MONTANA FISH AND GAME DEPARTMENT
FISHERIES DIVISION

JOB COMPLETION REPORT
RESEARCH PROJECT SEGMENT

State of Montana

Project No. F-7-R-13 Name: Northwest Montana Fishery Study

Job No. II Title: An age and growth analysis of pumpkinseed (*Lepomis gibbosus*) from Horseshoe Lake, Montana. 1/

C O R R E C T I O N

On pages 1, 19 and 24 the length-weight relationship for Horseshoe Lake pumpkinseed is described by the formula $W = -5.2231L^{3.2383}$

This formula should be changed to $W = 0.000017L^{3.2383}$

Prepared by George D. Holton
August 24, 1965

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Period covered June 1963 to September 1963

ABSTRACT

Seven age groups of Horseshoe Lake pumpkinseed were determined and validated with a length-frequency distribution, comparison of calculated and empirical length of capture and comparison of goodness and poorness of growth in different calendar years. A body-scale relationship described by the linear equation, $Y = 16.8962 + 1.0379 X$, was calculated. The intercept value, 16.8962 mm. represents the theoretical fish length at scale formation. The males grew better than females with divergence in growth rate occurring in the O-I age growth-increment. The ultimate or asymptotic length of Horseshoe Lake pumpkinseed was determined as 277 mm. Growth fluctuated as much as 13.04 and 11.06 percent for males and females respectively. Correlations of growth fluctuations and weather factors in different calendar years indicated a possible positive relationship between the goodness and poorness of growth of Horseshoe Lake pumpkinseed and both temperature means in May through September and total rainfall in April through July. Growth of Horseshoe Lake pumpkinseed was below that of most other areas considered and increments of growth after the first year are significantly smaller than other areas.

A length-weight relationship was computed and is described by the formula, $W = -5.2231IL^{3.2383}$. Growth in weight followed the same pattern as growth in length with males exhibiting greater growth after their first year of life. The average coefficient of condition value (Ponderal index) was significantly below that of other areas considered and no trends were established in either relative condition factors (K_N) or coefficients of conditions (K).

RECOMMENDATIONS

The lower growth of pumpkinseed in Horseshoe Lake appears to be a function of either water fertility or population density or a combination of both. Further research is recommended to determine the relationships between fish growth and these two factors. No management program is advised for this species until these relationships have been determined.

1/ The field portion of this study was financed through Project F-7-R-13, Job II. This report was adapted with slight revision from a report prepared as a special project for a fisheries management class at the University of Minnesota.

OBJECTIVE AND DESCRIPTION OF STUDY AREA

Warmwater fish species were planted in numerous lakes of the Flathead Valley in the early 1900's. Yellow perch (Perca flavescens), largemouth bass (Micropterus salmoides), smallmouth bass (Micropterus dolomieui) and pumpkinseed sunfish (Lepomis gibbosus) were among those introduced. The waters of this area are essentially cold water fish habitat; however, several of the warmer lakes provide fishing for the warmwater species. Investigations of these introductions have consisted of reconnaissance surveys and limited netting. Recent surveys and management activities in the area have indicated a need for additional information on these species. Limited information has been collected on some of these species; however, none is presently available for the pumpkinseed of the area. It will be the objectives of this study to describe and analyze the age and rate of growth of pumpkinseed in Horseshoe Lake near Ferndale, Montana. This information will be applied to the management policy of this species in the state.

Horseshoe Lake is a shallow, eutrophic body of water lying at the base of the Rocky Mountains in northwestern Montana. It has a total area of 35 surface acres, a maximum depth of 32 feet and more than 90 percent of the lake basin is shoal area of less than 15 feet in depth (Figure 1). The lake is of low fertility with a total alkalinity of 9 to 15 ppm, total dissolved solids of 110 ppm and is essentially homothermal except for the deep area of 32 feet which stratifies thermally. Almost the entire lake basin is covered with submersed and floating aquatic plants including Potamogeton natans L., Potamogeton americanus, Nuphar rubrodiscum Morong., Polygonum natans, Myriophyllum Farwellii Morong., Zannichellia palustris L. and Chara sp. Water temperatures in summer reach a maximum of ± 78°F. The lake is entirely spring fed and there are no surface outlets or inlets in the lake.

Smallmouth bass is the only fish species in the lake, other than the pumpkinseed, and is also exotic to the area. Neither the bass nor pumpkinseed are significantly exploited at the present time.

METHODS AND MATERIALS

The scale method was used for all age and growth determinations in this study. The validity of this method for pumpkinseed age and growth analysis has been demonstrated by Creaser (1926), Reid (1930), Swingle and Smith (1942), and Eddy and Carlander (1942). Creaser (1926) showed the scale method to be an important means of interpreting the life history of fish with special reference to the pumpkinseed. Breder (1936) and Carbine (1939) described the spawning and reproduction of pumpkinseed and Beckman (1943) described the annulus formation in this species. Regier (1962) discussed the validation of the scale method for age and growth estimates in Centrarchids. No literature was available on pumpkinseed age and growth for any Montana waters or waters of the Rocky Mountain region.

The author is indebted for the field assistance received from personnel of the Montana Fish and Game Department and for their help in collecting the data contained herein.

Fish samples from which scales and length and weight measurements were taken were collected during the summer of 1963. The principle collecting gear used were 125-foot nylon graduated experimental gill nets of 3/4-1-1-1½-2½-3½ inch stretch-measure mesh distribution. Three-inch stretch mesh monofilament gill nets; 50 feet long and 12 feet deep, were also employed to collect the larger size classes. A 110-220 volt A.C. electrofishing device was used to collect pumpkinseed in size classes that were unavailable through gill netting. A fyke net of ½-inch mesh was tried but proved ineffective in collecting either species of fish. Weight to the closest .01 pound, length to the closest .10 inch and

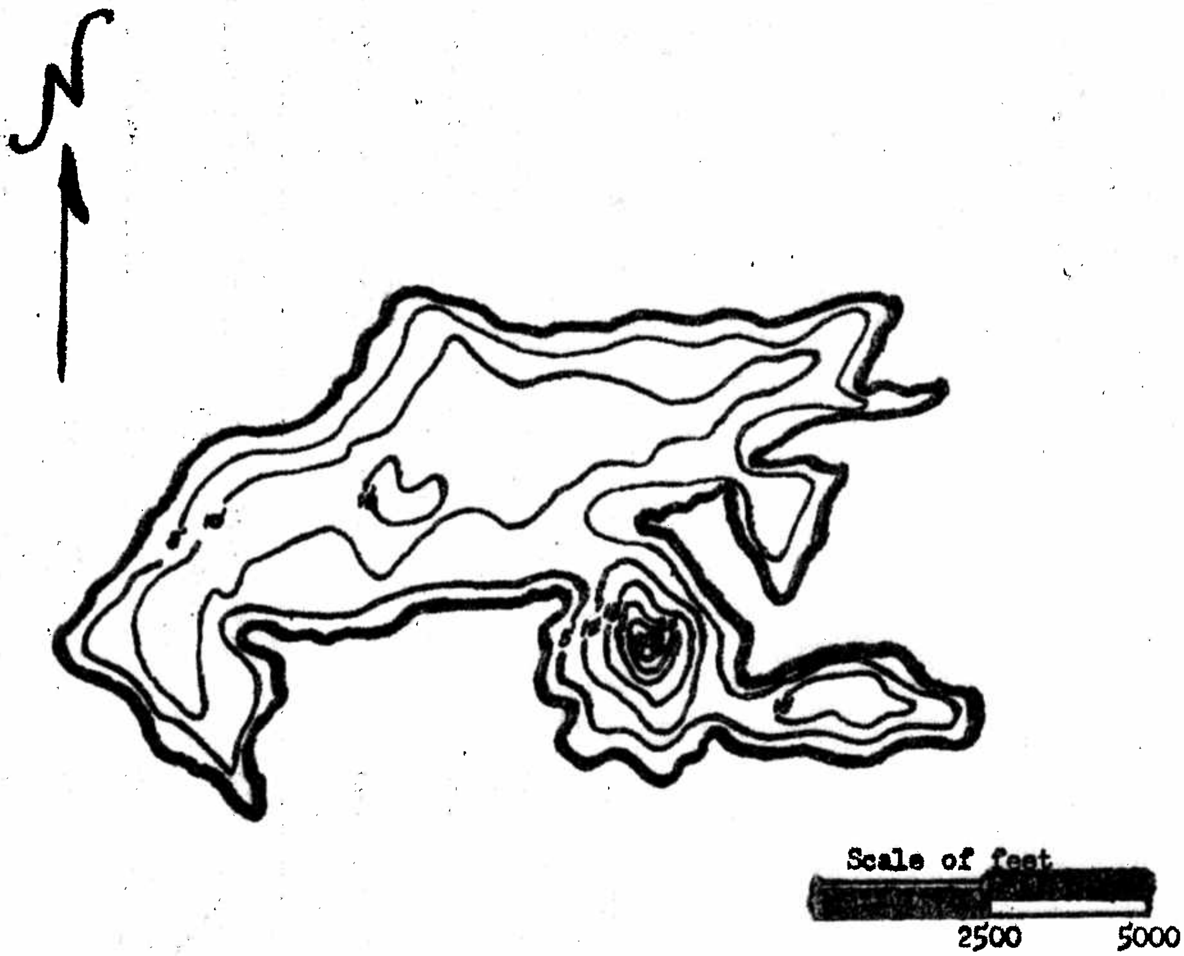


Figure 1. - Map of Horseshoe Lake, Montana.

scales were taken from all fish collected. The weights and lengths were later converted to grams and millimeters respectively for purposes of calculations. The scales were impressed on cellulose acetate slides using the method described by Butler and Smith (1953). The scale impressions were projected and magnified (X41) on a scale projector.

