STUDIES ON THE LIFE HISTORY OF THE YELLOW PERCH, PERCA FLAVESCENS (MITCHILL) IN BIG BAY DE NOC, LAKE MICHIGAN

Thesis for the Degree of M. S.

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STUDIES ON THE LIFE HISTORY OF THE YELLOW PERCH, *PERCA FLAVESCENS* (MITCHILL), IN BIG BAY DE NOC, LAKE MICHIGAN

By

ROBERT JOSEPH TOTH

AN ABSTRACT

Submitted to the College of Agriculture of Michigan State University of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Department of Fisheries and Wildlife

1959

Approved Eugene W. Roelofs

ABSTRACT

The yellow perch, Perca flavescens (Mitchill), is an important food and sport fish in the Big Bay de Noc area of Lake Michigan. Between 10 and 30 percent of the total annual commercial catch in Lake Michigan comes from the waters of Big Bay de Noc.

This study is based on 1095 specimens collected in 1957 and 1958 by gill-nets from five sample areas in Big Bay de Noc. Of these specimens, 1045 were used in the calculation of previous growth. The body-scale relationship was determined and the computed intercept was used in calculating growth histories. Analysis of the length-weight relation was based on 392 specimens taken during July, 1958.

Calculated lengths at a given age were consistently larger in the older fish. It is felt that these discrepancies were due in part to inter-specific competition. There were no major differences noted in growth rates between the sample areas.

The growth of males and females was disproportionate, with the females maintaining a slight length advantage. There were no differences in the condition factor for males and females. Both sexes required five years of growth to reach the legal commercial size of 8½ inches.

Mayflies, crayfish, aquatic isopods, amphipods, and midge larvae were the food items most frequently encountered in analysis of stomach contents.

The incidence of parasitism in the yellow perch of Big Bay de Noc is extremely light. Only four species of internal parasites were recorded.

The relative abundance of perch in Green Bay in 1958 is at a peak level, and the degree of inter-specific competition it is subjected to will determine in part whether this high level of abundance can be maintained.

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INTRODUCTION

The yellow perch, Perca flavescens (Mitchill) is one of the important food and sport fishes found in the United States. It is soundly established throughout the northeastern sections of the country as well as in southern Canada. It is found in great abundance in all of the Great Lakes except Lake Superior, and contributes significantly to the economic status of the states bordering on the Great Lakes. Despite its wide range, commercial production of perch is largely concentrated in three general areas; the western part of Lake Erie, Saginaw Bay in Lake Huron, and the Green Bay area of Lake Michigan.

In Lake Michigan alone, the commercial catch of yellow perch has, over the past thirty-eight years, averaged 300 thousand pounds per year. A record catch of 1,012,000 pounds was taken from this lake in 1955 with an economic value estimated in excess of 112,000 dollars (Michigan Department of Conservation Biennial Report for the years 1955-1956). The yellow perch ranks fifth in terms of commercial value, and fourth in total weight production in the commercial fishery in Lake Michigan. Smelt, chubs, and lake herring, in that order, are the three species having a higher total annual catch.

The economic value of the perch as a sport fish can only be estimated, but it is known that in many localities the catch of perch by the sport fishery is in excess of the recorded commercial catch.

Big Bay de Noc is one area of Lake Michigan that supports an extensive population of yellow perch. This population contributes substantially to the total lake production of perch. The towns of Garden, Fayette, Fairport and Isabella are the primary fishing ports for the bay. In 1956 and 1957, Big Bay de Noc alone produced 17% and 30%, respectively, of the total poundage of perch caught commercially in the waters of Lake Michigan (Catch Records of the Michigan Department of Conservation).

Since the yellow perch of Bay de Noc has contributed a major portion of the annual catch over a period of thirty-eight years, it was deemed necessary to investigate the present status of this exploited species to uncover any significant changes that may have occurred as the result of exploitation or biological occurrences.

The objectives of this present study were: (a) To determine, by comparisons with previous reports, whether the yellow perch of Big Bay de Noc constituted a stable population in so far as growth and relative abundance are concerned after being under exploitation for the past thirty-eight years; (b) To determine what biological effect the virtual elimination of the whitefish, _Coregonus clupeaformis_, and the lake trout, _Salvelinus namaycush_, from the biomass had on the present stock of yellow perch.

Few studies have been made of the yellow perch in the Great Lakes. Hile and Jobes (1941) reported the growth rate of perch from Saginaw Bay, Lake Huron; while Jobes (1952) published a detailed life history of the perch in Lake Erie. El-Zarka (1958) made a recent extensive study of the population structure and growth of perch in Saginaw Bay. A paper was published in 1942 by Hile and Jobes concerning the growth rates of yellow perch in the Wisconsin waters of Green Bay and waters of northern Lake Michigan. The results of this study will be compared primarily with the findings of Hile and Jobes to determine the changes in the status of the yellow perch stock in Big Bay de Noc.

The changing concepts of fisheries research in the Great Lakes have been well described by Hile (1953):

> "The principal accomplishment of fishery biology in the Great Lakes, then, has been to teach us that for more effective understanding we must focus our attention on how fish live together in a constantly changing environment. Circumstances may require that we study species individually, and we may never achieve the goal of simultaneous research on every variety in a population; but we must never think in terms of one species alone, for it does not live alone."

With these important concepts in full view, this study was undertaken.

DESCRIPTION OF AREA

Big Bay de Noc is a large bay extending north from the mouth of Green Bay in Lake Michigan. It has a length of 20 miles, a maximum width of 8 miles and an average depth of approximately 27 feet. Most of the shoreline of the bay is heavily wooded, mixed hardwoods and softwoods being the predominant cover type, with localized stands of pine and cedar occurring in lesser abundance.

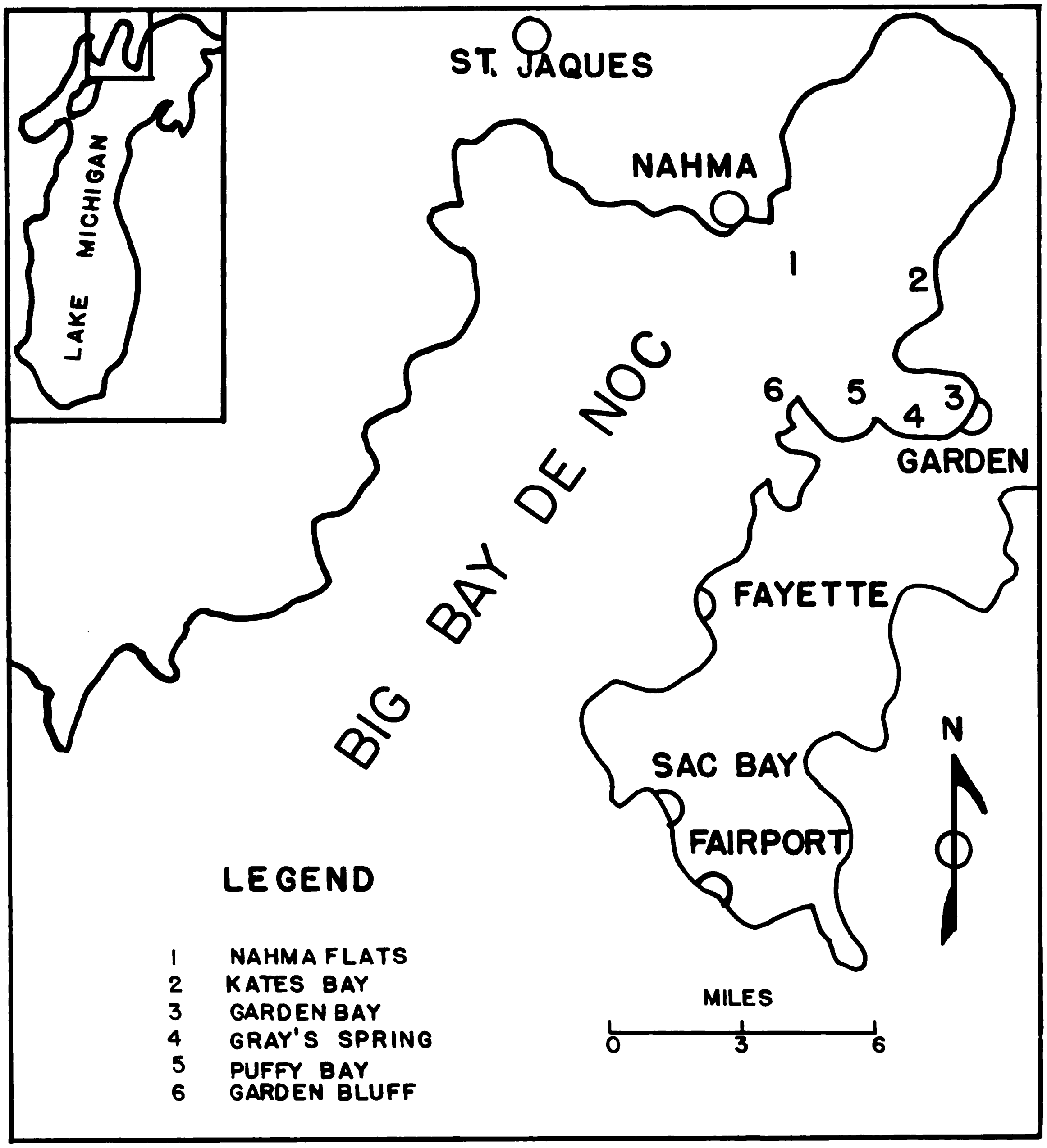
The bottom type of the northern half of the bay is sand. Rock and rubble are the major bottom types of the southern shores and shoals, with loose peat and silt in the deeper areas and in the smaller coves and bays. Aquatic plants are sparse and confined to a few sheltered areas.

Sampling Areas

Because of limited time and funds, the whole of Big Bay de Noc could not be sampled randomly. Therefore, areas were chosen for samples which would demonstrate the characteristics of the yellow perch comprising the commercial catch and also areas which were easily accessible. See Figure 1.

1. Nahma Flats is an area utilized to a great extent by commercial fishermen. It consists of a shoal in the middle of the northern end of Big Bay de Noc.

Figure I. Big Bay de Noc, showing location of sample areas.



ST. JAQUES
NAHMA
LAKE MICHIGAN
BIG BAY DE NOC
1
2
6
5
4
3
GARDEN
FAYETTE
SAC BAY
FAIRPORT
N
LEGEND
1 NAHMA FLATS
2 KATES BAY
3 GARDEN BAY
4 GRAY'S SPRING
5 PUFFY BAY
6 GARDEN BLUFF
MILES
0
3
6

2. Kates Bay is also under heavy exploitation by commercial fishermen. It is located on the east shore and specimens were taken at the mouth of the bay in 12 to 18 feet of water.
3. Garden Bay, extending eastward from Gray's Springs, is closed to commercial fishing throughout the year. It was the only sample area with a bottom type consisting of silt and peat. Beds of submerged aquatics were in evidence throughout the shallow end of the bay. Samples were obtained from depths of 3 to 6 feet.
4. Gray's Springs was chosen for its unusual physical characteristics. A large flow of cold water enters Garden Bay over a 50 foot section of exposed shoreline. Large mats of green algae cover the bottom and extend out into the bay for a distance of more than 100 feet. Numbers of yearling fish were noted here and the area provided the only specimens of this age-group taken throughout the entire sampling period.
5. Puffy Bay is a small, shallow bay just east of, and sheltered by, Garden Bluff. Samples were taken from depths of 8 to 12 feet.
6. Garden Bluff is situated just south of the mouth of Garden Bay. It is characterized by a steep

shoreline drop-off to approximately 50 feet and strong shifting currents. Nets were set in depths of 9 to 15 feet and 35 to 40 feet of water.

