THE WHITEFISH, *COREGONUS CLUPEAFORMIS* (MITCHILL), OF NORTHERN LAKE MICHIGAN, WITH SPECIAL REFERENCE TO AGE, GROWTH, AND CERTAIN MORPHOMETRIC CHARACTERS

By

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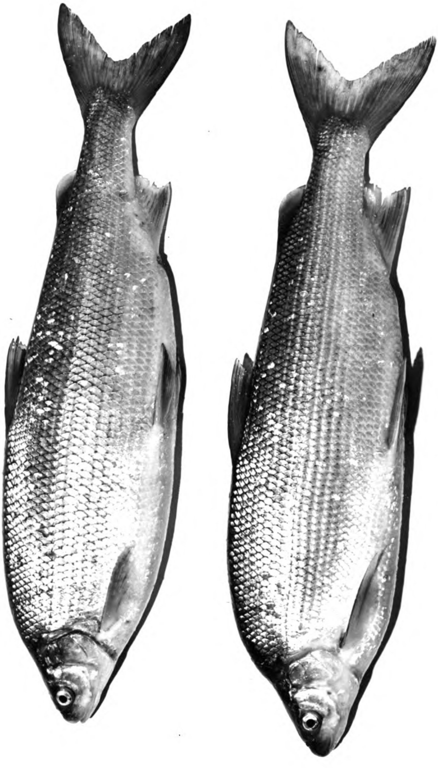

Prentice A. Cr[illegible]y

The whitefish, Coregonus clupeaformis (Mitchill), of northern Lake Michigan, with special reference to age, growth, and certain morphometric characters

ABSTRACT

Data are presented pertaining to age composition, strength of year classes, growth in length and weight, and measurements of several body proportions of whitefish from northern Lake Michigan. Samples were taken of the commercial fisheries during portions of the years 1948, 1949, and 1950, from three principal areas: Big Bay de Noc, Gull Island, and High Island.

Length-frequency distributions arranged according to age show considerably more overlapping of the lengths of fish belonging to different age groups in samples from Gull Island and High Island than among Big Bay de Noc samples.

In the 1950 collections year classes 1943 and 1944 made up slightly over 50 percent of the Gull Island and High Island samples, while Big Bay de Noc collections showed an especially poor representation by these year classes. The especially high dominance of the 1943 year class is shown in the Big Bay de Noc collections of 1948 and 1949.

Calculated total lengths for each year of life through 8 years show that an advantage of Big Bay de Noc whitefish over Gull Island and High Island fish increased from 0.7 inches at the end of the first year of life to 1.3 inches and 2.3 inches, respectively, at the end of the eighth year.

Formulae expressing the length-weight relationship of fish from three localities are presented. The weights of the northern Lake Michigan whitefish increased to the following

powers of the lengths: Big Bay de Noc, [illegible]; Gull Island, [illegible]; High Island, [illegible].

Commercial catches were examined for incidence of scars caused by sea lamprey, *Petromyzon marinus*. Tabulation of marked fish on basis of age-groups revealed no fish belonging to age-groups I, II, III, and only 6.4 percent of age-group IV, with either fresh or healed scars.

The method of analysis of variance, based upon the year classes, is applied to several body proportion measurements of fish from different localities. Four measurements (SL, H, CPL, CPD) taken of fish from four localities and belonging to five different year classes (age-group III to VII) are compared. In general, differences between Gull Island and High Island fish are not significant, except for some measurements among the young fish (III, IV). Fish from each of these localities differs from the Big Bay de Noc fish at the level of high significance. St. Helena Island fish closely approach those of Big Bay de Noc. Among the Big Bay de Noc samples there are no significant differences. The method of analysis of variance applied to values of the ratios SL/H and CPL/CPD as determined for the several samples reveal no significant differences between fish from any of the localities. Tests of the four measurements and the ratios show that the differences between the sexes of Big Bay de Noc fish are not significant.

P. I. Tack

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INTRODUCTION

The whitefish, Coregonus clupeaformis (Mitchill), is one of the important species of commercial prominence in the Great Lakes region. Koelz (1929, 1931) presents a general account of the natural history and distribution of the coregonid fishes of this region and northeastern America.

The outstanding catches of whitefish in Lake Huron during 1948 (2,971,905 pounds), followed by the sudden near collapse of this fishery in 1949 (530,000 pounds) and further reduction to 104,232 pounds in 1950 (Michigan Biennial Reports, Fish Division), very strongly suggests the need for further information of this species relative to strength of year classes making up the commercial catches. Especially, it is imperative to know something of the nature of the influence of those strongly represented year classes that may dominate the catches for a relatively short time in a certain localized area. Little is known, from the current sampling methods used, of the existence or nature of local populations or stocks among whitefish or their influence upon the fisheries of a particular locality. When a species of fish as the whitefish, with distribution throughout Lake Michigan, is exploited over a large portion of this area, it is important to know whether that species consists of several populations each keeping to a limited area or whether there is intermingling between different areas.

The trend of this fishery in Lake Michigan has not fluctuated so drastically as that of Lake Huron, in general, in the recent years. However, within the period 1945-1950, the Lake Michigan catches have increased from 1,326,235 pounds in 1945 to a peak of 4,262,678 pounds in 1948, and declined to 2,095,202 pounds in 1950 (Michigan Biennial Reports, Fish Division).

Studies of age and growth of this species from many of the larger lakes of northern and northeastern North America are available in the literature, but none have been presented for Lake Michigan as far as the writer can ascertain. Associated with this study of growth and age composition of the commercial catches of whitefish from northern Lake Michigan, the method of analysis of variance is applied to several body porportion measurements of fish from several widely separated collecting areas (Figure 1). The analyses of measurements are based upon the age group of the fish examined. Mottley (1941) applies the method of covariance to head-length measurements of trout to illustrate significant difference between two separate populations. His measurements are taken of fish making up a random sample and belonging to all available size groups. Hile (1935) uses the age of the fish (age-groups and year class) as a basis for comparing several morphometric measurements of lake herring, *Leucichthys artedi* (Le Sueur). However, the values of the means are shown without statistical treatment.

MATERIALS

The specimens of whitefish for this study were taken directly from the commercial fishery. Field collections were made during 1948, 1949 and 1950 from the waters of northern Lake Michigan (Figure 1). Additional information pertaining to dates of collection, locality of catch, type of gear, body of water, and total number of fish making up the individual samples is given in Table 1.

All fish were weighed and measured immediately upon collecting. This was done either by working in the cabin of the tug during the lifting of the nets or by working on the deck while returning to port. Taking of data was continued upon arrival at the fish house, in most instances, until packing of the catch for shipment was completed. Length measurements were made with a conventional "measuring" board by placing the fish on the board, the axis of the body at right angles to, and the tip of the snout just touching a raised end piece. The total length and standard length were read by means of a millimeter scale set into the measuring board along the midline. All measurements were taken by the writer.

In the 1949 and 1950 collections body proportion measurements (Figure 2) were taken of the fish upon arrival of the boats at the fish house in order to eliminate possible error due to boat movement. Body proportion measurements were taken only from those catches of live fish from pound nets. Usually body proportion measurements were begun

Figure 1. A portion of northern Lake Michigan, showing the collecting localities of this study.

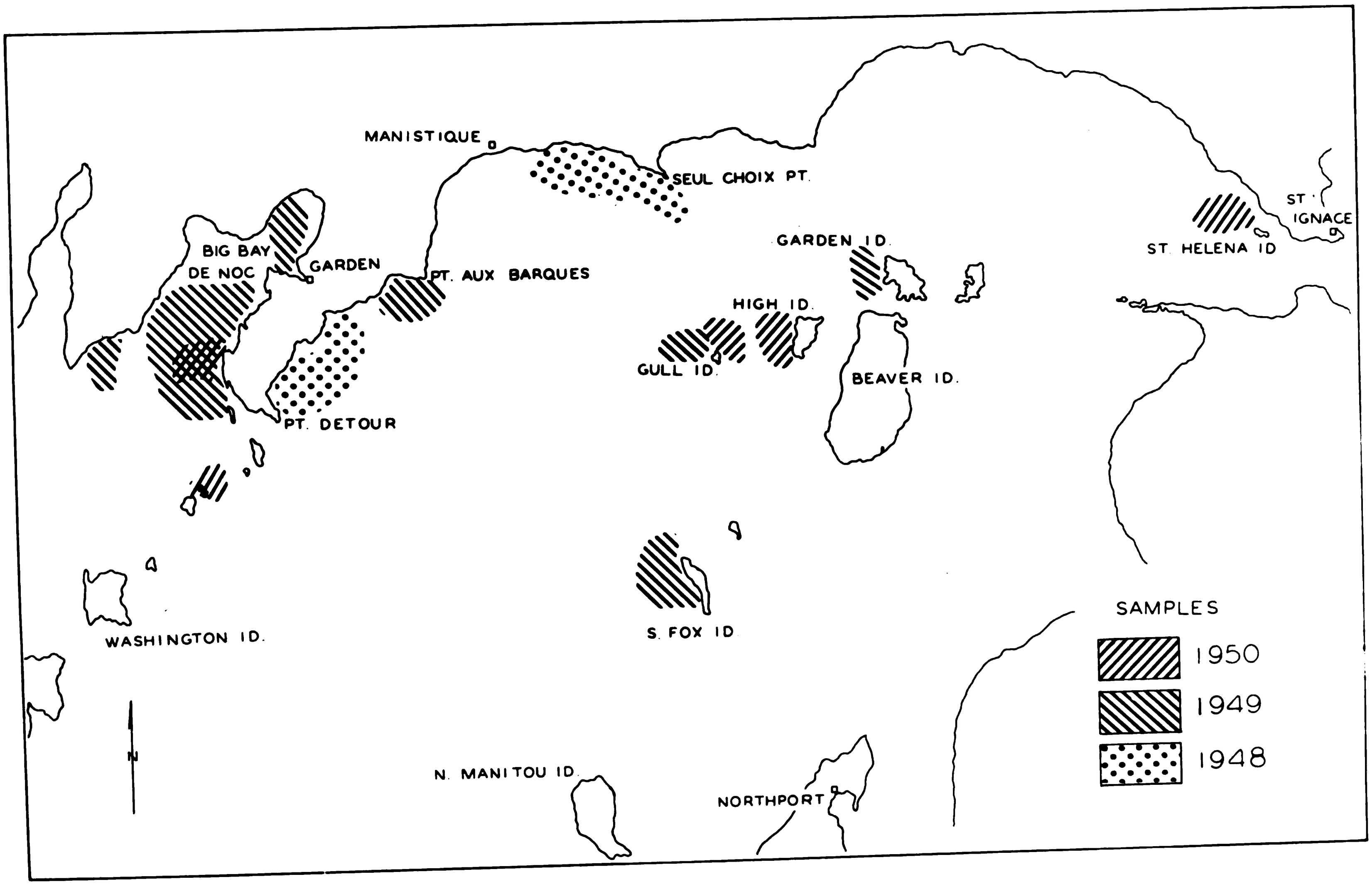

MANISTIQUE
SEUL CHOIX PT.
ST IGNACE
ST. HELENA ID
GARDEN ID.
BIG BAY DE NOC
GARDEN
PT. AUX BARQUES
HIGH ID.
GULL ID.
BEAVER ID.
PT. DETOUR
WASHINGTON ID.
S. FOX ID
N
N. MANITOU ID.
NORTHPORT
SAMPLES
1950
1949
1948

Table 1.-Samples of Lake Michigan whitefish employed for age-growth and morphometric studies

Date	Locality	Body of water	Gear	Fish
1948				
July 3	Seul Choix Pt.	Lake Michigan	trap nets	102
Aug. 7	Pt. Detour	Lake Michigan	trap nets	159
Aug. 14	Pt. Detour	Lake Michigan	trap nets	156
1949				
July 29	Gull Island	Lake Michigan	trap nets	19
Sept. 7	Pt. Aux Barques	Lake Michigan	trap nets	41
Sept. 8	Round Island	Big Bay de Noc	pound nets	31
Sept.10	Round Island	Big Bay de Noc	pound nets	9
Sept.12	Round Island	Big Bay de Noc	pound nets	24
Sept.13	Round Island	Big Bay de Noc	pound nets	203
Sept.15	Fairport	Big Bay de Noc	gill nets	39
Sept.16	Burnt Bluff	Big Bay de Noc	pound nets	26
Sept.16	Round Island	Big Bay de Noc	pound nets	68
Oct. 6	Round Island	Big Bay de Noc	pound nets	156
Oct. 10	Round Island	Big Bay de Noc	pound nets	107
Oct. 12	Round Island	Big Bay de Noc	pound nets	65
Oct. 13	Round Island	Big Bay de Noc	pound nets	66
Oct. 14	Garden Bluff	Big Bay de Noc	pound nets	67
Oct. 15	Isabella	Big Bay de Noc	gill nets	51
Oct. 28	Garden Island	Lake Michigan	pound nets	25
Oct. 28	S. Fox Island	Lake Michigan	gill nets	86
1950				
Aug. 12	St. Helena Id.	Lake Michigan	pound nets	45
Aug. 14	High Island	Lake Michigan	pound nets	57
Aug. 16	Burnt Bluff	Big Bay de Noc	pound nets	20
Aug. 17	Gull Island	Lake Michigan	pound nets	71
Aug. 22	Gull Island	Lake Michigan	pound nets	93
Aug. 26	High Island	Lake Michigan	pound nets	117
Aug. 26	Gull Island	Lake Michigan	pound nets	80
Aug. 31	Gull Island	Lake Michigan	pound nets	34
Sept.12	Burnt Bluff	Big Bay de Noc	pound nets	117
Sept.13	Burnt Bluff	Big Bay de Noc	pound nets	44
Sept.15	Burnt Bluff	Big Bay de Noc	pound nets	383
Sept.16	Burnt Bluff	Big Bay de Noc	pound nets	101

within two or three hours after the fish were taken from the nets and before being covered with ice for shipment. Body proportion measurements were taken by the use of needle point dividers or jaw type vernier calipers which were read to the nearest millimeter (except measurements of H, CPL, and CPD which were read to the nearest 0.1 millimeter). Figure 2 shows graphically the coded designation of some of the measurements that were taken. All measurements were made in a straight line on the left side. A description of body proportion measurements of the whitefish, the actual points from which measurements were made, and the symbols by which the measurements are designated in the tables and in Figure 2 are given below.

Total length (TL). Measured from the junction of the premaxillaries to the tip of the caudal fin with the lobes squeezed together so as to give the maximum possible measurement.

Standard length (SL). Measured from the tip of the snout (junction of the premaxillaries) to the end of the last vertebra or structural base of the caudal rays.

Head length (H). Measured from the junction of the premaxillaries to the extreme bony margin of the operculum, not including the opercular membrane.

Snout to dorsal (SD). Measured from the tip of the snout (junction of the premaxillaries) to the base of the first

ray of the dorsal fin.

Snout to anal (SA). Measured from the tip of snout to the base of the first ray of the anal fin.

Body depth (D). Greatest vertical depth of the body.

Dorsal-anal distance (DA). Measured from the origin (anterior end of the base) of the dorsal fin to the origin of the anal fin.

Ventral-anal distance (VA). Distance between origins of the ventral and anal fins.

Depth of caudal peduncle (CPD). Measured least depth of caudal peduncle.

Length of caudal peduncle (CPL). The oblique distance between the posterior end of the anal base and the end of the vertebral column (structural base of the middle caudal rays).

Dorsal-pectoral distance (DP). Distance between origins of dorsal and pectoral fins.

Pectoral-ventral distance (PV). Distance between origins of pectoral and ventral fins.

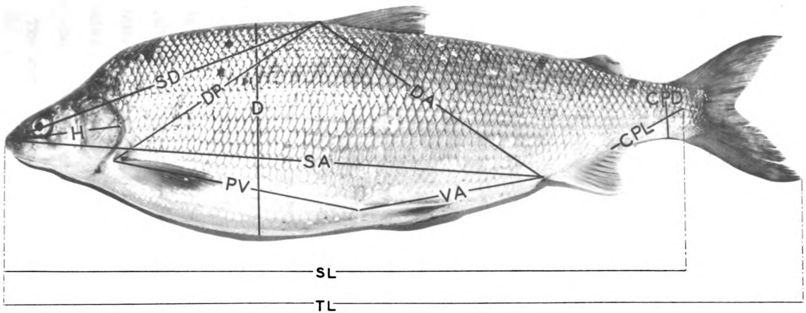


FIG. 2.— A WHITEFISH, SHOWING SOME OF THE MEASUREMENTS THAT WERE TAKEN

SD_SNOUT-DORSAL DISTANCE
SA_SNOUT-ANAL DISTANCE
SL_STANDARD LENGTH
TL_TOTAL LENGTH
H_HEAD LENGTH
D_DEPTH

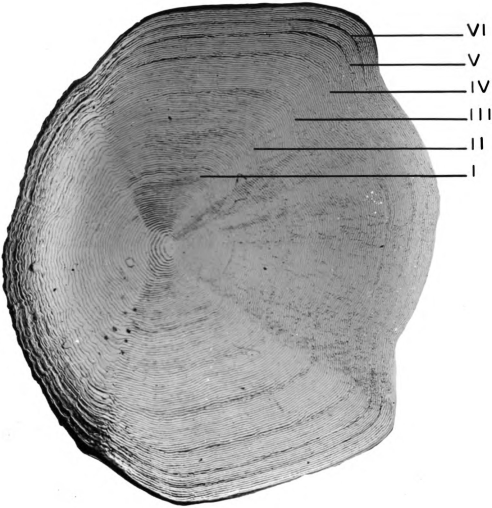
DA_DORSAL-ANAL DISTANCE
VA_VENTRAL-ANAL DISTANCE
CPD_CAUDAL PEDUNCLE DEPTH
CPL_CAUDAL PEDUNCLE LENGTH
DP_DORSAL-PECTORAL DISTANCE
PV_PECTORAL-VENTRAL DISTANCE

Scale samples were taken from the area immediately anterior to the dorsal fin just above the lateral line. These samples are preserved in small envelopes showing the catalogue number assigned to the fish and information relative to length, weight, sex, locality of catch, and other data. The scales were cleaned and mounted on slides in a solution of glycerin and gelatin to which a few crystals of phenol had been added for preservation. The scale reading was done by projecting the image through a scale projection apparatus similar to that used by Van Oosten, et al (1934). The positions of the essential scale features were marked on a strip of Manila tagboard. In order to measure the radii of the annuli, the strip was placed along the anterior radius of the scale image (x28 approximately) and the position of the focus of the scale was marked. Then, without moving the strip, the positions of the various annuli and the anterior margin of the scale were also marked along the edge of the tagboard. The tagboard was coded with the assigned catalogue number of the fish, as designated on the glass slide, and used subsequently in computing the growth rates. Ages are expressed by Roman numerals and indicate the number of annuli found on the scales. Figure 3 shows a scale that exhibits six annuli and is thus from a fish that was in its seventh year. The marginal increment surrounding the last annulus indicates that the major portion of the seventh year of growth had been completed at the time of capture in October.

Figure 3. Scale of a whitefish taken from southwest of Round Island, Big Bay de Noc, October, 1949.

Female, standard length 458 mm. (T.L. 21.9 inches) weight 3.63 pounds

(Six annuli are evident and the fish is assigned to age-group VI)


VI
V
IV
III
II
I

Growth computations are based on the assumption that, after completion of the first annulus, the scales grow at a relatively constant ratio to fish growth. A direct proportion nomograph, calibrated in metric units, as described by Carlander and Smith (1944) was utilized for rapid calculations of yearly growth from the scale measurements. The value of "c" (see Appendix I), length of fish when the scales first appear, is placed at 35-40 millimeters for the whitefish (Van Oosten 1929). For these calculations the value of "c" is arbitrarily set at 40 millimeters. It is not the purpose of this study to determine the exact length of the whitefish at the time the scales are formed. However, for purposes of general comparison of growth rates, it seems that the small variation in the values obtained for the initial years by using either 40 or 35 millimeters as the value of "c" does not produce an alarming distortion from the general trends of the growth rates as may be seen in the section on calculated growth.

AGE COMPOSITION AND LENGTH FREQUENCY DISTRIBUTION OF THE SAMPLES

The length-frequency distribution of the whitefish of northern Lake Michigan in the collections of 1950 are given in Tables 2 to 12. All fish were taken in August or September by pound nets and represent the total commercial catch for the date indicated. The samples are arranged according to age groups and standard length intervals of 10 millimeters. The midpoints of the intervals of standard length (millimeters) are converted to total lengths (inches) in each sample by means of factors determined for each sample area (Tables 30 and 31). The midpoints of the class intervals for all samples were designated as follows: e.g., the midpoint of the class interval of 340-349 used for purposes of calculating total length in inches was arbitrarily taken as 345.