Age Assessment and Growth Calculations:

All scales were read twice and the age determined by the number of annuli on the scale. The criteria used for identification of annuli follow those given by Regier (1962) for bluegills (Lepomis macrochirus), although no simple combination of criteria was found to be entirely dependable. The primary problem in age determination was the frequent occurrence of apparent false annuli. The regularity of a growth pattern was used as a main criterion for separating out these false growth checks. Calculations of growth were made from the projected scale images by recording the distances on a paper tab from the focus to each annulus in the anterior field. These measurements were then applied to a nomograph which incorporated the body-scale relationship following the method described by Carlander and Smith (1944). Year class is used herein to designate the calendar year of spawning and age group denotes the particular age of fish.

The accuracy of age determination assumes that each annulus is a true year mark and that only one true annulus is formed for each year of life. Three methods of validating the scale reading were applied to this data. The histogram representing a length-frequency distribution (Figure 2) will show a mode for each age group since the fish progress in length as they become older. There were seven age groups of fish, I-VII, covered in the calculations. This method assumes that each size class (i.e. age group) is sampled in proportion to its abundance. The histogram (Figure 2) failed to show 7 distinct modes representing 7 age groups and is probably a reflection of inadequate sampling. The arrows indicate the length ranges for each age group.

A second method of age validation used was to compare calculated length at each annulus with empirical length at capture (Table 1). The large difference in empirical and calculated lengths in age groups I and II is explained by the fact that the younger fish were not collected until late summer and thus had nearly completed a full summer's growth before capture. The differences in the remaining age groups is attributed to the fact that sampling was not initiated until late June, after fish growth had begun.

A final validation of aging used was the comparison of goodness and poorness of growth in different calendar years. Figure 8, Table 9 illustrates the percentage deviations from a mean annual increment of growth in the different calendar years for both males and females. By noting the uniformity in fluctuations between sexes in the different calendar years, the validity of the scale reading was materially strengthened. This last validation of age assignment most clearly showed the aging to be reliable.

FINDINGS

Body-Scale Relationship:

A body-scale relationship was determined from the measurements of 192 fish and their scales. Five scales from each fish were measured to the closest millimeter and the measurements then averaged. A body-scale relationship was then computed following the method of Whitney and Carlander (1956). A least squares regression line was computed for the data represented by the equation, $Y = 16.8962 + 1.0379 X$ where Y is fish length, X is scale length, 16.8962 is the intercept of the fish length axis and 1.0379 is the slope of this regression line. Table 2 represents the body length-scale length ratio averaged for

Figure 2. - Length-frequency distribution of Horseshoe Lake pumpkinseed. - arrows indicate length ranges of age groups.

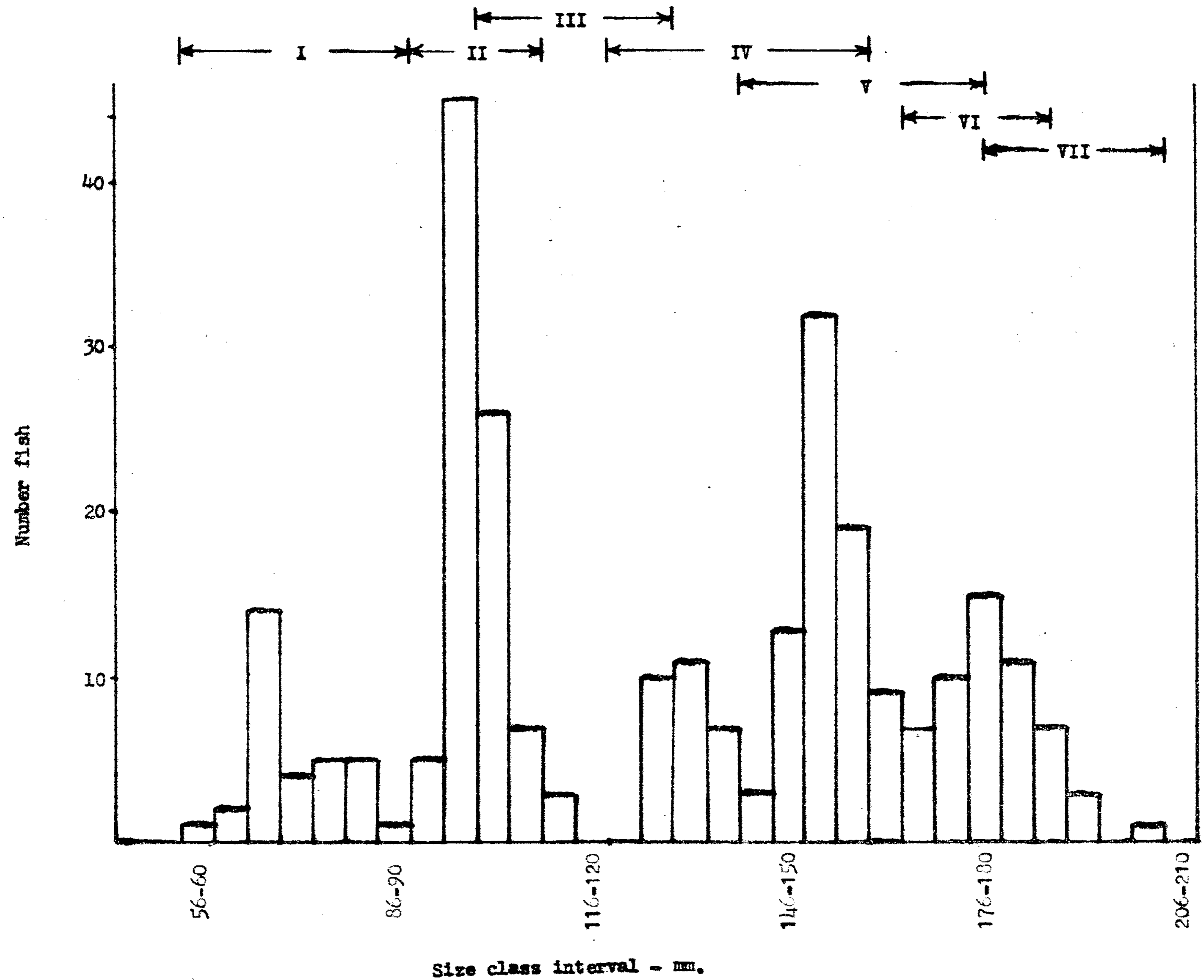


Table 1. Empirical length at capture and calculated length at annulus formation for each age group of Horseshoe Lake pumpkinseed.

Age group	Calculated length at annulus formation (mm.)	Empirical length at capture (mm.)
I	52.9	71.0
II	82.9	99.0
III	105.9	110.0
IV	125.3	134.0
V	143.5	153.0
VI	162.2	172.0
VII	177.5	186.0

Table 2. Body length-scale length (X41) ratio averaged for the scale lengths in each 5 millimeter interval.

Scale length interval (mm.)	Number of fish	Mean fish length (mm.)	Mean scale length (mm.)
41-45	3	61.0	43.8
46-50	4	66.6	48.6
51-55	12	69.3	53.3
56-60	11	73.1	57.9
61-65	2	81.5	64.7
66-70	7	89.0	68.7
71-75	7	94.4	74.7
76-80	8	97.8	78.4
81-85	16	102.5	82.7
86-90	8	108.5	88.8
91-95	3	110.0	93.3
96-100	2	114.3	97.2
101-105	5	131.5	103.6
106-110	9	130.8	109.2
111-115	8	139.3	113.3
116-120	4	144.8	117.8
121-125	7	151.0	123.2
126-130	10	153.9	128.2
131-135	18	158.9	132.9
136-140	10	162.1	138.2
141-145	11	167.2	143.4
146-150	4	169.6	148.1
151-155	10	182.5	153.7
156-160	7	182.6	157.2
161-165	4	178.4	164.6
166-170	--	-----	-----
171-175	1	180.5	172.1
176-180	1	203.0	179.0

each 5 mm. interval of scale length. Figure 3 shows this data to fall very close to the computed regression line. Table 3 represents a table of corrections for the body-scale relationship expressed in 5 mm. scale length intervals, and Figure 4 represents this same table graphically. Sexes were combined for the body-scale relationship because the sample size was not sufficient to determine if a valid significant difference existed between males and females.

Growth in Length

Average calculated length at each annulus:

Using the body-scale relationship, the total fish length was back calculated for each annulus. Grand average calculated lengths for the 1956-62 year classes were determined for the seven years of growth (Tables 4, 5, and 6). At age VII, females and males had an average total length of 177.1 and 181.0 mm. respectively. The males grew at a better rate throughout the life of the fish. Figure 5, table 7 describes the growth as the sum of the grand average increment and the percentage increment for each age group. At age VII, the growth rate of males and females is almost parallel with the males being greater in average length (Figure 5). The divergence in growth between males and females appears to occur in the 0 to I age increment of growth. Unfortunately no young-of-the-year fish were collected to substantiate this. The percentage annual increment varied from 55.27 to 57.14 percent for males and females respectively in the second growing season to 8.54 in males and 9.51 for females during the seventh growing season (Table 7). Table 8 represents the increments of growth for each growing season of the various year classes.

Walford Line and Instantaneous Growth Rate:

The Walford line (Walford, 1946) is another method of expressing the growth of fish. This method allows the upper portion of the growth curve to be interpreted since it describes growth from a hypothetical initial size at true age zero and goes to the average maximum or asymptotic length of the fish. Both k, the slope of the line and l, the asymptotic or ultimate fish length can be obtained. By plotting average length at ages I-VI (l_t) against lengths at ages II-VII (l_{t+1}) and computing a least squares regression line for this plot, a k value of .88 was obtained.

