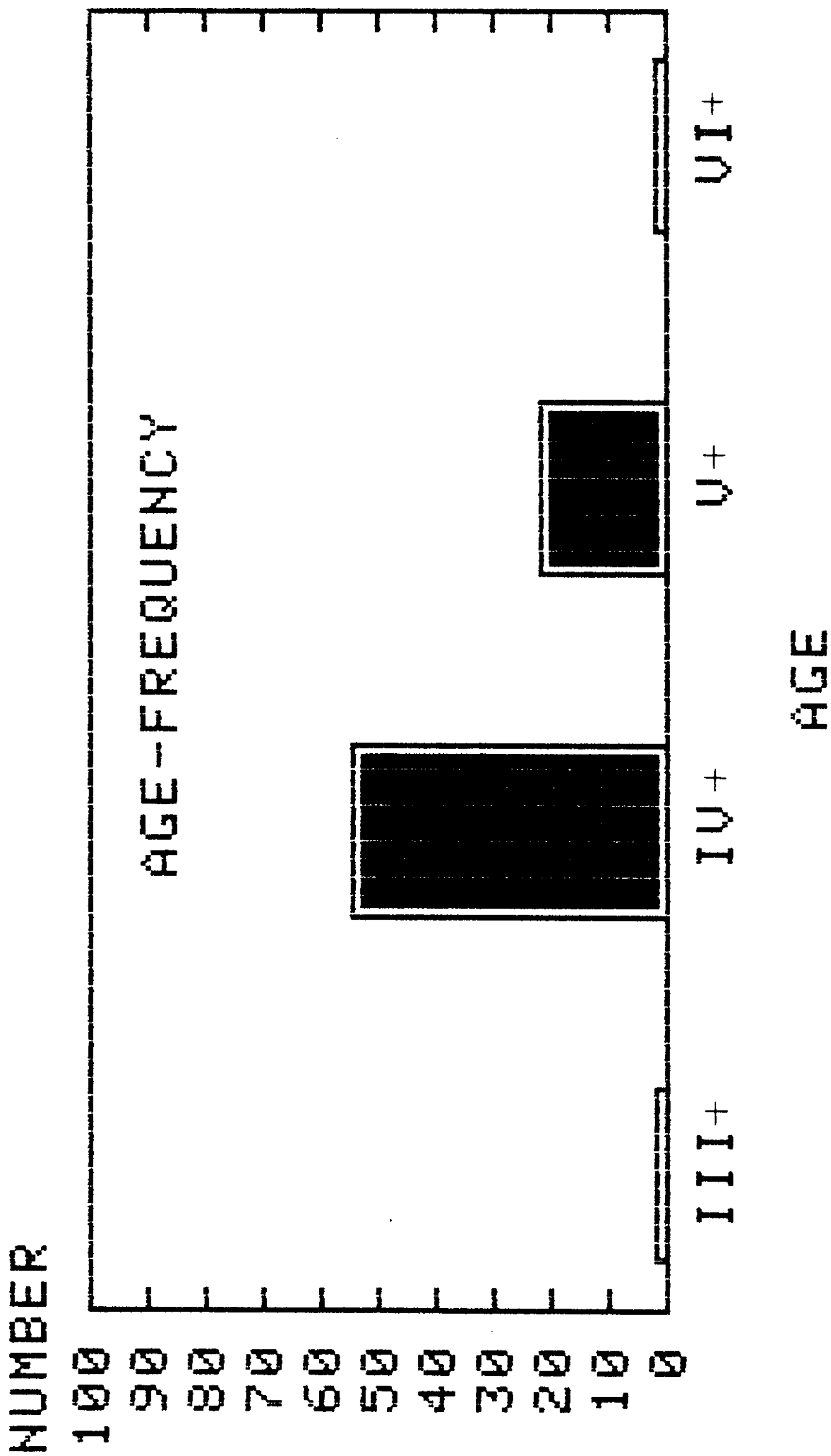
LENGTH-FREQUENCY
NUMBER
20 18 16 14 12 10 8 6 4 2 0
170 190 210 230 250 270 290
TOTAL LENGTH (MM)

Table 2. Mean lengths by age for the 83 fish used in fecundity analysis in the present study, compared to back-calculated lengths at annulus for Gallinat's (1987) large sample collected during the same time period as the present study (1985-86).

	Length in mm (n in parentheses)			
Source	III	IV	V	VI
Gallinat (1987)	154	192	230	270
	(158)	(118)	(44)	(6)
Present study	187	199	233	226
	(2)	(55)	(23)	(2)

present study were collected early in the growing season, their lengths approximated the length at annulus. The mean lengths of ages IV+ and V+ fish in the current study agree closely with the corresponding back-calculated lengths at annulus found by Gallinat (1987). A similar comparison of ages III+ and VI+ is not meaningful because each class contained only two fish used for fecundity analysis. In addition, there was obvious selection for only large III+ fish, since few fish were mature at this age (see Literature Review; Size at Maturity).

The age-frequency distribution for the fish used in fecundity analysis reveals the vast majority of the fish analyzed were age IV+ or V+ (Figure 6). Recall that Gallinat (1987) found in the same study area and time period as the present study, only 27% of the female yellow perch were mature at age III, but 86% were mature at age IV and 100% at age V (Figure 1). In addition, he showed that mortality was very high after age III. Thus, the first two year classes in which the majority of the females were mature correspond to the predominant year classes of the fish analyzed in the present study. The small number of age III+ fish in the sample is explained by the fact that very few females were mature at this age, and the small number of age VI+ fish may readily be explained by high mortality of older fish. The relatively small sample in the present study agrees closely with Gallinat's extensive data for the same population, implying that with regard to age,


AGE-FREQUENCY
NUMBER
100
90
80
70
60
50
40
30
20
10
0
III+
IV+
V+
VI+
AGE

the fecundity models were based on a representative sample of the female spawning population.

Regression Models

The fecundity model derived from the volumetric estimates of fecundity (Appendix 5) is:

$$\log F = -4.0396 + (3.5834)\log L \quad (r = 0.982),$$

where F = fecundity and L = total length. The corresponding fecundity model based on gravimetric estimates of fecundity (Appendix 6) is:

$$\log F = -3.8258 + (3.5097)\log L \quad (r = 0.986).$$

Basic similarity of the models is apparent and both have high correlation coefficients. The models with the data points (means for 10 mm length intervals) used in their calculation show the relationship graphically (Figure 7).

