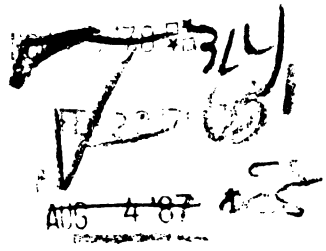

OBSERVATIONS ON THE GROWTH RATE OF THE LARGEMOUTH BLACK BASS (MICROPTERUS SALMOIDES) IN WINTERGREEN LAKE KALAMAZOO COUNTY, MICHIGAN

by

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ABSTRACT

A study of the rate of growth of the largemouth bass in a eutrophic lake should furnish important information to fishery biologists. Wintergreen Lake, Kalamazoo County, Michigan is atypical, because the lake is located on the W. K. Kellogg Bird Sanctuary; the droppings of the birds using this lake is of unknown intensity, probably high as evidenced by the abundance of plankton. This fertilization is doubtlessly reflected in the growth rate of the fish.

Scales were pressed in plastic, and the resulting impression projected by means of a scale projector as described by Van Oosten, et. al. (1934). Magnifications were 45 and 22 diameters depending upon the size of the scale being read. The diameters of the annuli were marked directly on the Keysort card; previous lengths were determined by the use of a nomograph as described by Carlander (1950).

The data is presented in two sections; observations at the time of capture, and calculated lengths. The mean length, standard deviation, and coefficient of variability are presented for each group. The K factor is given for the mean values at the time of collection.

The annulus apparently is formed during May. A possible quantitative method for determining the time of

annulus formation is presented, based on the April collections having maximum weights and lengths while the May collections have minimum.

The production of largemouth bass is probably high as indicated by the very rapid growth until the formation of the fourth annulus. The rate of growth of the older age groups show a marked decrease when compared with other Michigan largemouth bass. The total length at any age for the fish in this study is greater than that for Michigan fish because of the rapid growth during the early years being so great that the comparable fish never approach these lengths at a given age, in spite of the growth rate for comparable fish exceeding that of these fish during the latter years of life.

Introduction

Of the many species of fish found in the lakes of southern Michigan, the largemouth bass has received little scientific attention with regard to its growth. It is true that Eschmeyer (1939) and Beckman (1942, 1948, 1949) mention the rate of growth of the largemouth bass. Inasmuch as this fish is possibly the most popular game fish of warm waters, and thus because of its economic importance, a study of its rate of growth in a eutrophic lake, the most common lake type in southern Michigan, should furnish valuable information to those interested in the further utilization of our natural resources.

Description of the lake.

Wintergreen Lake, located within the W. K. Kellogg Bird Sanctuary in Kalamazoo County, Michigan, has a surface area of 38.3 acres with an approximate maximum depth of 21 feet and a mean depth of 7.5 feet. Throughout most of the lake is found submerged or floating vegetation of various kinds. The lake, a part of the bird sanctuary, has a large resident waterfowl population, and furthermore many migratory waterfowl rest and feed at the lake in the spring when they are flying north and in the fall on their southward trips. Their droppings furnish an unknown quantity of fertilizer,

but it may be presumed from the vigorous and heavy phytoplankton bloom and the abundance of cladocerans and other small crustacea that the quantity is quite great.

Materials and Methods

Method of capture.

The largemouth bass is notorious for its ability to avoid capture by gill netting or seining; therefore, in order to get the 228 for this study it was necessary to capture them by angling (see table no. 1). The January and February collections were made by fishing through the ice; the remainder of the collections were caught by bait casting and fly fishing. Of all the various lures used the most effective were surface plugs cast as near to the shore as possible and retrieved with a quick pull alternated with a pause, an effective means of collection. "Popping bugs," fly casting lures, were used similarly, but they caught more bluegills than largemouth bass. Bait fishing, while effective, resulted in injury to the fish from the removal of swallowed hooks and made this method of capture impractical. It was desirable to return the fish to the lake with minimum injury because of the population study being conducted concurrently with the age and growth study.

Table 1

Period of capture for the various age groups.

Table 1.

Collection period	Age group I	II	III	IV	V	VI	VII
Jan.		14	4	2	1	1	1
Feb.		6		1	1	2	1
Mar.							
April		21	19	26	16	8	3
May	6	21	3	1	3		
June				3	2	1	
July		15	2		2	1	
Aug.		18	5	8	2	3	2
Total	6	96	33	41	27	16	7

Recording of data.

At the time of capture the fish were held in a milk can with several gallons of water until four or five fish were collected. As each individual was removed from the can, it was measured for its standard and total lengths to the nearest millimeter, and weighed to the nearest gram. These data were recorded on the scale collection envelope, after which a scale sample was taken from each fish.

Scale sample.

The scale sample was removed from the left side, below the lateral line, ventral to the insertion of the dorsal fin. The scales were placed in the scale collection envelope and the date of capture was recorded on the envelope.

Scale cleaning and pressing.

For the convenience of the investigator, and to insure more accurate observations, the scale impression method was used rather than the mounting of the scale proper. Scales from each sample were prepared in the following manner. First, several were cleaned in the laboratory by soaking the sample in a watch glass of warm water and detergent for thirty minutes following which the foreign matter was removed with the aid of a small brush. Each scale which was selected for pressing was then examined by means of a binocular microscope

(magnification forty diameters), the regenerated and damaged scales were discarded. Four scales were selected and dried with absorbent toweling and fastened to a plastic sheet with the sculptured side of the scale in contact with the plastic.

This plastic sheet consisted of clear cellulose acetate, two and one half inches by four and one half inches by twenty thousandths of an inch in thickness. A metal stylus was used to rule the plastic sheet into six divisions each of which measured three quarters of an inch by two and one half inches. Each division of the sheet was inscribed with its appropriate collection number, and the scales corresponding to the numbers were fastened to the section by means of cellophane tape.

This plastic sheet with the scales attached was then placed in a heated hydraulic press for two minutes (temperature: seventy-five degrees centigrade; pressure: twenty-five hundred pounds per square inch). Excessive pressure (above thirty-five hundred pounds per square inch) and/or a temperature greater than eighty degrees centigrade caused a change in the shape of the plastic sheet which resulted in distortion of the scale impression. After pressing, the plastic sheet was withdrawn from the press and the cellophane tape and scales were removed from the plastic sheet. The sheet was next cut into the previously inscribed divisions which made placement in the scale projecting machine easier. The scale impression was then ready for study by projection.

Scale projection.

In order to study the scale impressions they were projected for reading by the use of a scale viewing machine described by Van Oosten, et. al. (1934). The objective lenses which were used were of thirty-two and forty-eight millimeter focal length, respectively, depending upon the size of the scale being projected. The magnification with these lenses was forty-five diameters for the thirty-two and twenty-two diameters for the forty-eight millimeter lens.

Scale measurement.

The greatest length from the focus to the most anterior edge of the scale was the radius used for the scale measurement. The annuli were marked directly on the Keysort cards which were adapted for this use. (For a discussion of these cards and their use see Casey, (1946) and Adams (1960).) Collection number and diameters of magnification were recorded on the card at the time of reading. Later, other data were copied from the scale collection envelope and placed on the corresponding Keysort card.

Calculations.

Of the 225 samples studied, several were not included in the calculations because excessive scale erosion made accurate reading doubtful.

Statistical analysis of the data was used to give a better measure of variation and assist in comparison with other studies.

The determination of lengths at the time of annulus formation; that is, the length of the fish at a known period prior to its capture, was accomplished by the use of a straight line nomograph as described by Carlander and Smith (1944).

For determining the mean length and standard deviation for each group the measurements were grouped to the nearest centimeter: if the length was recorded as ending in .5 the next larger centimeter class was used provided the .5 was preceded by an odd number; if the .5 was preceded by an even number the smaller class was used.

It was desirable to compare various divisions of the data with regard to variability. To aid in this comparison the coefficient of variability is given for each division. Snedecor (1946), speaking of the coefficient of variability, says it is desirable "....to compare the standard deviations of samples, after making some compensation for the differing sizes of their means." To determine the coefficient of variability, the standard deviation is divided by the mean; and the result expressed as percent.

For determining whether mean values differ significantly, the t test has been used (Snedecor 1946).

The coefficient of condition, K, has been used to describe the condition or "well-being" of fish. The K factor (K is equal to 10^5 times the weight in grams, divided by the cube of the length in millimeters) for the mean value of the various collection periods is presented for comparison with other data. These values of K were determined by the use of the alinement chart (Carlander 1950).

"Age group" as used in this study is determined by the number of annuli present on the scale. For example, a scale having two annuli is placed in age group II.

Presentation of data.

The data are presented in two sections; one considering the measurements at capture and the other including the calculated lengths. The first section presents the total weight in grams and the total length in centimeters at the time of collection. This section is divided into groups according to age classes and month of collection. The second section presents the calculated lengths at the time of annulus formation. The divisions of this section are by age groups determined by the number of annuli present. By using the length at the time of capture, growth occuring during the time of collection (January 1951 through August 1951) is eliminated from the calculations. This in effect, gives an instantaneous sample of the population for calculation. The

data are presented in this manner to simplify statistical analysis or comparison with other data.

Annulus Formation

The annuli are marks on a scale that denote breaks in the growth of the scale (Carlander 1950); one annulus is formed each year. The annuli are used to determine the age of the scale, and therefore the age of the fish from which the scale was removed. As an aid in determining age it is desirable to know when the annulus is formed.

Beckman (1943) states "....in all but exceptionally cold years the formation of the annulus may be expected to be completed in zone one by the middle of May... ." Zone 1 includes Wintergreen Lake.