In the 1950 collections all samples were from the same type of gear, set at a fixed point in each locality, and were made within a period of five weeks. The samples for each date are preserved in their original identity rather than combining them on the basis of sample areas. While the large number of tables is objectionable, nevertheless, the individual sample identity is retained to facilitate statistical comparison of body proportion measurements of individuals of several age-groups which make up samples taken from the same area on closely related dates. Further results of the statistical analyses

Table 2.— Length-frequency distribution of Lake Michigan whitefish

(St. Helena Island sample of August 12, 1950. The sexes are combined)

Standard length interval (millimeters)	Total length* (inches)	Age group					
		III	IV	V	VI	VII	III-VII
		Year class					
		1947	1946	1945	1944	1943	1947-1943
340-349	16.4	1					1
350-359	16.9	3					3
360-369	17.3	6					6
370-379	17.8	8					8
380-389	18.3	6	1				7
390-399	18.8	1					1
400-409	19.2	1	1				2
410-419	19.7		4				4
420-429	20.2		3				3
430-439	20.6			1			1
440-449	21.1		2	1			3
450-459	21.7		1	2			3
460-469	22.1						
470-479	22.6						
480-489	23.1						
490-499	23.6						
500-509	23.9						
510-519	24.4					1	1
Average standard length (millimeters)		372	422	451	-	510	
Average total length (inches)		17.7	20.0	21.4	-	24.2	
Total number of fish		26	12	4	0	1	43
Percentage of total		60.5	27.9	9.3	0	2.3	100.0

*Equivalent to midpoints of intervals of standard length

of several of these measurements may permit consolidation of some of the samples.

St. Helena Island. One sample of August 12, 1950 is available for this locality (Table 2). This small sample represents the total catch of one pound net for that date. Age-groups III and IV dominate the sample (88.4 percent). Age-group V is represented by 9.3 percent and age-group VII by 2.3 percent. The 1944 year class (VI group) is not represented. The Big Bay de Noc samples of 1950 (Tables 9 to 12) also show a complete absence of this year class. In Table 2 the length-frequency distributions of the individuals on the basis of age groups and class intervals of standard length are presented. As expected, the length distributions and the averages of the age groups in the sample show a progressive increase in length with each increase in age. However, there is some overlapping of the lengths of fish in the different age groups.

Gull Island. Four collections made in August, 1950, are presented in Tables 3 to 6. The youngest fish taken belong to age-group III and the oldest to age-group XI. Percentage representation of these age groups are combined in Table 19 and presented in the section pertaining to strength of year classes. There is extensive overlapping of the lengths of fish in the different age groups in the Gull Island samples. Several of the 10-millimeter intervals of standard length contain representatives of as many as four age groups. In general, the standard lengths show a pro-

Table 3.— Length-frequency distribution of Lake Michigan whitefish

(Gull Island sample of August 17, 1950. The sexes are combined)

Standard length interval (millimeters)	Total length* (inches)	Age group III	IV	V	VI	VII	VIII	IX	III-IX
		1947	1946	1945	1944	1943	1942	1941	1947-1941
330-339	15.9	1							1
340-349	16.4	1							1
350-359	16.9	1							1
360-369	17.4	1							1
370-379	17.8			1					1
380-389	18.3						1		1
390-399	18.8		1	1					2
400-409	19.3			1	1				2
410-419	19.7		1	3	1				5
420-429	20.2			1	2				3
430-439	20.7			2				1	3
440-449	21.2			5		2	1		8
450-459	21.5			2	3	1	1	1	8
460-469	22.0			2	2	1	1		6
470-479	22.4			5	4		1		10
480-489	22.9				6				6
490-499	23.4				2	3	1		6
500-509	23.7			1					1
510-519	24.2				1				1
520-529	24.7				3				3
. . .									
560-569	26.5							1	1
Average standard length (millimeters)		350	407	444	474	469	452	481	
Average total length (inches)		16.6	19.5	21.1	22.4	22.3	21.5	22.8	
Total number of fish		4	2	24	25	7	6	3	71
Percentage of total		5.6	2.8	33.8	35.2	9.9	8.5	4.2	100.0

*Equivalent to midpoints of intervals of standard length

Table 4.— Length-frequency distribution of Lake Michigan whitefish

(Gull Island sample of August 22, 1950. The sexes are combined)

Standard length interval (millimeters)	Total length* (inches)	Age group III	IV	V	VI	VII	VIII	IX	X	XI	III - XI
		Year class 1947	1946	1945	1944	1943	1942	1941	1940	1939	1947-1939
330-339	15.9	1									1
340-349	16.4	1	1								2
350-359	16.9	2	1	1							4
360-369	17.4	2	1								3
370-379	17.8	2	1								3
380-389	18.3	2	2								4
390-399	18.8		2								2
400-409	19.3		2	1							3
410-419	19.7		1	3							4
420-429	20.2			4	3	1					8
430-439	20.7			5	1	1		1			8
440-449	21.2			3	3	1	3				10
450-459	21.5			2	3	3	1				9
460-469	22.0			2	4	1					7
470-479	22.4			5	2	1	1				9
480-489	22.9			1	3	1					5
490-499	23.4			1	1						2
500-509	23.7				1						1
510-519	24.2					2					2
520-529	24.7										
530-539	25.1				3				1		4
540-549	25.6										
550-559	26.1										
560-569	26.5					1					1
570-579	27.0										
. .											
630-639	29.8									1	1
Average standard length (millimeters)		363	383	442	469	473	453	436	536	630	
Average total length (inches)		17.3	18.3	21.0	22.1	22.2	21.5	20.7	25.0	29.5	
Total number of fish		10	11	28	24	12	5	1	1	1	93
Percentage of total		10.7	11.8	30.1	25.8	12.9	5.4	1.1	1.1	1.1	100.0

*Equivalent to midpoints of intervals of standard length

Table 5.— Length-frequency distribution of Lake Michigan whitefish

(Gull Island sample of August 26, 1950. The sexes are combined)

Standard length interval (millimeters)	Total length* (inches)	Age group							
		III	IV	V	VI	VII	VIII	IX	III-IX
		Year class							
		1947	1946	1945	1944	1943	1942	1941	1947-1941
350-359	16.9	2	2						4
360-369	17.4								
370-379	17.8	1		1					2
380-389	18.3			2					2
390-399	18.8	1	1	1			1		4
400-409	19.3			2	1	1			4
410-419	19.7		1	2	1	1			5
420-429	20.2			2	1	2			5
430-439	20.7			3	2		1		6
440-449	21.2					2			2
450-459	21.5			5	1	1	2		9
460-469	22.0			1	2	1	1		5
470-479	22.4			3	1		1	1	6
480-489	22.9			1	6				7
490-499	23.4								
500-509	23.7				2				2
510-519	24.2				2		1	1	4
520-529	24.7						1	1	2
530-539	25.1								
540-549	25.6							1	1
Average standard length (millimeters)		369	380	433	468	432	464	512	
Average total length (inches)		17.5	18.0	20.6	22.2	20.5	21.9	24.2	
Total number of fish		4	4	23	19	8	8	4	70
Percentage of total		5.7	5.7	32.9	27.2	11.4	11.4	5.7	100.0

*Equivalent to midpoints of intervals of standard length

Table 6._ Length-frequency distribution of Lake Michigan whitefish

(Gull Island sample of August 31, 1950. The sexes are combined)

Standard length interval (millimeters)	Total length* (inches)	Age group						
		IV	V	VI	VII	VIII	IX	IV - IX
		Year class						
		1946	1945	1944	1943	1942	1941	1946-1941
350-359	16.9	1						1
360-369	17.4	1						1
370-379	17.8	1		1				2
380-389	18.3		1					1
390-399	18.8	1	1					2
400-409	19.3		1			1		2
410-419	19.7		4	1				5
420-429	20.2		4	3	1			8
430-439	20.7			2		1		3
440-449	21.2			1		1		2
450-459	21.5			1				1
460-469	22.0			1				1
470-479	22.4							
480-489	22.9							
490-499	23.4				1			1
500-509	23.7						1	1
510-519	24.2						1	1
520-529	24.7							
530-539	25.1							
540-549	25.6							
550-559	26.1							
560-569	26.5							
570-579	27.0						2	2
Average standard length (millimeters)		373	412	429	460	429	542	
Average total length (inches)		17.7	19.6	20.4	22.0	20.5	25.5	
Total number of fish		4	11	10	2	3	4	34
Percentage of total		11.8	32.3	29.4	5.9	8.8	11.8	100.0

*Equivalent to midpoints of intervals of standard length

gressive increase with increase in age. However, several poorly represented age groups show observed lengths below those of age groups one and even two years younger. Further consideration is given to this relationship in the section on calculated growth. Age-groups V, VI, and VII make up the major portion of the samples. There is extreme paucity of old individuals belonging to age groups above VIII. The oldest fish in the samples belong to the 1939 year class (XI group). However, in the High Island collections (Tables 7 and 8) one individual exhibits 15 annuli. The data of Tables 3 to 6 suggest that the commercial fishery exercises considerable fishing pressure on the younger age groups as they reach legal size and enter the fishery. The wider range and the extensive overlapping of the lengths of fish in some of the age groups are discussed further at the end of this section.

High Island. Length-frequency distribution of two collections from this sample area are presented in Tables 7 and 8. As in the Gull Island samples, there exists extensive overlapping of the lengths in the different age groups. Statistical analyses of the standard lengths and body proportion measurements are discussed in the section on analysis of variances of these measurements. The percentage composition of the samples is presented in Table 21.

Table 7.— Length-frequency distribution of Lake Michigan whitefish

(High Island sample of August 14, 1950. The sexes are combined)

Standard length interval (millimeters)	Total length* (inches)	Age group								
		III	IV	V	VI	VII	VIII	IX	XV	III-XV
		Year class								
		1947	1946	1945	1944	1943	1942	1941	1935	1947-1935
340-349	16.5	1								1
350-359	16.9	1								1
360-369	17.3			1						1
370-379	17.8		1							1
380-389	18.3									
390-399	18.8			2	1	1				4
400-409	19.2		2	2		1				5
410-419	19.7		2	2	1	1				6
420-429	20.2						3			3
430-439	20.7		1	3	2					6
440-449	21.1		1	2	4		1			8
450-459	21.5				2					2
460-469	22.0			1	2			1		4
470-479	22.4			1	2	1				4
480-489	22.9				2	1				3
490-499	23.4			1	1					2
500-509	23.8				3	1				4
510-519	24.2				1					1
. . .										
. . .										
630-639	29.9								1	1
Average standard length (millimeters)		353	412	428	464	446	429	460	634	
Average total length (inches)		16.8	19.6	20.2	21.9	21.1	20.4	21.8	29.6	
Total number of fish		2	7	15	21	6	4	1	1	57
Percentage of total		3.5	12.3	26.3	36.8	10.5	7.0	1.8	1.8	100.0

*Equivalent to midpoints of intervals of standard length

Table 8.— Length-frequency distribution of Lake Michigan whitefish

(High Island sample of August 26, 1950. The sexes are combined)

Standard length interval (millimeters)	Total length* (inches)	Age group: I	II	III	IV	V	VI	VII	VIII	IX	X	I - X
		Year class: 1949	1948	1947	1946	1945	1944	1943	1942	1941	1940	1949-1940
190-199	9.3	1										1
200-209	9.8	2										2
210-219	10.3	3										3
220-229	10.8		1									1
230-239	11.2		1									1
240-249	11.7		1									1
250-259	12.2		1									1
260-269	12.7		1									1
270-279	13.1											
280-289	13.6		3									3
290-299	14.1		1									1
300-309	14.6		3	4								7
310-319	15.1			1								1
320-329	15.5			2								2
330-339	16.0			2								2
340-349	16.5			3	4							7
350-359	16.9			1	2							3
360-369	17.3			3								3
370-379	17.8			1	1	2						4
380-389	18.3			1	3	1						5
390-399	18.8			1	2	3						6
400-409	19.2			1		2	3					6
410-419	19.7				2	2	4					8
420-429	20.2				1		1	1	1			4
430-439	20.7				1	2		2	1			6
440-449	21.1					2	4	2	1			9
450-459	21.5					3	1		2			6
460-469	22.0					1	2					3
470-479	22.4					1	3	2	1			7
480-489	22.9						2		1	1		4
490-499	23.4						2	1			1	4
500-509	23.8						2	1				3
510-519	24.2											
520-529	24.7							1				1
530-539	25.2											
540-549	25.7							1				1
Average standard length (millimeters)		210	274	344	380	421	452	472	451	489	493	
Average total length (inches)		10.0	13.1	16.4	18.1	20.0	21.5	22.4	21.4	23.1	23.4	
Total number of fish		6	12	20	16	19	24	11	7	1	1	117
Percentage of total		5.1	10.2	17.1	13.7	16.2	20.5	9.4	6.0	.9	.9	100.0

*Equivalent to midpoints of intervals of standard length

Big Bay de Noc. Four collections were made in 1950 from this area. Data pertaining to the samples are presented in Tables 9 to 12. Age groups II to XII are represented. Percentage representation of the year classes and age groups are shown in Table 18. There is less overlapping of the lengths of fish in different age groups (Tables 10 and 12) than in the Gull Island and High Island samples. The Big Bay de Noc samples of September and October, 1949, (Tables 13 and 14) exhibit relationships very similar to the collections of 1950. Collections were made in September and October, 1949, while the samples of 1950 were taken in September (except the small sample on August 16, 1950, containing 20 fish). The observed lengths for each well represented age group show very little difference in the samples for the two collecting years. Further analysis of the Big Bay de Noc samples is presented in the section relative to calculated growth.

Garden Island. One sample of October 28, 1949 is available for this locality (Table 15). The total catch is represented by 25 fish. Age groups III to VI are represented. The III group is represented by 20 percent, IV group by 40 percent, V group by 32 percent, and VI group by 8 percent. The observed lengths for the age groups very closely approximate those of the Big Bay de Noc samples.

Table 9. — Length-frequency distribution
of Big Bay de Noc whitefish

(Burnt Bluff sample of August 16, 1950. The sexes are combined)

Standard length interval (millimeters)	Total length* (inches)	Age group						
		III	IV	V	VI	VII	VIII	III-VIII
		Year class						
		1947	1946	1945	1944	1943	1942	1947-1942
360-369	17.4	1						1
370-379	17.9	4						4
380-389	18.4							
390-399	18.8	1						1
400-409	19.3		1					1
410-419	19.8							
420-429	20.3		2					2
430-439	20.7		3					3
440-449	21.2		3	1				4
450-459	21.5							
460-469	22.0		1					1
470-479	22.4							
480-489	22.9					2		2
490-499	23.4						1	1
Average standard length (millimeters)		374	434	445	-	486	492	
Average total length (inches)		17.8	20.5	21.0	-	22.9	23.2	
Total number of fish		6	10	1	0	2	1	20
Percentage of total		30.0	50.0	5.0	0	10.0	5.0	100.0

*Equivalent to midpoints of intervals of standard length

Table 10.—Length-frequency distribution of Big Bay de Noc whitefish

(Burnt Bluff sample of September 12, 1950. The sexes are combined)

Standard length interval (millimeters)	Total length* (inches)	Age group										
		III	IV	V	VI	VII	VIII	IX	X	XI	XII	1947-1938
		Year class										
		1947	1946	1945	1944	1943	1942	1941	1940	1939	1938	1947-1938
350-359	16.9	1										1
360-369	17.4											
370-379	17.9	7										7
380-389	18.4	13	1									14
390-399	18.8	5	1									6
400-409	19.3	1	3									4
410-419	19.8		6									6
420-429	20.3		4	1								5
430-439	20.7		4	2								6
440-449	21.2											
450-459	21.5			1								1
460-469	22.0					2						2
470-479	22.4		1	1		7	1					10
480-489	22.9			1		13	1					15
490-499	23.4					8						8
500-509	23.8					14	1					15
510-519	24.3					7	1					8
520-529	24.7					5						5
530-539	25.2					1		1				2
540-549	25.7										1	1
Average standard length (millimeters)		383	419	450	-	496	495	530	-	-	540	
Average total length (inches)		18.3	20.0	21.4	-	23.4	23.2	25.0	-	-	25.6	
Total number of fish		27	20	6	0	57	4	1	0	0	1	116
Percentage of total		23.3	17.2	5.2	0	49.1	3.4	.9	0	0	.9	100.0

*Equivalent to midpoints of intervals of standard length

Table 11.— Length-frequency distribution of Big Bay de Noc whitefish

(Burnt Bluff sample of September 13, 1950. The sexes are combined)

Standard length interval (millimeters)	Total length* (inches)	Age group III	IV	V	VI	VII	III-VII
		Year class 1947	1946	1945	1943	1942	1947-1942
350-359	16.9	3					3
360-369	17.4	11					11
370-379	17.9	6					6
380-389	18.4	6					6
390-399	18.8	1					1
400-409	19.3	1	3				4
410-419	19.8						
420-429	20.3		5				5
430-439	20.7						
440-449	21.2						
450-459	21.5						
460-469	22.0					1	1
470-479	22.4						
480-489	22.9					2	2
490-499	23.4					1	1
500-509	23.8					2	2
510-519	24.3						
520-529	24.7					1	1
530-539	25.2						
540-549	25.7					1	1
Average standard length (millimeters)		372	417	-	-	501	
Average total length (inches)		17.8	19.9	-	-	23.7	
Total number of fish		28	8	0	0	8	44
Percentage of total		63.6	18.2	0	0	18.2	100.0

*Equivalent to midpoints of intervals of standard length

Table 12.—Length-frequency distribution of Big Bay de Noc whitefish

(Burnt Bluff sample of September 16, 1950. The sexes are combined)

Standard length interval (millimeters)	Total length* (inches)	Age group II	III	IV	V	VI	VII	VIII	II-VIII
		Year class 1948	1947	1946	1945	1944	1943	1942	1948-1942
300-309	14.8	1							1
310-319	15.3	1							1
320-329	15.8								
330-339	16.2		1						1
340-349	16.7								
350-359	16.9		4						4
360-369	17.4		6						6
370-379	17.9		24						24
380-389	18.4		19	4					23
390-399	18.8		8	1					9
400-409	19.3		1	7					8
410-419	19.8			3					3
420-429	20.3			1					1
430-439	20.7			3					3
440-449	21.2			2	1				3
450-459	21.5			1	1				2
460-469	22.0						1		1
470-479	22.4								
480-489	22.9						1		1
490-499	23.4						1	2	3
500-509	23.8						1		1
510-519	24.3						2	1	3
520-529	24.7						1		1
530-539	25.2							1	1
Average standard length (millimeters)		309	376	411	447	-	501	508	
Average total length (inches)		14.9	18.0	19.5	21.0	-	23.7	24.1	
Total number of fish		2	63	22	2	0	7	4	100
Percentage of total		2.0	63.0	22.0	2.0	0	7.0	4.0	100.0

*Equivalent to midpoints of intervals of standard length

Table 13.–Length-frequency distribution of Big Bay de Noc whitefish

(The samples taken during October, 1949, are combined)

Standard length interval (millimeters)	Total length* (inches)	Age group II		III		IV		V		VI		VII		VIII		XII		Total
		Year class 1947		1946		1945		1944		1943		1942		1941		1937		
		M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	
280-289	13.8	1																1
290-299	14.3																	
300-309	14.7	2																2
310-319	15.2	2																2
320-329	15.7	2		1														3
330-339	16.2	1		1														2
340-349	16.7			1														1
350-359	16.9			8														8
360-369	17.4			7														7
370-379	17.9			8														8
380-389	18.4			2														2
390-399	18.8			6	1	2												9
400-409	19.3				1	2												3
410-419	19.8					5	3				1							9
420-429	20.3			1		3	1			2								7
430-439	20.8					3	3			4	1							11
440-449	21.2					3				5	3							11
450-459	21.5						2		1	10	9							22
460-469	22.0					1				20	11							32
470-479	22.5									9	15							24
480-489	22.9									13	15							28
490-499	23.4									8	6		1					15
500-509	23.8									3	4							7
510-519	24.3									1	1							2
520-529	24.7																	
530-539	25.2														1			1
540-549	25.7																	
550-559	26.1																	
560-569	26.6														1			1
570-579	27.1																	
580-589	27.6																	
590-599	28.0																2	2

		II	III	IV	V	VI	VII	VIII	XII	Total
Average standard length (millimeters)	M	312	370	423	-	470	-	-	-	
	F	-	401	431	456	473	490	550	595	
Average total length (inches)	M	15.1	17.7	20.2	-	22.3	-	-	-	
	F	-	19.1	20.4	21.5	22.4	23.0	25.9	28.2	
Total Sample Standard length		312	372	425	456	471	490	550	595	
Total length (inches)		15.1	17.8	20.2	21.5	22.3	23.0	25.9	28.2	
Total number of fish		8	37	28	1	141	1	2	2	220
Percentage of total		3.64	16.82	12.73	.45	64.09	.45	.91	.91	100.0

*Equivalent to midpoints of intervals of standard length

Table 14.–Length-frequency distribution of Big Bay de Noc whitefish

(The samples taken during September, 1949, are combined)

Standard length interval (millimeters)	Total length* (inches)	Age group: III	IV	V	VI	VII	VIII	IX	X	XIII	Total
		Year class: 1946	1945	1944	1943	1942	1941	1940	1939	1936	
340-349	16.7	4									4
350-359	16.9	16									16
360-369	17.4	32									32
370-379	17.9	27	1								28
380-389	18.4	11	4								15
390-399	18.8	7	5								12
400-409	19.3	2	8								10
410-419	19.8	1	19	2							22
420-429	20.3		17		3						20
430-439	20.8		7		13						20
440-449	21.2		6		23						29
450-459	21.5		3		38	2					43
460-469	22.0		1	1	32						34
470-479	22.5				32	1					33
480-489	22.9			1	20	2					23
490-499	23.4				13	1					14
500-509	23.8				4	2	1				7
510-519	24.3						2				2
520-529	24.7					1					1
530-539	25.2							1			1
540-549	25.7							2			2
550-559	26.1							1	1		2
560-569	26.6							1			1
570-579	27.1										
580-589	27.6										
590-599	28.0										
600-609	28.5										
610-619	29.0									1	1
Average standard length (millimeters)		373	418	444	457	486	509	545	559	615	
Average total length (inches)		17.6	19.9	21.1	21.9	23.0	23.8	25.5	25.9	28.7	
Total number of fish		100	71	4	178	9	3	5	1	1	372
Percentage of total		26.9	19.1	1.1	47.8	2.4	.8	1.3	.3	.3	100.0

*Equivalent to midpoints of intervals of standard length

Table 15.—Length-frequency distribution of Lake Michigan whitefish

(Garden Island sample of October 28, 1949. The sexes are combined)

Standard length interval (millimeters)	Total length* (inches)	Age group III / Year class 1946	IV / 1945	V / 1944	VI / 1943	Total
380-389	18.3	1				1
390-399	18.8					
400-409	19.3	2	2			4
410-419	19.7		2			2
420-429	20.2	2	2	1		5
430-439	20.7			2		2
440-449	21.2		2	2		4
450-459	21.4		1	1		2
460-469	21.8		1			1
470-479	22.3			2		2
480-489	22.8					
490-499	23.2				1	1
500-509	23.7					
510-519	24.1				1	1
Average standard length (millimeters)		408	429	448	500	
Average total length (inches)		19.4	20.3	21.2	23.7	
Total number of fish		5	10	8	2	25
Percentage of total		20.0	40.0	32.0	8.0	100.0

*Equivalent to midpoints of intervals of standard length

South Fox Island. Data of one collection made on October 28, 1949 are presented in Table 16. This sample comprised the total catch from commercial gill nets (4 1/2-5 inch mesh, stretched). Comparison of such a sample with collections from pound nets must be undertaken with caution. However, there exists wide ranges of lengths within the same age group and extensive overlapping of the lengths of fish belonging to several different age groups. A similar relationship is exhibited in the Gull Island and High Island samples.