The point where this line cuts the 45° diagonal represents the asymptotic length of the fish (Figure 6). This value is approximately 2777 mm. The value can be validated as the correct estimate of asymptotic length by plotting $\log_e (l_{\infty}-l_t)$ against age (Figure 6). This plot should be a straight line if l_{∞} has been estimated correctly since its straightness is sensitive to changes in l_{∞}. The plot showed the estimate to be correct. This method allows the comparison of absolute growth of species in different areas but requires truly representative samples for the plot. A selection of precocious younger fish in sampling will depress the left end of the line. A second possible error is in reading scales of older fish consistently too low which will cause a depression of the right end of the line. This method is however useful in detecting small changes in growth over a period of time.

Growth can also be expressed as instantaneous growth rate, g, following the method described by Ricker (1958). If l_t is the length of fish at time t and l_o is its length at t = 0, then the equation of exponential growth is $\frac{l_t}{l_o} = e^{gt}$ and instantaneous growth is represented by the equation:

$$g = \log_e \frac{l_t}{l_o}$$ if the initial length is taken as unity.

Figure 7 represents the values of instantaneous growth rate, g, plotted against age.

Figure 3. - Body-scale relationship, Y = 16.8962 + 1.0379X, of pumpkinseed in Horseshoe Lake. - Sexes combined.

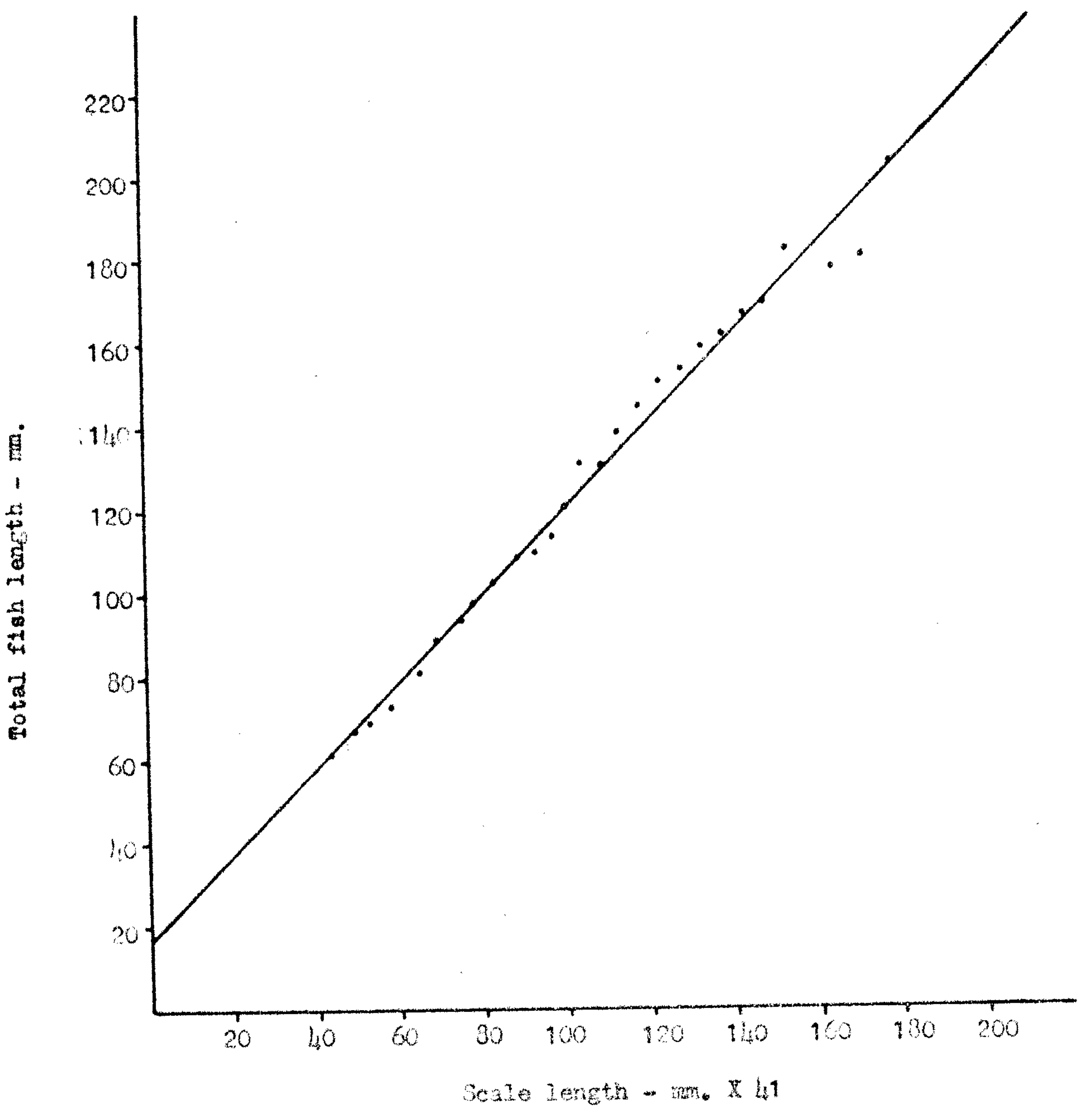


Table 3. Table of corrections from body-scale relationship, $Y = 16.8962 + 1.0379 X$, from Horseshoe Lake pumpkinseed.

Total fish length (mm.)	Total scale length (mm.)
Y	X
22.1	5
27.3	10
32.5	15
37.7	20
42.8	25
48.0	30
53.2	35
58.4	40
63.6	45
68.8	50
74.0	55
79.2	60
84.4	65
89.5	70
94.7	75
99.9	80
105.1	85
110.3	90
115.5	95
120.7	100
125.9	105
131.1	110
136.3	115
141.4	120
146.6	125
151.8	130
157.0	135
162.2	140
167.4	145
172.6	150
177.8	155
183.0	160
188.1	165
193.3	170
198.5	175
203.7	180
208.9	185
214.1	190
219.3	195
224.5	200

Figure 4. - Corrected body-scale relationship, Y = 16.8962 + 1.0379X, for Horseshoe Lake pumpkinseed. - derived from repeated solutions of equation.

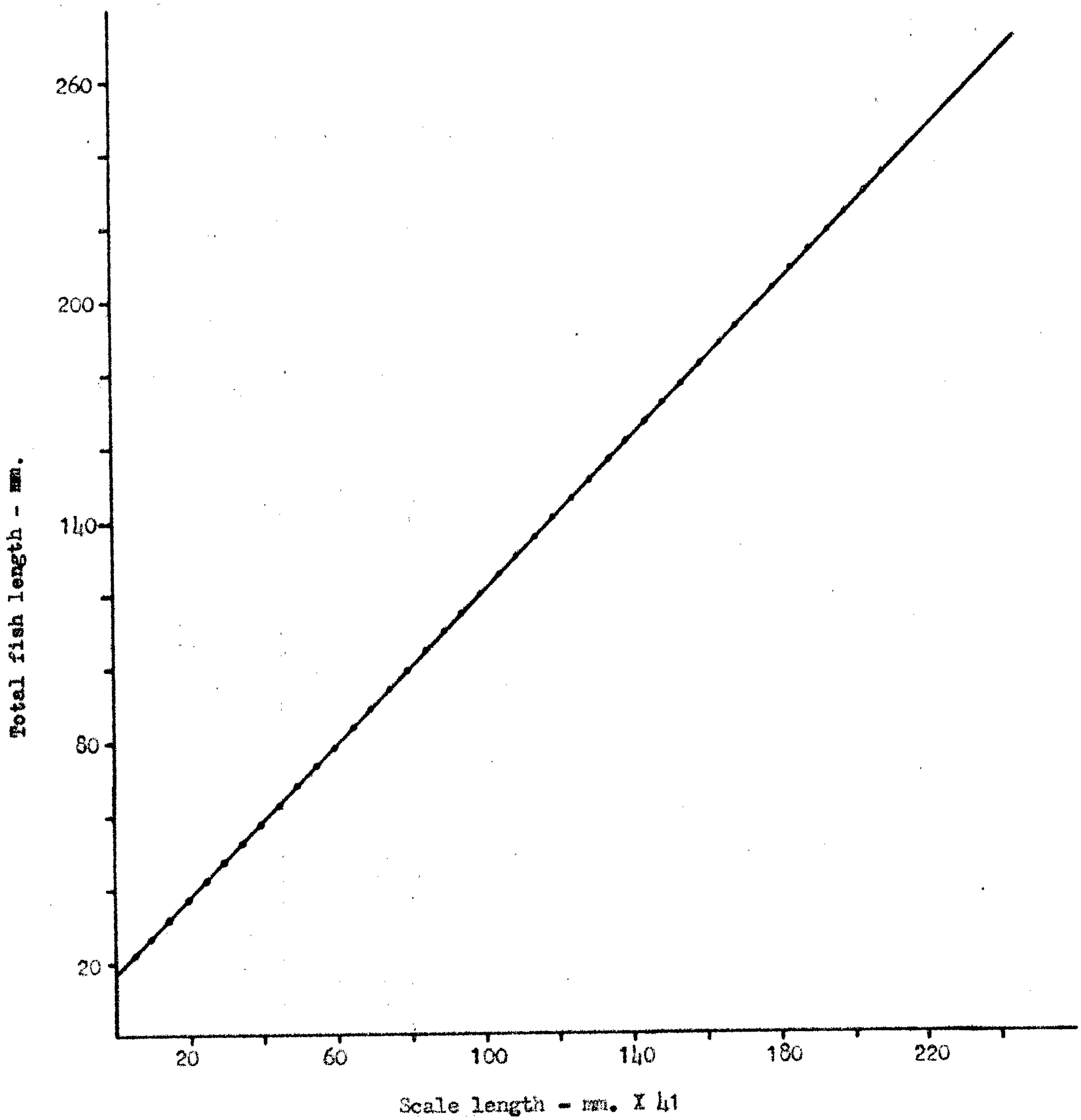


Table 4. Grand average calculated total length of male pumpkinseed in Horseshoe Lake, 1956-1962 year classes-expressed in millimeters.

