ABSTRACT

The annual commercial take of Saginaw Bay walleyes averaged 1,149,000 pounds in 1891–1919, 652,000 pounds in 1920–31, 1,466,000 pounds in 1932–43, and only 396,000 pounds in 1944–51. The catch was under 100,000 pounds in each of the years 1949–51. Overfishing does not appear to have been a significant factor in the collapse of the fishery; many fishermen attribute the decline to pollution.

Age was determined for 3,652 fish and growth calculated for 2,427 specimens collected in 1926–30 and 1943. The average age (number of annuli) and the dominant age group at various seasons in 1926–30 were as follows: Spawning season—7.60 years, VII group; late spring—3.90 years, IV group; fall—1.28 years, I group. The percentage of legal fish (minimum total length, 15½ inches) in the catch of commercial impounding nets ranged from as high as 100 in the 1929 spawning season to as low as 1 in the fall in 1926 and 1928. The late-spawning-run sample of 1943 averaged 4.06 years old, was dominated by the III group, and included 96 percent legal-sized walleyes.

The strength of the year classes was well above average in 1919, 1925, 1937, and 1940, and weaker than average in 1917, 1924, 1928, 1938, and 1941.

Females were larger than males in all but the first 2 years of life, and walleyes of the 1943 collection had grown much more rapidly than fish captured in 1926–30. Times of attainment of legal length of 15½ inches (corresponding weight 1.12 pounds) were as follows: 1926–30 fish—males, early in fifth growing season and females in latter part of fourth; 1943 fish—males near the end and females past the middle of the third season. Calculated lengths and weights for latest years of life for which data were available were for 1926–30 males—14 years, 21.3 inches, 3.05 pounds; 1926–30 females—15 years, 25.0 inches, 4.91 pounds; 1943 males—10 years, 23.3 inches, 4.00 pounds; 1943 females—13 years, 29.5 inches, 8.14 pounds. Annual fluctuations in growth showed an irregular but pronounced downward trend in 1916–29. The growth advantage of the 1943 over the 1926–30 specimens was established in the early and middle 1930's.

The weight of walleyes in the combined samples from Saginaw Bay increased as the 2.989 power of the length. Walleyes taken in the fall were heavier than fish taken in late spring. Pronounced short-term fluctuations in weight during the late spring indicated heterogeneity of the stock with respect to the length-weight relation at that season. Sound walleyes were from 5½ to 6½ percent heavier than fish infected with *Lymphocystis*.

The percentage of males was higher in the younger than in the older age groups and during the spawning run than in late spring. A higher rate of exploitation for males than for females was suggested as a major cause of the change of the sex ratio with increase in age. Lengths at which 50 percent of the walleyes had reached maturity were about 15½ inches for males and 17 inches for females.

UNITED STATES DEPARTMENT OF THE INTERIOR, Douglas McKay, *Secretary*

FISH AND WILDLIFE SERVICE, John L. Farley, *Director*

FLUCTUATIONS IN GROWTH AND YEAR-CLASS STRENGTH OF THE WALLEYE IN SAGINAW BAY

By Ralph Hile

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FLUCTUATIONS IN GROWTH AND YEAR-CLASS STRENGTH OF THE WALLEYE IN SAGINAW BAY

By RALPH HILE, *Fishery Research Biologist*

Saginaw Bay normally stands second only to western Lake Erie in the commercial production of the walleye, *Stizostedion v. vitreum* (Mitchill), in the Great Lakes; and among the fishes of the bay, the walleye customarily ranks first in economic importance. Despite its importance, no previous major investigation of the Saginaw Bay walleye has been undertaken. Available information has been limited largely to that given in Hile's (1937) study of the relation between plantings of fry and the later abundance and production of walleyes, in Krumholz's (1945) investigation of the loss of weight on filleting, and in the account by Van Oosten, Hile, and Jobes (1946) of bathymetric distribution and vertical movements of walleyes in late spring, summer, and early autumn.

This report presents additional information on the Saginaw Bay walleye in such matters as age, growth, the length-weight relation, maturity, sex ratio, ... The 1926–30 collections which form the basic material for this study, were mostly made as opportunity presented itself during the course of experimental studies of pound-net meshes carried on cooperatively by the United States Bureau of Fisheries (since incorporated in the Fish and Wildlife Service) and the Michigan State Department of Conservation. It was the generous financial support of the latter agency that made the project possible.

In many respects the data leave much to be desired and the conclusions based on them are correspondingly restricted. It is believed, nevertheless, that the results presented here may provide reasonably sound, fundamental information on certain phases of the natural history of the walleye in Saginaw Bay, and offer a basis for the planning of continuing studies of population changes.

For the principal purpose of this publication—the presentation of basic information on the life history of the walleye—the 1926–30 samples would suffice. Data on the 1943 samples are included primarily to bring out the pronounced change in growth rate that occurred between 1929 and 1943.

I am much indebted to the following persons for the collection of materials and recording of field data: Dr. T. H. Langlois, the late Dr. Jan Metzelaar, Edward W. Ross, and Russell Robertson of the Michigan Department of Conservation, and Dr. Frank W. Jobes. Dr. L. A. Krumholz, Michigan Institute for Fisheries Research, assisted in the collection of the 1943 samples.

Dr. Hilary J. Deason determined ages for most of the fish collected in 1926 and prepared the original tabulations of relationships among total, fork, and standard lengths. He also had derived the body-scale equation used in this study from his earlier work with the Lake Erie walleye. Dr. John Van Oosten gave valuable advice during the course of this study. Dr. James W. Moffett and Dr. Paul H. Eschmeyer read the original manuscript.

Field operations were greatly facilitated by the cooperation of the Bay Port Fish Co., the R. L. Gillingham Fishing Co., and conservation officer A. J. Neering.

MATERIALS AND METHODS

COLLECTION OF MATERIALS

Investigation of age and growth rates of the Saginaw Bay walleye was based on the determination of the age of 3,652 fish and the computation of individual growth histories (from scale measurements) of 2,427 specimens collected in 1926–30 and 1943 as recorded in table 1.

A lack of sex data is principally responsible for the lower number of fish employed in the growth studies than in age studies. In the collections of May 15 to June 18, 1929, sex was determined only for the larger, mature walleyes; in these samples, therefore, only fish older than the VI group (at which age nearly all or all fish are mature) could be used for the investigation of growth. Sex was determined for fewer than half the fish collected in 1928, but there was no selection on the basis of maturity; hence, no blocks of age groups were excluded.

TABLE 1.—*Ports and dates of collection of Saginaw Bay walleyes used in age and growth studies*

Dates of collection	Port	Number of fish used for study of—	
		Age composition	Rate of growth
Nov. 11–20, 1926	Bay City	305	304
Mar. 30–Apr. 16, 1927	Bay Port	127	113
Nov. 5–12, 1928	Bay City	119	52
Apr. 4–23, 1929	Bay Port	570	548
May 15–June 18, 1929	Bay Port	1,183	64
Apr. 30–June 20, 1930	Bay Port	1,060	1,060
May 4, 1943	Bay Port	288	286
Total		3,652	2,427

In the spawning-run samples of 1927 and April 4–23, 1929, all walleyes younger than the VI group were excluded from the growth materials as probably not representative by reason of selection on the basis of maturity (spawning runs are made up almost entirely of mature fish). The 1943 collection, although taken at a time when numbers of fish had not yet spawned, could not be considered a true spawning-run sample since the catch included a considerable number of immature fish. In this collection all fish were used in the study of growth except the II-group individuals which were held to be of uncertain status because of their small number.

The numbers of walleyes employed in the study of other phases of the life history—length-weight relation, ratios of the various length measurements, sex ratio, maturity—varied according to the materials available or required.

All samples were captured by experimental or commercial impounding nets (pound nets and shallow trap nets) of 2- to 3-inch mesh, extension measure, as manufactured.[1]

RECORDS FOR INDIVIDUAL FISH

The following procedures were used in compiling length, weight, and maturity records for individual fish.

Length

The method of measurement differed from sample to sample. In the periods of most extensive sampling—in 1929 after the spawning season had ended and in 1930—both the total length (from tip of the head to tip of the tail, with the lobes compressed to give the maximum measurement) and the standard length (tip of the head to base of the caudal peduncle) were measured for almost all the fish. In addition to these measurements, fork length (tip of the head to fork of the tail) was recorded for a majority of the walleyes collected in the fall of 1928. Only standard lengths were recorded in the fall of 1926. Total lengths alone were measured in the spawning-run samples of 1927 and 1929, in the fall of 1929, in 1943, and for a few fish in the fall of 1928.

Walleyes of the 1926–30 collections were measured with a steel tape. The tape is held with its 0-graduation at the tip of the head, follows the curve of the body to the point of greatest thickness, and then runs parallel to the surface on which the fish is lying. A measuring board was used in 1943. The tape length exceeds the board length by about 2.5 percent.

Lengths of the bulk of the samples were recorded to the nearest millimeter. Measurements were to the nearest 0.5 centimeter for most of the 1929 spawning-run collection and to the nearest quarter inch for the remainder of the 1929 spawning-run fish and for the samples of 1927 and 1943.

The diversity of procedure necessitated a large number of conversions to attain the uniformity required. The original compilations and analyses were carried on in terms of standard lengths in millimeters (tape measurement), and where conversions were necessary, they were made for the individual fish by means of factors given in table 2.

TABLE 2.—*Factors for conversions between standard and total lengths of Saginaw Bay walleyes, with and without change of unit*

[S. L. = standard length; T. L. = total length]

Interval of standard length	Number of fish	Conversion factor			
		S. L. to T. L. (no change of unit)	T. L. to S. L. (no change of unit)	S. L. (millimeters) to T. L. (inches)	T. L. (inches) to S. L. (millimeters)
<225 mm	447	1.179	0.848	0.0464	21.54
225-447 mm	4,190	1.159	.863	.0456	21.92
>447 mm	162	1.136	.880	.0447	22.35

Since the relative size of the tail of the Saginaw Bay walleye decreases with increase in the length of the fish, different factors were determined for each of three intervals of length. Good argument could be offered for the establishment of more than three intervals or for the use of a continuous curve, since the differences between the factors for the successive intervals are sufficiently great to introduce irregularities into the converted data, and thus call for certain arbitrary adjustments. In table 18, for example, the total lengths corresponding to the standard lengths of 219 and 229 millimeters were computed as 10.2 and 10.4 inches, respectively. In order that the sequence of total lengths might proceed more regularly, however, they were written as 10.1 and 10.5 inches, respectively. At the second change of factor the required adjustments were larger. The total lengths equivalent to standard lengths of 434, 443, and 453 millimeters, respectively, were computed as 19.8, 20.2, and 20.2(5) inches but entered in the table as 19.7, 20.0, and 20.3 inches. Similar adjustments, never exceeding 0.2 inch for any particular length, were made for other tables of length-weight relation and length-frequency distributions and also for the tables showing the calculated growth in length of the year classes.

Comparisons of group averages were affected little by the irregularities resulting from the changes in conversion factors since the conversions were made for individual fish and hence underestimates on the one side of the point of change were compensated by overestimates on the other. Furthermore, both standard and total lengths were at hand for the large majority of the specimens.

From the measurements of both fork and total lengths of 550 fish, a fork-length/total-length ratio of 0.944 was determined. No change in the ratio with increase in length could be detected; the length range was small, however—most of the fish falling in the second of the three intervals of table 2.

Following completion of the original tabulations, tape lengths were converted to board lengths by means of the factor 0.9756. Only board lengths are presented in this paper, and the conversions to board lengths account for the fact that in certain tables the differences between the midpoints of successive length intervals, set up originally as 10 millimeters (tape length) are occasionally only 9 millimeters.[2]

Weight

Weights were recorded in the field to the nearest quarter ounce or 0.1 ounce. For purposes of compilation and analysis, conversions were made to decimal fractions of pounds or to grams, as desired.

Records of weight were not made in the fall collections of 1926 or for the spawning-run samples of 1927 and 1929. This reduced enormously information on the average weights of the older age groups. Fortunately, a considerable number of weights was at hand for large fish not in the scale collections. It was accordingly possible to derive a general length-weight equation that could be applied to the calculated lengths for the later years of life, and provide a good estimate of the growth in weight in those years.

Maturity

No records of maturity were made in the fall of 1926 or in the spawning-run collections of 1927 and 1929. This deficiency was not particularly damaging for the last two collections, since immature fish are taken rarely at the time of the spawning run. Maturity was recorded in the fall of 1928, but records of sex were not taken for a majority of the immature fish. In 1929 (late spring), sex was determined for only a small percentage of the immature individuals, but in 1930 and 1943 both sex and maturity were recorded.

DETERMINATION OF AGE

Age, as determined from the scales,[3] has been expressed in Roman numerals corresponding to the number of annuli, or year-marks. Thus, a fish in the first year of life belongs to age-group 0, one in its second year to age-group I, ... As a convention, each fish was held to pass into the next higher age group on January 1. This usage required in turn that a "virtual" annulus be credited at the edge of the scale from that date until such time as the current season's year-mark was completed. For practically all Saginaw Bay walleyes captured in the spring and early summer the outermost annulus was virtual, since only a negligible number of the scales exhibited marginal growth even as late as mid-June. The season's growth appears to begin later in Saginaw Bay (in 1929 and 1930, at least) than in Lake of the Woods where Carlander (ms. 1942) found annulus formation to take place "during the latter part of May or early June."

Carlander (op. cit.) demonstrated that the annulus is a true year-mark in the Lake of the Woods walleye. Data for the Saginaw Bay stock also support strongly the belief that annuli are valid indicators of age. An extended consideration of this matter does not seem to be desirable here; nor are all of the supporting data presented, but certain points may be listed as follows:

1. Agreement between the modal length of the youngest fish (those that had completed 2 growing seasons) as determined from scales and from modes in certain length-frequency distribution of all ages combined.
2. Systematic increase of mean size with increase in number of annuli.
3. Generally good agreement of calculated lengths at the end of various years of life as computed from the scales of fish of the same or different age groups and year classes.
4. Better agreement between calculated growth histories of different age groups of the same year class than between the growth histories of the same or different age groups of different year classes.
5. Agreement between year classes as to good or poor growth in certain calendar years.
6. Close correlation between data for the sexes on annual fluctuations in growth rate.
7. Numerical strength or weakness of certain year classes in different calendar years.[4]

The agreement among year classes and between the sexes with respect to annual fluctuations in growth rate is especially significant because of the

[1] The mesh sizes of the nets as actually fished were smaller than those given here, since their treatment with a preservative produces a certain amount of shrinkage. See Van Oosten, Hile, and Jobes (1946) for data on extent of shrinkage.

[2] The long hours spent converting lengths of Saginaw Bay walleye provided much of the stimulus for the preparation of my 1948 article on standardization of methods of expressing lengths and weights of fish (Hile 1948).

[3] Scales were mounted on glass slides in a glycerin-gelatin medium and examined by means of a microprojection apparatus.

[4] The bearing of certain of these points on the validity of the annulus as a year-mark may not be immediately obvious. To avoid repetition here, reference is made to Hile (1941).

evidence it affords that scales of the Saginaw Bay walleye can be read with a high degree of accuracy up to relatively advanced ages. Males that had completed as many as 11 years of life and females that had completed as many as 13 were employed in those analyses.

Difficulties encountered in the reading of scales were the usual type: annuli that could not be determined as true or false; annuli crowded together from slow growth; semiopacity and pronounced light and dark markings; pitting of the scale surface; peripheral resorption. Scales that gave evidence of earlier resorption along the anterior edge were discarded since they could not yield reliable measurements for the computing of past growth.

Age determinations were more difficult for older fish, especially those more than 7 or 8 years of age. The scales of all older fish were read twice. At the first examination an age was assigned, if possible. At the second examination, the earlier reading was confirmed or corrected, a decision made whether to retain the fish, and if usable, the scale was measured.

Rate of growth also affected ease of reading the scales. The scales of females were considerably easier to interpret than those of the more slowly growing males, despite the generally higher average age of the females. Fish of the 1943 sample, which had grown more rapidly than the walleyes captured in 1926–30, had the clearest scales collected at any time. Whereas, 5.5 percent of the scales were discarded from the spawning run of 1929, an age was assigned to every one of the 288 fish taken in 1943.

A third factor bearing on ease of interpretation is the size and shape of the individual scales. Comparisons of extremely small scales with larger ones from the same individual suggested that annuli in undersized scales might be overlooked as the result of faint marking or closeness to neighboring annuli. In extremely large scales the transmission of light often is inadequate and the shading (light and dark bands that bear no fixed relation to annuli) may be accentuated. The largest scales are often extremely wide (dorso-ventral axis) in relation to their length (antero-posterior axis). In such scales, annuli readily visible in the lateral field can be most difficult to trace through the anterior field. Highly elongate scales likewise are undesirable since on them the cutting over in the lateral fields, a most helpful criterion of the annulus, is much reduced.

The scales best suited to age determination in the walleye, then, are those of medium size and ordinary shape (reasonably nearly symmetrical about the antero-posterior axis[5] and neither excessively long nor broad). Scales from the middle of the body of walleyes and just above the lateral line meet these specifications most satisfactorily.

CALCULATION OF GROWTH

Measurements of the magnified (× 40.7) scales for the calculation of individual growth histories were made along the anterior radius most nearly collinear with the focus. The distances from the focus to each annulus and to the edge of the scale were recorded to the nearest millimeter.

Since materials were not available for investigation of the body-scale relation of the Saginaw Bay walleye, use has been made of Deason's unpublished work with the Lake Erie population. Deason determined that the body-scale relation of the Lake Erie walleye was described satisfactorily by a straight line intersecting the length axis at a standard length of 50 millimeters.

The body-scale relation as derived for the Lake Erie walleye and applied here to the Saginaw Bay stock differs notably from the one determined for the Lake of the Woods walleye by Carlander (1945) who made use of an equation of the type:

$$L=a+bS+cS^2+dS^3,$$

where a, b, c, and d=constants. The values of the constants were such that the graph of the equation followed a distinctly sigmoid course. It is obvious from Carlander's figure 1 that the theoretical curve fitted his empirical data extremely well. Eschmeyer (1950) also obtained a sigmoid curve (from key scales). He fitted the curve by inspection and calculated lengths from scale measurements by means of a nomograph of the type described by Hile (1950).

Differences in the location on the body of the fish from which the scales were taken may account for the dissimilar body-scale relation as determined by Deason, by Carlander, and by Eschmeyer. Deason used scales from the middle of the body and above the lateral line, Carlander took his samples near the lateral line immediately above

[5] Curvature of the radii in asymmetrical scales makes measurement more difficult and less accurate.

the posterior edge of the pectoral fin, and Eschmeyer's key scales came from the third row below the lateral line. That the body-scale relation can vary considerably according to the location from which the scales are taken is indicated in the works of Hile (1941) and Beckman (1941) on the rock bass (*Ambloplites rupestris*). Hile found that the mathematical relation between the length (anterior radius) of "key scales" from the second row above the lateral line and the length of fish of the Nebish Lake (Wis.) population was described satisfactorily by the general parabola, $L=cS^n$, in which n had a value of approximately 0.7. Using essentially the same procedures but taking his scales from the third row below the lateral line (actual position not stated in paper but communicated privately by author), Beckman obtained an equally satisfactory fit for the Standard Lake (Mich.) stock with a straight line that intersected the length axis at a standard length of 15 millimeters.

COMMERCIAL PRODUCTION IN SAGINAW BAY, 1885–1951

Records of the production of walleyes in Saginaw Bay (table 3) through 1940 were adapted from Gallagher and Van Oosten (1943). Figures for later years were compiled in the Great Lakes offices of the United States Fish and Wildlife Service from commercial fishing reports turned over to the Service by the Michigan Department of Conservation. These reports are submitted each month by commercial fishermen licensed to operate in State of Michigan waters of the Great Lakes.

In 1885, the first year for which we have statistics, the take amounted to 673,000 pounds. The level of production was much higher (1,558,000 pounds) in 1891, the next year for which there is a record. This year was the first in a relatively extended period (1891–1919) in which the catch varied widely (and gave some indication of cyclic fluctuations) but was without a long-term trend (fig. 1). Of the 22 years within this period for which there are statistics, the take exceeded 1½ million pounds in 5 (maximum catch, 1,885,000 pounds in 1894), fell between 1 and 1½ million pounds in 9, and was less than a million pounds in 8 (minimum of 654,000 pounds in 1916). The 1891–1919 average was 1,149,000 pounds.

TABLE 3.—*Commercial production of walleyes in Saginaw Bay, 1885, 1891–1908, and 1916–51*

[In thousands of pounds]

Year	Production	Year	Production	Year	Production
1885	673	1908	801	1933	1,455
1891	1,558	1916	654	1934	1,340
1892	1,035	1917	1,002	1935	1,293
1893	686	1918	1,803	1936	1,401
1894	1,885	1919	1,246	1937	1,529
1895	878	1920	758	1938	1,179
1896	723	1921	546	1939	1,492
1897	1,217	1922	1,098	1940	1,443
1898	1,242	1923	622	1941	1,463
1899	1,167	1924	314	1942	2,050
1900	800	1925	335	1943	1,559
1901	716	1926	589	1944	988
1902	1,003	1927	621	1945	560
1903	1,771	1928	630	1946	909
1904	1,652	1929	632	1947	366
1905	1,415	1930	1,004	1948	142
1906	1,044	1931	681	1949	78
1907	980	1932	1,375	1950	62
				1951	65

The 12-year period, 1920–31, was one of rather consistently low yield. Production was above a million pounds in only 2 years (maximum of 1,098,000 pounds in 1922) and fell below 500,000 pounds twice (minimum of 314,000 pounds in 1924). The mean for 1920–31 was 652,000 pounds—43 percent below the 1891–1919 level. The statistics suggest a general downward trend during the early years and an upward trend during the later years of the period.

The irregular upward trend that started in 1925 carried the take to 1,375,000 pounds in 1932. This year was the first of a 12-year period during which the catch did not fall below 1,179,000 pounds (the figure for 1938) and reached the record high of 2,050,000 pounds in 1942. The 1932–43 average of 1,466,000 pounds was 2.25 times the mean for 1920–31 and 1.28 times the 1891–1919 average.

The decline from the record high of 2,050,000 pounds in 1942 was both rapid and disastrous. The catch dropped to less than a million pounds (988,000) in 1944 and almost to a half million (560,000) in 1945. A recovery to 909,000 pounds in 1946 was followed by a further decrease to only 62,000 pounds in 1950. The catches of 1948, 1949, and 1950 set new record lows, and the 1951 take of 65,000 pounds represented insignificant improvement over the preceding year. The average output in 1944–51 was only 396,000 pounds. Many commercial fishermen of Saginaw Bay believe that industrial pollution brought about the collapse of the walleye fishery.

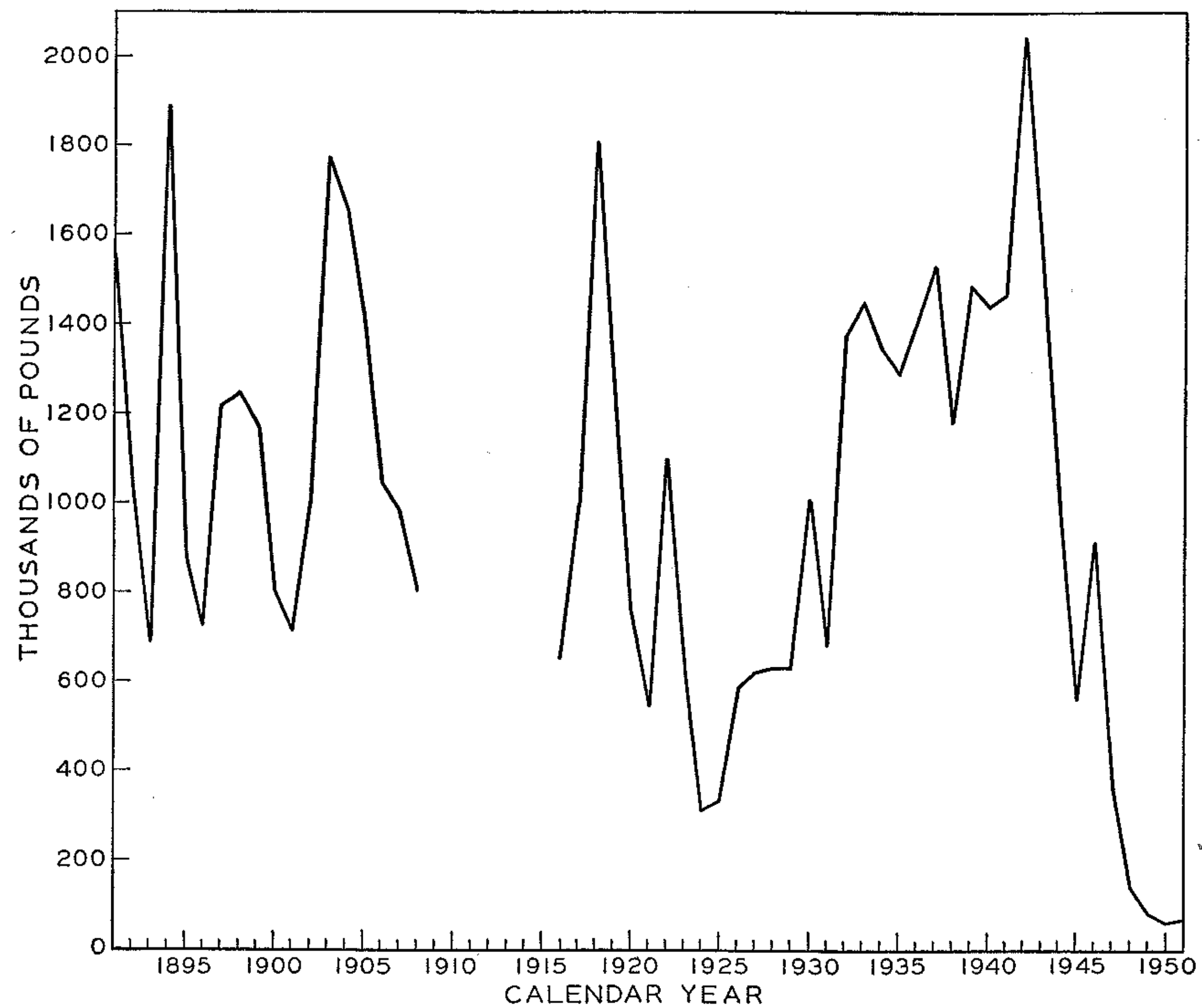

FIGURE 1.—Commercial production of walleyes in Saginaw Bay, 1891–1908 and 1916–51.

An earlier publication (Hile 1937) discussed fluctuations in the production and abundance of walleyes in Saginaw Bay in 1929–35. Similar information, and also statistics on fishing intensity, now available through 1951, give no evidence that overfishing was a significant factor in the recent collapse of the walleye fishery in Saginaw Bay.

AGE COMPOSITION AND YEAR-CLASS STRENGTH

AGE COMPOSITION OF 1926–30 COLLECTIONS

Seasonal differences

The records of age composition of the several collections made from 1926 to 1930 (table 4) indicate that greatly different age segments of the walleye population of Saginaw Bay are available at various periods of the year.

Both of the fall samples were made up of extremely young fish. Age-group I was overwhelmingly dominant in both years (95.5 percent in 1926; 73.1 percent in 1928) and only 4 individuals older than the IV group were present in the combined total of 424 specimens. Even though the number of annuli be increased by 1 to give ages in terms of completed growing seasons each collection has an average age of less than 2.5 and the unweighted mean for the two is 2.28.

The spawning-run samples of 1927 and April 4–23, 1929, on the other hand, were composed of old fish. Age-group VII was dominant in both

years (27.6 percent in 1927; 29.3 percent in 1929), fish younger than the VI group were scarce (11.0 percent in 1927; 3.9 percent in 1929) and no walleyes younger than the IV group were captured. Fish more than 8 years old, however, made up 16.5 percent of the 1927 and 31.9 percent of the 1929 collection. The average age of spawning-run fish was between 7 and 8 years in both collections (unweighted mean of 7.60).

The late-spring collections of 1929 and 1930 were of intermediate age. Age-group IV was dominant in both years (38.5 percent in 1929; 38.7 percent in 1930) and fish of this age and younger made up 85.7 and 70.5 percent, respectively, of the total in the 2 years. No age group older than the VII group in 1929 or the VIII group in 1930 had a representation as great as 1 percent. The unweighted mean age for the two collections was 3.90.

Fluctuations within a collecting period

In three collections (spawning-run, 1929; late-spring, 1929 and 1930) sufficiently large samples were taken on different dates to permit inquiry into the variation of age composition during the collecting period.