MATERIALS AND METHODS

Collection of Specimens

The study of the yellow perch of Big Bay de Noc was based on a total of 1095 specimens taken from the six sample areas. See Table 1.

The 1957 Kates Bay sample, the May, 1958 samples from Garden Bluff and Nahma Flats, and that sample taken from Garden Bay in November, 1958 for parasitological examination were obtained from commercial fishermen using standard 2½-inch mesh gill-nets. The two samples from Gray's Springs were taken by hook and line. All other fish were caught by means of 125-feet experimental gill-nets having a stretched-mesh size graded from 2 inches to 3½ inches. These experimental gill-nets were set at an angle of 45° to the shoreline as it was felt that this position would catch fish moving in and out of the shallow water as well as fish moving parallel to the shoreline.

Individual Fish Measurements

The total length, in millimeters, of each fish was taken on a standard measuring board by compressing the lobes of the caudal fin to give the greatest possible measurement. All lengths given in this thesis are total lengths unless otherwise indicated.

Table 1

Collections of Yellow Perch from Sample Areas in Big Bay de Noc

Date	Area	Number of Fish
January 29, 1957	Kates Bay	405
May 23, 1958	Nahma Flats	51
May 23, 1958	Garden Bluff	53
May 24, 1958	Garden Bluff	83
July 9, 1958	Puffy Bay	46
July 10, 1958	Garden Bluff	69
July 11, 1958	Garden Bay	28
July 12, 1958	Gray's Springs	61
July 13, 1958	Kates Bay	86
July 15, 1958	Gray's Springs	12
July 15, 1958	Kates Bay	51
July 16, 1958	Garden Bluff	100
November 27, 1958	Garden Bay	50
Total		1095

Weights were recorded to the nearest gram using a dietary pan balance calibrated by 4-gram intervals. All fish with the exception of the Kates Bay sample of January, 1957, and those spawning-run samples taken throughout May, 1958, were used in the study of the length-weight relationship.

The sex was noted on those fish taken during July, 1958, and sex differences compiled from these data.

Age Determinations

Scales were taken from the left side of the body below the lateral line and directly behind the posterior end of the pectoral fin. The position of "key" scales taken for purposes of determining the body-scale relationship is described in detail under a subsequent heading.

The scales were impressed on cellulose acetate, 0.020 inches in thickness, by a roller press constructed after that described by Smith (1954). These impressions were examined and measured using a Bausch and Lomb Tri-Simplex Microprojector under a magnification of 43 times. The length of each "key" scale was measured from the focus to the anterior edge along the interradial space most nearly collinear with the anterior-posterior axis. The distance from the focus to each annulus was measured along the greatest radius of the scale. All measurements were made to the nearest millimeter and recorded on calibrated IBM cards.

The age of each fish is given in terms of completed years of life and was determined by counting the number of annuli on the scale. (All young-of-the-year fish were assigned to age-group 0.) Joeris (1956) found that the number of annuli on the scales of the yellow perch of Green Bay, Lake Michigan, is a dependable criterion for age determination.

Because of the variation as to time of annulus formation among the perch of northern Lake Michigan, all fish taken during the month of May were credited with an annulus at the edge of the scale regardless of whether one was present.

BODY-SCALE RELATIONSHIP

Before calculating past growth, a study was made of the relationship between body and scale growth. This relationship had already been described for the yellow perch of Green Bay by Joeris (1956) but, in accordance with his proposal, it was believed necessary to determine the relationship for the stock under study.

Other studies of the body-scale relationship in yellow perch have been reported for Saginaw Bay (Hile and Jobes, 1941), Lake Erie (Jobes, 1952) and Lake of the Woods (Carlander, 1950). Carlander described the relationship in Lake of the Woods by two second-degree parabolas, one fitted to data from fish 50-150 millimeters in length, the other to fish from 19-256 millimeters, inclusive.

Jobes (1952) found that the body-scale ratio for scales taken below the lateral line in the perch of Lake Erie was constant for those fish over 4.6 inches. This ratio was best described by a straight line which passed through the origin. The body-scale ratio of fish from 2.3 to 4.6 inches was not constant due to the more rapid increase of the scale diameter. This increase in relative size follows approximately a straight line but its slope is less than that of the line fitted to the data for the larger fish. Due to the discontinuity of the body-scale relationships, all direct-proportion computations of length less than 4.6 inches were corrected. Because of the consistency in the average ratios no corrections were made for lengths of 4.6 inches or more. Hile and Jobes (1941) and Joeris (1956) found these same relationships held approximately true for the perch of Saginaw Bay and Green Bay, respectively.

In order to best describe the body-scale relationship for the stock under study, key scales were taken from 104 yellow perch having a size range from 30 to 310 millimeters. This key scale came from the third row below the lateral line directly beneath the sixth spine of the dorsal fin; it is the same key scale that was used by Hile and Jobes (1941), Jobes (1952), and Joeris (1956). These fish were selected for size distribution and were taken from the four major sample areas: Kates Bay (12 fish), Garden Bay (24 fish), Garden Bluff (38 fish), and Gray's Springs (20 fish). The regression of body length on scale radius was determined for each area separately by the method of least squares. According to Whitney and Carlander (1956) this regression is the proper one to use in describing the relationship between body and scale for growth computations.

The following equations were determined:

Kates Bay	$Y = 41.73 + 1.1636\ X$
Garden Bay	$Y = 71.85 + 0.8592\ X$
Garden Bluff	$Y = 26.31 + 1.3227\ X$
Gray's Springs	$Y = 80.78 + 0.7452\ X$

An analysis of covariance was then computed as described by Snedecor (1956) to see if a common line might be used to best describe the relationship in all sample areas. The results of this analysis are shown in Table 2. These lines have both significantly different slopes and intercepts.

From Figure 2 it can be seen that the two most widely divergent regression lines are those representing Gray's Springs and Garden Bluff. It was also noted that the mean length of fish from the Garden Bluff sample was 201.9 mm. which far surpassed the mean length of the Gray's Springs sample, 163.6 mm. Jobes (1952) pointed out that neither the stage of maturity nor the sex should influence the body-scale ratio, and that length of the fish was the only factor to have an effect on this ratio.

To compare the body-scale relationships between these two areas, those fish with a total length of 200 millimeters or greater (10) were excluded from the Garden Bluff sample to reduce this sample mean length to approximate

Table 2

Covariance Analysis of Body-Scale Relationship of Yellow Perch from Major Sample Areas.

Line	Sample Area	f	x^2	xy	y^2	Reg. Coef.	f	d^2	Mean Square
1	Garden Bluff (201.9)*	37	43,504.0	57,543.6	83,621.9	1.3227	36	7,508.0	208.6
2	Garden Bay (184.8	23	11,039.9	9,485.6	11,972.6	0.8592	22	3,822.4	173.7
3	Gray's Springs (163.6)	19	8,834.5	6,583.2	6,668.8	0.7452	18	1,763.2	97.9
4	Kates Bay (187.1)	11	8,616.9	10,027.1	12,536.9	1.1636	10	868.8	86.8
5	Within						86	13,962.4	162.4
6	Reg. Coef						3	3,671.4	1,224.0
7	Common	90	71,995.3	83,639.5	114,800.2	1.1617	89	17,633.8	198.1
8	Adj. Means						3	4,329.4	1,443.1
9	Total	93	78,839.2	94,118.9	134,323.4	1.1938	92	21,936.2	

1. Is there a difference between the four sample regression coefficients?

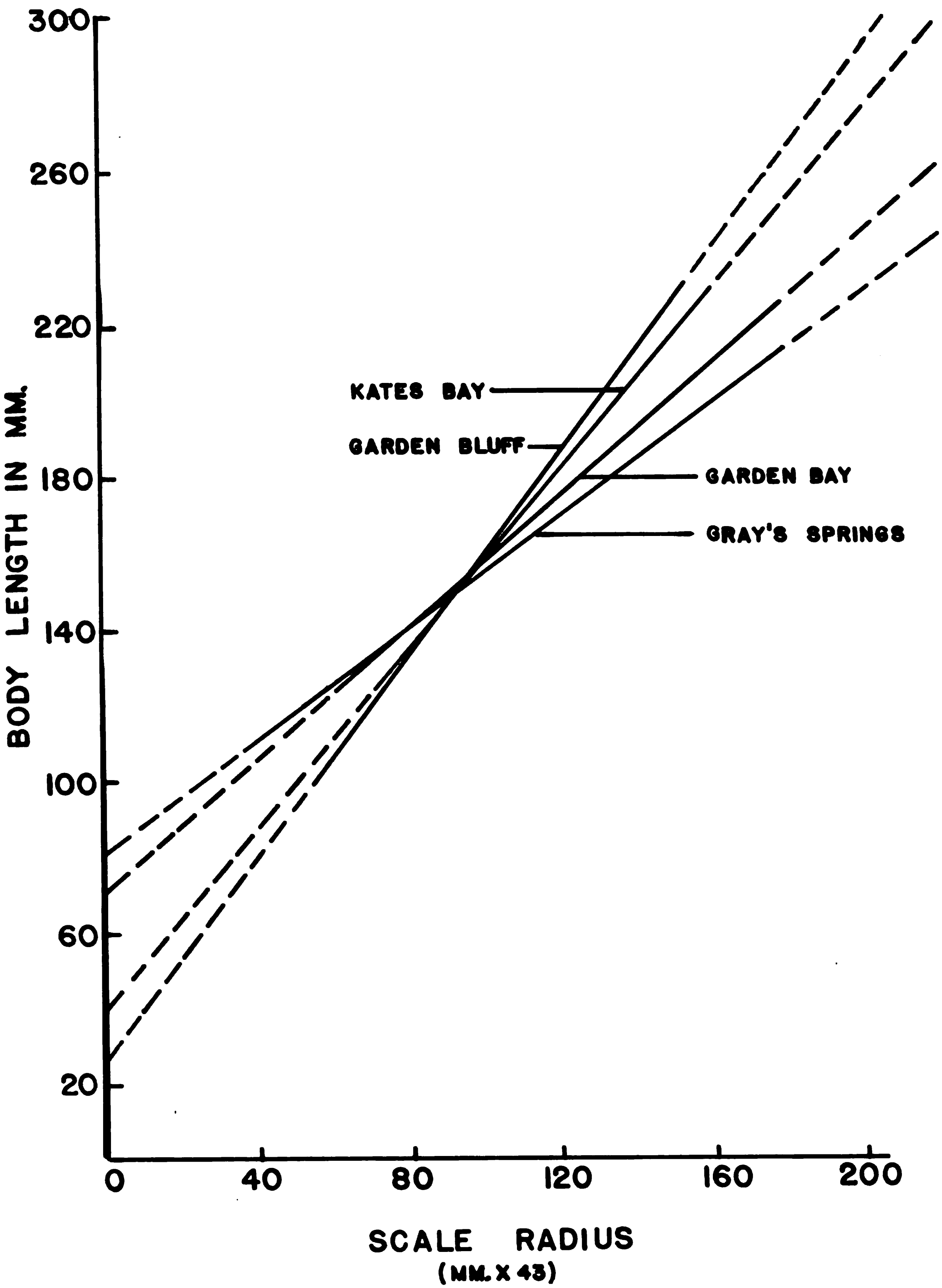
$F = \frac{1224.0}{162.4} = 7.56$ The answer is yes.