Males

Year class	No. fish	1	2	3	4	5	6	7
1962	20	56.60						
1961	39	57.80	83.55					
1960	6	54.67	83.83	100.08				
1959	9	51.72	85.72	110.89	127.94			
1958	16	53.41	82.47	103.44	126.00	145.09		
1957	14	51.39	83.07	105.46	127.21	146.14	163.43	
1956	2	55.25	86.00	110.25	128.50	145.00	167.00	181.00
Total and grand average length	106	54.41	84.11	106.02	127.41	145.41	165.22	181.00

Table 5. Grand average calculated total length of female pumpkinseed in Horseshoe Lake, 1956-1962 year classes-expressed in millimeters.

Females

Year class	No. fish	1	2	3	4	5	6	7
1962	20	56.60						
1961	39	57.80	83.55					
1960	7	50.64	82.64	103.64				
1959	14	50.86	82.46	107.50	124.32			
1958	36	51.83	80.41	103.86	124.41	141.96		
1957	22	47.86	77.86	103.70	123.07	143.12	161.14	
1956	16	49.72	80.69	105.97	125.38	143.13	161.69	177.09
Total and grand average length	154	52.19	81.27	104.93	124.30	142.74	161.42	177.09

Table 6. **Grand average calculated total length of Horseshoe Lake pumpkinseed for sexes combined, 1956-1962 year classes—expressed in millimeters.**

Year class	No. fish	1	2	3	4	5	6	7
1962	40	56.60						
1961	78	57.80	83.55					
1960	13	52.50	83.19	102.00				
1959	23	51.20	85.30	108.83	125.74			
1958	52	52.32	83.96	107.61	124.90	142.93		
1957	36	49.25	79.92	104.39	124.70	144.34	162.04	
1956	18	50.33	81.28	106.44	125.67	143.33	162.39	177.53
Total and grand average length	260	52.86	82.87	105.85	125.25	143.53	162.22	177.53

Figure 5. - Grand average calculated length at each annulus for each sex and percentage increment of growth in each year for Horseshoe Lake pumpkinseed. Dashed line, males; solid line, females.

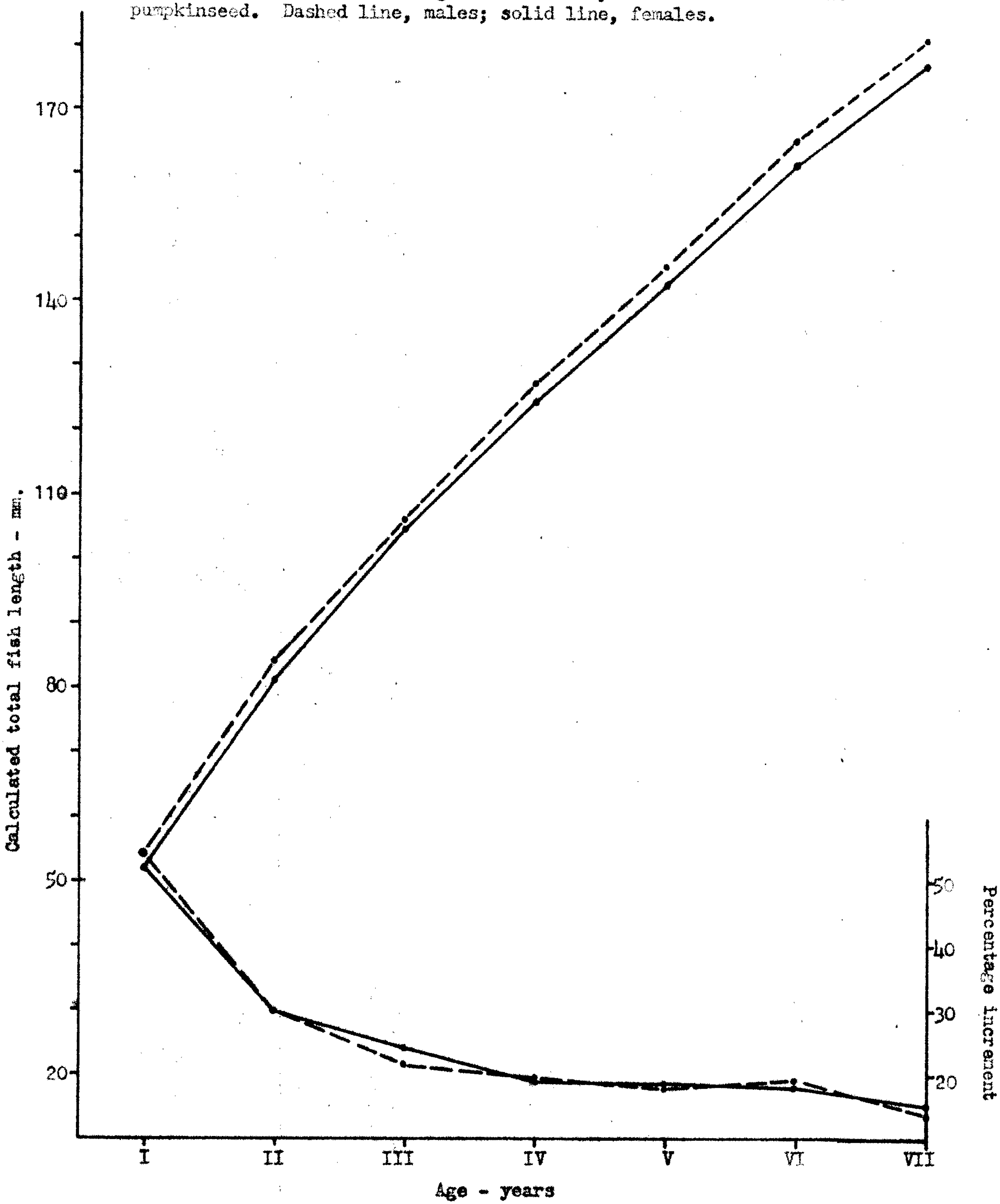


Table 7. Grand average annual increment in length (mm.) of male and female pumpkinseed of age groups I-VII in year classes 1956-1962.

Age group	Male			Female		
	Mean	Sum of means	Percentage increment	Mean	Sum of means	Percentage increment
I	54.41	54.41	-----	52.19	52.19	-----
II	30.07	84.48	55.27	29.82	82.01	57.14
III	21.81	106.29	25.82	24.12	106.13	29.41
IV	19.90	126.19	18.72	19.04	125.17	17.94
V	18.17	144.36	14.40	18.45	143.62	14.74
VI	19.65	164.01	13.61	18.29	161.91	12.73
VII	14.00	178.01	8.54	15.40	177.31	9.51

Table 8. Average annual increments of growth in length of male and female pumpkinseed from Horseshoe Lake-expressed in millimeters.

Males

Age group	Year class 1956	1957	1958	1959	1960	1961	1962
7							14.00
6						22.00	17.29
5					16.50	18.93	19.09
4				18.25	21.75	22.56	17.05
3			24.25	22.39	20.97	21.17	16.25
2		30.75	31.68	29.06	34.00	29.16	25.75
1	55.25	51.39	53.41	51.72	54.67	57.80	56.60

Females

Age group	1956	1957	1958	1959	1960	1961	1962
7							15.40
6						18.56	18.02
5					17.75	20.05	17.55
4				19.41	19.37	20.55	16.82
3			25.28	25.84	23.45	25.04	21.00
2		30.97	30.00	28.58	31.60	32.00	25.75
1	49.72	47.86	51.83	50.86	50.64	57.80	56.60

Figure 6. - Walford line of length in mm. at age t + 1 against length at age t and validation of l_{∞} = 277 mm. for Horseshoe Lake pumpkinseed.