Pt. Aux Barques. One trap net sample of September 7, 1949 is available for this area. The total catch consisted of only 39 fish (Table 17). Age groups III to VIII are represented. Age group V (1944 year class) dominates the sample (41.0 percent). It is this same year class that is so very poorly represented in the Big Bay de Noc collections of 1949 and 1950. Age group IV is represented by 20.5 percent, VI group by 18.0 percent, and III group, the fourth most abundant group, by 12.8 percent.

Table 16.-Length-frequency distribution of Lake Michigan whitefish

(South Fox Island sample of October 28, 1949. The sexes are combined)

Standard length interval (millimeters)	Total length* (inches)	Age group IV	V	VI	VII	VIII	IX	X	XI	Total
		Year class 1945	1944	1943	1942	1941	1940	1939	1938	
390-399	18.8			1						1
400-409	19.3		1	2	2					5
410-419	19.8			10	3	3	1			17
420-429	20.2			8	13	4				25
430-439	20.7	1			11	3				15
440-449	21.2		1		5	5		1		12
450-459	21.6		2		2					4
460-469	22.1				3	1				4
470-479	22.6			1						1
480-489	23.0									
490-499	23.5		1						1	2
Average standard length (millimeters)		432	451	419	432	432	414	440	491	
Average total length (inches)		20.7	21.4	20.0	20.5	20.6	19.7	20.9	23.2	
Total number of fish		1	5	22	39	16	1	1	1	86
Percentage of total		1.2	5.8	25.5	45.3	18.6	1.2	1.2	1.2	100.0

*Equivalent to midpoints of intervals of standard length

Table 17.—Length-frequency distribution of Lake Michigan whitefish

(Pt. Aux Barques sample of September 7, 1949. The sexes are combined)

Standard length interval (millimeters)	Total length* (inches)	Age group III	IV	V	VI	VII	VIII	Total
		Year class 1946	1945	1944	1943	1942	1941	
350-359	16.8	1						1
360-369	17.3							
370-379	17.7	2						2
380-389	18.2	2						2
390-399	18.7							
400-409	19.2							
410-419	19.6		1					1
420-429	20.1		3	1				4
430-439	20.6		1					1
440-449	21.0		1	1				2
450-459	21.4			4				4
460-469	21.9		2	4				6
470-479	22.3			1	1			2
480-489	22.8			2	2			4
490-499	23.3			1	1			2
500-509	23.6			1	1	1		3
510-519	24.1			1				1
520-529	24.6				2			2
530-539	25.0						1	1
540-549	25.5							
550-559	26.0						1	1
Average standard length (millimeters)		375	435	469	500	505	546	
Average total length (inches)		17.8	20.5	22.0	23.3	23.9	25.6	
Total number of fish		5	8	16	7	1	2	39
Percentage of total		12.82	20.51	41.03	17.95	2.56	5.13	100.0

*Equivalent to midpoints of intervals of standard length

In the South Fox Island, Gull Island, and High Island samples of whitefish there exists wide ranges in lengths within a majority of age groups represented. This is accompanied by extensive overlapping of the lengths of fish in several different age groups. In contrast, the collections of Big Bay de Noc show less fluctuations and reduced overlapping of the lengths in different age groups. Preliminary statistical analyses of the standard lengths and other body proportion measurements (see section on analysis of variance of morphometric measurements) indicate significant (1 percent level) differences between the same age groups from some of the different sample areas. A feasible explanation of the factors responsible for these conditions is beyond the range of the present paper.

AGE COMPOSITION AND STRENGTH OF YEAR CLASSES

A study of the relative abundance of the various age groups and, at the same time, the consideration of the relative abundance of the different year classes should be undertaken with special consideration. Such problems as type of gear used, selective action of the gear, depth of set, and season are immediately encountered. However, for purposes of these comparisons, only samples collected in pound nets set in very nearly the same locality each year are utilized. Comparisons are made of those samples taken during August, September, and October.

In view of existing limitations, however, the members of a certain year class may appear so conspicuous or so scarce at all of the ages at which that year class appears over several years of collecting that it may be feasible to designate the year class as "good" or "poor."
An analysis of the age composition of the collection of the years 1948, 1949, and 1950 in this study suggests the presence of certain year classes that can be termed relatively poor and relatively good. In the Big Bay de Noc area the year class of 1943 as the age-group V of 1948 made up over 80 percent of that year's collection, and 2 years later as the VII group it was still relatively abundant, comprising approximately 28 percent of the combined collections in 1950 (Figure 5, Table 20). In contrast, the year class of 1944 as the IV group of 1948 was represented by 6.5 percent, as the V group of 1949

made up only 0.4 percent, and as the VI group in 1950 was not represented in the total catch samples (Figure 5).

Big Bay de Noc - Pt. Detour - Seul Choix Pt. areas. In the Seul Choix Pt. collection (Table 20) age-groups III and IV (year classes of 1945 and 1944 respectively) account for approximately 85 percent of the sample while the V group (1943) forms 12 percent. This sample represents the total catch of three trap nets for a period of 3 days and 2 nights.

Two samples were taken off Pt. Detour August 7 and August 14, 1948. Since they represent total catches for four trap nets for the dates indicated and the percentage composition of the original samples were very similar (Table 20), the data are combined. The V group (1943) dominates markedly, forming over 80 percent of the catch in each sample. Age-group IV (1944) is represented by 6.5 percent, and III group and VI group by 2.3 percent each. The other age groups represented are II, VII, and VIII, with none contributing greatly to the sample.

Samples taken in Big Bay de Noc during October, 1949, are combined; however, only those collections considered representative (those samples comprising the total catch) are treated in such a manner. Preliminary inspection of the data revealed that the age composition of representative samples taken during September and October, 1949, show a very similar composition. Larger samples are available for October and for this reason those data are utilized. In the Big Bay de Noc collections of October, 1949, (Table 20) it is evident that the 1943 year class (VI group) dominates the samples (64.2 percent of the total). Age-group III is represented by 16.8 percent, and age-group IV, the third most abundant group, by 12.7 percent of the total. The study of the age composition of the Big Bay de Noc - Pt. Detour collections indicates the presence of one year class (1943) which may be considered very successful and one year class (1944) which may be considered poor. Of approximately 1,100 fish examined from Big Bay de Noc during September and October, 1949, only 5 fish belonged to the V group (1944). Further, in the Big Bay de Noc collection of the following year (September, 1950) the VI group (1944 year class) is not represented in the total catches sampled. However, the 1943 year class (VII group) continued to make up 27.8 percent of the total. A further analysis of the Big Bay de Noc collections of September, 1950, (Table 18, Figure 4) indicates a definite trend in the fishery toward a reduced representation by the 1943 year class within the period of one week. Table 18 exhibits age composition of consecutive samples taken from the same pound nets set off Burnt Bluff. In the collection of September 12, 1950, the VII group (1943) is represented by 49.1 percent of the total. In the sample of September 13, 1950, the VII group is represented by 18.2 percent; however, the catch of September 16, 1950, indicates that the VII group made up only 7.0 percent of the total catch. All

Table 18.—Age composition of the samples of Big Bay de Noc whitefish taken during September, 1950

Date	Locality	II	III	IV	V	VI	VII	VIII	IX	XII	Fish
September 12	Burnt Bluff	0 (0)	23.3 1/ (27)*	17.2 (20)	5.2 (6)	0 (0)	49.1 (57)	3.4 (4)	.9 (1)	.9 (1)	116
September 13	Burnt Bluff	0 (0)	63.6 (28)	18.2 (8)	0 (0)	0 (0)	18.2 (8)	0 (0)	0 (0)	0 (0)	44
September 16	Burnt Bluff	2.0 (2)	63.0 (63)	22.0 (22)	2.0 (2)	0 (0)	7.0 (7)	4.0 (4)	0 (0)	0 (0)	100
Total samples combined		(2)	(118)	(50)	(8)	(0)	(72)	(8)	(1)	(1)	260
Percentage		.8	45.3	19.2	3.1	0	27.7	3.1	.4	.4	100.0

1/ Percentage
* Number of fish

Table 19.-Age composition of the Gull Island collections of whitefish

Date	III	IV	V	VI	VII	VIII	IX	X	XI	Fish
August 17, 1950	4	2	24	25	7	6	3	0	0	71
August 22, 1950	10	11	28	24	12	5	1	1	1	93
August 26, 1950	4	4	23	19	8	8	4	0	0	70
August 31, 1950	0	4	11	10	2	3	4	0	0	34
Total fish (combined)	18	21	86	78	29	22	12	1	1	268
Percentage (combined)	6.7	7.8	32.1	29.1	10.8	8.2	4.5	.4	.4	100.0

samples for this period comprise the total catch for the date indicated. Although the sample of September 13,1950, may be considered small, the trend is definitely exhibited. Further, an analysis of age composition of a sample of 383 fish (not included in this study) taken September 15, 1950, from the same nets off Burnt Bluff presents representation of the year classes in percentage composition very nearly that of the September 16, 1950, collection. Accompanying this rapid decline in the representation by the 1943 year class, there was a marked increase of the IV group and, especially, the III group (1947 year class) (Table 18). This situation was evident during the actual process of lifting the nets, since considerable difficulty was encountered in separating those individuals estimated to be of legal size (2 pounds) from those individuals of slightly less weight. In addition, conversation with several commercial fishermen in the Big Bay de Noc area further substantiated the fact that the catches in early September, 1950, consisted of more than half of "jumbo" whitefish, weighing 4 pounds or over, while that size of fish were poorly represented in the catches of late September, 1950. At the same time there appeared in the nets a marked increase in the number of individuals slightly less than 2 pounds in weight. This is in agreement with data presented in Table 18.

Table 20.—Age composition of northern Lake Michigan collections of whitefish.
Big Bay de Noc – Manistique areas

Date	Locality	II	III	IV	V	VI	VII	VIII	IX	XII	Fish
July 3, 1948	Seul Choix Pt.	1.0 1/	44.9	40.6	12.5	0	1.0	0	0	0	96
August 7, 1948	Pt. Detour	1.3	3.1	3.8	87.4	2.5	1.3	.6	0	0	159
August 14, 1948	Pt. Detour	0	3.9	9.2	83.7	2.0	.6	.6	0	0	149
September, 1949	Pt. Aux Barques	0	12.8	20.5	41.0	18.0	2.6	5.1	0	0	39
October, 1949	Big Bay de Noc	3.7	16.8	12.7	.4	64.2	.4	.9	0	.9	220
September, 1950	Big Bay de Noc	.7	45.4	19.3	3.0	0	27.8	3.0	.4	.4	258

1/ Percentage

From Figure 5, which exhibits graphically the percentage representation of the different year classes, the dominating influence of the very strong 1943 year class may be seen. Also, the combined collections of 1950 show a bimodal relationship in that the III group (1947) and the VII group (1943) are abundantly represented, while the V group (1945) and the VI group (1944) are very poorly represented. The collections of October, 1949, also indicate a bimodal relationship; however, the VI group (1943) dominates the catch, while the III group and the IV group are represented in next order of abundance. Again, the 1944 year class is very poorly represented.

Gull Island-High Island-Big Bay de Noc collections of 1950. Percentage representation of the different year classes in the 1950 collections are shown in Figure 4. The Gull Island collections (Table 19) represent total catches for the dates indicated. Since these samples show close similarity and are from the same pound nets, they are combined for comparison with the High Island and Big Bay de Noc collections.

In the Gull Island samples age-groups III (1947) to XI (1939) are represented. Age-group V (1945) is slightly more numerous (32.1 percent of the total) than age-group VI, which is represented by 29.1 percent, and age-group VII, the third most abundant group, is represented by

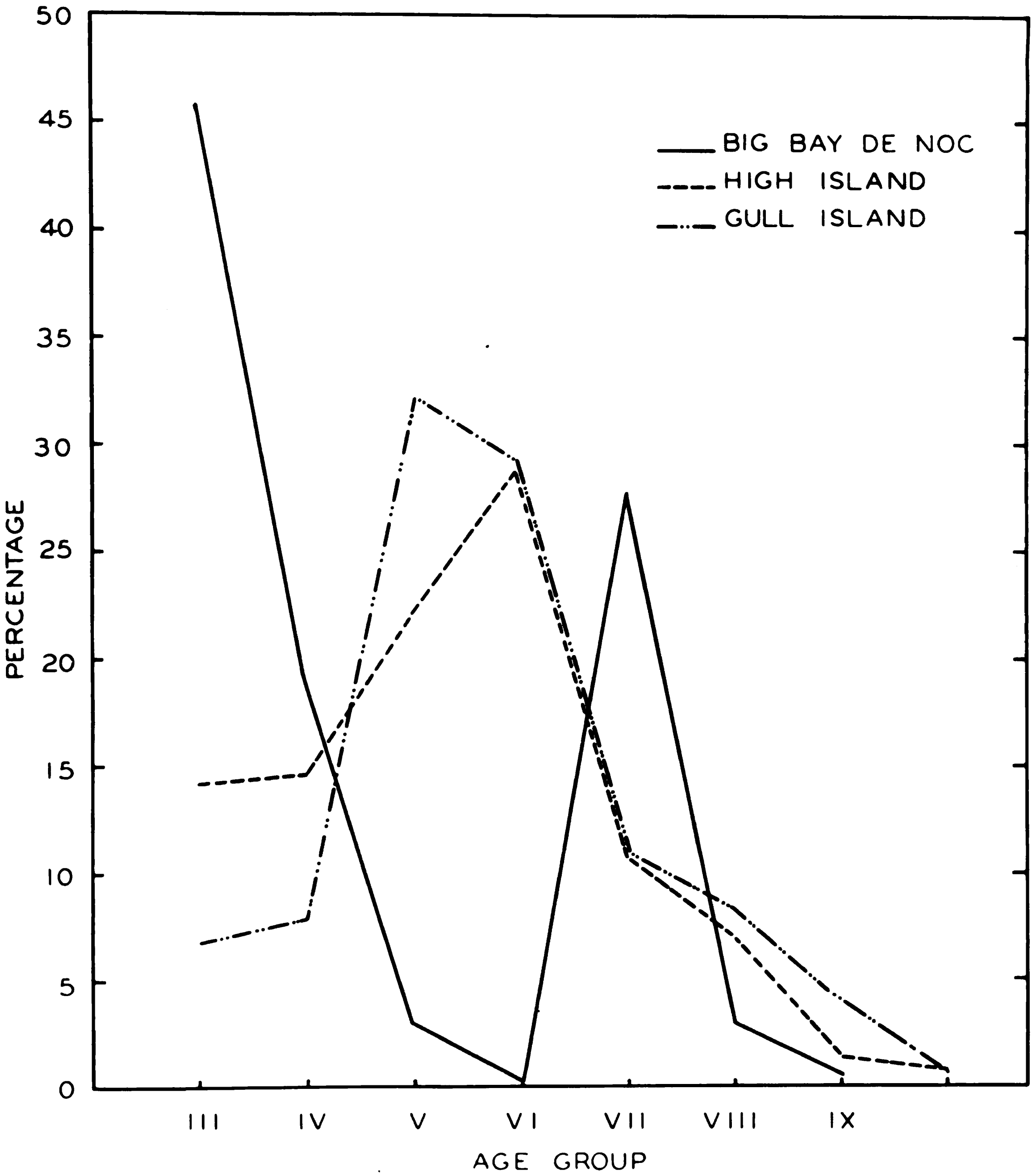
Table 21.—Age composition of the High Island collections of whitefish

Date	I	II	III	IV	V	VI	VII	VIII	IX	X	XV	Fish
August 14, 1950	6	12	20	16	19	24	11	7	1	1	0	117
August 26, 1950	0	0	2	7	15	21	6	4	1	0	1	57
Total number of fish	6	12	22	23	34	45	17	11	2	1	1	174
Percentage (I,II omitted)	.	.	14.1	14.7	21.8	28.8	10.9	7.2	1.3	.6	.6	

10.8 percent. Absence of the I and II groups may be considered largely due to the selectivity of the gear. However, Hart (1930) suggests that, at certain times, the larger forms of whitefish frequent water of less depth than the smaller forms. Groups I and II are represented in the High Island collection of August 14, 1950, but are not represented from the same nets in the collection of August 26, 1950. In the former collection, a special effort was made to collect all small whitefish that were schooling in the "pot" of the pound net with the larger fish. Usually these small fish, if brought out of the water during the process of lifting the nets, are immediately separated from the commercial catch because of their sublegal size and returned to the water. For this reason, representation of I group and II group in the High Island collection is considered atypical of a catch selected for commercial markets. In collections of this study, in most instances, the III group represents the youngest fish in the catch. Usually these individuals were retained in the catch because their weights were estimated to be approximately 2 pounds.

High Island samples. As mentioned above, the occurrence of the I and II groups in gear designed to select legal commercial catch is considered irregular. In final analysis of the samples these two groups are not considered. It may be seen from Table 21 and Figure 4 that age-groups IV, V, VI, and VII are well represented in the catch. In

Figure 4. Percentage representation of the different year classes in the 1950 whitefish collections from the three principal sample areas.



BIG BAY DE NOC
HIGH ISLAND
GULL ISLAND
PERCENTAGE
0
5
10
15
20
25
30
35
40
45
50
III
IV
V
VI
VII
VIII
IX
AGE GROUP

Figure 5. Percentage representation of the different age groups taken in the Big Bay de Noc - Pt. Detour collections for the years indicated.

Pt. Detour, _______ (1948); Big Bay de Noc, ----- (1949);

Big Bay de Noc, __ .. __ (1950).

contrast to the Big Bay de Noc collections, year classes 1945 and 1944 (V group, VI group) make up slightly over 50 percent of the catch. Similar strengths of these same year classes in the collections of Gull Island are evident. In contrast, the Big Bay de Noc samples show almost a complete absence of these year classes.

Pt. Aux Barques. Unfortunately, 1949 collections are not available for the Pt. Detour area. However, one sample taken off Pt. Aux Barques, which is very near that area (Figure 1), on September 7, 1949, presents age group composition quite unlike that indicated in Big Bay de Noc samples for the 1949 collections (Table 20). In the Pt. Aux Barques sample age-group V (1944 year class) is represented by 41.0 percent and age-group IV (1945 year class) by 20.5 percent. In contrast, the V group (1944) is very poorly represented (0.4 percent) in the Big Bay de Noc collections of the same year.