Error Analysis

It is important to determine which model more accurately describes the relationship of fecundity to length for the population. Evaluation of error analysis for volumetric and gravimetric estimates provides insight to the accuracy of the models (Table 3). For each of the three fish used in error analysis, the fecundity estimates were compared to the actual fecundity determined by the total egg count for the fish.

It is apparent that the volumetric method tended to underestimate slightly (-3.4%), while the gravimetric method tended to overestimate (+8.8%) (Table 3). Although the

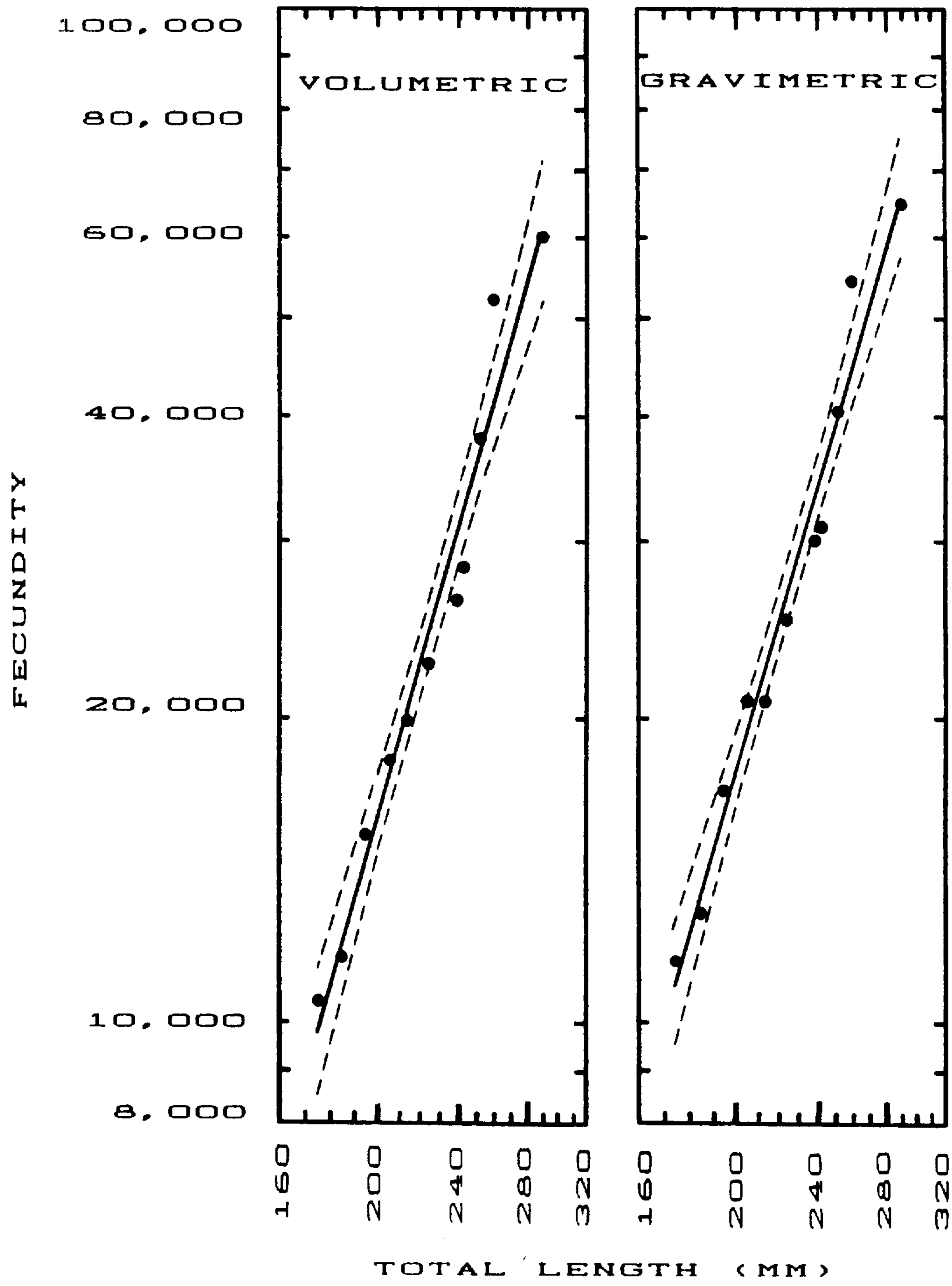

FECUNDITY
100,000
80,000
60,000
40,000
20,000
10,000
8,000
VOLUMETRIC
GRAVIMETRIC
160
200
240
280
320
160
200
240
280
320
TOTAL LENGTH (MM)

Table 3. Comparison of fecundity estimates to total egg counts. Deviations of the individual estimates from the actual counts appear in parentheses.

Fish I.D. Number	Length (mm)	Fecundity: Actual Count	Fecundity: Volumetric Estimate	Fecundity: Gravimetric Estimate
85-39	202	17 977	18 988 (+5.6%)	20 860 (+16.0%)
85-17	227	26 808	25 430 (-5.1%)	28 685 (+7.0%)
85-2	242	30 425	27 197 (-10.6%)	31 414 (+3.3%)
Mean Error (Standard Deviation)			-3.4% (8.2%)	+8.8% (6.5%)

gravimetric method was slightly less variable (SD 6.5%) than the volumetric method (SD 8.2%), the volumetric estimates were closer to the actual known number of eggs. The regression model based on volumetric estimates thus appears to more closely describe the actual population than the gravimetric model. The volumetric model was therefore utilized exclusively in all additional analyses presented.

Predictions From the Models

Fecundity models may be used to predict the number of eggs produced by a fish of a given length. In addition, if the mean length at a given age is known, the mean fecundity for that age class can be predicted. This information may in turn be used in estimates of population fecundity (Bagenal 1978).

Predicted fecundities and 95% confidence intervals for yellow perch within the length range of the present study were calculated from the volumetric model (Table 4). Equivalent predictions were also made for each age class in the present study (Table 5). The mean length for each age class was calculated from Gallinat's (1987) data for 1985-86. The prediction for age III+ is probably not meaningful, since the average fish in this age class would not be mature, as discussed earlier (see Figure 1).