The annulus of the largemouth bass used in this study appeared to form during the month of May for the year 1951: some of the individuals collected during the month of May show no annulus for the year 1951, and some show a recently formed annulus.

Another observed phenomen which may indicate the time of annulus formation is the apparent decrease of length and weight for a specific age group during the month of May in contrast to increases in length and weight during the other months. (See figures 1, 2, 3, and 4)

Figure 1

Age group II; growth increment in centimeters from January until time of collection.

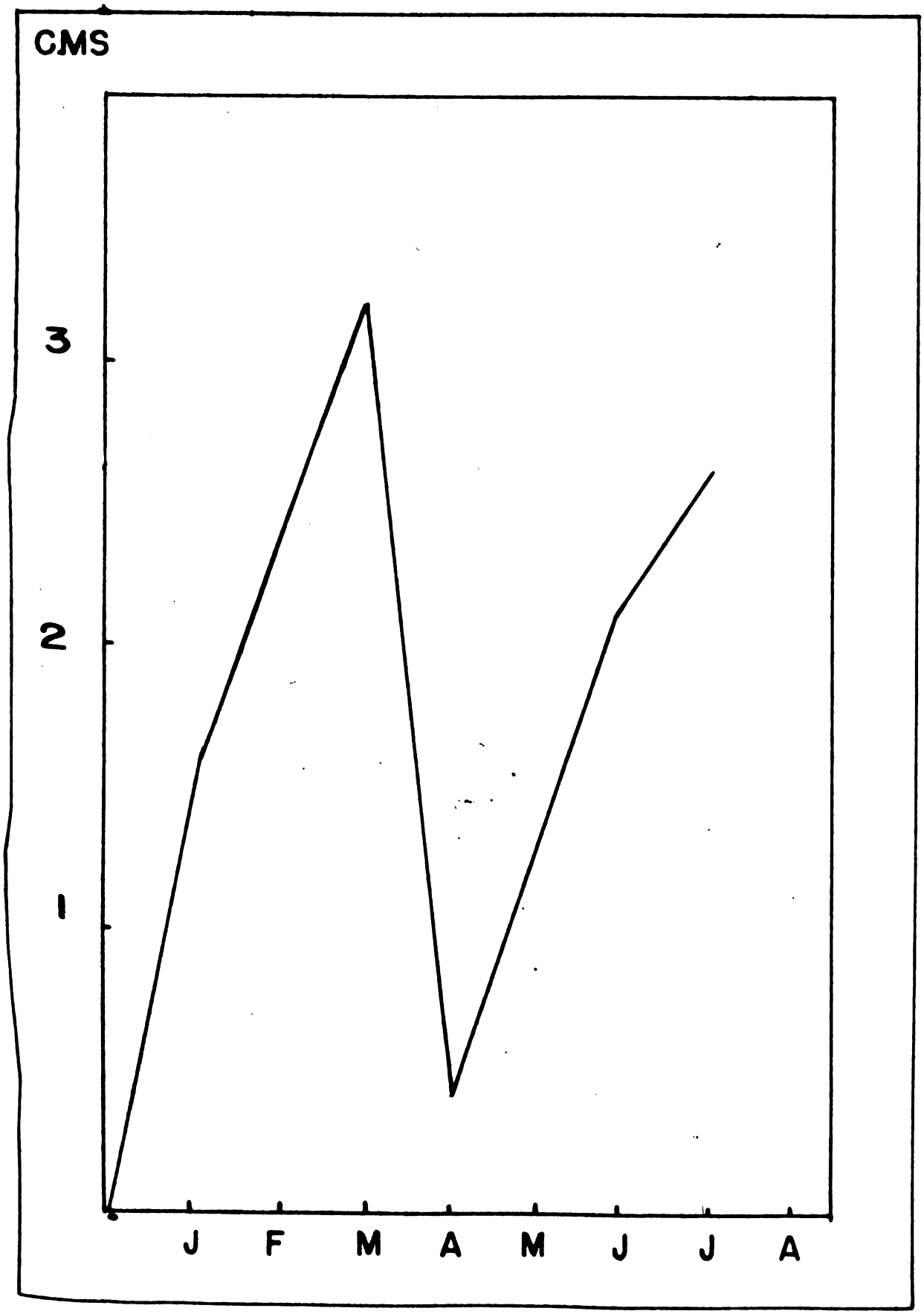

CMS
3
2
1
J
F
M
A
M
J
J
A

Figure 2

Age group II; mean weight increment in grams from January until time of collection.

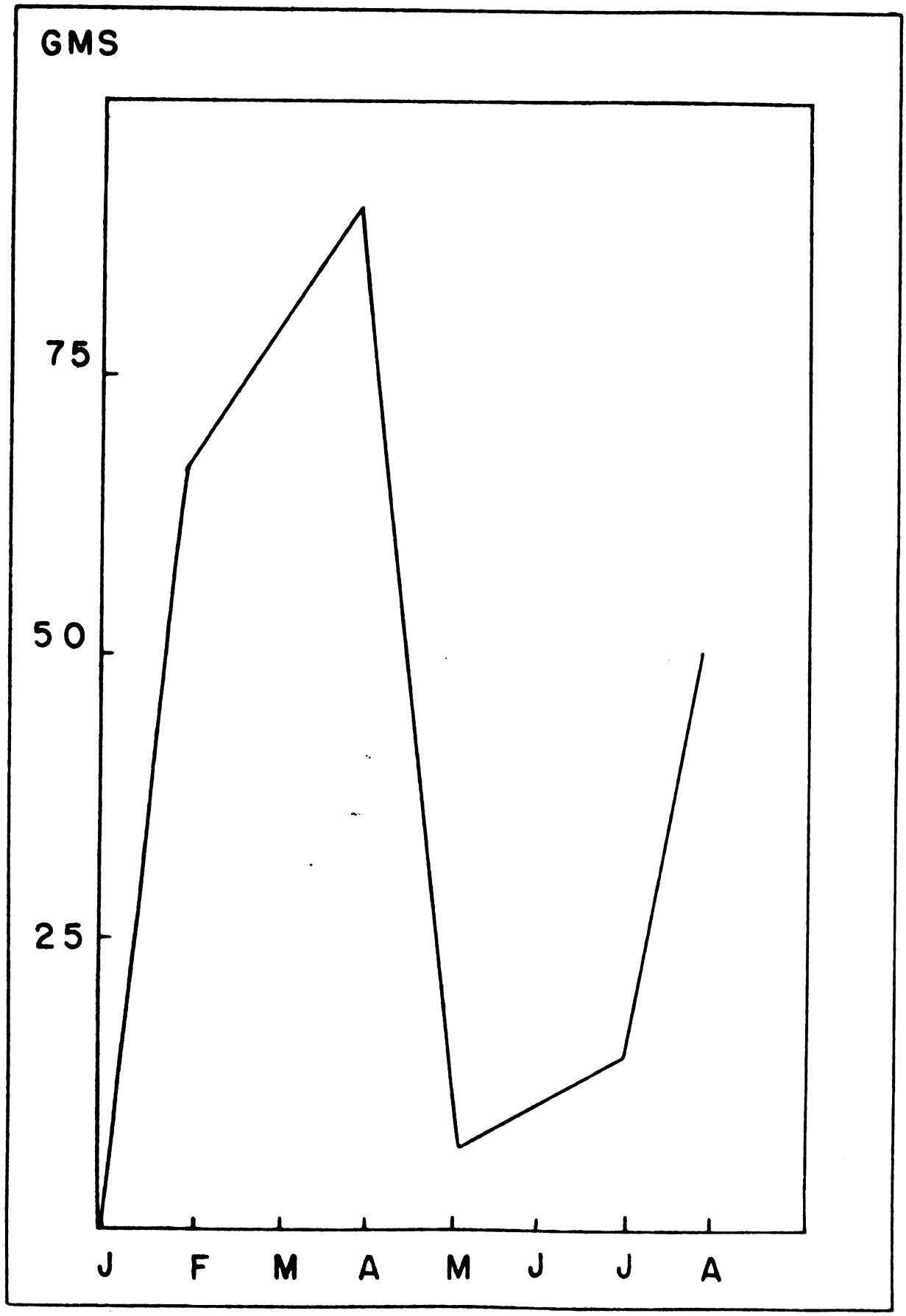

GMS
75
50
25
J
F
M
A
M
J
J
A

Figure 3

Age group II; mean total length in centimeters by month of collection.