2. Is there a difference between the intercepts of the four samples?

$F = \frac{1443.1}{198.1} = 7.28$ The answer is yes.

* Mean length of sample.

Figure II. Linear regression of body-scale relationships as determined for the four sample areas.



300
260
220
180
140
100
60
20
BODY LENGTH IN MM.
KATES BAY
GARDEN BLUFF
GARDEN BAY
GRAY'S SPRINGS
0
40
80
120
160
200
SCALE RADIUS
(MM. X 43)

that of the Gray's Springs sample. The regression lines were again compared by an analysis of covariance and were found not significantly different at the 5% level (See Table 3). It was then assumed that the differences in regression lines were not due to differences in the body-scale relationship in the different sample areas, but rather to the size range of the individuals making up the sample.

It may also be true that in the larger fish, the ratio of scale radius to body length is not constant and a curvilinear relationship does indeed exist, as was found for smaller fish by Carlander (1950). To check this assumption, a curvilinear regression was determined using all the data from the combined sample areas (See Figure 3). The data gave the following equation:

$$Y = 10.48 + 1.5636\ X - 0.001266\ X^2$$

This regression was compared to the common linear regression by an analysis of covariance (See Table 4) which showed the two lines did not differ at the 5% level of significance. The curvilinear relationship as shown in Figure 3 gives the impression that at larger body lengths, body growth is proportionately greater than scale growth.

Table 3

Covariance Analysis of Body-Scale Relationship of Yellow Perch from Gray's Springs and Garden Bluff (All fish over 200 mm. excluded from the Garden Bluff sample).

Line	Sample Area	f	x^2	xy	y^2	Reg. Coef.	f	d^2	Mean Square
1	Garden Bluff (166.3)*	20	7,325.0	6,833.0	7,784.7	0.9300	19	1,410.7	74.2
2	Gray's Springs (163.6)	19	8,834.5	6,583.2	6,668.8	0.7452	18	1,763.2	97.9
3	Within						37	3,173.7	85.8
4	Reg. Coef.						1	141.5	141.5
5	Common	39	16,159.5	13,416.2	14,453.5		38	3,315.2	87.2
6	Adj. Means						1	177.0	177.0
7	Total	40	16,190.0	13,368.0	14,530.0		39	3,492.1	89.5

1. Is there a difference between the two sample regression coefficients?

$F = \frac{141.5}{85.8} = 1.65$ The answer is no at the 5% level of significance.

2. Is there a difference between the intercepts of the two samples?

$F = \frac{177.0}{87.2} = 2.03$ The answer is no at the 5% level of significance.

* Mean length of sample.

Figure III. The linear and curvilinear relationships of body length to scale radius determined using the combined data for all sample areas.

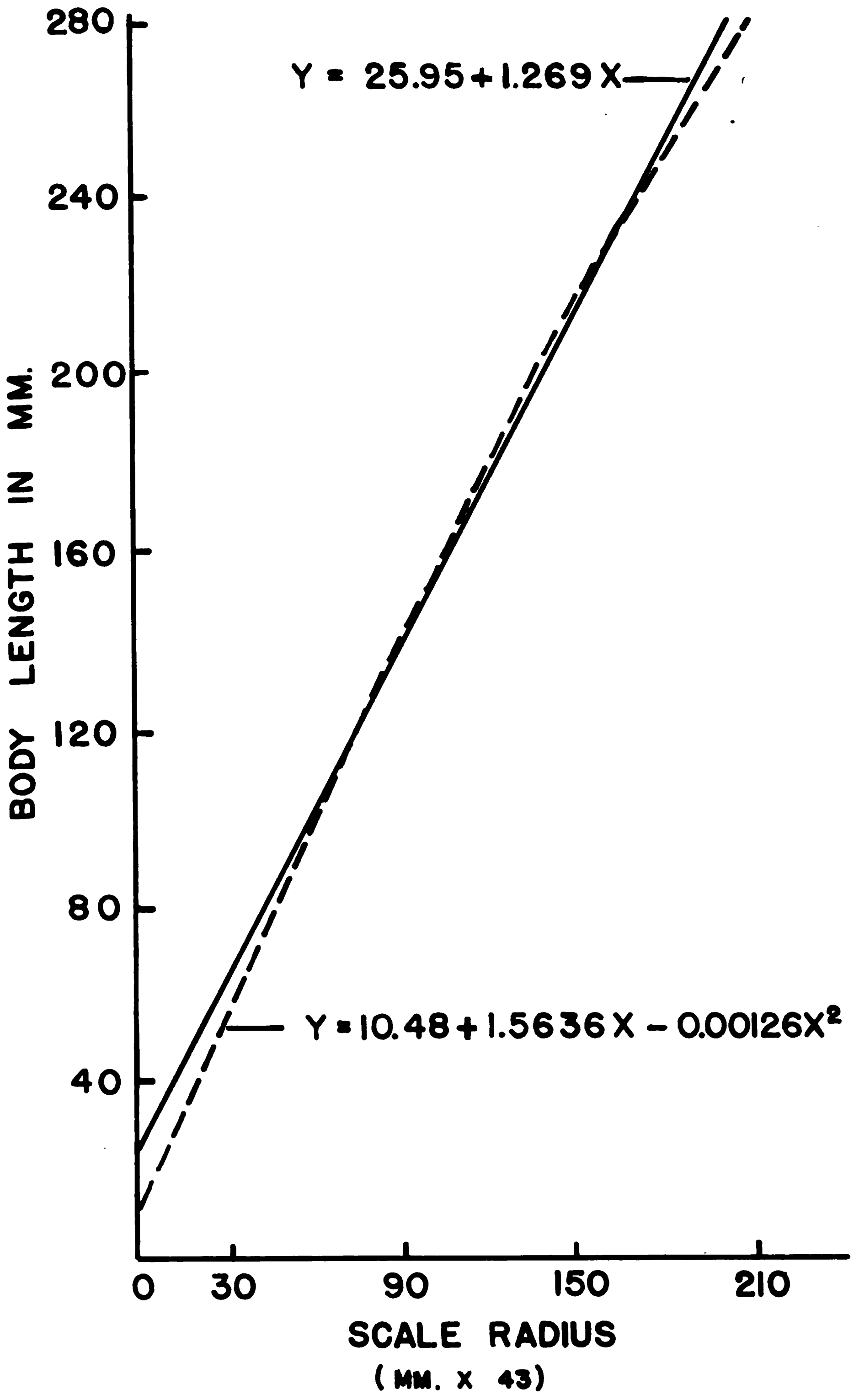

BODY LENGTH IN MM.
280
240
200
160
120
80
40
Y = 25.95 + 1.269 X
Y = 10.48 + 1.5636 X − 0.00126X²
0
30
90
150
210
SCALE RADIUS
(MM. X 43)

Table 4

Analysis of Covariance Between Linear and Curvilinear Regressions of Body-Scale Relationships

Source of Variation	Degrees of Freedom	D^2	Mean Square
Linear Regression	100	17,833	171.1
Curvilinear Regression	99	17,125	180.0
Difference	1	708	708.0

1. Is there a difference between the linear and curvilinear regression?

$F = \frac{708}{180} = 3.933$ The answer is no at the 5% level of significance.

Since this relationship did not seem biologically feasible it was then decided to run a curvilinear relationship on the data from Garden Bluff (35 specimens) to see if a given area followed the trend of growth portrayed by the general curve. The relationship from Garden Bluff showed a consistent increase in scale growth with increasing body lengths. It was then assumed that discrepancies in the data and perhaps inadequate representation of the larger individuals in the samples, were responsible for depicting the larger fish as having proportionately greater scale growth; and that this is not a biologically feasible relationship.

Since the overall curvilinear relationship and the common linear regression did not differ significantly, it was decided that the common linear regression,

$$Y = 25.95 + 1.269\ X,$$

although not in agreement with the results obtained by Joeris for the Green Bay stock, would best fit the data, would be easier to handle in subsequent calculations, and would give the most reliable results in determining previous growth.

The intercept was taken to be 26 millimeters. This value is very near the length of the fish at which Pycha and Smith (1955) were first able to detect scales on Red

Lakes perch in the body region from which the key scales were taken. This intercept also agrees well with personal observations on scale formation of young-of-the-year perch (25 to 30 mm.) taken from Garden Bay on the 15th of July, 1958. The scales of these fish were imbricated along the mid-lateral body walls.

Calculated lengths were then computed using the formula:

$$L_n = 26 + \frac{(L_t - 26)}{S_t} S_n$$

where L_n equals calculated length at end of "n" years,

L_t equals total length at capture,

S_n equals radius to the "nth" annulus,

and S_t equals total scale radius.

This method of calculating previous growth was devised by Fraser (1917) and is based on the assumption that body growth is related to the proportional growth of the scale and not to the absolute size of the scale. Whitney and Carlander (1956) found that this method, although not entirely satisfactory, gives results which are fairly accurate.

LENGTH-WEIGHT RELATIONSHIP

The length-weight relationship of fish having constant form and specific gravity can best be described by the equation, $W = CL^3$, where W equals weight, C equals a constant, and L equals length. This relationship is rarely encountered, however, due to the variation in weight and form of the different fish species. A more general equation, $W = cL^n$, where "c" and "n" are determined empirically, has been found by Hile and Jobes (1942) and Jobes (1952) to adequately describe the length-weight relationship for yellow perch.

In the study of the general length-weight relationship of the Big Bay de Noc perch, 392 specimens from 5 separate areas were used to calculate, by the method of least squares, the following linear equation:

$$\text{Log } W = -5.5361 + 3.257 \text{ Log } L$$

where W = weight in grams and L = total length in millimeters. This equation may also be written as:

$$W = 3.437 \times 10^{-5} L^{3.257}.$$

The 392 fish chosen were not selected for size or sex, but all samples taken during the spawning-run period of May, 1958, were omitted due to the possible bias resulting from varying stages of maturity of the gonads, and the differences in gonadal weights between males and females.

The graphical representation of the length-weight relationship as a smooth curve is shown in Figure 4. The curve represents calculated weights while the dots are derived from empirical data. The range of the empirical weights was from 27 to 399 grams.