Fluctuations in abundance of year classes of fish have long attracted the attention of fisheries biologists. Especially, studies of the populations of marine fishes have occupied prominent positions in research programs. Dymond (1948) reviews some European studies of populations. Studies of the age composition of herring stocks have produced evidence that different year classes vary markedly in their contributions to the stock of fish supporting the fishery. At a meeting of the International Council for the Exploration of the Sea (Rapp. Cons. Explor. Mer 65, 68) the problems of fluctuations were given special emphasis. In addition, Hjort (1914, 1926, 1930), Hodgson (1930, 1936), Lea (1930), H. Thompson (1930), Sund (1936) and others have conducted studies on fluctuations of such species as herring, cod, plaice, pilchard, hake and others. Investigations for an explanation of the causes of the wide differences in the size of different year classes have shown that there is no necessary connection between the number of eggs produced in a particular spawning season and the number of fry which survive. Poor spawning years have often been good brood-years. Several suspected causes of fluctuation in abundance are discussed by Dymond (1948).

The recent investigations of Burkenroad (1948), Huntsman (1938), W.F. Thompson (1937), Thompson and Bell (1934), Ricker (1940) and Walford (1946) pertain, largely, to studies of abundance of various marine fishery animals of economic value to industries in the United States and Canada.

In review, Figure 4 shows diverse representation of the different year classes in samples from three principal collecting localities. The 1944 year class is not represented in the Big Bay de Noc samples, yet this year class is well represented in the High Island and Gull Island samples. Also, the 1945 year class is very poorly represented in the

Big Bay de Noc collections. In contrast, this year class is well represented in the High Island samples and dominates the Gull Island samples. Further, Figure 5 shows the dominating influence of the very strong 1943 year class in the Big Bay de Noc area through three fishing seasons. It lies beyond the scope of this paper to indicate causes of such fluctuations in abundance of different year classes of whitefish in northern Lake Michigan. It is evident that the strength of a certain year class may vary markedly between locations that are not too widely separated. Van Oosten and Hile (1947) fail to indicate a correlation between meterological-limnological conditions and fluctuations in the strength of the year classes of Lake Erie whitefish. In order to detect and evaluate any one of a number of complex relationships, more extensive and uniform methods of sampling and recording of data probably will be devised.

CALCULATED GROWTH

The several samples of Lake Michigan whitefish used in these comparisons of calculated growth rates were taken primarily from the same type of gear (pound nets) during approximately the same months of the collecting years. The data on length at capture and the calculated length at the end of each year of life are presented in Tables 22 to 29. The grand averages of lengths and increments in length are given at the bottom of each table.

Collections of 1950. The principal sample areas of the 1950 collections were located in Big Bay de Noc and at Gull Island and High Island. All data are from specimens which made up the commercial catches from pound nets. A comparison of the Gull Island (Table 23) and High Island (Table 24) samples indicates very similar calculated growth rates, especially among the age groups that are well represented. Age-groups I and II are represented in the High Island collection due to special effort to collect these small individuals by means of a hand net. They were not restrained by the gear and the 18 individuals represent only a partial success of capture of individuals of this size that were actually schooling with the larger fish. Calculated lengths of these age groups (I,II) exhibit values higher than those of the first two years of life calculated from the older fish in the samples. If the I and II (Table 24) are removed from the sample, the annual increment in lengths for the first and second year become very nearly the same as those calculated for the Gull Island collections (Table 23). A comparison of the values obtained for the calculated total lengths, based on age-groups III through VIII, show close agreement of High Island and Gull Island collections. Growth of the whitefish is rapid during the first year and the length increment added during the second year is more than half that of the first year. The increment of length during the third, fourth, and fifth years continues to decrease but at a much slower rate. The higher age groups are represented by fewer individuals and the calculated lengths and observed lengths show considerable fluctuation. The grand average calculated lengths at the end of each year of life are plotted in Figure 6 for the High Island, Gull Island, and Big Bay de Noc samples of whitefish.

Data pertaining to the calculated lengths of the Big Bay de Noc samples are presented in Table 25. The calculated lengths for each year of life through 8 years are slightly higher than those of whitefish from Gull Island and clearly higher than those from High Island. The age groups above VIII can not be accurately compared.because of the small number of individuals representing the sample. The advantage of the Big Bay de Noc whitefish over the Gull Island specimens increases from 0.7 inches at the end of the first year of life to 1.3 inches at the end of the eighth. The advantage

Table 22.-Average length at capture of the whitefish collected in Lake Michigan and the average calculated lengths and increments attained by the age groups at the end of each year of life

(St. Helena Island sample of August 12, 1950. The sexes are combined)

Age group	Number of fish	Standard length (millimeters)	Total length (inches)	Calculated total length (millimeters) at end of year						
				1	2	3	4	5	6	7
III	26	372	17.7	153	268	396				
IV	12	422	20.0	171	268	376	470			
V	4	451	21.4	145	256	366	457	516		
VII	1	510	24.2	185	265	380	450	505	555	600
III-VII	43	-	-	158	267	387	466	514	555	600
Annual increment in length				158	109	120	79	48	41	45
Average total length (inches)				6.2	10.5	15.2	18.3	20.2	21.9	23.6
Annual increment (inches)				6.2	4.3	4.7	3.1	1.9	1.7	1.7

Table 23.—Average length at capture of the whitefish collected in Lake Michigan and the average calculated lengths and increments attained by the age groups at the end of each year of life

(Gull Island samples of August, 1950. The sexes are combined)

Age group	Number of fish	Standard length (millimeters)	Total length (inches)	Calculated total length (millimeters) at end of year										
				1	2	3	4	5	6	7	8	9	10	11
III	18	361	17.2	154	253	387								
IV	21	383	18.2	131	221	313	424							
V	86	436	20.7	122	210	303	399	492						
VI	78	465	22.0	120	206	299	395	472	534					
VII	29	460	21.7	116	192	277	368	444	492	532				
VIII	22	453	21.5	124	199	267	349	411	464	500	531			
IX	12	508	24.0	131	212	290	375	452	503	540	571	595		
X	1	536	25.0	150	275	390	450	505	545	570	590	615	625	
XI	1	630	29.5	135	225	300	400	495	585	630	665	700	720	740
III–XI	268	-	-	124	210	302	391	469	513	525	550	604	673	740
Annual increment in length				124	86	92	89	78	44	12	25	54	69	67
Average total length (inches)				4.9	8.3	11.9	15.4	18.5	20.2	20.7	21.7	23.8	26.5	29.1
Annual increment (inches)				4.9	3.4	3.6	3.5	3.1	1.7	.5	1.0	2.1	2.7	2.6

Table 24. Average length at capture of the whitefish collected in Lake Michigan and the average calculated lengths and increments attained by the age groups at the end of each year of life

(High Island samples of August, 1950. The sexes are combined)

Age group	Number of fish	Standard length (millimeters)	Total length (inches)	Calculated total length (millimeters) at end of year														
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
I	6	210	10.0	203														
II	12	274	13.1	152	284													
III	22	345	16.4	133	234	367												
IV	23	390	18.6	138	230	325	431											
V	34	424	20.1	120	204	293	389	481										
VI	45	458	21.7	120	206	300	392	467	526									
VII	17	463	21.9	118	200	283	377	440	495	536								
VIII	11	443	21.0	125	194	270	345	407	455	455	516							
IX	2	475	22.4	110	181	245	320	388	440	485	525	558						
X	1	493	23.4	105	195	280	375	455	515	550	565	580	590					
XV	1	634	29.6	120	130	265	370	445	500	565	605	640	565	690	705	720	735	745
I–XV	174	-	-	123	216	307	391	461	506	517	526	584	628	690	705	720	735	745
Annual increment in length				129	87	91	84	70	45	11	9	58	44	62	15	15	15	10
Average total length (inches)				5.1	8.5	12.1	15.4	18.1	19.9	20.4	20.7	23.0	24.7	27.2	27.8	28.3	28.9	29.3
Annual increment (inches)				5.1	3.4	3.6	3.3	2.7	1.8	.5	.3	2.3	1.7	2.5	.6	.5	.6	.4

of the Big Bay de Noc whitefish over the High Island specimens increased from 0.7 inches at the end of the first year to 2.3 inches at the end of the eighth year. The intermediate position of the Gull Island whitefish is also reflected in the length-weight relationship (Figure 10).

Data pertaining to calculated lengths of St. Helena Island whitefish are presented in Table 22. Age-group III forms over 50 percent of the sample. In general, the calculated total lengths exceed those of the Big Bay de Noc fish. With the exception of the first year, calculated values of total length for each year of life of the III group very closely approach the values determined for the Big Bay de Noc whitefish. The close agreement of these two age groups from such widely separated localities (Figure 1) is discussed further in the section pertaining to statistical analyses of measurements.

Collections of 1949. Big Bay de Noc samples of October 6-14 are combined in Table 26. The calculated total lengths for the combined age groups very closely approximates those of the 1950 collections of the same locality (Figure 6). However, only general conclusions can be made because of the pronounced differences in age group composition of the samples of the two consecutive years. The 1949 samples are heavily influenced by the dominant year class of 1943. In the 1950 collections the year classes of 1946 and 1947 dominate; a reduced effect of the 1943 year class is maintained by the VIII

Table 25. Average length at capture of the whitefish collected in Lake Michigan and the average calculated lengths and increments attained by the age groups at the end of each year of life

(Big Bay de Noc samples of September, 1950. The sexes are combined)

Age group	Number of fish	Standard length (millimeters)	Total length (inches)	Calculated total length (millimeters) at end of year											
				1	2	3	4	5	6	7	8	9	10	11	12
II	2	309	14.9	168	318										
III	124	377	18.0	145	266	394									
IV	60	418	19.9	143	239	350	455								
V	9	449	21.3	129	227	324	419	503							
VII	74	497	23.4	131	238	339	428	487	532	570					
VIII	9	500	23.6	152	246	327	408	468	511	544	580				
IX	1	530	25.0	175	350	450	490	530	570	585	610	625			
XII	1	540	25.6	160	330	405	490	530	560	580	595	610	625	645	651
II-XII	280	-	-	141	252	366	438	488	531	568	584	618	625	645	651
Annual increment in length				141	111	114	72	50	43	37	16	34	7	20	6
Average total length (inches)				5.6	9.9	14.4	17.2	19.2	20.9	22.4	23.0	24.3	24.6	25.4	25.6
Annual increment (inches)				5.6	4.3	4.5	2.8	2.0	1.7	1.5	.6	1.3	.3	.8	.2

Table 26. Average length at capture of the whitefish collected in Big Bay de Noc during October, 1949, and the average calculated lengths and increments attained by the age groups at each year of life

Age group	Number of fish	Standard length (millimeters)	Total length (inches)	Weight (pounds)	Sex	Calculated total length (millimeters) at end of year 1	2	3	4	5	6	7	8	9	10	11	12
II	8	312	15.1	1.07	M	152	290										
III	35	370	17.7	1.80	M	147	253	374									
	2	401	19.0	2.40	F	175	315	421									
	37	372	17.8	1.83		149	256	377									
IV	19	423	20.2	2.76	M	128	247	355	452								
	9	431	20.4	3.21	F	135	256	365	465								
	28	425	20.2	2.90		130	250	358	456								
V	1	456	21.5	3.63	F	133	245	345	431	512							
VI	75	470	22.3	3.95	M	129	242	343	422	485	527						
	66	473	22.4	4.40	F	134	250	351	443	498	539						
	141	471	22.3	4.17		131	246	347	432	491	533						
VII	1	490	23.0	5.50	F	146	301	354	413	469	515	551					
VIII	2	550	25.9	7.60	F	206	362	473	545	581	608	630	644				
XII	2	595	28.2	9.50	F	179	332	460	515	556	600	628	647	664	681	694	705
V-XII	147	-	-	-		133	249	350	435	493	535	613	646	664	681	694	705
V-XII	Annual increment in length					133	116	101	85	58	42	78	33	18	17	13	11
II-XII	220					136	252	356	438	493	535	613	646	664	681	694	705
II-XII	Annual increment in length					136	116	104	82	55	42	78	33	18	17	13	11
II-XII	Average total length (inches)					5.4	9.9	14.0	17.2	19.4	21.0	24.1	25.4	26.1	26.8	27.3	27.8
Annual increment (inches)						5.4	4.5	4.1	3.2	2.2	1.6	3.1	1.3	.7	.7	.5	.5

group. Conditions favoring such a comparison of these two collections are the similarity of gear and seasons of collecting. Fish were taken in both years from the same type of gear (pound nets), operated by the same commercial fishermen, and set very nearly in the same locality. The collections of the first year were made October 6-14 and those of the second year were made September 12-16.

The Big Bay de Noc collections of 1949 (Table 26) permit analysis of several age groups on the basis of calculated lengths, observed lengths, and observed weights of the sexes. Age-group III is made up largely of males, IV group shows increased representation by females, and in the VI group very favorable comparison of males and females (141 fish) may be made. The best represented age groups (IV and VI) indicate that the females are slightly longer than the males of the same age group (0.1 to 0.2 inches). The observed weights of the females are distinctly higher than those of the males. All VI group fish were sexually mature and females of this age group averaged 0.45 pounds above weights of the males. Since samples were taken in early October, these fish showed increased development of the gonads. Unfortunately, the scarcity of individuals belonging to age-group V does not permit study of their sexual maturity. Most of the males and females (percentage undetermined) of IV group exhibited advanced development of gonads but no collections are available immediately following the spawning to verify actual conditions of these organs. However, individuals of this age group (IV), for all practical purposes, had completed their fifth year of growth. Van Oosten (1939) states that in the Lake Huron whitefish the males were sexually mature or reached sexual maturity in the fifth year of life at a total length of 19.3 inches and a weight of 2.4 pounds. The length-weight values of Big Bay de Noc fish agree very favorably with these values. Age-group IV males (Table 26), nearing completion of their fifth year of growth at this time, exhibit a total length of 20.2 inches and a weight of 2.76 pounds. All VI group fish (Table 26) were sexually mature. The females show an advantage in total length of only 0.1 inch over males, but are 0.45 pounds heavier. The calculated total lengths at the end of each year of life are in close agreement; however, the females exhibit values at each year slightly above those determined for the males.

The Pt. Aux Barques collection of September 7, 1949, (Table 27) and the Garden Island sample of October 28, 1949, (Table 28) are relatively small samples and permit only a generalized comparison with the Big Bay de Noc samples (Table 26). In general, both samples exhibit calculated lengths and increments of growth very closely related to the Big Bay de Noc fish; however, age group composition varies widely between the samples and such conclusions should be regarded with caution.

The South Fox Island collection (Table 29) is the only gill net sample used in this study. Since it has been shown by many fishery bioligists that gill nets are extremely selective (see Hile, 1936, for review of literature), calculated values of total length and growth increments are entered here only for purposes of general information (Figure 6). The table of length-frequency distribution arranged according to age (Table 16) exhibits extensive overlapping of the lengths of fishes belonging to different age groups.

Table 27.-Average length at capture of the whitefish collected in Lake Michigan and the average calculated lengths and increments attained by the age groups at the end of each year of life

(Pt. Aux Barques sample of September 7, 1949. The sexes are combined)

Age group	Number of fish	Standard length (millimeters)	Total length (inches)	Calculated total length (millimeters) at end of year							
				1	2	3	4	5	6	7	8
III	5	375	17.8	137	267	386					
IV	8	435	20.5	124	250	368	462				
V	16	469	22.0	124	229	341	449	513			
VI	7	500	23.3	125	252	369	468	522	563		
VII	1	505	23.9	120	195	296	370	465	521	570	
VIII	2	546	25.6	146	316	425	498	545	580	607	632
III-VIII	39	-	-	127	246	360	452	516	562	595	632
Annual increment in length				127	119	114	92	64	46	33	37
Average total length (inches)				5.0	9.7	14.2	17.8	20.3	22.1	23.4	24.9
Annual increment (inches)				5.0	4.7	4.5	3.6	2.5	1.8	1.3	1.5

Table 28.-Average length at capture of the whitefish collected in Lake Michigan and the average calculated lengths and increments attained by the age groups at the end of each year of life

(Garden Island sample of October 28, 1949. The sexes are combined)

Age group	Number of fish	Standard length (millimeters)	Total length (inches)	Calculated total length (millimeters) at end of year 1	2	3	4	5	6
III	5	408	19.4	151	271	402			
IV	10	429	20.3	145	253	355	451		
V	8	448	21.2	143	238	339	421	490	
VI	2	500	23.7	165	271	383	423	512	558
III-VI	25	-	-	147	253	362	436	494	558
Annual increment in length				147	106	109	74	58	64
Average total length (inches)				5.8	10.0	14.3	17.2	19.4	22.0
Annual increment (inches)				5.8	4.2	4.3	2.9	2.2	2.6

Table 29. Average length at capture of the whitefish collected in Lake Michigan and the average calculated lengths and increments attained by the age groups at the end of each year of life

(South Fox Island sample of October 28, 1949. The sexes are combined)

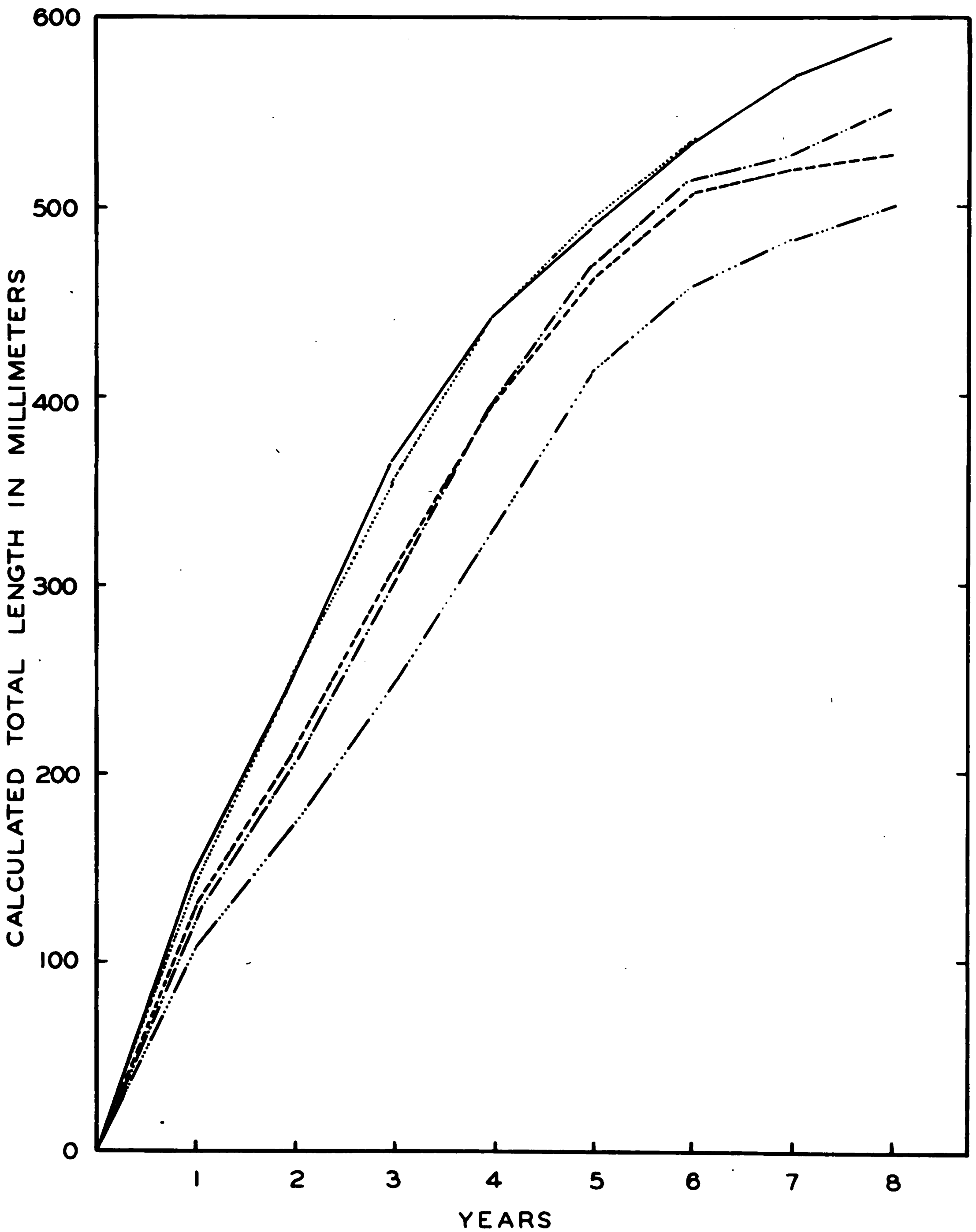
Age group	Number of fish	Standard length (millimeters)	Total length (inches)	Calculated total length (millimeters) at end of year										
				1	2	3	4	5	6	7	8	9	10	11
IV	1	432	20.7	107	191	315	435							
V	5	451	21.4	104	194	308	407	487						
VI	22	419	20.0	104	179	266	361	428	473					
VII	39	432	20.5	110	176	247	330	416	461	495				
VIII	16	432	20.6	109	177	242	315	385	442	476	502			
IX	1	414	19.7	100	170	246	317	383	425	456	475	490		
X	1	440	20.9	94	140	207	290	370	430	465	485	505	520	
XI	1	491	23.2	112	160	212	285	380	435	480	515	535	555	570
IV-XI	86	-	-	108	178	254	340	416	459	488	500	510	538	570
VI-XI	80	-	-	108	176	250	334	412	459	488	500	510	538	570
VI-XI Annual increment in length				108	68	74	84	78	47	29	12	10	28	32
VI-XI Average total length (inches)				4.3	6.9	9.8	13.1	16.2	18.1	19.2	19.7	21.1	21.2	22.4
Annual increment (inches)				4.3	2.6	2.9	3.3	3.1	1.9	1.1	.5	.4	1.1	1.2

Figure 6. Calculated growth in length of the whitefish in northern Lake Michigan based on total samples for the areas and years indicated. The sexes are combined.