Comparison to Previous Studies

The fecundity of Lake Michigan yellow perch has previously been reported by Brazo et al. (1975) for fish

Table 4. Fecundity predictions and 95% confidence intervals for yellow perch of the given lengths, calculated from the volumetric fecundity model, log F = -4.0396 + 3.5834 log L.

Length (mm)	Fecundity	
	Prediction	95% C. I.
180	11 010	9 630 - 12 600
190	13 370	11 950 - 14 960
200	16 070	14 620 - 17 660
210	19 140	17 620 - 20 780
220	22 610	20 940 - 24 410
230	26 510	24 520 - 28 660
240	30 880	28 360 - 33 620
250	35 740	32 460 - 39 360
260	41 140	36 860 - 45 910
270	47 090	41 580 - 53 330
280	53 650	46 660 - 61 690
290	60 840	52 100 - 71 060

Table 5. Fecundity predictions and 95% confidence intervals for yellow perch of the given ages, calculated from the volumetric fecundity model:
$\log F = -4.0396 + 3.5834 \log L$.

Age	Mean Length[1] (mm)	Fecundity: Prediction	Fecundity: 95% C. I.
III+	154	6 300	5 130 - 7 730
IV+	192	13 880	12 450 - 15 470
V+	230	26 510	24 520 - 28 660
VI+	270	47 100	41 580 - 53 330

[1] The mean length for each age class was calculated from Gallinat's (1987) data for 1985-86.

190-354 mm total length collected near Ludington, Michigan in 1972, and by Wells and Jorgenson (1983) for 174-355 mm fish collected at Saugatuck, Michigan in 1972 and 1979. The regression models of fecundity versus total length obtained in these studies are:

Brazo et al. (1975):

$$\log F = -3.712 + (3.451)\log L \quad \text{(no r value given)}$$

Wells and Jorgenson (1983):

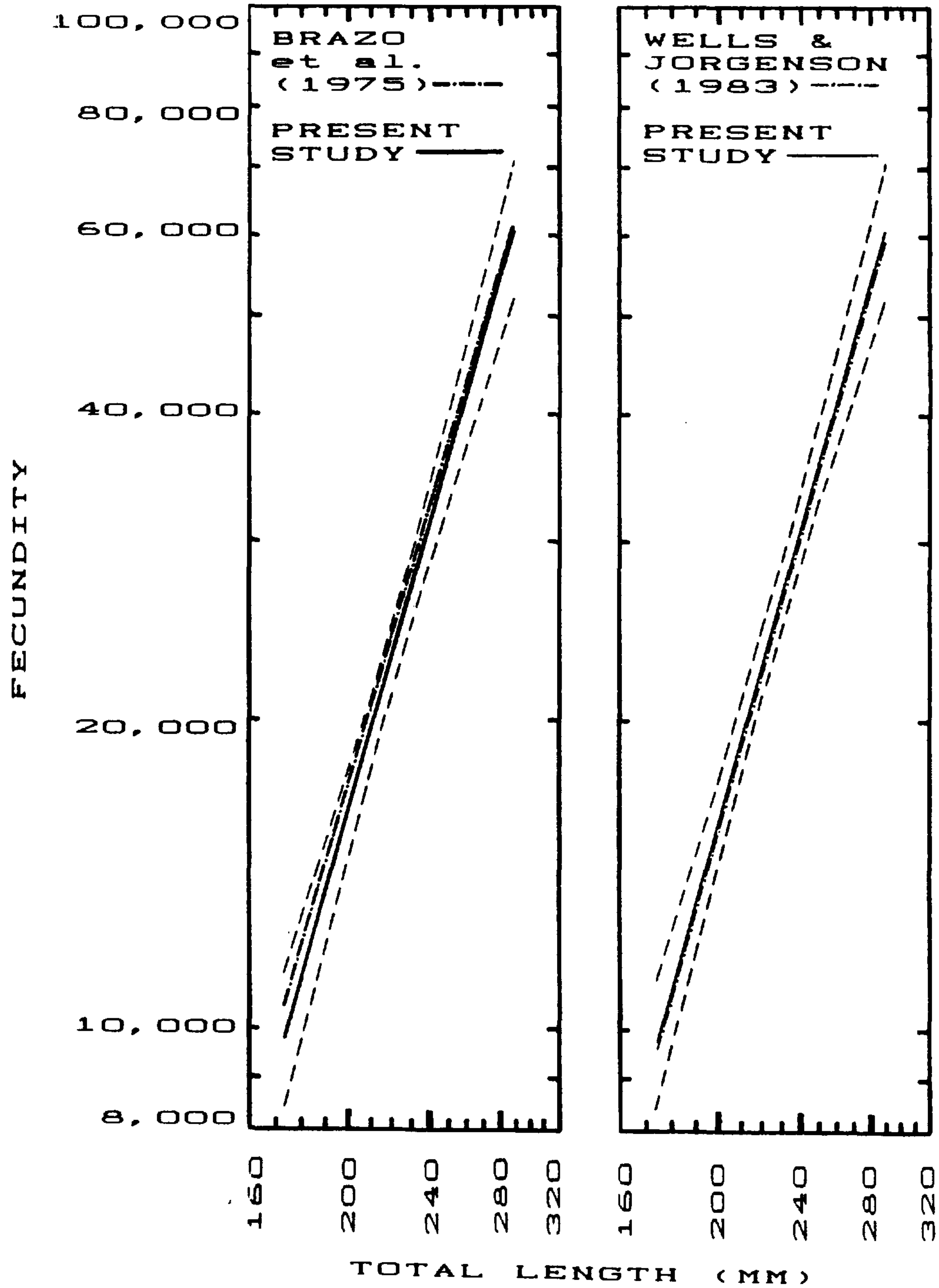
$$\log F = -3.99 + (3.56)\log L \quad (r = 0.96).$$

Recall that the model best describing the population in the present study (i. e., the volumetric model) is

$$\log F = -4.0396 + (3.5834)\log L \quad (r = 0.982).$$

When the previously reported models are plotted on the same axes as the present model based on volumetric estimates (confined to the length range of the present study) they fall within the 95% confidence contour of the present model (Figure 8). In fact, the model of Wells and Jorgenson is virtually identical to and superimposed on the current model. This indicates that over the length range compared, the fecundity-length relation determined in the present study does not significantly differ from those reported previously for Lake Michigan yellow perch by Brazo et al. (1975) and Wells and Jorgenson (1983).

