THE AGE AND GROWTH OF THE GREAT LAKES CISCO, *LEUCICHTHYS ARTEDI* (LESUEUR), FROM SAGINAW BAY, GREEN BAY, AND GRAND TRAVERSE BAY

BY

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CONTENTS

Introduction

The Great Lakes cisco, Leucichthys artedi (LeSueur), is one of the leading commercial fish of the Great Lakes. This species is often referred as Lake herring or cisco by many workers. In this paper, the names Lake herring and cisco are also considered as synonyms of the Great Lakes cisco. To date only three publications have appeared pertaining to the age and growth studies of cisco. One of them is on the extensive and excellant work done by Van Oosten (1929) on the Lake Huron Lake herring and the other two are on the Lake herring of Wisconsin lakes (Hile 1936) and Irondequoit Bay, New York (Stone 1938). This paper is an attempt to furnish further information on the age and growth history of Lake herring from the commercial centers, Saginaw Bay and Green Bay, of the Lakes Huron and Michigan respectively, and to compare them with cisco of Grand Traverse Bay of Lake Michigan, a region where commercial fishing operations are prohibited.

Materials and Methods

This study of the age and growth of the Great Lakes cisco is based on 1160 specimens. Of these, 686 specimens from Saginaw Bay and 415 specimens from Green Bay were collected from commercial fishermen. Majority of these specimens were taken from trap nets, while a few were taken by gill nets with 2 1/2-inch stretched mesh. The fifty-nine specimens from Grand Traverse Bay were collected by the experimental gill nets with meshes ranging from 2 1/2 to 4 inches. The data obtained from collections made in 1942, 1943, 1944, 1945 and 1946 and the

gelatine-glycerine scale slides for 844 specimens prepared by Dr. Peter I. Tack were at my disposal. The writer collected data for the 1950 samples from Green Bay.

Table 1 lists the source of the materials and data obtained in different years of collection. Excepting for the 1950 sample from Green Bay, the weights and lengths of the other samples were obtained immediately after landing. The 1950 samples were packed in cracked ice and shipped to the Fisheries Laboratory, Michigan State College, where the data were gathered.

Scale samples were taken from all specimens from the left side of the body below the dorsal fin and above the lateral line. The scales from this area were found less variable in shape and size Van Oosten (1929). The following data were recorded for all the specimens excepting the ones indicated in table 1: standard length and total length in millimeters, weight in grams, sex, date of collection and locality. In the 1943 collection of the Saginaw Bay sample, all the key scales of one fish showed regenerated condition and hence, this fish was discarded from this study. In the 1944 collection of the Green Bay sample the 66 fish for which no weight and sex data were obtained came in drawn condition from the fishermen.

Four scales from each fish were mounted in gelatine-glycerine medium and the one readily readable was used for age and growth determinations. The scales were projected on a scale viewing machine described by Van Oosten, et al. (1934) using a 32 mm. objective which yielded a magnification of 40.5 diameters. Each scale length was read along the greatest antero-lateral radius.

Table 1: Statistics obtained for the different years collection of the Great Lakes cisco

Source	Year of collection	Number of fish for which data were complete	Number of fish for which data were incomplete					Total number of fish
			without standard length	without total length	without weight	without sex	with regenerated scales	
Saginaw Bay	1942	5	-	-	-	-	-	5
	1943	406	-	1	-	2	1	410
	1944	137	32	-	1	1	-	171
	1945	98	-	2	-	-	-	100
							Sub-total	686
Green Bay	1944	33	-	-	66		-	99
	1945	38	-	6	-		-	44
	1950	272	-	-	-		-	272
							Sub-total	415
Grand Traverse Bay	1946	59	-	-	-	-	-	59
							Sub-total	59
							Grand Total	1160

The terms age groups and year classes used in this paper are defined as follows: An age group includes those individuals in a collection of fish which have completed a given number of winter marks based on which, the fish are classified as age group I if they show one winter mark, age group II when there are two annuli and so on. The fish which do not show any annulus in their scales are denoted as age group 0.

A year class refers to those fish which have hatched out in a particular year. For instance, in a catch of 1950, when we indicate a group of fish as year class 1945, it means that the members in that group were all hatched out in 1945 and caught 5 years after hatching. It should be carefully noted that a catch may have different year classes, i.e., groups that were hatched in different years. As an example, in our 1946 collection of Grand Traverse Bay sample, age group II may be referred as year class 1944, age group III as year class 1943, age group IV as year class 1942, and age group V as year class 1941.

Length frequency distribution and age composition

After careful examination, the 1942, 1943, 1944 and 1945 samples of the Saginaw Bay Lake herring did not show highly significant differences in their length distribution for the different age groups. Therefore, all collections were combined in the study of the length frequency distribution. For 32 fish the standard length was not recorded at the time of collection. Conversion factors, table 2, were computed for transforming total lengths into standard lengths and vice versa after the method of Van Oosten (1938). Standard lengths

Table 2: Factors for the conversion of total and standard lengths of the Saginaw Bay Lake herring

Standard length interval in millimeters	Number of fish	Conversion factors	
		Total length to Standard length (no change in units of length)	Standard length to Total length (no change in units of length)
Under 200	27	0.82501	1.21043
201 - 300	600	0.83134	1.20320
Over 300	23	0.83471	1.19848

Table 3: Length frequency distribution of 685 Saginaw Bay Lake herring collected in the years 1942, 1943, 1944 and 1945

Class Interval	Age Class Frequencies								Total
	I	II	III	IV	V	VI	VII	VIII	
160 - 169	2								2
170 - 179		2							2
180 - 189	5	7							12
190 - 199		12	1						13
200 - 209		18	3						21
210 - 219	1	17	7						25
220 - 229	1	24	21	9					55
230 - 239	1	27	36	12					76
240 - 249		8	20	13	3				44
250 - 259		7	29	18	13	2			69
260 - 269		9	43	47	27	9	1	1	137
270 - 279		2	16	40	38	10	1		107
280 - 289		1	9	15	23	15		1	64
290 - 299			1	11	9	6	5	1	33
300 - 309				3	3	4	3	1	14
310 - 319					1	2	1		4
320 - 329				1		1	2	3	7
Total	10	134	186	169	117	49	13	7	685
Mean Length	185.300	224.418	244.973	264.530	274.431	284.296	284.962	295.357	
Sd. Deviation	2.394	2.311	9.150	1.897	1.337	1.581	1.713	2.340	
Standard Error	0.757	0.200	0.975	0.146	0.124	0.226	0.475	0.884	

were computed for the above 32 fish using these conversion factors, and their calculated values were employed in this investigation.

Table 3 shows the length-frequency distribution of 685 Saginaw Bay Lake herring. The fishes in each age group are grouped into 10 millimeter length intervals. The total number of fish for each age group, their mean lengths, standard deviation and the standard error of the mean are recorded in the bottom rows of the table. At the extreme right column of the table the total number of fish for the corresponding length interval irrespective of the age groups is shown.

From the table it is seen that the four years' samples fall within the 160-329 millimeter range and the 260-269 millimeter size class is dominant with 137 individuals or 20% of the total catch. The age group III represents the dominant group with 186 individuals. Following this dominant age group the number of individuals in each age group drop off sharply until in the age groups VII and VIII only 13 and 7 individuals are represented. Since no fish of more than eight years of age were found in this collection it may be inferred that few individuals survive beyond this age. Van Oosten (1929) found a few individuals up to eleven years old. This, however, does not constitute an inconsistency. In either instance the number of individuals eight years of age or older represent an insignificant portion of the sample.

The length-frequency distribution of 415 Green Bay Lake herring is given in table 4. The samples of 1944, 1945 and 1950 are combined since the data do not show any evidence that the length distribution of any one year's sample differs from that of the others significantly. The three samples fall within a length range of 180-299 millimeters. The 220-229 millimeter size class is dominant with 128 specimens or 31%

Table 3: Length frequency distribution of 685 Saginaw Bay Lake herring collected in the years 1942, 1943, 1944 and 1945

Class Interval	Age Class Frequencies								Total
	I	II	III	IV	V	VI	VII	VIII	
160 - 169	2								2
170 - 179		2							2
180 - 189	5	7							12
190 - 199		12	1						13
200 - 209		18	3						21
210 - 219	1	17	7						25
220 - 229	1	24	21	9					55
230 - 239	1	27	36	12					76
240 - 249		8	20	13	3				44
250 - 259		7	29	18	13	2			69
260 - 269		9	43	47	27	9	1	1	137
270 - 279		2	16	40	38	10	1		107
280 - 289		1	9	15	23	15		1	64
290 - 299			1	11	9	6	5	1	33
300 - 309				3	3	4	3	1	14
310 - 319					1	2	1		4
320 - 329				1		1	2	3	7
Total	10	134	186	169	117	49	13	7	685
Mean Length	185.300	224.418	244.973	264.530	274.431	284.296	284.962	295.357	
Sd. Deviation	2.394	2.311	9.150	1.897	1.337	1.581	1.713	2.340	
Standard Error	0.757	0.200	0.975	0.146	0.124	0.226	0.475	0.884	

Table 4: Length frequency distribution of 415 Green Bay Lake herring collected in the years 1944, 1945 and 1950

Class Interval	Age Class Frequencies						Total
	II	III	IV	V	VI	VII	
180 - 189	1	2					3
190 - 199	3	3	2				8
200 - 209	4	22	1				27
210 - 219	5	37	19	5			66
220 - 229	12	30	62	24			128
230 - 239	10	19	31	20	5		85
240 - 249		18	11	12	3	1	45
250 - 259	1	10	6	4	1		22
260 - 269		2	10	2	3	1	18
270 - 279		1	4	2	1		8
280 - 289			2	1	1		4
290 - 299				1			1
Total	36	144	148	71	14	2	415
Mean Length	215.140	215.507	225.284	234.655	254.143	244.500	
Sd. Deviation	1.496	1.726	1.672	1.609	1.692	1.414	
Standard Error of the Mean	0.249	0.144	0.137	0.191	0.452	1.000	

of the total catch. The age group IV is represented by 148 individuals or 35.6% of the sample. Van Oosten (1929) in his study on the Lake Huron Lake herring refers the age group IV as the dominant class, a case similar to the Green Bay samples in this investigation. The difference in the number of individuals in age groups III and IV in this study is so small, i.e., 4, that we should not lay too much emphasis on the apparent observation of the dominancy of the age group IV.

Table 5 refers to the length-frequency distribution of 59 Grand Traverse Bay Lake herring caught in 1946. Their standard lengths fall within 150-319 millimeter interval, the 190-199 size class being dominant with 13 individuals. The age group III is dominant represented by 29 specimens or 49.1% of the sample.

It is interesting to note that the age composition of the three samples varies with one another. The Saginaw Bay sample is represented by eight age groups, from I to VIII, the Green Bay sample by six age groups from II to VII and the Grand Traverse Bay by four age groups from II to V. Hile (1936) found that that the entire lack of age group I in his 1928 collection of Trout Lake cisco and the scarcity of them in the Muskellunge Lake collections were the result of the selectivity of gear. The scarcity of the age group I in the Saginaw Bay sample and the lack of them in the Green Bay and Grand Traverse Bay samples may be considered the result of the selectivity of the net. The lack of age groups beyond, in spite of the use of experimental nets with mesh sizes 2 1/2 to 4 inches in the Grand Traverse Bay sample indicates the possible suggestions that Lake herring beyond five years of age suffered heavy mortality or they had migrated to some other place in that season of the year. It is, of course,

Table 5: Length frequency distribution of 59 Grand Traverse Bay Lake herring collected in 1946

Class Interval	Age Class Frequencies				Total
	II	III	IV	V	
150 - 159	1				1
160 - 169		1			1
170 - 179		2			2
180 - 189	6	1			7
190 - 199	3	10			13
200 - 209	1	5	1		7
210 - 219		1	1		2
230 - 239		4		1	5
240 - 249			2		2
250 - 259		1	3	1	5
260 - 269		2	2	1	5
270 - 279		2	2	1	5
280 - 289				3	3
310 - 319				1	1
Total	11	29	11	8	59
Mean Length	184.500	214.259	245.045	274.500	
Sd. Deviation	1.183	3.666	2.252	2.390	
Standard Error of the Mean	0.357	0.569	0.679	0.845	

true that the small sample warns us from over emphasizing the above suggestions.

Sex ratio

Of the 682 Saginaw Bay specimens examined, 311 and 371 were males and females respectively. The three hundred and forty-nine Green Bay Lake herring consisted of 133 males and 216 females. The Grand Traverse Bay sample of 59 individuals was composed of 30 males and 29 females. With the exception of the Grand Traverse Bay sample, the females tend to be relatively more abundant.

The distribution of the sexes in the different age groups according to the year of collection is given in table 6. In the next to last column the ratio of the females to males with all age groups combined is shown. The last column shows the number of females per 100 males in the year of collection. It is seen from the table that there is a great variation of the sex ratio with age. It is apparent, however, that the females outnumber the males in the well represented years excepting the 1943 sample of the Saginaw Bay and 1946 collection of the Grand Traverse Bay Lake herring. In the 1943 collection of the Saginaw Bay Lake herring the females of age groups, I, III, IV and V, are outnumbered by the males. In three, II, IV and V, out of four age groups of the Grand Traverse Bay sample the males are more numerous than the females. In spite of the discrepancies in the relationship between the sex ratio and age, it can be observed from the table that the males decrease in number faster than the females as the age of the fish increases from five years and onward.

Table 6: Sex ratio in each age group of each year's collection of the Lake herring samples from Saginaw Bay, Green Bay and Grand Traverse Bay

Year of Collection	Sex	Age Groups								Total	Females per 100 males
		I	II	III	IV	V	VI	VII	VIII		
Saginaw Bay Sample:											
1942	Males		1			1	1			3	
	Females		-			1	1			2	67
1943	Males	3	17	50	71	51	22	5	2	221	
	Females	2	18	27	56	48	22	8	5	186	84
1944	Males	-	16	24	7	2	1			50	
	Females	1	29	60	23	6	1			120	240
1945	Males	1	26	5	2	3	-			37	
	Females	3	26	20	10	3	1			63	181
Green Bay sample:											
1944	Males		1	4	8	1	1			15	
	Females		-	4	7	5	3			19	127
1945	Males		-	5	2	-				7	
	Females		8	20	7	1				36	514
1950	Males		4	29	49	27	2	-		111	
	Females		5	48	65	34	7	2		161	145
Grand Traverse Bay sample:											
1946	Males		8	8	8	6				30	
	Females		3	21	3	2				29	97

The 1942 sample of Saginaw Bay is so small, 5 in number, that it is doubtful if this sample is the true measure of the relative abundance of the sexes in that year. The 1944 and 1945 samples of Saginaw Bay show 240 and 181 females per 100 males. In 1943 sample, the ratio of the females to males is 84 to 100. When the Saginaw Bay samples of the years 1942, 1943, 1944 and 1945 are grouped together, the ratio of the males to females is 311 to 371 or 45.6 per cent males and 54.4 per cent females. Van Oosten (1929) found in the Lake Huron Lake herring taken at Bay City that the males and females were approximately equally abundant, the males forming 49.5 per cent of the entire sample. He also observed discrepancies in the sex ratio in the different age groups. Hile (1936) in the Wisconsin lakes samples found similar results as follows: Trout Lake 267 females per 100 males, Silver Lake 124 females per 100 males, Muskellunge Lake 137 females per 100 males and Clear Lake 104 females per 100 males.

Cahn (1927) found in his studies on Lake Mendota cisco that the males outnumber the females and that the males migrated into the shallows earlier than the females when the water temperature was 4.3°C. The females arrived a few days later when the water temperature dropped to 3.8°C. Whether the greater abundance of males in the 1943 collection of the Saginaw Bay sample and in the 1946 collection of the Grand Traverse Bay sample is due to a similar condition is difficult to judge at present since there are no data on the water temperatures at the time of capture of samples.

The sex ratio for the entire sample of Green Bay collected in 1944, 1945 and 1950 is 100 males to 162 females or the males form 32 per cent of the population. The abundance of the males here is 13.6 per cent

less than those of Saginaw Bay population.

The Grand Traverse Bay sample shows a sex ratio of 100 males to 97 females or the males forming 50.8 per cent of the sample.

Carlander (1945a and 1945b) found in the Tullibee and Yellow pike perch populations of the Lake of the Woods, Minnesota, that the percentage of the males varied from year to year and that the ratio of the females to males increased as the age of the fish increased, suggesting that the males were shorter-lived than the females.

Geiser (1924) had pointed out in his field collections of Gambusia that the females invariably exceeded the males in number and that the ratios varied with different seasons of the year. The greater abundance of females for other kinds of fish was shown by many workers: Hile and Jobes (1941) for Saginaw Bay perch as 296 females per 100 males, the same authors (1942) for the combined collections of Green Bay perch as 356 females per 100 males, Daiber (1947) for Traverse Bay yellow perch as 377 females per 100 males and Sigler (1949a) for White bass in Storm Lake as 138 females per 100 males.

Van Oosten (1938) determined the sex ratio of the common whitefish of Lake Huron as 50 males to 50 females and also the tendency for the males to become relatively less in number than the females as the age of the fish increased. He further observed that in the fall collection of 1924 the males exceeded the females in number indicating the male whitefish migrated to the spawning grounds earlier than females. In this study the 1943 fall collection of Saginaw Bay Lake herring shows a ratio of 166 males to 147 females. In the 1944 fall collection of the Saginaw Bay sample, the females exceeded the males and for the 1942 and

1945 collections there are not sufficient data in different seasons so as to warrant any comparison. Until more data are collected in different seasons of the year and compared, the 1943 fall collection may not be reliable to state that the male Lake herring behaves like the common whitefish in visiting the breeding grounds earlier than the females.

Among the factors that might cause differential sex ratio in adult fish, two alternative ones are put forth by Geiser (1924): "(a) a possible differential death-rate of the sexes during the embryonic, juvenile, and adult period, coupled with a normal sex ratio at fertilization, and (b) an atypical primary sex-ratio, due to an atypical distribution of sex-determining chromosomes to the two daughter cells in the maturation divisions of the germ cells." His studies on the spermatogenesis of Gambusia failed to show any special chromosomes that would explain the differential sex ratios. Moreover, the Gambusia raised by him in the aquaria showed approximately equal numbers of males and females at the time of birth. These evidences led Geiser to believe that the males had an inherent character for higher death-rate than females thus resulting in the differential sex ratios in the adult population.

Hile (1936 and 1941) believed that the differences in the sex ratios of the cisco and rock-bass in the Wisconsin lakes were due to the greater stability or survival value of the females. Geiser (1923) in his general discussion on the sex ratios in various animals, after quoting many cases, observed that the females had greater inherent viability than the males. If the observations of Geiser and Hile are accepted, then, a possible explanation for the greater abundance of the females in Lake herring may be a higher survival value of

the females than males.

Eschmeyer (1938) in his perch populations in Michigan and Hile (1936 and 1941) in his cisco and rock bass populations have pointed out that gill nets are highly selective with respect to sexes. If such selectivity had occurred for the Lake herring, then, the collections of gill nets may not be a reliable basis for any such discussion.

Whether the Lake herring tend to be equally distributed as shown by Hasler (1945) in his winter collection of yellow perch or they tend to school sexually and separately as shown by Eschemeyer (1938), Weller (1938) and Hasler (1945) in their perch population studies, no definite remark can at present be made until further work is carried out.

Body-scale length relationship

The scale method of growth analysis was demonstrated to be valid for Leucichthys artedi (LeSueur) by Van Oosten (1929). The body-scale relationship has been shown to be very close to a straight line regression in a considerable number of fish populations Lewis and English (1949), Tate (1949), Scott (1949), Perlmutter and Clarke (1949), Beckman (1941), Wright (1929) and Van Oosten (1942).

Hile (1941), in the rock bass sample of Nebish and Muskellunge Lakes, Wisconsin, established a body-scale length relationship that was expressed by a weak third order parabola. Carlander (1945a and 1945b) in his Tullibee and Yellow pike perch populations showed that the relationship between the scale radius and standard length was not a straight line, but could be described by a third degree parabola.

In this study the body-scale length relationship was assumed to be a linear regression since the L/Sc (L = length, Sc = scale radius) ratio in the three samples did not show any trend towards a parabolic relationship. Moreover, plotting the observed standard lengths against the anterior scale radii indicated a relationship very close to a straight line.

Saginaw Bay sample:

The body-scale relationship of 652 Lake herring from Saginaw Bay was determined by plotting the mean standard lengths at 5 millimeter intervals against the mean of the anterior radii of the scales for these intervals and fitting a line to the data, table 7, by the least squares method.

The straight line equation is: $y = a + bx$, where y is the standard length in millimeters and x is the scale radius and a and b are constants.