The variation in the mean age of spawning-run walleyes captured on different dates in April 1929 (table 5) exhibited no clear-cut trends. For the males, the average number of annuli ranged from 6.66 on April 23 to 8.31 on April 13, a maximum difference of 1.65. The variation of average age was less for the females (from 7.84 on April 7 to 8.89 on April 4—difference, 1.05) and still smaller for the combined sexes (7.75 on April 23 to 8.28 on April 13—difference of 0.53; 7.68 on April 6 to 8.28 on April 13—difference of 0.60, if we include the former collection which contained no females). The lesser range of age for the combined sexes can be traced to the fact that the ages of males and females varied more or less independently.

Age-group VII was dominant [6] both in the combined samples and in 5 of the 6 individual collections from the 1929 spawning run. The exception, sample of April 6, not only contained relatively few fish (53) but was abnormal in that females were entirely lacking. There is little evidence that had fewer samples been available time of collection would have affected greatly the conclusions relative to the age composition of the 1929 spawning run.

The mean age, sexes combined, of late-spring samples in 1929 varied from 3.12 on May 17 to 4.32 on June 3—a difference of 1.20. This maximum

[6] Statements in this section relative to dominance are based on the combined numbers of males and females.

TABLE 4.—*Age and year-class composition of the 1926–30 collections of Saginaw Bay walleyes*

[A "virtual" annulus at the edge of the scale was credited to fish captured in the spring before the onset of the current season's growth]

Date of capture [1]	Year class—															Total or average [2]
	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	
Nov. 11–20, 1926:																
Age group		XI		IX				V	IV	III	II	I				1.13
Number of fish		1		1				1	3	1	7	291				305
Percentage		(0.3)		(0.3)				(0.3)	(1.0)	(0.3)	(2.3)	(95.5)				
Mar. 30–Apr. 16, 1927:																
Age group	XIII	XII	XI	X	IX	VIII	VII	VI	V	IV						7.24
Number of fish	2	2	4	5	8	24	35	33	13	1						127
Percentage	(1.6)	(1.6)	(3.1)	(3.9)	(6.3)	(18.9)	(27.6)	(26.0)	(10.2)	(0.8)						
Nov. 5–12, 1928:																
Age group				XI							IV	III	II	I		1.43
Number of fish				1							1	8	22	87		119
Percentage				(0.8)							(0.8)	(6.8)	(18.5)	(73.1)		
Apr. 4–23, 1929: [3]																
Age group		XIV	XIII	XII	XI	X	IX	VIII	VII	VI	V	IV				7.96
Number of fish		3	9	14	31	61	64	109	167	90	16	6				570
Percentage		(0.5)	(1.6)	(2.5)	(5.4)	(10.7)	(11.2)	(19.1)	(29.3)	(15.8)	(2.8)	(1.1)				
May 15–June 18, 1929:																
Age group	XV		XIII	XII	XI	X	IX	VIII	VII	VI	V	IV	III	II	I	3.67
Number of fish	1		1	1	3	5	7	10	41	41	59	456	308	248	2	1,183
Percentage	(0.1)		(0.1)	(0.1)	(0.2)	(0.4)	(0.6)	(0.8)	(3.5)	(3.5)	(5.0)	(38.5)	(26.0)	(21.0)	(0.2)	
Apr. 30–June 20, 1930:																
Age group					XII	XI	X	IX	VIII	VII	VI	V	IV	III	II	4.14
Number of fish					4	2	4	10	15	23	25	230	410	297	40	1,060
Percentage					(0.4)	(0.2)	(0.4)	(0.9)	(1.4)	(2.2)	(2.3)	(21.7)	(38.7)	(28.0)	(3.8)	

[1] Extreme dates of the collecting period.
[2] Average number of annuli; the averages for the fall collections should be increased by 1 to obtain the mean number of completed growing seasons.
[3] From spawning run.

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TABLE 5.—*Age composition and mean age of Saginaw Bay walleyes in 1929*

[Sex data lacking for the bulk of fish collected in May and June]

Date of collection, and sex	Number in age group—															Total	Average age [1]	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV		By sex	Both sexes [2]
April 4:																		
Males				1	2	7	19	9	9	2						49	7.39	8.05
Females					1	1	9	7	5	6	6	2	1			38	8.89	(87)
April 6: Males [3]				1	2	7	12	19	7	3	2					53	7.08	
April 7:																		
Males					2	10	24	23	5	7	2	1				74	7.72	7.77
Females						11	17	6	6	8	3					51	7.84	(125)
April 13:																		
Males					1	6	11	7	10	5	2	2		1		45	8.31	8.28
Females						8	23	12	7	7	5	5				67	8.25	(112)
April 15, 19:																		
Males						10	14	6	2	3	2		1			38	7.61	8.13
Females					4	8	15	8	6	11	4	4	3			63	8.44	(101)
April 23:																		
Males				3	4	19	8	5	3	1				1		44	6.66	7.75
Females				1		3	15	7	4	8	5		4	1		48	8.75	(92)
May 15: Both sexes		42	33	94	8	4	8		1	2						192		3.69
May 17: Both sexes	1	73	49	46	3	2	5	2			1					182		3.12
June 3: Both sexes		32	51	113	27	20	16	5	3	2	2	1	1		1	274		4.32
June 8: Both sexes	1	40	54	90	9	10	8	3	1	1						217		3.72
June 12: Both sexes		21	62	66	6	3	1									159		3.44
June 14, 18: Both sexes		40	59	47	6	2	3		2							159		3.31
Total:																		
April 4–23:																		
Males				5	11	59	88	69	36	21	8	3	1	2		303	7.58	
Females				1	5	31	79	40	28	40	23	11	8	1		267	8.40	
Both sexes				6	16	90	167	109	64	61	31	14	9	3		570		7.96
May 15–June 18:																		
Both sexes	2	248	308	456	59	41	41	10	7	5	3	1	1		1	1,183		3.67

[1] Average number of annuli. [2] Number of fish in parentheses. [3] No females taken on April 6.

difference was twice that of spawning-run samples (0.53 or 0.60). Furthermore, since the average age in late spring (3.67) was less than half that in the spawning run (7.96), the relative variation of age was even greater during the later collection period. The trend in the variation of age was irregular in the early part of the collecting period. The average age dropped from 3.69 on May 15 to 3.12 (the minimum average) on May 17 and rose sharply to the maximum of 4.32 on June 3. Over the period June 3 to June 14 and 18, however, the mean age decreased consistently (from 4.32 to 3.31) as the season advanced. Age-group IV was dominant in 4 of the 6 collections (in the combined collections also) with age-groups II and III the strongest in 1 sample each. Because of the considerable variation of age in late spring, conclusions based on a single sample might vary considerably according to the date of collection. On the basis of only the May 15 collection, for example, one might be inclined to conclude with some confidence that age-group IV (94 fish, or 49 percent of the total sample of 192) was dominant in the late-spring season. Had the one available collection been taken 2 days later (May 17) one might believe that the II group (73 fish, or 40 percent in a total of 182 walleyes) was the strongest. Thus, for the late-spring period a series of samples is desirable. Even so, the variability of the age composition from date to date leaves in some doubt the actual conditions within the population as a whole.

In 1930 (table 6) the mean age of the samples (sexes combined) increased from 4.31 on April 30 to a maximum of 5.05 on May 8, 11, and 13, and thereafter followed a distinct although irregular downward trend. The range of variation was from 5.05 to 3.30 (June 3)—a difference of 1.75. The extent to which ages differed in the earlier and later parts of the collecting period is illustrated by the fact that the highest average age after the May 15 and 17 collection was below the mean in that collection or any earlier one. Furthermore, the average age over the period May 22–June 20 was only 3.74 as compared with 4.50 for April 30–May 17—a difference of 0.76.

The variations in the average age of walleyes from sample to sample in the late spring of 1930 were accompanied by shifts in the dominance of age groups. Three of the first four collections were

TABLE 6.—*Age composition and average age of Saginaw Bay walleyes in 1930*

Date of collection	Number in age group—											Total	Average age [1]	
	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII		By sex	Both sexes [2]
April 30:														
Males		19	49	27	3							98	4.14	4.31
Females		4	27	28	6							65	4.55	(163)
May 3, 5:														
Males	1	19	50	25	2	2						99	4.14	4.36
Females		4	19	9	1	1	3		1		1	39	4.92	(138)
May 8, 11, 13:														
Males		7	31	30	3	1	2					74	4.54	5.05
Females		6	16	37	5	9	5	5	1		1	85	5.49	(159)
May 15, 17:														
Males	4	10	31	16								61	3.97	4.12
Females		8	21	7		1		1		1		39	4.36	(100)
May 22, 24:														
Males	2	25	18	1	1	1						48	3.52	3.89
Females	2	32	24	8	2	2		1		1	2	74	4.13	(122)
May 26, 29:														
Males	3	26	21	5		1						56	3.57	4.02
Females	3	26	23	20	2	4	3	1	1			83	4.32	(139)
June 1, 3:														
Males	3	25	19	3								50	3.44	3.30
Females	9	26	16	1								52	3.17	(102)
June 9, 18, 20:														
Males	4	23	27	3		1						58	3.57	3.66
Females	9	37	18	10			2	2	1			79	3.73	(137)
Total:														
Males	17	154	246	110	9	6	2					544	3.94	
Females	23	143	164	120	16	17	13	10	4	2	4	516	4.36	
Both sexes	40	297	410	230	25	23	15	10	4	2	4	1,060		4.14

[1] Average number of annuli. [2] Number of fish in parentheses.

dominated by age-group IV, the fourth (May 8, 11, and 13) by the V group. Every one of the last four collections was dominated by age-group III. Thus 5 of 8 samples each containing 100 or more walleyes [7] disagreed with the combined collections (in which age-group IV dominated) as to which age group was strongest. Again it is seen that a single sample from the late-spring collecting period, even though it be of fair size, can prove misleading and that even with an abundance of samples the variation in age composition inevitably leaves doubt as to the actual situation in the general population.

In earlier discussion of the age composition of the 1929 spawning run it was observed that the mean ages of males and females varied "more or less independently" from sample to sample. In the late-spring collections of 1930 the variations of the ages of males and females were closely correlated. Although this relation is clearly detectable from the data of table 6, the closeness of the correlation can be brought out more forcefully by the figures in table 7 in which the daily mean ages of the sexes are recorded in the descending order of the average ages of the males. So similar were these day-to-day variations that the coefficient of correlation (r) between the two series of averages was 0.913. This figure is far beyond that which ordinarily would be termed highly significant (at $df=15$, $r=0.606$ for $p=0.01$). It is concluded therefore that the factors which determine the day-to-day changes of age composition in late-spring collections operate in the same way on males and females.

[7] A minimum sample of 100 fish was the basis for combining the catches of certain days to form a single sample.

TABLE 7.—*Variation in average age of male and female Saginaw Bay walleyes in daily samples collected in 1930*

[Collections arranged in descending order of mean age of males]

Date of collection	Males		Females	
	Number of fish	Average age [1]	Number of fish	Average age [1]
May 8	9	4.89	18	6.06
May 11	40	4.72	43	5.58
May 3	50	4.24	20	5.45
April 30	98	4.14	65	4.55
May 15	23	4.13	14	5.29
May 13	25	4.12	24	4.92
May 5	49	4.04	19	4.37
May 26	28	3.93	54	4.81
May 17	38	3.87	25	3.84
June 9	29	3.72	33	3.88
June 3	30	3.60	30	3.33
May 24	30	3.57	47	4.55
June 18	4	3.50	3	4.00
May 22	18	3.44	27	3.41
June 20	25	3.40	43	3.60
May 29	28	3.21	29	3.41
June 1	20	3.20	22	2.95
Total or average	544	[2] 3.87	516	[2] 4.35

[1] Average number of annuli.
Unweighted means of averages for the individual collections.

RELATIVE STRENGTH OF YEAR CLASSES

1926–30 collections

The great seasonal variation in age composition of the Saginaw Bay walleye imposes severe limitations on the use of the data of table 4 to estimate the relative strength of the year classes. Obviously, the comparisons of the representation of age groups on which such estimates are based can be made only between samples taken at the same time of year (spawning period, late spring, fall). Difficulties are increased by the circumstance that for only 1 of the 3 periods, late spring, were the two available collections made in consecutive calendar years (1929 and 1930). Despite these limitations, some general ideas concerning the strength of the year classes may be developed.

Year-classes 1914–16 were represented by too few fish to warrant speculation as to their probable strength. For the remaining year classes, estimates of relative strength will be made from (1) comparisons of the percentage age composition of samples from the same collecting season (spawning period, late spring, fall) but from different calendar years, and (2) comparisons of the ratios of numbers of fish in consecutive age groups in different collections.

The evidence from the percentage age composition probably can be presented most effectively in a condensed form (table 8). The manner of reading the table perhaps can be illustrated best by specific examples. The first line, for example, states that the year-class 1917 which made up 3.9 percent of a spawning-run collection as age-group X is estimated to have been weaker than year-class 1919 which accounted for 10.7 percent of a spawning-run sample at the same age. Similarly, the high representation (95.5 percent) of year-class 1925 as the I group of a fall collection suggests that it was stronger than year-class 1927 which accounted for only 73.1 percent at the same age. Finally, the nearly equal representations of 1926 and 1927 year classes as age-group III (26.0 and 28.0 percent, respectively) in late-spring samples indicates that they were of approximately the same strength.

The estimates in table 8 are by no means equally reliable as both the numbers of fish and the differences between pairs of percentages varied widely. Neither can it be assumed that any one of the pairs of percentages offers an unbiased estimate of the true relative strength of the year classes involved. Important but undeterminable factors can intervene to distort the data. It is conceivable, for example, that the relatively weak percentage representation of the older age groups (and hence stronger representation of younger fish) in the 1927 samples as compared with the 1929 spawning run (table 4) may have resulted from a particularly intensive fishery in the years prior to 1927, and hence reflect only a high fishing mortality. Again, the much stronger representation of the I group in 1926 (95.5 percent) than in 1928 (73.1 percent) does not necessarily mean a correspondingly greater relative strength for the 1925 year class as compared with year-class 1927. Year-class 1925 may seem strong only because year-class 1924 was too weak to give the II group its "normal" representation in 1926, or conversely, year-class 1927 may appear weak only because a strong 1926 year class contributed more than the usual number of II-group walleyes in 1928 (actually, there is evidence that year-class 1924 was weak). The same, of course, holds for all collections—age composition can be influenced by earlier fishing intensity and exceptionally strong percentage representation of one age group makes others appear relatively weak, and *vice versa.*

TABLE 8.—*Relative strength of certain year classes of the Saginaw Bay walleye as indicated by their percentage representation at corresponding ages in different collections*

Estimated relative strength of year classes	Time of collection [1]	Age group	Percentage representation of age group as—	
			Earlier year class	Later year class
1917<1919	SR	X	3.9	10.7
1918<1920	SR	IX	6.3	11.2
1919=1921	SR	VIII	18.9	19.1
1920=1922	SR	VII	27.6	29.3
1921>1923	SR	VI	26.0	15.8
1922>1924	SR	V	10.2	2.8
1922>1923	LS	VII	3.5	2.2
1923<1925	F	III	.3	6.8
1923>1924	LS	VI	3.5	2.3
1924<1926	F	II	2.3	18.5
1924<1925	LS	V	5.0	21.7
1925>1927	F	I	95.5	73.1
1925=1926	LS	IV	38.5	38.7
1926=1927	LS	III	26.0	28.0
1927>1928	LS	II	21.0	3.8

[1] SR=spawning run; LS=late spring; F=fall.

Although the best evidence concerning the relative strength of the year classes probably is that provided by comparisons of the percentage age composition of the samples, some valuable additional information is to be had from data on the ratio of the numbers of fish in successive age groups within collections. The numerical distribution of fish within a sample according to age usually follows a characteristic pattern. Some of the younger age groups may be poorly represented (gear selection or segregation on the basis of maturity or size) but among the older fish increase of age normally is accompanied by a regular decrease in numbers. Any sharp deviation from the typical pattern of decrease is suggestive of abnormal strength or weakness in the year class or classes responsible for the irregularity. To illustrate this point, let us assume that the numbers of fish in age-groups VI and V ordinarily are in about the ratio of 1:2. If a particular collection contains 20 VI-group and 20 V-group fish (ratio of 1:1) we have evidence of weakness in the year class represented by the V group or of strength in the one represented by the VI group. Similarly, a collection with 10 VI-group and 50 V-group individuals (ratio of 1:5) indicates the younger fish belong to the relatively stronger year class. Even among those younger age groups that are subject to selection, deviations from the customary ratio can provide information.

Preliminary to the employment of ratios of numerical representation of age groups, it is necessary to establish as accurately as possible the general pattern of the variation in numbers with age. The basic usable data for the Saginaw Bay walleye (table 9) demonstrate at once that in ratios of numbers as in percentage age composition different kinds of collections (spawning-run, late-spring, and fall) follow different trends. It is true that over the age range XII–XI to VIII–VII the averages at the bottom of the table were based on combinations of spawning-run and late-spring samples. In the data for age-groups VII–VI and VI–V, however, the materials had to be separated since selection as to maturity decreased the representation of the younger age groups of the spawning runs. Similarly, the fall and late-spring collections were treated separately since the trends of numerical abundance with increase in age were dissimilar.

The number of collections contributing to the averages of table 9 was only two or four (the averages given in the footnotes were based on two collections) and certain of the individual ratios were based on extremely small numbers of fish. Despite these obvious inadequacies the averages exhibited remarkably small variation over the range XII–XI to VIII–VII. For the combined collections the range of the ratios was 0.52 to 0.84; the means of the individual ratios varied from 0.56 to 0.82. At the lower ages VII–VI to III–II (data based only on late-spring collections of 1929 and 1930) the ratios ranged from 0.23 to 2.10 (combined collections) and from 0.34 to 4.33 (mean of ratios). Some of them certainly cannot be held to represent typical conditions. The value of 0.96 as the ratio of the numbers of walleyes in age-groups VII and VI, for example, should not be interpreted to indicate that normally the two groups are almost equally plentiful in random samples.

TABLE 9.—*Ratios of the numbers of fish in successive age groups of the Saginaw Bay walleye in the 1926–30 collections*

[Numbers in age groups in parentheses]

Collection	Ratio of numbers and numbers in age groups—										
	XII–XI	XI–X	X–IX	IX–VIII	VIII–VII	VII–VI	VI–V	V–IV	IV–III	III–II	II–I
Fall 1926									[1] 3.00 (3–1)	[1] 0.14 (1–7)	0.02 (7–291)
Fall 1928									[1] 0.12 (1–8)	[1] 0.36 (8–22)	0.25 (22–87)
Spawning run 1927	0.50 (2–4)	0.80 (4–5)	0.62 (5–8)	0.33 (8–24)	0.69 (24–35)	[2] 1.06 (35–33)	[2] 2.54 (33–13)	[2] 13.00 (13–1)			
Spawning run 1929	0.45 (14–31)	0.51 (31–61)	0.95 (61–64)	0.59 (64–109)	0.65 (109–167)	[2] 1.86 (167–90)	[2] 5.62 (90–16)	[2] 2.67 (16–6)			
Late spring 1929	0.33 (1–3)	0.60 (3–5)	0.71 (5–7)	0.70 (7–10)	0.24 (10–41)	1.00 (41–41)	0.69 (41–59)	0.13 (59–456)	1.48 (456–308)	1.24 (308–248)	
Late spring 1930	2.00 (4–2)	0.50 (2–4)	0.40 (4–10)	0.67 (10–15)	0.65 (15–23)	0.92 (23–25)	0.11 (25–230)	0.56 (230–410)	1.38 (410–297)	7.42 (297–40)	
Combined collections:											
Ratio	0.52	0.53	0.84	0.56	0.59	0.97	0.23	0.33	1.43	2.10	0.08
Total number	(21–40)	(40–75)	(75–89)	(89–158)	(158–266)	(64–66)	(66–289)	(289–866)	(866–605)	(605–288)	(29–378)
Average of ratios	0.82	0.60	0.67	0.57	0.56	0.96	0.40	0.34	1.43	4.33	0.14

[1] Data not included at bottom of table. The ratios (combined collections and average ratios, respectively) for the fall collections are 0.44 and 1.56 for age-groups IV–III and 0.31 and 0.25 for age-groups III–II.

[2] Ratio probably affected by selection on basis of maturity; data not included at bottom of table. The ratios (combined collections and average ratios, respectively) in the spawning run are 1.64 and 1.46 for age-groups VII–VI, 4.24 and 4.08 for age-groups VI–V, and 4.14 and 7.83 for age-groups V–IV.

For the next two comparisons (VI–V and V–IV), the ratios are almost certainly too low as the result of a large difference between the original abundance of year-classes 1924 and 1925. High values more than 1.0 at IV–III and III–II in the late-spring collections may be in part the result of a normal scarcity of the younger fish on the grounds at that season. At least one of the ratios, 7.42 at III–II in 1930, must have been high because the younger age group represented a weak year class.

Values of the ratio consistently above 1.0 for comparisons of age-groups VII and VI and for younger fish in the spawning-run samples can be explained, as stated previously, on the basis of selection according to maturity. Despite this selection the ratios indicate conditions at the spawning period and hence have some usefulness in the estimation of the strength of the year classes.

The value of the data for the fall collections is limited greatly by the scarcity of walleyes older than the I group. Here, as with the younger age groups of the late-spring collections, the ratios varied widely, and here also the lowest ratio, 0.02 at II–I in 1926, came from a comparison of year-classes 1924 and 1925.

The sources of error and of distortion of the data just outlined were kept in mind when estimates of the relative strength of successive year classes were made from the data of table 10. Some of the decisions were most difficult, some probably incorrect; yet it is encouraging to observe that the general trends as estimated from the ratios and from the percentage age composition of the samples were similar (table 11).

It is possible from the data of table 11 to form some idea of the rankings of the several year classes. If, for example, 1917 is assigned a "position" of 0 and the later year classes successively assigned higher or lower positions according to their indicated strength (in comparison with the preceding year class or classes), it is possible to arrive at the following sequence of positions which is in conflict with only two estimates of the table (1919=1921; 1925=1926). Both disagreements were unavoidable because of discrepancies among the estimates.

Year class	Position	Year class	Position
1917	0	1923	1
1918	1	1924	0
1919	3	1925	2
1920	2	1926	1
1921	2	1927	1
1922	2	1928	0

Although these rankings are valid to the extent that they conform well with the data of table 11 they are defective in the sense that the positions were determined by the mere occurrence of a stronger or weaker year class in the sequence and took no account of their actual relative strengths. (The increases of two in the positions from 1918 to 1919 and from 1924 to 1925 were required by the estimates of table 11 and are not attempts to measure the advantage of the more recent year classes.) The original data are not as a whole sufficiently extensive or dependable to warrant an attempt at greater exactitude than that involved in the assignment of successive positions. In two situations, however, the evidence of extremely large differences between successive year classes is so strong as to make desirable an adjustment of the preceding tabulation. There can be little question that year-class 1925 was far stronger than year-class 1924 and that year-class 1928 was much weaker than year-class 1927. These large differences, if not to be measured exactly, can be accorded some recognition if the change of position from 1924 to 1925 is increased from 2 to 3 and that from 1927 to 1928 from 1 to 3. With these adjustments the new positions for year-classes 1925 to 1929 become: 1925, 3; 1926, 2; 1927, 2; 1928, −1.

TABLE 10.—*Estimates of the relative strength of certain year classes of the Saginaw Bay walleye as indicated by the ratios of the numbers of fish in successive age groups*

Relative strength of year classes	Time of collection [1]	Earlier year class: Age group	Earlier year class: Number	Later year class: Age group	Later year class: Number	Ratio of numbers	General ratio of age groups—: From total numbers	General ratio of age groups—: Mean of ratios
1917<1918	1927SR	X	5	IX	8	0.62	0.84	0.67
	1929SR	XII	14	XI	31	.45	.52	.82
	1929LS	XII	1	XI	3	.33		
1918<1919	1927SR	IX	8	VIII	24	.33	.56	.57
	1929SR	XI	31	X	61	.51	.53	.60
	1929LS	XI	3	X	5	.60		
	1930LS	XII	4	XI	2	2.00	.52	.82
1919>1920	1927SR	VIII	24	VII	35	.69	.59	.56
	1929SR	X	61	IX	64	.95	.84	.67
	1929LS	X	5	IX	7	.71		
	1930LS	XI	2	X	4	.50	.53	.60
1920=1921	1927SR	VII	35	VI	33	1.06	1.04	1.46
	1929SR	IX	64	VIII	109	.59	.56	.57
	1929LS	IX	7	VIII	10	.70		
	1930LS	X	4	IX	10	.40	.84	.67
1921=1922	1927SR	VI	33	V	13	2.54	4.24	4.08
	1929SR	VIII	109	VII	167	.65	.59	.56
	1929LS	VIII	10	VII	41	.24		
	1930LS	IX	10	VIII	15	.67	.56	.57
1922>1923	1926F	IV	3	III	1	3.00	.44	1.56
	1927SR	V	13	IV	1	13.00	4.14	7.83
	1929SR	VII	167	VI	90	1.86	1.64	1.48
	1929LS	VII	41	VI	41	1.00	.97	.96
	1930LS	VIII	15	VII	23	.65	59	.56
1923>1924	1926F	III	1	II	7	.14	.31	.25
	1929SR	VI	90	V	16	5.62	4.24	4.08
	1929LS	VI	41	V	59	.69	.23	.40
	1930LS	VII	23	VI	25	.92	.97	.96
1924<1925	1926F	II	7	I	291	.02	.08	.14
	1928F	IV	1	III	8	.12	.44	1.56
	1929SR	V	16	IV	6	2.67	4.14	7.83
	1929LS	V	59	IV	456	.13	.33	.34
	1930LS	VI	25	V	230	.11	.23	.40
1925>1926	1928F	III	8	II	22	.36	.31	.25
	1929LS	IV	456	III	308	1.48	1.43	1.43
	1930LS	V	230	IV	410	.56	.33	.34
1926=1927	1928F	II	22	I	87	.25	.08	.14
	1929LS	III	308	II	248	1.24	2.10	4.33
	1930LS	IV	410	III	297	1.38	1.43	1.43
1927>1928	1930LS	III	297	II	40	7.42	2.10	4.33

[1] SR=spawning run; LS=late spring; F=fall.

TABLE 11.—*Summary of estimates of the relative strength of year-classes 1917 to 1928 of the Saginaw Bay walleye*

[Based on tables 8 and 10]

Basis of estimate	*Estimated relations among year classes*											
Ratios of numbers in successive age groups	1917<	1918<	1919>	1920=	1921=	1922>	1923>	1924<	1925>	1926=	1927>	1928
Percentage age composition of samples	1917	<	1919	=	1921	>	1923	<	1925	>	1927	----
	------	1918	<	1920	=	1922	>	1924	<	1926	------	----
	------	------	------	------	------	1922>	1923>	1924<	1925=	1926=	1927>	1928

If the adjusted positions just given are used and the whole series shifted to a mean position of 0.00, the following final estimate of rank is obtained (see fig. 2):

Year class	Rank	Year class	Rank
1917	−1.42	1923	−0.42
1918	−.42	1924	−1.42
1919	1.58	1925	1.58
1920	.58	1926	.58
1921	.58	1927	.58
1922	.58	1928	−2.42

The preceding "final rankings" are offered merely as the best estimate of the relative strength of the various year classes that could be obtained from difficult data. The treacherous nature of chains of estimates is realized fully. Nor is any claim made that individual decisions were based on fixed objective standards. Because the estimates were based so largely on personal interpretation of diffuse and indefinite evidence, full tabular materials have been provided.