Comparison with the Length-Weight Relationship of Other Great Lakes Stocks of Perch

The length-weight relationship of the yellow perch in the Great Lakes has previously been reported as follows:

Lake Erie - (Jobes, 1952)

$$W = 1.766 \times 10^{-5} L^{3.015}$$

Saginaw Bay - (El-Zarka, 1958)

$$W = 3.9975 \times 10^{-3} L^{2.620}$$

Lake Michigan - (Hile and Jobes, 1942)

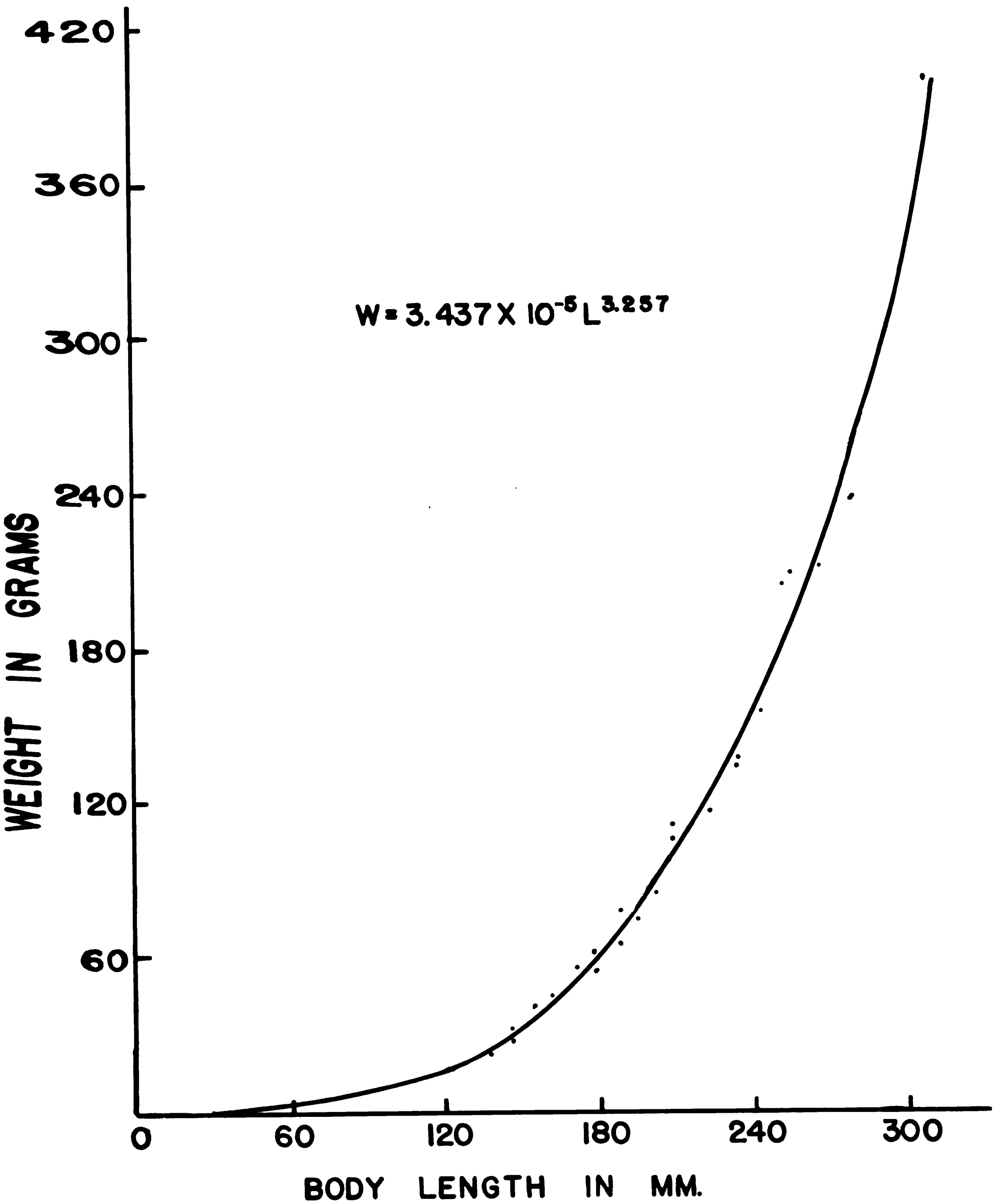
$$W = 5.8405 \times 10^{-5} L^{2.81}$$

Green Bay - (Hile and Jobes, 1942)

$$W = 0.9319 \times 10^{-5} L^{3.133}$$

These relationships are all based on standard length, therefore they cannot be directly compared to the relationship found in the Bay de Noc fish since it was derived using total length. Weights were calculated from the different length-weight equations of Great Lakes yellow perch population by El-Zarka (1958). (See Table 5.) The only weight differences noted in a comparison between Big Bay

Figure IV. The length-weight relationship of 392 yellow perch from Big Bay de Noc.



W = 3.437 X 10-5 L3.257
WEIGHT IN GRAMS
420
360
300
240
180
120
60
0
60
120
180
240
300
BODY LENGTH IN MM.

Table 5

Length-Weight Relationship of Yellow Perch Populations in Different Great Lakes Waters*

(Data from: Hile and Jobes, 1942; Jobes, 1952; El-Zarka, 1958)

Total Inches	Length Millimeters	Calculated Weights in Ounces: Green Bay	Lake Michigan	Big Bay de Noc	Saginaw Bay	Lake Erie
5.0	127	0.7	1.0	0.7	0.8	0.8
5.5	140	1.0	1.4	1.0	1.0	1.1
6.0	152	1.4	1.8	1.3	1.4	1.4
6.5	165	1.7	2.2	1.7	1.8	1.9
7.0	178	2.2	2.7	2.2	2.3	2.3
7.5	191	2.8	3.4	2.8	2.9	2.9
8.0	203	3.4	4.0	3.4	3.5	3.5
8.5	216	4.1	4.8	4.2	4.3	4.1
9.0	229	4.9	5.6	5.0	5.2	5.0
9.5	241	5.8	6.6	5.9	6.2	6.1
10.0	254	7.0	7.7	7.1	7.3	7.0
10.5	267	8.1	8.9	8.3	8.6	8.3
11.0	279	9.4	10.1	9.6	10.0	9.4
11.5	292	10.8	11.4	11.1	11.5	10.9
12.0	305	12.2	12.8	12.8	13.2	12.3
12.5	318	13.9	14.4	14.7	15.1	14.1
13.0	330	15.8	16.0	16.6	17.2	15.8

* Taken in part from El-Zarka (1958).

de Noc fish and those from Green Bay were in the larger lengths. The overall rate of weight increase up to a total length of ten inches in the Bay de Noc perch was less than that found in other waters with the exception of Green Bay. Fish between eleven and thirteen inches total length grew at a proportionately greater rate in Bay de Noc than did the fish from any of the other areas, and at a total length of thirteen inches only the Saginaw Bay stock outweighed them.

AGE AND GROWTH

Growth in Length of the Age-Groups

In presenting the data for the calculated growth histories of the yellow perch in Big Bay de Noc, growth in the different sample areas was determined separately to see whether any significant differences in the growth rate prevailed between the sample areas, thereby giving indications of the possible occurrence of isolated sub-populations. Also, the sexes were kept separate in as much as differential growth was found between male and female perch by Hile and Jobes (1941, 1942) and by Jobes (1952), and was assumed to be present in the perch of Big Bay de Noc. Data for the calculated growth of age-groups I to VIII (See Table 6) are derived from all samples taken throughout the course of the study to give the most accurate estimate of actual growth conditions.

Comparisons of the calculated lengths for all age-groups showed a tendency for calculated length at a given age to be consistantly larger in the older age-groups. In other words, there was a progressive decrease in the calculated lengths at the end of any given year of life from fish of age-group VIII to age-group I. These discrepancies are the opposite of those described by Lee (1920). Lee's

Table 6

Calculated Total Length at the End of the Different Years of Life for Yellow Perch (Sexes Combined) from Big Bay de Noc, Lake Michigan

Age Group	No. of Fish	Length (Millimeters) at End of Year 1	2	3	4	5	6	7	8
I	2	66	...	...	...	...	...	...	...
II	7	62	102 (40)*	...	...	...	...	...	...
III	670	70	109 (39)	152 (43)	...	...	...	...	...
IV	168	69	115 (46)	157 (32)	193 (36)	...	...	...	...
V	149	72	116 (44)	164 (48)	199 (35)	228 (29)	...	...	...
VI	35	72	117 (45)	162 (45)	198 (36)	225 (27)	251 (26)	...	...
VII	3	74	122 (48)	169 (47)	202 (33)	227 (25)	253 (26)	279 (26)	...
VIII	2	79	121 (42)	157 (36)	201 (44)	234 (33)	258 (24)	280 (22)	303 (23)
Grand average calculated length		70	111	155	196	227	252	279	303
Grand average increment of length		70	41	44	36	29	26	24	23
Accumulation of average increments		70	111	155	191	220	246	270	293

* Increments in parentheses.

"Phenomenon of apparent decrease in growth rate" shows wide disagreements occurring in the calculated lengths whereby those of older fish are decidedly less at a given age than for the younger individuals. The possible explanations given by Lee for these discrepancies are: greater longevity of the slower growing individuals due to a differential mortality rate; or a constant decrease of scale diameter caused by erosion, reabsorbtion, or compaction. The reverse of Lee's "Phenomenon," found in the perch of Big Bay de Noc, is not thought to be due to the addition of materials to increase the diameter of the scale. Wallin (1957) reports that although reabsorbtion and consequent replacement of the scale periphery is a common occurrence in fish whose metabolic rate is upset by a lack of required minerals or who are subjected to a heavy incidence of parasitism, the addition of materials to the osseous or fibrous layers of the scale, once calcification has occurred, is not possible. And, since the body-scale relationship of this stock has been determined, the possibility of large errors in calculated lengths resulting from the method of computing these lengths is highly unfeasible. A differential mortality rate with the faster growing individuals attaining an older age does not seem to be an explanation , due to the constant removal of these fish by exploitation beginning as soon as they reach the legal size limit of 8½ inches.

Similar growth discrepancies have been reported for yellow perch in Saginaw Bay, Green Bay and northern Lake Michigan by Hile and Jobes (1941, 1942). These differences were thought to have been due to either the selective action of the standard 2½-inch mesh gill-nets used for sampling, or the segregation of the fish according to size and maturity.

It was felt that the method of sampling the Bay de Noc perch (experimental gill-nets) had little influence on these discrepancies due to the fact that fish of all sizes, regardless of growth rate, had equal opportunity to be taken in the varying mesh sizes of the nets.