Big Bay de Noc, _____ (1950); Big Bay de Noc, ... (1949);

High Island, ----- (1950); Gull Island, __ .. __ (1950);

South Fox Island, ___ .... (1949).


600
500
400
300
200
100
0
CALCULATED TOTAL LENGTH IN MILLIMETERS
1
2
3
4
5
6
7
8
YEARS

LENGTH-WEIGHT RELATIONSHIP

The data for this relationship are analyzed on the basis of combined collections from three principal sample areas: Big Bay de Noc, Gull Island, and High Island. All fish were taken from pound nets in August and September, 1950, with the exception of the Big Bay de Noc collections of September, 1949. Length-weight relationships were obtained from 254 fish taken off Gull Island, 174 fish taken off High Island, and 848 fish from Big Bay de Noc. The sexes are combined. The individuals were placed in 10 millimeter length groups and average lengths and weights obtained for each group.

The length-weight data of the northern Lake Michigan whitefish are fitted to the following formulae:

$$W = c\,(L)^n$$

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

The values of log c and n are determined empirically. Regression lines are calculated for the three sample areas by methods presented by Snedecor (Sec. 6.10, 1946).

Big Bay de Noc. The formula expressing the length-weight relationship was calculated from the means of 18 size groups (each containing 10 or more fish) between 340 and 519 millimeters in standard length. These means are based on measurements from 848 fish. The values for these and the regression line calculated from them are plotted in Figure 7. Open circles indicate those groups represented by less than 10 individuals. The correspondence of the better represented groups to a straight line is very close. The length-weight relationship for the Big Bay de Noc whitefish of the 1949 collections may be expressed by the formula:

$$\log W = -8.4271 + 3.2544 \ (\log L)$$

where W = weight in kilograms

and L = standard length in millimeters.

Figures 8, 10, and 12 are presented for the principal sample areas to permit rapid conversion between the metric and English systems of measurement. Factors used for converting standard length in millimeters to total lengths in inches are presented in Tables 30 and 31. The values obtained for the Big Bay de Noc whitefish are slightly higher than those given for the Lake Huron whitefish (Van Oosten, 1939) and the Lake Erie whitefish (Van Oosten and Hile, 1947). Factors for the conversion of total lengths in inches to standard lengths in millimeters and for conversions between total and standard

Table 30.-Factors for conversions between standard length (millimeters) and total length (inches) of the northern Lake Michigan whitefish

Standard length interval (millimeters)	Standard length (millimeters) to total length (inches)					
	Number of fish	St. Helena Island 1950	Number of fish	High Island 1950	Number of fish	Gull Island 1950
0 - 349	1	0.04748	35	0.04780	5	0.04756
350 - 449	38	0.04747	89	0.04750	137	0.04754
450 - 499	3	0.04761	39	0.04724	98	0.04726
>499	1	0.04739	11	0.04707	28	0.04699

Table 31.--Factors for conversions between standard length (millimeters) and total length (inches) of Big Bay de Noc whitefish

Standard length interval (millimeters)	Standard length (millimeters) to total length (inches)			
	Number of fish	Big Bay de Noc 1949	Number of fish	Big Bay de Noc 1950
0 - 349	11	0.04831	3	0.04848
350 - 449	75	0.04771	185	0.04767
450 - 499	121	0.04729	51	0.04726
>499	13	0.04710	41	0.04712

Figure 7. Length-weight relationship of Big Bay de Noc whitefish taken in September, 1949.

The regression line was calculated from the size groups containing 10 or more fish (represented by black dots). Size groups containing less than 10 fish are shown by circles.

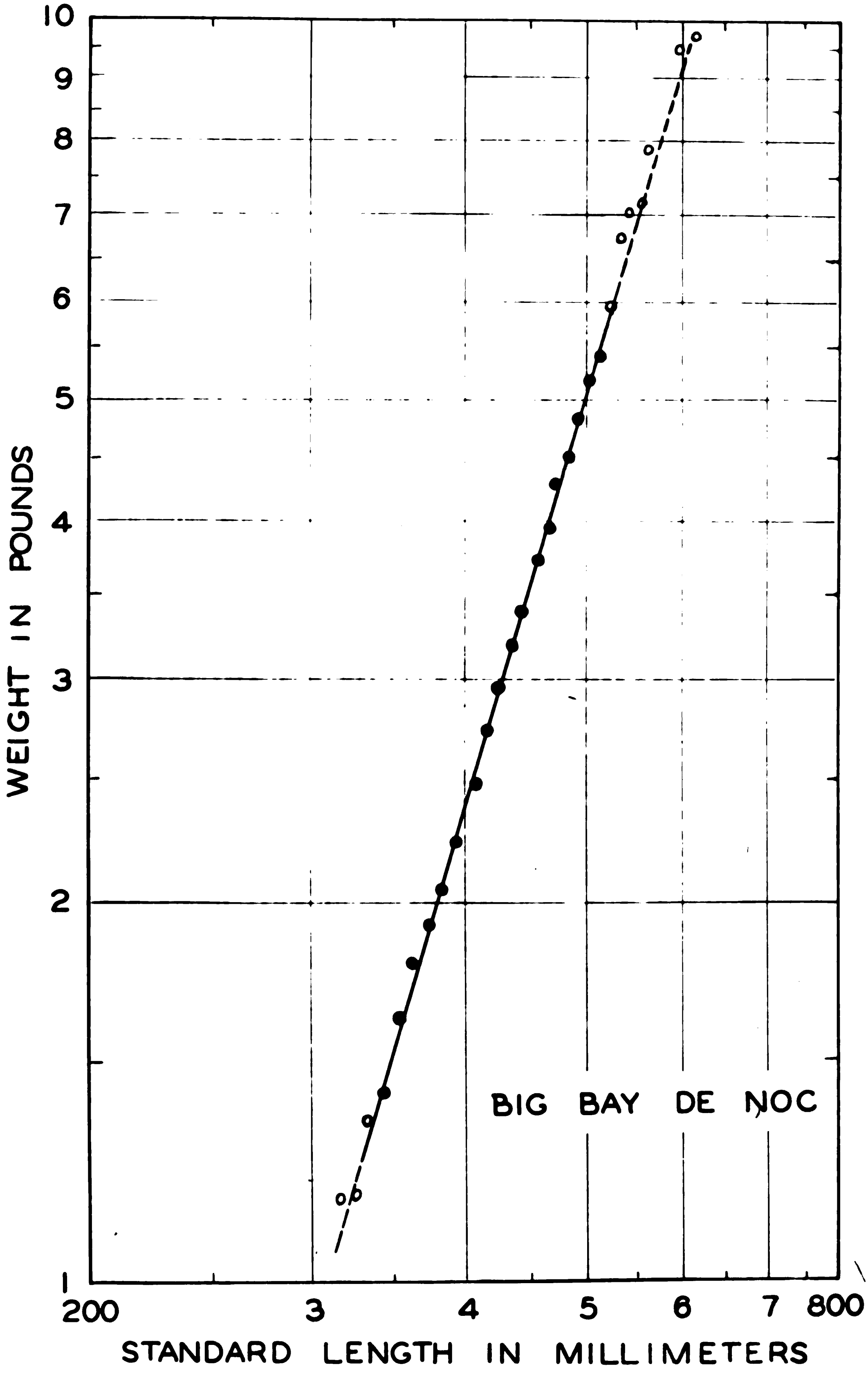
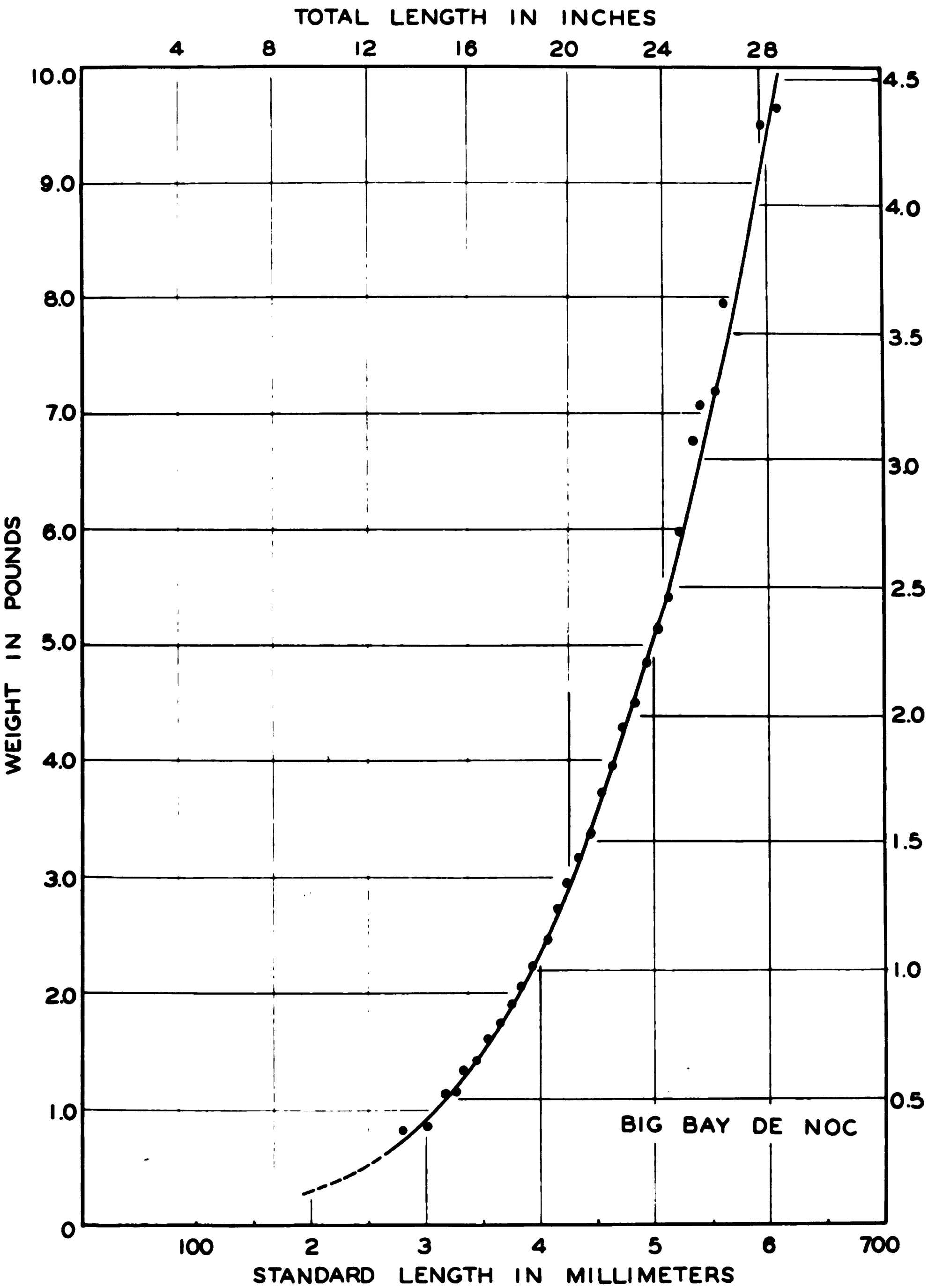

WEIGHT IN POUNDS
10
9
8
7
6
5
4
3
2
1
200
3
4
5
6
7
800
STANDARD LENGTH IN MILLIMETERS
BIG BAY DE NOC

Figure 8. Length-weight relationship of Big Bay de Noc whitefish.


TOTAL LENGTH IN INCHES
4
8
12
16
20
24
28
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
WEIGHT IN POUNDS
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
WEIGHT IN KILOGRAMS
BIG BAY DE NOC
100
2
3
4
5
6
700
STANDARD LENGTH IN MILLIMETERS

length without change in the unit of measurement are computed for several samples but are not included in this paper. However, preliminary results indicate that the values agree very closely with those of the above authors.

Gull Island. The formula expressing the length-weight relationship was calculated from the means of 17 size groups (each containing 5 or more fish) between 350 and 529 millimeters in standard length. The means are based on measurements from 254 fish. The values of these are plotted in Figure 9 along with the regression line calculated from them.

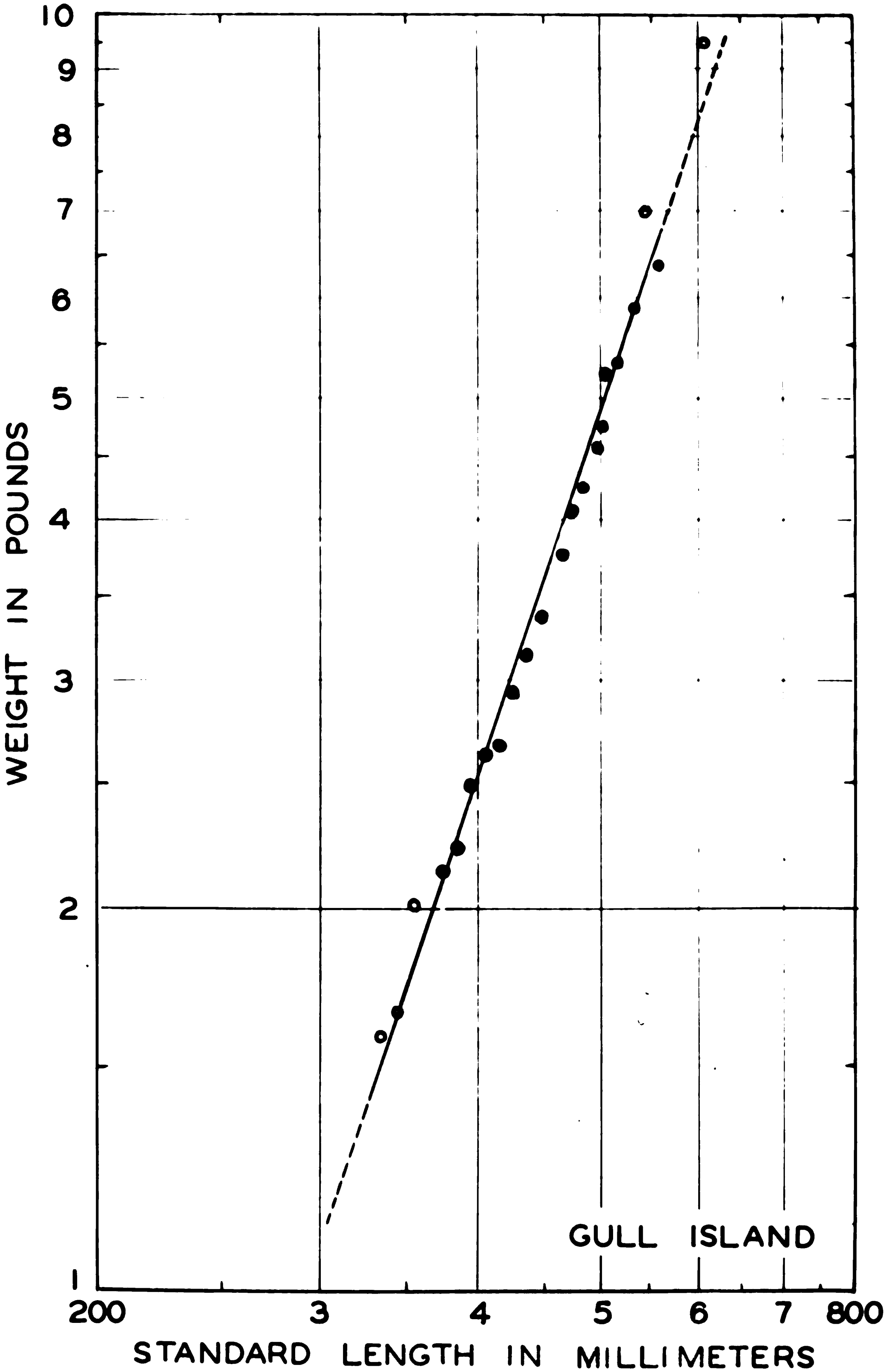
The length weight relationship for the Gull Island whitefish of the 1950 collections may be expressed by the formula:

$$\log W = -7.7239 + 2.9886 \ (\log L)$$

where W = length in kilograms

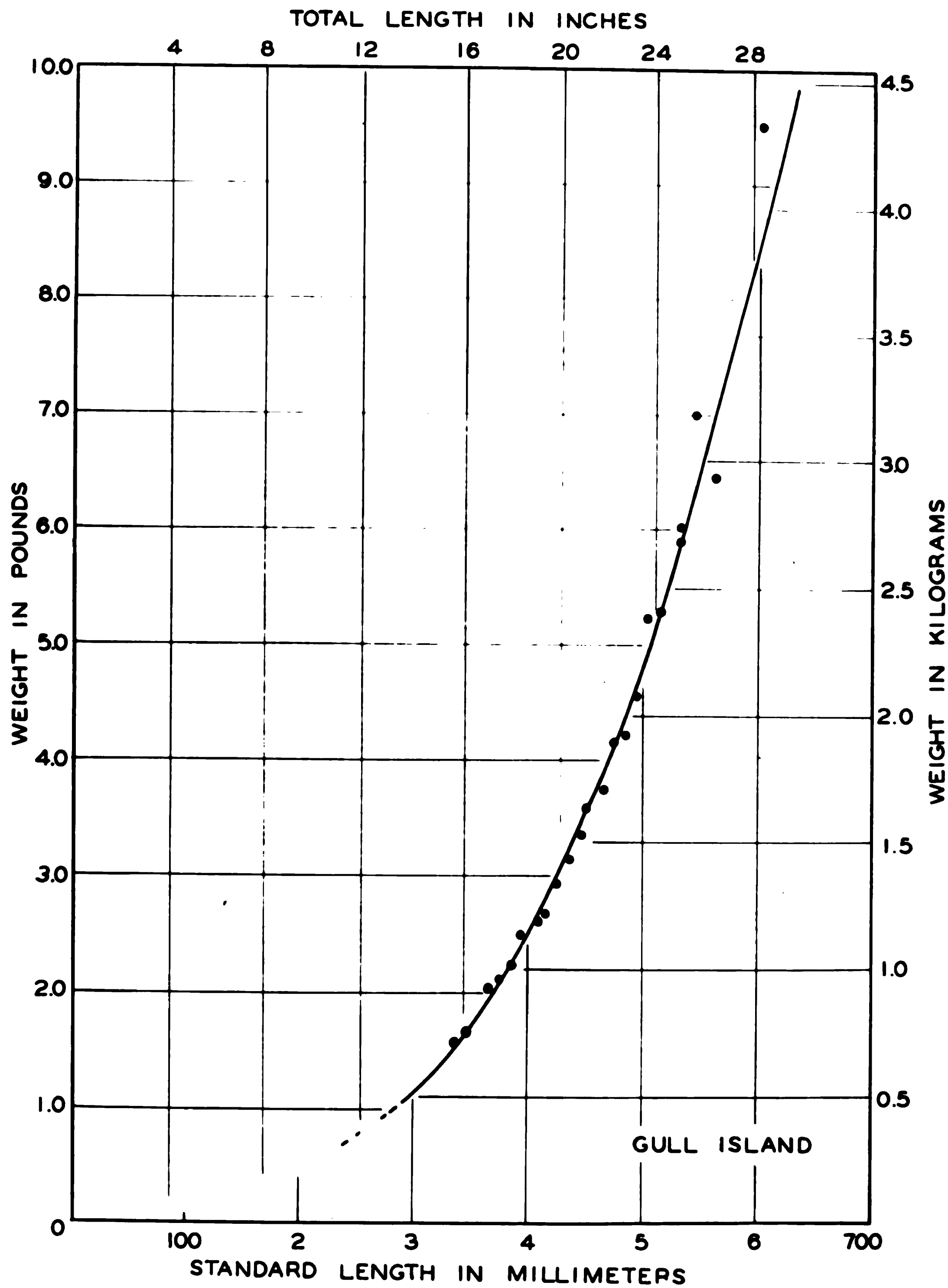
and L = standard length in millimeters.

Figure 9. Length-weight relationship of Gull Island whitefish.



WEIGHT IN POUNDS
10
9
8
7
6
5
4
3
2
1
200
3
4
5
6
7
800
STANDARD LENGTH IN MILLIMETERS
GULL ISLAND

Figure 10. Length-weight relationship of Gull Island whitefish.