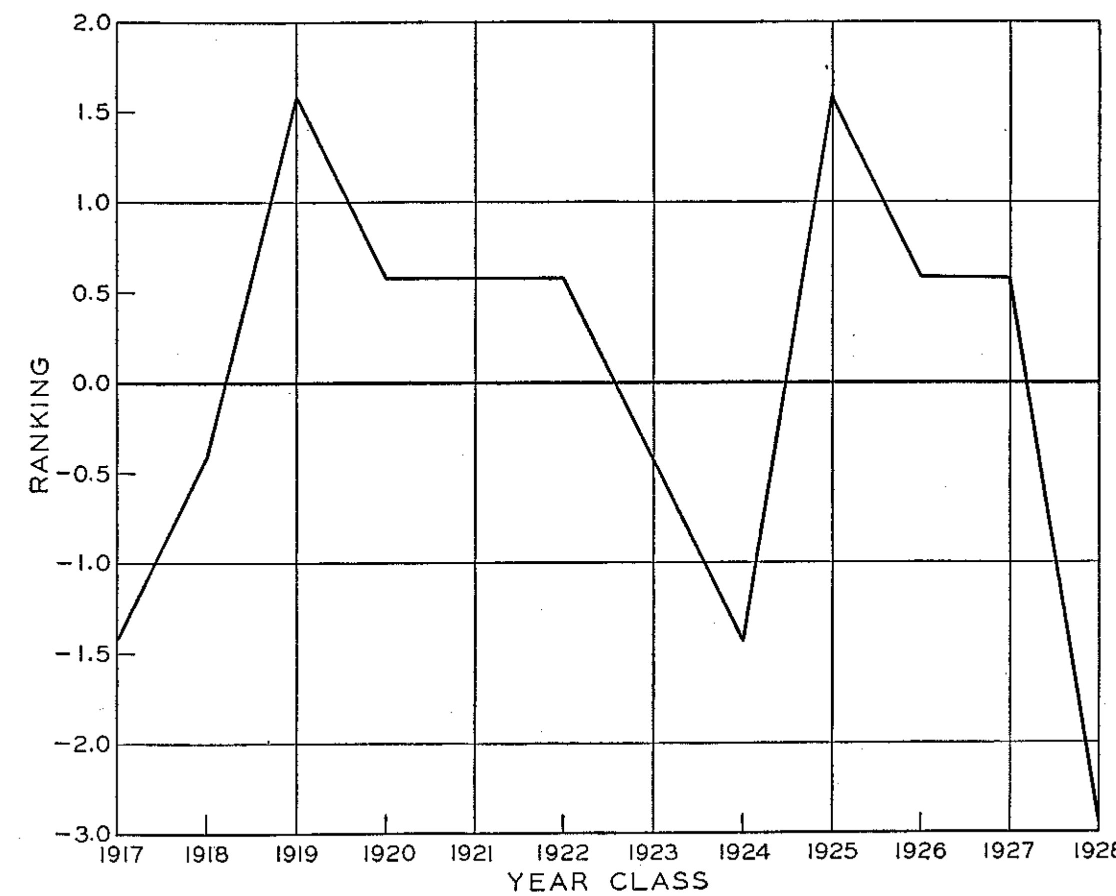

FIGURE 2.—Fluctuations in the relative strength of year-classes 1917 to 1928 of the Saginaw Bay walleye.

Preliminary analyses gave strong evidence for correlation between certain meteorological conditions and the fluctuations in the strength of the 1917 to 1928 year classes. The indicated relation failed completely, however, to hold up for year classes of the 1943 collection, a discussion of which follows. Inquiry into factors influencing the strength of year classes of the Saginaw Bay walleye must wait until work now in progress makes information available over a longer series of years.

1943 collection

Interpretation of the data on age and year-class composition in 1943 (table 12) is made difficult not only by the lack of comparable data for adjacent years but also by some uncertainty as to the proper classification of the sample with respect to "type" of collection. Examination of the gonads revealed that spawning was still in progress; on the other hand, immature fish, ordinarily absent or rare in spawning-run collections, were numerous among the younger females. Presumably the 1943 collection was intermediate between the spawning-run and late-spring samples of earlier years.

TABLE 12.—*Age and year-class composition of Saginaw Bay walleyes collected May 4, 1943*

Year class	Age group	Sex: Males	Sex: Females	Sex: Both	Percentage of total
1930	XIII	------	2	2	0.7
1931	XII	------	1	1	.3
1933	X	3	1	4	1.4
1934	IX	3	2	5	1.8
1935	VIII	2	------	2	.7
1936	VII	5	3	8	2.8
1937	VI	14	16	30	10.4
1938	V	3	1	4	1.4
1939	IV	49	30	79	27.4
1940	III	101	50	151	52.4
1941	II	1	1	2	.7
Total	------	181	107	288	------
Average age [1]	------	3.91	4.30	4.06	------

[1] Average number of annuli.

Age-group III was strongly dominant (52.4 percent) in 1943 with the IV group second (27.4 percent). The VI group (10.4 percent) held third place. The remaining age groups were represented sparsely (0.3 to 2.8 percent). The extremely low percentage (1.4) for age-group V indicates that the 1938 year class was exceptionally weak. Conceivably, unusual strength of year-class 1937 made year-class 1938 seem weaker than it was in fact. On the other hand, the point should be made that age-groups IX and X were represented as well as or better than the V group. It is highly probable that year-class 1941 also was extremely weak. Segregation on the basis of maturity cannot explain the low representation of the year class since immature fish made up the large majority of the III-group females. Neither does segregation as to size offer a satisfactory explanation as growth of walleyes of the 1943 sample was much more rapid than in earlier years when II-group fish were taken in abundance.

SIZE AT CAPTURE

LENGTH AND WEIGHT OF THE AGE GROUPS

For the presentation of the average lengths and weights of the age groups at capture (table 13) data for fish of the 1926–30 collections that had completed the same number of growing seasons (see footnote to table) have been combined. True, walleyes of corresponding age and sex in different years did not agree perfectly as to average size. The differences that did occur, however, were not large and could be accounted for satisfactorily on the basis of the small numbers of fish in certain collections or as the result of the annual fluctuations in growth rate that are known to have occurred during and preceding the years of collection. Data for the 1943 collection have been tabulated separately since walleyes captured in that year had grown much more rapidly than had the fish of the earlier samples.

A detailed discussion of table 13 is not desirable, as more adequate and detailed information will be available from later tabulations of calculated growth in length and weight. Treatment will be limited, therefore, to brief comments on the general trends of increase of size with age, on sex differences in growth, and on the increased growth of fish of the 1943 collection.

At the end of 2 growing seasons the male and female walleyes of the 1926–30 samples had the same average length (10.0 inches). In 3 years (in this section the terms "years" and "growing seasons" are used interchangeably) the females (12.7 inches) were 0.1 inch longer than the males (12.6 inches). To this advantage the females added consistently to the end of 9 growing seasons when their average length (22.8 inches) was 3.5 inches greater than that of the males (19.3 inches). During the later years of life the length advantage of

TABLE 13.—*Average total lengths and weights of the age groups of male and female Saginaw Bay walleyes collected in 1926–30 and 1943*

[Number of fish in parentheses]

Age groups and number of completed growing seasons [1]	1926–30 collections: Males Length	Males Weight	Females Length	Females Weight	1943 collection: Males Length	Males Weight	Females Length	Females Weight
	Inches	*Lbs.*	*Inches*	*Lbs.*	*Inches*	*Lbs.*	*Inches*	*Lbs.*
I–II	10.0	0.32	10.0	0.31	------	------	------	------
(2 seasons)	(170)	(25)	(195)	(50)	------	------	------	------
II–III	12.6	0.59	12.7	0.59	16.4	1.41	17.0	1.59
(3 seasons)	(161)	(158)	(153)	(149)	(101)	(101)	(50)	(50)
III–IV	14.4	0.89	14.7	0.96	17.5	1.69	18.6	2.10
(4 seasons)	(251)	(250)	(166)	(166)	(49)	(49)	(30)	(30)
IV–V	15.9	1.28	16.5	1.44	18.5	2.04	21.2	3.38
(5 seasons)	(113)	(110)	(121)	(121)	(3)	(3)	(1)	(1)
V–VI	17.3	1.36	18.6	1.88	19.8	2.59	22.1	3.45
(6 seasons)	(81)	(9)	(68)	(16)	(14)	(14)	(16)	(16)
VI–VII	18.0	1.83	20.1	2.62	20.3	2.61	23.4	4.25
(7 seasons)	(131)	(25)	(131)	(35)	(5)	(5)	(3)	(3)
VII–VIII	18.5	1.85	21.3	3.05	20.2	3.05	------	------
(8 seasons)	(87)	(5)	(70)	(19)	(2)	(2)	------	------
VIII–IX	19.3	2.42	22.8	4.25	21.2	3.33	24.6	4.59
(9 seasons)	(41)	(2)	(48)	(15)	(3)	(3)	(2)	(2)
IX–X	21.1	3.19	23.8	4.91	22.3	3.84	25.0	5.56
(10 seasons)	(24)	(2)	(52)	(7)	(3)	(3)	(1)	(1)
X–XI	21.7	3.71	24.9	5.48	------	------	------	------
(11 seasons)	(10)	(1)	(30)	(4)	------	------	------	------
XI–XII	22.1	------	25.9	5.96	------	------	26.5	5.75
(12 seasons)	(3)	------	(19)	(5)	------	------	(1)	(1)
XII–XIII	23.5	------	26.1	6.88	------	------	28.9	7.60
(13 seasons)	(2)	------	(10)	(1)	------	------	(2)	(2)
XIII–XIV	21.3	------	27.3	------	------	------	------	------
(14 seasons)	(2)	------	(1)	------	------	------	------	------
XIV–XV	------	------	28.2	6.75	------	------	------	------
(15 seasons)	------	------	(1)	(1)	------	------	------	------

[1] The age groups at left apply to fall collections taken after completion of season's growth, and those at right to spring collections, made before growth began. Fish enter the next higher age group on January 1.

the females varied irregularly between the minimum of 2.6 inches at the end of 13 seasons (males, 23.5 inches; females 26.1 inches) and the maximum of 6.0 inches at the end of 14 when two males averaged 21.3 inches and the single female was 27.3 inches long. Much of this variation can be ascribed to the small numbers of fish at the higher ages.

The increments of length for the males were 2.6 inches for the third growing season, between 1 and 2 inches in the fourth through the sixth, and less than 1 inch in the seventh through the ninth. For older ages the increments ranged between 1.8 (tenth season) and −2.2 inches (fourteenth). The length increments of the females were 2.7 inches in the third year and from 1.8 to 2.1 inches in the fourth through the sixth years; they did not fall below 1 inch before the thirteenth season.

The weights[8] of the male and female walleyes of the 1926–30 samples were the same or nearly the same at the end of 2 (males, 0.32 pound; females, 0.31 pound) and 3 growing seasons (each sex, 0.59 pound). At the end of 4 years, however, the mean weight of the females (0.96 pound) was 0.07 pound greater than that of males (0.89 pound). The females added to this advantage with a fair degree of consistency during subsequent years. The weight advantage of the females first amounted to more than a half pound at the end of 6 seasons (males, 1.36 pounds; females, 1.88 pounds) and first exceeded a pound at the end of 8 (males, 1.85 pounds; females, 3.05 pounds). In the ninth through the eleventh years the females were the heavier by about 1¾ pounds (no males older than 11 growing seasons were weighed).

The increments of weight of both the male and female walleyes of the 1926–30 collections varied erratically. For the males in the third through the eighth years the values ranged between 0.02 pound (eighth year) and 0.47 pound (seventh). The increments of the ninth through the eleventh years all exceeded a half pound (0.52 to 0.77 pound). The increments of weight for the females were all less than a half pound (0.28 in the third year to 0.48 in the fifth) in the third through the sixth growing season. During the later years the values ranged from 0.43 pound (eighth growing season) to 1.20 pounds (ninth). In only 1 year (tenth) did the weight increment of the males (0.77 pound) exceed that of the females (0.66 pound).

Both the males and females of the 1943 collection averaged longer and heavier than walleyes of corresponding age and sex of the 1926–30 samples (the only exception—weight of females at the end of 12 growing seasons was based on only 5 fish in 1926–30 and 1 in 1943). For the males the length advantage of the 1943 walleyes was greatest at 3.8 inches at the end of 3 years and thereafter followed a downward trend to a minimum of 1.2 inches at the end of the tenth year. For the females the maximum advantage of the 1943 fish (4.7 inches) occurred at the end of the fifth year beyond which point the trend again was downward. The advantages of the 1943 over the 1926–30 walleyes were relatively much greater with respect to weight than length. In 4 of the comparisons the fish of the more recent collection were more than twice as heavy as those of the earlier, and in 7 of them the advantage of the 1943 fish exceeded a pound.

[8] Since in most age groups fewer fish were weighed than were measured, the mean length and the mean weight of an age group do not necessarily correspond.

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Sex differences in average size were established at an earlier age in the 1943 than in the 1926–30 collections. At the end of 3 growing seasons, for example, the 1943 females (length, 17.0 inches; weight, 1.59 pounds) averaged 0.6 inch longer and 0.18 pound heavier than the males (length, 16.4 inches; weight, 1.41 pounds). At the same age the advantage of the 1926–30 females over the males was only 0.1 inch with respect to length and was nil with respect to weight. For walleyes of approximately the same average size, however, sex differences in the two collections were similar. As an illustration, the difference between the 1926–30 males and females at the end of 5 seasons (0.6 inch; 0.16 pound) was much the same as that between 1943 males and females (0.6 inch; 0.18 pound) at the end of 3 years. Similarly at the end of 6 seasons the advantage of 1926–30 females over males of the same age (1.3 inches; 0.52 pound) was only a little greater than the advantage of the 1943 females at the end of 4 years (1.1 inches; 0.41 pound). It appears, therefore, that size rather than age determines the time of appearance and the extent of sex differences in the growth of the Saginaw Bay walleye.

LENGTH DISTRIBUTION OF THE AGE GROUPS

Data on the length-frequency distribution of the age groups (tables 14, 15, and 16) are so arranged that the collections of 1926–30 and 1943 are treated separately, and walleyes of the earlier collections that had completed the same number of growing seasons are combined regardless of their age designation.

The range in length of most of the well-represented age groups of males collected in 1926–30 (table 14) fell within the limits of 5 to 8 inches[9] (exception for walleyes that had completed 6 growing seasons). For the females (table 15), which had a somewhat greater scatter, the ranges were mostly between 6 and 9 inches (exception at 9 growing seasons).

These relatively large ranges of length were so much greater than the annual increments of length that extensive overlapping of the distributions characterized the data for both sexes. In a random sample from the general population only one of the ages represented—walleyes that had completed 2 growing seasons—could be expected to form a distinct mode in the frequency distribution for all ages combined (see also p. 25). In later years (and for some 2-year fish) length *per se* is a poor index of age. In the males, for example, every length interval from the one with its center at 13.8 inches to the one at 23.1 inches was represented by from 3 to 7 ages. The maximum range of age was 9 years at 21.8 inches; representatives actually were present for 7 of the 9 ages. The mean range of ages at 13.8 to 23.1 inches was 5.1. Similarly with the females, every length from 12.0 to 28.3 inches was represented by 3 to 7 ages. The maximum range of ages (at 20.5 inches) was 8, of which 7 were represented. The mean range at 12.0 to 28.3 inches was 4.9 years.

The data on the length-frequency distribution of the age groups of the 1943 sample (table 16) are too few to warrant a detailed discussion. The length ranges of the age groups ran smaller in the 1943 than in the 1926–30 samples, but the difference might not have existed had the numbers of fish been greater in 1943.

Changes since 1926 in the minimum legal size of walleyes in Saginaw Bay waters make it desirable to give the percentages of legal fish at different ages as estimated from each of three size limits. A minimum size of 1½ pounds[10] (in the round) was in effect during the 1926–30 collecting period and subsequently through 1932. From 1933 to 1938, inclusive, the minimum legal size was 16½ inches total length, and since that time it has been 15½ inches.

With the exception of a single 3-year-old male that was more than 15½ but less than 16½ inches long, no walleyes of the 1926–30 collections were legal-sized in less than 4 growing seasons under any of the three limits. Some fish were legal (1 to 22 percent according to sex and size limit) at the end of 4 seasons, and the percentage increased rapidly with increase in age. Among the males more than half were legal-sized in 5 years at the 15½-inch limit (57 percent) and in 6 years at limits of 16½ inches (83 percent) and 1½ pounds

[9] In estimating ranges from the tables, 0.8 or 0.9 inch must be added to the differences between the midpoints of the terminal frequency intervals.

[10] Because records of weight were lacking for some of the 1926–30 collections, the percentages of legal-sized fish under the 1½-pound limit as given in tables 14 and 15 were determined on the basis of a legal minimum length of 375 millimeters, standard length (17.1 inches, total length). This length was computed from the general length-weight equation (p. 27) to be equivalent to a weight of 1½ pounds. For table 16 the percentage legal at 1½ pounds was determined from actual weights at capture.

TABLE 14.—*Length frequencies of male Saginaw Bay walleyes of the 1926–30 collections according to number of completed growing seasons*

[Age groups of fall collections combined with next higher age groups of spring collections. Fish enter the next higher age group on January 1]

Total length	Standard length	Number of fish that completed growing season—												
		2	3	4	5	6	7	8	9	10	11	12	13	14
	Mm.													
8.6 in.	185	13												
9.5 in.	204	74												
10.3 in.	224	65	4											
11.1 in.	244	14	16	2										
12.0 in.	263	3	45	4										
12.9 in.	282		64	43										
13.8 in.	302	1	24	63	4	1	1							
14.7 in.	322		7	76	26									
15.5 in.	341			46	32	4								
16.4 in.	360		1	13	32	21	14	2						
17.3 in.	380			3	13	35	42	17	2					
18.2 in.	400			1	6	11	37	21	3					
19.1 in.	419					5	21	25	15					
19.8 in.	438						12	17	15	6				
20.5 in.	458					2	4	2	3	4	1			
21.3 in.	478					2		3	2	8	5	2		2
22.2 in.	497								1	4	2		1	
23.1 in.	516									1	2	1		
24.0 in.	536									1				
24.8 in.	556												1	
Total		170	161	251	113	81	131	87	41	24	10	3	2	2
Average total length (in.)		10.0	12.6	14.4	15.9	17.3	18.0	18.5	19.3	21.1	21.7	22.1	23.5	21.3
Average standard length (mm.)		214	276	314	348	380	397	412	430	472	484	494	525	476
Percentage legal at—														
1½ pounds		0	0	1	13	52	79	93	100	100	100	100	100	100
16½ inches		0	0	4	30	83	94	100	100	100	100	100	100	100
15½ inches		0	1	15	57	98	99	100	100	100	100	100	100	100

TABLE 15.—*Length frequencies of female Saginaw Bay walleyes of the 1926–30 collections according to number of completed growing seasons*

[Age groups of fall collections combined with next higher groups of spring collections. Fish enter next higher age group on January 1]

Total length	Standard length	Number of fish that completed growing season—													
		2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Mm.														
7.7 in.	165	1													
8.6 in.	185	20													
9.5 in.	204	64	2												
10.3 in.	224	87													
11.1 in.	244	20	10												
12.0 in.	263	2	40	5											
12.9 in.	282	1	59	11											
13.8 in.	302		33	43	1										
14.7 in.	322		9	52	9										
15.5 in.	341			34	26	2									
16.4 in.	360			14	41	6	1								
17.3 in.	380			4	26	12	5		1						
18.2 in.	400			1	15	11	9								
19.1 in.	419			2	3	16	13	5	1						
19.8 in.	438					10	33	15	1						
20.5 in.	458					7	36	9	3	2	1		1		
21.3 in.	478					3	26	18	7	2	1				
22.2 in.	497					1	6	10	8	7	1	1			
23.1 in.	516						2	6	10	14	3	2			
24.0 in.	536							3	11	9	5				
24.8 in.	556							3	1	7	5	2	1		
25.7 in.	575							1	3	6	5	5	2		
26.6 in.	595								2	3	7	4	2		
27.4 in.	614									1	1	2	2	1	
28.3 in.	634									1	1	2	2		1
29.2 in.	653											1			
Total		195	153	166	121	68	131	70	48	52	30	19	10	1	1
Average total length (in.)		10.0	12.7	14.7	16.5	18.6	20.1	21.3	22.8	23.8	24.9	25.9	26.1	27.3	28.2
Average standard length (mm.)		216	280	322	364	412	447	475	510	533	557	579	583	610	634
Percentage legal at—															
1½ pounds		0	0	4	32	84	98	100	100	100	100	100	100	100	100
16½ inches		0	0	6	49	94	100	100	100	100	100	100	100	100	100
15½ inches		0	0	22	84	100	100	100	100	100	100	100	100	100	100

TABLE 16.—*Length frequencies of the age groups of Saginaw Bay walleyes of the 1943 collection*

[Ages correspond to numbers of completed growing seasons]

Total length	Standard length	III M	III F	IV M	IV F	V M	V F	VI M	VI F	VII M	VII F	VIII M	IX M	IX F	X M	X F	XII F	XIII F
	Mm.																	
14.7 in.	322	5																
15.5 in.	341	20	7	2	1													
16.4 in.	360	38	19	12	1													
17.3 in.	380	38	18	17	6	1												
18.2 in.	400		6	14	8			2				1						
19.1 in.	419			4	6	2		5		1								
19.8 in.	438				6			3	2	2			1					
20.5 in.	458				2			3		1			1					
21.3 in.	478						1	1	3	1								
22.2 in.	497								9		1	1	1		3			
23.1 in.	516								2		1							
24.0 in.	536										1			1				
24.8 in.	556													1		1		
25.7 in.	575																	
26.6 in.	595																1	1
27.4 in.	614																	
28.3 in.	634																	
29.2 in.	653																	
30.1 in.	673																	
30.9 in.	692																	1
Total		101	50	49	30	3	1	14	16	5	3	2	3	2	3	1	1	2
Average total length (in.)		16.4	17.0	17.5	18.6	18.5	21.2	19.8	22.1	20.3	23.4	20.2	21.2	24.6	22.3	25.0	26.5	28.9
Average standard length (mm.)		360	372	383	409	406	475	436	494	448	523	448	470	550	499	559	592	645
Percentage legal at—																		
1½ pounds		41	70	80	93	100	100	100	100	100	100	100	100	100	100	100	100	100
16½ inches		53	80	88	97	100	100	100	100	100	100	100	100	100	100	100	100	100
15½ inches		91	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

(52 percent). The maximum ages in completed growing seasons, of undersized males under the three limits were: 15½ and 16½ inches, 7; 1½ pounds, 8. A majority or nearly a majority of female walleyes of the 1926–30 samples reached legal size in 5 seasons under the 15½-inch (84 percent) and 16½-inch limits (49 percent) and in 6 years with the 1½-pound minimum (84 percent). The oldest undersized females were: 15½ inches, 5 seasons; 16½ inches, 6; 1½ pounds, 7. On the whole, males required in the neighborhood of a year longer than females to attain legal size.

As the result of their much more rapid growth, walleyes of the 1943 collection were predominantly legal at a relatively early age (table 16). Only one percentage was less than 50 (41 percent of III-group males legal-sized under the 1½-pound limit) and not one fish that had completed more than 4 growing seasons was undersized under any of the three limits.

LENGTH DISTRIBUTION OF THE CATCH OF IMPOUNDING NETS

The earlier data on age composition and the length-frequency distributions of the age groups were sufficient to make it apparent that the lengths of walleyes in random samples from commercial impounding nets vary considerably not only from year to year but also by seasons within a year. Information on the extent of this variation is summarized in table 17 which is based both on the scale collections [11] and on the measurements of large numbers of walleyes not employed in the study of age or growth. The arrangement of the table is such as to facilitate the ready comparison of the distributions of walleyes captured at the same season but in different years. The major sections illustrate the general trends within a year from the spawning season (in early spring) to autumn.

The spawning-run samples of 1927 and 1929 were distributed so irregularly that it is not possible to discuss them in terms of sharp modes or distinct trends.[12] In 1927, walleyes were most plentiful over the range,[13] 16.6 to 19.3 inches, which included 78 walleyes, or 60 percent of the entire sample. Most of the remaining fish (42 walleyes, or 32 percent of the total) were longer than 19.3 inches. The larger walleyes were relatively even more plentiful in the 1929 than in the 1927 spawning run. For example, 56 percent (336 fish) of the 1929 collection exceeded 19.3 inches as compared with the 32 percent in 1927. Fish less than 16 inches long were scarce in both years—only 5 in 1927 and 2 in 1929. The greater relative abundance of the larger fish in the 1929 spawning run led to an average length (20.1 inches) 1 inch greater than in 1927 (19.1 inches).

[11] Fish for which ages could not be determined (reading too uncertain; scales with regenerated centers or otherwise defective) were included in the preparation of the length distributions of table 17.

[12] Transformations of data that were necessary to fit the information on the 1929 spawning run into table 17 have introduced some irregularities that were not present in the original measurements. Most of the walleyes of the collection were measured to the nearest half centimeter of total length. When these measurements were tabulated in terms of centimeter intervals of standard length some intervals included two and others three of the original units of measurement. At some intervals distortion from this source was augmented by an apparent bias in the original measurements favoring full over half centimeters.

TABLE 17.—*Length-frequency distribution of Saginaw Bay walleyes according to year and season of capture*

[Random samples from commercial and experimental impounding nets]

Total length	Standard length	Spawning run 1927	Spawning run 1929	Spawning run 1943 [1]	Late spring 1929	Late spring 1930	Autumn 1926	Autumn 1928	Autumn 1929
	Mm.								
7.0 in.	151				2				
7.4 in.	160				1				
7.9 in.	170						1	2	
8.4 in.	180					2	3	5	
8.8 in.	190				8	2	26	12	2
9.3 in.	200				16	1	56	33	
9.7 in.	209				71	11	76	72	1
10.1 in.	219				114	9	86	123	1
10.5 in.	229				166	11	35	146	3
10.9 in.	239				142	14	15	109	
11.3 in.	248				98	25	8	41	6
11.8 in.	258				89	59		35	10
12.2 in.	268				134	69		39	13
12.7 in.	278				172	92	1	30	14
13.1 in.	287				190	133		30	3
13.5 in.	297	1			193	110		18	9
14.0 in.	307			1	207	115		13	3
14.5 in.	317			1	221	119	1	9	5
14.9 in.	326			4	218	107	1	12	7
15.3 in.	336	2		6	178	104	1	8	11
15.8 in.	346	2	2	25	129	74		2	11
16.2 in.	356	6	14	29	88	70		1	20
16.6 in.	365	10	26	41	57	60		2	7
17.1 in.	375	11	69	51	59	36		1	15
17.6 in.	385	11	26	29	43	31			5
18.0 in.	395	13	21	10	30	19			10
18.4 in.	404	12	38	21	21	18	1	1	1
18.9 in.	414	10	42	10	20	6			1
19.3 in.	424	11	30	8	7	6			1
19.7 in.	434	3	58	8	13	2			1
20.0 in.	443	4	37	6	19	4			1
20.3 in.	453	7	21	2	12	3			
20.7 in.	463	3	23	5	8	8		1	
21.2 in.	473	7	38	2	15	7			
21.6 in.	482	3	21	4	7	5			
22.0 in.	492	1	17	8	3	6			
22.5 in.	502		19	7	6	4			
22.9 in.	512	3	11	2	4	4			1
23.3 in.	521		18	1	1	1			
23.8 in.	531	3	11		6	3			
24.2 in.	541	2	11	2	2	2	1		
24.7 in.	551	1	10	2	2	1			
25.1 in.	560		4		2	5			
25.5 in.	570		15		3	4			
25.9 in.	580		3			2			
26.4 in.	590	3	9	1	5	1			
26.8 in.	600	1	5	1		1			
27.2 in.	609		3		2	2			
27.7 in.	619				1	2			
28.1 in.	629	1	2			1			
28.6 in.	639				2	1			
29.0 in.	648						1		
29.4 in.	658								
29.9 in.	668								
30.3 in.	678								
30.7 in.	687			1					
Total		131	604	288	2,787	1,372	313	745	162
Average total length (in.)		19.1	20.1	17.9	13.8	14.7	10.0	11.1	14.8
Average standard length (mm.)		422	445	394	304	323	217	242	324
Percentage legal at—									
1½ pounds		80	88	55	10	12	1	[2] 0	18
16½ inches		92	97	75	12	17	1	1	26
15½ inches		98	100	96	21	30	1	1	48

[1] From late spawning run.
[2] Less than 0.5 percent.

The 1943 collection, as explained previously (p. 8), appears to have been intermediate between the spawning-run and late-spring samples, since it contained considerable numbers of immature fish along with some adults that had not yet spawned and more that were freshly spent. In this sample the walleyes were rather well concentrated toward the lower end of the length range. The interval 15.8 to 17.6 inches included 175 fish, or 61 percent of the total, and a distinct mode was present at 17.1 inches. Only 101 (35 percent) of the fish exceeded 17.6 inches. The mean length of the 1943 walleyes (17.9 inches) was 1.2 and 2.2 inches, respectively, below the averages for the bona fide spawning-run samples of 1927 and 1929.

The late-spring collections of 1929 and 1930 were characterized by large numbers of smaller walleyes with a scattering of larger individuals. In 1929, 2,349 walleyes, or 84.3 percent of the total, were less than 16 inches long and in 1930, 1,057, or 77 percent of the entire collection, were below that length. This situation contrasts sharply with that in the spawning-run samples of 1927 and 1929 in which almost all walleyes were longer than 16 inches. The comparison between spawning-run and late-spring collections of 1929 provides a particularly striking illustration of the extensive changes that can occur in the length distribution of samples in a matter of weeks.