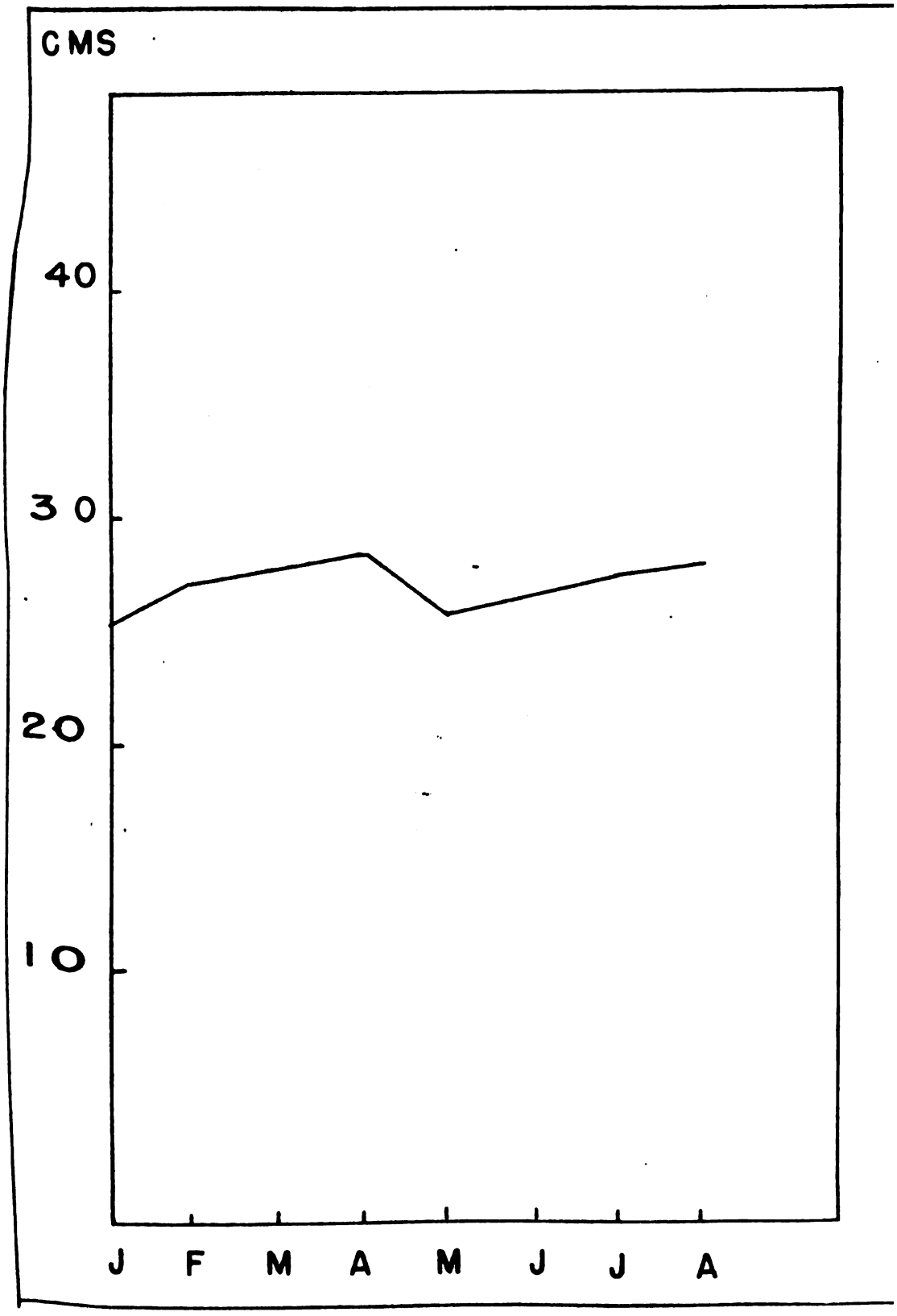
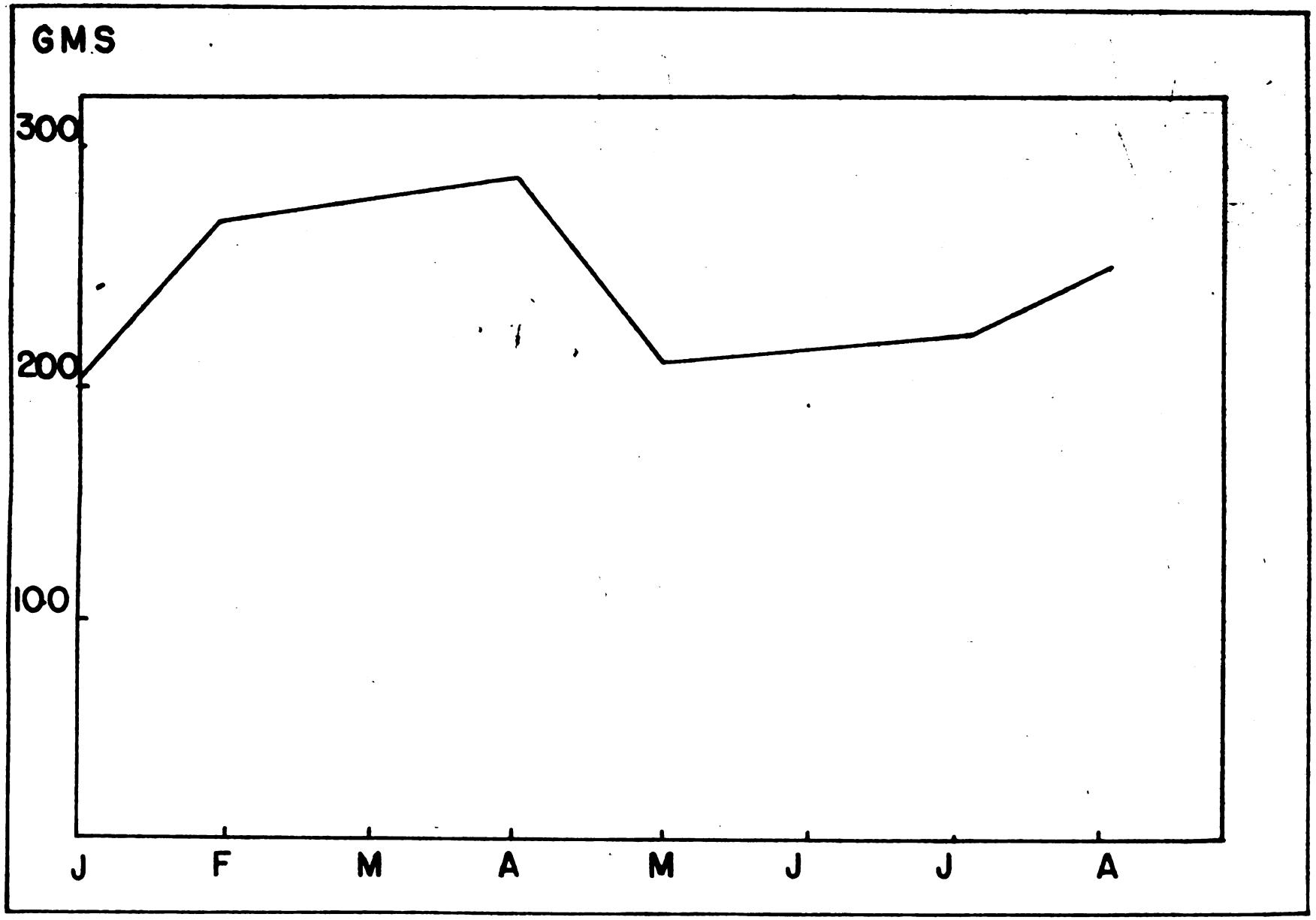

CMS
40
30
20
10
J
F
M
A
M
J
J
A

Figure 4

Age group II; mean weight in grams

by month of collection.


GMS
300
200
100
J
F
M
A
M
J
J
A

A possible explanation for this paradoxical apparent decrease of mean length for the members of age group II is as follows: during the period of annulus formation, the collection may have included some individuals with a recently formed annulus and some which had not yet formed their annulus. As an age group, x for example, forms its annulus, it then becomes a part of the next older age group, x + 1. Fish of the next younger age group, x - 1, of lesser mean length, form their annuli during the same period and then become members of the age group x. A sample of the population collected during this particular period includes a number of individuals which had just entered the class by reason of the recently formed annulus and, therefore, have achieved little or no growth while members of this class. This results in the observed decrease of mean length for a given age group during the time the annulus is being formed.

The same factors are believed to account for the difference of mean weights for the fish collected during May and those collected during April. The t test reveals the difference to be significant at the five percent level for weights, although not for the lengths, for the fish of age group II.

This apparent contradiction may be explained as follows: the difference of mean weights (61 g.) is large enough to show a significant difference by the t test, while the difference of mean lengths (2.9 cm.) is not large enough for this test

to show significance. This may be accounted for, in part, by a small difference in length resulting in a much greater difference in weight, since the weight increases approximately with the cube of the length.

Weight and length comparisons

Collection period discussed.