TOTAL LENGTH IN INCHES
4
8
12
16
20
24
28
WEIGHT IN POUNDS
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
WEIGHT IN KILOGRAMS
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
GULL ISLAND
100
2
3
4
5
6
700
STANDARD LENGTH IN MILLIMETERS

High Island. The formula expressing the length-weight relationship was calculated from the means of 14 size groups (each containing 5 or more fish) between 370 and 509 millimeters in standard length. These means are based on measurements from 174 fish. The values for these and the regression line calculated from them are plotted in Figure 11.

The length-weight relationship for the High Island whitefish of the 1950 collections may be expressed by the formula:

$$\log W = -7.2567 + 2.8166 (\log L)$$

where W = weight in kilograms

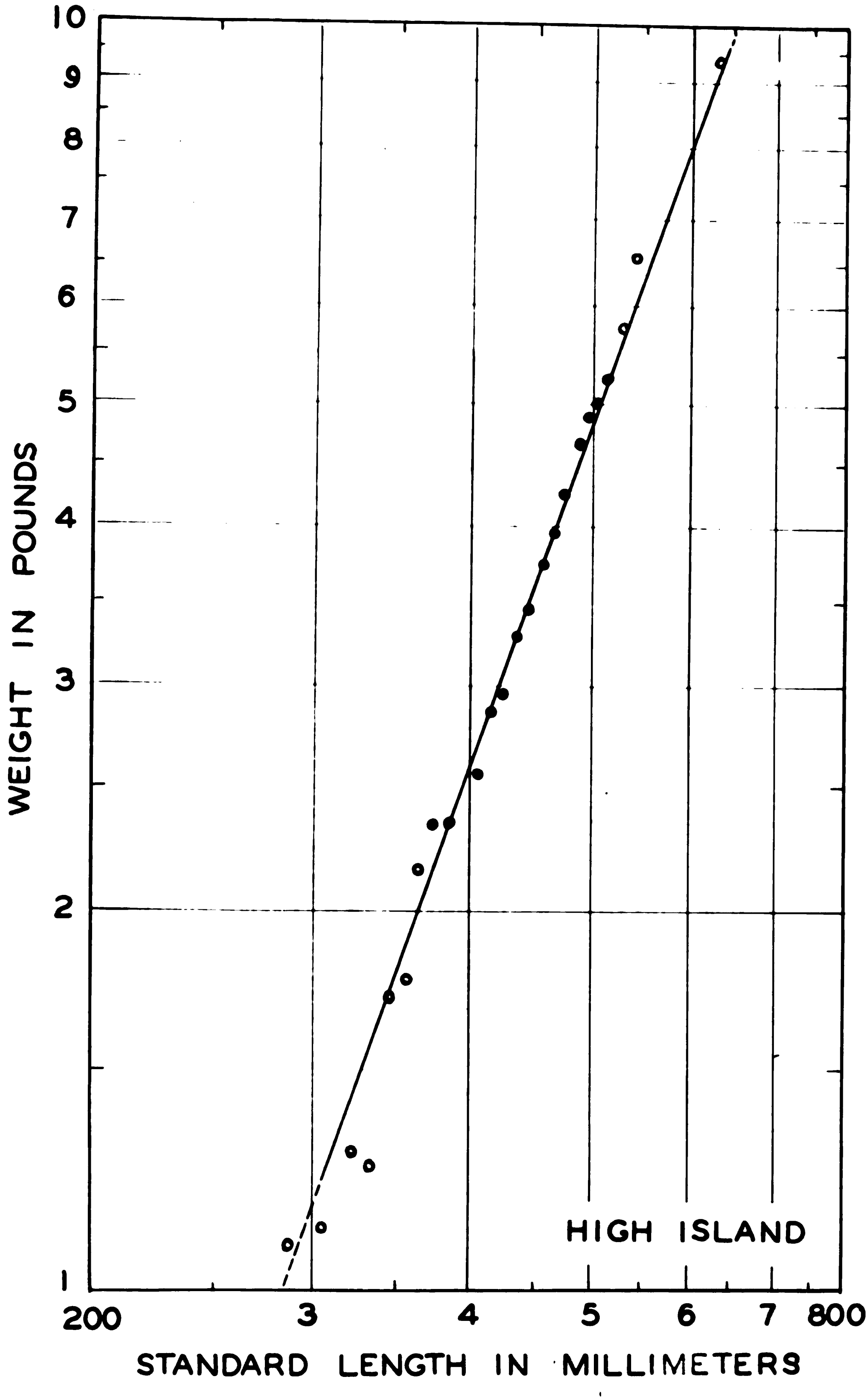
and L = standard length in millimeters.

An inspection of the formulae expressing the regression line for length-weight relationship of fish from the three principal sample areas indicates a distinct advantage of the Big Bay de Noc whitefish over fish from Gull and High Islands, especially at the higher lengths. The length-weight relationship of fish from Gull Island show a very slight advantage over those taken off High Island.

The weights of the northern Lake Michigan whitefish increased to the following power of the lengths: Big Bay de Noc, 3.2544; Gull Island, 2.9886; High Island, 2.8166.

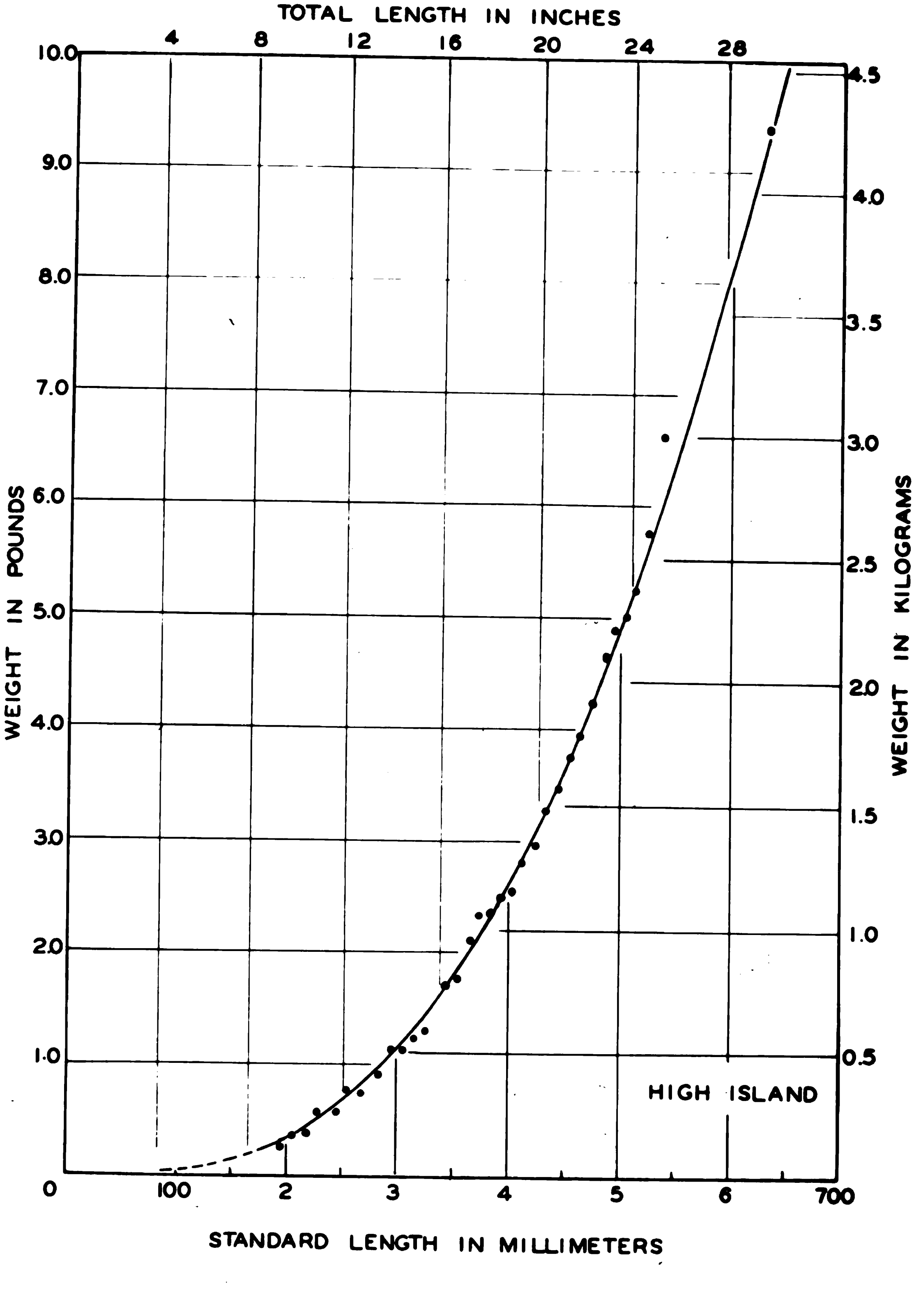
Comparative growth curves of fish from these three sample areas, based on average calculated lengths at the end of each year of life (Figure 6), exhibit a very similar relationship.

Figure 11. Length-weight relationship of High Island whitefish.



WEIGHT IN POUNDS
10
9
8
7
6
5
4
3
2
1
200
3
4
5
6
7
800
STANDARD LENGTH IN MILLIMETERS
HIGH ISLAND

Figure 12. Length-weight relationship of High Island whitefish.



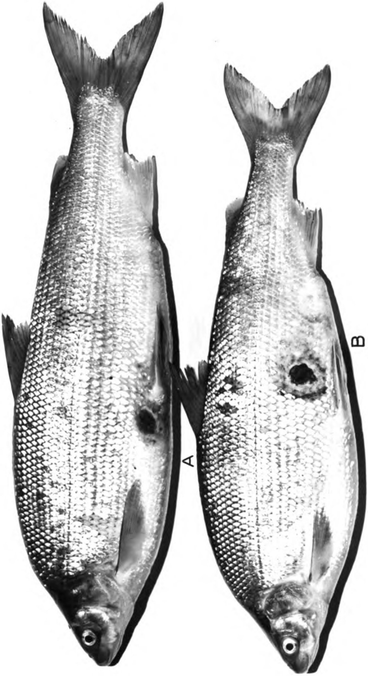
TOTAL LENGTH IN INCHES
4
8
12
16
20
24
28
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
WEIGHT IN POUNDS
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
WEIGHT IN KILOGRAMS
HIGH ISLAND
100
2
3
4
5
6
700
STANDARD LENGTH IN MILLIMETERS

PARASITIZATION BY LAMPREY

The total collections of 1950 were examined for evidence of scars suspected to be caused by lampreys (especially the sea lamprey, Petromyzon marinus). For purposes of this study deeply injured areas (Figure 13, A,B) were regarded to be the result of very recent parasitization by the sea lamprey. In some instances the lampreys were observed attached to the fish during the lifting of the nets and, on rare occasions, remained attached after the fish were removed from the nets. These observations were made of fish making up the actual commercial catch. It is beyond the scope of this paper to estimate the population density of either parasite or host, or to indicate degree of error in recording incidence due to death and nonrecovery of severely affected fish. Results of observations are presented due to current interest in possible effect of this form on the Great Lakes fishery.

Data relative to observations of scars shown by individual fish making up catches of three principal sample areas are presented in Tables 32 to 34. "New" (fresh) scars were designated as deep bloody injuries, piercing the skin and causing injury to the muscle tissue (Figure 13, A). A further aid in identification and classification of these damaged areas was the common occurrence of "teeth" markings at the periphery

Figure 13. Two whitefish taken off Round Island, Big Bay de Noc, October 12, 1949, showing typical lamprey scars.


A
B

of the scar (Figure 13,B) caused by the horny circum-oral teeth of the lamprey as compared to an injury caused by mechanical means. "Old" (healed) scars were designated as injured areas, devoid of scales, that indicated recovery from previous injury by growth of scar tissue. Deformities or tears in the skin that obviously were the results of mechanical injuries were not recorded.

The total fish observed and the number of fish exhibiting old scars and new scars, by number and percentage of total, are presented in Tables 32 to 34 for each collecting area. As a further interest the injured fish were arranged on the basis of age groups. The available data are considered insufficient to permit a concise comparison of incidence of infection to relative abundance of the age groups. Such inferences must be approached with caution. However, age composition of these samples on a percentage basis are presented in Tables 18, 19, and 21. A comparison of the number of individuals in each age group exhibiting new scars follows very closely the rank order of the age groups dominating the catch, with the exception of the younger age groups (I, II, III). In addition, samples from Big Bay de Noc for two successive years indicate that scars recorded as healed scars in 1950 collections (Table 34) exhibit their highest frequency in age-group

Table 32.-Gull Island whitefish exhibiting scars; arranged according to age groups

TYPE OF SCAR	AGE						TOTAL NUMBER OF EFFECTED FISH	NUMBER OF FISH EXAMINED	PERCENTAGE OF TOTAL
	IV	V	VI	VII	VIII	IX			
NEW	0	8	3	4	1	0	16	278	5.75
OLD	0	1	1	3	0	1	6	278	2.16
COMBINED	0	9	4	7	1	1	22	278	7.91

Table 33.-High Island whitefish exhibiting scars; arranged according to age groups

TYPE OF SCAR	AGE IV	V	VI	VII	VIII	IX	XV	TOTAL NUMBER OF EFFECTED FISH	NUMBER OF FISH EXAMINED	PERCENTAGE OF TOTAL
NEW	0	1	3	2	1	0	0	7	144	4.86
OLD	1	1	3	0	0	1	1	7	144	4.86
COMBINED	1	2	6	2	1	1	1	14	144	9.72

Table 34.-Big Bay de Noc whitefish exhibiting scars; arranged according to age groups

TYPE OF SCAR	AGE IV	V	VI	VII	VIII	IX	XII	TOTAL NUMBER OF EFFECTED FISH	NUMBER OF FISH EXAMINED	PERCENTAGE OF TOTAL
NEW	4	0	0	7	0	0	1	12	262	4.58
OLD	1	0	0	5	0	0	0	6	262	2.29
COMBINED	5	0	0	12	0	0	1	18	262	6.87

VII (1943 year class) which had been the dominant year class in that area for the two previous years.

The younger age groups (I,II, and III), forming their respective part of the samples presented in Tables 32 to 34 and examined at the same time, consisted of a total of 178 fish which did not exhibit scars of any type. Of a total of 94 fish belonging to age-group IV (1946), only 4 fish exhibited fresh scars and 2 fish showed healed scars. These data suggest that comparative enumerations of incidence of lamprey (?) damage upon fish from different collecting localities may be biased by age composition of the respective samples. Especially, this may be true among those samples in which the age groups III and IV dominate the commercial catches. Royce (1949) shows that the larger lake trout in Seneca Lake, N. Y., suffered more attacks and were more vulnerable to attack by lamprey. However, his data are not correlated with age, but are correlated with length and weight of the fish parasitized.

The points of occurrence of the damaged areas were recorded in each case. Seventy-five percent of the scars occurred very near the origin or insertion of the ventral fins as shown in Figure 13,A. Infrequently scars appeared on the side of the body or on the ventral surface. Only on rare occurrences were scars recorded from the dorsal region.

ANALYSES OF MORPHOMETRIC MEASUREMENTS

Body proportion measurements, as designated in Figure 2, were taken of the 1950 collections. Summaries of six of these measurements, based on age groups of the fish examined, are presented. Studies of the remaining measurements by means of analysis of variance and regression are to be presented in a separate paper.

Various methods have been suggested and devised as a tool for distinguishing separate populations or stocks of fish, especially marine forms. Dymond (1948) presents an excellent review of the literature pertaining to European investigations of populations. Body proportion measurements, counts of fin-rays, scale counts and other characters such as the number of vertebrae have been used to distinguish populations of fish. Godsil (1948) defines the term "population" as a group of intermingling fish inhabiting a restricted area and constituting a separate and distinct unit, the fish of which may collectively be distinguished and identified by minor morphological characteristics. In his study of the Pacific tunas, an assumption is made that distinct populations do not normally intermingle, with the corollary that differences existing between populations are constant.

Body proportion measurements have been used by many early workers to study the differences between local populations. Results were expressed largely as ratios and general limits were set up without statistical evaluation of these measurements. However, many of the recent investigations exhibit refined use of various statistical methods as a tool for designating local populations or stocks. Carp rearing techniques and the means of defining local populations have been thoroughly investigated by such workers as Eichler (1938), Kühne (1938), and Lechler (1938). Primarily, these authors have used body proportion measurements and based their conclusions upon means and standard deviations of these measurements or ratios for the different populations. Martin (1949) reviews the relative-growth method in the interpretation of the environmental control of body form in fishes. Relative-growth curves are given for some twenty species.

Among the coregonid fish, ratios of various body parts have been used to separate many of the species and subspecies. Koelz (1929, 1931) reviews extensively the coregonid fishes of northeastern America. Several body proportion measurements and ratios of these measurements are set up for the whitefish, Coregonus clupeaformis, by Koelz (1929), but none are treated statistically. Hile (1935, 1937) casts doubt as to the validity of this method for determining subspecies of the lake herring, Leucichthys artedi. His reports do not pertain to the whitefish; however, he reviews some of the recent European works relative to the genus Coregonus.

Recent European investigations concerning coregonid variations have demonstrated conclusively that, under the influence of changed environment, these fish may undergo extensive morphological modifications. Svärdson (1948, 1949) presents results of ecological and speciation studies of the whitefish, Coregonus, in Sweeden. Twenty-two body proportion measurements are utilized. Transplantations from one lake to another indicate that the morphological characteristics of a single population are dependent largely upon the nature of the local environment.

It is one of the purposes of this paper to apply the method of analysis of variance to several body measurements. The fish are compared on the basis of age groups as determined from the scales. Only fish belonging to the same year class (year of hatching) are compared.

AGE GROUP IV (1946 YEAR CLASS)

Summaries of six body proportion measurements of whitefish from several localities are given in Table 35. The values of the locality means and their standard errors and the extremes of individual measurements are listed. Standard errors are computed on the basis of the pooled standard deviation as determined in the analysis of variance.

Body proportion measurements of age-group IV fish are used to illustrate methods used in this study. Methods of testing the significance of two or more means by the analysis of variance as described by Baten (1938) and Snedecor (Chapter 10, 1946) are utilized. Summaries of data pertaining to head lengths (H) of whitefish from six samples are presented in Table 36. Symbols are those used by Snedecor (1946). Similar computations were made for all measurements tested. Although a few age groups in some samples are represented by a relatively small number of fish, these samples were analyzed separately rather than combining all collections for a particular locality.

Table 37 gives the analysis of variance for the head length (H) of age-group IV (1947 year class) whitefish of northern Lake Michigan. To determine whether the results are significantly different we obtain the value of F:

$$F = \frac{\text{Larger variance}}{\text{Smaller variance}} = \frac{2.4852}{0.1789} = 13.89^{**}$$

Table 35.-Morphometric measurements of age-group IV whitefish from northern Lake Michigan

(The fish belong to the 1946 year class. Means, standard errors, and extremes of the measurements are in millimeters)

Locality	Number of fish	SL	H	SL/H	CPL	CPD	CPL/CPD
St. Helena Island	12	421.90±6.59 382-451	83.49±1.22 76.0-89.0	5.056	54.67±1.00 48.5-60.0	34.48±0.67 30.5-38.1	1.588
Gull Island	12	376.48±6.59 346-415	74.00±1.22 68.0-86.0	5.091	49.21±1.00 43.5-55.0	30.47±0.67 27.5-34.0	1.650
High Island	23	389.27±4.76 340-442	78.11±0.88 70.0-87.5	4.982	50.12±0.72 41.5-56.5	31.51±0.48 26.3-35.5	1.595
Big Bay de Noc	10	434.30±7.22 400-468	84.25±1.34 79.0-90.0	5.154	57.45±1.09 55.0-64.5	34.83±0.73 33.0-37.5	1.615
Big Bay de Noc	20	418.95±5.11 383-470	84.45±0.95 80.0-93.0	4.963	53.90±0.77 50.5-58.0	34.68±0.52 31.0-38.0	1.558
Big Bay de Noc	22	410.60±4.87 380-450	82.13±0.90 76.0-88.0	5.003	54.31±0.74 50.0-62.0	33.67±0.49 30.5-38.0	1.650

Table 36.-Summary of data pertaining to head length (H) of age-group IV (1946 year class) Lake Michigan whitefish

	St. Helena Id. August 12, 1950	Gull Island August, 1950	High Island August, 1950	Big Bay de Noc (Burnt Bluff) August 16	September 12	September 16
N	12	12	23	10	20	22
SX	100.19*	88.80	179.68	84.25	168.90	180.70
$\bar{X}$	8.349	7.400	7.811	8.425	8.445	8.213
$S(X)^2$	838.403	659.745	1,409.297	710.423	1,429.175	1,487.460
$(SX)^2$	10,038.036	7,885.440	3,228.902	7,098.063	28,527.210	32,652.490
$(SX)^2/N$	836.503	657.120	1,403.870	709.806	1,426.361	1,484.204
Sx^2	1.900	2.625	5.427	.617	2.814	3.256
$s_{\bar{x}}$	.122	.122	.088	.134	.095	.090

*computations are based on measurements in centimeters

Table 37.-Analysis of variance of head length (H) of age-group IV (1946 year class) northern Lake Michigan whitefish

Source of variation	Degrees of freedom	Sum of squares	Variance	Standard deviation
Total	98	29.065		
Between samples	5	12.426	2.4852**	
Within samples	93	16.639	0.1789	0.4230

**Highly significant

Referring to tables for distribution of F, we find the F value for n_1 = 5 and n_2 = 93 (n_2 = 80 used) degrees of freedom is approximately 2.35 at the 5 percent point and 3.25 at the 1 percent point. Since an F value of 13.89 is obtained, it may be concluded that the difference between at least two of the means of the samples is highly significant, that is, that the chance of obtaining differences as large or larger due to sampling variation alone is less than one in a hundred.