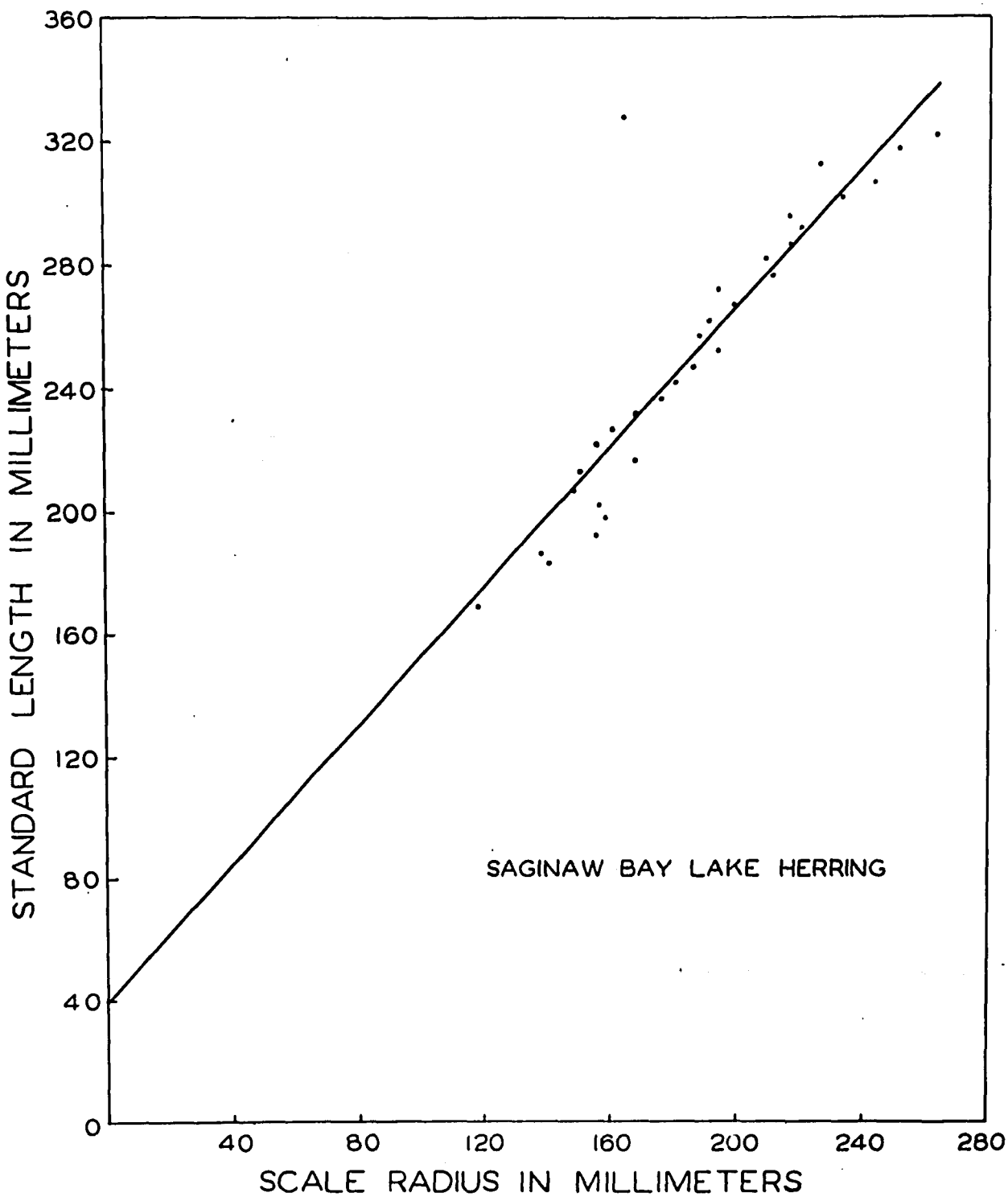
Figure 1 represents the equation: $y = 39.90723 + 1.13244x$

This straight line having an intercept on the y axis of 39.91 millimeters and a slope of 1.13 gave a satisfactory fit. Consequently, growth calculations were made with the aid of a nomograph on a direct proportion basis using 40 millimeters as a base rather than zero (Carlander and Smith 1944). For this population we may presume that the scale is formed when the fish is about 40 millimeters in standard length.

Table 7: Body-scale relationship (L/Sc) of 652 Saginaw Bay cisco grouped in 5 millimeter intervals of standard length

Class interval	Mean standard length	Mean scale measurement	L/Sc ratio	Number of fish
165 - 169	169	118	1.47	2
180 - 184	183	141	1.32	4
185 - 189	186	139	1.40	8
190 - 194	192	156	1.24	6
195 - 199	198	159	1.27	7
200 - 204	202	157	1.33	8
205 - 209	207	149	1.43	12
210 - 214	213	151	1.43	6
215 - 219	217	169	1.30	13
220 - 224	222	156	1.43	20
225 - 229	227	161	1.44	24
230 - 234	232	169	1.40	39
235 - 239	237	177	1.36	27
240 - 244	242	181	1.37	20
245 - 249	247	187	1.35	21
250 - 254	252	195	1.31	28
255 - 259	257	189	1.38	41
260 - 264	262	192	1.41	74
265 - 269	267	200	1.36	63
270 - 274	272	195	1.43	65
275 - 279	277	212	1.34	42
280 - 284	282	210	1.37	38
285 - 289	287	218	1.34	26
290 - 294	292	221	1.36	25
295 - 299	296	217	1.39	8
300 - 304	302	234	1.33	9
305 - 309	307	244	1.27	5
310 - 314	313	227	1.38	2
315 - 319	318	252	1.27	2
320 - 324	322	263	1.23	5
325 - 329	328	165	2.04	2

Fig. 1. Body-scale relationship of the Saginaw Bay Lake herring. The dots are based on the means in table 7. The equation of the straight line is $y = 39.90723 + 1.13244x$


360
320
280
240
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160
120
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40
0
STANDARD LENGTH IN MILLIMETERS
40
80
120
160
200
240
280
SCALE RADIUS IN MILLIMETERS
SAGINAW BAY LAKE HERRING

Green Bay sample:

The method used in determining the body-scale relationship of 415 Green Bay sample was similar to the one used for the Saginaw Bay Lake herring. Figure 2 was constructed to the data, table 8.

The slope of the straight line fitted to the equation, $y = 32.76055 + 1.14847x$, cut the length axis at 32.76 millimeters. Consequently, 33 millimeters were considered as the length of the fish before scale formation.

Grand Traverse Bay sample:

The data, table 9, of the Grand Traverse Bay sample yielded a straight line equation as:

$$y = 17.40290 + 1.15910x$$

The straight line, figure 3, having a slope of 1.16 intercepts the y axis at 17.40 millimeters. Growth calculations, consequently, were made using 17 millimeters as the base.

A comparison of these three samples shows that the standard length before scale formation is highly variable from one sample to another, 40 millimeters in Saginaw Bay, 33 millimeters in Green Bay and 17 millimeters in Grand Traverse Bay Lake herring. Van Oosten's (1929) actual observations had shown a range of 35 to 40 millimeters standard length before scale formation for the Lake Huron Lake herring. The Saginaw Bay and Green Bay samples have values of standard length, 40 and 33 millimeters respectively, before scale formation which fall near the range mentioned by Van Oosten. The two millimeters difference observed in the Green Bay sample from the minimum length, 35

Table 8: Body-scale relationship (L/Sc) of 415 Green Bay cisco grouped in 5 millimeter intervals of standard length

Class interval	Mean standard length	Mean scale measurement	L/Sc ratio	Number of fish
185 - 189	187	159	1.23	3
190 - 194	194	147	1.33	3
195 - 199	197	151	1.33	5
200 - 204	202	152	1.37	8
205 - 209	207	152	1.37	19
210 - 214	212	158	1.35	26
215 - 219	217	161	1.38	40
220 - 224	222	167	1.35	60
225 - 229	227	175	1.32	68
230 - 234	232	172	1.38	43
235 - 239	237	188	1.29	42
240 - 244	242	186	1.33	31
245 - 249	247	189	1.33	14
250 - 254	252	177	1.46	9
255 - 259	257	198	1.32	13
260 - 264	262	204	1.30	10
265 - 269	266	204	1.33	8
270 - 274	272	191	1.43	5
275 - 279	278	224	1.24	3
280 - 284	282	215	1.32	3
285 - 289	289	168	1.72	1
290 - 294	290	224	1.29	1

Fig. 2. Body-scale relationship of the Green Bay Lake herring. The dots are based on the means in table 8. The equation of the straight line is $y = 32.76055 + 1.14847x$

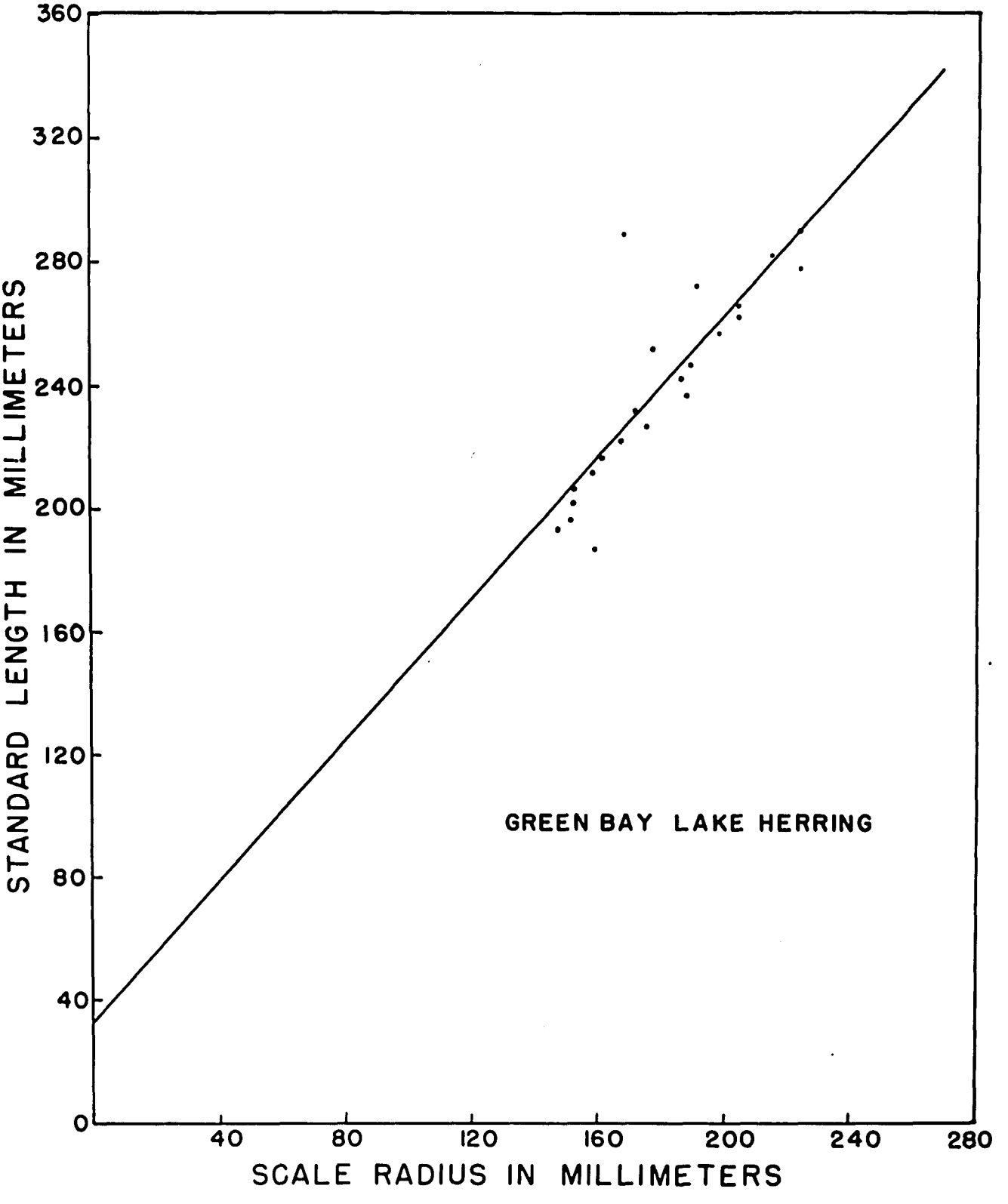
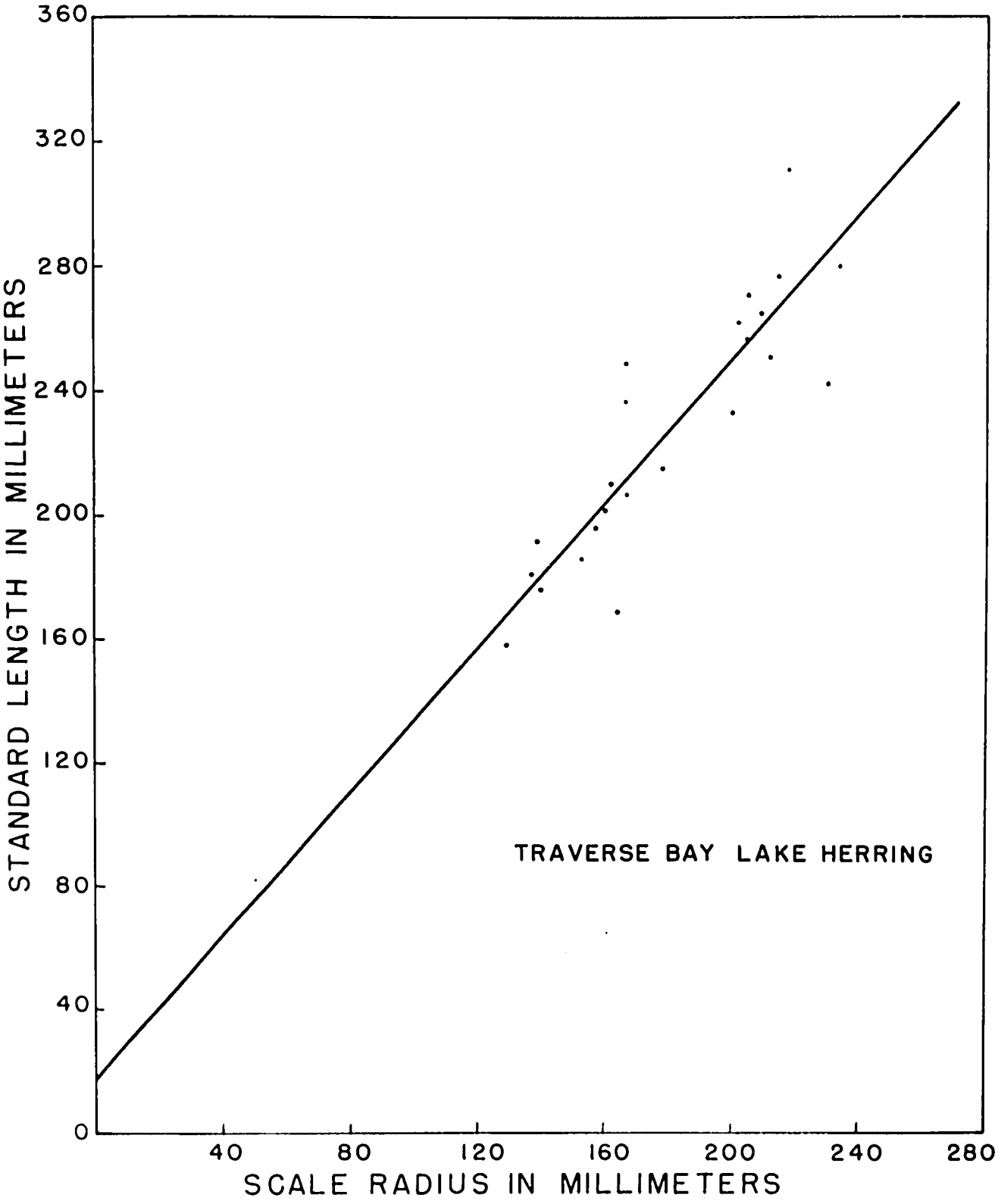

360
320
280
240
200
160
120
80
40
0
STANDARD LENGTH IN MILLIMETERS
40
80
120
160
200
240
280
SCALE RADIUS IN MILLIMETERS
GREEN BAY LAKE HERRING

Table 9: Body-scale relationship (L/Sc) of 59 Grand Traverse Bay cisco grouped in 5 millimeter intervals of standard length

Class interval	Mean standard length	Mean scale measurement	L/Sc ratio	Number of fish
155 - 159	158	129	1.22	1
165 - 169	169	164	1.03	1
175 - 179	176	143	1.23	2
180 - 184	181	137	1.32	4
185 - 189	187	153	1.25	3
190 - 194	192	149	1.29	8
195 - 199	196	157	1.26	5
200 - 204	202	160	1.28	3
205 - 209	207	167	1.26	4
210 - 214	210	162	1.30	1
215 - 219	215	178	1.21	1
230 - 234	233	200	1.17	1
235 - 239	237	167	1.45	4
240 - 244	242	230	1.05	1
245 - 249	249	167	1.49	1
250 - 254	251	212	1.19	2
255 - 259	256	205	1.26	3
260 - 264	262	202	1.32	4
265 - 269	265	209	1.27	1
270 - 274	271	205	1.35	2
275 - 279	277	215	1.29	3
280 - 284	280	234	1.21	3
310 - 314	311	218	1.43	1

Fig. 3. Body-scale relationship of the Grand Traverse Bay Lake herring. The dots are based on the means in table 9. The equation of the straight line is $y = 17.40290 + 1.15910x$


360
320
280
240
200
160
120
80
40
0
STANDARD LENGTH IN MILLIMETERS
40
80
120
160
200
240
280
SCALE RADIUS IN MILLIMETERS
TRAVERSE BAY LAKE HERRING

millimeters, observed by Van Oosten in Lake Huron Lake herring may not be significant.

The 17 millimeters standard length before scale formation in the Grand Traverse Bay sample is used provisionally for growth calculations. This value may be due to the small number of fish employed.

Growth in length

Tables 10 to 12 present the data for the calculated growth in length for the cisco of Saginaw Bay, Green Bay and Grand Traverse Bay. A preliminary analysis of calculated length data of Saginaw Bay and Green Bay cisco failed to show significance in length growth between samples taken in different years, hence the samples were combined for growth analysis. The cisco from Grand Traverse Bay were all collected in one year, 1946.

The differences in the calculated lengths of the two sexes were not large enough to warrant separate growth curves for males and females. Figures 4 to 6 were made to illustrate the growth curves of the populations where the sexes were combined. The figures in the tables are the average calculated lengths at the end of the respective years. The average lengths of the combined sexes are weighted means. The number of fish for which sex was not identified at time of collection are indicated in parentheses in the second column of the tables 10 and 11.

Growth in length in Saginaw Bay cisco:

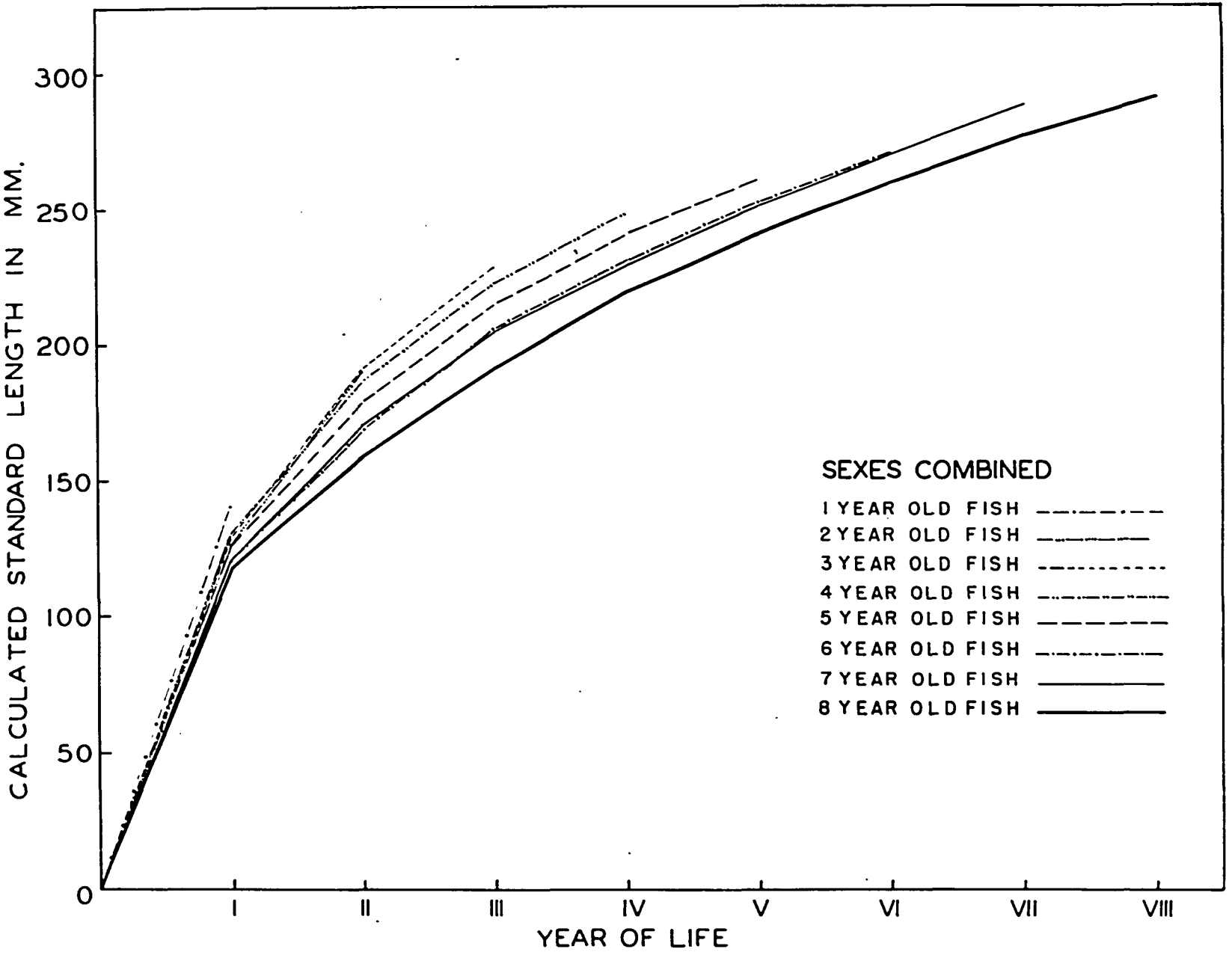
An inspection of the figures as they stand in table 10 reveals

Table 10: Average standard lengths for each year of life of 685 Saginaw Bay cisco collected in the years 1942, 1943, 1944 and 1945

Age Group		Number of fish	Calculated length (mm) at end of year of life							
			I	II	III	IV	V	VI	VII	VIII
I	Male	4	139							
I	Female	6	143							
I	Sexes combined	10	141							
II	Male	60	128	192						
II	Female	73	125	191						
II	Sexes combined	134 (1)	126	191						
III	Male	79	132	195	231					
III	Female	107	126	188	226					
III	Sexes combined	186	129	191	228					
IV	Male	80	133	189	227	252				
IV	Female	89	128	183	219	245				
IV	Sexes combined	169	131	186	223	248				
V	Male	57	129	181	217	243	262			
V	Female	58	125	177	214	239	261			
V	Sexes combined	117 (2)	126	178	215	240	261			
VI	Male	24	120	169	202	228	249	267		
VI	Female	25	123	168	207	234	256	272		
VI	Sexes combined	49	121	168	205	231	252	270		
VII	Male	5	122	173	207	234	252	269	287	
VII	Female	8	120	168	203	227	250	271	288	
VII	Sexes combined	13	121	170	204	229	251	270	288	
VIII	Male	2	118	162	200	231	252	273	293	309
VIII	Female	5	119	158	189	215	235	254	270	284
VIII	Sexes combined	7	118	159	192	219	240	259	277	291

In column 2, figures in parentheses indicate the number of fish for which sex was not determined.