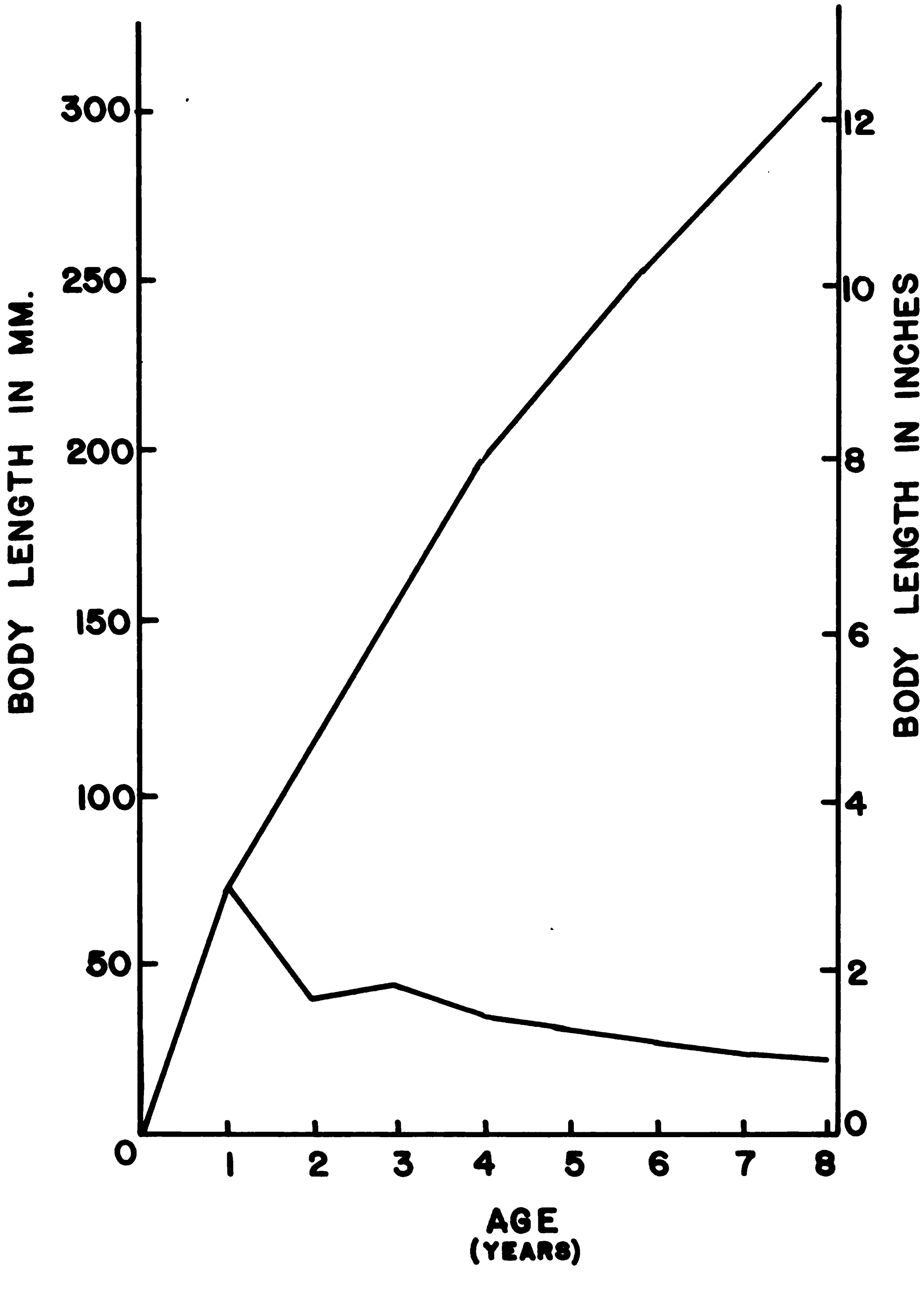
A consideration of the biological changes that took place in Big Bay de Noc and vicinity during the last 16 years might lead to an explanation of the discrepancies in calculated growth between the age-groups. A decline in the lake trout and whitefish populations due to the action of the predatory sea lamprey should have resulted in the replacement to the biomass of these fish by other species. Although the yellow perch is not a consistant deep water form, as are both the lake trout and the whitefish, it is felt that this species should have responded somewhat to such a biological change. This response may have been short-lived due to the appearance of the alewife, *Alosa pseudoharengus*, which first appeared in Lake Michigan waters in 1949 (Miller, 1957). This species has now become firmly established in Lake Michigan where it is found in abundance. It is possible that the alewife has now not only filled the niche left in the biomass by the disappearance of the lake trout and whitefish, but has affected the balance of the remaining species and is a strong competitor for food and space.

This increased inter-specific competition between the perch and the alewife is a logical explanation for the decrease in growth rates between the 1950 year class (age-group VIII) and the 1957 year class (age-group I). From the scope of this present study, it is not possible to predict how this inter-specific competition will affect the growth and abundance of Big Bay de Noc perch in the future.

General Growth History

The growth curve in Figure 5 is a general curve derived to best typify the growth of the Big Bay de Noc perch population as a whole. The curve was determined by combining data for all age-groups (1036 fish) and since the age-groups have heterogeneous growth histories, the

Figure V. General growth in length and annual increment in length of Big Bay de Noc yellow perch collected during 1957 and 1958. (Sexes combined).



BODY LENGTH IN MM.
300
250
200
150
100
50
0
BODY LENGTH IN INCHES
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
AGE
(YEARS)

resulting curve is one which may better be applied to the population rather than a typical individual. Two expressions of growth are given on the bottom of Table 6. The first, the grand average calculated length, is an indication of the growth rate occurring in an exploited stock, while the second, the accumulation of the average increments, serves to show the slower growth potential of the stock if it were not subjected to exploitation (El-Zarka, 1958). It was felt that the grand average calculated length would be more closely correlated with actual growth patterns and would clearly illustrate the growth as it occurs in this exploited population.

Disproportionate Growth of Sexes

Calculated growth histories for female and male yellow perch are shown in Tables 7 and 8, respectively. The length of both sexes was similar for the first year of life. The growth curves of the sexes started to diverge after the first year, the females being longer (See Figure 6). The females maintained this constant advantage (about 5 mm.) for all age-groups older than age-group II. This difference in growth between the sexes did not affect the age at which legal size (8½ inches) was attained. Both sexes required an average of five years growth to reach legal commercial size. (The average age of fish in the

Table 7

Calculated Total Lengths at the End of the Different Years of Life for Female Yellow Perch from Big Bay de Noc Collected During July, 1958

Age Group	No. of Fish	Length (Millimeters) at End of Year 1	2	3	4	5	6	7	8
I	2	66	...	...	...	...	...	...	...
II	6	62	100 (38)*	...	...	...	...	...	...
III	247	72	108 (36)	145 (37)	...	...	...	...	...
IV	39	68	115 (47)	152 (37)	185 (33)	...	...	...	...
V	17	71	113 (42)	161 (48)	192 (31)	222 (30)	...	...	...
VI	4	64	107 (43)	149 (42)	185 (36)	218 (33)	246 (28)	...	...
VII	1	71	118 (47)	160 (42)	205 (45)	229 (24)	259 (30)	294 (35)	...
VIII	1	78	127 (49)	169 (42)	213 (46)	238 (25)	260 (22)	284 (24)	308 (24)
Grand average calculated length		71	109	147	188	222	251	289	308
Grand average increment of length		71	38	38	33	30	27	30	24
Accumulation of average increments		71	109	147	180	210	237	267	291

* Increments in parentheses.

Table 8

Calculated Total Length at the End of the Different Years of Life for Male Yellow Perch from Big Bay de Noc Collected During July, 1958

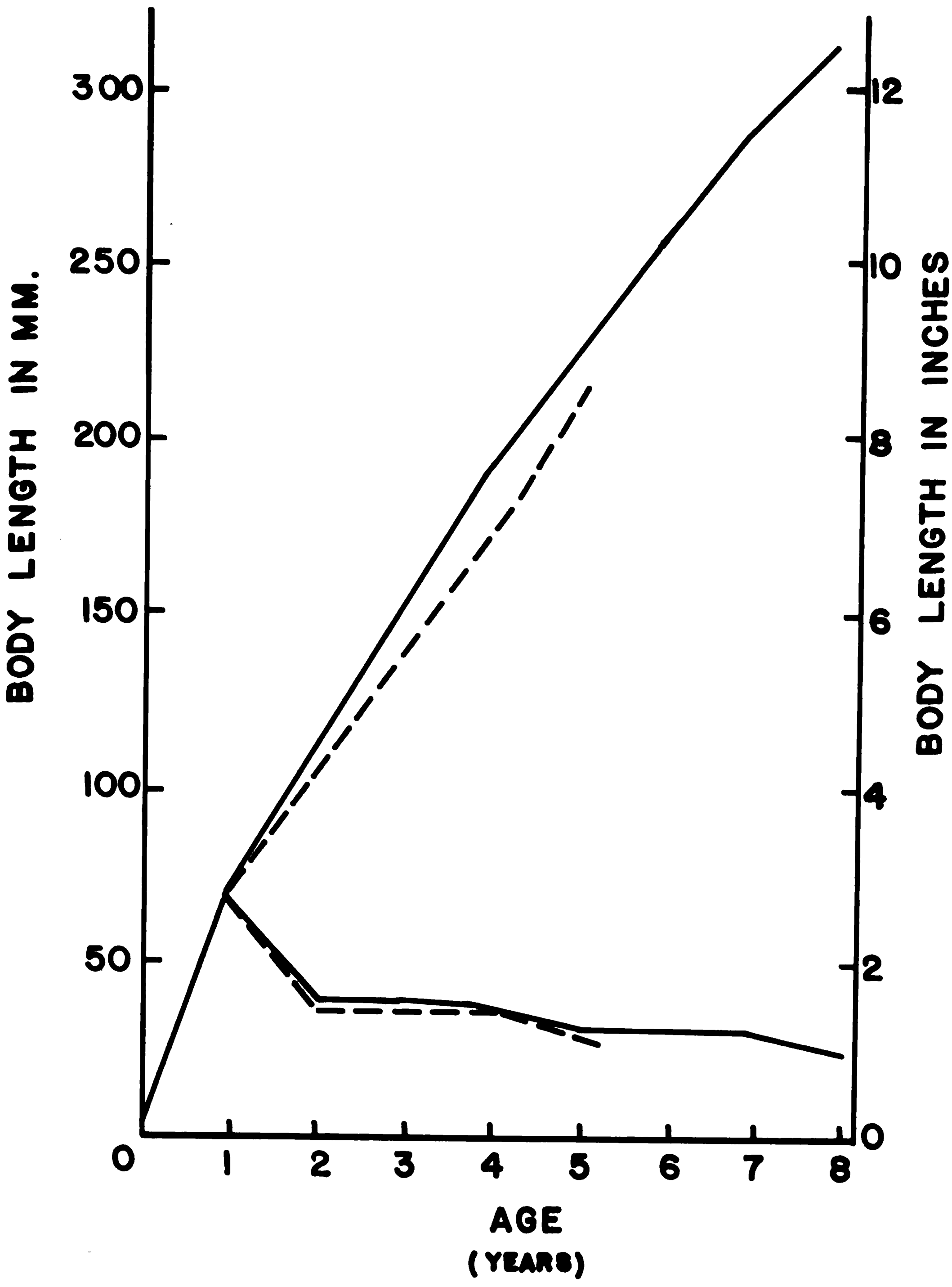
Age Group	Number of Fish	Length (millimeters) at End of Year 1	2	3	4	5
II	1	64	113 (49)*	...	...	...
III	105	72	105 (33)	138 (33)	...	...
IV	25	67	107 (40)	152 (45)	184 (32)	...
V	4	69	106 (37)	152 (46)	189 (37)	215 (26)
Grand average calculated length		71	105	141	185	215
Grand average increment of length		71	35	36	33	26
Accumulation of average increments		71	106	142	175	201

* Increments in parentheses.

three commercial samples taken in May, 1958, from Nahma Flats and Garden Bluff was 5.04 years.)

This differential growth pattern has been noted in the four stocks of yellow perch previously studied in the Great Lakes. The differences in length were not as pronounced

Figure VI. General growth in length and annual increments in length of Big Bay de Noc perch collected during July, 1958. (Male, broken line; female, solid line).



BODY LENGTH IN MM.
300
250
200
150
100
50
0
1
2
3
4
5
6
7
8
AGE
(YEARS)
BODY LENGTH IN INCHES
12
10
8
6
4
2
0

in the present study as were found in southern Green Bay by Hile in 1942. Older males (over age-group V) were lacking in this study and had these fish been adequately represented, a greater length discrepancy might occur between sexes in these older age-groups.

Despite the differences in growth, the same general description of the course of growth may be applied to both males and females. The most rapid growth takes place in the first year of life, after which annual increments decreased continuously as is shown in Figure 6.