The standard deviation of differences of means and value of "t" are determined by methods described by Baten (p. 273, 1938). Results of "t" tests of these data are presented in Table 38. The conventional terms "significant" and "highly significant" are used to designate differences significant at the 5 percent level (denoted by single asterisk) and the 1 percent level (denoted by double asterisk), respectively, in this paper when stating the statistical significance of differences between means. Any difference beyond the 5 percent level is termed "not significant." For purposes of illustration of methods used, the following example is given.

It may be seen from Table 36 that the mean head-lengths of the St. Helena Island and High Island fish are 8.349 and 7.811, respectively. The pooled standard deviation of all age-group IV is 0.4230 (Table 37) for this measurement. This quantity (s) is obtained by pooling the sums of the squares of items from their respective means. The following method is that used by Baten (1938). The standard errors of the means of the two samples are

$$\text{S.E. } \bar{X}_1 = \frac{s}{\sqrt{12}} = 0.122 \text{ cm.,} \quad \text{S.E. } \bar{X}_2 = \frac{s}{\sqrt{23}} = 0.088 \text{ cm.}$$

The standard error of the difference of the means is

$$\text{S.E. Difference of means} = \sqrt{(\text{S.E.}\bar{X}_1)^2 + (\text{S.E.}\bar{X}_2)^2}$$
$$= 0.150$$

The value of t is

$$t = \frac{\bar{X}_1 - \bar{X}_2 - 0}{\text{S.E. Difference of means}} = \frac{8.349 - 7.811}{0.150} = 3.59^{**}$$

If we consult a table for t-values (Snedecor p.65, 1946) at 33 degrees of freedom (30 used), we find that the t-value at the 5 percent point is 2.042, and at the 1 percent point 2.750. The value of t obtained is larger than the values obtained from the table. This indicates that the difference between the means ($\bar{X}_1 - \bar{X}_2 = 0.538$) differs significantly from zero and that the probability that the two samples were taken at random from the same population is very small; from the t-table this probability

Table 38.-H: values of "t" relating to paired comparisons between samples of age-group IV (1946 year class) whitefish from Lake Michigan

Source of sample	St. Helena Island	Gull Island	High Island	Big Bay de Noc (Burnt Bluff)		
Date (1950)	August 12	August	August	August 16	Sept.12	Sept. 16
Number	12	12	23	10	20	22
St. Helena Island	-					
Gull Island	5.49**	-				
High Island	3.59**	2.74**	-			
Big Bay de Noc	0.04	5.66**	3.84**	-		
Big Bay de Noc	0.06	6.74**	4.76**	0.12	-	
Big Bay de Noc	0.09	5.35**	5.03**	1.32	1.77	-

** Highly significant

is less than 0.01.

In addition, the graphical method of Dice and Leraas (1936) has been used to show relationship of the samples in the head-length measurements (Figure 14). Means are represented by crossbars. Rectangles show twice the standard error each side of the means. Vertical lines represent observed ranges of measurements. A similar arrangement is followed in Figures 15-18. Samples are arranged in the same order, from left to right, as listed in tables of summary of measurements. In general, where rectangles do not overlap, the means differ significantly. This relationship is discussed by Hubbs and Perlmutter (1942). Figure 14 suggests that two samples (Gull Island and High Island) should be tested further. Values of "t" tests for this age group are presented in Table 38. These values indicate that, on basis of head length, the difference between Gull Island and High Island fish are highly significant. Further, that each of these samples differs from the Big Bay de Noc and St. Helena Island fish at the level of high significance. Among the Big Bay de Noc samples there are no significant differences in head length. In addition, the differences between the sample from St. Helena Island and each of the Big Bay de Noc samples are not significant.

Means and standard errors pertaining to additional body measurements are given in Table 35. Preliminary graphic inspection of CPL, CPD, and SL measurements

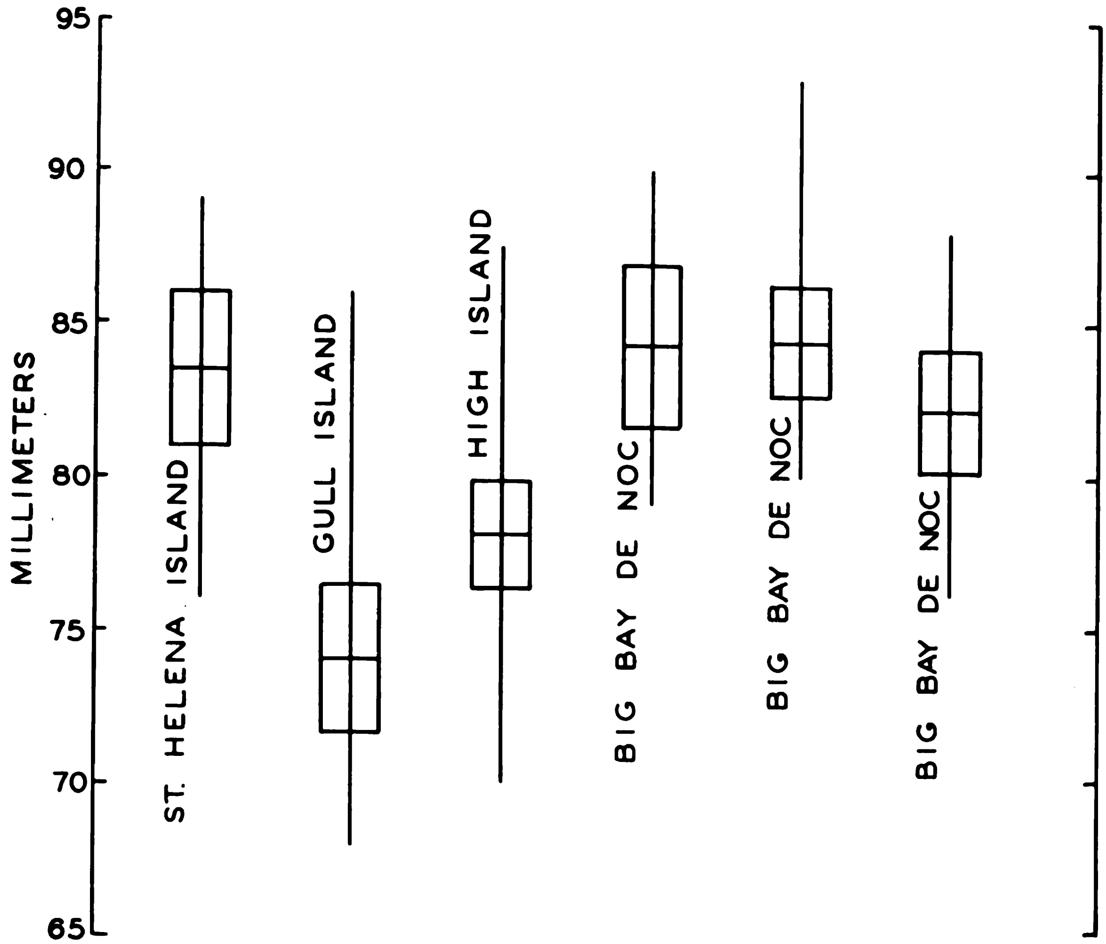


Fig. 14—Variance of head length of whitefish (*Coregonus clupeaformis*) from Lake Michigan. Age group IV, 1946 year class.

indicated a very similar pattern as presented by head measurements. From the method of analysis of variance, the following F values were obtained:

CPL, 10.87**; CPD, 9.38**; SL, 12.11**

Values of "t" for these measurements are presented in Tables 39-41. It may be seen that, with the exception of Gull and High Island samples, the localities show the same relationship in levels of significance for these measurements as displayed by the head lengths.

On the basis of the measurements analyzed, the age-group IV (1946 year class) whitefish from Gull Island and High Island do not differ significantly (except in head measurement) from each other, but exhibit differences between St. Helena Island and Big Bay de Noc that are highly significant. Differences between Big Bay de Noc and St. Helena Island are not significant and differences within Big Bay de Noc are not significant.

Analysis of the ratios SL/H and CPL/CPD exhibit values that indicate differences between the samples are not significant.

Table 39.-CPL: values of "t" relating to paired comparisons between samples of age-group IV (1946 year class) whitefish from Lake Michigan

Source of sample	St. Helena Island	Gull Island	High Island	Big Bay de Noc (Burnt Bluff)		
Date (1950)	August 12	August	August	August 16	Sept.12	Sept.16
Number	12	12	23	10	20	22
St. Helena Island	-					
Gull Island	3.88**	-				
High Island	3.75**	0.75	-			
Big Bay de Noc	1.88	5.59**	5.61**	-		
Big Bay de Noc	0.61	3.73**	3.58**	1.65	-	
Big Bay de Noc	0.29	4.11**	4.17**	2.39*	0.39	-

*Significant
**Highly significant

Table 40.--CPD: values of "t" relating to paired comparisons between samples of age-group IV (1946 year class) whitefish from Lake Michigan

Source of sample	St.Helena Island	Gull Island	High Island	Big Bay de Noc (Burnt Bluff)		
Date (1950)	August 12	August	August	August 16	Sept. 12	Sept. 16
Number	12	12	23	10	20	22
St. Helena Island	-					
Gull Island	4.25**	-				
High Island	3.66**	1.27	-			
Big Bay de Noc	0.36	4.42**	3.80**	-		
Big Bay de Noc	0.24	4.99**	4.50**	0.17	-	
Big Bay de Noc	0.98	3.86**	3.14**	1.32	1.42	-

**Highly significant

Table 41.- SL: values of "t" relating to paired comparisons between samples of age-group IV (1946 year class) whitefish from Lake Michigan

Source of sample	St. Helena Island	Gull Island	High Island	Big Bay de Noc (Burnt Bluff)		
Date (1950)	August 12	August	August	August 16	Sept.12	Sept.16
Number	12	12	23	10	20	22
St. Helena Island	-					
Gull Island	4.87**	-				
High Island	4.06**	1.57	-			
Big Bay de Noc	1.27	5.91**	5.20**	-		
Big Bay de Noc	0.35	5.09**	4.25**	1.73	-	
Big Bay de Noc	1.38	4.16**	3.13**	1.94	1.18	-

**Highly significant

AGE GROUP III (1947 YEAR CLASS)

Morphometric measurements were taken of 115 fish belonging to age-group III. A summary of these measurements is presented in Table 42.

Applying the method of analysis of variance to the several body proportion measurements, in order to test the statistical homogeneity of the 5 samples, the following F values were obtained:

SL	H	SL/H	CPL	CPD	CPL/CPD
19.75**	17.83**	1.69	11.69**	18.12**	1.97

The above F values are to be interpreted with degrees of freedom 4 and 108 (or 110, see Table 42). The corresponding 5 percent and 1 percent F values are about 2.46 and 3.51 respectively. With the exception of the two ratios, SL/H and CPL/CPD, the differences are highly significant.

The differences between means were tested by use of "t" tests. The values obtained for CPL and CPD measurements are shown in Tables 43 and 44. Since a very similar relationship between samples is shown for SL and H measurement, t values are not presented.

Variations in mean length of head among the localities follow much the same pattern as do the age-group IV fish (Figure 14 and 15). However, in contrast to the IV group, the High Island sample exhibits larger head measurement than Gull Island fish, their difference being only significant as compared to highly significant in age IV.

Table 42.—Morphometric measurements of age-group III whitefish from northern Lake Michigan

(The fish belong to the 1947 year class. Means, standard errors, and extremes of the measurements are in millimeters)

Locality	Number of fish	SL	H	SL/H	CPL	CPD	CPL/CPD
St. Helena Island	26	372.07±3.28 [1/] 344–400	74.24±0.67 68.0–79.0	5.015±0.024 4.736–5.273	48.90±0.57 45.50–54.50	30.90±0.37 28.1–35.0	1.584±0.016 1.451–1.700
Gull Island	15	359.36±4.32 334–394	71.84±0.88 66.0–79.0	5.003±0.031 4.859–5.137	46.30±0.75 45.5–52.5	29.13±0.48 26.4–32.5	1.589±0.021 1.455–1.800
High Island	17*	339.47±4.06 308–400	68.89±0.78 62.5–76.0	4.927±0.029 4.719–5.257	44.83±0.68 40.0–52.5	27.60±0.43 23.0–32.5	1.632±0.018 1.466–1.755
Big Bay de Noc	27	383.30±3.22 358–409	77.26±0.66 71.5–83.5	4.964±0.023 4.759–5.288	50.07±0.56 42.0–56.0	31.85±0.36 30.0–34.0	1.573±0.015 1.377–1.723
Big Bay de Noc	28	372.25±3.17 355–409	75.01±0.66 71.0–80.0	4.963±0.023 4.710–5.141	48.98±0.55 45.0–53.0	31.17±0.36 28.5–33.5	1.571±0.015 1.418–1.700

1/ $s_{\bar{x}}$ are computed from pooled standard deviation

* 19 fish are used in H, CPL, CPD, and CPL/CPD measurements

The mean head length in each of the two Big Bay de Noc samples exceeds those of the remaining samples. The difference between samples from Big Bay de Noc and the island samples, Gull and High Island, is highly significant. In general, the St. Helena Island sample agrees closely with the Big Bay de Noc samples and differs significantly from the island samples.

Values of "t" for CPL and CPD measurements are given in Table 43 and 44. Since SL values follow the same pattern, they are omitted. Generally, the following pattern or relationships are shown between the samples when each measurement is considered separately. The Big Bay de Noc samples are clearly larger than the Gull Island and High Island samples and their differences from these two samples are highly significant. The St. Helena Island sample closely approaches those of Big Bay de Noc; however, in a few instances (SL, H) the difference between this sample and the Big Bay de Noc sample of September 12, 1950, are significant. Among Big Bay de Noc samples there are no significant differences.

A comparison between Gull Island and High Island samples show significant differences for SL, H, and CPD measurements. In CPL measurement the samples do not differ significantly. The means of all measurements considered are lowest in the Gull Island and High Island fish. Differences between these two samples and the other localities are, in general, above the level of high significance; however, in a few instances the St. Helena Island and Gull Island fish show differences only at the significant level.

Table 43.—CPL: values of "t" relating to paired comparisons between samples of age III (1947 year class) whitefish from Lake Michigan

Source of sample	St. Helena Island	Gull Island	High Island	Big Bay de Noc	Big Bay de Noc
Date (1950)	Aug. 12	Aug. 22	Aug. 26	Sept.12	Sept.16
Number	26	15	19	27	28
St. Helena Island	-				
Gull Island	2.76**	-			
High Island	4.67**	1.50	-		
Big Bay de Noc	1.50	4.09**	6.09**	-	
Big Bay de Noc	0.13	2.89**	4.86**	1.40	-

** Highly significant

Table 44.-CPD: values of "t" relating to paired comparisons between samples of age-group III (1947 year class) whitefish from Lake Michigan

Source of sample	St. Helena Island	Gull Island	High Island	Big Bay de Noc	Big Bay de Noc
Date (1950)	Aug. 12	Aug.22	Aug.26	Sept.12	Sept.16
Number	26	15	19	27	28
St. Helena Island	-				
Gull Island	2.92**	-			
High Island	5.84**	2.37*	-		
Big Bay de Noc	1.85	4.53**	7.59**	-	
Big Bay de Noc	0.53	3.40**	6.42**	1.35	-

* Significant
** Highly significant

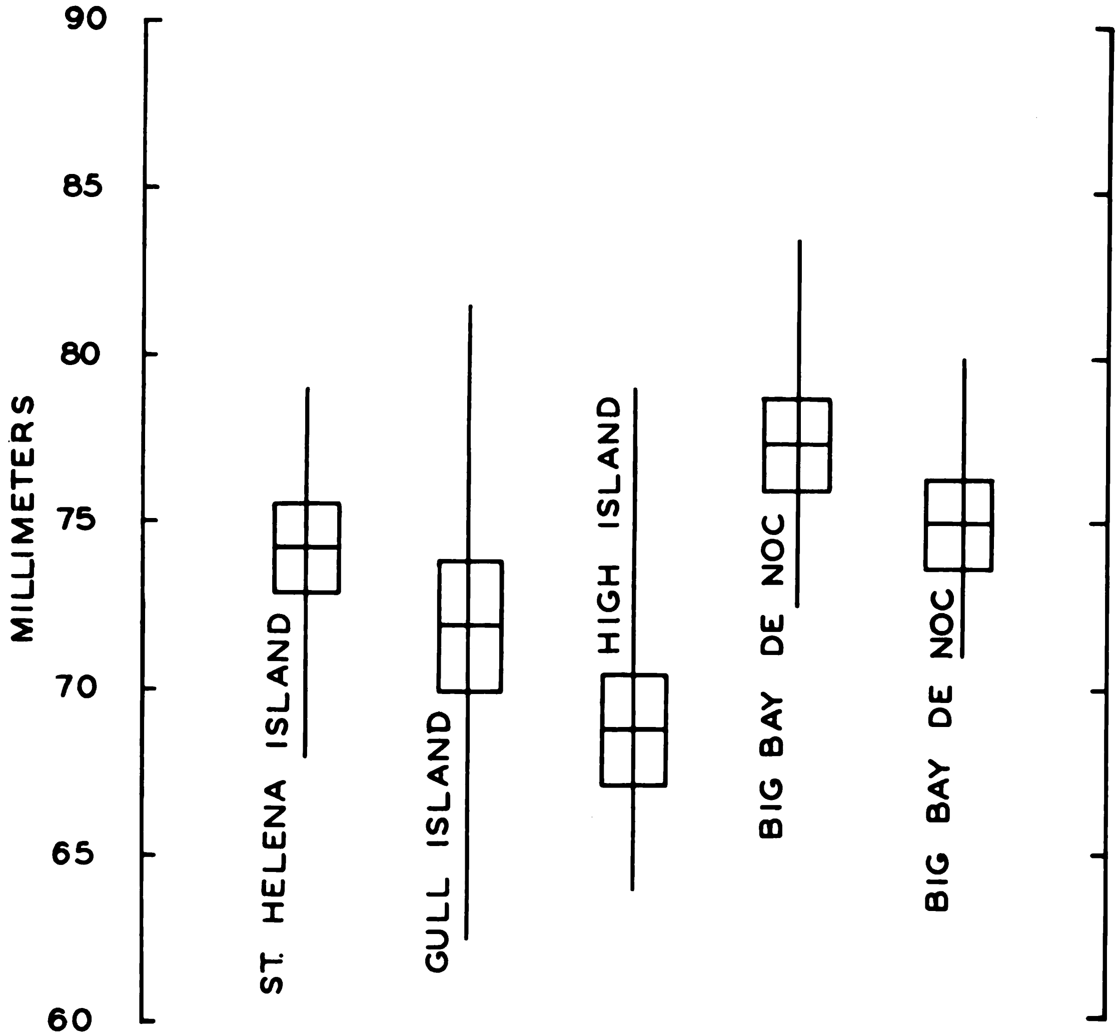


Fig. 15—Variance of head length of whitefish (*Coregonus clupeaformis*) from Lake Michigan. Age group III, 1947 year class.

AGE GROUP V (1945 YEAR CLASS)

Table 45 presents a summary of morphometric measurements of 85 fish belonging to age-group V (1945 year class). Due to paucity of V group individuals in the Big Bay de Noc and St. Helena Island samples, only collections from Gull Island and High Island are compared. From Table 45 it is evident that the means of the measurements agree very closely. The analysis of variance was applied to the several body proportion measurements and the following F values were obtained:

SL	H	SL/H	CPL	CPD	CPL/CPD
2.21	1.45	1.29	1.66	1.10	1.29

The above F values are to be interpreted with degrees of freedom 3 and 78 (or 80, see Table 45). The corresponding 5 percent and 1 percent F values are about 2.72 and 4.04 respectively. In all measurements considered, the differences between Gull Island and High Island samples of fish belonging to age-group V (1945) are not significant.

In order to illustrate the close agreement between separate collections from the same areas, head measurements of the four samples are graphically presented in Figure 16.