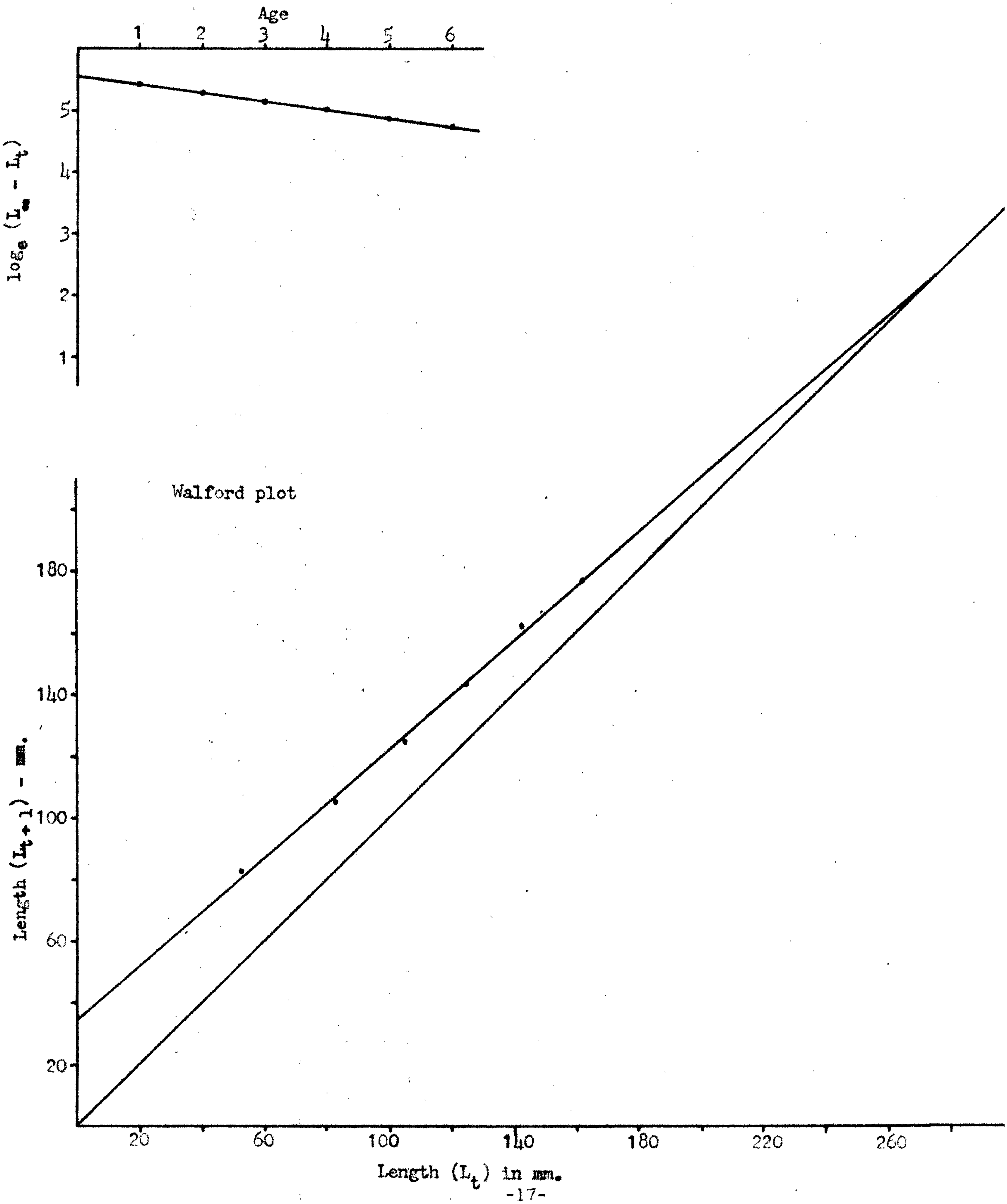
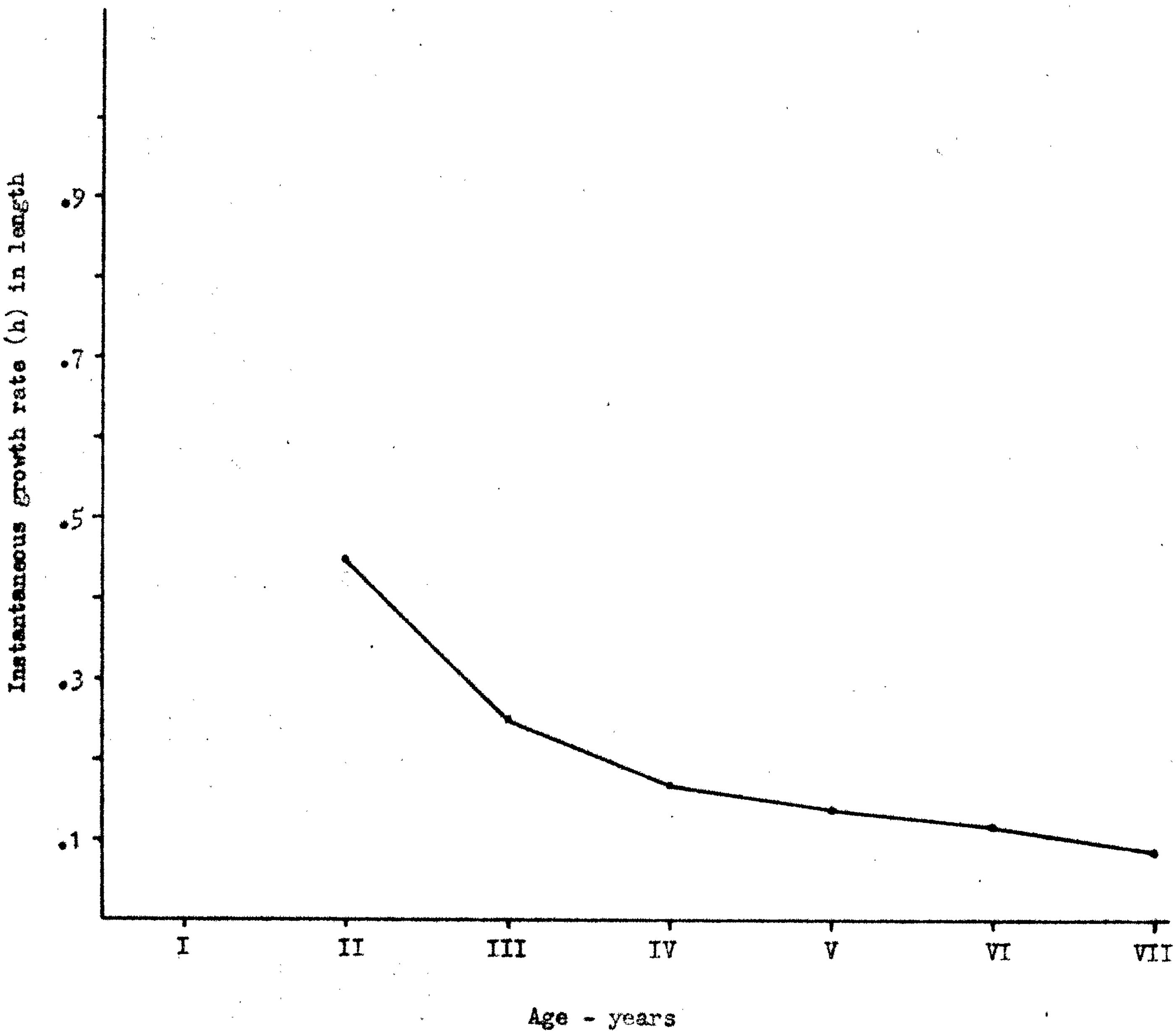


Figure 7. - Instantaneous growth in length for Horseshoe Lake pumpkinseed.



Growth in Different Calendar Years:

The total annual increment of growth will vary from year to year about a mean. The method of showing these variations is on the basis of percentage deviation from the mean increment of growth for all year considered after the method outlined by Hile (1941). Calculations of percentage deviations from a mean annual increment were made for the period, 1956-1962, for each sex (Table 9, Figure 8). The deviations varied from 7.94 percent below the mean to 5.10 percent above the mean for males and from 3.46 percent below the mean to 7.60 percent above the mean for females. This represents a difference in growth of 13.04 to 11.06 percent for males and females respectively for different calendar years. In general, there is good agreement between percentage deviations of males and females and the discrepancies are presumed to be due to small sample size and sampling error.

Possible factors causing variations in growth increments from year to year are environmental conditions to which the fish are subjected. Seven different combinations of weather factors were correlated with the percentage deviations from mean annual increments of growth for the years, 1956-1962. The necessary weather data was collected at Creston, Montana for the same period of years. This station is approximately 10 miles from Horseshoe Lake and there is assumed to be no difference in weather data due to different locations of the lake and the weather station.

Table 10 lists the seven correlations computed and the level of significance for each. The correlations were computed for sexes combined since there is good agreement between males and females for the percentage deviations from the mean growth increments (Figure 9).

Of the four positive correlations obtained, three are significant at the .70 percent and one at the .80 percent level. These significant correlations show possible positive relationships between the weather factors and annual growth increments although no direct cause-and-effect relationship is implied between the two variables.

Comparison of Growth with Other Areas:

The growth of Horseshoe Lake pumpkinseed has been compared with growth in waters of other areas (Table 11). The total length at each annulus of Horseshoe Lake pumpkinseed is below that for most areas considered. The growth after the first year is significantly slower compared to most other areas. This slower growth may be related to length of growing season, water fertility, population density factors or combinations of these. No data is available to demonstrate these possible relationships.

Length-Weight Relationship:

A length-weight relationship was calculated from the measurements of 331 fish and is described by the formula, W = -5.2231 L 3.2383 where W is weight in grams and L is length in millimeters. No significant difference was found between the length-weight relationships of males and females so sexes were combined. Figure 9 shows the total body length plotted against weight and Figure 10 represents this same length-weight relationship plotted logarithmically.

Growth in Weight:

Growth in weight of Horseshoe Lake pumpkinseed was approximately the same for both sexes during the first year of life but the rate of increase declined in the females after their first year and remained below that of the males throughout their remaining life (Table 12, Figure 11). At the time of seventh annulus formation, males and females had

Table 9. Calculation of percentage deviation from mean annual increment of growth of the period 1956-1962.

Males

Years	Growth earlier year	Growth after year	Mean	Change in growth	% change in growth	% deviation from 1956 growth	% deviation from mean increment
1955-56	---	---	---	---	---	0	+5.10
1956-57	55.25	51.39	53.32	-3.86	-7.24	-7.24	-2.14
1957-58	41.07	42.54	41.81	+1.47	+3.52	-3.72	+1.30
1958-59	36.45	34.39	35.42	-2.06	-5.82	-9.54	-4.44
1959-60	30.36	32.85	31.61	+2.49	+7.88	-1.66	+3.44
1960-61	29.58	29.92	29.75	+0.34	+1.14	-0.52	+4.58
1961-62	28.60	25.23	26.92	-3.37	-12.52	-13.04	-7.94

Females

Years	Growth earlier year	Growth after year	Mean	Change in growth	% change in growth	% deviation from 1956 growth	% deviation from mean increment
1955-56	---	---	---	---	---	0	+0.60
1956-57	49.72	47.86	48.79	-1.86	-3.81	-3.81	-3.21
1957-58	39.42	40.92	40.17	+1.50	+3.73	-0.08	+0.52
1958-59	35.70	35.09	35.40	-0.61	-1.72	-1.80	-1.20
1959-60	31.17	31.27	31.22	+0.10	+0.32	-1.48	-0.88
1960-61	28.56	31.09	29.83	+2.53	+8.48	+7.00	+7.60
1961-62	29.00	25.96	27.48	-3.04	-11.06	-4.06	-3.46

Figure 8. - Percentage deviation from mean annual increment of growth in different calendar years. Solid line, males; dashed line, females.