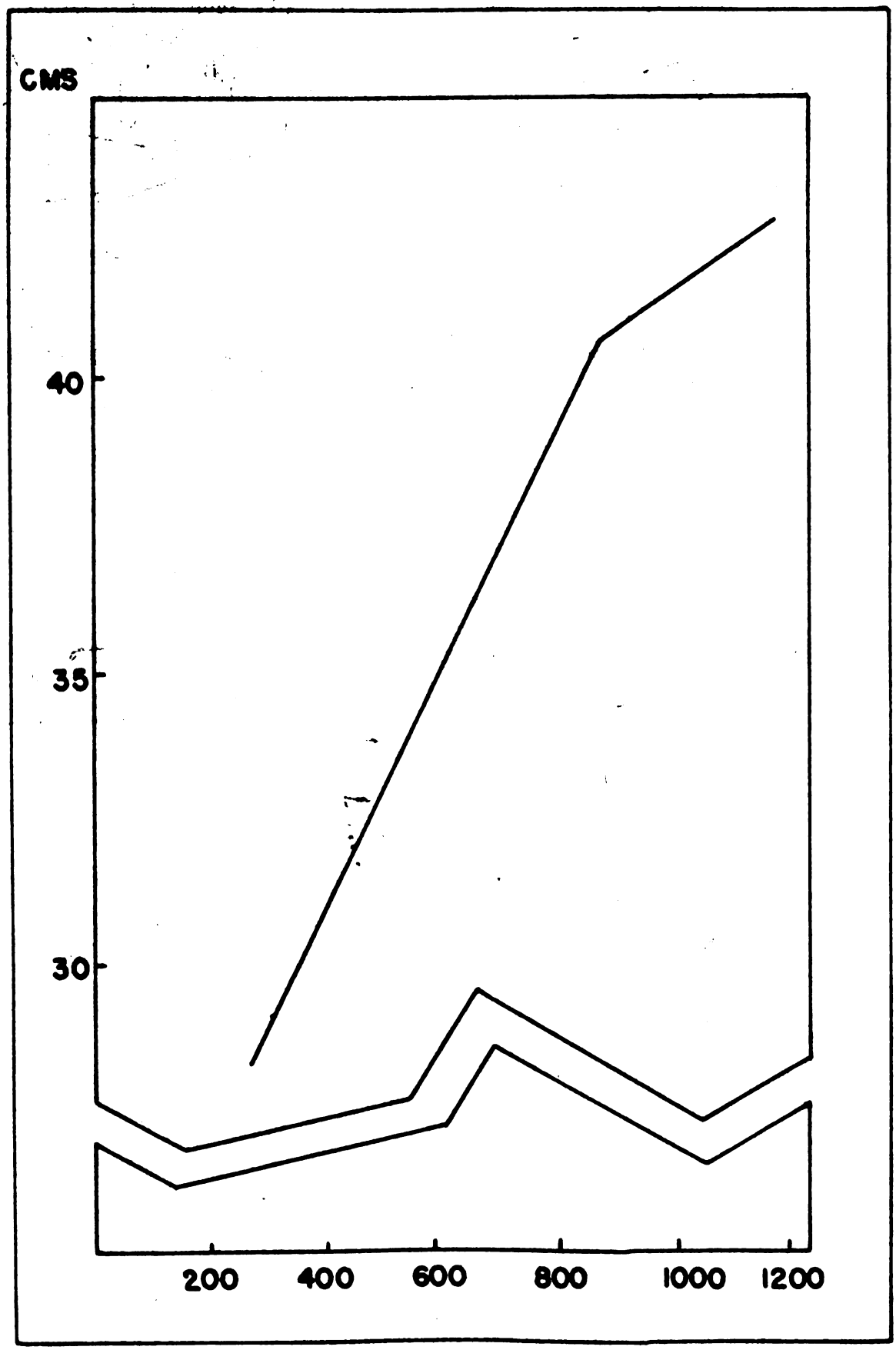
The discussion of weight and length at the time of collection is based upon the April collections for all age groups, with the exception of age group I. Age group I was represented in the May collection and absent during the other periods.

As discussed previously (see annulus formation section), at the time of annulus formation the lengths and weights are at a minimum for a particular class; while during the period immediately prior to annulus formation the values are at a maximum for any age group. The fish in this study formed their annuli during May; therefore, the period with maximum values for each age group is April. The effects of spawning; i.e., weight reduction, limited feeding, etc., should be at a minimum during April since spawning does not begin until later. Of the various collection periods, April represented the greatest number of fish collected.

It is apparent from an examination of the coefficient of variability for the various groups that at the time of capture weight varies more than length. This may be due to weight being more dependent upon the habits of the fish immediately prior to capture than is length: time of capture in relation to previous feeding, type and quantity of food available, state of digestion, etc. ...all have a more immediate effect on weight than length.

Figure 5

The mean length weight relationship of fishes for all age groups collected during April 1961.


CMS
40
35
30
200
400
600
800
1000
1200

Age groups at the time of collection

Age group I.

Age group I is represented by six fish in the May collection. Some members of age group I may have been changed to age group II by the formation of the second annulus; however, it is more probable that age group I was less vulnerable to angling, or they are less abundant than expected. The appearance of age group II in later collections indicates that the fish were present, although not caught as age group I before May.

The fish in age group I, tables 2 and 3, are more variable in weight (mean 113 g., ± 49 g.) than length (mean 20 centimeters, ± 2.1 centimeters) as indicated by the coefficients of variability of 43.6% for weight, and 10.5% for length.

Table 2

Length and weight observations for fish of age group I. collected May 1951.

Collection number	Weight in grams	Total length in cm.
171	163	24.0
174	89	19.3
170	108	19.9
199	72	17.7
153	87	19.5
165	80	19.0
Range	80 to 168	17.7 to 24.0
Sum	679	120
Mean	113	20.0
Standard deviation	49.3	2.1
Coefficient of variability	43.6%	10.5%
Condition factor (K)	1.42	

Table 3

Calculated length in centimeters for fish of age group I at time of formation of respective annuli.

Collection number	First annulus
171	12.1
174	11.8
170	10.0
199	6.9
153	9.0
165	13.0
Range	6.9 to 13.0
Sum	63
Mean	11.0
Standard deviation	2.3
Coefficient of variability	20.9%

Age group II.

Age group II is numerous because these fish were not vulnerable to angling before entering this group. The older age groups show the effect of natural mortality. It is possible that the method of collection may have introduced bias favoring capture of certain age groups. It would require another season of collections to yield data to determine if this is true.

The coefficient of variability of weight for all collection periods of age group II (except January) is above 30%. This indicates considerable variability of weights. The January collection of age group II includes 14 fish with a coefficient of variability of 10.2%; which indicates comparatively small variability. This difference in variability of collection periods is probably due to sampling error; for the weights of other fish in this study were not more uniform during January than during other collection periods.

The lengths at the time of collection for age group II are more uniform than age group I, with a coefficient of variation near 10% for all collection periods except January which has an unusual uniformity (coefficient of variability 4.5%). As indicated for the January weight uniformity, sampling error is the most probable reason for the low

variability. The high variability of the May collection is doubtless due, in part, to the formation of the annulus during this period and inclusion of fish of two year classes in one age group.

The April collection includes twenty-one fish, whose mean weight is 289 g., with the standard deviation of 135 g.; and a mean length of 28.3 centimeters, with the standard deviation 3.7 centimeters.

These values may be compared with those of age group I. and age groups, with the exception of age group I, are at the minimum weight and length immediately following annulus formation (May in the fish of this study), and the maximum weight and length just prior to annulus formation (April for this study). The reasons for this were discussed under annulus formation.

The exception, age group I, occurred because the annulus formed represents the entire growth until then; the o age group would not easily be confused with age group I.

The mean weight at capture of age group II exceeds that of age group I by approximately 175 g., an increase of 150% over the weight at the time of the previous annulus formation. The mean length increase at capture is approximately eight centimeters, an increment of slightly less than fifty percent for the same period.

Table 4

Length and weight observations for fish of age group II.

Collection number	Weight in grams	Total length in cm.
	Collected January 1961.	
1	205	25.0
2	180	24.5
3	190	24.0
10	218	26.0
11	169	25.0
12	169	24.0
15	250	27.5
16	220	26.0
17	190	25.5
18	210	25.5
19	210	25.0
21	215	25.5
22	190	24.0
23	210	25.5
Range	169 to 250	24.0 to 27.5
Sum	2826	353
Mean	202	25.2
Standard deviation	20.6	1.14
Coefficient of variability	10.2%	4.5%
Condition factor (K)	1.26	

Table 4 (continued)

Collection Number	Weight in grams	Total length in cm.
	Collected February 1951.	
26	230	26.5
27	225	26.5
29	205	25.0
31	550	34.0
34	154	23.0
35	245	27.0
Range	154 to 550	23.0 to 34.0
Sum	1609	161
Mean	268	26.8
Standard deviation	142	3.7
Coefficient of variability	52.9%	13.8%
Condition factor (K)	1.36	
	Collected April 1951.	
32	454	32.7
36	460	33.2
37	188	26.0
91	168	24.7
98	236	26.0
39	276	28.6

Table 4 (continued)

Collection number	Weight in grams	Total length in cm.
Collected April 1951 (continued)		
103	280	29.4
104	390	33.5
106	156	24.7
119	360	33.2
140	186	25.0
142	116	21.5
176	240	27.0
177	228	26.8
178	216	25.9
179	164	25.0
186	220	26.5
187	284	28.5
188	536	35.3
194	220	26.5
197	500	33.2
Range	116 to 560	21.5 to 35.3
Sum	6078	594
Mean	289	28.3
Standard deviation	135	3.7
Coefficient of variability	46.7%	13.1%
Condition factor (K)	1.27	

Table 4 (continued)

Collection number	Weight in grams	Total length in cm.
	Collected May 1961	
156	100	20.5
241	168	25.2
216	163	24.9
215	160	25.1
211	168	24.2
159	124	22.7
157	290	28.8
155	187	25.0
154	164	24.5
152	163	24.9
151	198	25.2
169	136	22.6
168	133	22.8
167	117	22.3
166	315	29.7
161	290	28.1
160	167	24.3
178	147	23.1
173	184	25.6
127	390	30.7
114	586	33.3

Table 4 (continued)

Collection number	Weight in grams	Total length in cm.
Collected May 1961 (continued)		
Range	100 to 586	20.5 to 33.3
Sum	4389	533
Mean	208	25.4
Standard deviation	115	6.4
Coefficient of variability	54.3%	25.2%
Condition factor (K)	1.28	
Collected July 1961		
204	141	23.9
221	429	32.8
220	245	27.8
236	221	26.5
233	282	26.6
238	208	26.5
229	126	22.3
227	176	25.3
226	196	25.5
225	261	27.7
224	238	26.7
223	246	26.8

Table 4 (continued)

Collection number	Weight in grams	Total length in cm.
Collected July 1961 (continued)		
232	166	24.2
217	225	26.6
201	166	24.8
Range	166 to 450	23.2 to 33.2
Sum	3225	373
Mean	215	27.5
Standard deviation	89	2.9
Coefficient of variability	41.4%	10.5%
Condition factor (K)	1.21	
Collected August 1961		
244	270	28.0
245	184	26.3
247	206	26.3
284	166	28.3
281	420	33.2
280	204	25.3
276	450	32.3
268	170	25.1
286	191	26.0

Table 4 (continued)

Collection number	Weight in grams	Total length in cm.
Collected August 1951 (continued)		
287	220	27.4
288	412	32.9
295	290	29.4
302	240	28.7
300	261	29.1
297	178	23.8
291	217	25.9
296	220	27.2
298	182	25.1
Range	166 to 450	23.2 to 33.2
Sum	4451	497
Mean	249	28.0
Standard deviation	89.2	2.9
Coefficient of variability	35.8%	10.4%
Condition factor (K)	1.15	

Table 8

Calculated length in centimeters for fish of age group II at time of formation of respective annuli.