Although the late-spring samples of 1929 and 1930 both contained large numbers of the smaller walleyes, they differed as to the distribution of these shorter fish. In 1929, the numbers of the lesser lengths increased with increase in length to a mode at 10.5 inches, declined to a minimum at 11.8 inches, and then increased again. The second interval with large numbers of fish was relatively long (roughly 12.2 to 15.8 inches) and without sharp peaks. The 1930 collection had the second,

[13] For convenience, statements of range in this section are given in terms of midpoints of the extreme intervals. It is to be understood that the actual range extends about 0.2 or 0.25 inch beyond each of these midpoints.

long, flat concentration but lacked the first one almost entirely. The difference between the 2 years can be attributed to the great scarcity of II-group walleyes (weak 1928 year class—see p. 19). In the 1929 distribution the concentration with a mode at 10.5 inches was made up principally of II-group walleyes and the depression between 11 and 12 inches marks the transition from predominance of age-group II to that of older fish.[14] Age-group II was so sparsely represented in 1930, however, that it did not form a distinct mode in the length-frequency distribution of that year's collection. The scarcity of II-group walleyes was the most important cause of a higher mean length in 1930 (14.7 inches) than in 1929 (13.8 inches).

The three fall collections agreed in that walleyes above a length of about 18 inches were rare in all of them. Below that length, however, the distributions varied widely. The 1926 sample was made up almost exclusively of extremely small fish; 98 percent fell at 11.3 inches and less. This concentration at small lengths can be traced to the overwhelming dominance of age-group I (2 growing seasons) in that year (table 4). The distribution of the 1928 collection which contained a small but appreciable representation of age-group II was less concentrated although by far the bulk of the sample (73 percent) still lay at 11.3 inches or less. The smallest fish were as scarce in 1929 as they were abundant in the earlier fall collections. Intervals at 11.3 inches and less included only 8 percent of the total collection. The bulk of the walleyes (92 percent) were distributed irregularly over the range, 11.8 to 18.0 inches. The scarcity of I-group walleyes in the fall of 1929[15] is in agreement with that of the II group in 1930; both groups were members of year-class 1928 which, according to all evidence, was extremely weak. The overwhelming dominance of age-group I in 1926, the presence of some older fish (especially the II group) in 1928, and the scarcity of the I group in 1929 account for successive increases in the mean length of walleyes captured in the fall from 10.0 to 11.1 to 14.8 inches.

[14] This statement is supported by age records for a large sample of fish—see table 4 for the numbers in the different age groups.

[15] No scale collections were made in the fall of 1929. The general size range of walleyes that had completed 2 growing seasons can be considered well established, however, from data for other 1926–30 collections.

The percentage of legal-sized walleyes, of course, varied enormously according to the mean lengths and length distributions in the different seasons and years. Commercial fishermen could have retained the bulk of the walleyes in the spawning-run samples of 1927 and 1929 (80 and 88 percent, respectively) even at the 1½-pound size limit[16] then in effect. Under the limits that were subsequently in force (see p. 22 for statement of times of change of legal minimum size limits) they could have kept even more (92 and 97 percent at 16½ inches; 98 and 100 percent at 15½ inches). Most of the walleyes (96 percent) of the 1943 late-spawning-run sample were of legal size under the 15½-inch minimum then in force. At 16½ inches 75 percent and at 1½ pounds only 55 percent could have been retained.

The sorting of the catch of walleyes must have been an irritating task for the commercial fishermen of Saginaw Bay in the late spring of 1929 and 1930 and the falls of 1926, 1928, and 1929. Under the 1½-pound limit only 10 and 12 percent, respectively, of the take could be retained in the two late-spring samples. A 16½-inch limit would have been of some small benefit (increases to 12 and 17 percent) whereas a 15½-inch minimum would have permitted better than a doubling of the number of walleyes kept (21 and 30 percent).[17] In the fall of 1926 and of 1928 only a negligible few of the walleyes were legal and no reasonable lowering of the size limit could have benefited the fishermen materially. In 1929, however, 18 percent were legal, at the 1½-pound limit and 26 and 48 percent respectively could have been marketed legally at limits of 16½ and 15½ inches.

LENGTH-WEIGHT RELATION

GENERAL RELATION

Annual and seasonal fluctuations in the length-weight relation and variations related to sex, maturity, and the state of organs have been observed so frequently that their occurrence can be accepted as general. Because of these fluctuations, some of which may be large, a curve based on fish captured at one time may describe poorly the length-weight relation at another time. From a practical standpoint, it is important to have a single curve that best depicts the general relation even though the curve is not exact for any particular time. To arrive at such a general relation, the most satisfactory procedure appears to lie in the lumping together of the available materials regardless of the year or season of capture, the sex, ... This procedure was followed in the preparation of table 18.

[16] All estimates in table 17 of percentages of legal-sized walleyes under the 1½-pound limit were based on the length distributions. See footnote 10 for statement of procedure.

[17] The high percentages of undersized walleyes in the catches together with a strong market demand for the smaller fish must have been responsible for the large-scale traffic in illegal-sized walleyes that existed prior to the enactment of the 15½-inch limit.

The calculated weights of table 18 were computed by means of the following length-weight equation which was fitted to the empirical mean values of length and weight for length intervals represented by more than 5 fish:

$$W=1.376\times 10^{-5}L^{2.989},$$

where W=weight in grams,
and L=standard length in millimeters.

In logarithmic form actually used for calculation the equation is written:

$$\log W=2.988737 \log L-4.8613315.$$

The agreement between the empirical and computed weights of the Saginaw Bay walleye (table 18 and fig. 3) can be termed satisfactory. The discrepancy between the two did not exceed 0.03 pound at any point over the range, 7.0 to 16.6 inches (corresponding range of theoretical weight, 0.10 to 1.38 pounds) and was nil or only 0.01 pound at 15 of the 23 intervals. All discrepancies in excess of 0.10 pound were at lengths greater than 19.3 inches (theoretical and empirical weights both 2.16 pounds at that length) and even at these larger sizes the maximum difference in an interval represented by 10 or more fish was only 0.11 pound (at 19.7 inches where the empirical weight was 2.43 pounds and the computed weight was 2.32 pounds). Better agreement than that just described could hardly be expected from heterogeneous materials, particularly when one considers the potential distorting effects of seasonal fluctuations in the length-weight relation (see next sections) in combination with seasonal differences in the length-frequency distributions (table 17).

The total lengths corresponding approximately to certain computed weights of the Saginaw Bay walleye are: ½ pound, 11.9 inches; 1 pound, 14.9 inches; 1½ pounds, 17.1 inches; 2 pounds, 18.9 inches; 3 pounds, 21.2 inches; 5 pounds, 25.2 inches.

TABLE 18.—*Length-weight relation of Saginaw Bay walleye based on combined collections of 1928–30 and 1943*

[Lengths are board measurements equivalent to midpoints of centimeter intervals of standard length as measured with steel tape]

Number of fish	Total length	Weight		Standard length	Weight		K
		Empirical	Calculated [1]		Empirical	Calculated [1]	
	Inches	*Pounds*	*Pounds*	*Millimeters*	*Grams*	*Grams*	
2	7.0	0.10	0.10	151	44	45	1.28
1	7.4	.09	.12	160	40	53	.98
2	7.9	.16	.14	170	71	64	1.45
7	8.4	.18	.17	180	82	76	1.41
17	8.8	.19	.20	190	87	89	1.27
34	9.3	.24	.23	200	107	104	1.34
117	9.7	.26	.26	209	117	118	1.28
207	10.1	.30	.30	219	136	136	1.29
254	10.5	.34	.34	229	153	155	1.27
217	10.9	.37	.39	239	170	177	1.25
148	11.3	.42	.43	248	191	197	1.25
179	11.8	.48	.49	258	219	222	1.28
239	12.2	.54	.55	268	246	249	1.28
296	12.7	.60	.61	278	270	278	1.26
344	13.1	.66	.67	287	299	305	1.26
321	13.5	.72	.75	297	327	338	1.25
332	14.0	.81	.82	307	368	373	1.27
353	14.5	.89	.91	317	405	411	1.27
343	14.9	.97	.99	326	440	447	1.27
304	15.3	1.08	1.08	336	490	489	1.29
240	15.8	1.16	1.18	346	526	534	1.27
208	16.2	1.29	1.28	356	587	581	1.30
170	16.6	1.41	1.38	365	640	626	1.32
166	17.1	1.55	1.50	375	703	679	1.33
119	17.6	1.68	1.62	385	760	734	1.33
72	18.0	1.81	1.75	395	822	793	1.33
64	18.4	1.88	1.87	404	854	848	1.30
41	18.9	2.09	2.01	414	946	912	1.33
26	19.3	2.16	2.16	424	979	980	1.28
28	19.7	2.43	2.32	434	1,103	1,051	1.35
31	20.0	2.53	2.46	443	1,150	1,117	1.32
21	20.3	2.60	2.63	453	1,180	1,194	1.27
23	20.7	2.91	2.81	463	1,319	1,275	1.33
24	21.2	2.95	3.00	473	1,339	1,359	1.27
18	21.6	3.13	3.17	482	1,419	1,437	1.27
18	22.0	3.38	3.37	492	1,532	1,528	1.29
17	22.5	3.63	3.58	502	1,648	1,623	1.30
11	22.9	3.84	3.80	512	1,741	1,722	1.30
3	23.3	4.27	4.00	521	1,937	1,814	1.37
10	23.8	4.22	4.23	531	1,915	1,920	1.28
7	24.2	4.34	4.48	541	1,970	2,030	1.24
6	24.7	4.98	4.73	551	2,257	2,144	1.35
7	25.1	4.59	4.96	560	2,082	2,251	1.19
8	25.5	5.08	5.23	570	2,305	2,373	1.24
2	25.9	4.45	5.51	580	2,020	2,499	1.04
7	26.4	5.68	5.80	590	2,575	2,630	1.25
2	26.8	6.33	6.10	600	2,870	2,766	1.33
4	27.2	6.42	6.38	609	2,913	2,892	1.29
4	27.7	6.74	6.69	619	3,058	3,036	1.29
2	28.1	7.25	7.02	629	3,289	3,185	1.32
3	28.6	6.73	7.36	639	3,052	3,339	1.17
1	30.7	8.91	9.14	687	4,040	4,146	1.25

[1] See text for equation used to determine calculated weights.

The heaviest fish of the combined samples (taken in 1943) had an actual weight of 8.91 pounds and a calculated weight of 9.14 pounds at the length of 30.7 inches. The weight corresponding to the present legal minimum length of 15½ inches is 1.12 pounds. The size limit of 1½ pounds, in effect at the time of collection of the 1926–30 samples was equivalent to total length of 17.1 inches, and the 1933–38 minimum legal length of 16½ inches corresponded to a weight of 1.36 pounds.

Since the value of the exponent in the length-weight equation (2.989) was so close to 3, no distinct trend was to be anticipated in the variation

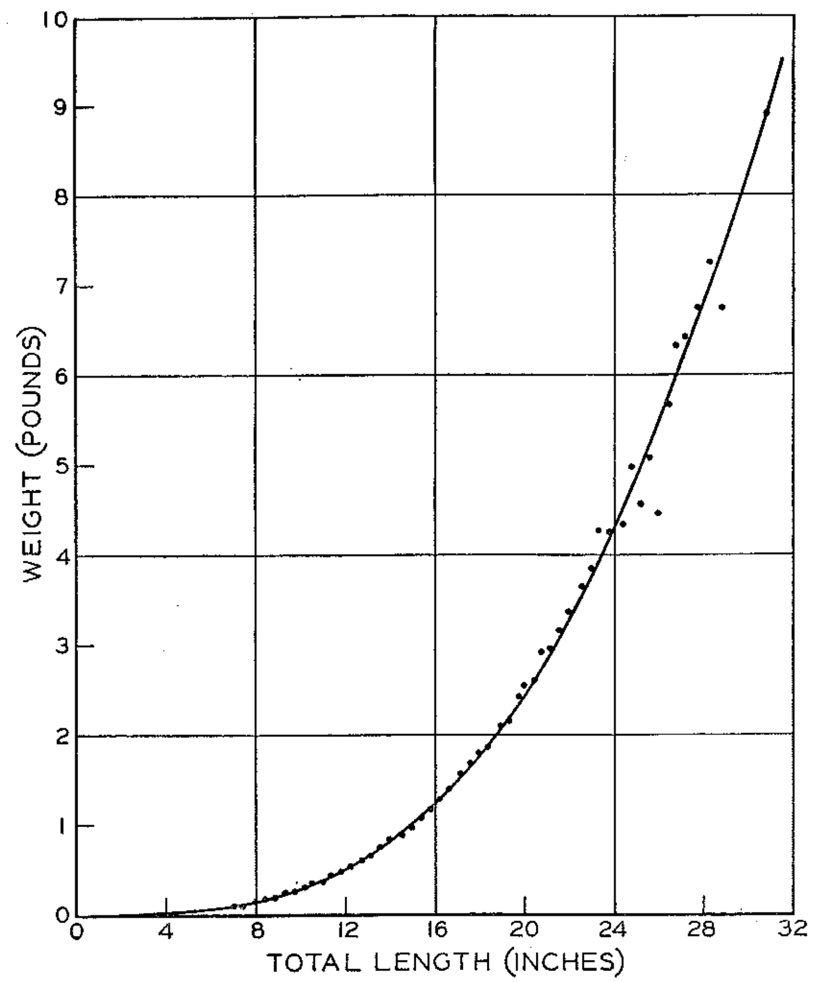

FIGURE 3.—Length-weight relation of the Saginaw Bay walleye. The dots represent the empirical data of table 18. The smooth curve is the graph of the length-weight equation given in the text.

of the coefficient of condition, K,[18] with increase of length. (If the value of the exponent is n, K varies as the $n-3$ power of the length.) The actual values of K (of table 18) conform to this expectation. The mean value of the coefficient for all fish was 1.28. The weight of the walleye seems to be relatively lighter in Saginaw Bay than in Lake of the Woods for which Carlander (1945) reported an average K of 1.47 and in Trout Lake, Wis., where the mean coefficient was 1.45 (Schloemer and Lorch 1942).

FLUCTUATIONS OF WEIGHT IN LATE-SPRING COLLECTIONS

The frequent sampling during late spring of 1929 and of 1930 has made it possible to investigate short-term fluctuations in the weights of walleyes captured in the same nets[19] over periods of approximately 6 weeks and 2 months. Attention will be given first to the data for 1930 since for that year's collections alone were records of sex and maturity available for the individual fish. It is considered desirable to establish the degree to which those factors may affect data on the length-weight relation during the late-spring period.

The preliminary tabulations of the 1930 data brought out the following points: In fish of the same collection no consistent differences occurred between the weights of mature and immature males of corresponding length or between males and immature females; mature females tended

[18] $K=\frac{W\times 10^5}{L^3}$, where W=weight in grams, and L=standard length in millimeters.

[19] The 1929 and 1930 collections were from experimental pound nets fished near Bay Port.

to be somewhat heavier than males and immature females (exceptions to this trend can be ascribed to inadequate numbers of fish); the length-weight relation varied but little within two individual periods, April 25–May 13 and May 19–June 20; walleyes captured during the earlier of these two periods were distinctly the heavier for their length.

The consistency with which weights were higher in the collections of April 25–May 13 than in those of May 19–June 20 may be seen in table 19 (here data are recorded separately for males and immature females despite the small differences between the two groups). Not one exception is to be found even though some of the weights were based on only one or a few fish.[20] Furthermore, the percentage advantage of walleyes of the April 25–May 13 samples over the May 19–June 20 fish tended to group closely about a characteristic value; 27 of 38 values were within the range, 15 to 25 percent, and most of the 11 percentages outside that range came from comparisons based on small numbers of specimens. The unweighted mean values of the percentages were almost identical for the three series of comparisons: males, 20.4 percent; immature females, 19.3 percent; mature females, 19.7 percent. There is no indication that the relative advantage of the walleyes collected April 25–May 13 varied with the length of the fish except possibly in the immature females where the percentages of the last three length intervals were much lower than those of shorter fish. Comments on the possible explanation for a decline of approximately 20 percent in the weight of walleyes within a period of 6 days[21] will be deferred until after the presentation of the data on short-term fluctuations in weight during the spring of 1929.

Changes in the average weights of walleyes captured in the experimental pound nets at Bay Port in 1929 (table 20), although generally smaller than those of 1930, occurred several times rather than once during the collecting season. At the beginning of the collecting period (May 8–15) the walleyes were of intermediate weight but still on

[20] The table covers the range of length over which at least one of the three categories was represented by 5 fish or more in both the April 25–May 13 and May 19–June 20 periods. At an interval meeting this requirement data were included for the remaining categories even though the numbers of fish were less than five.

[21] That a change in the weight composition was occurring between May 13 and 19 was indicated by small numbers of fish taken May 15 and 17. The weights of these fish tended to be intermediate to those of walleyes of the April 25–May 13 and May 19–June 20 periods.

TABLE 19.—*Comparison of weights of Saginaw Bay walleyes captured April 25–May 13 and May 19–June 20, 1930*

[Figures in parentheses listed under average weight are the number of specimens and under difference are the percentage advantage of fish captured April 25–May 13 over those taken May 19–June 20]

Standard length	Total length	Weight of males			Weight of immature females			Weight of mature females		
		Average, April 25–May 13	Average, May 19–June 20	Difference	Average, April 25–May 13	Average, May 19–June 20	Difference	Average, April 25–May 13	Average, May 19–June 20	Difference
	Inches	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*
248 mm	11.3	7.3 (6)	5.8 (5)	1.5 (25.9)	8.0 (1)	5.7 (8)	2.3 (40.4)			
258 mm	11.8	8.6 (9)	6.9 (18)	1.7 (24.6)	8.2 (5)	6.7 (14)	1.5 (22.4)			
268 mm	12.2	9.6 (12)	8.1 (23)	1.5 (18.5)	9.4 (2)	8.1 (20)	1.3 (16.0)			
278 mm	12.7	10.1 (14)	8.6 (25)	1.5 (17.4)	11.0 (7)	8.7 (27)	2.3 (26.4)			
287 mm	13.1	11.3 (37)	9.5 (40)	1.8 (18.9)	11.6 (10)	9.8 (27)	1.8 (18.4)	12.2 (1)	11.0 (2)	1.2 (10.9)
297 mm	13.5	12.5 (28)	10.7 (27)	1.8 (16.8)	12.3 (10)	10.6 (36)	1.7 (16.0)			
307 mm	14.0	14.0 (32)	11.7 (28)	2.3 (19.7)	14.6 (20)	11.8 (19)	2.8 (23.7)	13.8 (1)	11.5 (2)	2.3 (20.0)
317 mm	14.5	15.4 (42)	12.8 (19)	2.6 (20.3)	15.0 (19)	12.6 (17)	2.4 (19.0)			
326 mm	14.9	16.9 (31)	13.0 (15)	3.9 (30.0)	17.6 (21)	14.1 (26)	3.5 (24.8)	17.8 (1)	14.5 (5)	3.3 (22.8)
336 mm	15.3	18.3 (36)	15.6 (17)	2.7 (17.3)	18.4 (19)	15.6 (12)	2.8 (17.9)	18.8 (3)	15.6 (3)	3.2 (20.5)
346 mm	15.8	19.6 (26)	16.7 (7)	2.9 (17.4)	20.9 (9)	17.2 (20)	3.7 (21.5)	21.9 (4)	17.5 (3)	4.4 (25.1)
356 mm	16.2	21.7 (15)	17.7 (8)	4.0 (22.6)	20.6 (13)	18.7 (13)	1.9 (10.2)	23.1 (10)	18.5 (4)	4.6 (24.9)
365 mm	16.6	23.6 (17)	20.5 (9)	3.1 (15.1)	20.3 (6)	19.6 (11)	0.7 (3.6)	24.4 (9)	19.3 (2)	5.1 (26.4)
375 mm	17.1	25.3 (11)	21.3 (6)	4.0 (18.8)	25.5 (1)	23.2 (3)	2.3 (9.9)	26.3 (11)	24.1 (4)	2.2 (9.1)
385 mm	17.6	28.8 (8)	23.5 (1)	5.3 (22.6)				29.9 (12)	25.5 (9)	4.4 (17.3)

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TABLE 20.—*Comparison of the weights of Saginaw Bay walleyes, sexes combined, captured on various dates, May and June 1929*

[Number of specimens in parentheses]

Standard length	Total length	Average weight of fish caught during period—				
		May 8-15	May 17-27	May 29-31	June 3-8	June 12-18
	Inches	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*
209 mm	9.7	4.1 (12)	3.8 (27)	4.3 (12)	4.0 (12)	4.3 (8)
219 mm	10.1	4.5 (21)	4.4 (56)	5.3 (14)	4.4 (13)	4.9 (10)
229 mm	10.5	5.2 (27)	5.1 (80)	5.6 (19)	5.0 (25)	5.4 (15)
239 mm	10.9	6.1 (20)	5.8 (85)	6.4 (7)	5.7 (14)	6.0 (16)
248 mm	11.3	6.6 (11)	6.3 (49)	7.8 (9)	6.6 (13)	6.7 (16)
258 mm	11.8	7.9 (11)	7.2 (35)	8.1 (20)	7.5 (6)	7.9 (17)
268 mm	12.2	8.6 (23)	8.1 (47)	9.4 (23)	8.2 (19)	8.9 (22)
278 mm	12.7	9.6 (28)	9.2 (65)	10.5 (25)	9.0 (20)	9.8 (34)
287 mm	13.1	10.6 (24)	10.1 (69)	11.4 (26)	10.3 (32)	10.7 (39)
297 mm	13.5	12.0 (19)	11.2 (84)	12.1 (30)	11.2 (30)	11.9 (30)
307 mm	14.0	13.1 (32)	12.7 (71)	14.0 (24)	12.3 (49)	13.2 (31)
317 mm	14.5	14.2 (40)	13.7 (85)	14.9 (34)	14.2 (42)	14.9 (20)
326 mm	14.9	16.2 (41)	15.1 (96)	16.3 (14)	14.8 (52)	15.3 (15)
336 mm	15.3	17.1 (33)	16.5 (74)	17.6 (19)	16.8 (32)	17.6 (20)
346 mm	15.8	18.3 (28)	17.6 (61)	18.7 (4)	18.1 (28)	18.3 (8)
356 mm	16.2	20.2 (15)	19.3 (48)	22.2 (6)	20.4 (14)	19.4 (5)

the average 5.0 percent[22] heavier than fish captured May 17–27. The highest level of weight was attained May 29–31. Walleyes captured in this period averaged 12.5 percent heavier than fish of the May 17–27 collections and 10.9 percent heavier than those taken June 3–8. Another increase of weight occurred June 12–18.

In the 1929 data, as in the 1930, the variations of average weight were remarkably consistent. In the entire table only one exception is to be found with respect to the characteristic direction of change of weight in a particular period; at 16.2 inches the walleyes of June 12–18 averaged smaller, not heavier than fish of the preceding period. This average was based, however, on only 5 specimens.[23] Nor does the consistency end here. At the various length intervals the average weights for the five periods tended to fall in the same order of rank (table 21). As an illustration, walleyes collected May 29–31 were heaviest in 13

[22] Unweighted mean of the percentages for the individual length intervals; percentages not included in the table.

[23] The range of length covered by table 20 was determined from the requirement that each average weight be based on five or more fish. One exception was made for the average at 15.8 inches in the May 29–31 samples.

TABLE 21.—*Number of length intervals at which the walleyes of five collecting periods held particular ranks with respect to average weight*

[Based on data of table 20]

Rank	Number of times a rank was held—				
	May 8–15	May 17–27	May 29–31	June 3–8	June 12–18
1			14½		1½
2	4		1½	1	9½
3	11			1	4
4	1	6		8	1
5		10		6	
Average rank	2.8	4.6	1.1	4.2	2.3

of the 16 intervals and were tied for first rank with fish of June 12–18 in the remaining 3. May 29–31, therefore, held first rank 14½ times and second 1½ times. Each of the remaining collecting periods held its "characteristic" ranking in at least half of the length intervals. Thus fish of the June 12–18 samples were second 9½ times; those of May 8–15, third 11 times; those of June 3–8, fourth 8 times; and those of May 17–27, fifth 10 times.

The chance is remote that differences from one period to another in the composition of the samples with respect to sex and maturity had an appreciable effect on the 1929 data. From the 1930 data it was determined that no large or consistent differences existed among the weights of mature males, immature males, and immature females of corresponding length. Only differences in the relative abundance of mature females (which tended to be heavier in 1930 than males and immature females), therefore, could be expected to influence the average weights. In 1929, however, most of the 16 length intervals for which data were available were in a range over which mature females were lacking or scarce (table 47).

It is not believed that the observed short-term fluctuations in the average weights of walleyes in the 1929 and 1930 late-spring samples reflect corresponding losses and gains of weight by individual fish. In 1930, for example, it could hardly be expected that the weight should drop 20 percent from May 13 to May 19, even under conditions of total starvation. The changes were less extreme in 1929 (5 to 12½ percent) but even here it is difficult to believe that the environmental factors contributing to gain or loss of weight were subject to the sudden and sharp changes that would be required to explain the alternating periods of high and low weight.

Fluctuations from period to period in the weight of the stomach contents could produce "apparent" changes in the weight of the whole fish, but this explanation, too, appears to be far from adequate, especially for 1930 when we should have to hypothesize stomachs stuffed to bursting, April 25–May 13, and almost totally unsuccessful foraging, May 19–June 20. A similar explanation for the fluctuations of weight in 1929 may impose a lesser strain on the investigator's credulity. Even so the large and frequent fluctuations of feeding activity that would have to be postulated are too great to make the explanation attractive.

It is believed that the fluctuations of weight of Saginaw Bay walleyes in late spring in 1929 and in 1930 can be explained most logically by the assumption that the population is heterogeneous with respect to the length-weight relation and that different segments of that population dominated the samples during different periods. Speculation as to the source of this heterogeneity, whether it be hereditary or ecological, and as to the basis of the segregation of elements with different length-weight relationships would not be profitable.

The numbers of walleyes measured in the fall (November 7–December 1, 1928, and October 15–November 21, 1929) were too few to permit detailed analysis but such data as were available failed to indicate the existence of short-term fluctuations comparable to those of late spring in 1929 and 1930. No data are available on fluctuation of weight during the spawning period.[24]

DIFFERENCES BETWEEN SPRING AND FALL WEIGHTS

The grand average weights for all walleyes collected in late spring of 1929 and of 1930 (tabulation not presented here) revealed that at most lengths the fish were somewhat the heavier in the former year. These annual differences were small, however, in relation to the within-season fluctuations; the combination of the data for 1929 and 1930 to obtain a general estimate of the length-weight relation in late spring (table 21) accordingly was held to be legitimate. The fall collections likewise exhibited annual differences, for at most lengths fish captured in 1929 were a little heavier than those taken in 1928. Again a combination of materials has been considered justified since in both autumns the walleyes were notably heavier than in late spring of either 1929 or 1930.

It may be seen from table 22 that without exception walleyes collected in the fall were heavier than fish of corresponding length taken in late spring. The examination of the percentage advantages of the autumn-caught fish reveals that

[24] The only collection containing spawning fish for which weights were recorded was that of May 4, 1943. Even this sample perhaps should be designated as intermediate between a true spawning and a postspawning collection.

TABLE 22.—*Comparison of weights of Saginaw Bay walleyes, sexes combined, captured in the fall and spring*

[Figures in parentheses listed under average weight are number of specimens and under difference the percentage advantage of fish captured in fall over those taken in spring]

Standard length	Total length	Weight			Standard length	Total length	Weight		
		Average in fall[1]	Average in spring[2]	Difference			Average in fall[1]	Average in spring[2]	Difference
	Inches	*Ounces*	*Ounces*	*Ounces*		*Inches*	*Ounces*	*Ounces*	*Ounces*
190 mm	8.8	3.6 (7)	2.7 (10)	0.9 (33.3)	297 mm	13.5	13.0 (18)	11.4 (303)	1.6 (14.0)
200 mm	9.3	3.9 (17)	3.6 (17)	0.3 (8.3)	307 mm	14.0	13.5 (9)	13.0 (322)	0.5 (3.8)
209 mm	9.7	4.4 (35)	4.0 (82)	0.4 (10.0)	317 mm	14.5	15.8 (12)	14.2 (340)	1.6 (11.3)
219 mm	10.1	5.2 (84)	4.6 (123)	0.6 (13.0)	326 mm	14.9	17.5 (14)	15.4 (325)	2.1 (13.6)
229 mm	10.5	5.9 (77)	5.2 (177)	0.7 (13.5)	336 mm	15.3	20.5 (16)	17.1 (282)	3.4 (19.9)
239 mm	10.9	6.5 (61)	5.8 (156)	0.7 (12.1)	346 mm	15.8	21.9 (12)	18.3 (203)	3.6 (19.7)
248 mm	11.3	7.5 (25)	6.6 (123)	0.9 (13.6)	356 mm	16.2	24.1 (21)	20.1 (158)	4.0 (19.9)
258 mm	11.8	8.4 (30)	7.6 (148)	0.8 (10.5)	365 mm	16.6	25.9 (8)	21.9 (121)	4.0 (18.3)
268 mm	12.2	9.6 (36)	8.5 (203)	1.1 (12.9)	375 mm	17.1	28.6 (16)	23.8 (99)	4.8 (20.2)
278 mm	12.7	10.3 (32)	9.4 (264)	0.9 (9.6)	385 mm	17.6	28.6 (5)	26.4 (85)	2.2 (8.3)
287 mm	13.1	11.7 (21)	10.5 (323)	1.2 (11.4)	395 mm	18.0	34.2 (10)	27.8 (52)	6.4 (23.0)

[1] Includes fish captured Nov. 7–Dec. 1, 1928, and Oct. 15–Nov. 21, 1929.