Growth Histories in Individual Sample Areas

As was previously mentioned, the growth histories of fish from the sample areas were determined separately to see if any single area differed from the others with respect to rate of growth, thereby giving possible indication of the existance of sub-populations. The tabular results of the calculated lengths for males and females for each year of life from the different sample areas are given in Appendix A.

Analyses of variance were performed between the sample areas and the calculated lengths of each age-group at given years of life with the sexes held constant. The only significant differences at the 5% level resulted between the areas and calculated lengths of age-group III males at both the third and second annulus, and between areas and the calculated lengths of age-group III females at both the third and second annulus.

Although these discrepancies in growth were noted between the areas, it is felt that they do not give positive evidence of existing sub-populations, but rather indicate a trend toward variation of growth between younger individuals inhabitating the different areas. This trend may finally result in the creation of isolated sub-populations through inter-specific competition for food and space between the alewife and the yellow perch.

Comparisons of Growth With That in Other Great Lakes Waters

Comparisons of growth in length between Big Bay de Noc and other Great Lakes waters (See Table 9) showed that fish from Lake Erie had a decidedly faster rate of growth throughout their life. Saginaw Bay and northern Lake Michigan fish both had comparable rates of growth, with those perch from Lake Michigan growing at a slightly more accelerated pace. The males of southern Green Bay and Big Bay de Noc also showed similar rates of growth. The Bay de Noc females grew at approximately the same rate as the males, while in Green Bay the disproportionate growth of the sexes was more pronounced in the later years of life.

Table 9

Growth in Length of Yellow Perch from Different Localities of the Great Lakes

(Sources of data: Lake Erie, Jobes (1952); Saginaw Bay, El-Zarka (1958); southern Green Bay and northern Lake Michigan, Hile and Jobes (1942); Big Bay de Noc, 1958 samples, present study)

Locality and Sex	Ave. Calculated Length (In.) at end of year						
	1	2	3	4	5	6	7
Lake Erie							
Male	3.6	6.6	8.4	9.4	10.1	....	....
Female	3.7	6.7	8.6	9.8	10.7	....	....
Sexes combined[1]	3.6	6.6	8.5	9.6	10.4	....	....
Saginaw Bay							
Male	2.6	4.2	5.6	6.7	7.6	8.5	9.3
Female	2.7	4.3	5.9	7.5	8.8	10.2	11.3
Sexes combined[1]	2.6	4.2	5.8	7.1	8.2	9.4	10.2
Southern Green Bay							
Male	2.9	4.6	6.0	7.4	8.4	9.6	10.3
Female	2.8	4.6	6.4	8.0	9.0	10.4	11.3
Sexes combined[1]	2.8	4.6	6.2	7.7	8.7	10.0	10.8
Northern Lake Michigan[1 & 2]	2.8	4.4	5.9	7.1	8.3	9.6	....
Big Bay de Noc							
Male	2.8	4.2	5.6	7.3	8.5	....	....
Female	2.8	4.4	5.8	7.4	8.7	....	....
Sexes combined[3]	2.8	4.3	5.7	7.4	8.7	....	....

[1]Unweighted means.

[2]No data for sexes separately.

[3]Weighted means.

Table 10 gives a comparison of the growth in weight at time of annulus formation between Great Lakes waters. As suspected, the faster growing Lake Erie stock was considerably heavier and maintained its consistent weight advantage over all other stocks. The Green Bay perch were heavier than those from Bay de Noc in the earlier years of life with the females maintaining their heavier status throughout. During the fifth year of life the Bay de Noc males surpassed those from Green Bay in weight.

Table 10

Growth in Weight of Yellow Perch from Different Localities of the Great Lakes

(Sources of data: Lake Erie, Jobes (1952); Saginaw Bay, El-Zarka (1958); southern Great Bay and northern Lake Michigan, Hile and Jobes (1942); Big Bay de Noc, 1958 samples, present study).

Locality and Sex	Average Calculated Weight (Ounces) at End of Year 1	2	3	4	5	6	7
Lake Erie							
Male	0.28	1.98	3.98	5.64	7.20	....	.....
Female	0.32	2.08	4.41	6.70	8.68	....	.....
Sexes Combined[1]	0.30	2.03	4.20	6.17	7.94	....	.....
Saginaw Bay							
Male	0.09	0.43	1.10	1.98	2.98	4.30	5.77
Female	0.10	0.46	1.31	2.86	4.82	7.79	10.27
Sexes Combined[1]	0.10	0.44	1.20	2.42	3.90	6.04	8.02
Southern Green Bay							
Male	0.14	0.60	1.38	2.57	4.16	6.28	7.90
Female	0.14	0.60	1.62	3.39	5.08	8.01	10.83
Sexes Combined[1]	0.14	0.60	1.50	2.98	4.62	7.14	9.36
Northern Lake Michigan[1 & 2]	0.21	0.78	1.73	2.93	4.73	7.16	.....
Big Bay de Noc							
Male	0.11	0.41	1.04	2.52	4.17	....	.....
Female	0.11	0.49	1.19	2.61	4.56	....	.....
Sexes Combined[3]	0.11	0.47	1.14	2.58	4.50	....	.....

[1]Unweighted means.

[2]No data for sexes separately.

[3]Weighted means.

COEFFICIENT OF CONDITION

The coefficient of condition, "K," is accepted as an index which describes the general "well-being" or "plumpness" of fish. This index value may be affected by any environmental factor having an influence on condition, such as availability of food. This value is also under the influence of many physiological factors, such as disease or state of sexual maturity, which may weaken or emaciate the individual, thereby causing a decline in relative heaviness. According to Jobes (1952) individual growth rate does not influence condition values in yellow perch and therefore condition cannot be correlated, as such, with growth.

The average coefficient of condition of the perch in Big Bay de Noc was derived by the formula:

$$K_{TL} = \frac{W \times 10^5}{L^3}$$

where K_{TL} is the condition factor based on total length,
W is the weight in grams,
and L is the total length in millimeters.

The K_{TL} value was determined for 135 males and 311 females from five different localities (Garden Bay, Gray's Springs, Puffy Bay, Garden Bluff, and Kates Bay). These data were compared by an analysis of variance, correcting for the unequal number of individuals per sample area and for the disproportion of sexes, as described by Snedecor (1956). The results of this analysis are shown in Table 11. The K_{TL} values between sample areas differed significantly at the 5% level, but they did not differ with regard to sex. That is to say, that K_{TL} values of males and females taken from the same locale did not differ, but there were differences between the K_{TL} values of sample areas. This might possibly be explained by the presence of sub-populations within the general stock, all other factors being equal.

A Multiple Range test (See Appendix B for explanation of test) described by Duncan (1955, 1957) was then performed on the separate sexes to determine which of the five areas these differences did occur. The ranked means of the males (See Table 12) singled out Kates Bay as having the lowest K_{TL} value and Garden Bay as having the highest. The test showed no significant differences at the 5% level between the means of the Garden Bay, Garden Bluff, Puffy Bay and Gray's Springs samples; and Gray's Springs and Kates Bay did not differ. The ranked means of the K_{TL} values of females exhibited the same order as those of the males with Kates Bay again having the lowest value. The test on the females (See Table 13) gave the following results: the means of Garden Bay, Garden Bluff, Puffy Bay

Table 11

Analysis of Variance Between "K_{TL}" Values of Sample Areas and Sexes.

(Interaction negligible with disproportionate sub-class numbers).

Area	Male n_1	Male X_1	Female n_2	Female X_2	W^1	D^2	WD
Gray's Springs	8	1.04	60	1.10	7.059	-0.6	-0.4235
Kates Bay	45	0.97	92	1.04	30.219	-0.7	-2.1153
Puffy Bay	15	1.13	31	1.12	10.109	0.1	0.1011
Garden Bluff	57	1.14	110	1.13	37.545	0.1	0.3755
Garden Bay	10	1.16	18	1.15	6.429	0.1	0.0643
					91,361		-1.9979

Preliminary Analysis of Variance of Original Data

Source	Degrees of Freedom	Sum of Squares	Mean Square
Total	445	8.4781	
Sexes	1	0.0583	0.0583
Areas	4	0.9999	0.2499
Individual	436	7.1902	0.0164

Interaction sum of squares: $\Sigma WD^2 - (\Sigma WD)^2/\Sigma W = 0.1352$

Correction for disproportion: S.S. of sexes $- \frac{(\Sigma WD)^2}{\Sigma W} = 0.01461$

Completed Analysis

Source	Degrees of Freedom	Mean Square
Sexes	1	0.04369
Areas	4	0.2463
Interaction	4	0.0338
Individuals	436	0.01649

Tests:

Sex $\frac{0.04369}{0.01649} = 2.64 \quad F_{(1,400)} = 3.86$

Area $\frac{0.24630}{0.01649} = 14.94^{**} \quad F_{(4,400)} = 2.39$

Interaction $\frac{0.03380}{0.01649} = 2.04 \quad F_{(4,400)} = 2.39$

$^1W = \frac{n_1 n_2}{n_1 + n_2}$ $\qquad$ $^2D = \bar{X}_2 - \bar{X}_1$

Table 12

Multiple Range Test to Determine the "K_{TL}" Values of Male Yellow Perch Not Significantly Different Between Sample Areas.

a) Analysis of Variance

Source	Degrees of Freedom	Mean Square
Between Areas	4	0.2162
Error	130	0.0213

s = 0.1459

b) Critical Values

p	(2)	(3)	(4)	(5)
Zp	2.77	2.92	2.92	3.09
R'p	0.4041	0.4260	0.4410	0.4510

c) Ranked Area Means and Replication Numbers.*

A	B	C	D	E
0.97	1.04	1.13	1.14	1.16
(45)	(8)	(15)	(57)	(10)

d) Test Sequence

			Results**
(E-A)'	= 0.7685	0.4510	
(E-B)'	= 0.3577	0.4410	(BCDE)
(D-A)'	= 1.2050	0.4410	
(C-A)'	= 0.7588	0.4260	
(B-A)'	= 0.2579	0.4041	(BA)

* Area code:

A - Kates Bay
B - Gray's Springs
C - Puffy Bay
D - Garden Bluff
E - Garden Bay

** The means within the parentheses are not significantly different at the 5% level.

Table 13

Multiple Range Test to Determine the "K_{TL}" Values of Female Yellow Perch Not Significantly Different Between Sample Areas

a) Analysis of Variance

Source	Degrees of Freedom	Mean Square
Between Areas	4	0.09120
Error	306	0.01446

s = 0.12024

b) Critical Values

p	(2)	(3)	(4)	(5)
Zp	2.77	2.92	3.02	3.09
R'p	0.3330	0.3511	0.3631	0.3715

c) Ranked Area Means and Replication Numbers.*

A	B	C	D	E
1.048	1.10	1.12	1.13	1.15
(92)	(60)	(31)	(110)	(18)

d) Test Sequence

			Results**
(E-A)'	= 3.369	0.3715	
(E-B)'	= 0.2631	0.3631	(BCDE)
(D-A)'	= 0.821	0.3631	
(C-A)'	= 0.4903	0.3511	
(B-A)'	= 0.44315	0.3330	(A)

* Area code:

A - Kates Bay
B - Gray's Springs
C - Puffy Bay
D - Garden Bluff
E - Garden Bay

** The means within the parentheses are not significantly different at the 5% level.

and Gray's Springs samples did not differ at the 5% level of significance as was found in the males. On the other hand, the mean value of the Kates Bay sample differed significantly from all other areas.