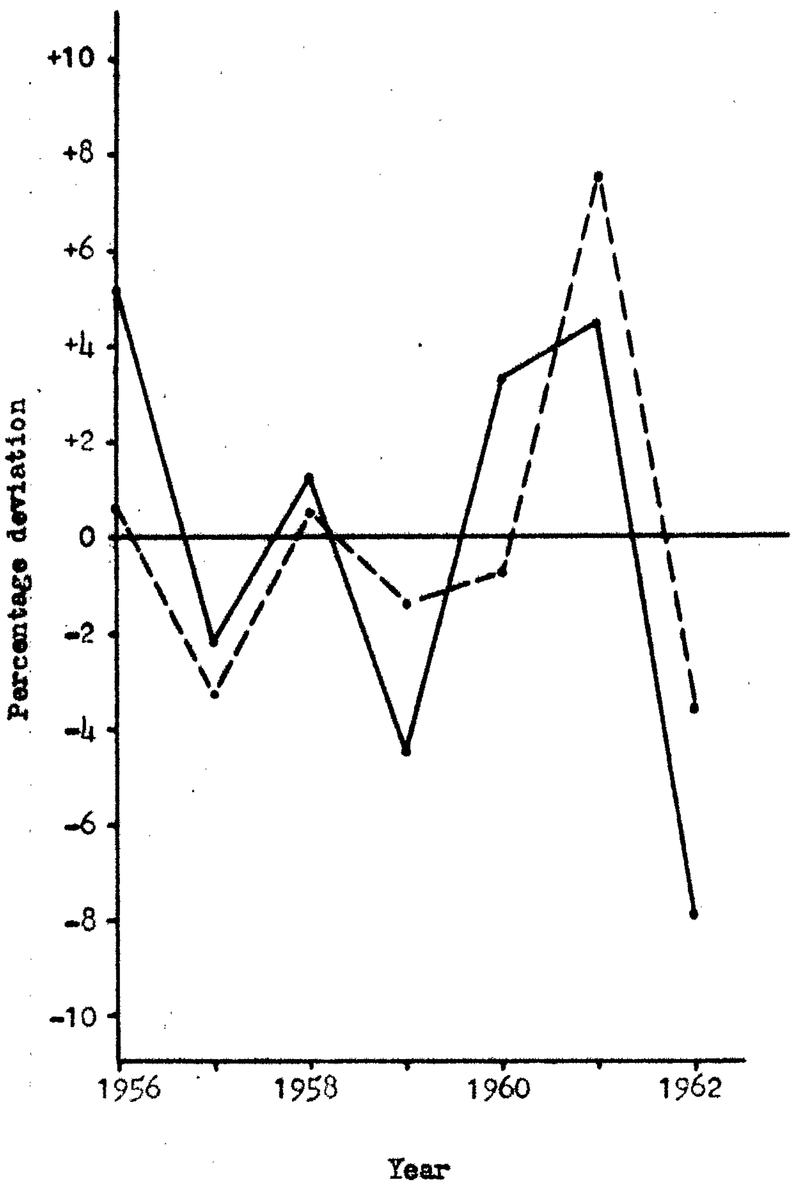


Table 10. Correlations of weather factors and percentage deviations of mean annual growth increments in calendar years 1956-1962 for Horseshoe Lake pumpkinseed.

Weather factor	Correlation coefficient	t-test at n-2 degrees of freedom	Level of significance
Length of growing season	.2449	.5648	non-significant
Temperature means in May and June combined	.5096	1.324	significant at .70 level
Tempt. means in July	.5274	1.388	significant at .70 level
Tempt. means in May through September combined	.5276	1.389	significant at .70 level
Total rainfall in May	.0826	.0829	non-significant
Total rainfall in June	.2661	.6172	non-significant
Total rainfall in April through July combined	.5914	1.6399	significant at .80 level

Table 11. Total length of pumpkinseed at succeeding annuli from various waters-expressed in millimeters.

Water	Age Group I	II	III	IV	V	VI	VII
3rd. Sister Lake, Mich.[1] (Brown & Ball, 1943)	50.8	99.06					
Deep Lake, Mich.[1] (Carbine & Applegate, 1948)	55.9	94.0	116.8	134.6	149.9	167.6	170.2
Wisconsin[1] (MacKenthun, 1948)	--	111.8	134.6	149.9	157.5	203.0	
Welch Lakes, New Brunswick[1] (Reid, 1930)	74.3	88.7	104.9	111.0	115.5	119.9	124.7
Minnesota[1] (Kuehn, 1949)	43.2	78.7	111.8	139.7	162.6	182.9	195.6
Minnesota[1] (Smith & Moe, 1944)	45.7	104.1	129.5	165.1	195.6	243.8	
Horseshoe Lake, Montana	52.9	82.9	105.9	125.3	143.5	162.2	177.5

[1] Converted to millimeters from original data

Figure 9. - Length-weight relationship, $W = -5.2331L^{3.2383}$, for Horseshoe Lake pumpkinseed.

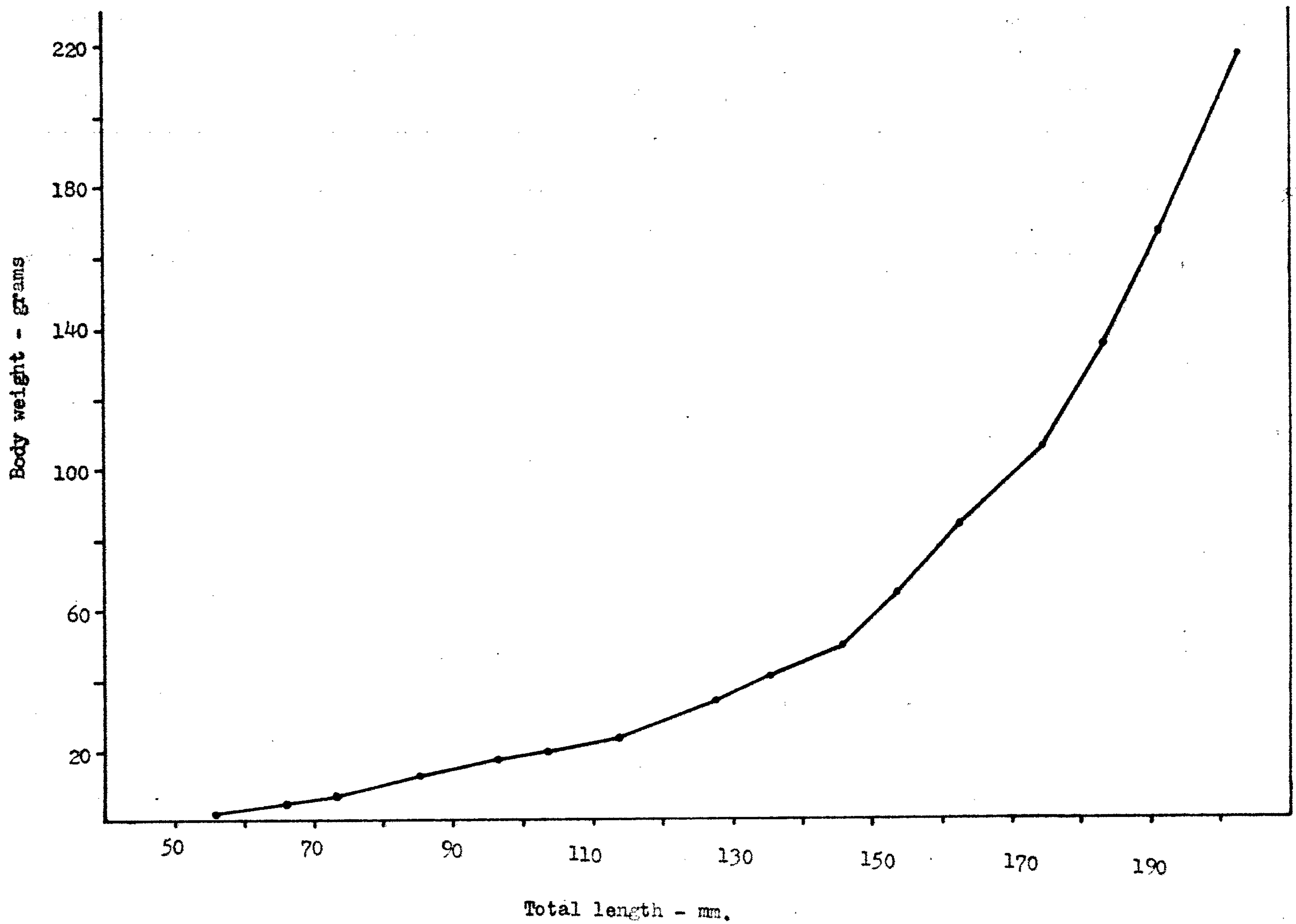


Figure 10. - Length-weight relationship plotted logarithmically, log W = -5.2231 + 3.2383 log L, for Horseshoe Lake pumpkinseed.