Fig. 4. Mean calculated lengths at the end of each year of life of Saginaw Bay Lake herring based on table 10


CALCULATED STANDARD LENGTH IN MM.
300
250
200
150
100
50
0
I
II
III
IV
V
VI
VII
VIII
YEAR OF LIFE
SEXES COMBINED
1 YEAR OLD FISH
2 YEAR OLD FISH
3 YEAR OLD FISH
4 YEAR OLD FISH
5 YEAR OLD FISH
6 YEAR OLD FISH
7 YEAR OLD FISH
8 YEAR OLD FISH

that the males had grown longer than the females in all the years of age groups excepting the cases mentioned below. In age group I, the females exceed the males in length by 4 millimeters. This difference may not be considered valid because of the small size of sample, 4 males and 6 females. The age group VI is characteristic in that the females show greater length than the males in all years of life excepting the second year where the males exceed the females by 1 millimeter. This one millimeter difference may not be considered significant and for all purposes we can assume that the females in age group VI had exceeded the males in length in all the years. The one millimeter increment in length in the females of age group VIII is invalid since the number of fish to represent the sexes is very small,2 males and 5 females.

Growth in length in Green Bay cisco:

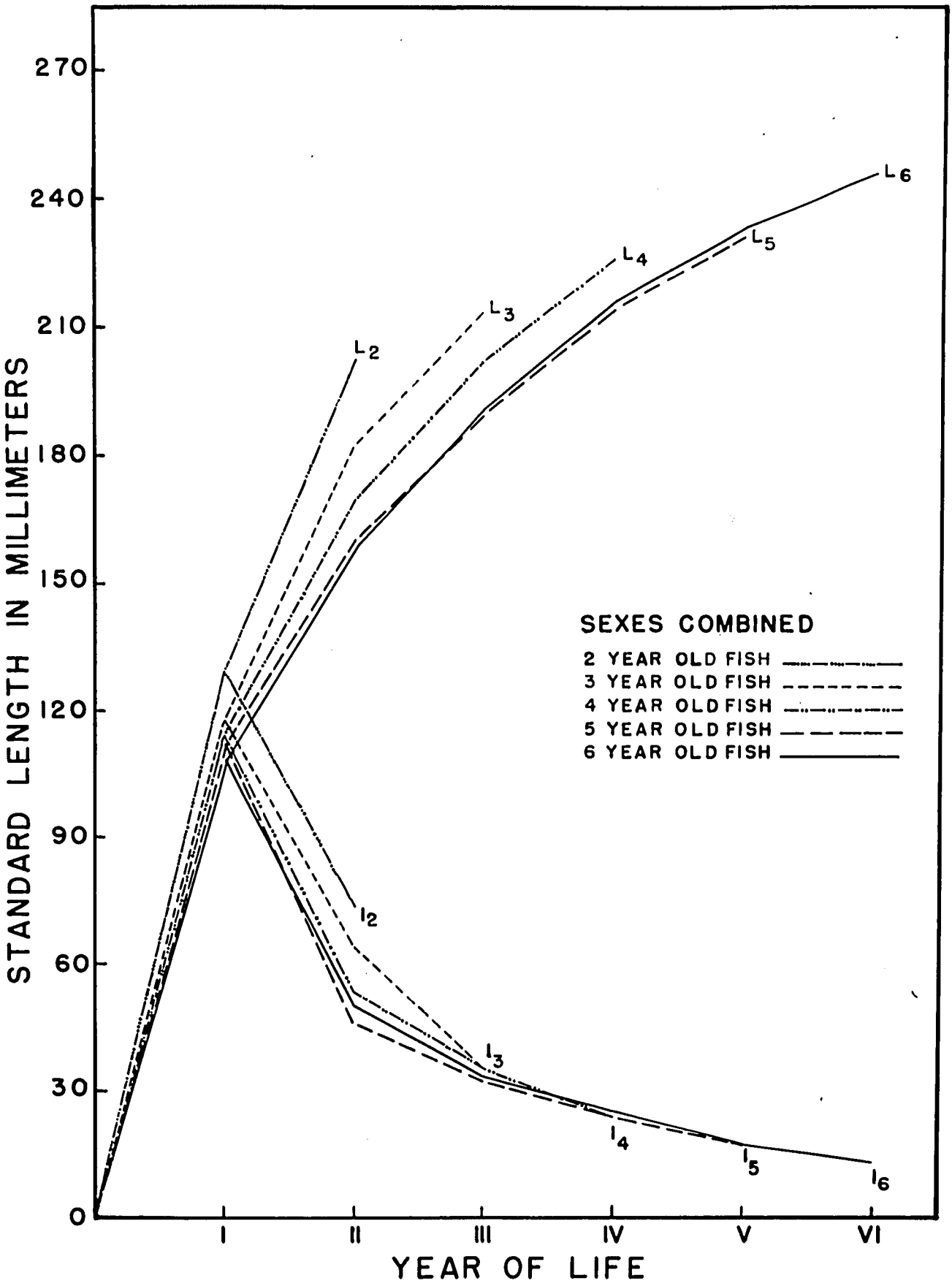
The calculated lengths at the end of respective years of life for the age groups II to VII from Green Bay are presented in table 11. The growth history of the males and females in age groups II to VI is of considerable interest, for it does not fall under the definite pattern we find in the Saginaw Bay sample where the males exceed the females in length. In age group II the males outgrow the females in the first year of life by 12 millimeters, but in the second year the reverse is true, the females exceeding the males by 8 millimeters. In age group III, the males and females attain the same length, 117 millimeters, in the first year and, in the second and third years the females grow faster than the males by 1 and 2 millimeters respectively. These variations are insignificant and we may presume the males and females of age group III have almost grown the same length in all years.

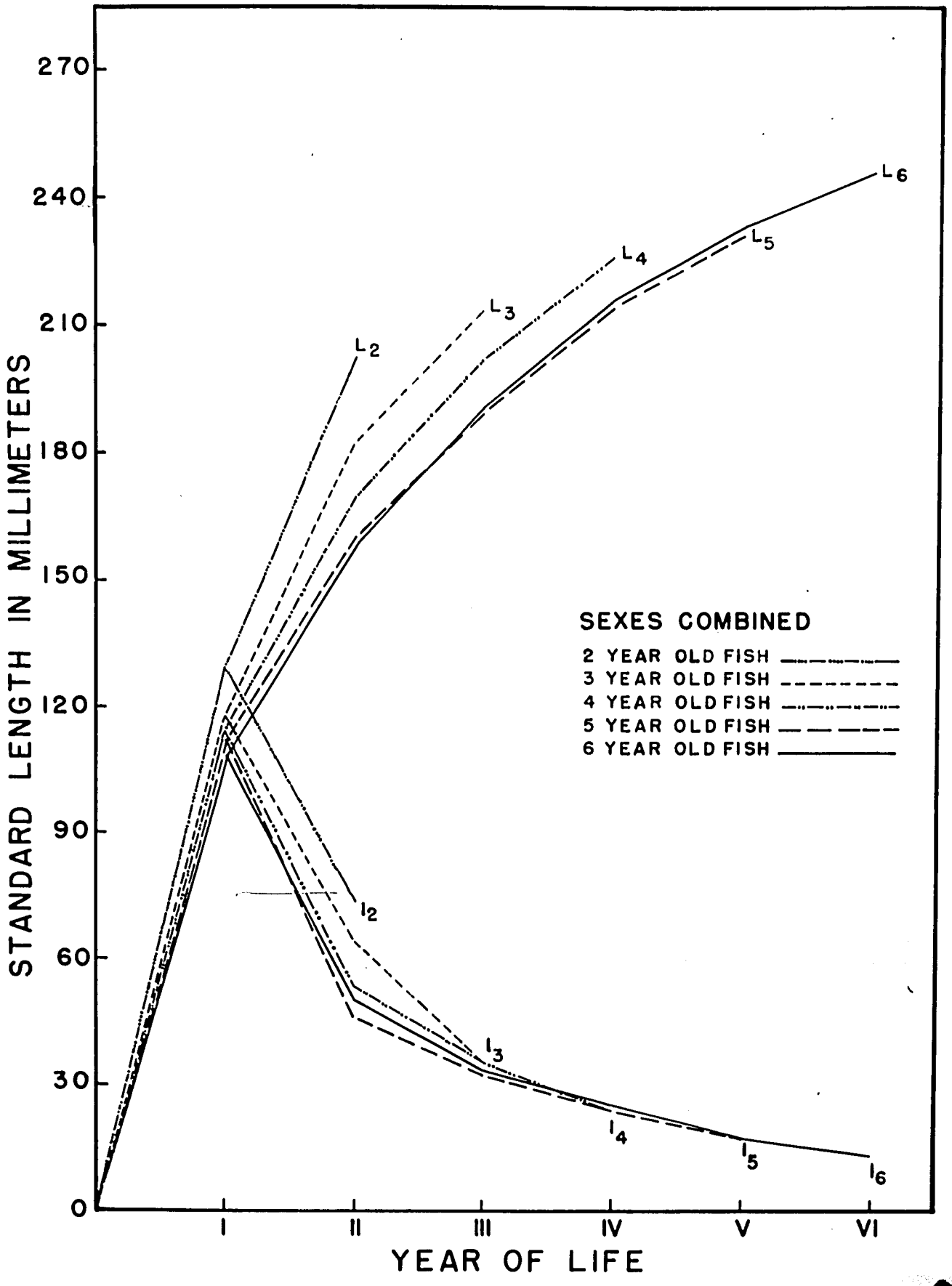
Table 11: Average standard lengths for each year of life of 415 Green Bay cisco collected in the years 1944, 1945 and 1950

Age Groups		Number of fish	Calculated length (mm) at end of year of life						
			I	II	III	IV	V	VI	VII
II	Male	5	141	196					
II	Female	13	129	204					
II	Sexes combined	36 (18)	129	202					
III	Male	38	117	178	214				
III	Female	72	117	179	216				
III	Sexes combined	144 (34)	118	182	217				
IV	Male	59	113	165	200	223			
IV	Female	79	115	167	202	227			
IV	Sexes combined	148 (10)	114	169	202	226			
V	Male	28	116	161	190	212	228		
V	Female	40	110	158	191	216	234		
V	Sexes combined	71 (3)	112	159	190	214	231		
VI	Male	3	110	162	196	219	239	252	
VI	Female	10	107	154	186	212	229	242	
VI	Sexes combined	14 (1)	108	158	191	216	233	246	
VII	Male	-	-	-	-	-	-	-	-
VII	Female	2	115	161	185	207	224	242	253
VII	Sexes combined	-	-	-	-	-	-	-	-

In column 2, figures in parentheses indicate the number of fish for whichsex was not determined.

Fig. 5. Mean calculated lengths at the end of each year of life and increments of growth in length of Green Bay Lake herring based on tables 11 and 15. Ls and ls indicate the length and length-increment curves of the corresponding age group.


270
240
210
180
150
120
90
60
30
0
STANDARD LENGTH IN MILLIMETERS
I
II
III
IV
V
VI
YEAR OF LIFE
L2
L3
L4
L5
L6
l2
l3
l4
l5
l6
SEXES COMBINED
2 YEAR OLD FISH
3 YEAR OLD FISH
4 YEAR OLD FISH
5 YEAR OLD FISH
6 YEAR OLD FISH


270
240
210
180
150
120
90
60
30
0
STANDARD LENGTH IN MILLIMETERS
I
II
III
IV
V
VI
YEAR OF LIFE
L2
L3
L4
L5
L6
l2
l3
l4
l5
l6
SEXES COMBINED
2 YEAR OLD FISH
3 YEAR OLD FISH
4 YEAR OLD FISH
5 YEAR OLD FISH
6 YEAR OLD FISH

In age group IV the females show greater length than the males in all the years, the differences being 2 millimeters in the first, second and third years and 4 millimeters in the fourth year. The males of the age group V exceed the females in the first two years by 6 and 3 millimeters respectively; but, in the next three years they are exceeded in length by the females by 1, 4 and 6 millimeters. In age group VI, the males show consistently greater growth in length than the females in all years of life, the differences from the females being 3, 8, 10, 7, 10 and 10 millimeters in the years one to six. The age group VII is represented by 2 females only.

The shifting of the greater growth in length from females to males in some years of life and from males to females in other years, as shown in the preceding paragraph, raises the question of, whether fish of different populations with greater or lower rates of growth in length, as the case may be, are represented in the catch; or, whether there is a difference in the response of different age groups to the environment. The data in this investigation do not reveal the solution to the above questions. The writer believes that investigations on the migratory and spawning activities of Lake herring will throw more light on these problems, particularly the differential growth rates of males and females in different years of life.

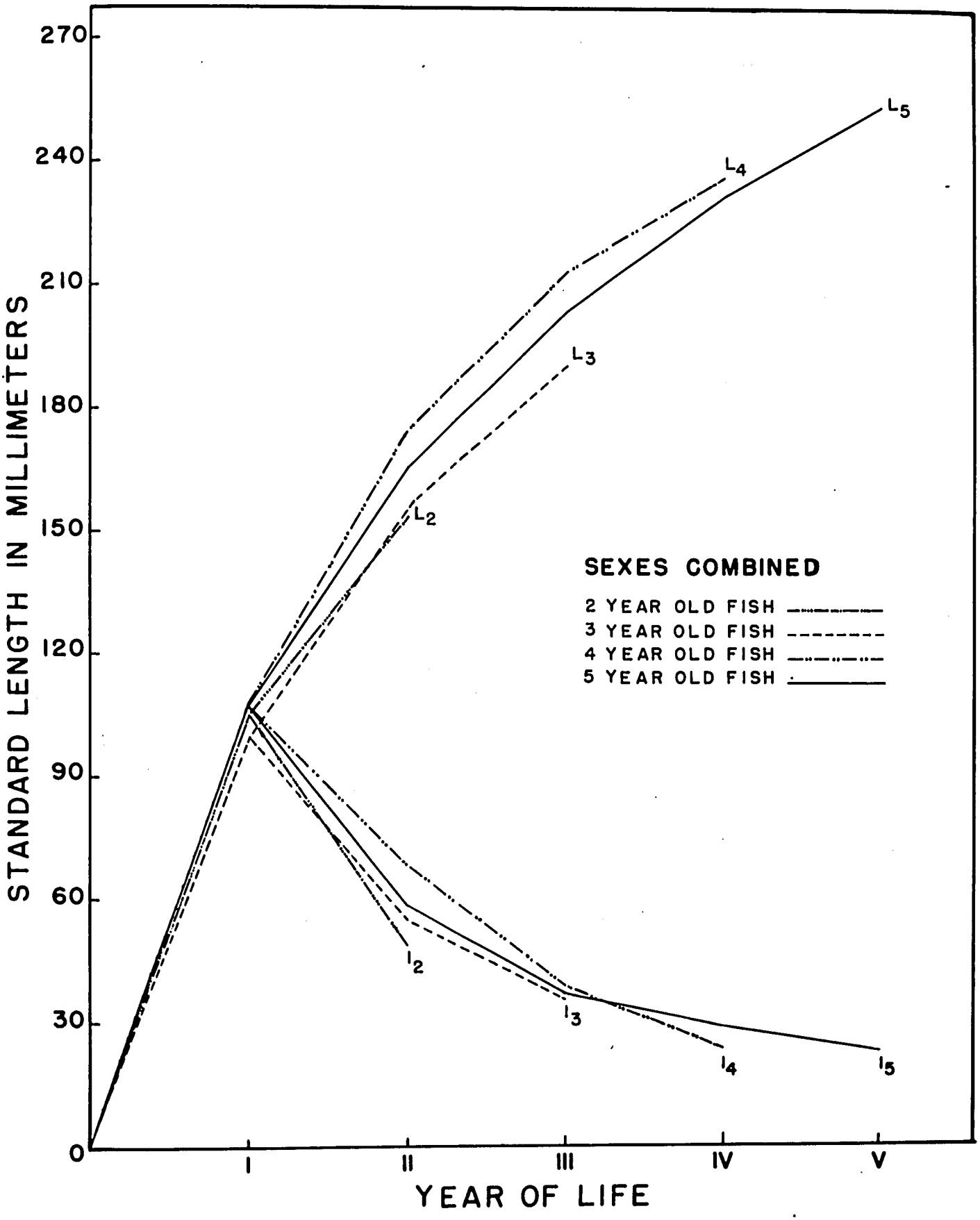
Growth in length in Grand Traverse Bay cisco:

The mean calculated lengths at the respective years of life of the age groups II to V of the Grand Traverse Bay sample are given in table 12. It is interesting to note that in age groups II, III and V the males exceed the females in length. In age group IV the females out-

Table 12: Average standard lengths for each year of life of 59 Grand Traverse Bay cisco collected in 1946

Age Group		Number of fish	Calculated length (mm) at end of year of life				
			I	II	III	IV	V
II	Male	8	108	155			
II	Female	3	99	151			
II	Sexes combined	11	105	154			
III	Male	8	105	167	213		
III	Female	21	98	151	181		
III	Sexes combined	29	100	155	190		
IV	Male	3	107	162	212	234	
IV	Female	8	107	181	214	237	
IV	Sexes combined	11	107	175	213	236	
V	Male	2	121	173	213	249	271
V	Female	6	103	164	200	226	249
V	Sexes combined	8	107	166	203	232	254

Fig. 6. Mean calculated lengths at the end of each year of life and increments of growth in length of Grand Traverse Bay Lake herring based on tables 12 and 16. Ls and ls indicate the length and length-increment curves of the corresponding age group.


270
240
210
180
150
120
90
60
30
0
STANDARD LENGTH IN MILLIMETERS
I
II
III
IV
V
YEAR OF LIFE
L5
L4
L3
L2
l2
l3
l4
l5
SEXES COMBINED
2 YEAR OLD FISH
3 YEAR OLD FISH
4 YEAR OLD FISH
5 YEAR OLD FISH

grow the males in length by 19, 2, and 3 millimeters in the second, third and fourth years and in the first year they attain the same length, 107 millimeters, as those of males. Whether the accelerated growth of the females in age group IV is due to any one of the four years favorable for their growth, or these females compose a different population having a higher growth rate may not be accounted for in view of the smallness of the sample.

Comparison of the growth in length of cisco from Saginaw Bay, Green Bay and Grand Traverse Bay:

The data in tables 10, 11 and 12 are regrouped in table 13 to facilitate comparison of the growth in length of the samples from Saginaw Bay, Green Bay and Grand Traverse Bay. It is plainly evident from table 13 that in the amount of growth the Saginaw Bay cisco stands far above the other two populations in all years of life excepting the variations described below. The Green Bay sample takes up a position in between the Saginaw Bay and Grand Traverse Bay cisco.

The variations exhibited by the three populations are the following: 1. The age group II from Green Bay exceeds in length the cisco from Saginaw Bay in both years of life. 2. In age group IV of the Grand Traverse Bay cisco, the males in their third and fourth years, the females in their second, third and fourth years and the sexes-combined year classes in their second, third and fourth years take up a position intermediate between the Saginaw Bay and Green Bay populations. 3. In age group V from Grand Traverse Bay, the males in their first, second and third years outgrow the males of the Green Bay cisco in these years and in their fourth and fifth years exceed in length

grow the males in length by 19, 2, and 3 millimeters in the second, third and fourth years and in the first year they attain the same length, 107 millimeters, as those of males. Whether the accelerated growth of the females in age group IV is due to any one of the four years favorable for their growth, or these females compose a different population having a higher growth rate may not be accounted for in view of the smallness of the sample.

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Table 13: Comparison of the growth in length of cisco of different age groups from Saginaw Bay (S.B.), Green Bay (G.B.), and Grand Traverse Bay (G.T.B)

Age Group	Year of life	Males			Females			Sexes combined		
		S.B.	G.B	G.T.B.	S.B.	G.B.	G.T.B.	S.B.	G.B.	G.T.B.
II	1	128	141	108	125	129	99	126	129	105
	2	192	196	155	191	204	151	191	202	154
III	1	132	117	105	126	117	98	129	118	100
	2	195	178	167	188	179	151	191	182	155
	3	231	214	213	226	216	181	228	217	190
IV	1	133	113	107	128	115	107	131	114	107
	2	189	165	162	183	167	181	186	169	175
	3	227	200	212	219	202	214	223	202	213
	4	252	223	234	245	227	237	248	226	236
V	1	129	116	121	125	110	103	126	112	107
	2	181	161	173	177	158	164	178	159	166
	3	217	190	213	214	191	200	215	190	203
	4	243	212	249	239	216	226	240	214	232
	5	262	228	271	261	234	249	261	231	254
VI	1	120	110		123	107		121	108	
	2	169	162		168	154		168	158	
	3	202	196		207	186		205	191	
	4	228	219		234	212		231	216	
	5	249	239		256	229		252	233	
	6	267	252		272	242		270	246	

the males of the Saginaw Bay population; and, the females and the sexes-combined classes show greater growth in length than the Green Bay cisco in their second, third, fourth and fifth years.