[2] Includes fish captured May 8–June 18, 1929, and Apr. 25–June 20, 1930.

their values tended to be higher at 15.3 inches or longer than at the lesser lengths, but that within each of these ranges the percentages clustered rather closely about a characteristic value. Over the range, 8.8 to 14.9 inches, the unweighted mean percentage was 12.7 and 11 of the 15 individual values were from 10.0 to 14.0 percent. The two extreme deviations from the mean—33.3 percent at 8.8 inches and 3.8 percent at 14.0 inches—both came from comparisons in which one of the average weights was based on fewer than 10 fish. At 15.3 to 18.0 inches the mean percentage was 18.5 and 6 of the 7 individual values were within the range of 18.3 to 23.0 percent. Again the outstanding exception—8.3 percent at 17.6 inches—can be attributed to inadequate data since the average weight for fall walleyes was determined from only 5 specimens.

EFFECT OF *LYMPHOCYSTIS* INFECTION ON WEIGHT

The incidence of *Lymphocystis* in the Saginaw Bay walleye was relatively high in the fall of 1942 and the spring of 1943. Although no quantitative data on its occurrence were obtained in 1942, casual observations indicated that the infection was relatively more frequent that fall than in the following spring. Of the 288 walleyes in the sample from which scales were taken on May 4, 1943, 19, or 6.6 percent, were infected.

During visits to Bay Port in mid-November 1942 and early May 1943 the weights of infected walleyes were compared with those of sound fish. The infected fish included, in addition to the 19 specimens mentioned above, legal-sized walleyes that had been discarded by commercial fishermen as unmarketable and undersized fish that had been brought ashore under special authorization from Michigan law-enforcement officials. The sound fish were in part from the collection of May 4, 1943, and in part were weighed during the course of filleting experiments conducted in November 1942 and May 1943 (see Krumholz 1945, for an account of those experiments).

The average weights of sound walleyes exceeded those of fish infected with *Lymphocystis* at 13 of 14 lengths in November 1942 and at 18 of 19 lengths in May 1943 (table 23). The percentage advantage of the sound over the diseased fish varied widely as should be expected in view of the small numbers on which some of the average weights were based. At most lengths with the better numerical representation, however, the percentage was below 10. The weighted-mean percentage (see footnote 2 of the table) was 5.6 for the November 1942 samples and 6.6 for the May 1943. The differences between the weights of sound and diseased walleyes doubtless would have been greater had the "warty" growths been removed from the latter before they were weighed.

TABLE 23.—*Comparison of weights of Saginaw Bay walleyes infected with* Lymphocystis *with weights of uninfected fish collected on the same dates*

[Figures in parentheses under average weight are the numbers of specimens and under difference the percentage difference of weight. Weights given in ounces]

Total length	November 12–16, 1942			May 3–5, 1943		
	Average weight of infected fish	Average weight of uninfected fish	Difference [1]	Average weight of infected fish	Average weight of uninfected fish	Difference [1]
13½ in.	12.5 (1)	13.9 (6)	1.4 (11.2)	10.5 (1)	12.7 (8)	2.2 (21.0)
14 in.	12.9 (10)	13.4 (11)	0.5 (3.9)	12.5 (1)	13.9 (17)	1.4 (11.2)
14¼ in.	14.2 (8)	15.0 (17)	0.8 (5.6)	12.0 (1)	14.8 (19)	2.8 (23.3)
14½ in.	15.9 (9)	15.5 (22)	−0.4 (−2.5)	14.2 (4)	15.9 (26)	1.7 (12.0)
14¾ in.	16.3 (15)	16.9 (21)	0.6 (3.7)	15.2 (2)	16.3 (25)	1.1 (7.2)
15 in.	17.5 (28)	17.6 (19)	0.1 (0.6)	15.4 (8)	17.3 (29)	1.9 (12.3)
15¼ in.	18.5 (27)	18.8 (19)	0.3 (1.6)	16.6 (11)	17.7 (22)	1.1 (6.6)
15½ in.	19.4 (26)	20.3 (16)	0.9 (4.6)	18.3 (14)	19.1 (25)	0.8 (4.4)
15¾ in.	19.3 (31)	21.7 (20)	2.4 (12.4)	18.1 (14)	19.8 (20)	1.7 (9.4)
16 in.	21.0 (30)	22.5 (17)	1.5 (7.1)	20.0 (18)	21.2 (25)	1.2 (6.0)
16¼ in.	21.9 (18)	23.0 (17)	1.1 (5.0)	21.2 (6)	21.8 (30)	0.6 (2.8)
16½ in.	22.7 (24)	24.8 (18)	2.1 (9.3)	22.3 (13)	23.0 (32)	0.7 (3.1)
16¾ in.	23.7 (11)	25.9 (11)	2.2 (9.3)	23.2 (2)	24.7 (37)	1.5 (6.5)
17 in.	23.8 (9)	26.5 (11)	2.7 (11.3)	22.4 (4)	24.9 (36)	2.5 (11.2)
17¼ in.				27.2 (3)	26.1 (29)	−1.1 (−4.0)
17¾ in.				21.5 (1)	28.6 (12)	7.1 (33.0)
18 in.				28.0 (1)	30.3 (9)	2.3 (8.2)
18½ in.				32.0 (2)	32.3 (11)	0.3 (0.9)
19¾ in.				31.5 (1)	40.6 (6)	9.1 (28.9)
Average [2]			5.6			6.6

[1] Advantage of sound over infected fish.
[2] Weighted mean percentages for all fish. The weight for each percentage was the product of the numbers of infected and uninfected fish. For example, the percentage 3.9 at 14 inches in November 1942 received the weight 10×11=110.

CALCULATED GROWTH

GROWTH IN LENGTH

Since, as was explained previously (p. 20), differences (other than those that could be ascribed to inadequate numbers of fish in the samples) in the growth of walleyes of the same age in the

1926–30 collections but taken in different years could be explained on the basis of annual fluctuations in growth rate and members of the same year class captured at different ages in general had closely similar growth, it is not desirable to present the large amount of tabular material required to show the calculated growth history of each age group in each year's collection. Presentation of data on calculated growth in length, accordingly, has been limited to the growth histories of the individual year classes. To obtain the data of tables 24 and 25, the calculated lengths of all age groups belonging to the same year class were combined.[25] In the computation of the growth history of a year class, weighted means of the calculated lengths were employed up to and including the length at capture of the youngest age group. The later calculated lengths were determined by successive addition of the weighted-mean-annual increments of length.

The calculated lengths of the year classes at corresponding years of life varied rather widely. This variation followed a distinct pattern which was similar for the sexes. Among the walleyes of the 1926–30 collections (year-class 1928 and earlier) the older year classes had the higher calculated lengths. From the generally high levels of the earlier year classes, the calculated lengths started on a downward trend, usually with the year class of 1917 or 1918; the onset of the trend varied somewhat according to year of life. The lowest general level of growth was exhibited by year-class 1924. Year-classes 1925 to 1928 grew faster than the 1924 year class but more poorly than the year classes before 1924 (exception in the second-year calculated length of females of year-class 1915).[26]

In the examination of tables 24 and 25 to ascertain the extent of the variations of the average calculated lengths in the 1926–30 collections, attention should be centered on year-classes 1918 to 1928 for the males and 1916 to 1928 for the females as the earlier year classes were represented by only 1 to 4 fish. Among the males the range of the average calculated lengths rose from 1.9 inches at the end of the first year of life (maximum of 7.7 inches and minimum of 5.8) to 3.2 inches at the end of 4 years and thereafter declined to 0.2 inch at the end of 10. The increase of range during the early years indicates an in-

[25] Only one age group was represented in each year class later than 1928.

[26] The relation of this general pattern of growth to annual fluctuations in growth rate will be brought out later.

TABLE 24.—*Calculated growth in length of the males of the year classes of Saginaw Bay walleyes*

Year class	Number of fish	Calculated total length (inches) at end of year of life—													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1914	1	6.3	12.1	14.6	17.2	18.1	18.9	19.8	20.2	20.8	21.1	21.5	21.9	22.2	
1915	2	7.2	10.3	13.2	15.5	16.6	17.6	18.4	19.2	19.8	20.2	20.5	20.7	20.9	21.3
1916	2	7.4	10.9	14.0	16.5	18.0	19.6	20.7	21.5	22.3	22.9	23.4	23.7	24.0	
1917	4	7.6	12.0	14.7	16.9	18.3	19.6	20.6	20.8	21.3	21.9	22.3	22.8		
1918	12	7.4	11.7	14.3	16.1	17.6	18.5	19.2	19.8	20.3	20.7	21.1			
1919	36	7.2	11.5	14.3	16.5	17.5	18.3	19.1	19.7	20.1	20.5				
1920	56	7.2	11.2	13.8	15.7	16.9	17.7	18.4	18.9	19.5					
1921	85	7.7	11.5	14.0	15.5	16.6	17.5	18.1	18.7						
1922	112	7.5	11.2	13.3	15.3	16.5	17.3	18.0	18.9						
1923	66	7.4	11.1	14.0	15.6	16.8	17.6	18.3							
1924	12	5.8	9.5	11.5	13.3	14.9	16.1								
1925	259	6.1	9.9	12.4	14.6	15.9									
1926	250	5.8	9.7	12.6	14.3										
1927	162	6.3	10.5	12.6											
1928	17	6.5	10.3												
1933	3	7.3	12.3	15.4	17.7	19.1	20.1	20.8	21.2	21.7	22.3				
1934	3	6.5	11.4	13.7	15.8	17.6	18.8	19.6	20.4	21.2					
1935	2	5.4	11.2	15.0	16.5	18.0	19.0	19.6	20.2						
1936	5	5.5	10.8	14.4	16.6	18.0	19.3	20.3							
1937	14	6.2	11.0	14.9	17.1	18.7	19.8								
1938	3	6.6	11.2	15.1	17.3	18.5									
1939	49	5.7	10.7	15.1	17.5										
1940	101	6.9	13.0	16.4											
Year-classes 1914–28: [1]															
Standard length (mm.)		144	234	293	336	365	385	401	415	428	440	451	460	468	476
Total length (in.)		6.7	10.7	13.4	15.3	16.6	17.6	18.3	18.9	19.5	20.0	20.4	20.7	21.0	21.3
Increment		6.7	4.0	2.7	1.9	1.3	1.0	.7	.6	.6	.5	.4	.3	.3	.3
Year-classes 1933–40: [1]															
Standard length (mm.)		139	264	346	396	430	456	476	491	507	521				
Total length (in.)		6.4	12.0	15.8	18.1	19.5	20.6	21.4	21.9	22.7	23.3				
Increment		6.4	5.6	3.8	2.3	1.4	1.1	.8	.5	.8	.6				

[1] See text for method of deriving these general growth data.

TABLE 25.—*Calculated growth in length of the females of the year classes of Saginaw Bay walleyes*

Year class	Number of fish	Calculated total length (inches) at end of year of life—														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1914	2	8.6	12.4	14.8	17.0	17.9	19.6	20.2	20.9	21.5	22.1	22.7	23.5	23.9	24.4	24.9
1915	4	8.5	12.0	15.5	17.4	19.7	21.6	22.9	23.6	24.8	25.4	26.1	26.7	27.0	27.4	
1916	12	8.5	12.4	15.5	17.6	19.5	21.1	22.2	23.0	23.9	24.5	25.2	25.7	26.2		
1917	17	8.1	12.3	15.5	17.8	19.9	21.5	22.5	23.2	23.9	24.4	24.9	25.3			
1918	34	7.8	11.9	15.1	17.6	19.6	21.0	21.9	22.6	23.4	24.1	24.7	25.4			
1919	56	7.9	11.9	15.2	17.8	19.4	20.7	21.6	22.3	22.8	23.5	24.0				
1920	54	7.7	12.1	15.2	17.4	19.1	20.2	20.9	21.6	22.3	22.9					
1921	77	7.9	11.9	14.6	16.4	18.1	19.4	20.3	20.9	21.6						
1922	110	7.9	11.7	14.0	16.4	18.1	19.4	20.4	21.2							
1923	48	7.4	11.0	14.5	16.7	18.6	19.7	20.5								
1924	21	5.4	9.5	12.1	14.3	16.1	17.5									
1925	267	6.3	10.1	12.7	15.0	16.3										
1926	170	5.9	9.8	12.8	14.6											
1927	170	6.3	10.5	12.7												
1928	23	6.3	10.2													
1930	2	6.5	12.9	15.5	17.5	20.3	22.0	23.9	25.1	25.9	26.6	27.2	28.1	28.9		
1931	1	6.1	10.6	13.2	16.3	18.9	20.3	21.7	22.6	23.6	24.8	25.6	26.5			
1933	1	7.1	13.0	15.6	18.0	19.9	21.3	22.5	23.2	24.0	25.0					
1934	2	7.0	11.7	15.2	17.3	19.4	21.3	22.5	23.5	24.6						
1936	3	6.6	11.3	14.7	18.1	20.2	21.8	23.4								
1937	16	5.9	10.7	15.4	18.2	20.5	22.1									
1938	1	7.9	13.4	17.0	19.5	21.2										
1939	30	5.9	11.1	16.1	18.6											
1940	50	6.9	13.0	17.0												
Year-classes 1914–28: [1]																
Standard length (mm)		148	238	302	351	391	423	447	466	484	499	513	526	537	547	558
Total length (in.)		6.9	10.9	13.8	16.0	17.8	19.3	20.3	21.0	21.7	22.3	22.9	23.5	24.0	24.5	25.0
Increment		6.9	4.0	2.9	2.2	1.8	1.5	1.0	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.5
Year-classes 1930–40: [1]																
Standard length (mm)		139	264	357	416	471	509	544	568	589	610	624	644	661		
Total length (in.)		6.4	12.0	16.3	18.9	21.3	22.9	24.3	25.4	26.3	27.3	27.9	28.8	29.5		
Increment		6.4	5.6	4.3	2.6	2.4	1.6	1.4	1.1	0.9	1.0	0.6	0.9	0.7		

[1] See text for method of deriving these general growth data.

creasing variability of the means. The decrease in the range during the later years of life, however, can be considered to a large extent the result of the decreasing number of years for which data were available and hence of lesser opportunity for variation. The extremes and ranges for the ninth and tenth years of life, for example, had to be determined from only three and two mean lengths, respectively. The ranges of the means for the females varied irregularly. From a value of 3.1 inches at the end of the first year (maximum of 8.5 inches and minimum of 5.4) the range dropped to 2.9 at the end of 2 years (12.4 and 9.5 inches) rose to a maximum of 4.0 at the end of 6 (21.5 and 17.5 inches), and then declined (with an irregularity at 8 and 9 years) to 0.4 inch at the end of 12. Here, as with the males, the earlier increases of the range suggest increasing variability of the means, but the subsequent declines cannot be interpreted to represent decreasing variability.

The year classes of the 1943 collection (year-class 1933 and later in table 24; year-class 1930 and later in table 25) had, on the whole, far better growth than those of the 1926–30 samples. An exception must be made for the first-year lengths which were mostly at about the same level of those of year-classes 1924 to 1928 and below that of year classes before 1924. In the second and later years, however, the calculated lengths of the walleyes collected in 1943 were commonly near or above the highest to be found in the 1926–30 samples. The advantage of the 1943 walleyes is more apparent in the later than in the earlier years of life.

To facilitate comparisons of the growth of males and females and of walleyes of the 1926–30 and 1943 collections, the data on "general" growth in length have been summarized in table 26. The lengths in this table were obtained by the successive addition of the average annual increments of length. For the 1926–30 collection, each increment is the weighted mean of the increments for the individual year classes after correction for annual fluctuations in growth rate.[27] Since the data from the 1943 collection provided a much less-

[27] To illustrate the method of correction—a 25-millimeter increment made in a year in which growth was 10.3 percent above average is subject to adjustment as follows: 25/1.103=22.6. See pp. 42–45 for data on the extent of the fluctuations in growth rate.

dependable estimate of annual fluctuations in growth, the increments for the walleyes of that sample are merely the weighted means of the increments for all available fish.

TABLE 26.—*General growth in total length of Saginaw Bay walleyes of the 1926–30 and 1943 collections*

[Data transcribed from tables 24 and 25 to facilitate comparison. Lengths given in inches]

Year of life	1926–30 collections				1943 collection			
	Males		Females		Males		Females	
	Length	Increment	Length	Increment	Length	Increment	Length	Increment
1	6.7	6.7	6.9	6.9	6.4	6.4	6.4	6.4
2	10.7	4.0	10.9	4.0	12.0	5.6	12.0	5.6
3	13.4	2.7	13.8	2.9	15.8	3.8	16.3	4.3
4	15.3	1.9	16.0	2.2	18.1	2.3	18.9	2.6
5	16.6	1.3	17.8	1.8	19.5	1.4	21.3	2.4
6	17.6	1.0	19.3	1.5	20.6	1.1	22.9	1.6
7	18.3	.7	20.3	1.0	21.4	.8	24.3	1.4
8	18.9	.6	21.0	.7	21.9	.5	25.4	1.1
9	19.5	.6	21.7	.7	22.7	.8	26.3	.9
10	20.0	.5	22.3	.6	23.3	.6	27.3	1.0
11	20.4	.4	22.9	.6			27.9	.6
12	20.7	.3	23.5	.6			28.8	.9
13	21.0	.3	24.0	.5			29.5	.7
14	21.3	.3	24.5	.5				
15			25.0	.5				

The females of the Saginaw Bay walleyes were longer than the males in all but the earliest years of life (fig. 4). In the 1926–30 collection the females averaged the longer even at the end of the first year (females 6.9 inches; males 6.7 inches). The females were unable to add to this 0.2-inch advantage during the second year (second-year length of females, 10.9 inches, and of males, 10.7 inches) but were the longer by 0.4 inch at the end of 3 years (females, 13.8 inches; males, 13.4 inches). The females added to this early advantage in each succeeding year of life with a resulting divergence of the growth curves for the sexes. At the end of 5 years the length of the females (17.8 inches) was more than an inch greater than that of the males (16.6 inches). The advantage of the females had reached 2 inches in 7 years (females, 20.3 inches; males, 18.3 inches), 3 inches in 13 years (females 24.0 inches; males, 21.0 inches), and was 3.2 inches at the end of 14 years, the highest age attained by the males. How great this disparity of growth became with respect

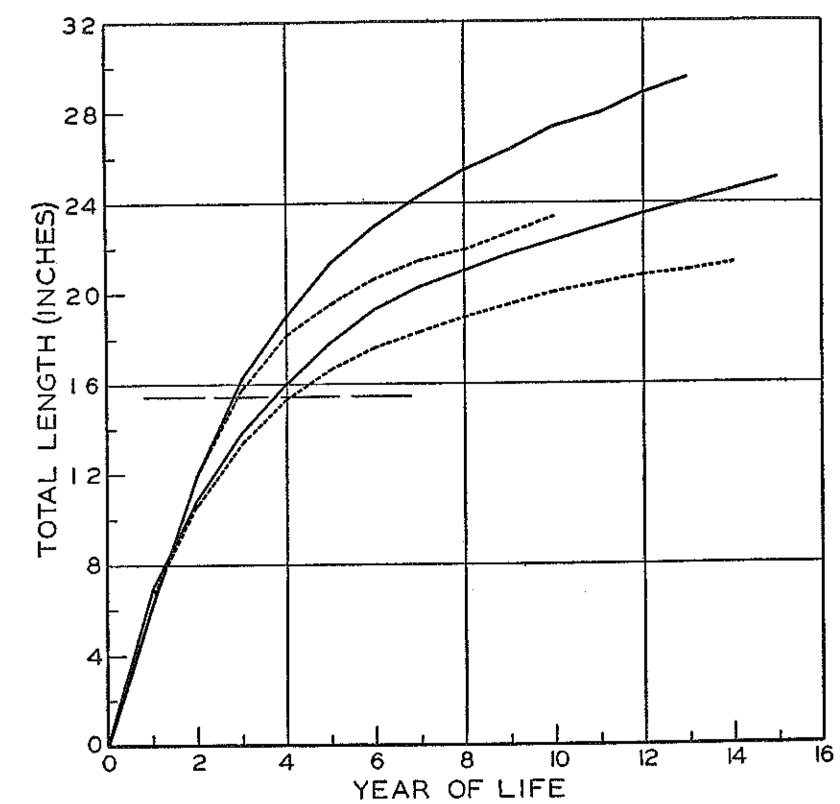

FIGURE 4.—Calculated general growth in length of male (broken lines) and female walleyes (solid lines) of the 1926–30 (lower curves) and 1943 collections (upper curves). The broken horizontal line indicates the minimum legal length of 15½ inches.

to time is well illustrated by the fact that females were longer at the end of 9 years (21.7 inches) than males at the end of 14 years (21.3 inches).

The present legal minimum size of 15½ inches was attained by the 1926–30 males early in the fifth growing season and by the females in the latter part of the fourth. The size limit of 1½ pounds (equivalent to a length of 17.1 inches) which was in effect at the time of collection was reached by the males in the sixth and by females in the fifth year. Finally, males reached the 1933–38 legal minimum length of 16½ inches near the end and the females in the earlier part of the fifth growing season.

Walleyes of both sexes in the 1926–30 collections made by far their greatest growth in length during the first year of life. Beyond that year the increments decreased rather consistently (were equal over periods of 2 or 3 years at certain higher ages). All increments were less than an inch beyond the sixth year of life of the males and the seventh year of the females.

The comparison of the annual increments of the sexes of the walleyes of the 1926–30 collection reveals that the advantage of the females over the males with respect to yearly growth was 0.2 inch in the first year and nil in the second, rose thereafter to a maximum of 0.5 inch in the fifth and sixth years, and ranged from 0.1 to 0.3 inch in the seventh through the fourteenth. Although the absolute advantage of the females over the males tended first to increase and then to decrease, the trend was toward an increase in the relative advantage with advancing age as the following tabulation proves:

Years of life	Growth		Ratio
	Males	Females	
	Inches	*Inches*	
1–2	10.7	10.9	1.02
3–6	6.9	8.4	1.22
7–14	3.7	5.2	1.41

The relation between the growth of the sexes in the 1943 collection was similar to that in the 1926–30 samples (fig. 4). In fish collected in 1943, the calculated lengths of the males and the females were the same at the end of the first (6.4 inches) and second (12.0 inches) years of life. In the succeeding years the females established an advantage that reached 1.8 inches at the end of 5 years (females, 21.3 inches; males, 19.5 inches) and was 4.0 inches at the end of 10 years (females, 27.3 inches; males 23.3 inches). In the seventh growing season females reached a length as great as that of males at the end of 10 full years. In the third through the tenth year of life the advantages of the females over males were consistently greater at corresponding ages in the 1943 than in the 1926–30 collections. The greatest difference occurred at the end of the tenth year when the 1943 females were 4.0 inches longer than the males as compared with a sex difference of only 2.3 inches at the same age in the 1926–30 fish.

The times of attainment of legal length by both males and females of the 1943 sample at the various limits were as follows: 15½ inches—late in the third growing season; 16½ inches and 1½ pounds (17.1 inches)—during the fourth season. The females reached each of these limits earlier than did the males.

In the 1943 sample as in the 1926–30 collections the best growth in length was made in the first year (6.4 inches for each sex) and the trend of the increments was downward during the succeeding years. All length increments of the 1943 males were less than 1.0 inch beyond the sixth year; the same holds for the females beyond the eighth year with the exception of the tenth-year increment of 1.0 inch.

Comparisons of the corresponding annual growth increments of the males and females of the 1943 collection reveal that in the first and second years the sex differences were nil but that in each of the later years the growth of the females was the greater. The largest difference is to be found in the fifth year when the growth of the females (2.4 inches) was a full inch greater than that of the males. In other years the advantage of the females ranged between 0.1 inch (ninth year) and 0.6 inch (seventh and eighth years). Again, we find the relative advantage of the females increasing with increase in age as the following tabulation demonstrates:

Years of life	Growth		Ratio
	Males	Females	
	Inches	*Inches*	
1–2	12.0	12.0	1.00
3–6	8.6	10.9	1.27
7–10	2.7	4.4	1.63

Comparison of this tabulation with the one given previously for the 1926–30 collections shows that the ratios for years 1–2 and 3–6 were closely similar (1.02 and 1.22 for the 1926–30 samples; 1.00 and 1.27 for the 1943 collection). Beyond the sixth year, however, the relative advantage of the females was much greater in the 1943 walleyes (ratio of 1.63) than in the 1926–30 fish (ratio of 1.41). As a result the rate of divergence of the growth curves for the sexes (fig. 4) was greater for the 1943 than for the 1926–30 specimens.

The increase with age in the growth advantage of the females is of interest in connection with the problem of the relation between sex differences in growth rate and in the time of attainment of maturity (with a concomitant depression of growth rate). The earlier attainment of sexual maturity by males frequently has been offered as the explanation of the more rapid growth of females in certain species of fish.[28] In the Saginaw Bay walleye, males do mature at a lesser size and age than do females (p. 56). If attainment of maturity in this stock causes a depression of growth rate, then sex differences in the age at first maturity contributed to the sex differences in growth rate in some of the earlier years. On the other hand, the females maintained their (relative) advantage in growth at ages at which all or practically all walleyes of both sexes were mature (no immature walleyes beyond the VI group in 1930 or the IV group in 1943—see table 48). To a large extent, therefore, the more rapid growth of the females of the Saginaw Bay walleye represents a true sex difference in growth potential and is not the result of later attainment of maturity by fish of that sex.

In earlier comments relative to the data of tables 24 and 25 it was stated without elaboration that the first-year growth of the walleyes of the 1943 collection was no better than that of the 1926–30 samples—indeed was inferior to the first-year growth of the earlier year classes—but that in the later years of life the calculated lengths of fish of the 1943 collection were characteristically near or above the highest corresponding lengths of those of the 1926–30 collections. The true extent of the differences in the growth of the two groups, however, is probably brought out best by the general growth data of table 26.

[28] See Svärdson (1943) for an excellent review of the problem of the relation between sexual maturity and the growth of fish.

Although the walleyes of the 1943 collection were shorter at the end of the first year (calculated length of 6.4 inches for each sex) than the fish of the 1926–30 collections (males, 6.7 inches; females, 6.9 inches) the second-year growth of fish of the more recent sample was so rapid that in 2 years they were the longer by more than an inch. To this advantage they added materially in subsequent years.

By the end of the fourth year of life the 1943 males (18.1 inches) were 2.8 inches longer than 1926–30 fish (15.3 inches). Beyond the fourth year the advantage of the males caught in 1943 varied irregularly and within rather narrow limits from 2.9 inches in the fifth year (lengths of 19.5 and 16.6 inches) to 3.3 inches in the tenth (lengths of 23.3 and 20.0 inches). The 1943 males were as long at the end of 5 years (19.5 inches) as the 1926–30 males at the end of 9 and were longer in 7 years (21.4 inches) than 1926–30 males at the end of 14 (21.3 inches).

Females of the 1943 sample differed from the males in that their advantage over the 1926–30 fish did not tend to level off after 4 years. Rather, they added to their advantage in every later year of life but the eleventh. The length advantage of the 1943 females amounted to 2.5 inches at the end of 3 years (lengths of 16.3 and 13.8 inches), was 4.0 inches in 7 years (lengths of 24.3 and 20.3 inches) and reached a maximum of 5.5 inches in 13 years (lengths of 29.5 and 24.0 inches). Female walleyes of the 1943 sample were longer at the end of 5 years than 1926–30 females at the end of 8 years and were longer in 8 years (25.4 inches) than 1926–30 fish in 15 (25.0 inches).

GROWTH IN WEIGHT

The data of tables 27, 28, and 29 were computed (by means of the length-weight equation given on p. 27) from the standard lengths on which tables 24, 25, and 26 were based. The solutions of the equation, obtained in grams, were subsequently converted to pounds. (Tables 27 and 28 give the general growth in weight in both pounds and grams.)