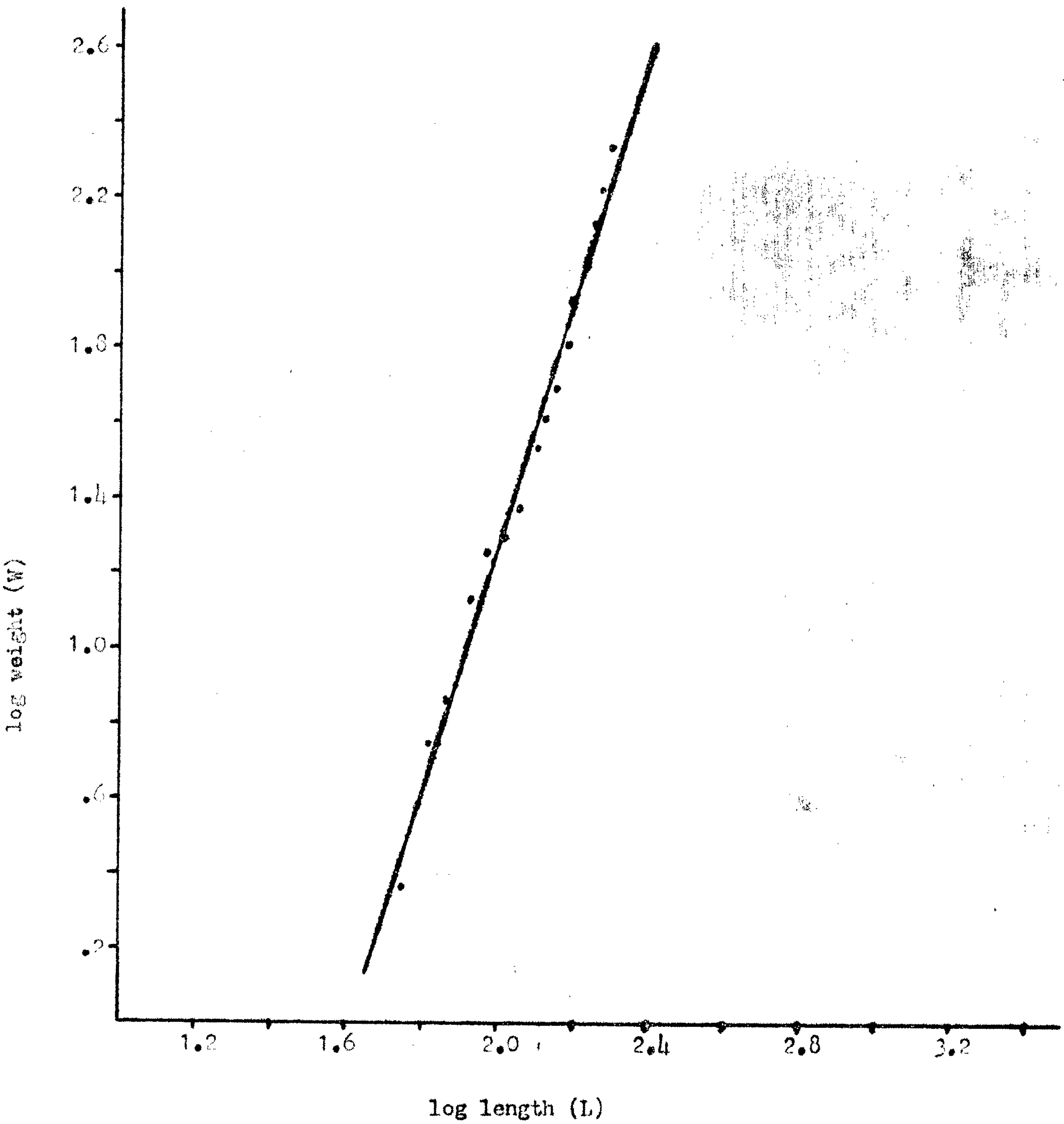


Figure 11. - Weight of Horseshoe Lake pumpkinseed at time of annulus formation in succeeding age groups. - based on calculated lengths and weights. Solid line, males; dashed line, females.

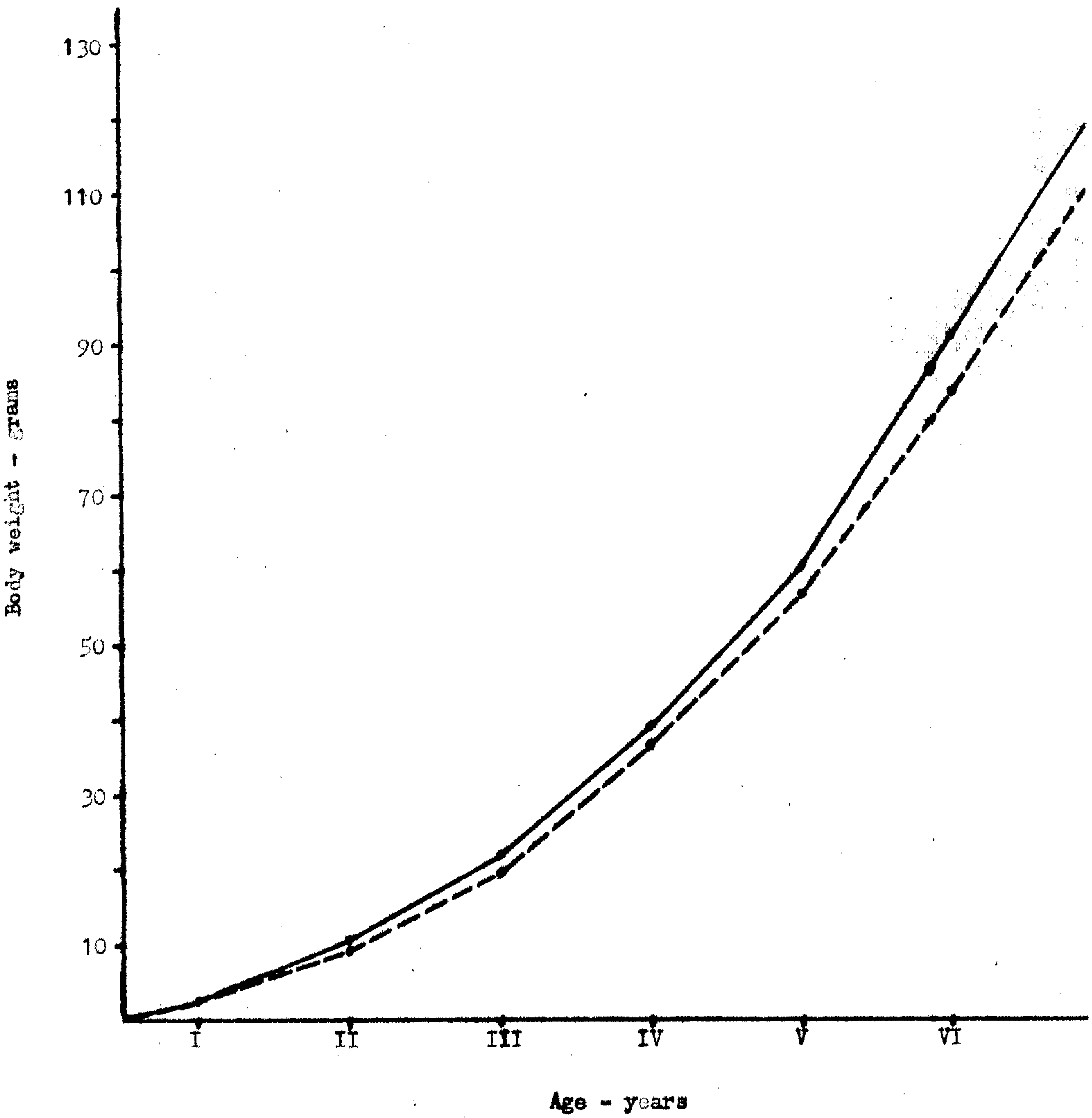


Table 12. Growth in weight (grams) of male and female pumpkinseed in Horseshoe Lake.

	Male			Female		
Age group	Mean weight	Sum of means	Percentage increment	Mean weight	Sum of means	Percentage increment
I	2.50	2.50	---	2.18	2.18	---
II	7.98	10.48	319.5	6.98	9.16	319.7
III	11.18	21.66	106.7	10.27	19.43	112.2
IV	17.61	39.27	81.3	16.83	36.26	86.6
V	20.97	60.24	53.4	20.50	56.76	56.5
VI	30.86	91.10	51.2	27.71	84.47	48.8
VII	31.40	122.50	34.5	29.63	114.10	35.1

average weights of 31.4 and 29.6 grams respectively. Figure 12 illustrates the instantaneous growth rate in weight following the method of Parker and Larkin (1959) and Ricker (1958).

Other means of representing growth in weight is through the use of Brody curves as described by Brody (1945). The three curves used (Figure 13) include the instantaneous relative growth rate, k, expressed as a percentage using the formula, $k = 100 \times \frac{l_n W_2 - l_n W_1}{t_2 - t_1}$, where l_n = natural logarithm, W_2 = weight at end of time period, W_1 = weight at beginning of time period, $t_2 - t_1$ = time interval expressed as one year. The second curve used was the average absolute growth rate which is described by the formula $\frac{W_2 - W_1}{t_2 - t_1}$.

The average relative growth rate described by the formula, $\frac{W_2 - W_1}{\frac{1}{2}(W_2 + W_1)}$ was the third Brody curve used to illustrate growth in weight (Figure 13).

These growth curves are not truly representative of the growth pattern since they are expressed at specific times and give only limited indications of growth during the time interval itself. The average relative growth rate assumes growth rate to be linear which in practice is true only for short intervals of time. The values of instantaneous percentage rate of growth do not necessarily mean that the percentage growth rate values are constant throughout the time interval considered.

Condition Factors:

Information may be obtained from the length-weight relationship which has been used to describe the relative heaviness or form of fish. The coeffieient of condition or condition factors is determined from the general equation, $C = \frac{W}{L^n}$. A special form of the condition factor called the ponderal index, K, is derived from the assumption that n = 3, thus the equation becomes, $K = \frac{W10^5}{L^3}$ where W = weight L = Length and 10^5 = a factor of equality. The coeffieient, K, is thus an index of weight in relation to the weight expected if growth in length and weight were isometric. The ponderal index was computed for 10 mm. intervals of length (Table 13).

A second index as outlined by LeCren (1951) is the relative condition factor described by the formula, $K_N = \frac{W}{aL^n}$ where W = weight, L = length, a = intercept value of fish length axis from the length-weight relationship and n = the slope of the length-weight relationship. Relative condition values were computed for 10 mm. intervals of length (Table 14).

Factors of age, sex, maturity, stomach content, state of gonads and changes associated with length will affect these condition factors. Sampling selection may also affect the K and K_n values. For these reasons, the use of condition factor as a means of comparison between different areas is undesirable except where the sources of variation are controlled or eliminated.