Collection number	First annulus	Second annulus
1	10.8	22.8
2	10.6	22.3
204	10.6	18.3
201	11.8	22.0
217	10.7	25.0
221	13.4	26.5
222	8.6	19.7
223	11.8	24.0
224	9.2	21.7
225	13.0	25.8
226	10.4	23.8
227	9.9	22.7
229	13.0	20.3
232	10.5	22.0
233	13.2	27.5
236	9.9	23.0
220	12.4	26.0
247	12.1	23.8
245	11.5	23.9
244	10.8	25.2
36	11.6	25.0

Table 5 (continued)

Collection number	First annulus	Second annulus
34	9.0	20.8
268	11.2	22.7
280	8.0	21.5
284	11.3	25.8
18	8.8	22.5
297	13.6	19.9
21	9.0	23.2
22	8.9	22.9
23	9.2	21.6
3	9.7	22.5
10	10.0	24.1
11	9.2	22.5
12	7.8	20.5
15	8.6	25.9
16	13.9	24.5
17	10.7	23.5
281	8.3	25.0
86	14.9	27.0
31	13.0	29.9
276	12.8	30.0
87	12.0	24.3
156	10.7	18.3

Table 5 (continued)

Collection number	First annulus	Second annulus
160	7.7	20.2
161	13.3	25.3
164	15.0	26.8
167	9.8	20.6
168	8.5	21.5
169	10.0	19.7
151	8.6	21.8
154	8.7	20.6
155	10.2	22.4
157	12.0	24.0
159	9.7	20.0
211	8.2	21.5
215	11.8	23.3
216	10.0	21.6
241	11.2	22.7
175	10.0	21.0
152	17.6	23.9
29	14.5	23.8
26	9.7	20.5
27	15.6	25.0
19	11.7	23.3
82	12.6	27.4

Table 5 (continued)

Collection number	First annulus	Second annulus
103	8.9	24.2
39	11.5	25.5
98	10.6	22.6
91	10.0	22.0
104	13.8	28.5
106	10.6	21.8
119	11.8	27.0
140	9.2	19.5
142	9.2	19.1
137	13.4	24.8
176	11.4	23.8
177	12.7	24.5
178	10.2	22.5
179	8.5	22.3
194	11.4	24.0
197	11.8	25.0
186	11.3	23.7
188	15.8	30.0
114	11.8	26.9
127	17.9	28.5
173	10.3	23.5
300	16.9	28.0

Table 5 (continued)

Collection number	First annulus	Second annulus
302	11.2	23.2
[illegible]	14.0	26.1
[illegible]38	14.0	26.1
[illegible]87	11.8	24.0
[illegible]86	9.8	23.9
[illegible]98	11.8	24.0
[illegible]96	12.0	25.9
[illegible]91	11.6	23.0
Range	7.7 to 17.9	14.2 to 30.0
Sum	1072	2246
Mean	11.3	23.6
Standard deviation	2.43	1.05
Coefficient of variability	21.5%	44.5%

Age group III.

The entire collection of all age groups include eleven fish for February and six fish for June, with age group III absent during both months. Sampling error could account for this.

The mean weights of age group III have nearly the same variability as the weights for other age groups (coefficient of variability near 35%) with the exceptions of the August collection (coefficient of variability 16%), and the July collection (coefficient of variability 2%). The July collection has two members, with a weight difference of 18 grams; hence the low variability. The high variability of the August collection is probably attributable to sampling error.

The mean lengths are less variable with a coefficient of variability near 10%. An exception is the July collection which has no variability because the two lengths are within one tenth of one centimeter; as explained previously, to simplify calculations lengths were grouped to the nearest centimeter.

The April collection includes nineteen fish whose mean weight is 574 g., ± 186 g. and mean length of 34.6 centimeters, ± 3.2 centimeters at time of capture. This is an increase in mean weight of 286 g. and a mean length increment of 6.5 centimeters, compared with the April collection of age group II. This increase of weight is approximately 100% and the length increase is more than twenty percent.

Table 6

Length and weight observations for fish of age group III

Collection number	Weight in grams	Total length in cm.
Collected in January 1951.		
24	950	29.0
14	440	32.0
9	623	36.0
277	778	39.1
Range	440 to 950	29.0 to 39.1
Sum	2791	136
Mean	697	34
Standard deviation	218	4.4
Coefficient of variability	31.2%	12.9%
Condition factor (K)	1.75	
Collected in May 1951.		
240	740	36.9
168	480	35.2
172	367	31.0
Range	367 to 740	31.0 to 36.9
Sum	1587	103
Mean	529	34.3
Standard deviation	191	1.8
Coefficient of variability	36.1%	5.2%
Condition factor (K)	1.31	

Table 6 (continued)

Collection number	Weight in grams	Total length in cm.
	Collected April 1961	
102	880	41.0
138	640	30.3
134	740	36.7
120	504	34.5
112	522	35.0
96	556	35.3
78	390	31.7
74	1070	42.5
73	692	36.1
53	445	33.5
125	610	35.6
137	348	30.5
100	456	32.6
117	438	32.4
115	664	37.1
136	502	34.3
77	670	36.3
46	360	31.7
60	417	33.2
Range	348 to 1070	30.3 to 42.5

Table 6 (continued)

Collection number	Weight in grams	Total length in cm.
Collected April 1951 (continued)		
Sum	10696	661
Mean	574	34.6
Standard deviation	186	3.18
Coefficient of variability	32.4%	9.2%
Condition factor (K)	1.38	
Collected July 1951		
234	627	37.1
19	609	37.2
Range	609 to 627	37.1 to 37.2
Sum	1238	74.3
Mean	619	37.2
Standard deviation	12.3	0
Coefficient of variability	2%	0
Condition factor (K)	1.8	
Collected August 1951		
273	520	34.8
267	679	31.5
250	650	37.5
290	216	26.2

Table 8 (continued)

Collection number	Weight in grams	Total length in cm.
Collected August 1951 (continued)		
299	202	27.9
Range	202 to 679	26.2 to 37.5
Sum	2267	159
Mean	453	31.8
Standard deviation	73.0	5.2
Coefficient of variability	16.1%	16.4%
Condition factor (K)	1.45	

Table 7

Calculated length in centimeters for fish of age group III at time of formation of respective annuli.

Collection number	First annulus	Second annulus	Third annulus
137	10.2	19.4	28.5
100	10.0	24.8	31.4
135	12.0	23.8	31.7
46	14.4	21.0	27.9
60	11.0	23.1	31.8
73	21.0	28.4	34.3
77	15.6	24.8	33.4
96	10.2	21.6	31.5
117	11.5	22.0	30.9
115	14.5	25.8	35.8
112	12.3	26.2	33.0
125	13.8	23.6	32.2
134	13.3	25.9	32.6
132	13.2	26.0	38.0
53	11.8	24.2	30.0
75	19.7	26.7	29.9
138	7.8	15.2	23.0
74	13.0	26.0	37.9
277	9.5	23.7	34.8
273	12.1	24.8	33.2
267	7.7	20.5	27.3

Table 7 (continued)

Collection number	First annulus	Second annulus	Third annulus
9	12.1	25.5	31.8
14	10.8	23.0	29.0
120	10.9	27.5	30.8
219	12.0	22.0	34.8
234	18.8	28.6	34.2
162	11.0	26.9	33.0
240	20.0	28.7	34.5
250	16.0	25.0	34.5
178	10.8	23.4	29.8
24	12.6	23.8	27.2
299	9.0	22.0	25.7
290	8.8	20.8	23.9
Range	7.7 to 21.0	15.2 to 28.7	23.9 to 36.0
Sum	418	794	1046
Mean	12.4	24.1	31.6
Standard deviation	3.2	3.0	3.36
Coefficient of variability	26.0%	12.4%	10.6

Age group IV.

The forty-one fish exhibiting four annuli were collected from January 1951 through August 1951, with twenty-six being collected during April.

Eleven more fish were present in this age group than in age group III. As mortality increases with age, one would expect fewer individuals in the older age group. This difference in numbers is probably due to sampling error.

The greatest variation of weights by month of collection is during April, the coefficient of variability being 53%. Of the twenty-six fish collected during this period three have weights greater than 1000 g.. Possibly these individuals weighing so much more than the mean weight of 713 g. may have been feeding actively immediately prior to capture; also, they may be the fastest growing fish of this age group. The other collection periods, with the exception of February and May which have one fish each, have a coefficient of variability near twenty percent.

The coefficient of variability for lengths is 7.2 percent; indicating little variation compared with previous age groups.

The April collection, at time of capture, has a mean weight of 790 g., ± 421 g.; the mean length is 38.6 centimeters, ± 2.8 centimeters. This is an increase of 216 g. in weight, and 4.8 centimeters length increase during the fourth year. The growth during this period is exceeded only by that of the third year.