It should be noted that the earlier studies (and the populations in general) included larger fish than the present study. Although it has been stressed that it is important to limit comparisons of regression equations to those generated from fish of the same size, this caution


BRAZO
et al.
(1975)
PRESENT
STUDY
WELLS &
JORGENSON
(1983)
PRESENT
STUDY
100,000
80,000
60,000
40,000
20,000
10,000
8,000
FECUNDITY
160
200
240
280
320
TOTAL LENGTH (MM)

seems to be relevant only to claims of <u>significant</u> differences. The fact that over the length range of the present study, the previously reported regression equations fall within the 95% confidence contour of the present model, is, if anything, even stronger support for a lack of significant differences than if comparisons were made among equations generated from fish of the same size.

In addition to Brazo et al. (1975) and Wells and Jorgenson (1983), regression models of fecundity versus length of yellow perch have been reported by Muncy (1962), Sheri and Power (1969), Tsai and Gibson (1971), Sztramko and Teleki (1977), and Hartman et al. (1980), for various geographic locations. Unfortunately, the fecundity predictions of the present study are only directly comparable to those of Muncy (1962; Severn River, Maryland) and Hartman et al. (1980; Lake Erie), because the regressions in the other studies utilized fork lengths instead of total lengths.[1]

Predicted fecundities over the length range of the present study were calculated from the regression models of Muncy (1962) and Hartman et al. (1980) (Table 6). These values may be compared to the equivalent 95% confidence intervals for the present study (Table 4). It is apparent that while there are no significant differences between the Lake Erie study of Hartman et al. (1980) and the present study, in Muncy's Severn River study the predicted fecundity

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1. No standard conversion factor for yellow perch fork length to total length was found.

Table 6. Predicted yellow perch fecundities over the length range of the present study, calculated from the regression models of Muncy (1962) and Hartman et al. (1980).

	Fecundity	
Total Length (mm)	Muncy (1962)	Hartman et al. (1980)
180	5 500	11 600
190	6 800	14 100
200	8 400	17 000
210	10 300	20 300
220	12 400	24 100
230	14 800	28 300
240	16 900	33 000
250	20 000	38 300
260	23 400	44 200
270	27 300	50 600
280	31 700	57 800
290	36 500	65 600

is below the lower confidence limit of the present study over the entire length range compared. It is not clear, however, whether this represents a true difference, because Muncy's data include some fecundity estimates from eggs which were stripped from live fish, possibly resulting in inaccurately low predicted fecundities.

The discovery that the fecundity of a given size yellow perch has not significantly changed in southern Lake Michigan since 1972 is somewhat surprising. As noted earlier, growth rates and length-weight relationships have declined dramatically in Indiana waters in recent years, apparently due to the current high population density (Gallinat 1987). Since fecundity is generally considered to be highly responsive to density-dependent factors and related influences such as food supply (see Literature Review), it was expected that fecundity would have decreased with increasing fish density. The apparent contradiction between decreased growth rates and constant fecundity suggests that some sort of threshold of density and/or food supply conceivably could be involved in influencing fecundity of yellow perch in southern Lake Michigan. If this were the case, a moderate increase in density and/or decrease in food supply might cause reduced growth rates without significantly affecting fecundity. Assuming that density and/or food supply in the study area have not crossed the hypothetical critical threshold, the hypothesis just proposed would explain why fecundity of yellow perch in southern Lake Michigan has not significantly changed since

1972 despite decreased growth rates.

Although the fecundity of a given size fish has apparently not changed with the increased density and reduced growth of yellow perch in the sample area, it is possible that the population fecundity has been altered due to a shift in the length-frequency distribution toward smaller fish. Subsequent research may provide insight as to whether or not this has indeed occurred.

SUMMARY AND CONCLUSIONS

Volumetric and gravimetric methods of fecundity determination were conducted on 83 yellow perch (ranging in total length from 172 to 290 mm) collected from Lake Michigan near Michigan City, Indiana in 1985 and 1986. Major findings of the project are as follows:

1. Linear regression models for fecundity versus total length developed separately for 1985 and 1986 samples were not significantly different from each other, based on overlap of the 95% confidence intervals of the slopes and intercepts of the equations. The 1985 and 1986 data were therefore pooled for each method of analysis.
2. The model for fecundity versus total length derived from the volumetric fecundity estimates was: $\log F = -4.0396 + (3.5834)\log L$ ($r = 0.982$). The corresponding model derived from the gravimetric fecundity estimates was: $\log F = -3.8258 + (3.5097)\log L$ ($r = 0.986$).
3. The volumetric estimates were determined to be more accurate than the gravimetric estimates by comparison to total egg counts of three ovaries. The volumetric model was therefore used for all subsequent analyses.
4. Predictions were made for the fecundities of yellow perch at 10 mm length intervals over the length range of the present study, utilizing the volumetric model. Mean lengths of the age classes represented were used to predict the mean fecundity of each age class.

5. The fecundity of a yellow perch of a given length from 172-290 mm has not changed significantly in southern Lake Michigan since 1972, despite the fact that population density has increased and growth rates have decreased. This was determined by comparing previously reported regression equations with the 95% confidence contour of the present equation.

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APPENDIX SECTION

Appendix 1. Maximum total length, body weight, fresh ovary weight, and fresh ovary volume of female yellow perch collected in Indiana waters of Lake Michigan on May 8, 1985. Ages are also given for selected fish.