The general tendency towards the diminution in calculated lengths of the cisco from Saginaw Bay to Green Bay and from Green Bay to Grand Traverse Bay reflects on the environmental conditions of these three regions. It is apparent that the conditions in Saginaw Bay are favorable for the growth of cisco, while in Grand Traverse Bay the conditions are very poor and in Green Bay the conditions are slightly better than those of Grand Traverse Bay for the growth of cisco.

Lee's Phenomenon

The "phenomenon of apparent change in growth rate" has been questioned and much discussed by fisheries biologists ever since it was proposed by Lee (1912). Lee defines this phenomenon as: 'a tendency by which with increasing age the groups of fish all show a decreasing rate of growth in the calculated values for <u>each</u> year of their lives, that is that as we compare the present with former years the amount of growth at corresponding ages is increasing regularly. For convenience and shortness this tendency will be referred to in this paper as "the phenomenon of apparent change in growth rate" '. It was originally believed by many workers that this phenomenon was the result of the error made in assessing growth by scale method or of the selective effect in sizes during sampling. The results of the detailed investigations by the improved methods of calculating growth from scales had led Van Oosten (1929) and Hile

(1936) to confirm that Lee's phenomenon was real and that it existed in their Lake herring populations.

Scott (1949) explains that the Lee's phenomenon "is produced by a selective mortality which eliminates the faster-growing members of a year-class early in life, thus allowing the slower-growing fish to live to a greater age and to comprise the bulk of the older fish in a population." The two primary factors resulting in the selective mortality of the fast growing individuals of a year class are: 1. the growth of the rapidly growing fish to such a catchable size as they are eliminated earlier than the slow-growing fish; and 2. a physiological correlation between growth rate and longevity of fish. In reviewing the relationship between the rate of growth and the span of life within a given species, McCay (1933) presents the evidence obtained in his feeding experiments on the brook trout, namely, that in the experimental trout fed on the same diet the faster growing fish died earlier than the slower growing fish.

Lee's phenomenon in Saginaw Bay and Green Bay cisco:

An inspection of the tables 10 and 11 (figures 4 and 5) distinctly brings out the presence of Lee's phenomenon in the Saginaw Bay and Green Bay populations. It is seen from the above tables that in these populations, excepting few discrepancies, there is a tendency for the decreasing rate of growth in the calculated values of length for each year of life as the fish increase in age.

In their first year of life, the age groups I and II of Saginaw Bay cisco show the tendency to decrease in growth as they advance in age.

For the same year of life the growth rate seems to increase in age groups III and IV and in the succeeding years the growth rate decreases from age to age until age group VIII.

In the Green Bay cisco, Lee's phenomenon is pronounced in all years of life of the age groups excepting age group VI which in its third, fourth and fifth years of life show greater lengths than those of age group V. Age group VII is not considered since it is represented by two females only.

The discrepancies in these two samples are negligibly small and no possible causes can be advanced to explain them.

Lee's phenomenon in Grand Traverse Bay cisco:

The Grand Traverse Bay cisco population is quite characteristic in that no "apparent change in growth rate" is observed in its life history (see table 12 and figure 6). The smallness of the sample warns the writer from carrying on a long discussion to explain the discrepancy in Lee's phenomenon in this sample. However, the writer believes that Grand Traverse Bay where commercial fishing is prohibited might contain a dissimilar distribution of different populations of cisco and this would have given rise to a wide discrepancy in the growth history of the cisco under investigation.

If we assume that growth had been better in age groups IV and V in all the years to explain the discrepancy in Lee's phenomenon, then, how can we explain the growth discrepancies that are found to occur between members of the same year class captured at different ages? Since no satisfactory answer can be had from the available data, the

better-growth explanation for age groups IV and V may be rejected.

Length increment

The length increment data (tables 14, 15 and 16) for the Saginaw Bay, Green Bay and Grand Traverse Bay samples indicate that in all the cases the greatest amount of growth was during the first year of life. Van Oosten (1929) observed the same condition in his Lake Huron Lake herring where the fish in their first year had shown the greatest amount of growth.

The growth increment curves, figures 7, 5 and 6 based on data from tables 14, 15 and 16 respectively, further reveal that growth in the second year had dropped down to almost 50 per cent of the growth in the first year and in the succeeding years the growth in length gradually diminished. The age groups III, IV and V of Grand Traverse Bay sample show better growths beyond their second year than those of Green Bay and Saginaw Bay samples. The age group VI of Saginaw Bay population had grown better in its sixth year than that of Green Bay population in the corresponding year, the difference in length being 4 millimeters.

The comparatively low values in growth for the first year of all the age groups of Grand Traverse Bay sample should not be considered as real for, the assumption we made on the pre-scale formation length in this sample, 17 millimeters, was only provisional and this might have introduced error in the first year growth.

The variations in length increments between males and females in

these samples were not conspicuous; and, therefore, no special consideration was given to differentiate the growth increments between the sexes.

Table 14: Average increments in length for each year of life of 685 Saginaw Bay cisco collected in the years 1942, 1943, 1944 and 1945

Age Group	Number of fish	Increments in length at end of year of life							
		I	II	III	IV	V	VI	VII	VIII
I Male	4	139							
I Female	6	143							
I Sexes combined	10	141							
II Male	60	128	64						
II Female	73	125	65						
II Sexes combined	134 (1)	126	65						
III Male	79	132	63	36					
III Female	107	126	62	38					
III Sexes combined	186	129	63	37					
IV Male	80	133	56	38	24				
IV Female	89	128	55	36	26				
IV Sexes combined	169	131	56	37	25				
V Male	57	129	52	37	25	19			
V Female	58	125	53	37	25	22			
V Sexes combined	117 (2)	126	52	37	25	20			
VI Male	24	120	49	34	26	21	19		
VI Female	25	123	45	39	27	22	16		
VI Sexes combined	49	121	47	36	26	22	17		
VII Male	5	122	51	34	27	19	16	19	
VII Female	8	120	48	35	24	23	21	17	
VII Sexes combined	13	121	49	34	25	22	19	18	
VIII Male	2	118	44	39	31	21	21	20	17
VIII Female	5	119	39	31	26	21	18	17	14
VIII Sexes combined	7	118	40	33	28	21	19	18	14

In column 2, figures in parentheses indicate the number of fish for which sex was not determined.

Fig. 7. Annual increments of growth in length of Saginaw Bay Lake herring based on table 14.

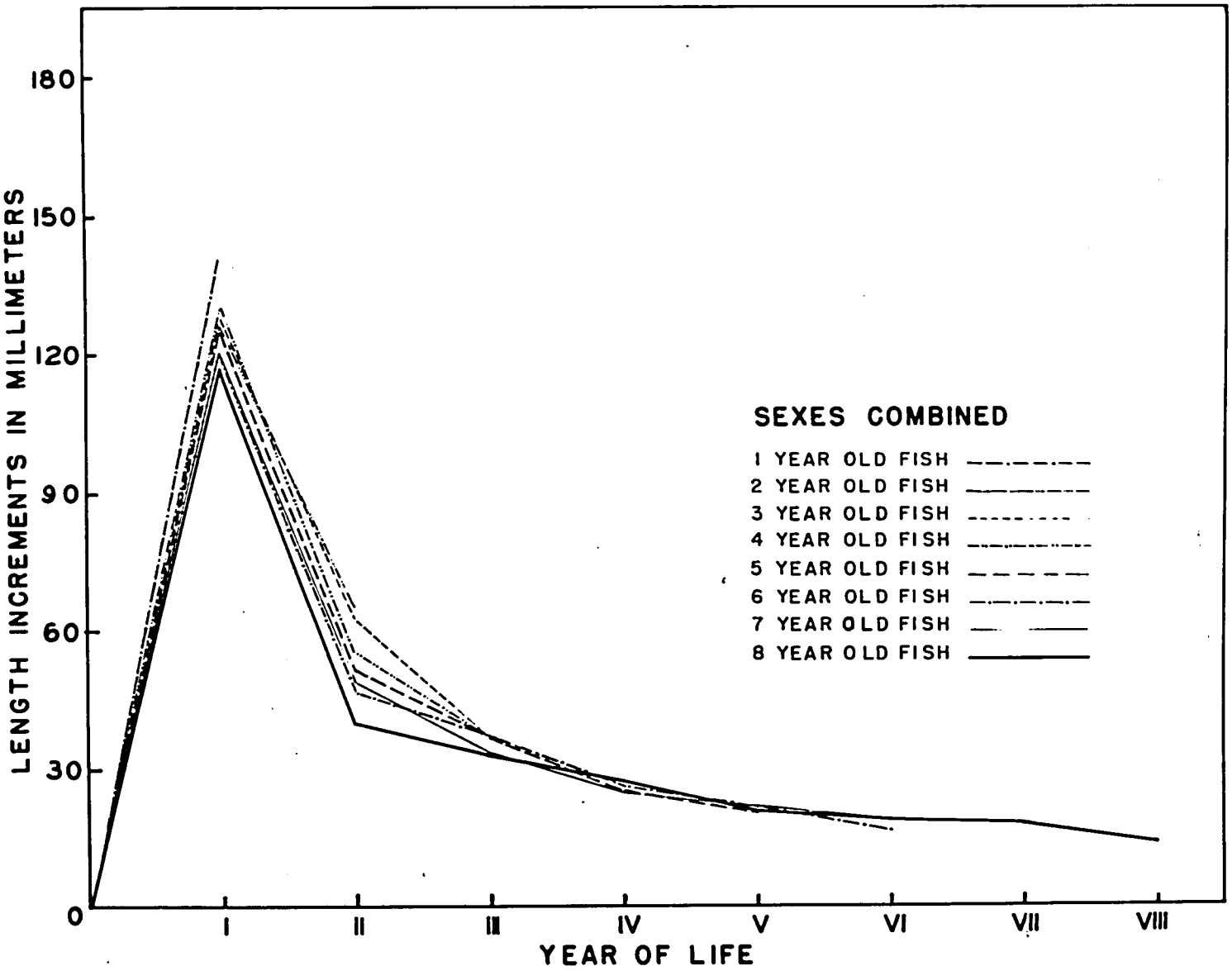

LENGTH INCREMENTS IN MILLIMETERS
180
150
120
90
60
30
0
I
II
III
IV
V
VI
VII
VIII
YEAR OF LIFE
SEXES COMBINED
1 YEAR OLD FISH
2 YEAR OLD FISH
3 YEAR OLD FISH
4 YEAR OLD FISH
5 YEAR OLD FISH
6 YEAR OLD FISH
7 YEAR OLD FISH
8 YEAR OLD FISH

Table 15: Average increments in length for each year of life of 415 Green Bay cisco collected in the years 1944, 1945 and 1950

Age Group		Number of fish	Increments in length (mm) at end of year of life						
			I	II	III	IV	V	VI	VII
II	Male	5	141	54					
II	Female	13	129	75					
II	Sexes combined	36 (18)	129	74					
III	Male	38	117	61	36				
III	Female	72	117	62	36				
III	Sexes combined	144 (34)	118	64	35				
IV	Male	59	113	53	35	23			
IV	Female	79	115	52	35	25			
IV	Sexes combined	148 (10)	114	53	35	24			
V	Male	28	116	45	29	22	16		
V	Female	40	110	48	33	26	17		
V	Sexes combined	71 (3)	112	46	32	24	17		
VI	Male	3	110	52	34	23	20	13	
VI	Female	10	107	47	32	26	17	13	
VI	Sexes combined	14 (1)	108	50	33	25	17	13	
VII	Male	-	-	-	-	-	-	-	-
VII	Female	2	115	46	24	22	17	17	12
VII	Sexes combined	-	-	-	-	-	-	-	-

In column 2, figures in parentheses indicate the number of fish for which sex was not determined.

Table 16: Average increments in length for each year of life of 59 Grand Traverse Bay cisco collected in 1946

Age group		Number of fish	Increments in length (mm) at end of year of life				
			I	II	III	IV	V
II	Male	8	108	48			
II	Female	3	99	52			
II	Sexes combined	11	105	49			
III	Male	8	105	62	46		
III	Female	21	98	53	31		
III	Sexes combined	29	100	55	35		
IV	Male	3	107	55	50	23	
IV	Female	8	107	73	34	23	
IV	Sexes combined	11	107	68	38	23	
V	Male	2	121	52	40	37	22
V	Female	6	103	61	35	27	23
V	Sexes combined	8	107	59	37	29	23

Length-weight Relationship

The application of Herbert Spencer's 'Cube Law' equation to fish measurements has been carried out by many investigators. If form and specific gravity were constant throughout life, the relationship between weight and length is described by the 'Cube Law' in the equation:

$$W = KL^3$$

where W = weight

and L = length

K = constant

The observations of Keys (1928), Hile (1936 and 1941) and others reveal that the 'Cube Law' is an incorrect formulation of the relationship between weight and length and that a true relation can be much more accurately described by the equation:

$$W = cL^n$$

where W = weight, L = length, c = constant dependent on the units employed and the general species form and n = the rate of change of weight with length.

Saginaw Bay sample:

Six hundred and eighty-four Lake herring covering a length range of 160 - 329 millimeters, standard length, were employed in the determination of length-weight relationship. The sexes and all age groups were combined. Each fish was treated as a separate unit in deriving the constants c and n in the formula.

The equation $W = cL^n$ when expressed in logarithmic form becomes a straight line. The logarithmic equation is:

$$\log W = \log c + n \log L$$

The values of log c and n were determined from the following normal equations:

$$\log c = \frac{\Sigma \log W \cdot \Sigma (\log L)^2 - \Sigma \log L \cdot [\Sigma \text{Log } L \cdot \text{Log } W]}{N \cdot \Sigma (\log L)^2 - (\Sigma \log L)^2}$$

$$\text{and} \quad n = \frac{\Sigma \log W - N.\log c}{\Sigma \log L}$$

Figure 8 is the graph of the equation:

$$W = 43.643 \times 10^{-5} L^{2.89065}$$

Logarithmically the equation is expressed as:

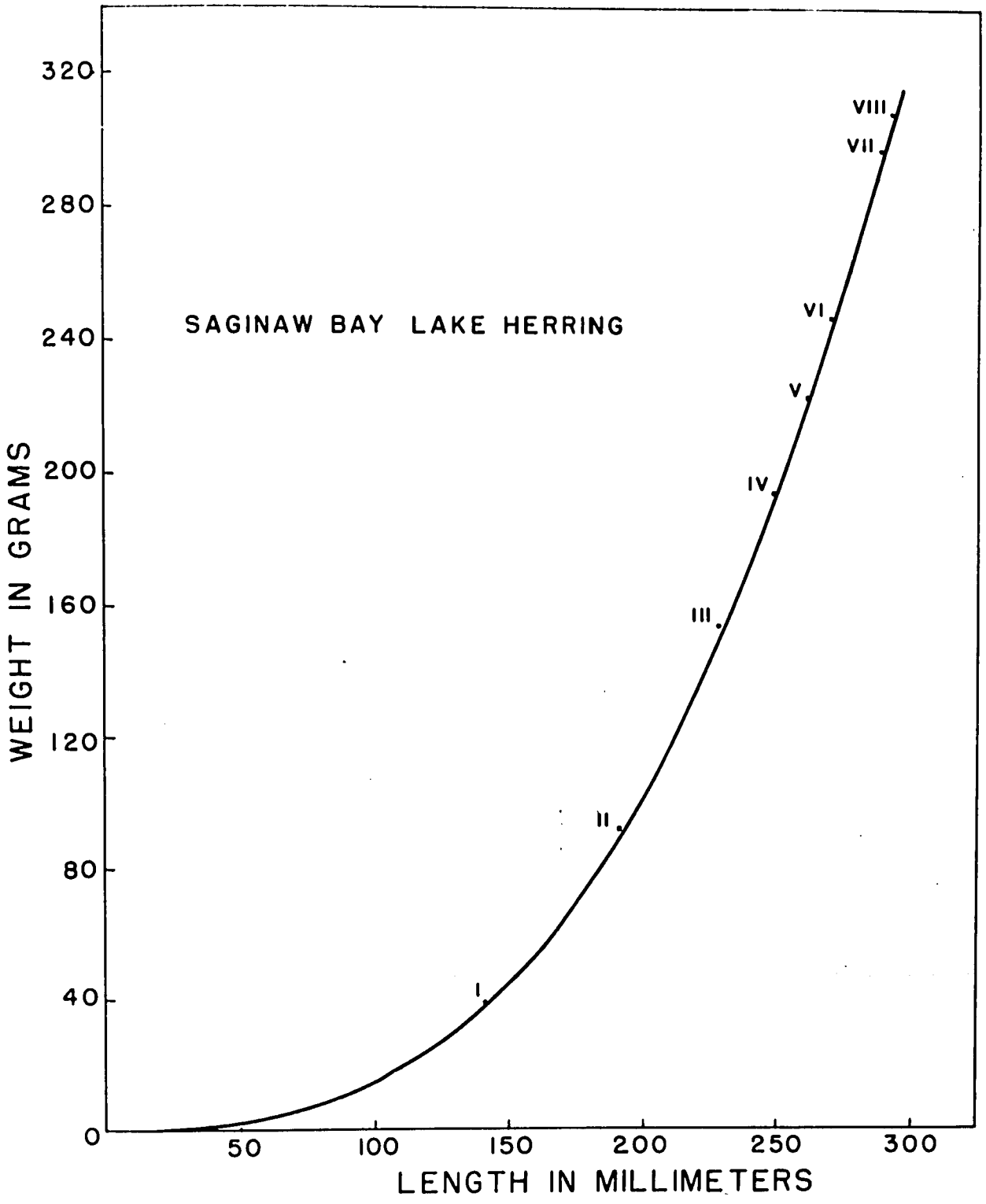
$$\log W = -4.63991 + 2.89065 \log L$$

The points in figure 8 represent the mean calculated weights plotted against the mean calculated lengths at the last winter mark of the age groups concerned. It is readily noted from the figure that these mean values fit the curve closely. The exponent 2.89065 of the length indicates that the weight does not increase proportionately to the third power of every linear dimension of the fish; but rather less than the cube of the length.

Green Bay sample:

The length-weight relationship of 349 cisco from Green Bay, falling in the length interval 180 - 299 millimeters, standard length, may be described by the following formula:

Fig. 8. Length-weight relationship of Saginaw Bay Lake herring. $W = 43.643 \times 10^{-5} L^{2.89065}$. The points represent the mean calculated weights plotted against the mean calculated lengths at the last winter mark of the age groups concerned.


SAGINAW BAY LAKE HERRING
WEIGHT IN GRAMS
LENGTH IN MILLIMETERS
0
40
80
120
160
200
240
280
320
50
100
150
200
250
300
I
II
III
IV
V
VI
VII
VIII

$$W = 23.025 \times 10^{-5} L^{2.76257}$$

Logarithmically: $\log W = -4.36220 + 2.76257 \log L$

Figure 9 represents the above equation. The points represent the averages of weights and lengths of the age groups at last winter mark. The n value, 2.76257, shows that the weight is not proportional to the cube of the length, but slightly less as in the case of the Saginaw Bay sample.

Grand Traverse Bay sample:

The length-weight relationship of 59 specimens covering the length interval 150 - 319 millimeters is determined by the equation:

$$W = 3.1161 \times 10^{-5} L^{3.26657}$$

Logarithmically: $\log W = -5.49361 + 3.26657 \log L$

Figure 10 is the graph of the above equation. The averages of lengths and weights at last winter mark of the age groups fit closely the curve as in the previous cases. It is interesting to note here that the n value is greater than 3 indicating that the weight increases more rapidly than the cube of the length.

A comparison of the above three samples reveals that while the weight of the Grand Traverse Bay specimens increases more rapidly than the cube of the length, those of the Saginaw Bay and Green Bay samples tend to increase less rapidly than the cube of the length. This observation forces one to presume that the environmental conditions in Grand Traverse Bay might have been so favorable for the Lake herring under investigation that caused the greater increase in weight than the

Fig. 9. Length-weight relationship of Green Bay Lake herring. $W = 23.025 \times 10^{-5} L^{2.76257}$. The points represent the mean calculated weights plotted against the mean calculated lengths at the last winter mark of the age groups concerned.