The four areas not significantly different with respect to mean K_{TL} values were within relatively close proximity to one another while Kates Bay was somewhat removed. It might therefore be postulated that the fish inhabitating the area between Garden Bluff and Gray's Springs are from one sub-population while those of the Kates Bay area are from another sub-population.

<u>Comparisons of the Average Condition Coefficient Between the Waters of the Great Lakes</u>

In order that comparisons might be made between the condition factor of Big Bay de Noc perch and other data previously reported for the Great Lakes, it was necessary to change the average K-total length value, (K_{TL}), to one corresponding to K-standard length, (K_{SL}). This conversion was done using the formula:

$$K_{SL} = r^3 K_{TL}$$

where K_{SL} is the condition factor based on standard length, K_{TL} is the condition factor based on total length, and r is the ratio of total length to standard length. The ratio of total length to standard length

(1.172), was determined by Hile (1942) for the yellow perch of Green Bay varying in standard length from 150 to 209 millimeters. This cubed ratio, multiplied by the average K_{TL} value (1.11), gave a resulting K_{SL} value of 1.79.

In comparison to other values reported from the Great Lakes, the Bay de Noc perch are considerably lighter for a given length. For Lake Erie perch, Jobes (1952) reports an average K_{SL} value of 1.91, while Hile and Jobes (1941) found a K_{SL} value of 1.8 for Saginaw Bay and Hile and Jobes (1942) reported values of 1.87 and 2.18 for Green Bay and northern Lake Michigan, respectively.

FOOD HABITS

The stomachs of 247 yellow perch were taken from five sample areas for subsequent food analysis. Table 14 gives the major groups of organisms consumed and the percentages of stomachs containing these food items. The percentages expressed are based only on the number of stomachs containing food and not the total number examined because it has frequently been demonstrated that fish may regurgitate their stomach contents after becoming entangled in the meshes of a gill-net.

Mayflies (*Hexagenia* and *Ephemera*), crayfish (*Cambarus*), isopods (*Asellus*), amphipods (*Gammarus* and *Hylalla*), and midge larvae (Tendipedidae) were the organisms represented most frequently in the stomachs of perch found in Big Bay de Noc. In the deeper waters of the Garden Bluff area a few larger perch were found to have fish remains in their stomachs. This was the only indication of fish predation encountered. The species of these fish could not be determined due to advanced state of digestion.

Coots (1956) reported small crustaceans, snails, and fish as the primary food of the yellow perch in the Klamath River, California. Ostracods, copepods, and midge larvae are the major food items of young perch, according to

Table 14

Frequency Distribution of Food Items in Stomachs of 247 Yellow Perch, Expressed as Percentage of Stomach in Which Various Items Were Found.

Sample Area and Date	No. of Stomachs With Food	Iso-pods	Cray-fish	Amphi-pods	Caddis-flies	May-flies	Midges	Fish	Snails	Others
Puffy Bay July 9, 1958	20	5	40	20	35	65	5	..	..	..
Garden Bluff July 10, 1958	46	2	4	4	13	61	13	17	2	..
Garden Bay July 11, 1958	53	13	87	20	67	27	7	..	17	7
Gray's Springs July 15, 1958	9	79	30	27	13	11	40	..	1	17
Kates Bay July 15, 1958	22	..	55	64	41	68	14	..	14	5

Turner (1920) and Langford and Martin (1941). Moffett and Hunt (1943) found that winter predation by large yellow perch on bluegills was prevalent.

PARASITES

A sample of 50 yellow perch ranging in size from 205 to 241 millimeters was taken by gill-nets from Garden Bay on November 27, 1958. The fish were immediately examined for external parasites. This examination covered the head, eyes, fins, body, gills, and opercula. No macroscopic parasites were noted.

The gills and vicera were then removed and placed in polyethylene bags. This material was kept under refrigeration from five to seven days at a temperature of approximately 38° F. after which a complete examination was made. This examination consisted of washing the gills and vicera with isotonic saline and then opening and inspecting the entire alimentary tract. All organs were checked for cysts or free parasites. The parasites found were transferred to tap water where they remained for 20 minutes. They were then killed by immersion in a mixture of hot alcohol-formalin-glacial acetic acid. No parasitic forms were found in 11 of the 50 fish examined.

The trematodes and acanthocephalans were stained in Semicon's carmine and mounted in a commercial medium, Permount. The nematodes were placed in vials containing a mixture of three parts 70% ethyl alcohol and one part glycerin, and the vials left unstoppered. More glycerin was added as the alcohol evaporated. After five days in highly concentrated glycerin, the specimens were mounted in a glycerin-gel medium.

Identifications were made using the keys and descriptions in Van Cleave (1932), Meyer (1954), and Hopkins (1934).

Only four species of parasites were found in the 50 perch comprising the sample. These species were:

TREMATODA

Order Digenea

Family Allocreadiidae

Bunodera lucioperidae (Mueller, 1776)

This small trematode was found in the stomach and intestine of 38% of the fish examined with an average incidence of 3.1 specimens per host. Van Cleave (1934) reported only a single specimen of B. lucioperidae taken from the yellow perch in Oneida Lake, while Pearse (1924) and Fischthal (1945) recorded the species as abundant in the perch of Wisconsin.

Van Cleave noted this genus not only to be of high intensity in perch populations inhabiting shallow water, but also as having seasonal limitations. No forms were recorded during the summer months of June and July. During the colder months Bunodera was found in abundance.

ACANTHOCEPHALA

Order Palaeacanthocephala

Family Echinorhynchidae

Echinorhynchus salmonis Mueller

E. salmonis occurred in 32% of the samples and was found exclusively in the lower intestine. The average number of individuals per host was 2.7.

This genus was not reported in fish from Oneida Lake by Van Cleave, in Wisconsin by Fischthal, or in Maine by Meyer (1954). Bangham (1955) found *E. salmonis* in 23 species of fish in Lake Huron; approximately 3% of the perch examined were infested.

NEMATODA

Order Camallanoidea

Family Cucullanidae

Dichelyne cotylophora (Ward and Magath, 1916)

The adult form of *D. cotylophora* occurred throughout the intestine while immature worms were found quite frequently encysted in the liver. A single adult specimen was located in the cystic duct. Twenty-four percent of the sample harbored this parasite with an average of 1.7 individuals per host.

Van Cleave reported yellow perch were the chief host of *D. cotylophora* in Oneida Lake, with an incidence of infestation running 60% and the occurrence of 10 to 15 worms per host. This form has no seasonal variation and is found in hosts from all depths. Bangham noted incidence of infestation to be 50% in the perch of Lake Huron. The species is also abundant both in Maine and Wisconsin.

NEMATODA

Order Spiruroidea

Family Spiruridae

Spinitectus gracilis (Ward and Magath, 1917)

A single larval form of the genus *Spinitectus* was collected from the stomach mucosa. This individual was tentatively identified as *S. gracilis*.

The genus is correlated with mud bottom and its occurrence is independent of depth according to Van Cleave who reported only larval forms infesting the yellow perch of Oneida Lake, while Bangham found mature individuals in the perch of Lake Huron.

RELATIVE ABUNDANCE

During the years 1944-1949, the fishing intensity for yellow perch was relatively stable in the State of Michigan waters of Green Bay as shown in Table 15. (The percentages given in this table are expressed as percentages of the 1929-1943 mean for both fishing intensity and abundance.) The average fishing intensity for this period of six years was 33.7 percent. With the decline in abundance of the lake trout and the whitefish in 1949 and 1950, commercial fishermen turned to the less economically desirable yellow perch as a "buffer" species in hopes it would sustain them until the two more profitable species reached their former levels of abundance. Between 1950 and 1957 the average intensity for perch increased to 62.6 percent. Relative abundance during this period showed a constant rise to a record high in 1957. Coupled with this sharp increase in abundance was the upward trend of production which, along with intensity, reached a peak in 1955 and after a slight decrease, held stable in 1956 and 1957.

The sharp increase in abundance of perch was first noticed in 1953. Going on the assumption that an average of 5 years of growth is required for a fish to reach commercial size, it would mean that the 1948 year class, and

Table 15

Production in Thousands of Pounds, Abundance and Fishing Intensity (Expressed as Percentages of the 1929-1943 Mean) of Yellow Perch in the State of Michigan Waters of Green Bay, 1943-1957.*

Year	Production	Abundance	Intensity
1943	125	67	52.6
1944	49	63	22.1
1945	151	150	28.4
1946	116	112	29.3
1947	70	64	31.1
1948	66	53	35.1
1949	65	49	37.6
1950	107	52	58.4
1951	66	46	41.0
1952	175	79	62.3
1953	251	121	58.3
1954	345	138	70.7
1955	411	141	82.3
1956	322	128	71.1
1957	330	165	56.4

* Data received from Hile, personal communication, 1959.

those immediately subsequent to it, were strong year classes. The strength of these year classes coincided well with the sharp decrease in abundance of the lake trout in particular. It is also interesting to note that in 1948 and 1949 the walleyed-pike reached a peak of abundance and this seemingly had no noticeable effect on the resulting abundance of these same years classes of yellow perch (Hile et al., 1953).

At present, the abundance of yellow perch is at an all time high. Whether this peak of abundance can stabilize or be maintained depends largely on the inter-specific competition afforded the perch by remaining species in the biomass such as the walleyed-pike and the alewife which utilize the same habitat as does the perch.

It is felt that the sudden "explosive" appearance of the alewife may, through direct and indirect competition, be a decisive factor in bringing about a decline in the overall abundance of the yellow perch in future times. The explanation of the consistent decline in growth rates of the 1955 and 1956 year classes of yellow perch in Big Bay de Noc may be found in this factor of inter-specific competition, and also may preview future occurrences.

SUMMARY

1. The yellow perch, Perca flavescens (Mitchill), is an important food and sport fish due to its wide distribution and abundant numbers.

2. In the Green Bay area of Lake Michigan the commercial production of yellow perch has, during the past 38 years, averaged well over 150 thousand pounds per year. Big Bay de Noc produces between 10 and 30 percent of this annual total.

3. This present study was based on 1095 specimens, 1045 of which were used in the calculation of growth histories.

4. The body-scale relationship for the yellow perch of Big Bay de Noc was determined by a linear regression of body length on scale radius for 104 perch ranging in size from 30-310 millimeters. The computed equation was:

$$Y = 25.95 + 1.269\ X$$

5. The relation between total length in millimeters and weight in grams of 392 Bay de Noc perch taken in July, 1958, was described by the equation:

$$W = 3.437 \times 10^{-5}\ L^{3.257}$$

6. The calculated lengths at a given age were consistently larger in the older fish. The discrepancies

noted were exactly the opposite of those described by Lee.

7. The cause of these discrepancies in the Big Bay de Noc perch is attributed to differential growth rates between the varying year classes due to inter-specific competition.

8. The length of the sexes was similar in the first year of life after which the females maintained a consistent 3-6 millimeter length advantage within each age-group.

9. The annual increments of growth in length decreased with age after the first year in both sexes. Both males and females reached the legal commercial size of 8½ inches after 5 years of growth.

10. The compared calculated growth histories of the different sample areas gave no indication of the presence of faster or slower growing sub-populations. Although differences in growth were found in the younger age-groups, they were attributed to the natural variation of growth between the sample areas.