Data obtained by this procedure have the distinct advantage that the length and weight at a particular age correspond exactly, whereas for a group of fish (as an age group) in which both length and weight vary, the mean weight may be expected to exceed the normal weight of a fish of average length.[29]

Because tables 27, 28, and 29 were derived from tables 24, 25, and 26, the general patterns of variation must be the same in corresponding pairs of tables. As a result of the increase of weight approximately as the cube of the length, however, the variations are much greater in the tables on weight.

In the 1926–30 collections (year-class 1928 and earlier) the greatest relative variation in calculated weight[30] occurred in the first year of life. In the males the maximum weight of 0.13 pound (year-class 1921) was more than twice the minimum of 0.06 (year-classes 1924 and 1926); in the females the maximum first-year weight of 0.18 pound (year-class 1916) was 3.6 times the minimum of 0.05 pound (year-class 1924). In the later years the relative variability of the calculated weights was less although the actual ranges were greater. The difference between the highest and the lowest calculated weights of male walleyes in corresponding years of life rose from 0.07 pound at the end of the first year to 0.64 pound at the end of the fifth and sixth years, ranged between 0.36 and 0.38 pound in the seventh through the ninth year, and was 0.07 pound at the end of the tenth. For the females this range increased from 0.13 pound at the end of the first year to 1.46 pounds at the end of the sixth, varied between 0.66 and 1.13 pounds in the seventh through the eleventh year, and was 0.24 pound at the end of the twelfth. With the weights, as was true with the lengths, the early increase in the range of the calculated values can be interpreted as an increase in the variability but the subsequent decreases can be ascribed in large part to the lesser number of year classes represented in the data for the later years of life.

As would be expected, since the weights were computed from the lengths, the calculated first-year weights of the year classes of the 1943 collection (year-class 1933 and later of the males; year-class 1930 and later of the females) were at about the same level as those of year-classes 1924 to 1928 of the 1926–30 collections but were generally below the first-year weights of year classes earlier than 1924. It was to be expected further that beyond the first year the calculated weights of walleyes of the 1943 collection would characteristically be above the level of the weights of fish of the 1926–30 collections, and that the advantage of the 1943 fish would be relatively greater with respect to weight than it was with respect to length. All of these expectations are met by the data of tables 27 and 28.

[29] To illustrate this point—given one fish with a length of 1 foot and a weight of 1 pound and another with a length of 2 feet and a weight of 8 pounds, we have a mean length of 1.5 feet and a mean weight of 4.5 pounds. Yet, in a stock with the indicated length-weight relation (weight in pounds equal to the cube of the length in feet) a 1.5-foot fish should weigh only 3.375 pounds.

[30] In statements of variations in calculated weight as with calculated length the data of year-classes 1914–17 of the males and of year-classes 1914–15 of the females have been excluded as inadequately represented.

TABLE 27.—*Calculated growth in weight of the males of the year classes of Saginaw Bay walleyes*

[Weights computed from the standard lengths corresponding to the total lengths of table 24. See p. 27 for length-weight equation]

Year class	Calculated weight (pounds) at end of year of life—													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1914	0.07	0.53	0.94	1.53	1.77	2.03	2.32	2.50	2.76	3.05	3.17	3.33	3.45	
1915	.11	.32	.69	1.12	1.37	1.63	1.86	2.10	2.33	2.50	2.67	2.79	2.90	3.05
1916	.12	.39	.82	1.35	1.74	2.28	2.74	3.09	3.49	3.82	4.07	4.21	4.40	
1917	.13	.52	.95	1.44	1.84	2.30	2.53	2.77	3.07	3.35	3.51	3.73		
1918	.12	.48	.87	1.26	1.63	1.90	2.11	2.35	2.58	2.76	2.98			
1919	.11	.46	.88	1.34	1.61	1.84	2.07	2.28	2.48	2.60				
1920	.11	.43	.79	1.16	1.44	1.67	1.86	2.03	2.21					
1921	.13	.46	.82	1.12	1.38	1.61	1.79	1.97						
1922	.12	.43	.71	1.08	1.35	1.56	1.75	2.03						
1923	.12	.41	.82	1.15	1.42	1.62	1.84							
1924	.06	.24	.46	.71	.99	1.26								
1925	.07	.28	.58	.94	1.20									
1926	.06	.26	.60	.88										
1927	.07	.35	.61											
1928	.08	.33												
1933	.11	.56	1.10	1.66	2.07	2.45	2.77	2.98	3.23	3.51				
1934	.08	.44	.78	1.19	1.62	1.98	2.30	2.60	2.94					
1935	.04	.43	1.02	1.35	1.74	2.04	2.28	2.55						
1936	.05	.37	.90	1.38	1.74	2.19	2.55							
1937	.07	.40	.99	1.48	1.97	2.35								
1938	.08	.42	1.04	1.56	1.90									
1939	.05	.37	1.04	1.59										
1940	.09	.65	1.32											
Year-classes 1914–28:														
Grams	39	166	325	480	626	734	829	919	1,008	1,095	1,178	1,250	1,316	1,385
Pounds	.09	.37	.72	1.08	1.38	1.62	1.83	2.03	2.22	2.41	2.60	2.76	2.90	3.05
Increment	.09	.28	.35	.36	.30	.24	.21	.20	.19	.19	.19	.16	.14	.15
Year-classes 1933–40:														
Grams	35	238	534	799	1,022	1,218	1,385	1,519	1,672	1,814				
Pounds	.08	.52	1.18	1.76	2.25	2.69	3.05	3.35	3.69	4.00				
Increment	.08	.44	.66	.58	.49	.44	.36	.30	.34	.31				

TABLE 28.—*Calculated growth in weight of the females of the year classes of Saginaw Bay walleyes*

[Weights computed from the standard lengths corresponding to the total lengths of table 25. See p. 27 for length-weight equation]

Year class	Calculated weight (pounds) at end of year of life—														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1914	0.18	0.57	0.97	1.46	1.72	2.27	2.55	2.85	3.17	3.41	3.71	4.09	4.33	4.57	4.86
1915	.18	.52	1.11	1.57	2.32	3.09	3.75	4.16	4.80	5.18	5.65	6.01	6.22	6.53	
1916	.18	.57	1.11	1.64	2.24	2.88	3.41	3.86	4.30	4.68	5.04	5.37	5.68		
1917	.15	.56	1.11	1.68	2.40	3.05	3.54	3.93	4.30	4.57	4.86	5.13			
1918	.14	.51	1.03	1.62	2.28	2.86	3.29	3.66	4.05	4.43	4.75	5.20			
1919	.15	.50	1.05	1.68	2.22	2.74	3.17	3.49	3.77	4.11	4.38				
1920	.13	.54	1.05	1.58	2.07	2.51	2.83	3.17	3.49	3.82					
1921	.14	.51	.93	1.32	1.79	2.19	2.53	2.83	3.17						
1922	.14	.48	.83	1.31	1.79	2.22	2.63	2.96							
1923	.12	.40	.91	1.40	1.91	2.35	2.70								
1924	.05	.24	.54	.88	1.26	1.59									
1925	.07	.29	.62	1.01	1.30										
1926	.06	.27	.63	.93											
1927	.07	.35	.62												
1928	.07	.30													
1930	.08	.64	1.11	1.63	2.58	3.33	4.30	5.02	5.48	5.98	6.34	6.99	7.57		
1931	.07	.36	.69	1.29	2.04	2.58	3.21	3.66	4.16	4.83	5.31	5.86			
1933	.10	.67	1.14	1.75	2.38	2.98	3.54	3.95	4.38	4.94					
1934	.10	.48	1.06	1.56	2.21	2.98	3.54	4.09	4.70						
1936	.08	.43	.96	1.76	2.51	3.25	4.05								
1937	.06	.37	1.10	1.83	2.70	3.41									
1938	.14	.72	1.46	2.27	3.03										
1939	.06	.41	1.24	1.94											
1940	.09	.67	1.46												
Year-classes 1914–28:															
Grams	42	174	355	557	769	973	1,147	1,299	1,455	1,594	1,732	1,866	1,985	2,098	2,227
Pounds	.09	.38	.78	1.23	1.70	2.15	2.53	2.86	3.21	3.51	3.82	4.11	4.38	4.63	4.91
Increment	.09	.29	.40	.45	.47	.45	.38	.33	.35	.30	.31	.29	.27	.25	.28
Year-classes 1930–40:															
Grams	35	238	586	926	1,342	1,692	2,064	2,348	2,617	2,906	3,110	3,417	3,694		
Pounds	.08	.52	1.29	2.04	2.96	3.73	4.55	5.18	5.77	6.41	6.86	7.53	8.14		
Increment	.08	.44	.77	.75	.92	.77	.82	.63	.59	.64	.45	.67	.61		

TABLE 29.—*General growth in weight of Saginaw Bay walleyes of the 1926–30 and 1943 collections*

[Data transcribed from tables 27 and 28 to facilitate comparisons. Weight given in pounds]

Year of life	1926–30 collections				1943 collection			
	Males		Females		Males		Females	
	Weight	Increment	Weight	Increment	Weight	Increment	Weight	Increment
1	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08
2	.37	.28	.38	.29	.52	.44	.52	.44
3	.72	.35	.78	.40	1.18	.66	1.29	.77
4	1.08	.36	1.23	.45	1.76	.58	2.04	.75
5	1.38	.30	1.70	.47	2.25	.49	2.96	.92
6	1.62	.24	2.15	.45	2.69	.44	3.73	.77
7	1.83	.21	2.53	.38	3.05	.36	4.55	.82
8	2.03	.20	2.86	.33	3.35	.30	5.18	.63
9	2.22	.19	3.21	.35	3.69	.34	5.77	.59
10	2.41	.19	3.51	.30	4.00	.31	6.41	.64
11	2.60	.19	3.82	.31			6.86	.45
12	2.76	.16	4.11	.29			7.53	.67
13	2.90	.14	4.38	.27			8.14	.61
14	3.05	.15	4.63	.25				
15			4.91	.28				

Male and female walleyes of the 1926–30 collections had the same calculated weight (table 29; fig. 5) at the end of the first year of life (0.09 pound), and at the end of 2 years the females (0.38 pound) were only 0.01 pound heavier than the males (0.37 pound). In the third year, however, the weight of the females (0.78 pound) was 0.06 pound greater than that of the males (0.72 pound). The females added to this advantage in each succeeding year of life. The sex difference was 0.53 pound at the end of 6 years (females, 2.15 pounds; males, 1.62 pounds), amounted to practically a pound (0.99 pound) in 9 years (females, 3.21 pounds; males, 2.22 pounds) and reached the maximum of 1.58 pounds at the end of 14 years (females, 4.63 pounds; males, 3.05 pounds).

The annual increments of weight of the 1926–30 males increased from 0.09 pound in the first year to a maximum of 0.36 pound in the fourth and thereafter declined (except for the equal ninth- to eleventh-year increments of 0.19 pound) to 0.14 pound in the thirteenth year. The fourteenth-year increment was 0.15 pound. In the females the increase from the first-year increment of 0.09

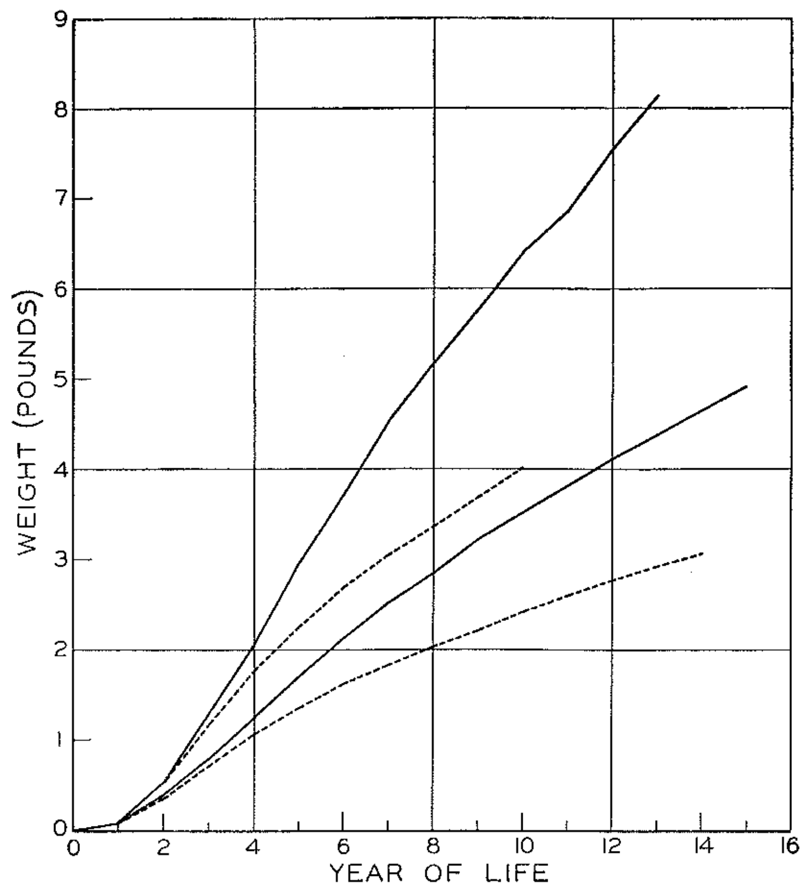

FIGURE 5.—Calculated general growth in weight of male (broken lines) and female walleyes (solid lines) of the 1926–30 (lower curves) and 1943 collections (upper curves).

pound continued through the fifth year when the maximum value of 0.47 pound was reached. During the later years the trend was irregularly downward; the lowest value in these years was 0.25 pound in the fourteenth year of life.

The annual increments of weight of female walleyes of the 1926–30 samples exceeded those of males in every year of life beyond the first. The greatest absolute advantage of the females occurred in the sixth year when their growth of 0.45 pound was 0.21 pound greater than that of males. The relative advantage of the females tended to become greater with advancing age as may be seen from the following tabulation:

Years of life	Growth		Ratio
	Males	Females	
	Pounds	*Pounds*	
1–2	0.37	0.38	1.03
3–6	1.25	1.77	1.42
7–14	1.43	2.48	1.73

A comparison of this tabulation with the corresponding one for growth in length of walleyes of the 1926–30 samples (p. 36) reveals that the progressive increase in the relative advantage of the females was considerably more rapid for weight than for length (higher ratios for growth in weight). The divergence of the curves of growth in weight was correspondingly more pronounced (*cf.* figs. 4 and 5).

The calculated weights of the male and female walleyes of the 1943 sample were the same at the end of the first and second years of life (0.08 and 0.52 pound, respectively). In the later years, however, females had a weight advantage that increased each year from 0.11 pound in the third year (females, 1.29 pounds; males, 1.18 pounds) to 1.04 pounds at the end of the sixth year (females, 3.73 pounds; males, 2.69 pounds), and to 2.41 pounds in 10 years (females, 6.41 pounds; males, 4.00 pounds).

The annual increments of weight of the male walleyes of the 1943 collection rose from 0.08 pound in the first year of life to a maximum of 0.66 pound in the third and then declined to 0.30 pound in the eighth. The ninth- and tenth-year increments were 0.34 and 0.31 pound, respectively. The trends in the annual increments of the females were much more irregular than were those of the males. The upward trend from the first-year increment of 0.08 pound to the maximum of 0.92 pound in the fifth year (2 years later than the maximum for the males) was interrupted in the fourth year, and the subsequent decline from the maximum was decidedly irregular. During the last 6 years of life (eighth through the thirteenth) the increments fluctuated more or less at random between a maximum of 0.67 pound in the twelfth year and a minimum of 0.45 pound in the eleventh.

In every year of life beyond the second the weight increments of the 1943 females exceeded those of the males. The greatest advantage of the females occurred in the seventh year when the increment of 0.82 pound was 0.46 pound greater than the increment of 0.36 pound for the males. The increase in the relative advantage of the females with increase in age was greater for the later years in the 1943 than in the 1926–30 walleyes as may be seen from the comparison of the following tabulation with the one previously given for the earlier collections:

Years of life	Growth		Ratio
	Males	Females	
	Pounds	*Pounds*	
1–2	0.52	0.52	1.00
3–6	2.17	3.21	1.48
7–10	1.31	2.68	2.05

Although the ratios for the periods of years 1 and 2 and 3 to 6 did not differ greatly in the two collections, the growth in weight of the females of the 1943 sample in the years 7 to 10 was 2.05 times that of males whereas the growth of the females of the 1926–30 collection in the years 7 to 14 was but 1.73 times that of the males. The curves of the growth in weight of the sexes accordingly diverge much more prominently in the later years in the 1943 than in the 1926–30 walleyes (fig. 5).

In the years 3 to 6 and 7 to 10 the relative advantages of the females of the 1943 sample were much greater with respect to growth in weight than to growth in length (compare preceding tabulation with the one on p. 36).

The superiority of the growth of the walleyes of the 1943 collection over fish of the 1926–30 collections, much like the advantage of females over males, becomes much greater when the comparison is based on weight rather than length.

Although the calculated weight of the 1943 males (0.08 pound) in the first year of life was slightly less than that of 1926–30 males (0.09 pound), the fish of the more recent collection established an advantage in the second year of life and added to it in every later year. From 0.15 pound at the end of the second year (1943 males, 0.52 pound; 1926–30 males, 0.37 pound), the advantage of the fish of the 1943 sample increased to more than a pound by the end of the sixth year (1943 males, 2.69 pounds; 1926–30 males, 1.62 pounds), and reached 1.59 pounds at the end of 10 years (1943 males, 4.00 pounds; 1926–30 males, 2.41 pounds). With the females, as with the males, the 1943 fish first established an advantage over walleyes collected in 1926–30 at the end of the second year of life when they weighed 0.52 pound or 0.14 pound more than fish of the earlier samples. This advantage had increased to more than 1¼ pounds by the end of the fifth year (1943 females, 2.96 pounds; 1926–30 females, 1.70 pounds), was above 2½ pounds in 9 years (1943 females, 5.77 pounds; 1926–30 females, 3.21 pounds), and at the end of 13 years amounted to more than 3¾ pounds (1943 females, 8.14 pounds; 1926–30 females, 4.38 pounds).

A striking feature of the comparative data lies in the high degree of stability that was attained in the later years of life in the ratios of the calculated weights of 1943 walleyes to the weights of 1926–30 fish of corresponding sex and age (table 30). In the males, this ratio rose sharply from 0.89 at the end of the first year of life to 1.64 at the end of the third, but thereafter exhibited only slight variation (within the range, 1.63–1.67). For practical purposes it can be said that in the third through the tenth year of life the 1943 males were 65 percent heavier than 1926–30 males of the same age. In the females, stability of the ratio was reached at a later age and at a higher level. From 0.89 at the end of the first year the value rose somewhat irregularly to 1.80 at the end of the seventh, and in the seventh through the thirteenth year was from 1.80 to 1.86. In years of life 7 to 13, therefore, the 1943 females were about 82 percent heavier than 1926–30 females, or, sacrificing some precision in favor of a longer span of years and a round figure, in years of life 5 to 13 the 1943 females were the heavier by 80 percent.

TABLE 30.—*Ratios of the calculated weights of walleyes of the 1943 collection to the weights of fish of corresponding age and sex of the 1926–30 collections*

[Based on data of table 29]

Year of life	Ratio of 1943 to 1926–30 weight		Year of life	Ratio of 1943 to 1926–30 weight	
	Males	Females		Males	Females
1	0.89	0.89	8	1.65	1.81
2	1.41	1.37	9	1.66	1.80
3	1.64	1.65	10	1.66	1.83
4	1.63	1.66	11	----	1.80
5	1.63	1.74	12	----	1.83
6	1.66	1.73	13	----	1.86
7	1.67	1.80			

ANNUAL FLUCTUATIONS IN GROWTH RATE

FLUCTUATIONS FROM 1916 TO 1929

Length

The basic data on the annual fluctuations in growth in length of Saginaw Bay walleyes (tables 31 and 32) are arranged in the following manner: Each column shows the increments for different years of life but in the same calendar year, each horizontal row the increments for the same year of life but in different calendar years, and each diagonal row the growth history of a year class that can be identified by the calendar year in which the first-year growth was made. Omitted from the tables are data for certain of the earlier and poorly represented year classes.

Examination of the length increments of tables 31 and 32 reveals certain rather definite trends that were similar for the males and females. It is obvious, for example, that years prior to 1923 constituted, on the whole, a period of relatively good growth and years subsequent to 1923 one of rather poor growth. Apparent also in certain calendar years is the tendency toward sharp improvement or decline from the growth in the preceding year, whereas in other calendar years no important change from the preceding year can be demonstrated. The downward trend in growth rate was extremely clear cut in 1923 when all 5 increments of the males and all 7 increments of the females were smaller than the corresponding increments for 1922 (table 33). The situation was similar in 1924 when 5 of the 6 increments of the males and all 8 increments of the females were smaller than those of 1923. The general trend was downward also in 1926 (5 of 8 increments of males and 7 of 10 increments of females smaller than in 1925). The most consistent improvements of growth occurred in 1921 (2 of 3 increments of the males and all 5 increments of females larger than in 1920) and in 1925 (5 of 7 increments of the males and 6 of 9 of the females larger than in 1924). In 1928, 8 of 10 increments of the males but only 6 of 12 of the females exceeded those of 1927.

TABLE 31.—*Annual increments of growth in length of male Saginaw Bay walleyes of the 1926–30 collections according to calendar year*

[Each diagonal row gives the growth history of a year class]

Year of life	Increment of standard length (millimeters) in year—											
	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929
11	----	----	----	----	----	----	----	----	----	----	12	----
10	----	----	----	----	----	----	----	----	----	10	12	----
9	----	----	----	----	----	----	----	----	14	12	12	----
8	----	----	----	----	----	----	----	15	14	12	13	20
7	----	----	----	----	----	----	15	16	14	14	15	17
6	----	----	----	----	----	20	18	19	19	18	17	27
5	----	----	----	----	32	23	26	25	26	25	35	27
4	----	----	----	41	47	41	34	44	37	39	48	38
3	----	----	57	62	57	54	46	63	49	59	67	47
2	----	96	96	91	87	85	83	78	82	83	94	86
1	160	156	155	165	161	160	126	132	126	136	140	----
Number of fish in—												
1926	----	----	----	----	3	1	3	145	----	----	----	----
1927	3	13	18	13	----	----	----	----	----	----	----	----
1928	----	----	----	----	----	----	----	4	4	8	----	----
1929	9	23	38	72	107	59	----	----	----	----	----	----
1930	----	----	----	----	2	6	9	110	246	154	17	----

The data of tables 31 and 32 offer little basis for the belief that the trends of the annual fluctuations in growth rate varied significantly for different years of life. It is true that in the 1927 data for the males the increments for the first 4 years of life all exceeded those for 1926, whereas beyond the fourth year the 1926 growth was the greater in 4 years of life and equalled 1927 growth in the remaining (the seventh). Again, in 1929 growth was superior to that in 1928 in years of life 6 to 8 but poorer in years of life 2 to 5. It might be judged from these two examples that fluctuations in growth tended to follow opposite trends in the earlier and later years of life. This same tendency was almost lacking, however, in the 1926–27 data for the females and was reduced in the 1928–29 data. Furthermore, the disagreements in the remaining data were distributed at

TABLE 32.—*Annual increments of growth in length of female Saginaw Bay walleyes of the 1926–30 collections according to calendar year*

[Each diagonal row gives the growth history of a year class]

Year of life	Increment of standard length (millimeters) in year—													
	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929
13	----	----	----	----	----	----	----	----	----	----	----	----	11	----
12	----	----	----	----	----	----	----	----	----	----	----	12	11	17
11	----	----	----	----	----	----	----	----	----	----	14	11	13	11
10	----	----	----	----	----	----	----	----	----	15	11	16	13	15
9	----	----	----	----	----	----	----	----	19	16	17	15	16	18
8	----	----	----	----	----	----	----	21	18	18	16	18	17	18
7	----	----	----	----	----	----	27	24	22	23	18	21	25	21
6	----	----	----	----	----	38	37	34	31	28	28	30	29	29
5	----	----	----	----	42	49	47	38	36	38	39	40	40	29
4	----	----	----	48	51	54	57	49	40	51	49	48	50	39
3	----	----	67	70	70	73	67	58	52	76	62	48	70	48
2	----	89	95	93	89	100	92	85	82	87	82	84	96	85
1	183	174	168	171	166	170	171	160	117	135	127	135	135	----
Number of fish in—														
1926	----	----	----	----	----	1	----	----	4	145	----	----	----	----
1927	3	5	5	11	17	20	----	----	----	----	----	----	----	----
1928	----	----	----	----	----	----	----	----	1	2	6	27	----	----
1929	9	12	25	43	33	46	97	31	----	----	----	----	----	----
1930	----	----	4	2	4	10	13	17	16	120	164	143	23	----

TABLE 33.—*Comparison of increments of length of Saginaw Bay walleyes for corresponding years of life in consecutive calendar years*

[Relative sizes of increments are based on comparisons of growth in the more recent with that in the preceding year]

Calendar years compared	Males			Females		
	Larger	Smaller	Same	Larger	Smaller	Same
1916 and 1917	----	----	----	0	1	0
1917 and 1918	----	----	----	1	1	0
1918 and 1919	0	1	0	2	1	0
1919 and 1920	0	1	1	1	2	1
1920 and 1921	2	1	0	5	0	0
1921 and 1922	1	3	0	2	4	0
1922 and 1923	0	5	0	0	7	0
1923 and 1924	1	5	0	0	8	0
1924 and 1925	5	2	0	6	2	1
1925 and 1926	2	5	1	2	7	1
1926 and 1927	4	4	1	7	3	1
1927 and 1928	8	1	1	6	4	2
1928 and 1929	3	4	0	4	6	1

random—that is, not detectably related to age, and in some years, as previously noted, the direction of change was the same at all or nearly all ages. The general conclusion seems warranted that the trends of the annual fluctuations in growth rate did not vary according to the age of the fish.

Although the examination of tables 31 and 32 and of the supplementary records of table 33 provides a useful preliminary measure of the changes which occurred from year to year in the growth of walleyes of the 1926–30 collections, it is only roughly quantitative. Much more exact information is to be had from the analysis of the data to determine the actual percentage changes. The results of this analysis [31] (table 34) are given in terms of percentage deviation from average growth in 1919–28, the longest term of calendar years with data for all three periods—first year, second and later years, and all years of life—for which computations were made. Percentages have been presented separately for the first and for the second and later years as well as for all years combined despite the earlier observation that the trends of the fluctuations were not demonstrably correlated with age. Since young of the year, to our best knowledge, spend the growing season in Saginaw Bay whereas most older fish desert the bay for offshore waters, the most exact comparison possible between growth in the two environments is desired.

It is at once obvious from the percentages of table 34 that the trends of the annual fluctuations all were rather closely similar. First-year growth followed a course resembling that of growth in the second and later years, and in both the first and the later years the fluctuations followed closely those for all years combined. Furthermore, the fluctuations in growth of the males and females were much the same in all three categories. How similar the percentage fluctuations were is well demonstrated by the coefficients of correlation (r) of table 35. Of the coefficients listed, four were far above the level ordinarily termed highly significant ($p=0.01$)—two of the four, indeed, exceeded the value corresponding to $p=0.001$—and the fifth (correlation between the annual fluctuations in the growth of males in the first and in the second and later years) was between the 5- and

[31] See Hile (1941) for a detailed account of the procedure.

1-percent levels of probability. Some differences are to be noted, however, in the ranges of the percentages, which over the common period, 1919 to 1928, were greater for the females than for the males and for the first year than for the later years of life.

The close agreement between the annual fluctuations in the growth of the male and female Saginaw Bay walleyes of the 1926–30 collections constitutes the strongest sort of evidence that the age determinations were accurate for the bulk of the fish up to relatively advanced ages. That these fluctuations should be similar is not surprising—in fact, is to be expected. On the other hand, for this similarity to be so apparent in the analyses made independently for the males and females required that increments showing a certain deviation from the mean be identified with a particular calendar year. This identification in turn called for a correct assessment of age. Furthermore, nearly all of the year classes had to be identified at two or three ages (only exceptionally at one or four—see bottom sections of tables 31 and 32) that were separated by as many as 4 calendar years.