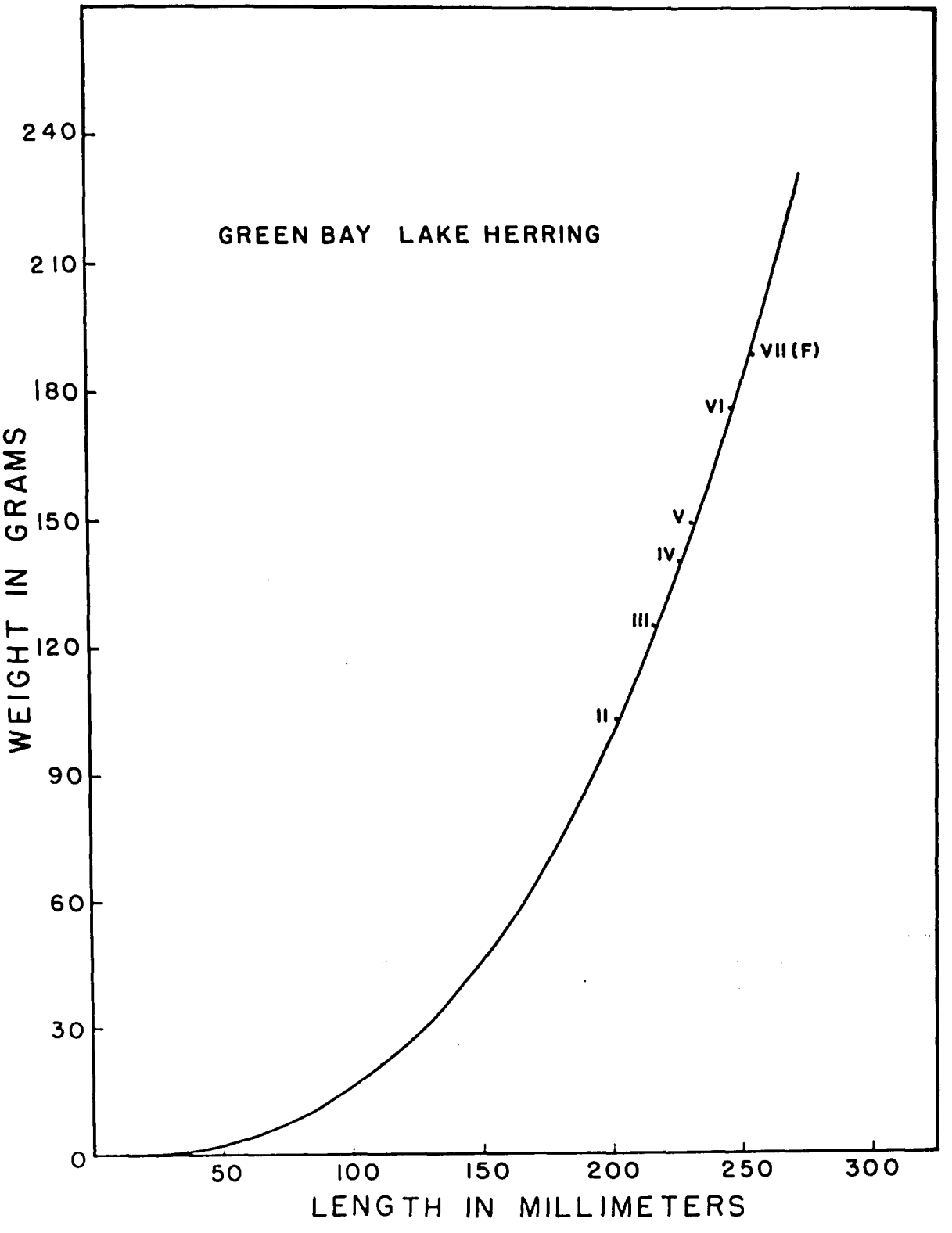
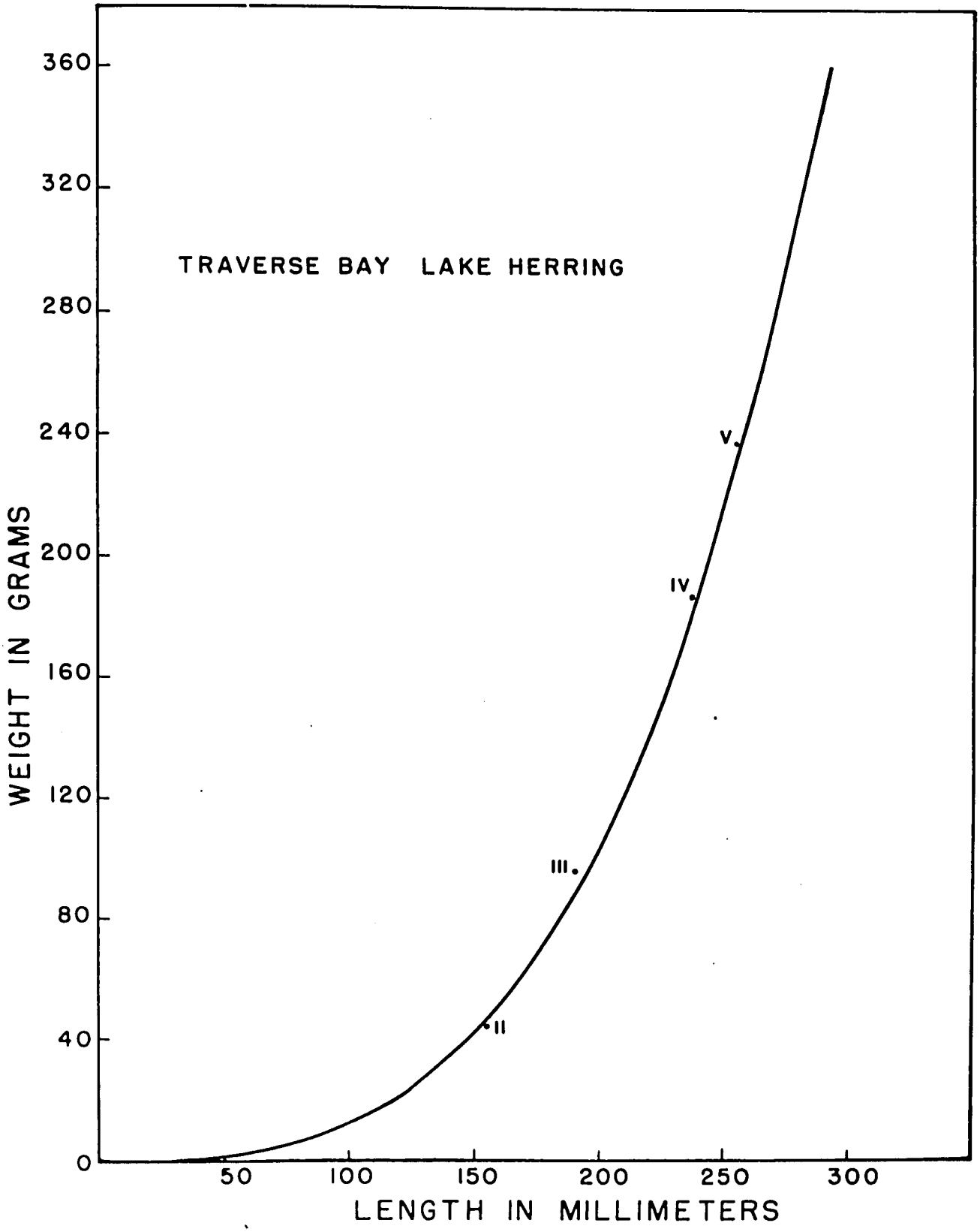

GREEN BAY LAKE HERRING
WEIGHT IN GRAMS
240
210
180
150
120
90
60
30
0
50
100
150
200
250
300
LENGTH IN MILLIMETERS
II
III
IV
V
VI
VII (F)

Fig. 10. Length-weight relationship of Grand Traverse Bay Lake herring. $W = 3.1161 \times 10^{-5} L^{3.2657}$. The points represent the mean calculated weights plotted against the mean calculated lengths at the last winter mark of the age groups concerned.


TRAVERSE BAY LAKE HERRING
WEIGHT IN GRAMS
0
40
80
120
160
200
240
280
320
360
50
100
150
200
250
300
LENGTH IN MILLIMETERS
II
III
IV
V

cube of the length and that in Saginaw Bay and Green Bay conditions were not favorable. To check this presumption table 17 is set up. The lengths and weights are the calculated averages at last winter mark of the age groups. The age groups I, VI, VII and VIII of Saginaw Bay and VI of Green Bay are left out of consideration since there are no specimens of these age groups from Grand Traverse Bay for comparison.

A careful survey points out that there is positive correlation between weights and lengths, excepting the age group V of Grand Traverse Bay where the fish of 254 millimeters length weigh 237 grams. The age group V of Saginaw Bay sample on the other hand weighs 223 grams for 261 millimeters length. The age group V of the Grand Traverse Bay sample deviates considerably from the direct weight-length relationship as calculated. There is some doubt whether this is the result of the small sample (8) or whether they are from a different population.

Growth in weight

The weight of an individual fish is to a considerable extent influenced by the available food and its condition of reproductive organs. These factors render difficult the problems of the fishery biologists in analysing the importance of weight data. However, since weight is the prevalent unit of measuring commercial yield of fish from a body of water, it is desirable that more attention be given to weight data.

Tables 18, 19 and 20 present calculated weight data of the cisco of Saginaw Bay, Green Bay and Grand Traverse Bay. Curves based on

Table 17: Averages of calculated lengths and weights at last winter mark of the age groups from Saginaw Bay, Green Bay and Grand Traverse Bay

Age Groups	Saginaw Bay		Green Bay		G. Traverse Bay	
	Length mm.	Weight gms.	Length mm.	Weight gms.	Length mm.	Weight gms.
I	141	39				
II	191	92	202	103	154	45
III	228	154	217	125	190	97
IV	248	194	226	140	236	187
V	261	223	231	149	254	237
VI	270	247	246	176		
VII	288	297	253*	189*		
VIII	291	308				

* The data refer to the 2 females of this age group.

these data are shown in figures 11, 12 and 13. The figures which appear in the tables are averages of the calculated weights. The averages for the sexes-combined groups are the weighted means. In this study calculations for weights were made from the calculated lengths at the end of each year of life using the appropriate formula given in the section for length-weight relationship.

It is seen from the tables and curves that the growth in weight followed the same trend as the growth in length for each sex, as well as when the sexes were combined. The foregoing statement is strengthened by the evidence of the relationships of the length and weight curves (figures 4 and 11) for the age groups VI and VII of the Saginaw Bay sample.

The males of the Saginaw Bay sample surpass the females in weight in all excepting age groups I and VI where the opposite condition is shown.

In Green Bay sample, the females outweigh the males to a greater extent as shown in second year of age group II; second and third years of age group III; all the years of age group IV; third, fourth and fifth years of age group V. It is only in the first year of age group II, V and VI and in the second year of age groupsV and VI the males have shown greater weight than the females.

The data of the Grand Traverse Bay cisco indicate that the males have grown heavier than the females in all the age groups, excepting the second and third years of age group IV where the females exceed the males in weight.

Comparing the weights of age groups II, III, IV and V of the three samples, it is apparent that the Saginaw Bay cisco outweigh the other two samples generally at comparative lengths; while, the Green Bay sample weighs less than the Grand Traverse Bay sample.

Weight increment data of the three populations of cisco are given in tables 21, 22 and 23 with their corresponding curves in figures 14, 12 and 13. It is indicated that in the Saginaw Bay cisco the weight increases progressively in each year upto the third year of life after which it gradually recedes. In the other two samples such wide variations in weight increments exist among year classes that we cannot draw any conclusions from them.

Table 18: Average weights for each year of life of 685 Saginaw Bay cisco collected in the years 1942, 1943, 1944 and 1945

Age Group	Number of fish	Calculated weights (gms.) at end of year of life							
		I	II	III	IV	V	VI	VII	VIII
I Male	4	37							
I Female	6	40							
I Sexes combined	10	39							
II Male	60	29	94						
II Female	73	27	91						
II Sexes combined	134 (1)	28	92						
III Male	79	32	99	159					
III Female	107	28	89	150					
III Sexes combined	186	30	93	154					
IV Male	80	33	90	151	202				
IV Female	89	29	82	136	187				
IV Sexes combined	169	31	86	143	194				
V Male	57	29	78	132	181	224			
V Female	58	27	74	127	174	223			
V Sexes combined	117 (2)	28	76	129	177	223			
VI Male	24	24	64	108	151	197	240		
VI Female	25	26	63	115	163	211	253		
VI Sexes combined	49	25	64	112	157	204	247		
VII Male	5	25	71	119	165	205	244	296	
VII Female	8	24	64	109	151	198	249	297	
VII Sexes combined	13	24	67	113	156	201	247	297	
VIII Male	2	23	56	103	156	200	252	309	361
VIII Female	5	23	53	87	127	166	206	248	286
VIII Sexes combined	7	23	54	91	135	176	219	266	308

In column 2, figures in parentheses indicate the number of fish for which sex was not determined.

Fig. 11. Calculated growth in weight for each year of life of Saginaw Bay Lake herring based on table 18.

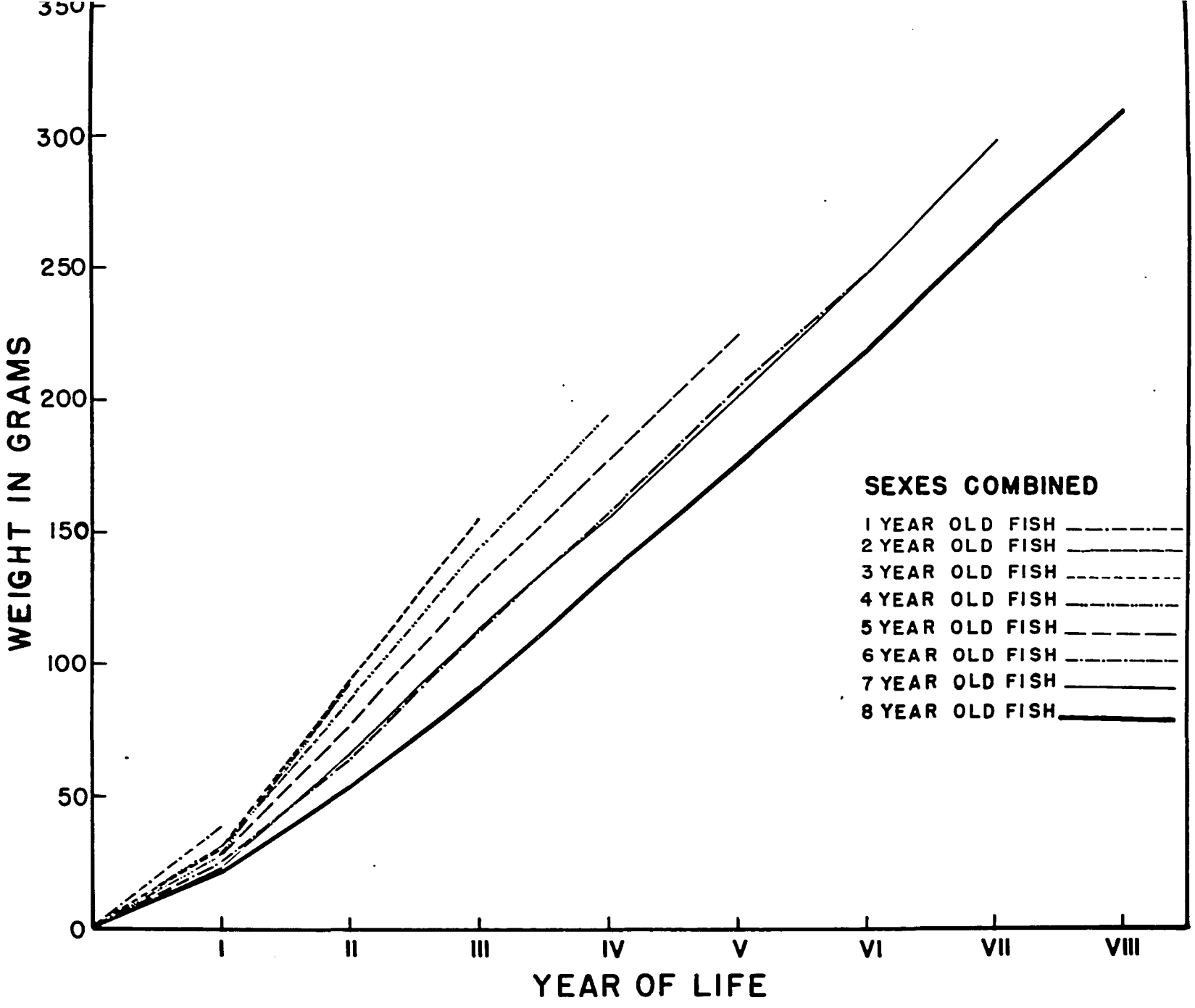

350
300
250
200
150
100
50
0
WEIGHT IN GRAMS
I
II
III
IV
V
VI
VII
VIII
YEAR OF LIFE
SEXES COMBINED
1 YEAR OLD FISH
2 YEAR OLD FISH
3 YEAR OLD FISH
4 YEAR OLD FISH
5 YEAR OLD FISH
6 YEAR OLD FISH
7 YEAR OLD FISH
8 YEAR OLD FISH

Table 19: Average weights for each year of life of 415 Green Bay cisco collected in the years 1944, 1945 and 1950

Age Group	Number of fish	Calculated weights (gms.) at end of year of life						
		I	II	III	IV	V	VI	VII
II Male	5	40	95					
II Female	13	31	106					
II Sexes combined	36 (18)	30	103					
III Male	38	23	73	121				
III Female	72	23	74	123				
III Sexes combined	144 (34)	23	77	125				
IV Male	59	21	60	101	136			
IV Female	79	22	61	103	141			
IV Sexes combined	148 (10)	22	62	103	140			
V Male	28	22	55	87	117	143		
V Female	40	19	52	88	124	154		
V Sexes combined	71 (3)	20	53	87	121	149		
VI Male	3	20	56	93	127	163	187	
VI Female	10	18	48	81	116	143	168	
VI Sexes combined	14 (1)	18	52	87	123	152	176	
VII Male	-	-	-	-	-	-	-	-
VII Female	2	22	54	79	103	135	165	189
VII Sexes combined	-	-	-	-	-	-	-	-

In column 2, figures in parentheses indicate the number of fish for which sex and weight were not determined.

Fig. 12. Calculated growth in weight (Ws) and weight-increments (ls) for each year of life of Green Bay Lake herring based on tables 19 and 22.

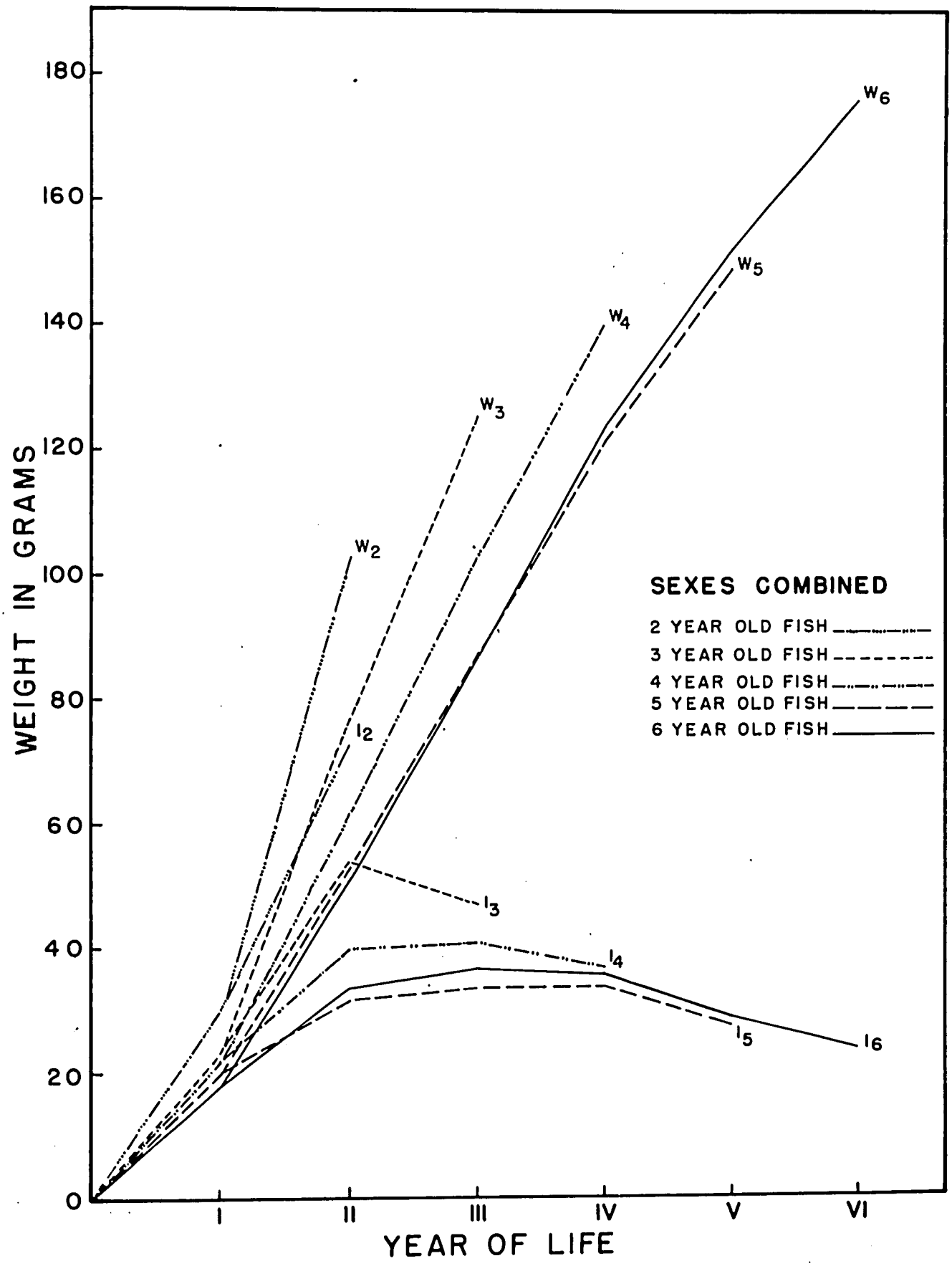

WEIGHT IN GRAMS
180
160
140
120
100
80
60
40
20
0
I
II
III
IV
V
VI
YEAR OF LIFE
W6
W5
W4
W3
W2
I2
I3
I4
I5
I6
SEXES COMBINED
2 YEAR OLD FISH
3 YEAR OLD FISH
4 YEAR OLD FISH
5 YEAR OLD FISH
6 YEAR OLD FISH

Table 20: Average weights for each year of life of 59 Grand Traverse Bay cisco collected in 1946

Age Group	Number of fish	Calculated weights (gms.) at end of year of life				
		I	II	III	IV	V
II Male	8	14	47			
II Female	3	11	42			
II Sexes combined	11	13	45			
III Male	8	13	63	141		
III Female	21	11	44	80		
III Sexes combined	29	11	49	97		
IV Male	3	14	54	134	188	
IV Female	8	14	81	137	187	
IV Sexes combined	11	14	73	136	187	
V Male	2	22	75	138	220	293
V Female	6	12	59	109	162	218
V Sexes	8	15	63	116	176	237

Fig. 13. Calculated growth in weight (Ws) and weight-increments (ls) for each year of life of Grand Traverse Bay Lake herring based on tables 20 and 23.