Table 8

Length and weight observations for fish of age group IV

Collection number	Weight in grams	Total length in cm.
Collected January 1951		
20	800	39.5
13	625	38.0
Range	625 to 800	38.0 to 39.5
Sum	1425	77.5
Mean	713	38.8
Standard deviation	124	1.1
Coefficient of variability	17.4%	2.8%
Condition factor (K)	1.22	
Collected February 1951		
32	600	38.0
Condition factor (K)	1.06	
Collected April 1951		
192	1028	41.2
138	844	40.5
88	460	32.2
90	800	38.4
76	690	38.4

Table 8 (continued)

Collection number	Weight in grams	Total length in cm.
	Collected April 1951 (continued)	
58	810	40.0
54	564	35.5
45	1620	44.3
55	740	39.2
61	1060	42.3
185	736	38.2
111	682	37.0
110	620	37.0
85	744	39.2
44	852	44.6
181	660	35.8
41	660	36.5
183	844	39.7
92	760	37.7
95	580	35.6
51	700	37.0
102	796	39.0
196	868	39.2
113	808	39.8
266	800	39.0
84	864	42.0

Table 8 (continued)

Collection number	Weight in grams	Total length in cm.
Collected April 1951 (continued)		
Range	460 to 1680	32.2 to 44.6
Sum	20690	1006
Mean	790	38.6
Standard deviation	421	2.8
Coefficient of variability	53%	7.2%
Condition factor (K)	1.34	
Collected May 1951		
149	920	41.2
Condition factor (K)	1.29	
Collected June 1951		
203	785	39.6
205	636	37.2
209	320	35.9
Range	320 to 735	35.9 to 39.6
Sum	1941	113
Mean	647	37.6
Standard deviation	133	14
Coefficient of variability	20.6%	3.7%
Condition factor (K)	1.22	

Table 8 (continued)

Collection number	Weight in grams	Total length in cm.
	Collected August 1951	
243	610	37.8
240	600	40.2
283	680	39.2
278	564	35.9
270	1004	42.6
269	668	37.0
294	540	36.7
301	710	39.8
Range	540 to 1004	35.9 to 42.6
Sum	5406	310
Mean	675	38.6
Standard deviation	143	2.0
Coefficient of variability	21.2%	5.2%
Condition factor (K)	1.66	

Table 9

Calculated length in centimeters for fish of age group IV at time of formation of respective annuli.

Collection number	First annulus	Second annulus	Third annulus	Fourth annulus
88	11.4	23.8	33.0	37.7
45	15.8	26.0	36.9	42.0
44	21.8	31.0	39.9	43.4
55	8.0	19.0	30.0	37.0
61	9.0	21.0	34.3	40.6
111	10.0	21.0	29.8	36.1
110	10.0	20.9	29.8	35.1
266	13.8	27.1	33.3	38.0
64	14.4	25.8	34.7	40.3
283	20.0	26.6	32.9	36.6
278	9.9	20.8	28.2	32.1
270	11.0	25.2	32.9	39.1
20	11.2	25.5	31.8	36.3
13	9.0	23.2	29.6	34.4
32	13.0	26.8	32.0	36.0
90	9.2	20.5	30.2	35.7
152	14.9	25.5	34.0	37.4
269	8.3	20.8	29.2	34.3
301	11.8	23.5	32.1	37.8
294	8.8	23.9	30.8	34.9
303	10.8	21.0	29.3	36.9

Table 9 (continued)

Collection number	First annulus	Second annulus	Third annulus	Fourth annulus
209	9.8	23.8	29.2	34.1
208	9.8	21.0	31.0	34.6
149	13.6	29.8	36.3	39.8
54	13.8	23.8	28.6	34.0
248	9.0	21.8	29.3	36.1
243	8.9	21.2	30.0	35.4
76	8.1	20.2	29.6	36.0
88	8.8	20.0	26.7	29.8
98	10.1	27.2	32.1	37.0
113	9.3	25.0	33.0	37.0
199	12.2	19.4	33.5	37.7
51	14.1	24.8	33.0	35.1
196	12.6	23.8	30.6	37.0
102	14.0	25.5	31.6	36.8
184	11.1	22.9	31.2	36.3
95	10.0	21.2	29.8	34.0
92	10.8	22.0	31.2	36.1
183	9.6	26.2	31.4	36.0
181	10.0	20.2	27.8	32.2
41	8.0	20.0	29.6	34.8
Range	8.0 to 21.8	19.0 to 31.0	26.7 to 39.9	29.8 to 43.4
Sum	478	941	1290	1489

Table 9 (continued)

Collection number	First annulus	Second annulus	Third annulus	Fourth annulus
Mean	11.7	22.9	31.5	36.3
Standard deviation	2.47	4.70	2.75	2.57
Coefficient of variability	21.1%	20.5%	8.7%	7.1%

Age groups V, VI, and VII.

These three age groups were represented by so few fish that comparisons were not deemed advisable, although the observations are presented. For example, age group VI is represented by one member for the January collection. Tentative comparisons may be made for the April collections which have the following number of individuals: age group V 16, age group VI 8, age group VII 3. Of the three age groups no other collection period has more than three fish.

The mean weights for the April collections are: age group V 885 g., ± 40.7 g.; age group VI 1186 g., ± 257 g.; age group VII 1079 g., ± 188 g.. This indicates an increase of weight of 301 g. from the fifth to the sixth year, with an increase of 95 g. from the fourth to the fifth year. This apparent decrease of growth rate for the fifth year with an increased rate for the sixth year might be possible, but a more probable reason is sampling error, especially since computed lengths do not show this.

The apparent decrease of weight from age group VI to age group VII may be an actual loss of weight as the fish ages, but as noted previously, sampling error is a better explanation in view of the small samples.

The mean lengths in centimeters of the various age groups collected during April are: age group V 40.7, ± 1.2; age group VI 42.7, ± 2.0; age group VII 42.0, ± 2.0. The reason for the decline in length from age group VI to age group VII is probably the same as for the decrease in weight, i.e., sampling error.

Table 10

Length and weight observations for fish of age group V

Collection number	Weight in grams	Total length in cm.
Collected January 1951		
7	925	40.5
Condition factor (K)	1.38	
Collected February 1951		
38	700	39.0
Condition factor (K)	1.18	
Collected May 1951		
242	730	40.0
214	718	38.9
163	858	40.3
Range	718 to 858	38.9 to 40.3
Sum	2306	120
Mean	768	39.7
Standard deviation	85.2	0.22
Coefficient of variability	3.3%	0.6%
Condition factor (K)	1.24	

Table 10 (continued)

Collection number	Weight in grams	Total length in cm.
	Collected June 1961	
206	734	39.1
231	784	39.5
Range	734 to 784	39.1 to 39.5
Sum	1518	78.6
Mean	759	39.3
Standard deviation	36	0.22
Coefficient of variability	4.6%	0.6%
Condition factor (K)	1.25	
	Collected April 1961	
67	736	38.6
68	1290	43.2
123	1320	43.8
69	776	41.0
70	690	40.2
108	644	40.8
184	885	41.0
56	836	39.8
65	816	40.0
118	760	39.5

Table 10 (continued)

Collection number	Weight in grams	Total length in cm.
Collected April 1951 (continued)		
47	620	40.0
49	880	39.9
48	980	41.4
128	904	40.7
131	824	40.5
93	880	40.8
Range	736 to 1320	38.6 to 43.8
Sum	14161	653
Mean	885	40.7
Standard deviation	182	1.2
Coefficient of variability	20.5%	2.9%
Condition factor (K)	1.38	
Collected July 1951		
228	716	38.5
218	916	40.8
Range	716 to 916	38.5 to 40.2
Sum	1632	79
Mean	816	39.5

Table 10 (continued)

Collection number	Weight in grams	Total length in cm.
Collected July 1951 (continued)		
Standard deviation	141	1.4
Coefficient of variability	17.3%	3.6%
Condition factor (K)	1.3	
Collected August 1951		
274	830	38.8
249	680	39.1
Range	680 to 830	38.8 to 39.1
Sum	1510	77.9
Mean	755	38.9
Standard deviation	106	0
Coefficient of variability	14.0%	0
Condition factor (K)	1.27	

Table 11

Calculated length in centimeters for fish of age group V at time of formation of respective annuli.

Collection number	First annulus	Second annulus	Third annulus	Fourth annulus	Fifth annulus
228	9.0	21.1	30.0	33.9	37.0
206	15.0	24.4	29.0	33.1	37.5
231	10.1	23.2	30.6	36.0	38.0
163	11.5	24.6	32.1	36.2	39.0
214	8.6	20.6	29.0	34.1	37.0
242	10.4	22.3	31.1	36.2	39.0
56	11.2	24.4	30.0	35.0	38.7
249	11.6	20.8	29.0	34.0	37.6
186	9.8	19.5	28.3	36.0	39.2
118	7.2	13.6	24.8	33.9	37.1
49	15.0	26.8	31.1	35.0	38.2
47	10.6	23.0	29.3	34.8	38.4
108	11.4	20.0	29.8	36.1	39.0
184	12.2	21.0	28.3	33.0	38.1
65	11.0	19.0	29.0	38.2	37.8
67	9.0	18.5	28.5	32.9	36.2
68	13.8	22.9	34.0	39.0	42.0
69	9.4	24.1	31.7	35.8	39.7
70	7.8	20.1	31.0	34.2	38.6
131	8.5	21.2	29.6	36.0	39.8
93	18.0	27.0	32.4	36.9	39.6

Table 11 (continued)