Table 45.—Morphometric measurements of age-group V whitefish from northern Lake Michigan

(The fish belong to the 1945 year class. Means, standard errors, and extremes of the measurements are in millimeters)

Locality	Number of fish	SL	H	SL/H	CPL	CPD	CPL/CPD
Gull Island	24*	443.79 ± 6.83 372–507	86.22 ± 1.16 74.0–93.0	5.146	56.09 ± 0.90 45.0–61.0	34.44 ± 0.54 29.5–38.5	1.630
Gull Island	24	441.92 ± 6.83 381–490	86.92 ± 1.16 75.0–99.5	5.086	56.65 ± 0.91 50.0–67.0	34.71 ± 0.55 29.5–39.0	1.635
High Island	15	427.56 ± 8.63 368–490	84.32 ± 1.47 79.0–92.5	5.065	54.99 ± 1.16 50.5–60.5	33.82 ± 0.69 29.5–38.0	1.628
High Island	19	421.36 ± 7.67 371–475	83.73 ± 1.30 73.5–92.5	5.033	54.08 ± 1.03 45.0–62.5	33.18 ± 0.61 28.8–37.5	1.629

* 25 fish are used in CPL, CPD, and CPL/CPD measurements

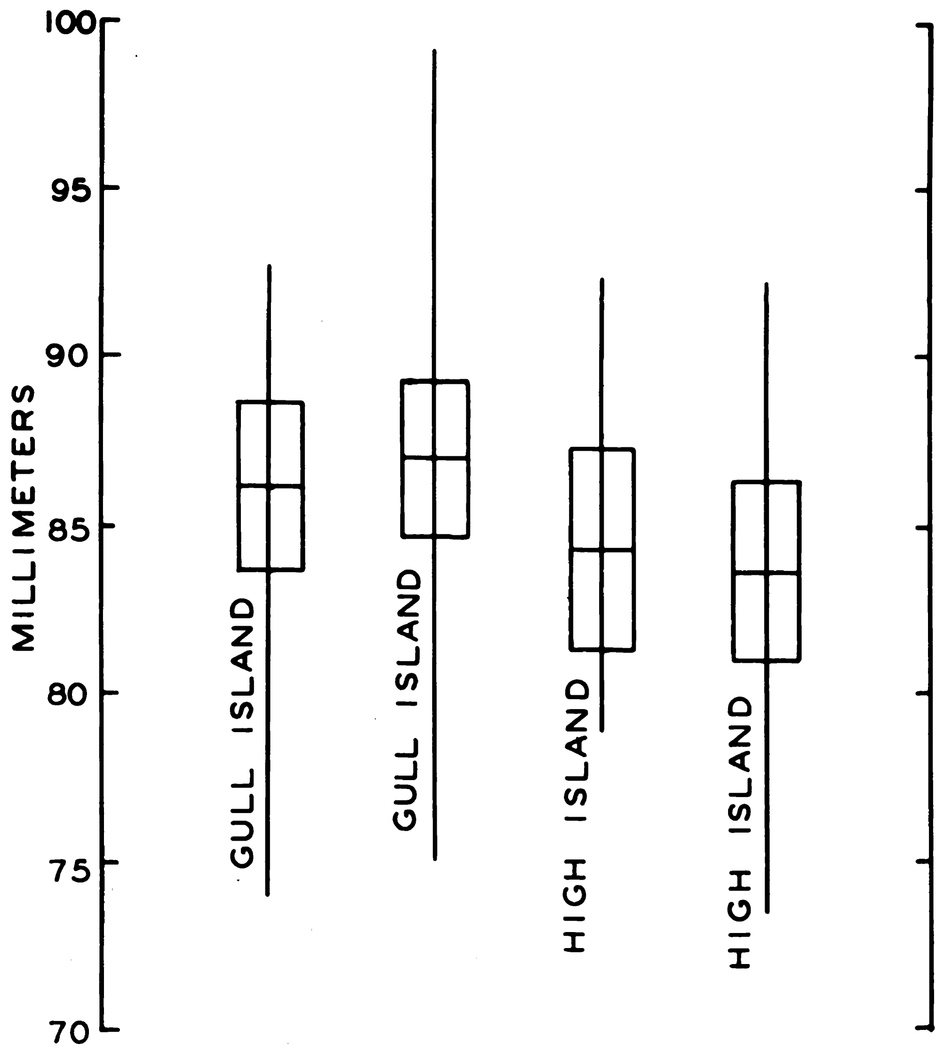


Fig. 16 _Variance of head length of whitefish (*Coregonus clupeaformis*) from Lake Michigan. Age group V, 1945 year class.

AGE GROUP VI (1944 YEAR CLASS)

Summaries of morphometric measurements of 89 fish belonging to age-group VI (1944) are presented in Table 46. As in age-group V, the Big Bay de Noc collections were poorly represented by this age fish and, consequently, only Gull Island and High Island fish are compared. The High Island fish show means slightly lower than those of Gull Island. This same general pattern is shown among age-group V fish from the same localities.

From the method of analysis of variance, the following F values were obtained:

SL	H	SL/H	CPL	CPD	CPL/CPD
2.30	1.33	1.45	1.51	1.30	1.49

The above values are to be interpreted with degrees of freedom 3 and 87 (or 85, see Table 46). The corresponding 5 percent and 1 percent F values are about 2.72 and 4.04 respectively. In all measurements considered, the differences between Gull Island and High Island samples of fish belonging to age-group VI (1944 year class) are not significant.

In order to illustrate the close agreement between the separate collections from the same areas, head-lengths of the four samples are graphically presented in Figure 17.

Table 46.-Morphometric measurements of age-group VI whitefish from northern Lake Michigan

(The fish belong to the 1944 year class. Means, standard errors, and extremes of the measurements are in millimeters)

Locality	Number of fish	SL	H	SL/H	CPL	CPD	CPL/CPD
Gull Island	25	473.60±6.36 401-529	91.26±1.04 80.0-103.5	5.187	60.36±0.83 52.5-70.0	36.58±0.55 30.0-40.0	1.653
Gull Island	16*	477.42±7.95 404-535	92.93±1.30 85.0-104.0	5.133	58.55±0.95 53.5-69.5	36.55±0.63 32.5-41.5	1.686
High Island	21	463.44±6.94 398-510	90.58±1.13 78.0-96.0	5.114	58.30±0.90 50.5-65.0	35.80±0.60 31.0-41.5	1.635
High Island	24	452.24±6.49 406-511	89.67±1.06 79.0-98.0	5.041	57.70±0.84 53.5-63.5	34.80±0.56 30.5-40.0	1.661

* 19 fish used in CPL, CPD, and CPL/ CPD measurements

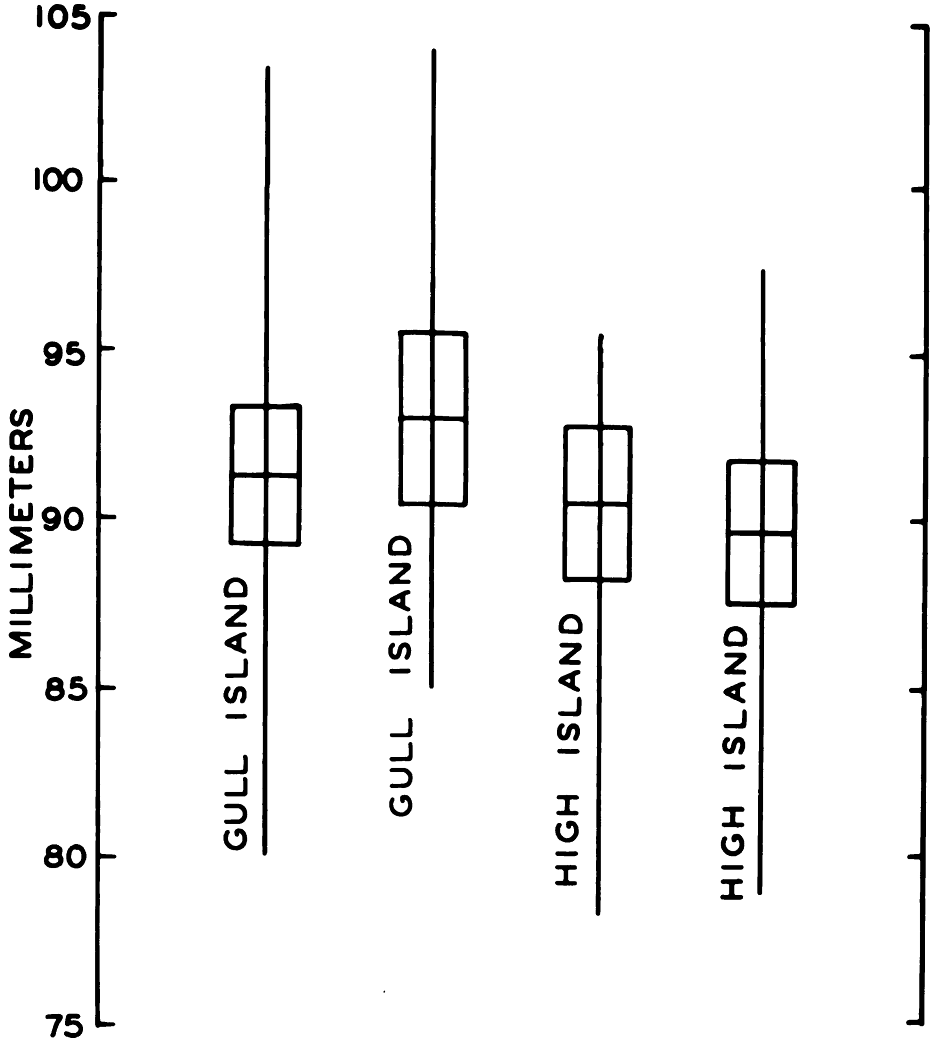


Fig. 17 — Variance of head length of whitefish (*Coregonus clupeaformis*) from Lake Michigan. Age group VI, 1944 year class.

AGE GROUP VII (1943 YEAR CLASS)

Table 47 presents a summary of morphometric measurements of 51 fish belonging to age-group VII (1943). Due to poor representation of this age group, the samples of August are combined in the High Island and Gull Island collections. The Big Bay de Noc sample was taken September 12, 1950. The six measurements listed in Table 47 were tested by the analysis of variance method and, with the exception of the two ratios, SL/H and CPL/CPD, all show F values above the level of high significance. The t-values for the measurements are presented in Tables 48-51. Without exception, these four measurements follow the same pattern. The Gull Island and High Island fish are not significantly different from each other; yet, the difference between each island collection and the Big Bay de Noc fish is highly significant.

Figure 18 shows graphically the variance of head-length of age-group VII (1943) fish. An additional sample of 33 Big Bay de Noc fish taken September 16, 1950, is shown. Since there is very close agreement of this sample with the Big Bay de Noc sample of September 12, 1950, data are not included in Table 47. Analyses of the six measurements of these two samples exhibit no significant difference among the Big Bay de Noc fish.

Table 47.-Morphometric measurements of age-group VII whitefish from northern Lake Michigan

(The fish belong to the 1943 year class. Means, standard errors, and extremes of the measurements are in millimeters)

Locality	Number of fish	SL	H	SL/H	CPL	CPD	CPL/CPD
High Island	17	463.09±8.94 404-540	91.55±1.53 83.0-103.5	5.055	58.35±1.13 53.0-64.0	35.54±0.62 31.0-41.0	1.644
Gull Island	19	465.83±8.46 400-562	92.26±1.45 82.5-105.0	5.057	58.49±1.07 50.0-69.5	35.49±0.59 31.0-39.5	1.652
Big Bay de Noc	15	501.08±9.52 464-542	98.32±1.63 91.5-104.0	5.097	65.16±1.20 57.5-70.0	40.36±0.66 37.5-43.0	1.615

Table 48.-CPL: values of "t" relating to paired comparisons between samples of age-group VII (1943 year class) whitefish from Lake Michigan

Source of sample	Gull Island	High Island	Big Bay de Noc
Date (1950)	August	August	September 12
Number	19	17	15
Gull Island	-		
High Island	0.09	-	
Big Bay de Noc	4.14**	4.13**	-

Table 49.-CPD: values of "t" relating to paired comparisons between samples of age-group VII (1943 year class) whitefish from Lake Michigan

Source of sample	Gull Island	High Island	Big Bay de Noc
Date (1950)	August	August	September 12
Number	19	17	15
Gull Island	-		
High Island	0.01	-	
Big Bay de Noc	5.53**	5.30**	-

**Highly significant

Table 50.—SL: values of "t" relating to paired comparisons between samples of age-group VII (1943 year class) whitefish from Lake Michigan

Source of sample	Gull Island	High Island	Big Bay de Noc
Date (1950)	August	August	September 12
Number	19	17	15
Gull Island	-		
High Island	0.22	-	
Big Bay de Noc	2.77**	2.91**	-

Table 51.—H: values of "t" relating to paired comparisons between samples of age-group VII (1943 year class) whitefish from Lake Michigan

Source of sample	Gull Island	High Island	Big Bay de Noc
Date (1950)	August	August	September 12
Number	19	17	15
Gull Island	-		
High Island	0.33	-	
Big Bay de Noc	2.78**	3.02**	-

**Highly significant

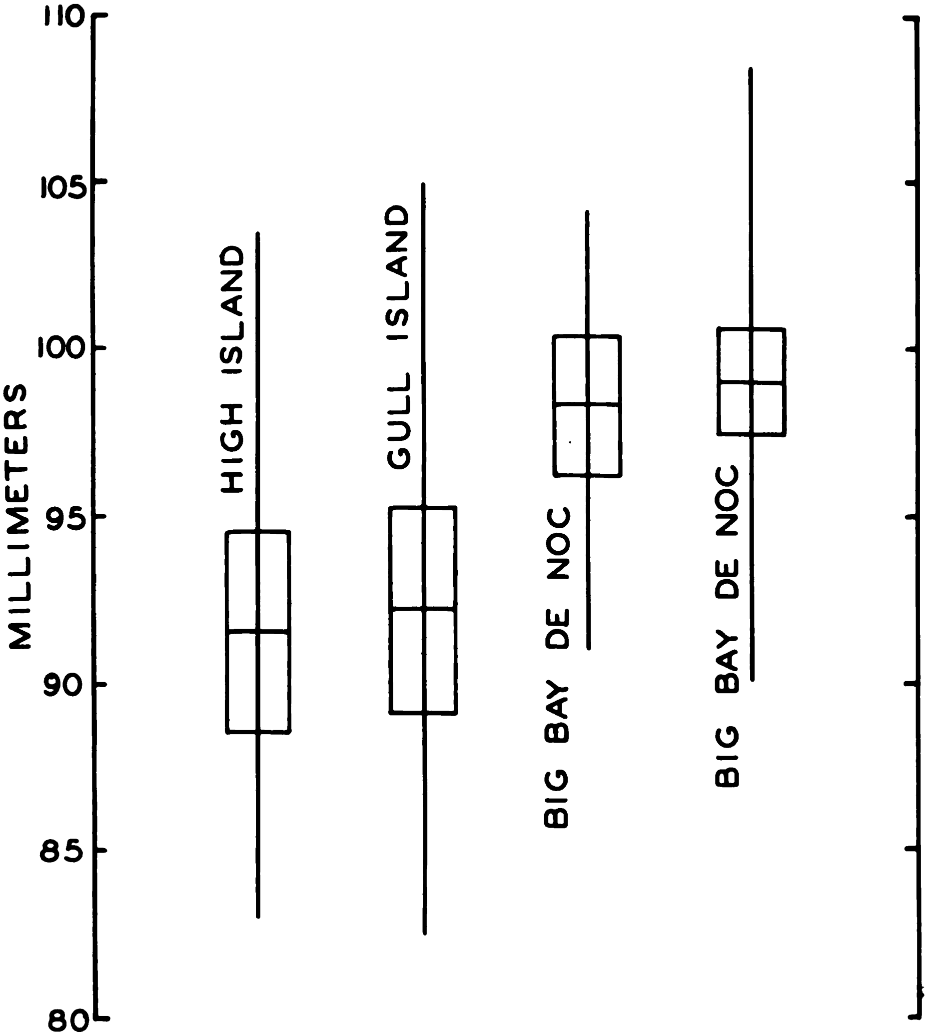


Fig. 18 Variance of head length of whitefish (*Coregonus clupeaformis*) from Lake Michigan. Age group VII, 1943 year class.

COMPARISON OF SEXES

Since most of the body proportion measurements were made of collections in which sex data were unknown, or the numbers of known individuals were so few that it was necessary to combine the data, it becomes a matter of special importance to test the relationship of the sexes.

Data relative to sex are available for the following age groups:

Age-group VI (1943 year class). These fish were taken from near Round Island, Big Bay de Noc, on October 6, 1949. Since this collection was made at a time during which enlargement of gonads is known to take place, differences between sexes relative to body form should be pronounced at this particular season. Tests of significance of the six measurements (SL, H, SL/H, CPL, CPD, CPL/CPD) were made between 75 males and 66 females. Differences between males and females, for the measurements considered, were far below the level of significance.

Age-group VII (1943 year class). Data relative to sex are available for 52 fish from the collection of September 12, 1950, taken in Big Bay de Noc off Burnt Bluff. Comparison of 33 males and 19 females, with respect to the measurements of SL, H, SL/H, CPL, CPD, CPL/CPD, show that the difference between males and females is not significant.

SUMMARY

1. Age composition, strength of year classes, growth in length and weight and measurements of several body proportions of whitefish from northern Lake Michigan are presented.

2. Collections were taken from three principal sample areas: Big Bay de Noc, Gull Island, and High Island. Data were taken directly from the commercial catches during portions of the years 1948, 1949, and 1950.

3. Length-frequency distributions arranged according to age of fish are presented for the samples. Gull Island and High Island samples show more overlapping of the lengths of fish belonging to different age groups than do the Big Bay de Noc samples.

4. In the 1950 collections year classes 1945 and 1944 (age-groups V and VI respectively) dominated the catches from Gull Island and High Island, and made up slightly over 50 percent of the total samples. Big Bay de Noc collections of the same year exhibited an especially poor representation by these year classes; the 1945 year class was represented by only 3.1 percent and the 1944 year class was not recorded in any of the catches sampled.

5. In the Big Bay de Noc - Pt. Detour samples, the especially high dominance of the 1943 year class is evident. This year class as the V group of 1948 accounted for over 80 percent of the total catch, as the VI group

of 1949 made up 64 percent, and as the VII group of 1950 made up 27 percent of the collections.

6. Calculated lengths for each year of life through 8 years indicate values for the Big Bay de Noc fish exceed those of Gull Island and High Island samples. The advantage of the Big Bay de Noc whitefish over Gull Island specimens increased from 0.7 inches at the end of the first year of life to 1.3 inches at the end of the eighth year. The advantage of the Big Bay de Noc whitefish over the High Island specimens increased from 0.7 inches at the end of the first year to 2.3 inches at the end of the eighth year. Calculated lengths for the St. Helena Island fish approach closely the values determined for the Big Bay de Noc whitefish.

7. The length-weight relationship of the 1949 collections of Big Bay de Noc whitefish with standard lengths of 340 to 519 millimeters is expressed by the equation

$$\log W = -8.4271 + 3.2544 (\log L)$$

8. The length-weight relationship of the 1950 collections of Gull Island whitefish with standard lengths of 350 to 529 millimeters is expressed by the equation

$$\log W = -7.7239 + 2.9886 (\log L)$$

9. The length-weight relationship of the 1950 collections of High Island whitefish with standard lengths of 370 to 509 millimeters is expressed by the equation

$$\log W = -7.2567 + 2.8166 (\log L)$$

10. The 1950 collections were examined for scars suspected to be caused by sea (lake) lamprey, Petromyzon marinus. Tabulation of marked fish on basis of age groups revealed no fish belonging to age-groups I, II, and III showing either fresh or healed scars. Of a total of 94 fish examined belonging to age-group IV (1946), only 4 fish showed fresh scars and 2 exhibited healed scars. The 1950 collections from Gull Island and High Island show slightly higher percentage of fish bearing scars than the Big Bay de Noc samples.

11. The method of analysis of variance, based upon the year classes, is applied to several body proportion measurements of fish from different localities.

12. Four measurements (SL, H, CPL, CPD) taken of fish from four localities and belonging to five different year classes (age-group III to VII) are compared. In general, differences between Gull Island and High Island fish are not significant, except among the young fish (III, IV). Fish from each of these localities differs from the Big Bay de Noc fish at the level of high significance. St. Helena Island fish closely approach those of Big Bay de Noc; however, in a few instances the differences for a few of the measurements are significant. Among the Big Bay de Noc samples there are no significant differences.

13. The ratios SL/H and CPL/CPD were determined for the several localities. Values of SL/H range from 4.927 to 5.187 and those of CPL/CPD from 1.558 to 1.686. The method of analysis of variance applied to values determined for the several samples reveal no significant differences between fish from any of the localities.

14. Tests of significance of the six measurements (SL, H, SL/H, CPL, CPD, CPL/CPD) show that the differences between males and females of Big Bay de Noc fish taken in October, 1949, and September, 1950, are not significant.

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APPENDIX

Calculated growth:

$$L_n = c + \frac{S_n}{S} (L - c)$$

where

L_n = length of fish at any annulus formation

L = length of fish at time of capture

c = length of fish when scales appeared

S = scale diameter (or radius) at time of capture (outside scale measurement)

and S_n = scale diameter (or radius) at any annulus.