11. The growth in length of Big Bay de Noc perch is comparable to that found in southern Green Bay and is slightly higher than reported for northern Lake Michigan.

12. The growth in weight of the Big Bay de Noc perch was slower in the younger fish when compared to other

Great Lakes stocks but had a more rapid proportional increase than any other stock after the third year of life.

13. The coefficient of condition was determined for 135 male and 311 female perch from five sample areas. The average coefficient of condition based on standard length of the Bay de Noc perch was 1.79, which was less than that reported for the other Great Lakes stocks.

14. There were no significant differences found between the coefficient of condition of males and females. The condition index was not found to be correlated with size or age, but significant differences were found to occur between the Kates Bay area and all other sample areas.

15. Mayflies, crayfish, aquatic isopods, amphipods, and midge larvae were the food items most frequently represented in the stomachs of yellow perch. Very little fish predation was exhibited by the perch of Big Bay de Noc at the time of sampling.

16. Only four species of internal parasites were found to infest the local perch population. None of these species was represented in great abundance and no external parasites were noted on any of the fish specimens.

17. The relative abundance of the yellow perch in Green Bay is now at an all time high. Whether the

population of perch now occurring is able to stabilize at its present level depends largely on the competition afforded it by the other species inhabiting the same ecological niche.

APPENDIX

APPENDIX A

Calculated Total Length at the End of the Different Years of Life for Yellow Perch (Sexes Combined) from Kates Bay Collected on January 27, 1958

Age Group	Number of Fish	Length (millimeters) at End of Year 1	2	3	4	5	6
III	318	68	112 (45)*	162 (50)	...	...	...
IV	72	68	113 (45)	155 (42)	191 (40)	...	...
V	10	70	110 (40)	150 (40)	188 (38)	224 (36)	...
VI	2	74	115 (41)	165 (50)	195 (30)	231 (36)	269 (38)
Grand average calculated length		68	112	160	191	225	269
Increment of average		68	44	48	31	34	44
Grand average increment of length		68	45	48	40	36	38
Accumulation of average increments		68	113	161	201	237	275

* Increments in parentheses.

Calculated Total Length at the End of the Different Years of Life for Yellow Perch (Sexes Combined) from Nahma Flats Collected on May 23, 1958

Age Group	Number of Fish	Length (millimeters) at End of Year 1	2	3	4	5	6	7
IV	9	76	126 (50)*	175 (49)	219 (44)	...	...	...
V	30	74	125 (51)	170 (45)	205 (35)	233 (28)	...	...
VI	8	74	119 (45)	160 (41)	198 (38)	225 (27)	251 (26)	...
VII	1	74	128 (54)	165 (37)	190 (25)	219 (29)	248 (29)	271 (23)
Grand average calculated length		74	124	169	206	231	251	271
Increment of average		74	50	45	37	25	20	20
Grand average increment of length		74	50	45	37	28	26	23
Accumulation of average increments		74	124	169	206	234	260	283

* Increments in parentheses.

Calculated Total Length at the End of the Different Years of Life for Yellow Perch (Sexes Combined) from Garden Bluff Collected on May 23 and May 24, 1958

Age Group	No. of Fish	Length (millimeters) at End of Year							
		1	2	3	4	5	6	7	8
IV	23	73	126 (53)*	172 (46)	209 (37)	...	...	...	...
V	88	72	115 (43)	165 (50)	200 (35)	228 (28)	...	...	...
VI	21	72	119 (47)	165 (46)	200 (35)	226 (26)	250 (24)	...	...
VII	1	77	120 (43)	183 (63)	211 (28)	234 (23)	253 (19)	273 (20)	...
VIII	1	79	114 (35)	144 (30)	188 (44)	229 (41)	257 (28)	276 (19)	297 (21)
Grand average calculated length		72	118	166	202	228	250	274	297
Increment of average		72	46	48	36	26	22	24	23
Grand average increment of length		72	45	49	35	28	24	20	21
Accumulation of average increments		72	117	166	201	229	253	273	294

* Increments in parentheses.

Calculated Total Length at the End of the Different Years of Life for Yellow Perch from Puffy Bay Collected on July 9, 1958

(Females)

Age Group	Number of Fish	Length (millimeters) at End of Year 1	2	3	4	5
III	23	71	106 (55)*	144 (38)	...	...
IV	7	69	109 (40)	143 (34)	180 (37)	...
V	1	71	113 (42)	166 (53)	194 (28)	229 (35)
Grand average calculated length		71	107	144	181	229
Increment of average		71	36	37	37	48
Grand average increment of length		71	51	38	36	35
Accumulation of average increments		71	122	160	196	231

(Males)

Age Group	Number of Fish	Length (millimeters) at End of Year 1	2	3	4
II	1	64	113 (49)	...	...
III	10	72	105 (33)	136 (31)	...
IV	4	66	113 (47)	155 (42)	186 (31)
Grand average calculated length		70	108	141	186
Increment of average		70	38	33	45
Grand average increment of length		70	38	34	31
Accumulation of average increments		70	108	142	173

* Increments in parentheses.

Calculated Total Length at the End of the Different Years of Life for Yellow Perch from Garden Bluff Collected on July 10 and July 16, 1958

Females

Age Group	No. of Fish	Length (millimeters) at End of Year							
		1	2	3	4	5	6	7	8
III	76	73	106 (33)*	140 (44)	...	...	...	...	...
IV	16	67	115 (48)	155 (40)	184 (29)	...	...	...	...
V	13	72	114 (42)	161 (47)	191 (30)	221 (30)	...	...	...
VI	4	64	107 (43)	149 (42)	185 (36)	218 (33)	246 (28)	...	...
VII	1	71	118 (47)	160 (42)	205 (45)	229 (24)	259 (30)	294 (35)	...
VIII	1	78	127 (49)	169 (42)	213 (44)	238 (25)	260 (22)	284 (24)	308 (24)
Grand average calculated length		72	109	145	188	222	251	289	308
Increment of average		72	37	36	43	34	29	38	19
Grand average increment of length		72	37	44	31	30	27	29	24
Accumulation of average increments		72	109	153	184	214	241	270	294

* Increments in parentheses.

Calculated Total Length at the End of the Different Years of Life for Yellow Perch from Garden Bluff Collected on July 10 and July 16, 1958

Males

Age Group	Number of Fish	Length (millimeters) at End of Year 1	2	3	4	5
III	47	74	106 (32)*	136 (30)	...	...
IV	8	68	107 (39)	148 (41)	181 (33)	...
V	2	71	107 (36)	151 (44)	195 (44)	223 (28)
Grand average calculated length		73	106	138	184	223
Increment of average		73	33	32	46	39
Grand average increment of length		73	33	32	35	28
Accumulation of average increments		73	106	138	173	201

* Increments in parentheses.

Calculated Total Length at the End of the Different Years of Life for Yellow Perch from Garden Bay Collected on July 11, 1958

Females

Age Group	Number of Fish	Length (millimeters) at End of Year 1	2	3	4
III	16	72	113 (41)*	161 (48)	...
IV	2	73	104 (31)	159 (55)	190 (31)
Grand average calculated length		72	112	161	190
Increment of average		72	46	49	29
Grand average increment of length		72	40	49	31
Accumulation of average increments		72	112	161	192

Males

Age Group	Number of Fish	Length (millimeters) at End of Year 1	2	3	4	5
III	5	68	101 (33)	131 (30)	...	...
IV	4	62	100 (38)	151 (51)	185 (34)	...
V	1	66	103 (37)	169 (66)	202 (33)	225 (23)
Grand average calculated length		65	101	143	188	225
Increment of average		65	36	42	45	37
Grand average increment of length		65	35	42	34	23
Accumulation of average increments		65	100	142	176	199

* Increments in parentheses.

Calculated Total Length at the End of the Different Years of Life for Yellow Perch from Gray's Springs Collected on July 12 and July 15, 1958

Females

Age Group	Number of Fish	Length (millimeters) at End of Year 1	2	3	4
I	2	66	...	...	...
II	6	62	100 (38)*	...	...
III	53	72	113 (41)	146 (33)	...
IV	3	66	119 (53)	155 (36)	190 (35)
Grand average calculated length		71	112	146	190
Increment of average		71	41	34	44
Grand average increment of length		71	41	33	35
Accumulation of average increments		71	112	145	180

Males

Age Group	Number of Fish	Length (millimeters) at End of Year 1	2	3	4	5
III	7	75	108 (33)	146 (38)	...	...
V	1	66	107 (31)	137 (30)	165 (28)	190 (25)
Grand average calculated length		74	108	145	165	190
Increment of average		74	34	37	20	25
Grand average increment of length		74	33	37	28	25
Accumulation of average increments		74	107	144	172	197

* Increments in parentheses.

Calculated Total Length at the End of the Different Years of Life for Yellow Perch from Kates Bay Collected on July 13 and July 15, 1958

Females

Age Group	Number of Fish	Length (millimeters) at End of Year 1	2	3	4	5
III	79	72	106 (34)*	146 (40)	...	...
IV	11	68	119 (51)	153 (34)	188 (35)	...
V	3	64	108 (44)	162 (54)	195 (33)	223 (26)
Grand average calculated length		71	108	147	190	223
Increment of average		71	37	39	43	33
Grand average increment of length		71	36	40	34	26
Accumulation of average increments		71	107	147	181	207

Males

Age Group	Number of Fish	Length (millimeters) at End of Year 1	2	3	4
III	36	69	104 (35)	140 (36)	...
IV	9	69	108 (39)	154 (46)	185 (31)
Grand average calculated length		69	105	143	185
Increment of average		69	36	38	42
Grand average increment of length		69	36	38	31
Accumulation of average increments		69	105	143	174

* Increments in parentheses.

APPENDIX B

Multiple Range Test

The mean K_{TL}, or coefficient of condition values, derived from five sample areas were subjected to an "F" test to determine whether area differences existed. The "F" test showed statistical differences, and the Multiple Range test as described by Duncan (1955, 1957) was performed to determine between which areas these differences occurred. This test is designed to group means that have unequal numbers of observations yet are not significantly different.

The procedure is as follows:

Section A, is a preliminary analysis of variance to determine the error standard deviation, "s".

Section B, is the computation of a critical value, R'p. This value is found by multiplying the "s" value from Section A by a Zp value which is obtained from a table of Studentized "t" values by Duncan (1955).

Section C, is the coding of sample means with respect to ascending magnitude. The number in parentheses is the number of observations (= replications) used to determine the mean.

Section D, is the test sequence. The lowest mean value is subtracted from the highest and the difference is altered to a prime value by multiplying it by A_{ij}.

$$A_{ij} = \sqrt{2r_i r_j/(r_i + r_j)}$$

Where: r_i = number of observations of lower mean

and r_j = number of observations of higher mean.

The prime values are then compared to the critical value, Zp, corresponding to the number of means lying between the two means being tested, plus two. If the prime value does not exceed the Zp value, then the means being tested along with those intermediate ones are not significantly different provided a larger replication number is not present between the two means being tested. If this is the case, then the test must be continued to see if the mean with the larger number of observations will be excluded from the group.

If the prime value does exceed the Zp value, then the test continues using the largest mean and the next smallest one. The test sequence is brought to a close after all possible combinations of non-different mean groups are obtained.

See Tables 12 and 13 for actual data analysis by the Multiple Range test.

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