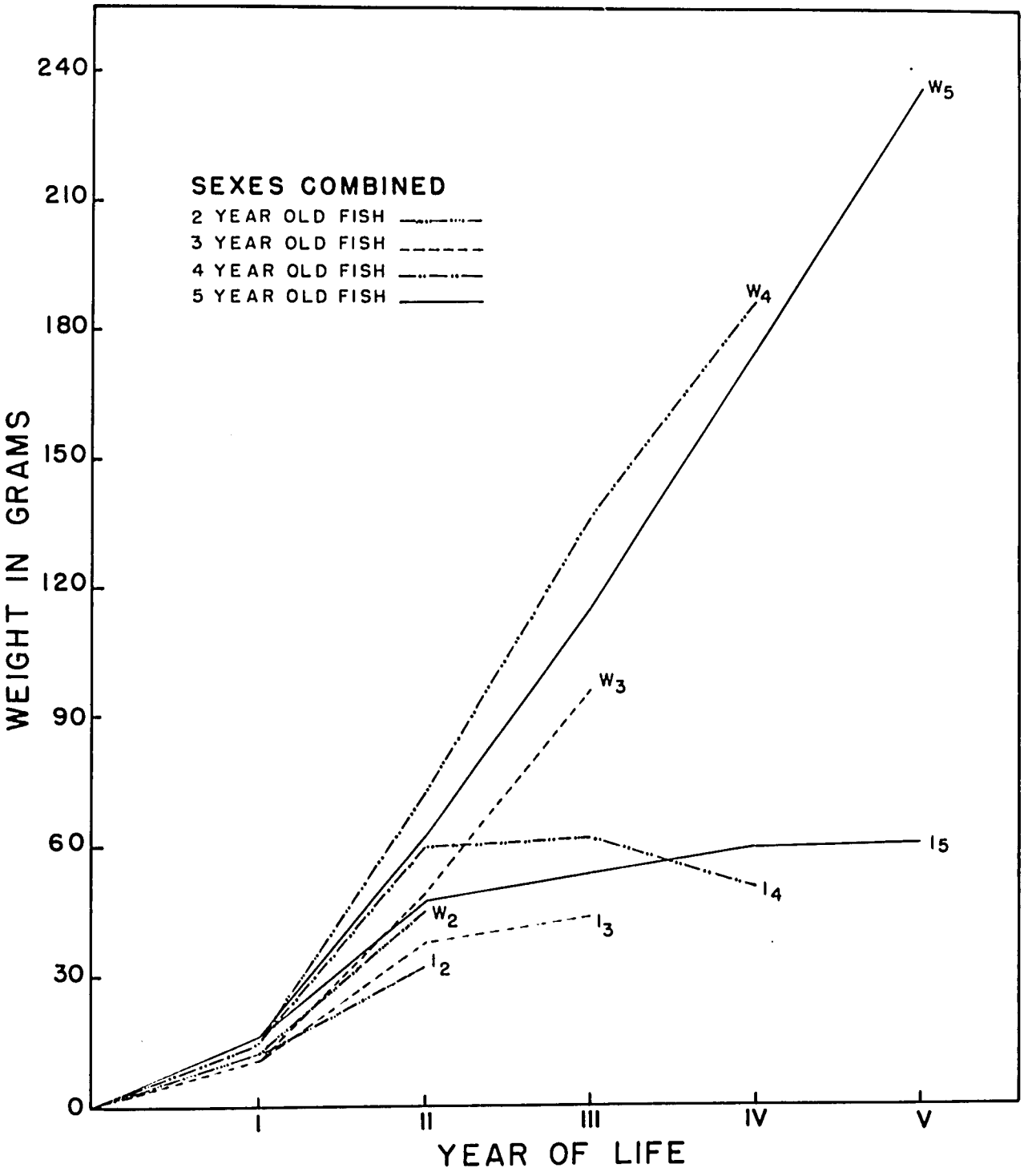

SEXES COMBINED
2 YEAR OLD FISH
3 YEAR OLD FISH
4 YEAR OLD FISH
5 YEAR OLD FISH
240
210
180
150
120
90
60
30
0
WEIGHT IN GRAMS
I
II
III
IV
V
YEAR OF LIFE
W5
W4
W3
W2
I5
I4
I3
I2

Table 21: Average increments in weight for each year of life of 685 Saginaw Bay cisco collected in the years 1942, 1943, 1944 and 1945

Age Group		Number of fish	Increments in weight (gms.) at end of year of life							
			I	II	III	IV	V	VI	VII	VIII
I	Male	4	37							
I	Female	6	40							
I	Sexes combined	10	39							
II	Male	60	29	65						
II	Female	73	27	64						
II	Sexes combined	134 (1)	28	64						
III	Male	79	32	66	60					
III	Female	107	28	61	61					
III	Sexes combined	186	30	63	60					
IV	Male	80	33	57	61	51				
IV	Female	89	29	53	54	51				
IV	Sexes combined	169	31	55	57	51				
V	Male	57	29	49	55	49	43			
V	Female	58	27	47	53	47	50			
V	Sexes combined	117(2)	28	48	53	48	46			
VI	Male	24	24	40	43	43	45	44		
VI	Female	25	26	38	52	47	49	42		
VI	Sexes combined	49	25	39	48	46	47	43		
VII	Male	5	25	46	48	46	40	39	32	
VII	Female	8	24	40	45	42	48	51	48	
VII	Sexes combined	13	24	42	46	43	45	46	42	
VIII	Male	2	23	33	47	54	44	52	57	53
VIII	Female	5	23	30	34	38	39	40	42	38
VIII	Sexes combined	7	23	31	38	42	40	44	46	42

In column 2, figures in parentheses indicate the number of fish for which sex was not determined.

Fig. 14. Weight-increments for each year of life of Saginaw Bay Lake herring based on table 21.

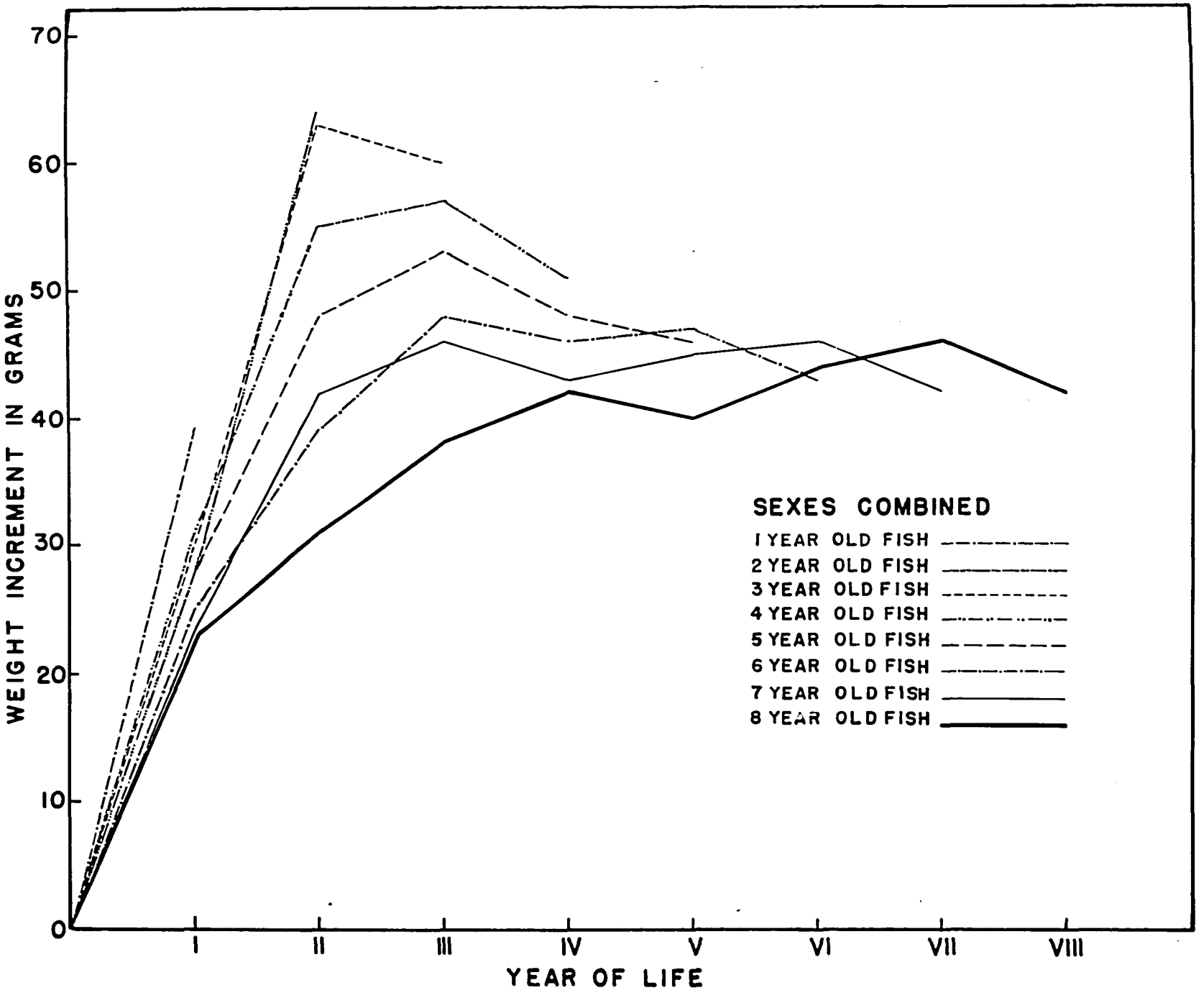

70
60
50
40
30
20
10
0
WEIGHT INCREMENT IN GRAMS
I
II
III
IV
V
VI
VII
VIII
YEAR OF LIFE
SEXES COMBINED
1 YEAR OLD FISH
2 YEAR OLD FISH
3 YEAR OLD FISH
4 YEAR OLD FISH
5 YEAR OLD FISH
6 YEAR OLD FISH
7 YEAR OLD FISH
8 YEAR OLD FISH

Table 22: Average increments in weight for each year of life of 415 Green Bay cisco collected in the years 1944, 1945 and 1950

Age Group	Number of fish	Increment in weight (gms.) at end of year of life						
		I	II	III	IV	V	VI	VII
II Male	5	40	55					
II Female	13	31	75					
II Sexes combined	36 (18)	30	73					
III Male	38	23	50	48				
III Female	72	23	51	49				
III Sexes combined	144 (34)	23	54	47				
IV Male	59	21	39	41	35			
IV Female	79	22	39	42	38			
IV Sexes combined	148 (10)	22	40	41	37			
V Male	28	22	32	32	30	26		
V Female	40	19	32	36	37	30		
V Sexes combined	71 (3)	20	32	34	34	28		
VI Male	3	20	36	37	34	35	24	
VI Female	10	18	31	33	35	28	24	
VI Sexes combined	14 (1)	18	34	35	36	29	24	
VII Male	-	-	-	-	-	-	-	-
VII Female	2	22	33	25	29	27	31	24
VII Sexes combined	-	-	-	-	-	-	-	-

In column 2, figures in parentheses indicate the number of fish for which sex and weight were not determined.

Table 23: Average increments in weight for each year of life of 59 Grand Traverse Bay cisco collected in 1946

Age Group	Number of fish	Increment in weight (gms.) at end of year of life				
		I	II	III	IV	V
II Male	8	14	33			
II Female	3	11	31			
II Sexes combined	11	13	32			
III Male	8	13	50	65		
III Female	21	11	33	36		
III Sexes combined	29	11	38	44		
IV Male	3	14	40	80	54	
IV Female	8	14	67	56	50	
IV Sexes combined	11	14	60	62	51	
V Male	2	22	53	63	83	73
V Female	6	12	46	50	53	57
V Sexes combined	8	15	48	53	60	61

Coefficient of condition

The coefficient of condition, "K", has been customarily used by many fisheries workers to measure the relative heaviness and other phases of biology of fish. The K value is derived from the equation:

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

where W weight and L length of fish

Hile and Deason (1934), Hile (1941), Jobes (1949), Carlander (1945a and 1945b), Tate (1949), Cleary (1948), Sigler (1949b) and several other investigators have indicated in their studies on the "condition" of fish that K is a direct measure of the relative plumpness or heaviness of fish.

Hile (1936), after commenting on the K values and interpretations of K by other fisheries investigators, remarks that K value determined from empirical exponents do not show the true condition of fish and that those derived by the use of cube relationship are more reliable in describing the "well being" of fish. In the study of the Wisconsin lakes cisco Hile (1936) has observed that the coefficient of condition is widely variable from population to population of the same species and in different sexes in different years' collections of the same population. The K values of the different lakes' samples are so highly significant that Hile mentions that one value cannot be compared with that of the other directly as a measure of condition. If this is true, then, there is little object in calculating K values.

Van Oosten (1929) found in the Lake Huron Lake herring that the sexes did not show consistent differences and that there was a slight tendency for the K value to increase with increase of length. Scott's (1949) K values of the rock bass reveal no significant trend with increasing size.

The wide variations of the K values in different populations of the same species, in different sexes, in different years' collections, in different length intervals of the same species and in extreme cases as those of Van Oosten (1929) and Scott (1949) where no significant trend in K values were shown, are problems yet to be satisfactorily investigated. The works on the coefficient of condition so far done by numerous investigators seem to be of statistical interest without throwing much light on the management of fisheries.

Summary

1. This paper presents the age and growth history of the representative samples of the Great Lakes cisco (Leucichthys artedi LeSueur) from Saginaw Bay, Green Bay and Grand Traverse Bay. A comparison of the growth history of cisco from commercial centers, Saginaw Bay and Green Bay, with that of the sample from Grand Traverse Bay, a region where commercial fishing operations are prohibited, is made wherever possible.

2. The study is based on 686 cisco from Saginaw Bay and 415 from Green Bay and 59 from Grand Traverse Bay. Most of the specimens from Saginaw Bay and Green Bay were collected by trap nets; while, a few were taken by gill nets with 2 1/2-inch stretched mesh. The Grand Traverse Bay specimens were collected with experimental gill nets with mesh ranging from 2 1/2 to 4 inches.

3. The data for the collections made in 1942, 1943, 1944, 1945 and 1946 and gelatine-glycerine scale slides for 844 specimens prepared by Dr. Peter I. Tack were at the writer's disposal.

4. The 1942, 1943, 1944 and 1945 collections from Saginaw Bay were distributed through the length range of 160-329 millimeters. The 260-269 millimeter size class is dominant with 137 individuals or 20 per cent of the total catch. The age group III represents the dominant group with 186 individuals.

5. The Green Bay samples collected in 1944, 1945 and 1950 were distributed through the length range of 180-299 millimeters, with 220-229 millimeter size class being dominant with 128 specimens or 31

per cent of the total. Age group IV is dominant in Green Bay collections.

6. The fifty-nine Grand Traverse Bay cisco were scattered through 150-319 millimeter length range. The 190-199 millimeter size class is dominant with 13 individuals. Age group III is dominant.

7. Net selectivity is evident in age group I of the three samples.

8. The relative abundance of males and females varies with age groups. In general, the females tend to be more numerous than the males with each higher age group, in Saginaw Bay and Green Bay samples. In Grand Traverse Bay sample, the opposite is true.

9. The body-scale length relationship is shown to be very close to a linear regression in the three samples. The interception of the straight line on the length axis is taken as the length before scale formation in the fish. Based on this, 40, 33 and 17 millimeters are considered as the pre-scale formation length in Saginaw Bay, Green Bay and Grand Traverse Bay samples respectively. The 17 millimeter length in Grand Traverse Bay cisco is provisional since the sample is small.

10. The growth in length is variable in these samples. In general, the males of the Saginaw Bay cisco have grown longer than the females. The male cisco of Green Bay does not follow a pattern similar to Saginaw Bay sample; on the other hand, the higher growth in length in male shifts from year to year and from age to age. The males of the Grand Traverse Bay sample show generally greater growth in length than the females excepting age group IV.

11. The variations in growth rate in Green Bay and Grand Traverse Bay samples are attributed either to environmental condition or to different populations represented in the catch.

12. In the amount of growth the Saginaw Bay cisco stands far above the other two populations excepting a few variations. The Green Bay sample takes up a position in between the Saginaw Bay and Grand Traverse Bay cisco.

13. Lee's phenomenon is distinctly evident in Saginaw Bay and Green Bay samples.

14. No apparent change in growth rate is observed in Grand Traverse Bay sample. This raises the question whether this sample represents different populations with varying growth rates.

15. In the three samples, the greatest amount of growth in length is during the first year of life. The growth in the second year has dropped down to almost 50 per cent of the growth in the first year and in the succeeding years the growth is gradually diminished.

16. The length-weight relationship is these samples is described by the equation: $W = cL^n$

17. The weights for the individuals at end of winter marks were determined from the formulas given below using the calculated lengths for the corresponding years.

Saginaw Bay cisco	$W = 43.643 \times 10^{-5} L^{2.89065}$
Green Bay cisco	$W = 23.025 \times 10^{-5} L^{2.76257}$
Grand Traverse Bay cisco	$W = 3.1161 \times 10^{-5} L^{3.26657}$

18. The growth in weight increases at a rate slightly less than the cube of the length in Saginaw Bay and Green Bay cisco, while the Grand Traverse Bay specimens increase more rapidly than the cube of the length.

19. Generally the growth in weight follows the same trend as the growth in length for each sex, as well as when the sexes were combined.

20. The conventional application of the equation, $K = \frac{W \times 10^5}{L^3}$, in determining the coefficient of condition is questioned as being useful in fisheries management. It is believed that this equation is more of statistical interest than of practical value for management of fishery.

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APPENDIX I

ORIGINAL CATALOG DATA OF THE SAGINAW BAY LAKE HERRING

I Age Group Male

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32
150	East Tawas	2/29/43	169	202	63	98
168	"	2/29/43	187	224	90	101
403	Bayport	11/ 2/43	237	288	176	143
948	Caseville	11/ 6/45	183	224	76	121

I Age Group Female

162	East Tawas	6/29/43	185	226	84	128
206	Bayport	10/11/43	213	255	128	142
732	East Tawas	11/ 9/44	222	264	124	136
912	Bay City	10/31/45	169	211	67	138
920	"	"	185	226	83	138
939	Caseville	11/ 6/45	188	227	84	147

II Age Group Male

4	Linwood	11/ 1/42	250	290	205	166
79	Bayport	5/25/43	247	293	210	144
159	East Tawas	6/29/43	216	258	113	154
165	"	"	218	260	114	160
167	"	"	184	223	81	125
170	"	"	201	242	106	107
171	"	"	208	246	115	128
190	Bayport	10/ 6/43	256	303	208	178
194	"	"	199	241	92	129
203	"	10/11/43	236	285	188	180
313	"	10/27/43	262	314	228	179
314	"	"	267	319	228	160
348	"	"	259	314	224	166
349	"	"	257	310	236	171
358	"	"	226	266	160	188
376	"	11/ 1/43	265	325	264	188
388	"	11/ 2/43	213	259	120	160
431	"	11/9/43	265	325	268	228
557	East Tawas	6/ 7/44	233	277	128	148
610	"	6/13/44	214	258	112	134
632	"	"	211	249	108	130
634	"	"	230	280	132	168
635	"	"	220	267	100	152
640	"	"	232	275	120	148
643	"	"	242	285	160	184
689	"	11/ 6/44	265	321	188	187
694	"	"	239	289	164	187
705	"	"	205	254	88	146
707	"	"	223	273	118	158

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32
			II Age Group Male (Cont'd)			
708	East Tawas	11/ 6/44	228	278	112	150
729	"	11/ 9/44	231	276	116	140
731	"	"	203	250	96	135
795	Caseville	12/ 4/44	277	326	212	146
799	"	"	269	315	208	191
902	Bay City	10/31/45	216	261	84	148
904	"	"	232	284	119	197
906	"	"	215	265	74	174
907	"	"	218	270	89	174
910	"	"	201	246	108	191
911	"	"	225	274	115	124
913	"	"	214	260	106	186
916	"	"	209	252	104	179
921	"	"	186	231	84	156
922	"	"	208	249	112	176
926	"	"	222	267	93	139
927	"	"	199	237	98	139
929	"	"	209	252	75	143
932	Caseville	11/ 6/45	190	230	84	143
938	"	"	193	230	84	158
943	"	"	193	231	84	152
949	"	"	208	248	92	162
950	"	"	225	271	104	165
956	"	"	236	285	104	206
958	"	"	231	278	112	151
963	"	"	225	266	92	137
964	"	"	230	278	120	148
968	"	"	175	-	68	160
969	"	"	174	-	72	149
970	"	"	188	226	84	190
971	"	"	183	220	72	166
			II Age Group Female			
155	East Tawas	6/29/43	217	259	125	151
161	"	"	206	255	88	132
163	"	"	230	278	158	142
164	"	"	224	271	134	148
184	Bayport	10/ 6/43	242	296	208	245
192	"	"	264	321	292	210
198	"	10/11/43	232	284	180	215
207	"	"	231	282	164	186
208	"	"	248	305	260	168
222	"	10/14/43	242	286	184	158
299	"	10/26/43	242	294	192	146
302	"	"	207	252	112	106
328	"	10/27/43	261	315	260	126
355	"	"	254	302	204	175
361	"	10/28/43	272	318	264	198
411	"	11/ 4/43	264	319	244	128
425	"	11/ 9/43	284	338	300	209
484	"	11/17/43	259	313	236	195