There were no trends in either the ponderal index, K, or relative condition factor, K_N, values for Horseshoe Lake Pumpkinseed (Table 13, 14). There were higher indexes of condition in the larger fish but there was extreme variation between all size classes considered. The average K value was determined as 1.8213. A comparison of average coefficients of condition with those from other areas showed the average index to be below that for all other areas considered (Table 15). Furthermore, the range of K values was above that of the Horseshoe Lake pumpkinseed (Table 13). This may be due to inadequate sampling or genetic factors of the fish.

Figure 12. - Instantaneous growth of weight for Horseshoe Lake pumpkinseed.

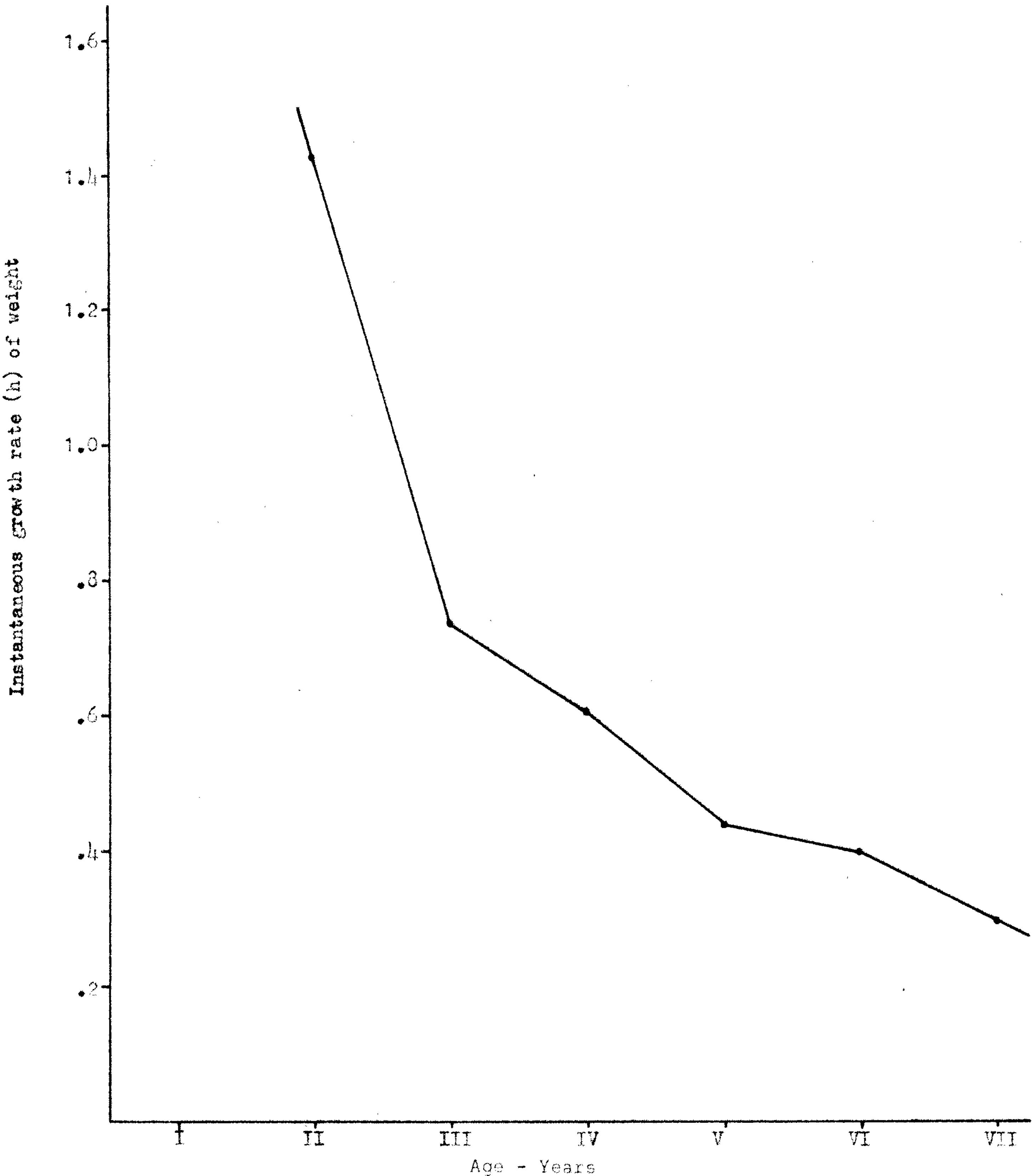


Figure 13. - Brody curves of growth in weight plotted against age: Average relative growth rate, dashed-dotted line; average absolute growth rate, dashed line; instantaneous relative growth rate, solid line.

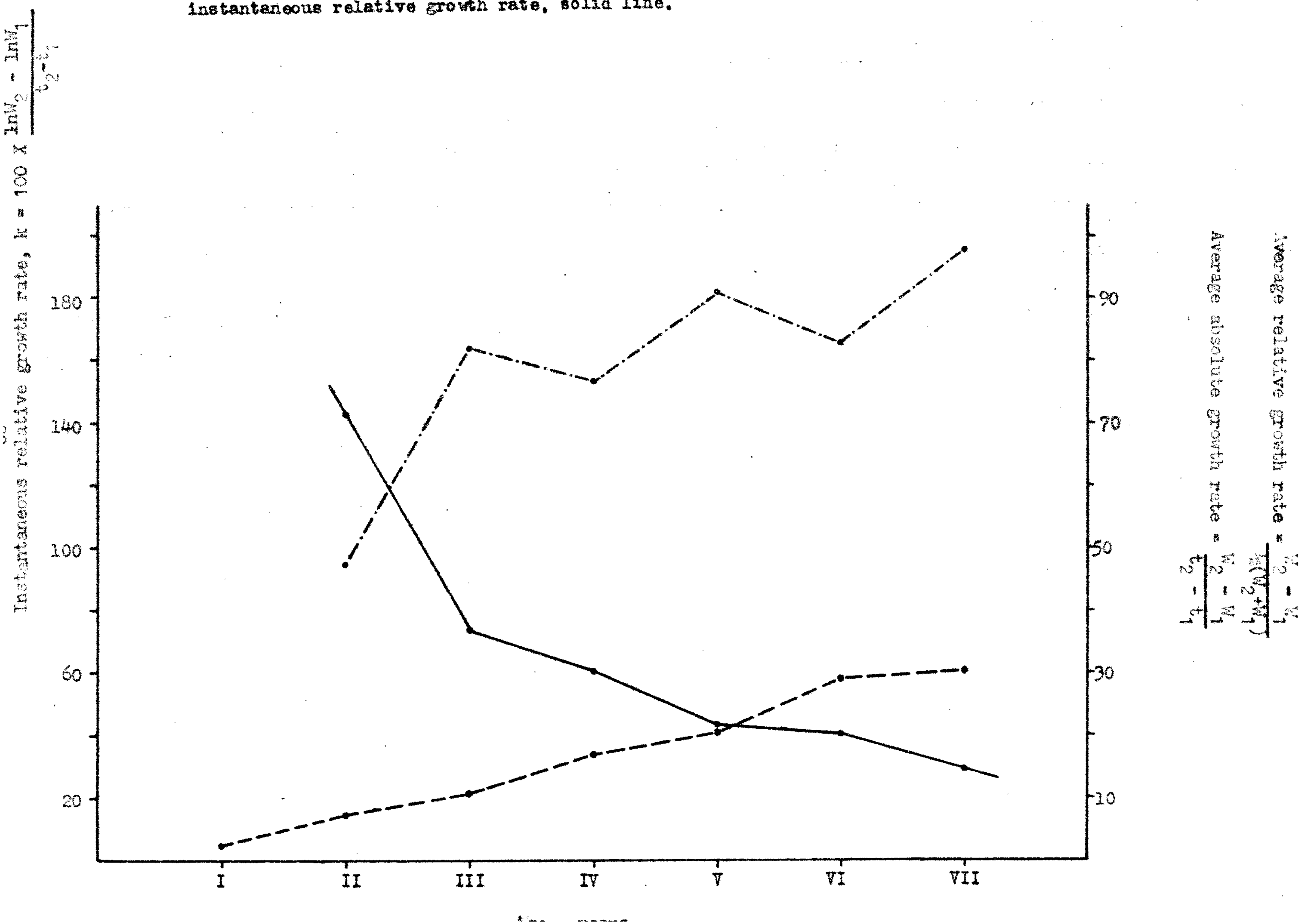


Table 13. Coefficient of condition values (K) computed for 10 mm. intervals of Horseshoe Lake pumpkinseed.

Length interval in mm.	Coefficient of condition
50-60	.1293
60-70	1.9194
70-80	1.8385
80-90	2.1928
90-100	1.9730
100-110	1.7744
110-120	1.5923
120-130	1.6222
130-140	1.6945
140-150	1.5783
150-160	1.7636
160-170	1.9375
170-180	1.9635
180-190	2.1698
190-200	2.3891
200-210	2.6026

Table 14. Relative condition factors (K_N) computed for 10 mm. intervals of Horseshoe Lake pumpkinseed.

Length interval in mm.	Relative condition factor
50-60	.8464
60-70	1.1169
70-80	1.1104
80-90	1.1271
90-100	1.1114
100-110	.9582
110-120	.8608
120-130	.8640
130-140	.8557
140-150	.8080
150-160	.8912
160-170	1.1047
170-180	.9671
180-190	1.1056
190-200	1.1137
200-210	1.1226

Table 15. Average coefficients of condition (K) from other areas.

Water	Range of total lengths	Average K value
Leech Lake, Minn. (Carlander & Hiner, 1943)	70-189 mm.	3.98
Iowa (Carlander & Parsons, 1949)	56-135 mm.	4.20 (range 3.41-4.70)
Michigan (Westerman & Van Oosten, 1939)	----	5.14
Minnesota (Carlander, 1944)	70-209 mm.	4.06
Horseshoe Lake, Montana	50.8-203.0 mm.	1.82 (range .13-2.60)

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