I.D. Number	Length (mm)	Age	Body Weight (g)	Ovary Weight (g)	Ovary Volume (mL)
85-1	190	IV+	80	13.3	13.0
85-2	242	V+	170	32.2	35.0
85-3	205		96	5.8	5.5
85-4	198	IV+	94	10.0	10.0
85-5	193	IV+	83	10.5	10.0
85-6	205	IV+	100	8.7	8.5
85-7	178	III+	68	10.7	11.0
85-8	245	V+	184	33.9	33.0
85-9	222	IV+	116	9.5	9.0
85-10	203		100	14.1	14.0
85-11	188		74	4.3	4.0
85-12	208		88	7.6	7.0
85-13	195	III+	82	12.7	12.5
85-14	200		96	16.2	16.0
85-15	290	V+	334	75.8	73.0
85-16	220	V+	126	20.0	19.0
85-17	227	V+	146	24.3	23.0
85-18	187	IV+	72	9.0	8.5
85-19	260	V+	244	48.5	47.0
85-20	216	IV+	124	22.5	22.0
85-21	214		110	7.9	7.5
85-22	186	IV+	68	6.8	6.5
85-23	194		86	13.6	13.5
85-24	197	IV+	86	13.4	13.0
85-25	204	IV+	96	11.8	11.5
85-26	184	IV+	74	9.3	9.0
85-27	178	IV+	66	8.8	9.0
85-28	198		86	10.0	9.5
85-29	184	IV+	72	12.2	12.0
85-30	201		92	11.2	11.0
85-31	202		98	13.7	13.0
85-32	189	IV+	74	10.3	10.0
85-33	208	V+	110	16.2	15.5
85-34	190		70	11.5	11.0
85-35	193	V+	83	8.1	8.0
85-36	200		90	8.7	8.0
85-37	181	IV+	74	9.2	9.0
85-38	201		92	11.5	11.5
85-39	202	IV+	96	15.6	15.0
85-40	204	IV+	98	10.4	10.0
85-41	200		90	9.7	9.5
85-42	206		100	7.6	7.0

Appendix 1 continued.

I.D. Number	Length (mm)	Age	Body Weight (g)	Ovary Weight (g)	Ovary Volume (mL)
85-43	196		76	7.2	7.0
85-44	206		84	7.8	7.0

Appendix 2. Date of capture, maximum total length, body weight, and fresh ovary weight of female yellow perch collected in Indiana waters of Lake Michigan in 1986. Ages are also given for selected fish.

I.D. Number	Date (mo./day)	Length (mm)	Age	Body Weight (g)	Ovary Weight (g)
86-1	5/8	181		65	9.6
86-2	5/8	203		86	15.0
86-3	5/8	176	IV+	71	12.8
86-4	5/8	220	IV+	120	17.6
86-5	5/8	203	IV+	92	14.3
86-6	5/8	190	IV+	79	11.8
86-7	5/8	202		97	19.0
86-8	5/8	205		100	15.5
86-9	5/8	228	V+	142	18.8
86-10	5/8	197		88	13.3
86-11	5/8	180		64	10.6
86-12	5/8	218	V+	122	21.4
86-13	5/8	188		79	15.6
86-14	5/8	229	IV+	102	15.3
86-15	5/8	172	IV+	60	8.8
86-16	5/8	207		104	22.4
86-17	5/8	204		95	15.5
86-18	5/8	192	V+	80	13.0
86-19	5/8	216	IV+	108	20.5
86-20	5/8	211	IV+	95	14.9
86-21	5/8	211	IV+	101	12.1
86-22	5/8	211	VI+	113	22.9
86-23	5/8	212	IV+	106	14.5
86-24	5/8	193		83	14.5
86-25	5/8	183		69	12.0
86-26	5/8	180	IV+	67	12.5
86-27	5/8	250	V+	194	38.7
86-28	5/8	199	IV+	86	13.5
86-29	5/8	202		99	13.4
86-30	5/8	196	IV+	91	14.6
86-31	5/8	198	V+	81	13.3
86-32	5/8	202		93	14.9
86-33	5/8	209		98	12.5
86-34	5/8	240	VI+	151	25.1
86-35	5/8	181		70	12.5
86-36	5/8	197		91	15.1
86-37	5/8	191		74	12.6
86-38	5/8	208	IV+	107	19.1
86-39	5/8	185	IV+	69	11.9
86-40	5/8	176	IV+	69	11.0
86-41	5/8	190		80	13.2
86-42	5/8	174	IV+	66	9.9

Appendix 2 continued.

I.D. Number	Date (mo./day)	Length (mm)	Age	Body Weight (g)	Ovary Weight (g)
86-43	5/8	191		77	6.8
86-44	5/8	192		85	12.8
86-45	5/8	186		77	13.0
86-46	5/8	209	IV+	99	14.3
86-47	5/8	205		103	17.1
86-48	5/8	180	IV+	70	10.7
86-49	5/8	175	IV+	55	7.3
86-50	5/27	173		52	10.7
86-51	5/27	189	IV+	65	13.8
86-52	5/27	242	V+	202	55.3
86-53	5/27	239	V+	163	31.4
86-54	5/27	184		67	11.7
86-55	5/27	245	V+	191	32.2
86-56	5/27	283		254	40.5
86-57	5/27	301		363	89.7
86-58	5/27	244	V+	191	32.8
86-59	5/27	240	IV+	176	29.5
86-60	5/27	223	IV+	139	28.0
86-61	5/27	242	V+	151	21.4
86-62	5/27	182	IV+	60	9.6
86-63	5/27	250	V+	198	41.4
86-64	5/27	208		103	18.4
86-65	5/27	225	V+	124	22.7
86-66	5/27	185		73	9.9
86-67	5/27	186		75	16.1
86-68	5/27	224	IV+	143	26.3
86-69	5/27	202		84	19.0
86-70	5/27	201		96	21.0
86-71	5/27	201		109	22.8
86-72	5/27	202		101	18.2
86-73	5/27	205		104	18.3
86-74	5/27	223	IV+	134	20.8
86-75	5/27	205		106	16.8
86-76	5/27	198		93	18.2
86-77	5/27	205		101	18.6
86-78	5/27	185		78	14.4
86-79	5/27	187		81	18.7
86-80	5/27	199		100	16.6
86-81	5/27	180		69	10.4
86-82	5/27	207		105	19.8
86-83	5/27	207		109	16.5
86-84	5/27	189		80	14.1
86-85	5/27	187	IV+	76	11.2
86-86	5/27	186		74	14.5
86-87	5/27	200	V+	99	20.0
86-88	5/27	210	IV+	112	19.8

Appendix 2 continued.