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32
		II Age Group Female (Cont'd)				
496	East Tawas	6/ 1/44	-	266	120	224
501	"	"	-	260	128	162
504	"	"	-	248	100	158
505	"	"	-	284	136	170
506	"	"	-	255	108	164
507	"	"	-	269	124	142
508	"	"	-	276	132	127
509	"	"	-	271	128	196
511	"	"	-	261	136	140
518	"	"	-	277	140	156
568	"	6/ 7/44	234	275	124	192
574	"	"	245	284	172	184
578	"	"	218	270	132	160
580	"	"	197	245	100	154
582	"	"	221	277	128	176
609	"	6/13/44	233	281	140	128
622	"	"	205	245	96	132
630	"	"	223	267	140	148
639	"	"	234	282	128	127
641	"	"	202	241	96	147
642	"	"	232	277	148	164
696	"	11/ 6/44	232	282	112	194
697	"	"	234	285	132	168
699	"	"	217	261	104	155
701	"	"	230	279	104	168
702	"	"	221	266	116	179
711	"	"	235	281	120	175
727	"	11/ 9/44	228	274	100	184
730	"	"	221	266	88	157
878	Caseville	10/19/45	253	304	172	220
903	Bay City	10/31/45	235	285	84	140
905	"	"	230	281	95	162
908	"	"	222	274	112	154
909	"	"	201	244	104	194
914	"	"	209	255	88	164
918	"	"	224	274	109	143
923	"	"	249	293	144	168
924	"	"	218	266	101	219
925	"	"	193	235	97	137
930	"	"	230	273	101	199
931	"	"	235	284	101	154
933	Caseville	11/ 6/45	198	238	92	181
934	"	"	195	235	92	179
936	"	"	187	224	76	126
937	"	"	193	235	84	165
942	"	"	201	244	96	176
944	"	"	221	271	100	169
945	"	"	197	237	100	184
946	"	"	192	233	92	182
951	"	"	181	216	76	151

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32
		II Age Group Female (Cont'd)				
952	Caseville	11/ 6/45	221	270	100	146
953	"	"	227	271	100	138
954	"	"	229	275	104	183
966	"	"	204	246	104	159
967	"	"	185	222	76	122
		II Age Group (Sex not determined)				
733	East Tawas	11/ 9/44	215	260	116	190
		III Age Group Male				
46	Bayport	5/12/43	264	313	246	188
47	"	"	266	317	237	193
55	"	"	227	268	157	201
111	"	5/26/43	249	-	186	175
146	East Tawas	6/29/43	231	279	126	166
151	"	"	216	262	121	152
154	"	"	205	243	100	137
160	"	"	245	291	180	222
169	"	"	202	239	101	147
176	Bayport	10/ 4/43	254	312	272	222
177	"	"	266	326	292	168
187	"	10/ 6/43	275	332	292	167
193	"	"	258	311	256	156
204	"	10/11/43	288	356	344	200
210	"	"	252	312	260	259
220	"	10/14/43	286	336	300	276
225	"	10/18/43	253	309	256	156
252	"	10/20/43	246	310	204	180
275	"	10/21/43	258	312	216	167
289	"	10/25/43	265	328	268	168
306	"	10/26/43	257	310	232	200
307	"	10/27/43	263	316	240	188
311	"	"	266	325	260	172
316	"	"	267	325	248	196
320	"	"	268	328	260	178
322	"	"	262	319	252	150
333	"	"	275	333	256	270
337	"	"	253	312	224	211
339	"	"	258	317	252	206
341	"	"	266	323	252	175
342	"	"	285	343	316	198
344	"	"	263	317	236	158
352	"	"	292	344	312	158
353	"	"	260	309	224	136
362	"	10/28/43	280	331	256	204
371	"	11/ 1/43	252	312	240	189
378	"	"	260	316	240	162

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32
			III Age Group Male (Cont'd)			
389	Bayport	11/ 2/43	250	296	188	201
391	"	"	275	334	272	134
393	"	"	267	323	256	207
396	"	"	263	320	232	139
400	"	"	260	317	220	171
407	"	11/ 3/43	261	309	248	182
418	"	11/8 /43	259	316	236	131
435	"	"	254	309	228	175
442	"	11/10/43	263	322	248	197
447	"	"	269	325	244	191
461	"	11/11/43	263	311	240	138
477	"	11/16/43	261	320	236	193
483	"	11/17/43	267	325	256	216
499	East Tawas	6/ 1/44	-	279	124	191
514	"	"	-	261	108	142
519	"	"	-	276	120	214
520	"	"	-	265	116	178
523	"	"	-	261	116	164
561	"	6/ 7/44	229	274	132	178
566	"	"	264	312	220	191
570	"	"	243	285	148	180
571	"	"	240	284	172	208
584	"	"	234	283	148	157
588	"	"	239	291	140	165
608	"	6/13/44	237	284	140	132
612	"	"	225	269	128	141
628	"	"	237	285	152	193
631	"	"	237	285	144	130
633	"	"	222	268	124	150
683	"	11/ 6/44	255	302	184	184
688	"	"	272	327	240	167
700	"	"	215	257	92	163
710	"	"	224	269	104	147
713	"	11/ 9/44	256	308	196	211
789	Caseville	12/ 4/44	284	322	236	232
798	"	"	264	305	184	166
803	"	"	275	317	192	176
874	"	10/19/45	266	317	184	209
894	"	"	258	312	216	180
917	Bay City	10/31/45	227	274	125	154
928	"	"	224	269	100	154
955	Caseville	11/ 6/45	237	290	124	199
			III Age Group Female			
143	East Tawas	6/29/43	247	295	178	186
145	"	"	242	284	140	151
148	"	"	223	270	145	166

Catalog No.	Source	Data	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32
		III Age Group Female (Cont'd)				
153	East Tawas	6/29/43	260	305	202	193
156	"	"	205	250	85	177
157	"	"	198	240	82	146
196	Bayport	10/11/43	254	306	244	189
209	"	"	284	338	316	193
229	"	10/18/43	267	330	300	210
232	"	"	268	325	312	252
234	"	"	278	334	300	179
295	"	10/26/43	273	332	316	188
301	"	"	245	303	188	184
308	"	10/27/43	262	318	256	200
323	"	"	276	331	288	213
324	"	"	276	330	280	192
332	"	"	288	339	300	182
351	"	"	257	306	252	177
372	"	11/ 1/43	262	317	272	206
379	"	"	251	306	228	178
380	"	"	255	306	240	168
383	"	"	261	320	272	148
387	"	11/ 2/43	252	306	228	195
410	"	11/ 4/43	262	315	260	184
416	"	11/ 8/43	262	315	196	167
443	"	11/10/43	267	326	256	216
462	"	11/11/43	272	327	276	178
495	East Tawas	6/ 1/44	-	267	128	190
497	"	"	-	288	148	168
498	"	"	-	289	144	174
500	"	"	-	270	116	161
503	"	"	-	281	136	152
510	"	"	-	279	140	124
521	"	"	-	272	128	168
522	"	"	-	260	116	148
524	"	"	-	280	128	140
525	"	"	-	295	160	167
558	"	6/ 7/44	288	334	232	184
559	"	"	255	289	144	204
560	"	"	213	254	108	154
562	"	"	232	276	132	184
563	"	"	234	277	148	152
564	"	"	230	275	140	175
565	"	"	235	275	120	172
567	"	"	256	299	160	165
572	"	"	243	283	144	199
576	"	"	248	289	180	201
581	"	"	220	268	116	169
583	"	"	229	283	124	174
587	"	"	231	277	136	145
611	"	6/13/44	246	299	164	156
613	"	"	235	286	124	180
614	"	"	241	287	132	126
615	"	"	238	290	156	193

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32.
		III Age Group Female (Cont'd)				
616	East Tawas	6/13/44	232	276	128	193
617	"	"	241	293	148	178
619	"	"	238	288	148	234
621	"	"	230	279	132	129
623	"	"	234	280	140	161
624	"	"	252	302	140	218
626	"	"	227	274	124	152
627	"	"	234	280	148	203
629	"	"	233	282	160	194
636	"	"	230	279	128	145
638	"	"	235	284	136	154
684	"	11/ 6/44	260	317	216	277
693	"	"	258	310	180	166
698	"	"	237	286	116	191
703	"	"	225	266	104	136
704	"	"	228	279	124	151
706	"	"	235	278	132	183
709	"	"	230	282	116	180
712	"	11/ 9/44	274	321	188	228
714	"	"	271	326	204	160
719	"	"	258	307	192	262
720	"	"	250	303	196	230
723	"	"	237	289	144	180
724	"	"	227	273	128	168
725	"	"	232	278	128	189
728	"	"	224	269	104	176
784	Caseville	12/ 4/44	270	317	216	180
787	"	"	271	317	252	152
790	"	"	283	328	260	205
791	"	"	266	311	200	188
792	"	"	274	322	212	186
794	"	"	264	313	208	191
796	"	"	270	312	188	165
872	"	10/19/45	266	320	200	210
875	"	"	266	315	200	246
876	"	"	257	306	200	236
880	"	"	255	308	188	166
884	"	"	260	311	160	220
885	"	"	247	293	168	212
886	"	"	263	316	208	184
887	"	"	255	302	168	188
895	"	"	247	301	220	174
897	"	"	264	319	224	195
915	Bay City	10/31/45	221	271	101	152
919	"	"	234	284	118	174
935	Caseville	11/ 6/45	260	307	148	168
940	"	"	234	282	100	194
941	"	"	249	304	140	200
957	"	"	244	298	124	188
960	"	"	241	290	112	176
961	"	"	235	282	120	190

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32
			III Age Group Female (Cont'd)			
962	Caseville	11/ 6/45	217	266	72	199
965	"	"	238	283	120	200
			IV Age Group Male			
29	Linwood	5/ 6/43	283	345	310	176
36	"	"	282	333	275	220
39	"	"	275	331	272	271
41	"	"	283	333	286	196
42	"	"	257	307	250	212
43	"	"	265	315	223	176
49	Bayport	5/12/43	287	341	297	174
51	"	"	272	326	262	172
56	"	"	309	362	353	210
93	"	5/25/43	273	320	262	169
98	"	5/26/43	269	313	250	175
102	"	"	285	-	262	197
110	"	"	261	309	222	218
142	East Tawas	6/29/43	230	275	126	155
147	"	"	227	270	142	130
152	"	"	232	283	142	186
178	Bayport	10/ 4/43	263	328	280	220
185	"	10/ 6/43	294	353	424	192
197	"	10/11/43	270	328	348	224
211	"	10/14/43	289	354	408	254
217	"	"	262	323	256	205
219	"	"	290	347	376	260
221	"	"	289	351	360	236
228	"	10/18/43	275	332	284	240
230	"	"	265	321	300	260
231	"	"	259	315	244	178
240	"	10/19/43	295	357	388	188
245	"	"	279	339	320	242
254	"	10/20/43	262	322	264	199
258	"	10/20/43	267	320	240	228
260	"	"	266	330	292	163
265	"	10/21/43	292	354	352	245
278	"	10/25/43	257	313	232	196
288	"	"	269	329	272	224
292	"	10/26/43	281	336	284	212
300	"	"	260	320	284	246
304	"	"	273	329	260	270
305	"	"	254	314	220	208
309	"	10/27/43	265	321	224	210
325	"	"	228	273	268	164
326	"	"	265	320	248	173
329	"	"	260	317	232	156
330	"	"	262	322	244	189
334	"	"	272	328	264	191
335	"	"	277	335	264	181
350	"	"	270	317	236	180

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32
			IV Age Group Male (Cont'd)			
356	Bayport	10/27/43	271	320	248	231
357	"	"	272	322	268	229
363	"	10/28/43	263	307	216	178
386	"	11/ 2/43	248	305	208	148
395	"	"	274	332	292	184
399	"	"	267	326	256	186
406	"	11/ 3/43	271	318	236	223
420	"	11/ 8/43	270	328	296	174
428	"	11/ 9/43	270	329	260	201
432	"	"	268	322	248	202
436	"	"	266	320	240	154
438	"	"	263	319	244	185
441	"	11/10/43	273	333	260	160
445	"	"	277	336	260	182
446	"	"	273	336	252	150
448	"	"	263	315	236	140
453	"	"	269	324	240	131
458	"	11/11/43	268	315	220	183
460	"	"	266	310	240	225
474	"	11/15/43	273	325	236	169
476	"	"	273	330	284	258
478	"	11/16/43	259	312	224	196
480	"	"	266	324	248	194
482	"	"	288	343	344	200
485	"	11/17/43	256	319	224	196
513	East Tawas	6/ 1/44	-	281	144	200
573	"	6/ 7/44	246	293	148	169
575	"	"	246	289	160	212
577	"	"	227	280	148	163
637	"	6/13/44	226	276	132	188
687	"	11/ 6/44	262	315	220	152
800	Caseville	12/ 4/44	281	330	224	162
892	"	10/19/45	261	315	168	240
896	"	"	261	316	184	199
			IV Age Group Female			
48	Bayport	5/12/43	263	317	266	175
53	"	"	259	303	249	184
78	"	5/25/43	273	320	282	216
80	"	"	276	332	290	165
92	"	"	278	325	270	207
95	"	5/26/43	261	316	234	143
144	East Tawas	6/29/43	227	268	113	122
149	"	"	242	289	159	167
158	"	"	240	287	161	161
179	Bayport	10/ 4/43	283	341	304	180
181	"	"	272	327	304	222
186	"	10/ 6/43	267	325	248	207
201	"	10/11/43	300	359	420	211

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams	Scale radius x32
		IV Age Group Female (Cont'd)				
213	Bayport	10/14/43	294	357	432	206
216	"	"	278	338	304	219
224	"	10/18/43	294	354	408	207
227	"	"	270	333	328	224
235	"	"	267	320	276	242
237	"	10/19/43	290	349	332	202
246	"	"	275	340	328	228
250	"	10/20/43	280	343	368	238
253	"	"	263	320	276	210
259	"	"	296	355	364	164
290	"	10/26/43	280	339	360	196
303	"	"	236	288	144	172
317	"	10/27/43	263	321	276	200
318	"	"	260	313	240	193
319	"	"	272	330	276	212
321	"	"	266	327	296	260
331	"	"	257	314	260	231
336	"	"	252	304	216	197
338	"	"	259	317	252	188
343	"	"	328	372	252	140
347	"	"	254	307	244	176
359	"	"	281	331	300	205
370	"	11/ 1/43	266	325	300	158
375	"	"	258	310	248	161
377	"	"	264	320	268	173
381	"	"	267	323	284	164
382	"	"	270	324	284	187
390	"	11/ 2/43	239	293	220	184
398	"	"	256	308	236	154
401	"	"	272	324	256	190
408	"	11/ 3/43	278	330	288	216
409	"	"	303	359	432	234
419	"	11/ 8/43	264	321	272	177
422	"	11/ 9/43	278	338	304	201
423	"	"	270	327	268	234
430	"	"	274	333	268	188
433	"	"	255	316	260	158
434	"	"	261	320	268	245
444	"	11/10/43	265	325	264	155
450	"	"	297	359	356	219
457	"	11/11/43	271	317	260	198
459	"	"	294	342	388	142
473	"	11/15/43	274	328	324	210
502	East Tawas	6/ 1/44	-	284	140	162
512	"	"	-	289	164	167
515	"	"	-	271	152	186
516	"	"	-	278	144	200
517	"	"	-	269	136	164
569	"	6/ 7/44	247	292	152	216
579	"	"	241	294	172	183

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams	Scale radius x32
		IV Age Group Female (Cont'd)				
585	East Tawas	6/ 7/44	231	279	156	175
618	"	6/13/44	226	268	136	170
620	"	"	238	290	140	186
625	"	"	227	276	132	211
685	"	11/ 6/44	251	300	204	184
690	"	"	271	316	240	169
695	"	"	230	278	144	198
715	"	11/ 9/44	236	285	184	170
716	"	"	265	321	204	180
722	"	"	241	291	156	166
726	"	"	240	290	144	206
786	Case Ville	12/ 4/44	275	320	232	188
788	"	"	283	332	256	228
793	"	"	291	340	280	210
797	"	"	255	299	184	175
802	"	"	267	315	204	151
873	"	10/19/45	264	316	220	211
882	"	"	245	303	168	240
883	"	"	235	281	120	190
890	"	"	262	314	188	182
898	"	"	242	299	152	202
899	"	"	274	333	232	191
900	"	"	253	305	240	209
901	"	"	244	302	148	202
947	"	11/ 6/45	256	313	112	229
959	"	"	262	320	164	219
		V Age Group Male				
1	Linwood	11/ 1/42	275	320	254	188
30	"	"	283	342	326	182
38	"	"	267	323	252	234
45	Bayport	5/12/43	277	329	253	259
50	"	"	271	322	247	222
54	"	"	271	322	254	162
57	"	"	258	305	213	193
58	"	"	283	324	295	255
86	"	5/25/43	272	321	276	174
89	"	"	287	334	286	214
91	"	"	301	351	373	203
94	"	5/26/43	272	323	290	202
97	"	"	262	305	222	225
101	"	"	255	308	230	204
105	"	"	284	356	314	175
106	"	"	273	329	269	218
109	"	"	272	328	274	246
174	"	10/ 4/43	286	350	352	287
188	"	10/ 6/43	264	319	242	191
202	"	10/11/43	299	362	484	219
205	"	"	302	372	280	238

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams	Scale radius x32
			V Age Group Male (Cont'd)			
218	Bayport	10/14/43	283	341	352	285
226	"	10/18/43	270	325	272	222
247	"	10/19/43	268	330	300	190
261	"	10/20/43	254	308	236	184
262	"	"	261	318	260	217
264	"	10/21/43	278	334	300	210
268	"	10/21/43	271	329	280	230
280	"	10/25/43	275	337	264	200
286	"	10/25/43	275	335	304	254
294	"	10/26/43	249	301	220	178
297	"	"	277	335	280	210
312	"	10/27/43	273	328	256	221
327	"	"	274	337	280	206
364	"	10/28/43	271	318	256	258
365	"	"	274	326	264	176
366	"	"	285	330	288	208
367	"	11/ 1/43	282	345	320	174
373	"	"	270	332	268	182
385	"	11/ 2/43	286	342	296	189
392	"	"	281	340	296	169
394	"	"	269	327	268	168
414	"	11/ 4/43	263	318	240	192
421	"	11/ 8/43	268	325	264	178
427	"	11/ 9/43	260	315	268	260
437	"	"	260	315	232	184
449	"	11/10/43	263	316	232	237
452	"	"	265	321	228	211
454	"	"	285	346	304	239
468	"	11/11/43	271	326	260	180
472	"	11/15/43	275	326	268	171
481	"	11/16/43	281	338	276	198
718	East Tawas	11/ 9/44	256	310	216	241
801	Caseville	12/ 4/44	276	320	-	196
877	"	10/19/45	275	332	288	202
881	"	"	258	320	180	225
889	"	"	274	327	244	180
			V Age Group Female			
3	Linwood	11/ 1/42	295	340	347	210
28	"	5/ 6/43	274	327	282	142
33	"	"	252	299	196	164
37	"	"	263	317	263	185
40	"	"	266	314	244	191
82	Bayport	5/25/43	260	306	209	190
83	"	"	283	327	315	236
84	"	"	274	317	278	180
87	"	"	289	336	302	226
88	"	"	312	361	398	228
96	"	5/26/43	258	312	257	220

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams	Scale radius x32
			V Age Group Female (Cont'd)			
99	Bayport	5/26/43	249	296	227	204
166	East Tawas	6/29/43	254	310	186	188
172	Bayport	10/4/43	281	340	336	240
175	"	"	279	335	348	232
200	"	10/11/43	277	332	348	197
212	"	10/14/43	275	335	288	258
214	"	"	292	357	384	208
223	"	"	271	325	308	250
238	"	10/19/43	290	356	344	244
243	"	"	251	302	228	204
249	"	10/20/43	282	340	300	155
251	"	"	282	339	320	256
256	"	"	279	342	304	263
257	"	"	264	313	248	222
270	"	10/21/43	269	325	288	183
283	"	10/25/43	284	340	324	189
287	"	"	306	368	448	214
291	"	10/26/43	263	321	288	228
293	"	"	276	334	320	292
298	"	"	285	348	476	238
310	"	10/27/43	272	335	276	232
315	"	"	269	328	268	214
340	"	"	287	346	380	186
346	"	"	278	337	276	182
360	"	"	290	345	376	282
397	"	11/ 2/43	268	329	264	196
402	"	"	260	315	268	191
404	"	11/ 3/43	275	324	276	262
405	"	"	293	339	328	202
417	"	11/ 8/43	255	308	260	177
426	"	11/ 9/43	250	306	228	227
429	"	"	267	326	268	223
455	"	11/10/43	279	334	276	204
464	"	11/11/43	272	324	280	136
467	"	"	292	355	424	241
469	"	"	289	345	340	168
470	"	"	264	320	244	172
475	"	11/15/43	270	327	212	139
586	East Tawas	6/ 7/44	243	292	164	185
686	"	11/ 6/44	295	352	328	276
691	"	"	267	321	248	228
692	"	"	282	335	236	240
721	"	11/ 9/44	264	320	224	208
785	Caseville	12/ 4/44	290	340	312	171
888	"	10/19/45	281	342	200	210
891	"	"	263	317	236	186
893	"	"	264	319	244	254

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams	Scale radius x32
			V Age Group (Sex not determined)			
103	Bayport	5/26/43	254	303	207	160
107	"	"	251	290	194	185
			VI Age Group Male			
5	Linwood	11/1/42	270	325	282	186
44	"	5/ 6/43	260	312	226	216
85	Bayport	5/25/43	287	343	321	192
90	"	"	269	305	256	248
104	"	5/26/43	261	312	238	224
180	"	10/ 4/43	279	333	344	248
191	"	10/ 6/43	305	367	496	279
195	"	10/11/43	284	343	320	266
215	"	10/14/43	287	348	404	258
233	"	10/18/43	286	346	330	267
236	"	10/19/43	316	371	480	230
242	"	"	291	350	412	238
248	"	10/20/43	289	348	328	268
263	"	"	250	305	248	200
272	"	10/21/43	275	338	368	217
279	"	10/25/43	266	324	288	226
281	"	"	294	354	376	247
296	"	10/26/43	289	353	352	214
368	"	11/ 1/43	272	333	276	205
413	"	11/ 4/43	278	340	300	219
424	"	11/ 9/43	284	345	296	244
451	"	11/10/43	280	331	304	185
479	"	11/16/43	269	324	268	202
783	Caseville	12/ 4/44	281	326	220	226
			VI Age Group Female			
2	Linwood	11/ 1/42	270	320	271	206
34	"	5/ 6/43	283	332	278	168
35	"	"	282	335	299	208
52	Bayport	5/12/43	272	322	313	152
108	"	5/26/43	282	341	293	200
189	"	10/ 6/43	304	367	520	282
199	"	10/11/43	302	365	428	188
241	"	10/19/43	273	332	268	140
255	"	10/20/43	290	351	392	215
266	"	10/21/43	288	348	380	210
274	"	"	301	360	448	216
276	"	10/25/43	274	335	276	220
282	"	"	293	359	428	268
284	"	"	323	389	572	272
345	"	10/27/43	288	350	376	212
354	"	"	294	341	336	253