Despite certain discrepancies as to detail and differences in range in the percentage fluctuations in growth in length of walleyes of different sex and/or in different years of life, the general agreement seems to be sufficiently strong to justify the description of the course of growth from 1916 through 1929 on the basis of the percentages as determined for all years of life, sexes combined (bottom row of table 34; see also fig. 6). According to these data the best growth, 12.8 percent above the 1919–28 mean, occurred in 1916, the first year for which we have an estimate. From this maximum the percentage dropped to 7.8 percent in 1917. Variations were small during the 4 years, 1917–20—range from 8.6 percent in 1918 to 6.8 percent in 1920. A rise to the second highest level of the 14-year period (11.7 percent) in 1921 was followed by a rapid decline to the minimum of −14.2 percent in 1924. The fluctuations in the succeeding years were irregular but the general level was low. In only one year (1928) was growth as good as average (0.2 percent). The remaining years were from 4.0 percent (1925) to 11.7 percent (1929) below the 1919–28 mean. This last value was the second lowest of the 1916–29 period. The general trend of growth for the 14-year period can be described as irregularly downward.

TABLE 34.—*Annual fluctuations in the growth in length of the Saginaw Bay walleye expressed as percentage deviations from the 1919–28 mean*

[Percentages for the sexes combined are the unweighted means of the values determined for the sexes individually]

Year of life, and sex	Percentage deviation in calendar year—													
	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929
First:														
Males	-------	-------	9.7	7.0	6.3	13.1	10.4	9.7	−13.4	−9.3	−13.4	−6.6	−3.9	-------
Females	22.1	16.3	12.4	14.4	11.2	13.7	14.4	7.3	−20.5	−8.9	−14.0	−8.9	−8.9	-------
Both sexes	22.1	16.3	11.0	10.7	8.8	13.4	12.4	8.5	−17.0	−9.1	−13.7	−7.8	−6.4	-------
Second and later:														
Males	-------	-------	-------	7.2	7.2	7.2	5.1	−4.3	−11.7	−1.8	−9.4	−6.7	7.3	−1.5
Females	-------	−1.5	5.1	5.6	5.2	14.2	9.7	−3.1	−12.5	−1.0	−9.8	−7.3	−1.0	−15.2
Both sexes	-------	−1.5	5.1	6.4	6.2	10.7	7.4	−3.7	−12.1	−1.4	−9.6	−7.0	3.2	−8.4
All years:														
Males	-------	-------	9.3	6.7	6.3	9.5	7.1	1.5	−12.5	−4.5	−11.1	−6.7	3.8	−6.0
Females	12.8	7.8	7.8	9.0	7.4	13.9	11.2	.6	−15.8	−3.4	−11.5	−7.9	−3.3	−17.4
Both sexes	12.8	7.8	8.6	7.8	6.8	11.7	9.2	1.0	−14.2	−4.0	−11.3	−7.3	.2	−11.7

TABLE 35.—*Correlations of annual fluctuations in the growth rate of Saginaw Bay walleyes*

Growth periods correlated	Period of years	Value of r		Degrees of freedom	Value of r at—		
		Length	Weight		$p=0.05$	$p=0.01$	$p=0.001$
First year, males; later,[1] males	1919–1928	0.724	0.806	8	0.632	0.765	0.872
First year, females; later,[1] females	1917–1928	.814	.911	10	.576	.708	.823
First year, males; first year, females	1918–1928	.966	.933	9	.602	.735	.847
Later,[1] males; later,[1] females	1919–1929	.816	.942	9	.602	.735	.847
All years, males; all years, females	1918–1929	.925	.945	10	.576	.708	.823

[1] Exclusive of the first year.

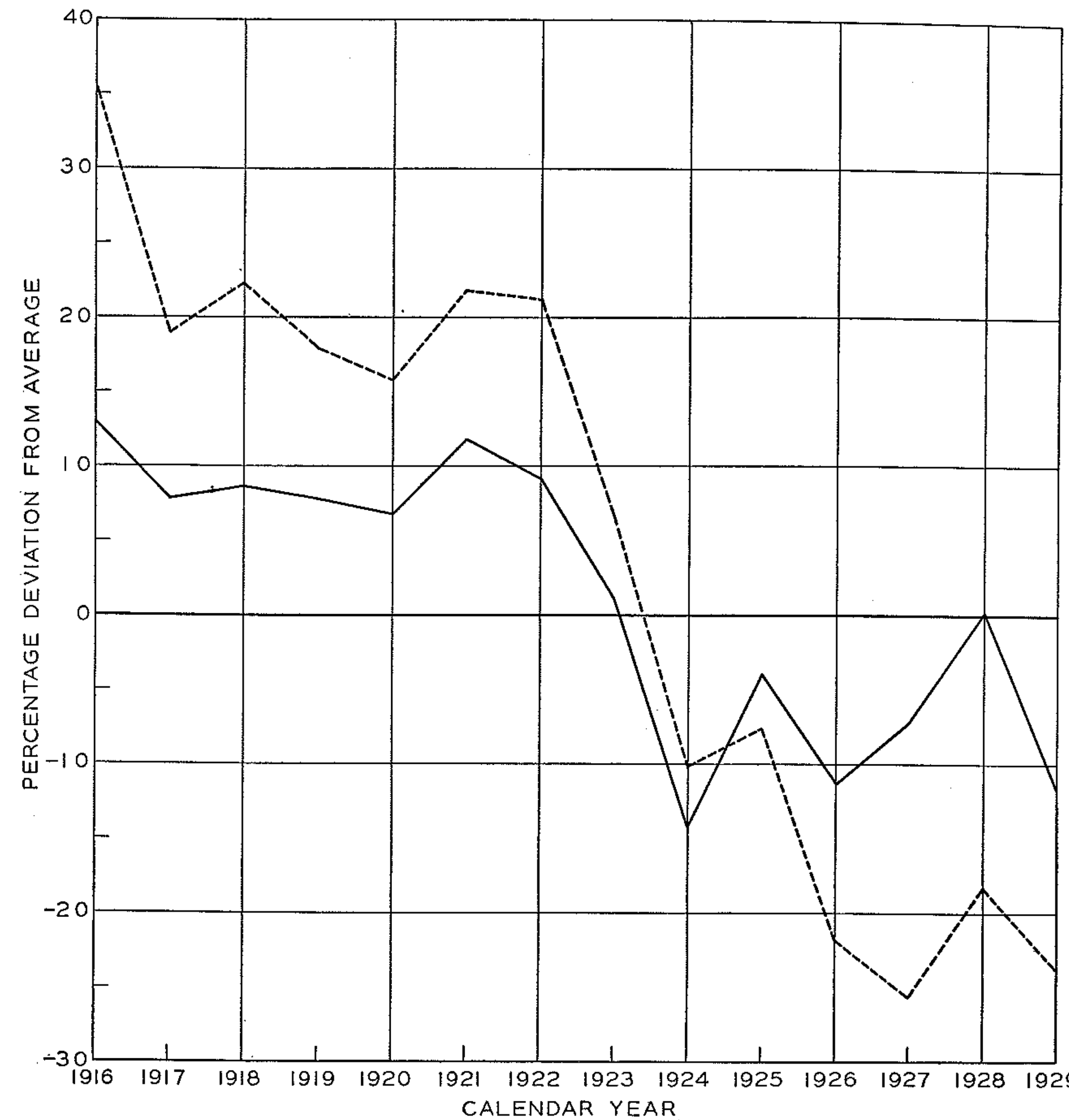

FIGURE 6.—Annual fluctuations in the growth of Saginaw Bay walleyes in length (solid line) and weight (broken line), 1916–29, expressed as percentages of the 1919–28 mean.

Weight

Inasmuch as the calculated weights of tables 36 and 37 were based on the calculated lengths from which tables 31 and 32 were derived, the annual fluctuations of growth in weight of walleyes of the 1926–30 collections can be expected to exhibit trends generally similar to those just described for growth in length. Comparisons of tables 36 and 37 with tables 31 and 32 do show that with weight as with length, in the years prior to 1923 the annual increments tended to be larger and in years later than 1923, smaller than in 1923 itself; the trend toward a sharp improvement or decline was especially noticeable in certain calendar years;

the fluctuations of males and females resembled each other; and, in general, the trends of fluctuations did not differ with age (year of life). The impression is gained also that the range of variations of the annual increments was relatively much greater for weight than for length. The points just listed can be substantiated by comparisons of the actual percentage fluctuations of growth, expressed as deviations from the 1919–28 mean, in length (table 34) and weight (table 38).

The outstanding difference between the annual fluctuations in growth in length and in weight of the 1926–30 collections of walleyes lies in the much greater variation of the latter. This difference has its origin largely in the nature of length-weight relation, namely, the increase of weight approximately as the cube of the length. In consequence of this relation, the increment of weight corresponding to a particular increment of length depends not only on the amount of growth in length but also on the size of the fish at the time the growth is made. To illustrate, under the cube relationship a fish that weighs 1 pound at a length of 10 inches will increase to 1.728 pounds when it grows to a length of 12 inches. A 12-inch fish that experiences the same 2-inch growth (from 12 to 14 inches), will increase its weight by 1.016 pounds (from 1.728 to 2.744 pounds)—an increase 0.288 pound greater than the 0.728-pound increment associated with growth from 10 to 12 inches. Thus it was that during the earlier years of the 1916–29 period the increments of weight were large not only because of above-average increments of length but also because the walleyes were relatively long for their age at the time the growth was made. In the later years, on the contrary, the increments of weight were small by reason both of the small increments of length and the shortness of fish for their age. Here we have the explanation for the fact that 1928, although a year of approximately average growth in length was far below average with respect to growth in weight. The slow growth of preceding years had so reduced the size of the walleyes that with average growth in length they could not make average growth in weight.

Contributing also to discrepancies between estimates of fluctuations of growth in length and in weight were differences with respect to the years of life that exerted greatest influence in the computation of year-to-year percentage changes. Under the procedure followed (comparison of 2 consecutive calendar years on the basis of the sums of the increments for all years of life represented in the data for both years), the earlier years of life (particularly the first and second) by reason of their larger increments dominated the estimates of fluctuations of growth in length. In the data on weight, however, the first-year increments were the smallest and those for the second year were far below the increments for intermediate ages (3 to 4 or 5 years of life) and were smaller than many of the increments at still higher ages. Thus the estimates of fluctuations of growth in length were dominated by the data for the earlier years whereas the intermediate years were most important and the later years of life enjoyed increased influence in the estimation of fluctuations of growth in weight. Since, as was brought out earlier, the data for different years of life were not fully consistent with respect to the extent of growth and direction of change of growth from one year to another, this shift in dominance of years of life inevitably affected comparisons of fluctuations of growth in length and weight.

The correlation between the sexes and between the first and the later years of life was even closer for fluctuations in growth in weight than for growth in length. Four of the five coefficients for weight (table 35) were larger than the corresponding coefficients for length and all had values well beyond the 1-percent level of probability (four beyond the 0.1-percent value). With weight as with length the range of the percentages was greater for the first than for the later years of life and for the females than for the males.

For the sexes and all years of life combined (bottom row of table 38; fig. 6) the growth in weight was best in 1916 when it stood at 35.2 percent above the 1919–28 mean. The percentages fluctuated about a lower level during the next 6 years—between a high of 22.3 percent in 1918 and a low of 15.7 percent in 1920. Successive large decreases in 1923 and 1924 carried the value to −10.2 percent in the latter year. A small improvement in 1925 (to −7.6 percent) was followed by a new decline to the minimum of −25.6 in 1927. A rise occurred again in 1928 (to −18.4 percent) but 1929 with a percentage of −23.8 had the second lowest value of the entire 1916–29 period. The year of relatively best growth for both length and weight was 1916. The poorest growth in weight, however, occurred in 1927, 3 years later than the season of poorest growth in length (1924).

With the fluctuations of growth in 1916–29 as with the strength of the year classes in 1917–28 (see p. 20), preliminary analyses indicated a significant correlation with certain meteorological conditions. Furthermore, the limited data on annual fluctuations in growth supplied by the 1943 sample (see section, Improvement in growth after 1929), contrary to the situation with the year classes, tended to confirm conclusions based on 1926–30 collections. Because the 1943 materials were so scanty, it is held desirable to postpone a detailed inquiry into environmental factors influencing changes of growth rate until more extensive information is at hand.

Table 36.—*Annual increments of growth in weight of male Saginaw Bay walleyes*

[Each diagonal row gives the growth history of a year class. See table 31 for numbers of fish]

Year of life	Increment of weight (grams) in year—											
	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929
11											100	
10										79	93	
9									106	89	82	
8								106	97	77	82	126
7							98	103	85	82	87	102
6						121	107	105	103	95	92	120
5					169	123	127	119	122	122	130	116
4				175	207	166	137	168	150	112	164	127
3			179	192	166	163	128	184	99	136	154	118
2		164	158	145	149	139	128	84	97	92	124	113
1	53	49	48	58	54	58	26	30	26	33	36	

Table 37.—*Annual increments of growth in weight of female Saginaw Bay walleyes*

[Each diagonal row gives the growth history of a year class. See table 32 for numbers of fish]

Year of life	Increment of weight (grams) in year—													
	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929
13													141	
12												149	122	204
11											166	128	148	119
10										169	123	173	154	147
9									200	169	173	127	148	154
8								205	179	170	148	154	136	148
7							239	219	193	195	143	153	186	161
6						293	208	263	234	201	183	197	198	152
5					269	324	302	245	222	210	215	231	172	132
4				244	261	267	287	241	178	219	221	156	178	136
3			242	250	237	249	233	191	160	232	133	149	165	121
2		180	184	168	162	184	168	152	130	89	100	95	128	106
1	80	68	62	65	59	64	65	53	21	32	27	32	32	

Table 38.—*Annual fluctuations in the growth in weight of the Saginaw Bay walleye expressed as percentage deviations from the 1919–28 mean*

[Percentages for the sexes combined are the unweighted means of the percentages determined for the sexes individually]

Year of life, and sex	Percentage deviation in calendar year—													
	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929
First:														
Males			26.2	16.9	14.5	37.9	28.6	37.9	−36.9	−27.5	−36.9	−20.5	−13.5	
Females	75.2	49.4	36.5	42.9	30.1	40.8	42.9	17.2	−51.6	−27.9	−38.7	−27.9	−27.9	
Both sexes	75.2	49.4	31.4	29.9	22.3	39.4	35.8	27.6	−44.2	−27.7	−37.8	−24.2	−20.7	
Second and later:														
Males				20.0	16.3	16.3	18.2	2.6	−10.1	−5.0	−19.3	−25.8	−12.7	−14.0
Females		15.5	17.7	15.8	15.5	25.2	23.0	7.8	−7.8	−8.5	−22.4	−25.1	−23.8	−33.2
Both sexes		15.5	17.7	17.9	15.9	20.8	20.6	5.2	−9.0	−6.8	−20.8	−25.4	−18.2	−23.6
All years:														
Males			26.4	18.6	15.3	17.9	18.9	5.1	−11.3	−5.9	−20.2	−25.7	−12.7	−14.0
Females	35.2	19.0	18.2	17.2	16.1	25.7	23.7	8.3	−9.2	−9.2	−23.2	−25.5	−24.2	−33.6
Both sexes	35.2	19.0	22.3	17.9	15.7	21.8	21.3	6.7	−10.2	−7.6	−21.7	−25.6	−18.4	−23.8

IMPROVEMENT IN GROWTH AFTER 1929

In the earlier comparison of the general growth of the walleyes of the 1926–30 and 1943 collections, it was brought out that first-year growth was much the same in the two groups but that fish of the 1943 collection had grown by far the better in the second and later years of life. Although the data for the 1943 sample (tables 39, 40, 41, and 42) do contain fragmentary information on first-year growth as far back as 1930 and on growth beyond the first year as early as 1931, the representation of some of the year classes was so weak (females of year-classes 1932 and 1935 were lacking; males included no year classes earlier than 1933) as to limit sharply the dependability of estimates of annual fluctuations by means of procedures followed with the 1926–30 collections. These tables do provide, however, some information on the question of the time of occurrence of the improvement in growth rate from the low level of the late 1920's to that which characterized walleyes of the 1943 collection as a group.

The trends of growth of the 1943 walleyes in the second and later years of life are not clear cut. A possible exception to this statement is offered by the increments for the third year of life which were at a distinctly higher level in the more recent years (after 1935 or 1936) than in earlier years. For other years of life this trend toward improved growth in the more recent years is relatively weak or lacking. It is largely the pronounced upward trend in the third-year increments together with the obviously good growth of 1941 that gives the impression that the general trend during the years covered by the data from the 1943 collection was irregularly upward.

TABLE 39.—*Annual increments of growth in length of male Saginaw Bay walleyes of the 1943 collection*

[Each diagonal row gives the growth history of a year class]

Year of life	Increment of standard length (millimeters) in year—									
	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942
10										14
9									13	19
8								11	18	16
7							19	21	16	22
6						24	27	22	32	25
5					30	38	32	29	37	26
4				50	46	32	49	48	48	51
3			69	52	84	80	85	87	97	76
2		112	108	130	118	107	103	113	136	
1	157	141	116	118	134	142	122	148		
Number of fish	3	3	2	5	14	3	49	101		

Regardless of what the trends of growth may have been during the years covered by the data of the 1943 collection, such information as we have suggests strongly that much of the advantage of the 1943 walleyes over those collected in 1926–30 had become established in the early and middle 1930's. For example, the second-year growth of females in 1929 was 85 millimeters (table 32), a figure far below any of the second-year increments of 1943 females in 1931–35 (101 to 143 millimeters). Similarly, the third-year increment in 1929 (48 millimeters) was less than the 1932–35 figures of 56 or 57 millimeters and was much below the 1936 value of 78 millimeters. The continuation of these comparisons to other years of life and to the data on growth in length of males and on growth in weight of walleyes of both sexes leads to the general conclusion that a sharp upturn in growth rate must have occurred soon after 1929. Any uncertainty arising from the small numbers of fish on which data on growth in the early and middle 1930's are based is more than compensated for by the consistency and the degree to which growth was better than in 1929.

TABLE 40.—*Annual increments of growth in length of female Saginaw Bay walleyes of the 1943 collection*

[Each diagonal row gives the growth history of a year class]

Year of life	Increment of standard length (millimeters) in year—												
	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942
13													17
12												20	19
11											12	18	
10										17	27		22
9									17	22		18	25
8								28	22		19	25	
7							44	34		28	28		37
6						40	34		34	45		40	37
5					64	59		43	47		50	56	44
4				47	68		53	46		73	63	59	57
3			57	56		56	78		75	103	79	108	86
2		143	101		134	106		105	108	123	117	138	
1	139	132		152	150		143	127	170	127	148		
Number of fish	2	1		1	2		3	16	1	30	50		

TABLE 41.—*Annual increments of growth in weight of male Saginaw Bay walleyes of the 1943 collection*

[Each diagonal row gives the growth history of a year class. See table 39 for numbers of fish]

Year of life	Increment of weight (grams) in year—									
	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942
10										130
9									114	155
8								92	135	119
7							148	144	110	161
6						171	165	139	207	172
5					187	196	176	161	220	155
4				254	186	148	219	226	234	251
3			246	152	270	237	266	282	304	305
2		202	164	173	149	150	153	144	254	
1	50	36	20	21	31	37	24	42		

GROWTH IN SAGINAW BAY COMPARED WITH THAT IN OTHER AREAS

Studies of the growth of the walleye in Lake Erie by Deason (1933) and in Lake of the Woods by Carlander (1945)[32] make possible the comparison of growth in three major centers of commercial production in the United States (table 43 and fig. 7). In the interest of uniformity, the data of those two investigators were submitted to certain adaptations. For Carlander's data only a conversion from standard length in millimeters to total length in inches was required. With the Lake Erie data the calculated lengths, which were computed by direct proportion for Deason's preliminary report, were recalculated on the basis of an intercept of 50 millimeters (see p. 10). These corrected calculated lengths were then converted from tape to board measurement (see p. 9) and from standard to total lengths. The data of table 43 were carried only through those years of life for which reasonably adequate data were available (records for Saginaw Bay walleyes were dependable beyond the ninth year but comparable data were not available from other localities).[33] The lengths for walleyes from Lake of the Woods and Lake Erie were based on the sexes combined; for Saginaw Bay they are the unweighted means of the lengths determined for males and females separately.

The most noteworthy features of the data of table 43 are the high calculated lengths of Saginaw Bay walleyes of the 1943 collection and the differences between Saginaw Bay fish and those from Lake of the Woods and Lake Erie in the trend of

[32] See Carlander's paper and Eschmeyer (1950) for additional references on the growth of the walleye.

TABLE 42.—*Annual increments of growth in weight of female Saginaw Bay walleyes of the 1943 collection*

[Each diagonal row gives the growth history of a year class. See table 40 for numbers of fish]

Year of life	Increment of weight (grams) in year—												
	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942
13													263
12												292	247
11											167	219	
10										225	303		254
9									211	226		192	277
8								323	207		189	252	
7							442	284		254	254		362
6						339	245		270	349		333	321
5					431	340		287	295		341	397	347
4				238	274		278	226		364	331	366	318
3			212	148		213	263		238	330	338	374	361
2		255	134		256	173		159	141	261	161	260	
1	35	30		46	44		38	27	64	27	42		

TABLE 43.—*Comparison of the growth of walleyes in Lake of the Woods and Lake Erie with that in Saginaw Bay*

[Total length in inches]

Year of life	Lake of the Woods[1]		Lake Erie[2]		Saginaw Bay			
					1926–30		1943	
	Length	Increment	Length	Increment	Length	Increment	Length	Increment
1	6.4	6.4	6.0	6.0	6.8	6.8	6.4	6.4
2	9.3	2.9	9.7	3.7	10.8	4.0	12.0	5.6
3	11.5	2.2	12.1	2.4	13.6	2.8	16.0	4.0
4	13.5	2.0	15.1	3.0	15.7	2.1	18.5	2.5
5	14.9	1.4	18.0	2.9	17.2	1.5	20.4	1.9
6	16.7	1.8			18.5	1.3	21.7	1.3
7	18.2	1.5			19.3	.8	22.8	1.1
8	19.9	1.7			20.0	.7		
9	21.6	1.7			20.6	.6		

[1] Data adapted from Carlander (1945).
[2] Data adapted from Deason (1933).

[33] The record of lengths for walleyes from Lake of the Woods was terminated at the end of 9 years because of the sharp disagreement at higher ages between growth curves as based on grand-average lengths and as determined from the summation of grand-average annual increments.

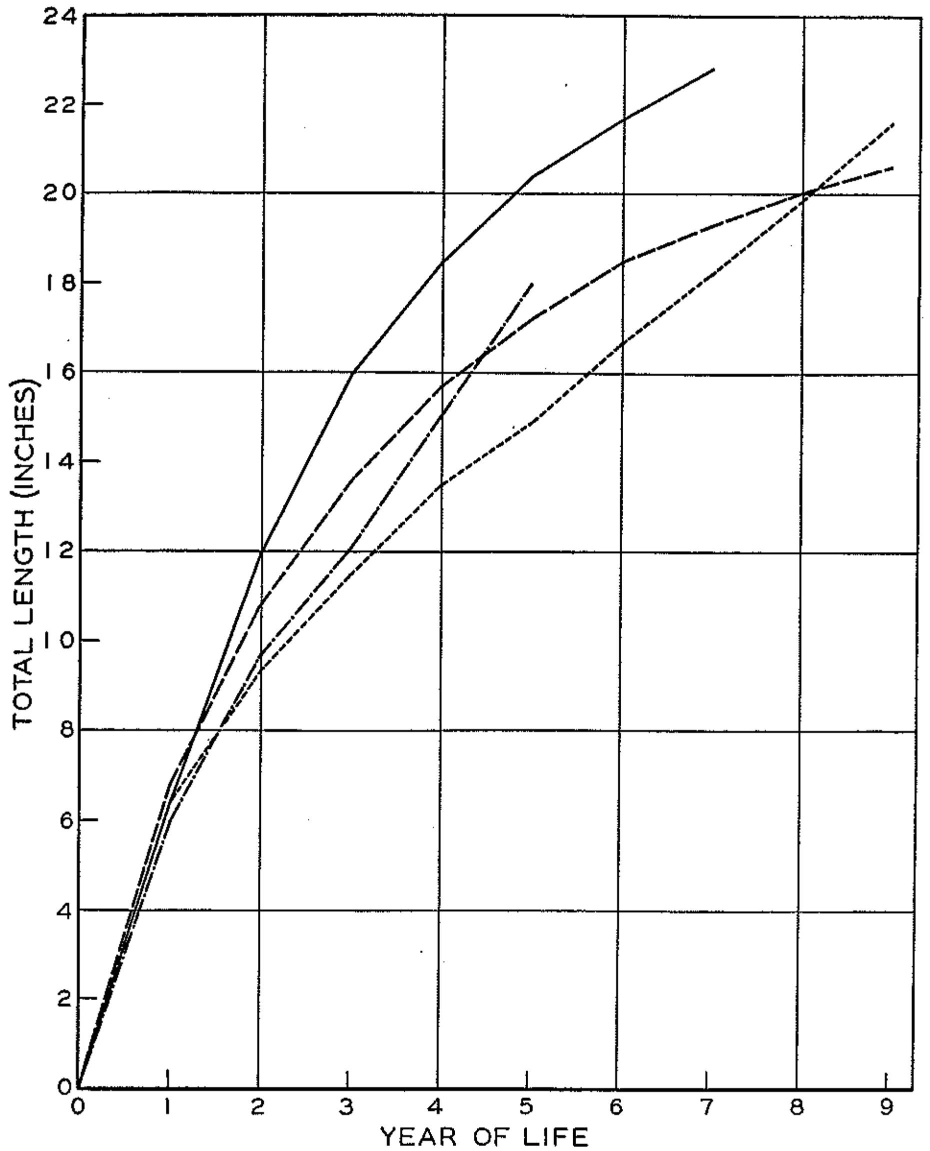

FIGURE 7.—Comparison of growth in length of walleyes in Saginaw Bay (1926–30 collection, long dashes; 1943 collection, solid line), Lake Erie (dots and dashes), and Lake of the Woods (short dashes).

the annual increments during the later years of life. Examination of the increments reveals that the advantage of Saginaw Bay walleyes of the 1943 collection over those of other localities or collections was established entirely or principally in the earlier years of life—in the first through the third with respect to Lake Erie fish and in the second through the fifth with respect to walleyes of Lake of the Woods and of the Saginaw Bay 1926–30 collections. The increments of Saginaw Bay walleyes collected in 1943 declined so rapidly with increase in length that Lake Erie fish had better growth in the fourth and fifth years and Lake of the Woods walleyes in the sixth and seventh; the growth of Saginaw Bay walleyes of the 1926–30 samples equaled that of the 1943 fish in the sixth year but again was the smaller in the seventh.

Differences between Saginaw Bay fish and walleyes from Lake of the Woods and Lake Erie in the trends of growth during the later years of life led to two distinct types of growth curves. In both of the Saginaw Bay collections the consistent decrease of the annual increments with increase of

age resulted in a progressive decrease in the slope of the curves. In Lake Erie, on the other hand, no downward trend can be demonstrated beyond the third year—in fact, the fourth- and fifth-year increments were greater than the third—and in fish from Lake of the Woods the variation of the increments in the fifth through the ninth years of life may be termed irregular. The sustained growth in the later years permitted Lake Erie walleyes to overtake and pass the Saginaw Bay fish of the 1926–30 collection during the fifth year. The Lake of the Woods walleyes, however, did not overtake the 1926–30 fish from Saginaw Bay until the ninth year of life. This relationship among growth curves of walleyes in which the populations (or collections) with the greater lengths in the earlier years lost much or all of their advantage during later years is closely similar to that observed in five populations of rock bass of northern Wisconsin (Hile 1942).

SEX RATIO

CHANGES WITH INCREASING AGE

Despite pronounced irregularities in the trends of changes in the sex ratio with each successive increase of age, male walleyes of the Saginaw Bay collections tended strongly to be relatively less abundant at the higher than at the lower ages in both the combined spawning-run samples of 1927 and 1929 and the late-spring collections of 1929[34] and 1930 (table 44). In the spawning-run collections, the representation of males dropped from 71.4 percent in age-group IV to 52.5 percent in age-group VII, increased to 61.7 percent in age-group VIII, and thereafter declined consistently to a minimum of 18.2 percent in age-group XIII. Two of the three fish in age-group XIV were males. The general trend in the changes of the percentage of males with increasing age is brought out by the following tabulation:

Age groups	Number of males	Number of females	Percentage males
IV–IX	322	244	56.9
X–XIV	37	94	28.2

Thus it is seen that the relative abundance of the males was twice as great in age-groups IV to IX as in age-groups X to XIV.

In late spring, the representation of males rose from 42.5 percent in age-group II to 60.0 percent in age-group IV, declined to 36.0 percent in age-group VI, increased again to 41.7 percent in age-group VII, and ranged between 22.0 and 11.8 percent in age-groups VIII to XI; all 7 fish more than 11 years old were females. The general trend may be seen in the following summary:

Age groups	Number of males	Number of females	Percentage males
II–V	527	450	53.9
VI–VII	34	51	40.0
VIII–XV	10	52	16.1

Here the extreme scarcity of males at the highest ages is striking. Relatively, males were 2½ times as plentiful in age-groups VI to VII and more than 3 times as abundant in age-groups II to V as in age-groups VIII to XV. The downward trend that culminated in this low percentage of males at the higher ages perhaps cannot be held to have started until after the fifth year since the percentage of males in the V group (47.8), although substantially less than that in the IV group (60.0) was still above the value for age-group II (42.5)

[34] Sex data available only for the VII group and older in 1929—see footnote to table 44.