I.D. Number	Date (mo./day)	Length (mm)	Age	Body Weight (g)	Ovary Weight (g)
86-89	5/27	219	IV+	108	17.8
86-90	5/27	228	IV+	161	31.3
86-91	5/27	209	IV+	107	21.7
86-92	5/27	208	IV+	100	15.7
86-93	5/27	174	IV+	62	10.3
86-94	5/27	202	IV+	92	16.7
86-95	5/27	194		93	16.0
86-96	5/27	191		88	14.8
86-97	5/27	200		89	11.4
86-98	5/27	189		87	14.7
86-99	5/27	172	IV+	63	9.3
86-100	5/27	211	IV+	106	20.9
86-101	5/27	216	IV+	124	21.0
86-102	5/27	189		81	12.9
86-103	5/27	253	V+	221	50.2
86-104	5/27	192		76	7.6
86-105	5/27	193		76	10.3
86-106	5/27	187		71	10.7
86-107	5/27	191	IV+	84	12.5
86-108	5/27	182		72	11.4
86-109	5/27	205		101	19.1
86-110	6/4	255	V+	219	43.0

Appendix 3. Data used in volumetric fecundity estimation.

Fish I.D. Number	Total Ovary Volume (mL)	Egg Counts of Subsamples		
		Sample a	Sample b	Sample c
85-1	4.65	317	323	333
85-2	9.95	265	274	281
85-4	3.53	384	435	421
85-5	3.81	393	415	435
85-6	2.95	462	516	483
85-7	3.62	308	313	321
85-8	10.80	313	335	325
85-9	4.40	535	529	549
85-13	4.00	352	371	384
85-15	22.17	255	286	274
85-16	6.50	396	408	417
85-17	7.15	344	365	358
85-18	2.33	338	362	363
85-19	16.52	309	316	325
85-20	7.29	346	338	346
85-22	1.93	499	513	503
85-24	4.50	359	352	373
85-25	3.72	464	474	451
85-26	3.24	424	433	420
85-27	2.95	327	315	346
85-29	3.81	331	315	330
85-32	3.38	324	330	329
85-33	5.15	457	458	477
85-35	2.64	549	576	592
85-37	2.90	383	398	404
85-39	4.70	399	418	395
85-40	3.72	464	460	481
86-3	4.30	343	340	342
86-4	5.55	330	333	341
86-5	4.30	440	435	449
86-6	4.35	509	518	522
86-9	7.29	372	381	385
86-12	7.24	265	273	268
86-14	5.55	376	378	371
86-15	2.85	303	305	315
86-18	4.55	254	258	258
86-19	7.44	289	276	283
86-20	5.70	361	355	350
86-21	3.91	300	310	299
86-22	8.18	385	389	394
86-23	4.65	310	304	321
86-26	4.00	298	301	298
86-27	14.76	264	261	274
86-28	4.65	265	266	268
86-30	5.40	293	303	286
86-31	4.90	376	401	390

Appendix 3 continued.

Fish I.D. Number	Total Ovary Volume (mL)	Egg Counts of Subsamples		
		Sample a	Sample b	Sample c
86-34	8.08	322	347	333
86-38	6.90	266	272	292
86-39	4.00	343	335	337
86-40	3.38	314	315	319
86-42	3.24	356	349	361
86-46	4.40	282	277	303
86-48	3.53	335	332	326
86-49	2.03	404	401	387
86-50	2.44	347	358	348
86-51	4.40	379	370	375
86-52	20.33	166	175	169
86-53	10.85	235	252	235
86-55	12.90	242	235	246
86-58	12.70	245	254	258
86-59	10.90	209	195	203
86-60	9.37	257	252	270
86-61	7.34	235	225	232
86-62	2.90	260	253	253
86-63	16.06	254	256	258
86-65	7.24	190	205	201
86-68	9.27	231	216	242
86-74	7.93	289	310	315
86-85	3.62	329	320	322
86-87	6.20	330	341	341
86-88	6.30	254	245	247
86-89	5.75	344	363	344
86-90	10.24	222	220	220
86-91	6.90	288	303	302
86-92	5.10	391	394	395
86-93	3.24	279	246	268
86-94	4.65	293	296	296
86-99	3.24	396	414	403
86-100	5.25	250	256	255
86-101	7.73	328	320	330
86-103	15.85	253	260	241
86-107	3.67	310	306	297
86-110	14.36	229	219	220

Appendix 4. Data used in gravimetric fecundity estimation. The egg counts of the subsamples were the same for each fish as those given in Appendix 3.

Fish I.D. Number	Total Dry Ovary Weight (g)	Dry Weights of Subsamples (g)		
		Sample a	Sample b	Sample c
85-1	1.5627	0.0295	0.0307	0.0312
85-2	3.6013	0.0305	0.0317	0.0318
85-4	1.0755	0.0266	0.0286	0.0283
85-5	1.3500	0.0296	0.0300	0.0305
85-6	0.9228	0.0282	0.0295	0.0281
85-7	1.2547	0.0316	0.0304	0.0307
85-8	3.6217	0.0300	0.0315	0.0309
85-9	1.2824	0.0282	0.0274	0.0281
85-13	1.3870	0.0295	0.0298	0.0312
85-15	7.0287	0.0284	0.0300	0.0294
85-16	2.0181	0.0282	0.0284	0.0285
85-17	2.5811	0.0312	0.0327	0.0321
85-18	0.7492	0.0285	0.0278	0.0283
85-19	5.2615	0.0298	0.0304	0.0314
85-20	2.3571	0.0306	0.0295	0.0299
85-22	0.6571	0.0300	0.0317	0.0310
85-24	1.5426	0.0309	0.0310	0.0324
85-25	1.2669	0.0322	0.0319	0.0308
85-26	1.0611	0.0298	0.0298	0.0290
85-27	1.0342	0.0315	0.0301	0.0324
85-29	1.3344	0.0320	0.0298	0.0281
85-32	1.0915	0.0302	0.0301	0.0302
85-33	1.7391	0.0306	0.0307	0.0312
85-35	0.8685	0.0297	0.0306	0.0306
85-37	1.0158	0.0313	0.0320	0.0327
85-39	1.5159	0.0297	0.0302	0.0282
85-40	1.2514	0.0298	0.0295	0.0309
86-3	1.4738	0.0320	0.0316	0.0326
86-4	1.6799	0.0281	0.0281	0.0291
86-5	1.4504	0.0312	0.0314	0.0317
86-6	1.3959	0.0290	0.0288	0.0285
86-9	2.4125	0.0293	0.0297	0.0303
86-12	2.2088	0.0283	0.0290	0.0288
86-14	1.9906	0.0329	0.0329	0.0317
86-15	0.9680	0.0301	0.0301	0.0308
86-18	1.3702	0.0274	0.0285	0.0285
86-19	2.1532	0.0269	0.0269	0.0272
86-20	1.7216	0.0304	0.0297	0.0294
86-21	1.3898	0.0319	0.0323	0.0316
86-22	2.7083	0.0307	0.0306	0.0316
86-23	1.5556	0.0299	0.0308	0.0317
86-26	1.2851	0.0288	0.0286	0.0283
86-27	4.7444	0.0307	0.0304	0.0318

Appendix 4 continued.