Collection number	First annulus	Second annulus	Third annulus	Fourth annulus	Fifth annulus
38	9.9	24.9	32.1	34.2	37.5
274	15.0	26.2	30.0	33.2	37.1
7	9.0	21.9	30.0	36.2	38.7
48	10.0	20.0	29.8	35.2	38.2
218	18.2	22.8	30.6	37.4	39.2
123	17.6	29.8	35.0	39.2	42.1
Range	7.2 to 18.0	13.6 to 29.8	24.8 to 35.0	32.2 to 40.6	36.2 to 43.8
Sum	302	604	786	948	1042
Mean	11.2	22.4	29.1	35.0	38.6
Standard deviation	2.83	3.74	6.10	1.73	1.41
Coefficient of variability	2.5%	1.7%	2.1%	5.0%	3.6%

Table 12

Length and weight observations for fish of age group VI

Collection number	Weight in grams	Total length in cm.
Collected January 1951		
6	675	37.0
Condition factor (K)	1.31	
Collected February 1951		
28	1060	40.0
36	1000	41.0
Range	1000 to 1060	40.0 to 41.0
Sum	2060	81.0
Mean	1040	40.5
Standard deviation	56	0
Coefficient of variability	5.4%	0
Condition factor (K)	1.6	
Collected June 1951		
207	899	41.0
Condition factor (K)	1.29	
Collected July 1951		
230	1044	41.6
Condition factor (K)	1.44	

Table 12 (continued)

Collection number	Weight in grams	Total length in cm.
Collected August 1951		
235	1530	46.1
246	588	38.0
292	1320	45.0
Range	588 to 1530	38.0 to 46.1
Sum	3438	129
Mean	1146	43.2
Standard deviation	494	4.4
Coefficient of variability	4.3%	1.8%
Condition factor (K)	1.55	
Collected April 1951		
83	830	41.0
84	1440	43.6
79	1440	43.3
78	1012	41.8
109	1320	44.6
148	1410	44.5
40	856	39.0
43	1176	44.4

Table 12 (continued)

Collection number	Weight in grams	Total length in cm.
Collected April 1951 (continued)		
Range	830 to 1440	39.0 to 44.6
Sum	9484	343
Mean	1186	42.7
Standard deviation	257	2.0
Coefficient of variability	21.6%	4.7%
Condition factor (K)	1.51	

Table 13

Calculated length in centimeters for fish of age group VI at time of formation of respective annuli.

Collection number	First annulus	Second annulus	Third annulus	Fourth annulus	Fifth annulus	Sixth annulus
207	13.0	24.0	29.4	34.0	37.0	39.2
83	8.0	20.3	28.2	34.0	37.4	39.7
64	12.8	25.0	30.0	34.8	39.0	42.0
43	8.0	21.6	29.0	34.0	38.8	42.8
246	10.0	20.1	26.9	31.1	34.8	36.7
109	12.8	21.2	32.2	36.6	39.9	42.8
230	16.0	27.1	32.1	35.0	37.6	40.2
79	10.9	25.0	31.0	34.9	39.8	42.0
36	14.5	26.5	29.8	33.0	36.0	39.0
6	11.3	21.1	27.0	32.0	35.0	36.8
78	9.4	22.0	29.1	33.6	39.0	40.6
28	10.6	22.0	31.0	34.0	36.1	38.1
40	10.8	20.2	29.4	33.3	35.8	37.6
148	14.0	26.4	34.0	38.8	41.2	43.1
285	13.6	25.2	35.8	39.8	43.4	45.1
292	15.1	29.8	38.3	38.6	41.5	43.8
Range	8.0 to 16.0	20.1 to 29.8	26.9 to 35.8	31.1 to 39.8	34.8 to 43.4	36.8 to 45.1
Sum	198	375	469	561	612	650
Mean	11.9	23.5	30.6	35.0	38.3	40.6
Standard deviation	2.41	2.95	2.68	2.58	2.58	2.66
Coefficient of variability	20.2%	12.6%	8.8%	7.4%	6.7%	6.5%

Table 14

Length and weight observations for fish of age group VII

Collection number	Weight in grams	Total length in cm.
Collected January 1951		
8	800	39.0
Condition factor (K)	1.4	
Collected February 1951		
33	1325	44.0
Condition factor (K)	1.6	
Collected April 1951		
139	1230	44.1
141	1140	41.8
134	868	39.8
Range	868 to 1230	39.8 to 44.1
Sum	3238	126.0
Mean	1079	42.0
Standard deviation	188	2.0
Coefficient of variability	17.4%	4.8%
Condition factor (K)	1.33	

Table 14 (continued)

Collection number	Weight in grams	Total length in cm.
	Collected August 1961	
289	1060	44.5
293	875	40.5
Range	875 to 1060	40.5 to 44.5
Sum	1935	85
Mean	968	43
Standard deviation	131	2.8
Coefficient of variability	13.5%	6.5%
Condition factor (K)	1.22	

Table 15

Calculated length in centimeters for fish of age group VII at time of formation of respective annuli.

Coll. number	First annulus	Second annulus	Third annulus	Fourth annulus	Fifth annulus	Sixth annulus	Seventh annulus
124	8.7	17.2	25.3	30.1	33.2	36.4	38.8
141	9.2	21.0	27.1	32.4	36.0	39.0	41.0
129	8.6	23.0	31.1	34.8	39.7	41.8	43.1
8	10.0	21.3	27.9	31.2	34.8	36.0	38.0
33	9.9	20.0	29.0	34.3	38.0	39.2	42.3
289	15.7	26.8	33.8	36.4	38.7	41.1	43.2
293	10.8	19.2	26.0	29.4	33.0	35.8	38.6
Range	8.6 to 15.7	17.2 to 26.8	25.3 to 33.8	29.4 to 36.4	33.0 to 39.7	35.8 to 41.8	38.0 to 43.2
Sum	74	148	200	227	253	269	286
Mean	10.6	21.1	28.6	32.4	36.1	38.4	40.7
Standard deviation	2.51	3.16	3.10	2.64	2.66	2.36	1.96
Coefficient of variability	23.7%	15%	10.8%	8.15%	7.4%	6.2%	4.8%

Table 16

Mean calculated lengths in centimeters for the various age groups, at the time of formation of the respective annuli.

Age group	Number in sample	Annulus 1	2	3	4	5	6	7
I	6	11.0						
II	95	11.2	23.2					
III	33	12.4	24.1	31.6				
IV	41	11.6	23.4	31.5	36.3			
V	27	11.1	22.5	30.3	34.4	39.8		
VI	16	11.9	23.5	30.6	35.0	38.3	40.6	
VII	7	10.0	19.8	27.6	32.0	36.2	33.6	40.8
Average mean value		11.3	23.8	30.3	34.4	38.1	39.6	40.8

Figure 6

Calculated lengths in centimeters

for age groups I, II, III, IV, V, VI and VII.