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32
			VI Age Group Female (Cont'd)			
369	Bayport	11/ 1/43	275	331	284	190
415	"	11/ 4/43	267	318	264	263
463	"	11/11/43	256	315	256	172
465	"	"	264	322	276	183
466	"	11/11/43	313	376	508	226
471	"	11/15/43	264	318	256	233
486	"	11/17/43	293	353	372	155
717	East Tawas	11/ 9/44	265	321	252	242
879	Caseville	10/19/45	282	335	268	238
			VII Age Group Male			
31	Linwood	5/ 6/43	294	356	333	254
81	Bayport	5/ 25/43	300	355	402	204
244	"	10/19/43	305	374	420	247
273	"	10/21/43	328	397	584	190
277	"	10/25/43	267	327	264	226
			VII Age Group Female			
32	Linwood	5/ 6/43	294	355	350	253
100	Bayport	5/ 26/43	278	330	271	239
173	"	10/ 4/43	309	376	520	271
239	"	10/19/43	319	384	536	274
269	"	10/21/43	292	352	384	250
285	"	10/25/43	320	390	536	254
412	"	11/ 4/43	295	359	368	232
456	"	11/11/43	290	341	296	231
			VIII Age Group Male			
267	Bayport	10/21/43	322	385	500	255
271	"	"	324	395	512	233
			VIII Age Group Female			
59	Bayport	5/12/43	283	338	321	209
182	"	10/ 4/43	301	366	444	327
183	"	"	320	389	568	300
439	"	11/10/43	299	362	396	230
440	"	"	268	325	296	246

APPENDIX II

ORIGINAL CATALOG DATA OF THE GREEN BAY LAKE HERRING

II Age Group Male

Catalog No.	Source	Data	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32
595	Escanaba	6/ 9/44	221	268	136	176
1262	"	2/22/50	206	254	125	135
1283	"	2/22/50	209	253	128	153
1287	"	"	210	255	122	135
1310	"	"	202	246	100	130

II Age Group Female

806	Escanaba	1/ 3/45	234	-	128	174
809	"	"	237	283	176	200
811	"	"	230	277	152	178
819	"	"	224	274	136	186
856	"	1/22/45	220	260	100	122
864	"	"	220	260	112	164
866	"	"	229	272	112	156
867	"	"	195	228	88	124
1136	"	2/13/50	196	235	96	135
1239	"	2/22/50	216	259	112	126
1243	"	"	194	235	112	146
1269	"	"	188	229	84	122
1278	"	"	209	250	108	151

II Age Group (Sex not determined)

530	Escanaba	6/3 /44	227	268	-	145
532	"	"	211	253	-	148
533	"	"	230	282	-	142
536	"	"	224	268	-	164
537	"	"	233	281	-	189
539	"	"	223	270	-	168
542	"	"	258	308	-	160
543	"	"	239	285	-	152
547	"	"	239	286	-	167
550	"	"	216	259	-	180
554	"	"	220	264	-	156
556	"	"	232	278	-	180
592	"	6/ 9/44	219	263	-	164
594	"	"	234	281	-	126
644	"	6/14/44	230	277	-	138
646	"	"	226	271	-	143
649	"	"	224	270	-	142
656	"	"	223	270	-	162

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32
			III Age Group Male			
754	Escanaba	12/ 2/44	259	300	184	210
764	"	"	254	301	188	169
776	"	"	254	294	188	169
808	"	1/ 3/45	224	-	120	204
853	"	1/22/45	201	235	96	154
858	"	"	240	284	144	174
859	"	"	225	266	100	154
861	"	"	265	305	200	188
869	"	"	225	266	96	155
1058	"	1/25/50	207	247	82	146
1060	"	"	219	256	114	148
1115	"	"	223	269	134	132
1117	"	2/13/50	223	260	122	130
1128	"	"	225	268	136	128
1131	"	"	207	251	112	176
1142	"	"	252	299	146	220
1155	"	"	219	265	120	139
1165	"	"	208	252	104	148
1176	"	"	205	250	108	152
1179	"	"	225	269	140	154
1186	"	"	208	255	108	170
1187	"	"	188	225	72	155
1192	"	"	208	250	112	134
1193	"	"	209	252	103	156
1195	"	"	226	272	141	166
1197	"	"	201	240	92	160
1199	"	"	219	263	132	147
1212	"	"	210	252	115	164
1215	"	2/22/50	210	250	109	160
1221	"	"	204	248	108	184
1227	"	"	209	251	108	142
1237	"	"	216	263	130	157
1249	"	"	218	260	117	201
1270	"	"	212	257	116	155
1275	"	"	224	267	124	150
1282	"	"	220	265	139	125
1296	"	"	200	241	96	114
1300	"	"	208	251	120	148
			III Age Group Female			
755	Escanaba	12/ 2/44	266	311	220	186
757	"	"	234	276	160	202
758	"	"	250	290	172	141
767	"	"	248	287	192	182
805	"	3/ 3/45	230	274	124	188
807	"	"	255	307	172	228
810	"	"	242	288	164	176
812	"	"	245	296	188	192
814	"	"	201	-	116	210

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32
			III Age Group Female (Cont'd)			
815	Escanaba	1/ 3/45	228	273	128	172
817	"	"	227	271	144	171
820	"	"	225	-	160	169
845	"	1/22/45	234	274	124	162
846	"	"	243	285	136	172
848	"	"	236	275	152	152
854	"	"	236	277	140	198
855	"	"	226	265	108	180
857	"	"	240	281	124	146
860	"	"	234	275	128	188
862	"	"	207	245	88	156
863	"	"	243	286	128	232
865	"	"	237	277	132	210
870	"	"	208	245	108	143
871	"	"	215	256	96	136
1052	"	1/25/50	231	271	142	172
1066	"	"	235	275	154	126
1074	"	"	240	282	161	167
1081	"	"	210	257	115	117
1084	"	"	214	258	108	137
1097	"	"	216	260	122	130
1113	"	"	223	266	129	156
1127	"	2/13/50	214	254	99	145
1130	"	"	223	267	129	141
1133	"	"	214	253	100	149
1145	"	"	219	262	132	148
1157	"	"	225	271	140	197
1163	"	"	210	251	100	152
1164	"	"	212	256	116	171
1169	"	"	217	264	116	155
1173	"	"	215	260	113	148
1174	"	"	208	255	120	190
1188	"	"	212	255	114	164
1189	"	"	217	263	124	185
1194	"	"	199	239	92	170
1196	"	"	223	265	120	188
1202	"	"	205	243	94	170
1210	"	"	219	264	116	116
1211	"	"	219	262	119	156
1213	"	"	200	241	101	139
1218	"	2/22/50	216	260	133	148
1220	"	"	210	251	112	140
1224	"	"	244	290	170	180
1225	"	"	215	260	136	146
1229	"	"	209	250	120	131
1232	"	"	225	269	148	152
1233	"	"	224	268	139	152
1234	"	"	211	253	121	146
1241	"	"	216	265	135	129

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32
		III Age Group Female (Cont'd)				
1242	Escanaba	2/22/50	218	263	120	180
1246	"	"	220	267	141	174
1247	"	"	218	262	136	139
1255	"	"	185	227	88	200
1258	"	"	204	253	97	128
1259	"	"	221	263	128	164
1260	"	"	210	251	124	154
1265	"	"	194	237	68	142
1274	"	"	218	260	141	155
1284	"	"	225	272	144	210
1290	"	"	197	238	83	144
1291	"	"	207	251	117	147
1294	"	"	212	256	127	186
1304	"	"	216	258	129	190
		III Age Group (Sex not determined)				
526	Escanaba	6/ 3/44	215	260	-	167
527	"	"	241	293	-	220
528	"	"	224	271	-	176
529	"	"	254	306	-	168
531	"	"	235	281	-	176
534	"	"	227	277	-	182
538	"	"	258	312	-	198
540	"	"	233	276	-	183
544	"	"	238	285	-	204
545	"	"	220	263	-	186
546	"	"	259	309	-	166
551	"	"	247	298	-	200
553	"	"	240	295	-	216
555	"	"	217	257	-	124
589	"	6/ 9/44	242	291	-	156
590	"	"	272	326	-	197
591	"	"	242	290	-	150
599	"	"	259	313	-	182
600	"	"	232	275	-	178
601	"	"	242	292	-	153
604	"	"	242	292	-	196
606	"	"	237	286	-	164
607	"	"	240	292	-	186
645	"	6/14/44	234	280	-	190
647	"	"	213	261	-	167
648	"	"	228	282	-	234
650	"	"	230	280	-	179
652	"	"	248	296	-	189
653	"	"	228	276	-	168
654	"	"	239	293	-	218
657	"	"	237	288	-	210
658	"	"	227	273	-	164
659	"	"	239	285	-	172
661	"	"	224	276	-	154

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams	Scale radius x32
			IV Age Group Male			
751	Escanaba	12/ 2/44	249	295	180	143
765	"	"	260	310	220	234
771	"	"	265	312	224	166
772	"	"	261	305	204	210
775	"	"	272	323	232	180
778	"	"	264	304	208	214
779	"	"	263	313	236	186
781	"	"	236	278	168	204
852	"	1/22/45	194	225	88	152
868	"	"	267	312	208	218
1043	"	1/25/50	224	272	120	175
1045	"	"	227	271	153	139
1054	"	"	214	255	128	179
1064	"	"	242	287	172	193
1077	"	"	237	279	156	166
1079	"	"	216	258	131	164
1085	"	"	224	265	130	210
1099	"	"	220	267	130	178
1103	"	"	231	277	146	132
1104	"	"	222	267	138	161
1107	"	"	236	280	151	150
1111	"	"	227	270	142	157
1112	"	"	215	255	108	163
1114	"	"	225	271	142	156
1116	"	"	228	268	146	142
1119	"	2/13/50	228	272	146	189
1122	"	"	214	252	104	182
1125	"	"	212	253	116	165
1129	"	"	224	270	152	194
1132	"	"	228	271	150	184
1141	"	"	218	260	126	176
1150	"	"	213	251	108	156
1151	"	"	226	270	140	166
1170	"	"	238	280	152	158
1171	"	"	217	263	136	164
1172	"	"	235	280	168	159
1182	"	"	221	266	152	152
1191	"	"	222	267	144	170
1198	"	"	226	269	142	194
1203	"	"	225	270	150	204
1206	"	"	225	266	136	193
1217	"	2/22/50	222	266	125	158
1219	"	"	226	271	152	174
1222	"	"	222	265	136	135
1231	"	"	227	275	144	137
1238	"	"	229	272	148	142
1244	"	"	226	272	136	173
1251	"	"	219	265	129	164
1257	"	"	216	261	132	178
1264	"	"	223	270	140	132
1277	"	"	232	277	154	182

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32
			IV Age Group Male (Cont'd)			
1280	Escanaba	2/22/50	227	271	142	200
1286	"	"	222	267	125	195
1288	"	"	231	272	152	121
1292	"	"	224	268	146	148
1295	"	"	213	257	124	172
1299	"	"	222	267	119	159
1301	"	"	227	270	136	177
1306	"	"	223	263	142	142
			IV Age Group Female			
752	Escanaba	12/ 2/44	258	304	236	216
759	"	"	279	322	224	222
760	"	"	261	304	224	197
762	"	"	274	319	220	202
766	"	"	260	307	204	159
773	"	"	239	282	180	219
782	"	"	289	333	244	168
804	"	1/ 3/45	251	296	172	166
813	"	"	225	-	140	149
816	"	"	231	276	144	197
818	"	"	232	-	124	154
847	"	1/22/45	243	285	164	181
850	"	"	252	294	152	148
851	"	"	235	270	120	170
1040	"	1/25/50	235	280	164	161
1044	"	"	234	280	146	146
1047	"	"	246	290	162	192
1049	"	"	229	270	148	194
1050	"	"	237	276	158	145
1053	"	"	242	280	160	155
1056	"	"	243	286	171	156
1059	"	"	222	264	130	182
1063	"	"	246	286	164	206
1070	"	"	224	271	132	132
1075	"	"	230	276	132	165
1078	"	"	227	272	140	191
1080	"	"	216	261	125	145
1082	"	"	233	276	158	134
1095	"	"	211	252	110	152
1096	"	"	230	274	144	210
1102	"	"	237	282	162	148
1118	"	2/13/50	205	240	106	146
1126	"	"	251	299	196	238
1135	"	"	215	258	168	226
1137	"	"	228	270	136	166
1138	"	"	227	272	136	203
1144	"	"	246	293	188	208
1146	"	"	199	240	106	182
1147	"	"	233	275	156	209

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32
		IV Age Group Female (Cont'd)				
1148	Escanaba	2/13/50	233	279	151	132
1152	"	"	228	271	136	178
1153	"	"	223	264	130	185
1154	"	"	240	285	164	171
1158	"	"	222	267	144	174
1161	"	"	226	272	136	183
1162	"	"	225	271	140	192
1166	"	"	222	270	133	180
1167	"	"	231	275	156	132
1175	"	"	228	275	144	151
1177	"	"	227	272	144	158
1178	"	"	236	282	159	189
1183	"	"	227	269	145	160
1185	"	"	217	260	136	176
1201	"	"	228	270	148	182
1204	"	"	230	272	146	128
1207	"	"	221	261	146	174
1208	"	"	224	266	136	171
1214	"	"	233	277	152	196
1216	"	2/22/50	218	257	132	166
1223	"	"	218	261	134	157
1226	"	"	220	259	116	178
1230	"	"	221	265	152	147
1235	"	"	255	300	201	154
1245	"	"	220	265	140	177
1248	"	"	223	271	133	150
1252	"	"	230	275	146	165
1253	"	"	232	281	160	199
1256	"	"	213	255	128	175
1261	"	"	221	265	137	185
1266	"	"	227	275	150	198
1273	"	"	222	267	148	205
1276	"	"	239	285	160	192
1279	"	"	248	292	201	166
1285	"	"	228	274	153	201
1289	"	"	227	268	136	174
1297	"	"	236	280	152	172
1298	"	"	228	269	144	162
1302	"	"	232	278	159	202
1307	"	"	223	269	132	146
		IV Age Group (Sex not determined)				
535	Escanaba	6/ 3/44	261	317	-	191
548	"	"	221	269	-	180
549	"	"	238	283	-	189
552	"	"	218	262	-	174
598	"	6/ 9/44	265	317	-	219
602	"	"	281	338	-	211
603	"	"	277	334	-	228
605	"	"	253	303	-	178
651	"	6/14/44	241	289	-	169
660	"	"	228	273	-	216

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32
			V Age Group Male			
780	Escanaba	12/ 2/44	258	300	204	241
1051	"	1/25/50	216	256	124	192
1065	"	"	235	279	148	254
1067	"	"	225	270	133	186
1069	"	"	228	273	144	200
1071	"	"	225	270	145	188
1072	"	"	233	274	144	171
1073	"	"	214	253	124	153
1100	"	"	245	289	166	168
1105	"	"	235	280	142	142
1106	"	"	241	284	160	173
1108	"	"	225	266	130	182
1109	"	"	220	261	129	151
1110	"	"	243	290	182	207
1140	"	2/13/50	228	272	151	168
1143	"	"	228	270	153	181
1149	"	"	215	261	132	174
1160	"	"	220	262	135	167
1181	"	"	235	283	184	192
1190	"	"	241	286	157	188
1205	"	"	245	286	180	180
1236	"	2/22/50	225	270	150	148
1250	"	"	225	271	152	200
1254	"	"	235	281	148	190
1268	"	"	240	286	177	200
1281	"	"	225	275	152	188
1293	"	"	239	290	180	228
1311	"	"	224	268	140	168
			V Age Group Female			
756	Escanaba	12/ 2/44	278	324	268	222
761	"	"	282	327	240	228
763	"	"	263	309	212	220
770	"	"	264	311	260	208
777	"	"	271	319	220	183
849	"	1/22/45	290	340	276	224
1041	"	1/25/50	244	290	164	224
1046	"	"	235	281	160	168
1048	"	"	256	304	196	201
1055	"	"	236	283	150	220
1057	"	"	245	290	175	192
1061	"	"	212	255	101	196
1062	"	"	233	274	158	208
1068	"	"	227	270	148	196
1076	"	"	242	289	185	210
1083	"	"	256	299	200	191
1090	"	"	229	275	150	156
1092	"	"	225	270	162	186
1093	"	"	222	269	133	208
1094	"	"	231	272	132	149

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32
			V Age Group Female (Cont'd)			
1098	Escanaba	1/25/50	223	267	133	182
1101	"	"	225	268	128	166
1121	"	2/13/50	236	277	152	230
1123	"	"	231	273	146	162
1124	"	"	228	272	132	180
1134	"	"	221	268	121	201
1139	"	"	220	262	120	176
1156	"	"	238	288	176	278
1159	"	"	242	287	169	203
1168	"	"	235	275	149	209
1184	"	"	234	282	156	180
1200	"	"	230	276	167	210
1209	"	"	230	273	148	208
1228	"	2/22/50	229	275	156	161
1263	"	"	231	280	168	190
1271	"	"	222	271	139	230
1272	"	"	233	281	160	178
1303	"	"	230	275	158	180
1308	"	"	227	272	144	202
1309	"	"	257	306	200	192
			V Age Group (Sex not determined)			
541	Escanaba	6/ 3/44	219	268	-	188
593	"	6/ 9/44	242	293	-	210
597	"	"	247	303	-	183
			VI Age Group Male			
768	Escanaba	12/ 2/44	257	305	200	240
1042	"	1/25/50	249	297	292	238
1180	"	2/13/50	262	316	216	220
			VI Age Group Female			
753	Escanaba	12/ 2/44	266	313	220	205
769	"	"	265	308	208	270
774	"	"	273	318	216	192
1087	"	1/25/50	235	277	141	186
1088	"	"	243	286	160	152
1089	"	"	237	285	160	176
1120	"	2/13/50	238	278	183	212
1240	"	2/22/50	237	285	180	206
1267	"	"	236	284	169	236
1305	"	"	240	285	170	204
			VI Age Group (Sex not determined)			
596	Escanaba	6/ 9/44	284	348	-	206

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32
			VII Age Group Female			
1086	Escanaba	1/25/50	244	290	172	234
1091	"	"	265	314	240	182

APPENDIX III

ORIGINAL CATALOG DATA OF THE TRAVERSE BAY LAKE HERRING

II Age Group Male

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32
978	Grand Traverse Bay	9/17/46	180	215	65	136
979	"	"	206	246	108	159
983	"	"	189	224	81	122
984	"	"	158	190	48	129
987	"	"	192	228	87	132
994	"	"	182	220	78	144
1012	"	"	185	220	81	176
1023	"	"	182	220	64	134

II Age Group Female

980	Grand Traverse Bay	9/17/46	185	224	90	162
986	"	"	190	225	91	158
989	"	"	192	227	91	144

III Age Group Male

981	Grand Traverse Bay	9/17/46	194	233	92	162
985	"	"	208	245	106	159
992	"	"	192	230	91	152
997	"	"	264	320	250	177
1002	"	"	270	317	234	178
1010	"	"	238	282	183	130
1011	"	"	276	332	234	208
1028	"	"	265	313	246	209

III Age Group Female

975	Grand Traverse Bay	9/17/46	196	236	104	160
976	"	"	169	202	64	164
977	"	"	176	219	70	150
982	"	"	207	241	104	147
988	"	"	198	237	105	184
990	"	"	200	238	107	144
991	"	"	190	224	90	157
993	"	"	175	210	73	136
1001	"	"	235	280	200	167
1013	"	"	195	232	90	138
1014	"	"	210	255	129	162
1015	"	"	207	248	125	204
1016	"	"	195	232	93	151
1018	"	"	204	242	112	151
1019	"	"	192	234	90	139

Catalog No.	Source	Date	Standard length in mm.	Total length in mm.	Weight Grams.	Scale radius x32
			III Age Group Female (Cont'd)			
1020	Grand Traverse Bay	9/17/46	192	232	93	148
1021	"	"	195	240	108	154
1022	"	"	180	220	82	134
1030	"	"	238	282	190	188
1032	"	"	233	284	219	200
1033	"	"	256	308	237	174
			IV Age Group Male			
1009	Grand Traverse Bay	9/17/46	256	309	232	209
1017	"	"	202	236	102	184
1031	"	"	278	327	305	212
			IV Age Group Female			
995	Grand Traverse Bay	9/17/46	242	295	206	230
1004	"	"	262	313	271	186
1005	"	"	215	260	159	178
1006	"	"	249	300	262	167
1007	"	"	260	313	237	212
1008	"	"	250	296	228	210
1025	"	"	271	328	267	232
1029	"	"	256	306	237	233
			V Age Group Male			
1024	Grand Traverse Bay	9/17/46	261	312	234	231
1027	"	"	311	368	435	218
			V Age Group Female			
996	Grand Traverse Bay	9/17/46	252	305	257	213
998	"	"	278	331	347	225
999	"	"	280	336	337	258
1000	"	"	280	336	327	221
1003	"	"	235	284	183	184
1026	"	"	280	334	304	223