Fish I.D. Number	Total Dry Ovary Weight (g)	Dry Weights of Subsamples (g)		
		Sample a	Sample b	Sample c
86-28	1.6137	0.0307	0.0304	0.0305
86-30	1.7968	0.0302	0.0312	0.0290
86-31	1.6224	0.0303	0.0316	0.0307
86-34	2.6649	0.0285	0.0294	0.0292
86-39	1.3212	0.0303	0.0296	0.0296
86-40	1.0642	0.0272	0.0276	0.0273
86-42	1.0485	0.0302	0.0295	0.0301
86-48	1.1448	0.0300	0.0312	0.0304
86-49	0.6912	0.0311	0.0307	0.0300
86-50	0.6680	0.0260	0.0252	0.0251
86-51	1.2961	0.0277	0.0272	0.0264
86-52	5.0308	0.0224	0.0237	0.0225
86-53	3.2729	0.0253	0.0270	0.0262
86-55	3.5211	0.0242	0.0240	0.0243
86-58	3.7196	0.0268	0.0284	0.0283
86-59	3.2905	0.0284	0.0256	0.0268
86-60	2.8967	0.0285	0.0280	0.0292
86-61	2.2868	0.0291	0.0286	0.0286
86-62	0.8488	0.0267	0.0266	0.0256
86-63	4.2037	0.0237	0.0245	0.0245
86-65	2.1033	0.0249	0.0257	0.0259
86-68	2.8450	0.0263	0.0262	0.0273
86-74	2.4860	0.0279	0.0292	0.0290
86-85	1.1462	0.0294	0.0283	0.0276
86-87	2.0159	0.0294	0.0301	0.0301
86-88	2.1122	0.0307	0.0299	0.0299
86-89	1.8504	0.0286	0.0302	0.0301
86-90	3.0734	0.0253	0.0245	0.0247
86-91	2.1863	0.0289	0.0291	0.0296
86-92	1.6969	0.0308	0.0302	0.0306
86-93	0.9892	0.0294	0.0275	0.0290
86-99	1.0312	0.0283	0.0285	0.0285
86-100	1.7264	0.0298	0.0303	0.0299
86-103	4.7182	0.0282	0.0293	0.0280
86-107	1.2032	0.0304	0.0299	0.0298
86-110	4.0100	0.0257	0.0249	0.0249

Appendix 5. Volumetric fecundity data: estimates of total fecundity using individual subsamples, calculated from F = nV (see Methods and Materials); means of the individual estimates; and standard deviations (SD) of the individual estimates.

Fish I.D. Number	Fecundity Estimate Sample a	Sample b	Sample c	Mean	SD
85-1	14 741	15 020	15 485	15 082	376
85-2	26 368	27 263	27 960	27 197	798
85-4	13 555	15 356	14 861	14 591	930
85-5	14 973	15 812	16 574	15 786	800
85-6	13 629	15 222	14 249	14 367	803
85-7	11 150	11 331	11 620	11 367	237
85-8	33 804	36 180	35 100	35 028	1190
85-9	23 540	23 276	24 156	23 657	452
85-13	14 080	14 840	15 360	14 760	644
85-15	56 534	63 406	60 746	60 229	3465
85-16	25 740	26 520	27 105	26 455	685
85-17	24 596	26 098	25 597	25 430	765
85-18	7 875	8 435	8 458	8 256	330
85-19	51 047	52 203	53 690	52 313	1325
85-20	25 223	24 640	25 223	25 029	337
85-22	9 631	9 901	9 708	9 747	139
85-24	16 155	15 840	16 785	16 260	481
85-25	17 261	17 633	16 777	17 224	429
85-26	13 738	14 029	13 608	13 792	216
85-27	9 647	9 293	10 207	9 715	461
85-29	12 611	12 002	12 573	12 395	341
85-32	10 951	11 154	11 120	11 075	109
85-33	23 536	23 587	24 566	23 896	580
85-35	14 494	15 206	15 629	15 110	574
85-37	11 107	11 542	11 716	11 455	314
85-39	18 753	19 646	18 565	18 988	578
85-40	17 261	17 112	17 893	17 422	415
86-3	14 749	14 620	14 706	14 692	66
86-4	18 315	18 482	18 926	18 574	316
86-5	18 920	18 705	19 307	18 977	305
86-6	22 142	22 533	22 707	22 461	290
86-9	27 119	27 775	28 067	27 653	485
86-12	19 186	19 765	19 403	19 452	293
86-14	20 868	20 979	20 591	20 813	200
86-15	8 636	8 693	8 978	8 769	183
86-18	11 557	11 739	11 739	11 678	105
86-19	21 502	20 534	21 055	21 030	484
86-20	20 577	20 235	19 950	20 254	314
86-21	11 730	12 121	11 691	11 847	238
86-22	31 493	31 820	32 229	31 848	369
86-23	14 415	14 136	14 927	14 493	401

Appendix 5 continued.