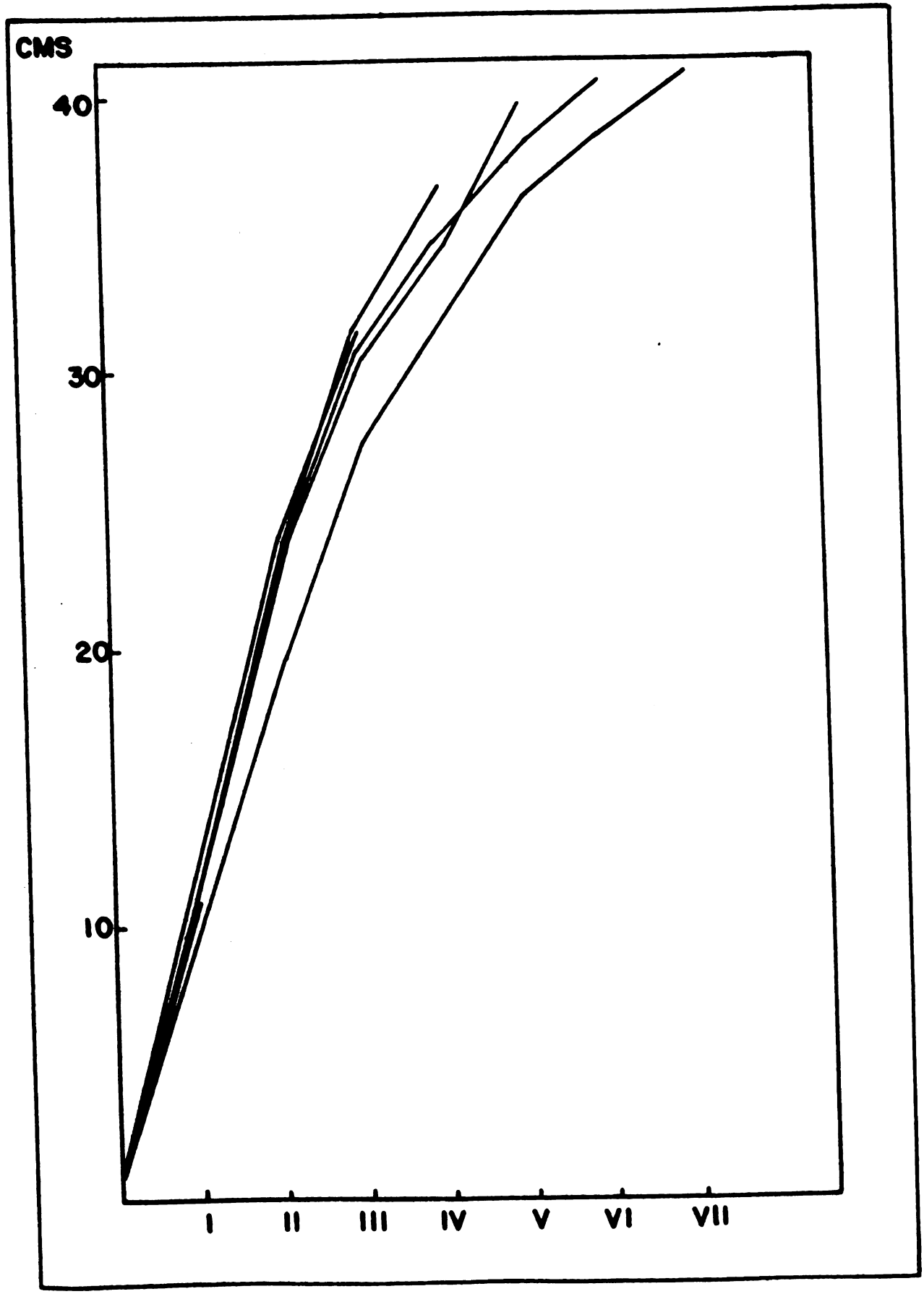
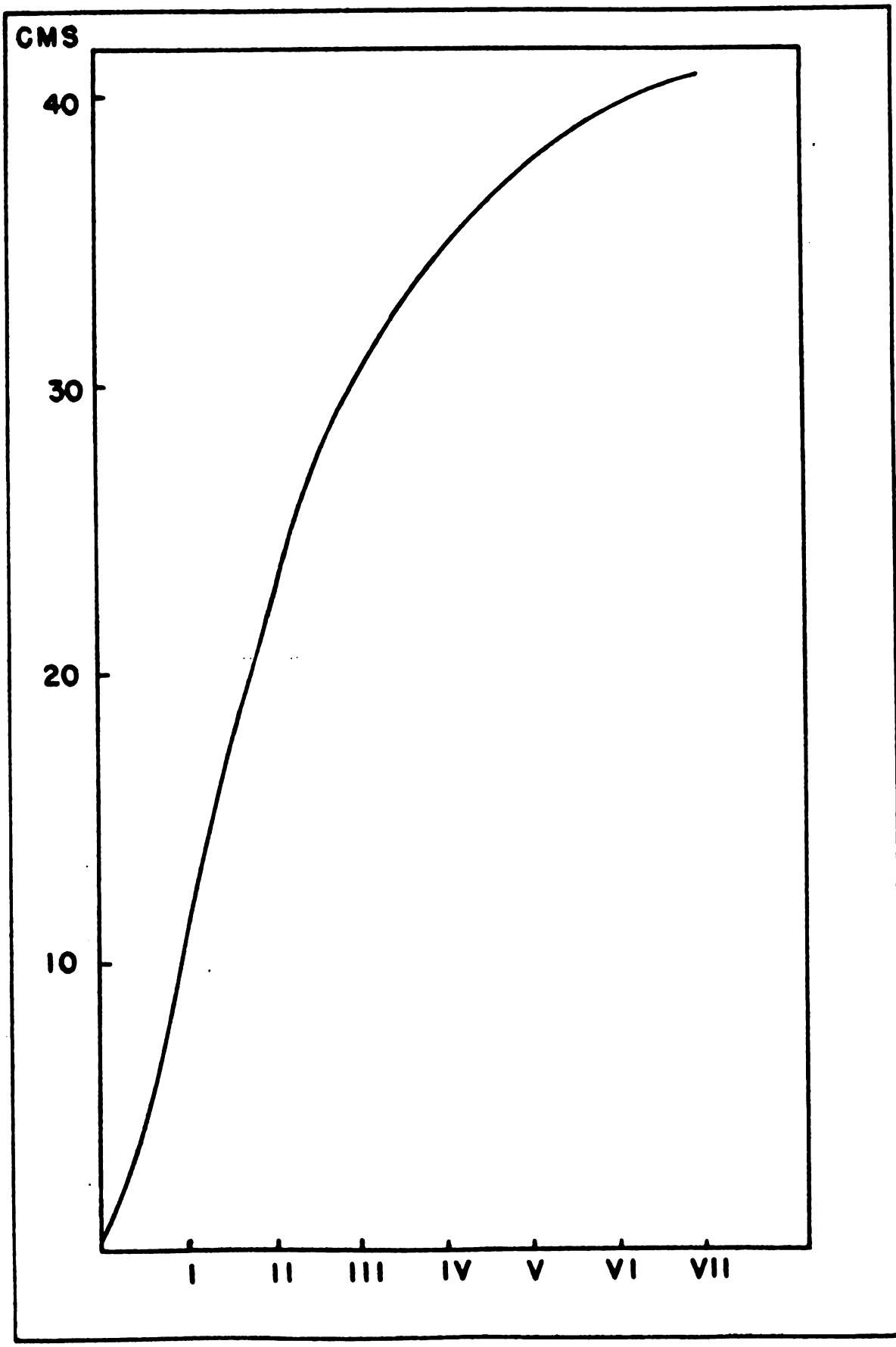

CMS
40
30
20
10
I
II
III
IV
V
VI
VII

Figure 7

The growth curve based on the fish in this study.


CMS
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Comparison of present study with other Michigan largemouth bass

The growth rate of the fish in the present study equals or exceeds that implied in previous studies of the largemouth bass in Michigan.

Beckman (1949) compiled average weights and lengths for various age groups of the largemouth bass in Michigan. The information given is for the entire state, and for an indefinite period. These data do not lend themselves readily to comparisons with the Wintergreen Lake data which are for a specific lake, and definite periods, with each collection period presented independently. However, the data are given on page 75, table 17. In his study Beckman (1948) found a legal largemouth bass in Michigan (ten inches or twenty-five centimeters) to be four summers old. The fish in the present study attained this length shortly after the formation of the second annulus. This illustrates the superior growth rate for fish from Wintergreen Lake.

Eschmeyer (1939) compared the growth of largemouth bass in Howe Lake with those from other waters including Wintergreen Lake. His tables (converted from inches to centimeters, no. 18) are presented, with a comparison of average mean calculated values of Wintergreen Lake fish collected during 1951. The lengths of the Wintergreen Lake fish of 1951 used in this comparison are those observed at the time of capture.

Table 17

A comparison of the mean weight and length data for Wintergreen Lake, April 1951 collection with comparable values of Beckman's (1949) study.

	Present Study		Beckman		Present Study		Beckman	
Age	Mean weight in gms.	Increment of mean weight in gms.	Average weight in gms.	Increment of average weight in gms.	Mean length in gms.	Increment of mean length in gms.	Average length in gms.	Increment of average length in gms.
I	113		45		20.0		15.5	
II	289	176	138	93	26.3	6.3	22.1	6.6
III	574	285	212	74	34.6	8.3	25.4	3.3
IV	790	216	362	150	38.6	4.0	30.7	5.3
V	886	96	538	176	40.7	2.1	34.8	4.1
VI	1180	301	705	167	42.7	2.0	38.4	3.6
VII	1079	-107	963	278	42.0	-.7	40.9	2.5

Eschmeyers, (1939) in referring to the Howe Lake data, says "....since the fish were taken in early September they were actually older in terms of growth than is indicated; the fish of the I age group (I annulus), for example, had completed the greater part of their second growing season." One should be aware of this difference when comparing the two studies.

The comparison of rate of growth for fish collected from Wintergreen Lake during 1951 with Eschmeyer's (1939) table, show that the fish in the present study are above average. The only fish having a greater growth rate, than that found in this study, are from southern Wisconsin.

As previously mentioned, the values for lengths of fish from Wintergreen Lake 1939 and from Watson Lake, as given by Eschmeyer, were actually higher than yearly averages should have been. It is apparent, from a comparison of data from the two studies (table 18), that the Wintergreen Lake fish were growing more rapidly during the 1951 collection than they were when Eschmeyer's data were taken from the same lake.

Table 18

Eschmeyer's (1939) table of lengths in centimeters

for fish from Howe Lake and other waters,

compared with the present study.

Eschmeyer's Data

Location	Date of capture	Age groups 0	I	II	III	IV	V
Howe Lake	September 7	5.3	21.1	25.9	29.2	32.0	38.6
Winterg reen Lake	Winter (various dates)	10.2	22.1	28.7	29.7	30.5	33.3
Watkins Lake	September 29	7.9	----	24.1	27.2	----	34.5
Average for 12 lakes in n. Misc.	Full growing season	7.1	16.5	24.6	29.7	33.5	35.3
Average for 4 lakes and 1 river in s. Misc.		9.4	22.1	30.2	34.3	37.2	41.4

Present Study

Winterg reen Lake. 1951	20.3	28.4	34.6	38.6	40.7	

Conclusion

Wintergreen Lake, Kalamazoo county, Michigan is a eutrophic lake rich in nutrients as evidenced by the abundance of cladocerans and other small crustacea, and a heavy phytoplankton bloom. The growth rate of the largemouth bass in this lake, as revealed by the present study, was found to be greater than that of comparable fish in Michigan. The rapid growth of these fish may be accounted for, in part, by the abundance of forage fish.

The collection of data was from January 1951 through August 1951; of this period, the month of greatest increment in growth is January, while the month of maximum lengths and weights for any age group is April.

A quantitative method for determination of time of annulus formation is presented, based on age group II collection for April having maximum weights and lengths, while the May collection, which includes the period of annulus formation, has minimum weights and lengths.

The graphs (figures 6 and 7) of the calculated lengths (as given in table 16) show the "classic" growth pattern; a very rapid rate during the early years of life, with a gradually decreasing rate as the age increases. In general, the growth rate as revealed by this study exceeds that of comparable fish for the early years (until the fourth annulus), while the others have a more rapid growth for the older ages.

Reduced mortality (due to limited fishing) among the older age groups would result in greater competition; this may explain their sharp decline in growth rate. Even though the growth rate of the older age groups in this study is less, the total lengths and weights remain larger than for comparable Michigan fish, due to the very rapid growth of younger age groups.

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