Fish I.D. Number	Fecundity Estimate Sample a	Sample b	Sample c	Mean	SD
86-26	11 920	12 040	11 920	11 960	69
86-27	38 966	38 524	40 442	39 311	1005
86-28	12 323	12 369	12 462	12 385	71
86-30	15 822	16 362	15 444	15 876	461
86-31	18 424	19 649	19 110	19 061	614
86-34	26 018	28 038	26 906	26 987	1012
86-38	18 354	18 768	20 148	19 090	939
86-39	13 720	13 400	13 480	13 533	167
86-40	10 613	10 647	10 782	10 681	89
86-42	11 534	11 308	11 696	11 513	195
86-46	12 408	12 188	13 332	12 643	607
86-48	11 826	11 720	11 508	11 684	162
86-49	8 201	8 140	7 856	8 066	184
86-50	8 467	8 735	8 491	8 564	148
86-51	16 676	16 280	16 500	16 485	198
86-52	33 748	35 578	34 358	34 561	932
86-53	25 498	27 342	25 498	26 112	1065
86-55	31 218	30 315	31 734	31 089	718
86-58	31 115	32 258	32 766	32 046	846
86-59	22 781	21 255	22 127	22 054	766
86-60	24 081	23 612	25 299	24 331	871
86-61	17 249	16 515	17 029	16 931	377
86-62	7 540	7 337	7 337	7 405	117
86-63	40 792	41 114	41 435	41 114	321
86-65	13 756	14 842	14 552	14 384	562
86-68	21 414	20 023	22 433	21 290	1210
86-74	22 918	24 583	24 980	24 160	1094
86-85	11 910	11 584	11 656	11 717	171
86-87	20 460	21 142	21 142	20 915	394
86-88	16 002	15 435	15 561	15 666	298
86-89	19 780	20 873	19 780	20 144	631
86-90	22 733	22 528	22 528	22 596	118
86-91	19 872	20 907	20 838	20 539	579
86-92	19 941	20 094	20 145	20 060	106
86-93	9 040	7 970	8 683	8 564	544
86-94	13 625	13 764	13 764	13 718	81
86-99	12 830	13 414	13 057	13 100	294
86-100	13 125	13 440	13 388	13 318	169
86-101	25 354	24 736	25 509	25 200	409
86-103	40 101	41 210	38 199	39 836	1523
86-107	11 377	11 230	10 900	11 169	244
86-110	32 884	31 448	31 592	31 975	791

Appendix 6. Gravimetric fecundity data: estimates of total fecundity using individual subsamples, calculated from F = nW/w (see Methods and Materials); means of the individual estimates; and standard deviations (SD) of the individual estimates.

Fish I.D. Number	Fecundity Estimate Sample a	Sample b	Sample c	Mean	SD
85-1	16 792	16 441	16 679	16 638	179
85-2	31 290	31 128	31 823	31 414	364
85-4	15 526	16 358	16 000	15 961	417
85-5	17 924	18 675	19 254	18 618	667
85-6	15 118	16 141	15 862	15 707	529
85-7	12 229	12 919	13 119	12 756	467
85-8	37 786	38 517	38 092	38 132	367
85-9	24 329	24 759	25 055	24 714	365
85-13	16 550	17 268	17 071	16 963	371
85-15	63 110	67 007	65 506	65 207	1966
85-16	28 339	28 992	29 528	28 953	595
85-17	28 458	28 810	28 786	28 685	197
85-18	8 885	9 756	9 610	9 417	466
85-19	54 557	54 692	54 458	54 569	117
85-20	26 652	27 007	27 276	26 978	313
85-22	10 930	10 634	10 662	10 742	163
85-24	17 922	17 516	17 759	17 732	204
85-25	18 256	18 825	18 551	18 544	284
85-26	15 098	15 418	15 368	15 294	172
85-27	10 736	10 823	11 044	10 868	159
85-29	13 803	14 105	15 671	14 526	1003
85-32	11 710	11 967	11 891	11 856	132
85-33	25 973	25 945	26 588	26 169	364
85-35	16 054	16 348	16 802	16 402	377
85-37	12 430	12 634	12 550	12 538	103
85-39	20 365	20 982	21 233	20 860	447
85-40	19 485	19 513	19 480	19 493	18
86-3	15 797	15 857	15 461	15 705	213
86-4	19 728	19 908	19 685	19 774	118
86-5	20 454	20 093	20 544	20 364	238
86-6	24 500	25 107	25 567	25 058	535
86-9	30 630	30 948	30 654	30 744	177
86-12	20 683	20 793	20 554	20 677	120
86-14	22 750	22 871	23 297	22 973	287
86-15	9 744	9 809	9 900	9 818	78
86-18	12 702	12 404	12 404	12 503	172
86-19	23 133	22 092	22 403	22 543	534
86-20	20 444	20 578	20 495	20 506	68
86-21	13 070	13 339	13 150	13 186	138
86-22	33 964	34 429	33 768	34 054	340
86-23	16 128	15 354	15 752	15 745	387

Appendix 6 continued.

Fish I.D. Number	Fecundity Estimate Sample a	Sample b	Sample c	Mean	SD
86-26	13 297	13 525	13 532	13 452	134
86-27	40 799	40 733	40 879	40 804	73
86-28	13 929	14 120	14 179	14 076	131
86-30	17 433	17 450	17 720	17 534	161
86-31	20 133	20 588	20 610	20 444	270
86-34	30 109	31 453	30 391	30 651	709
86-39	14 956	14 953	15 042	14 984	51
86-40	12 285	12 146	12 435	12 289	145
86-42	12 360	12 404	12 575	12 446	114
86-48	12 784	12 182	12 277	12 414	324
86-49	8 979	9 028	8 917	8 975	56
86-50	8 915	9 490	9 262	9 222	289
86-51	17 734	17 631	18 411	17 925	424
86-52	37 282	37 147	37 787	37 405	337
86-53	30 401	30 547	29 356	30 101	649
86-55	35 211	34 478	35 646	35 111	590
86-58	34 004	33 267	33 910	33 727	401
86-59	24 215	25 064	24 924	24 735	455
86-60	26 121	26 070	26 785	26 325	398
86-61	18 467	17 991	18 550	18 336	302
86-62	8 266	8 073	8 389	8 242	159
86-63	45 052	43 924	44 268	44 415	578
86-65	16 049	16 777	16 323	16 383	368
86-68	24 988	23 455	25 219	24 554	959
86-74	25 751	26 392	27 003	26 382	626
86-85	12 827	12 961	13 372	13 053	284
86-87	22 628	22 838	22 838	22 768	122
86-88	17 476	17 307	17 449	17 411	90
86-89	22 257	22 242	21 147	21 882	636
86-90	26 968	27 598	27 374	27 314	319
86-91	21 787	22 765	22 306	22 286	489
86-92	21 542	22 138	21 904	21 862	301
86-93	9 387	8 849	9 142	9 126	270
86-99	14 430	14 980	14 582	14 664	284
86-100	14 483	14 586	14 724	14 598	121
86-103	42 330	41 868	40 610	41 603	890
86-107	12 270	12 314	11 992	12 192	175
86-110	35 731	35 269	35 430	35 477	235