TABLE 44.—*Variation of the sex ratio with age in spawning-run and late-spring collections of Saginaw Bay walleyes*

Collection	Representation of sexes in age group—														All ages
	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
Spawning run (1927, 1929):															
Number of males	----	----	5	18	72	106	82	39	21	9	3	2	2	----	359
Number of females	----	----	2	11	51	96	51	33	45	26	13	9	1	----	338
Percentage males	----	----	71.4	62.1	58.5	52.5	61.7	54.2	31.8	25.7	18.8	18.2	66.7	----	51.5
Late spring (1929, 1930):[1]															
Number of males	17	154	246	110	9	25	5	2	2	1	----	----	----	----	544
Number of females	23	143	164	120	16	35	19	15	7	4	5	1	----	1	516
Percentage males	42.5	51.9	60.0	47.8	36.0	41.7	20.8	11.8	22.2	20.0	.0	.0	----	.0	51.3

[1] Adequate records of sex were available only for the VII group and older fish in 1929; although the 1929 records were included in the data for individual age groups, the totals at the right are based on the 1930 collections alone.

and not much less than that for age-group III (51.9).

At corresponding ages the percentages of males were consistently higher (usually by a wide margin) in the spawning-run samples than in those of late spring. The nearly equal percentages in the two collections for all age groups combined (51.5 percent males in the spawning run; 51.3 percent males in late spring—1930 only) was the result of the greater age of the spawning-run fish. Given the same age distribution, males should be much more plentiful in spawning-run than in late-spring collections.

The only collections in addition to those covered in table 44 for which sex data were recorded for all or nearly all individuals were poorly suited for the study of the relation of the sex ratio to age. In the samples taken in the fall of 1926, 291 of the 305 walleyes were of the same age (I group). In this group 145 were females, 145 were males, and sex of 1 fish was undetermined. Dominance of a single age group was not so sharp in the collection of May 4, 1943 (52.4 percent of the total in age-group III—see table 12), but even here only 3 of the 11 age groups contributed more than 90 percent of the total number. Although the data from the 1943 sample exhibited no distinct trend as to sex ratio, it is to be noted that all 3 fish more than 10 years old were females.

Greater destruction of males than of females in the fishery may have contributed to the lower percentages of males at the higher ages. During the spawning period, at which time the heaviest fishing is carried on and practically all fish captured are adults, the males may be much the more vulnerable sex, since as will be shown in the next section, they tend to mature at an earlier age than do females. Hence during the years of life when at least some of the males are mature, but below the age at which all fish of both sexes have attained maturity, males are on the spawning grounds in numbers out of proportion to their true representation in the age groups as a whole. To some extent the effects of earlier attainment of maturity of the males should have been offset at the time of collection of the 1926–30 samples by the fact they attained the then legal minimum size of 1½ pounds in the sixth year as compared with the fifth year for the females. To what degree the males actually benefited from this theoretically greater protection is problematic for it is known that in the years of the 1½-pound limit large if undetermined quantities of undersized males ("jacks" in the parlance of commercial fishermen) were marketed illegally.

The explanation of the decreasing relative abundance of males with increasing age on the basis of their earlier attainment of maturity cannot account for the continuing decline in the percentage of males at those higher ages at which no fish of either sex are immature (beyond age-group VI if the 1930 data hold for all fish of the 1926–30 collections). Here, a higher rate of destruction of the males can take place only if they are the easier to catch, that is, remain longer on the spawning grounds than do females or are the more active. That males may be more catchable than females during the spawning season is evidenced by the fact that for all ages, including those at which all fish are mature, the percentage of males ran higher in the spawning-run than in the late-spring samples.

There is no reason to believe that the rates of commercial exploitation of the sexes at corresponding ages differed at periods other than the spawning season except possibly for the questionable additional protection that males may have received as the result of their later attainment of legal size.

Belief that the reduced percentage of males in the higher age groups of the walleyes was the result of their greater mortality in the commercial fishery is supported by the earlier observation that no real downward trend in the percentage could be demonstrated among the younger fish (that is, fish largely immature and of less than legal size).

Even though a relatively high exploitation rate for spawning-run males resulting from their earlier maturity and greater activity may seem adequate to explain their decreasing percentage with increase of age, the possibility should not be overlooked that the natural mortality rate as well as the rate of exploitation may be higher for males than for females. Strong evidence that the natural death rate of males is higher than that of females has been presented by a number of investigators. (See Hile 1936 and 1941, and Deason and Hile 1947 for discussion and references to literature on the changes of the sex ratio with increase of age.)

CHANGES WITHIN COLLECTING PERIODS

Spawning period

It is commonly believed that males tend to predominate in the earlier and females in the later part of the spawning period. This belief is supported by the data on collections made over the period, April 4–23, 1929 (table 45). Males were in the majority on both April 4 (56.3 percent) and April 7 (59.2 percent) and made up 58.0 percent of the combined samples. (The April 6 sample, which is obviously abnormal, is discussed later in this section.) They were in the minority, however, in each of the three samples of April 13–23 and comprised but 41.6 percent of the combined samples.

In view of the relation between sex ratio and age demonstrated in the preceding section, changes in the age composition and hence in average age must be considered as a possible factor in fluctuations of that ratio. An explanation of the lower percentage of males in the April 13–23 samples on the basis of age is not acceptable, however. It is true that these fish averaged older than walleyes collected April 4 and 7, but the difference between the averages—only 0.19 year—was extremely small. Furthermore, the examination of the data on mean age and sex ratio for the individual samples fails to reveal a correlation between the two. Finally, the trend toward fewer males on the later collecting dates was exhibited by four of the five best-represented age groups as well as by all age groups combined.[35] The shift toward a lesser relative abundance of males in the last three samples, therefore, was a real, not an apparent phenomenon, traceable to changes in age composition. Whether the change represents a shifting about within a single stock or the successive domination of the catch by different stocks with different sex ratios cannot be stated.

The April 6 sample in which all 53 fish were males is precisely the type that causes grave concern as to the possible inaccuracy of records. Unfortunately it was impossible to consult the collector concerning the sampling.[36] The following circumstances, however, lead to the conclusion that the collection of April 6 almost certainly was a true sample of the catch: First, the serial numbers ran consecutively from the largest fish of the April 4 sample to the smallest one of the April 7 sample; second, in none of the remaining five collections had the scale envelopes for males and females been separated—hence the possibility seems remote that the envelopes were sorted according to sex and those for females subsequently lost.

To determine whether any unusual weather conditions existed near the time of the April 6 collection the meteorological records were examined for the Saginaw Bay area. This examination revealed that a severe storm accompanied by heavy rainfall (amounting to 2.10 inches at Bay City) occurred on April 5. Whether this storm actually caused males only to be taken on April 6, and if so, how that result was produced are strictly matters for speculation at this time.

Late spring

In the late spring of 1930, as in the spawning season of 1929, the sex ratio fluctuated considerably from sample to sample (table 46). Again it is possible to divide the collecting season into two periods. In the samples of April 30–May 17,

[35] See table 5 for the numerical representation of males and females in the various age groups on the several dates.

[36] Dr. Jan Metzelaar who made the collections from the 1929 spawning run met his untimely death later in that same year.

TABLE 45.—*Fluctuations in sex ratio and relation of the ratio to average age during the spawning season of 1929*

Date of collection	Percentage males in age group—					All ages combined			Average age (sexes combined)
	VI	VII	VIII	IX	X	Number of males	Number of females	Percentage males	
April 4	88	68	56	64	25	49	38	56.3	8.05
6	100	100	100	100	100	53	0	100.0	7.68
7	48	59	79	45	47	74	51	59.2	7.77
April 4–7	59	62	71	56	39	123	89	58.0	7.88
April 13	43	32	37	59	42	45	67	40.2	8.28
15, 19	56	48	43	25	21	38	63	37.6	8.13
23	86	35	42	43	11	44	48	47.8	7.75
April 13–23	65	38	40	47	26	127	178	41.6	8.07

males comprised 59.3 percent of the total whereas they made up only 42.4 percent of the collections of May 22–June 20. Within each of these two periods no trend is discernible. The largest deviation from the general level in the earlier period was the value of 46.5 percent for May 8, 11, and 13. This figure was still higher, however, than the mean for May 22–June 20. In the later period the percentage of 49.0 for June 1 and 3 was well above the average but still below the mean for the earlier period.

Differences of age do not account for the lower percentage of males in the second period. On the contrary, had age been an important factor the younger walleyes of May 22–June 20 (average age, 3.74 years) should have included a higher, not a lower, percentage of males than the fish of April 30–May 17 (average age, 4.50 years). Furthermore, in these samples, as in the spawning-run samples of 1929, the tendency toward a lower percentage of males in the latter part of the collecting period is to be found in the data for the best represented individual age groups III to V.[37]

TABLE 46.—*Fluctuations in sex ratio and relation of the ratio to average age in the spring of 1930*

Date of collection	Percentage males in age group—			All ages combined			Average age (sexes combined)
	III	IV	V	Number of males	Number of females	Percentage males	
April 30	83	64	49	98	65	60.1	4.31
May 3, 5	83	72	74	99	39	71.7	4.36
8, 11, 13	54	66	45	74	85	46.5	5.05
15, 17	56	60	70	61	39	61.0	4.12
April 30–May 17	71	66	55	332	228	59.3	4.50
May 22, 24	44	43	11	48	74	39.3	3.89
26, 29	50	48	20	56	83	40.3	4.02
June 1, 3	49	54	[1] 75	50	52	49.0	3.30
9, 18, 20	38	60	23	58	79	42.3	3.66
May 22–June 20	45	51	24	212	288	42.4	3.74

[1] Based on only four fish.

The question arises again as to whether the differences in the sex ratio in two parts of the same general collecting period represent a change in the distribution (or activity) of males and females within a single stock or whether the catches were dominated in successive periods by different stocks with different natural sex ratios. The data presented earlier (p. 29) on fluctuations of weight during the late spring of 1930 would seem to favor the latter assumption. At that time it was pointed out that walleyes captured April 25–May 13 were approximately 20 percent heavier than fish of corresponding length taken May 19–June 20. The opinion was expressed that this decline was greater than could reasonably be accounted for as the result of weight losses by individual fish and hence that the stock probably was heterogeneous as regards the length-weight relation. Since the late-spring samples of 1930 can be grouped in approximately the same periods with respect to weight and sex ratio (fish were weighed on some days scale samples were not taken; collections of May 15 and 17, held to be intermediate between the April 25–May 13 and May 19–June 20 fish in weight, agreed well with the walleyes of the earlier period in sex ratio), the assumption of heterogeneity in sex ratio as well as in weight is attractive.

SIZE AND AGE AT MATURITY

Data on both sex and state of organs on all or nearly all walleyes were recorded only for the collections of April 25–June 20, 1930, and May 4, 1943. The reliability of the latter collection for the study of maturity is held questionable, because of the presence of spawning fish and the consequent possibility of a certain, if unmeasured, segregation on the basis of maturity. This collection did contain numbers of immature fish (all of them females) but they might have been more plentiful in samples taken after the completion of spawning activities. The data on the relation between length and maturity (table 47) accordingly are based entirely on the 1930 materials. The necessary breakdown of the data so reduced the numbers of specimens in the individual entries that the variation of the percentages of maturity with length was at times decidedly irregular. To overcome the difficulty occasioned by these irregularities the percentages were plotted and curves fitted to them by inspection (fig. 8). Values read from the curves, although certainly approximations, have some superiority over individual percentages.

[37] See table 6 for the numerical representation of males and females in the different age groups on the several dates.

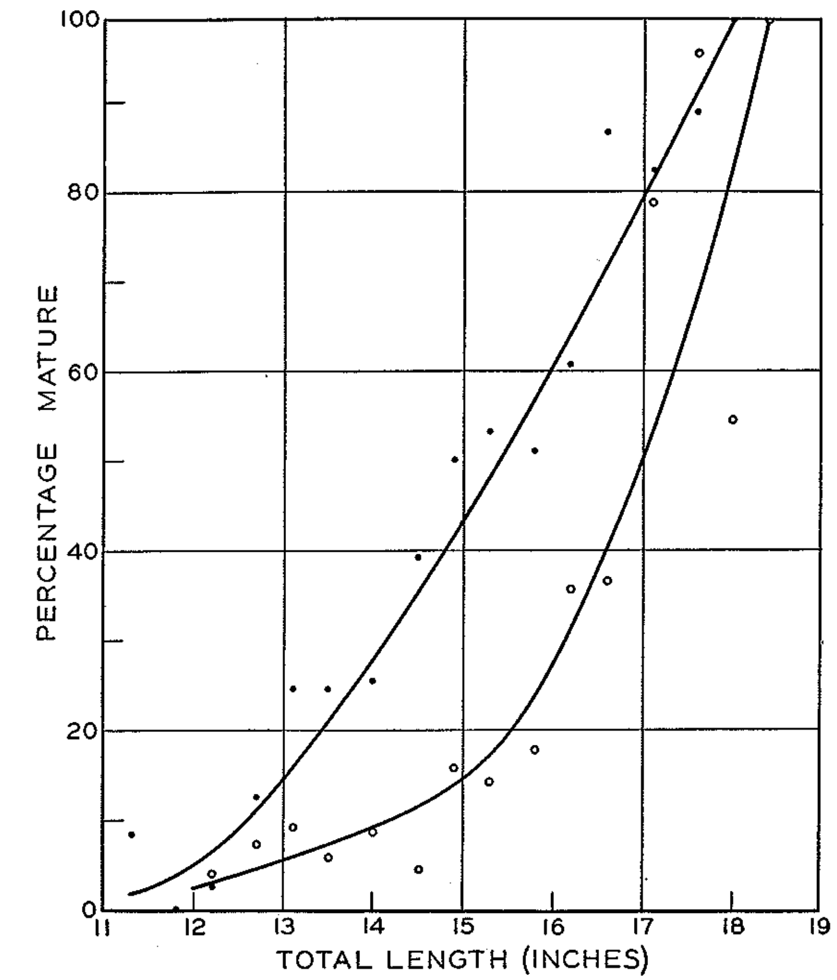

FIGURE 8.—Percentage maturity of male (open dots) and female (solid dots) Saginaw Bay walleyes according to length. The curves were fitted by inspection.

The difference between the sexes with respect to the size of the smallest sexually mature fish and that at which all were mature was small. The shortest mature female was 12.2 inches, and only one shorter mature male (11.3 inches) was observed. At the other extreme, the males attained 100-percent maturity at 18.0 inches and the females at 18.4 inches. Between these points the trends of the percentages of maturity with increase of length differed sharply in males and females. In the males, the percentage rose rather steadily as length increased. But for a slight upward curvature of the line the increases could be termed proportional. The line for the females, on the other hand, was flat at the smaller lengths, curved sharply upward at about 15–16 inches, and was steep at the greater lengths. The difference in the shape of the curves caused the disparity between the percentages of mature males and females to be greatest at intermediate lengths (with the largest disagreement at about 16 inches). At the 1½-pound (17.1-inch) minimum legal size in effect in 1930 the percentages of sexually mature fish as estimated from the curves were slightly above 80 percent for the males and a little better than 50 percent for the females. At the present minimum legal length of 15½ inches the percentages are just above 50 percent for the males and roughly 20 percent for the females.

The large percentage of immature females at 15½ inches indicates that they derive relatively small protection from the present minimum legal size. They do, however, enjoy a most effective "biological" protection. Since the heaviest catches are made during the spawning season and since walleyes captured at that time are almost exclu-

TABLE 47.—*Relation between length and sexual maturity of walleyes captured from April 25 to June 20, 1930*

Standard length [1]	Total length	Males			Females		
		Immature	Mature	Percentage mature	Immature	Mature	Percentage mature
	Inches						
180 mm	8.4	1	--------	0.0	1	--------	0.0
190 mm	8.8	--------	--------	--------	2	--------	.0
200 mm	9.3	--------	--------	--------	1	--------	.0
209 mm	9.7	4	--------	.0	7	--------	.0
219 mm	10.1	4	--------	.0	5	--------	.0
229 mm	10.5	7	--------	.0	4	--------	.0
239 mm	10.9	9	--------	.0	5	--------	.0
248 mm	11.3	11	1	8.3	12	--------	.0
258 mm	11.8	31	--------	.0	23	--------	.0
268 mm	12.2	39	1	2.5	24	1	4.0
278 mm	12.7	42	6	12.5	37	3	7.5
287 mm	13.1	64	21	24.7	40	4	9.1
297 mm	13.5	43	14	24.6	48	3	5.9
307 mm	14.0	50	17	25.4	42	4	8.7
317 mm	14.5	45	29	39.2	42	2	4.5
326 mm	14.9	25	25	50.0	48	9	15.8
336 mm	15.3	29	33	53.2	36	6	14.3
346 mm	15.8	17	18	51.4	32	7	17.9
356 mm	16.2	11	17	60.7	27	15	35.7
365 mm	16.6	4	26	86.7	19	11	36.7
375 mm	17.1	3	14	82.4	4	15	78.9
385 mm	17.6	1	8	88.9	1	21	95.5
395 mm	18.0	--------	8	100.0	5	6	54.5
404 mm	18.4	--------	5	100.0	--------	13	100.0

[1] All fish of lengths greater than those shown in the table (5 males and 76 females) were mature.

sively mature individuals, the mere state of immaturity provides almost complete exemption from capture during the period of greatest exploitation. That an excessive destruction of immature fish has not taken place under the 15½-inch limit is demonstrated by the continuing success of the spawning-run fishery. Because of this success there is no reason to believe that the recent scarcity of walleyes in Saginaw Bay is to be attributed to the destruction of immature fish. At the present time there is no reason to hold that an increase in the size limit is needed.

Walleyes seem to mature sexually at a greater size in Saginaw Bay than in Lake Erie where Deason (1933) found that males 13½ inches long and larger and females 15 inches long and larger were practically all mature.

The data on the percentage of sexually mature fish at different ages in 1930 (table 48) reveal that no II-group walleyes of either sex were mature and that the percentages were small in the III group (males, 13.6 percent; females, 4.2 percent). The percentages increased consistently in the succeeding age groups. In 5 years, 49.2 percent, or nearly half, of the females and 71.8 percent of the males were mature. Immature fish were distinctly in the minority in age-group VI (77.8 percent of the males and 68.8 percent of the females mature) and no immature fish were found beyond the VI group.

All males, including one II-group fish, and all females older than the IV group were mature in the rapidly growing fish of the May 4, 1943, collection. As was pointed out previously, however, the value of this sample for the study of maturity is open to question.

TABLE 48.—*Percentage maturity by age and sex of Saginaw Bay walleyes in 1930 and 1943*

Date of collection, and sex	Item	Age group—				
		II	III	IV	V	VI
Apr. 30–June 20, 1930: Males	Total length (inches)	10.6	12.7	14.4	16.0	16.4
	Number in age group	17	154	246	110	9
	Number mature	0	21	85	79	7
	Percentage mature	.0	13.6	34.6	71.8	77.8
Females	Total length (inches)	10.1	12.8	14.7	16.5	17.6
	Number in age group	23	143	164	120	16
	Number mature	0	6	26	59	11
	Percentage mature	.0	4.2	15.9	49.2	68.8
May 4, 1943: Males	Total length (inches)	15.2	16.4	17.5	18.5	19.8
	Number in age group	1	101	49	3	14
	Number mature	1	101	49	3	14
	Percentage mature	100.0	100.0	100.0	100.0	100.0
Females	Total length (inches)	14.0	17.0	18.6	21.2	22.1
	Number in age group	1	50	30	1	16
	Number mature	0	6	22	1	16
	Percentage mature	.0	12.0	73.3	100.0	100.0

SUMMARY

1. The average annual catch of the Saginaw Bay walleye was 1,149,000 pounds in 1891–1919, 652,000 pounds in 1920–31, 1,466,000 pounds in 1932–43, and only 396,000 pounds in 1944–51. The commercial take was under 100,000 pounds in each of the 3 years, 1949–51.

2. The age and growth studies were based on the determination of age for 3,652 fish and the computation of individual growth histories (from scale measurements) for 2,427 specimens collected in 1926–30 and 1943. Growth computations were made on the assumption that the body-scale relation of the Saginaw Bay walleye is described by a straight line with an intercept of 50 millimeters on the (standard) length axis.

3. Age composition and mean age varied widely according to season of capture in the 1926–30 collections. The two fall samples were dominated by age-group I and had a mean age (average number of annuli) of 1.28. Spawning-run collections were dominated by age-group VII and had a mean age of 7.60. Age-group IV dominated the two late-spring collections; the mean age was 3.90. The 1943 sample taken near the end of the spawning season was dominated by age-group III and had an average age of 4.06.

4. Records of age composition of the subsamples (that is, collections of fish made on a single day or over a few days) of the 1929 spawning run revealed only limited variation within the spawning season. Age composition was much more variable in the late-spring collections of 1929 and 1930, and in both years the mean age exhibited a distinct downward trend toward the end of the collecting period.

5. Shortcomings of the original data (variation of age composition between and within seasons; lack of fall and spawning-run samples in any 2 consecutive years) prohibited a precise evaluation of the relative strength of the year classes. A ranking of the 1917–28 year classes into five categories was made, nevertheless. From the strongest year classes (1) to the weakest (5), the rankings were as follows: (1) 1919, 1925; (2) 1920, 1921, 1922, 1926, 1927; (3) 1918, 1923; (4) 1917, 1924; (5) 1928. In the 1943 collection, year-classes 1937 and 1940 appeared to be stronger and year-classes 1938 and 1941 weaker than average.

6. Seasonal differences in the age composition of walleyes of the 1926–30 collections were reflected in differences in length distribution, mean length, and percentage of legal-sized fish in random samples from impounding nets. In the fall collections, the average total lengths and the percentages of walleyes legal at the present minimum length of 15½ inches were for 1926—10.0 inches, 1 percent; 1928—11.1 inches, 1 percent; 1929—14.8 inches, 48 percent. In the late-spring collections, the lengths and percentages of legal-sized fish were for 1929—13.8 inches, 21 percent; 1930—14.7 inches, 30 percent. In the spawning-run collections the figures were for 1927—19.1 inches, 98 percent; 1929—20.1 inches, 100 percent. The late-spawning-run sample of 1943 averaged 17.9 inches long and included 96 percent of legal-sized fish.

7. The length distributions of successive age groups overlapped extensively in both the 1926–30 and 1943 collections. At the higher lengths as many as 7 age groups were represented in a single length interval of approximately 0.9 inch.

8. The relation between the standard length in millimeters (L) and the weight in grams (W) of 5,080 Saginaw Bay walleyes captured in different seasons and calendar years was described satisfactorily by the equation, $W=1.376\times10^{-5}L^{2.989}$.

9. The weights of walleyes of corresponding lengths and captured in the same nets exhibited pronounced short-term fluctuations during the late spring in both 1929 and 1930. The period May 8–June 18, 1929, could be divided into 5 subperiods in which the mean weights of walleyes differed by 5 to 12½ percent from those of adjacent subperiods. In 1930 walleyes captured April 25–May 13 averaged about 19 to 20 percent heavier than fish captured May 19–June 20. It was concluded that the population is probably heterogeneous with respect to the length-weight relation and that different segments of the population dominated the samples at different times.

10. Walleyes collected in the fall in 1928 and 1929 averaged heavier than fish caught in the late spring in 1929 and 1930 by 12.7 percent at 8.8 to 14.9 inches and 18.5 percent at 15.3 to 18.0 inches. The mean weights of sound walleyes averaged 5½ to 6½ percent heavier than those of fish of corresponding length infected with *Lymphocystis*.

11. Differences of growth between the sexes and between the 1926–30 and 1943 samples made necessary the use of four separate curves for the description of the growth of the Saginaw Bay walleye. Sex differences of growth were small or nil during the first 2 years of life but in the third and later years both the average size and the annual growth increments of females exceeded those of males of corresponding age. The first-year growth of the 1943 walleyes was slightly less than that of fish of the 1926–30 collections. For all later years the actual sizes and for practically all years of life the annual increments of the fish collected in 1943 exceeded those of 1926–30 walleyes of corresponding sex and age.

12. The limited data on annual growth available from walleyes of the 1943 collection indicated that much of the advantage of the 1943 over the 1926–30 walleyes with respect to rate of growth had become established in the early and middle 1930's.

13. Maximum annual growth in length occurred during the first year of life of both males and females in both collecting periods. During later years the increments exhibited a rather consistent

downward trend. Times of attainment of the present minimum legal total length of 15½ inches were for 1926–30 males—early in fifth year (more properly fifth growing season); 1926–30 females—latter part of fourth year; 1943 males—near end of third year; 1943 females—past the middle of the third year. Latest years of life for which data were available and corresponding calculated lengths were for 1926–30 males—14 years, 21.3 inches; 1926–30 females—15 years, 25.0 inches; 1943 males—10 years, 23.3 inches; 1943 females—13 years, 29.5 inches.

14. Annual fluctuations of growth in length were similar for males and females and for first-year and later growth. The quality of growth for both sexes and all years of life expressed as percentage deviation from the 1919–28 mean, stood at the maximum of 12.8 percent above average in 1916. Growth was 6.8 to 11.7 percent above average during the next 6 years, 1917–22, but dropped rapidly from 9.2 percent in 1922 to 1.0 in 1923 and −14.2 percent in 1924. An improvement to −4.0 percent in 1925 was followed by another drop to −11.3 in 1926. Improvements in both 1927 and 1928 brought growth slightly above average (0.2 percent) in the latter year but another sharp decline occurred in 1929 (to −11.7 percent).

15. The first-year calculated increments of growth in weight were small (less than 0.1 pound) for both sexes in both collecting periods. These increments increased to (with one irregularity) a maximum in the third to fifth year of life and thereafter exhibited a fairly consistent downward trend (not pronounced in the 1943 females). Times of attainment of the weight of 1 pound were for 1926–30 males—near end of fourth year; 1926–30 females—middle of fourth year; 1943 males—latter part of third year; 1943 females—past the middle of third year. Latest years for which data were available and corresponding calculated weights were for 1926–30 males—14 years, 3.05 pounds; 1926–30 females—15 years, 4.91 pounds; 1943 males—10 years, 4.00 pounds; 1943 females—13 years, 8.14 pounds.

16. Growth in weight (as estimated from data for both sexes and for all years of life) was at the maximum of 35.2 percent above the 1919–28 mean in 1916. During the next 6 years, 1917–22, the percentage ranged between 15.7 and 22.3. Sharp decreases carried the value from 21.3 percent above average in 1922 to 6.7 in 1923 and −10.2 in 1924. A slight recovery (to −7.6 percent) in 1925 was followed by further declines that carried to the minimum figure of −25.6 in 1927. An improvement to −18.4 in 1928 was followed by another drop to −23.8 in 1929.

17. Comparison of the growth in length of Saginaw Bay walleyes of the 1926–30 and 1943 collections with published records of growth of walleyes in Lake Erie and Lake of the Woods revealed only small differences in first-year growth among the four groups. In the later years of life the Saginaw Bay fish collected in 1943 enjoyed a substantial advantage over the other groups at all ages for which comparative data were available. The 1926–30 walleyes from Saginaw Bay were longer than Lake Erie walleyes in the second through the fourth year but were shorter than Lake Erie fish at the end of the fifth year. The length of the 1926–30 walleyes exceeded that of fish from Lake of the Woods in the second through the eighth year but was smaller at the end of the ninth.

18. The percentage of males exhibited a distinct tendency to decrease with increase in age both in the spawning-run samples of 1927 and 1929 and in the late-spring collections of 1929 and 1930. In the spawning-run collections the percentage of males was 56.9 in the combined age-groups IV to IX and 28.2 in age-groups X to XIV. The percentages for various combinations of age groups in the late-spring collections were for II–V, 53.9 percent; VI–VII, 40.0 percent; VIII–XV, 16.1 percent. A higher rate of exploitation of males than of females was suggested as an important cause of the decrease in the percentage of males with increase in age.

19. Males were more plentiful (58.0 percent) in the early part of the 1929 spawning season (April 4–7) than in the latter part (41.6 percent—April 13–23). The percentage of males decreased also during the late spring of 1930 (59.3 percent males for collections of April 30–May 17 and 42.4 percent for May 22–June 20). With a single exception, shifts in the sex ratio occurred in individual age groups as well as in all age groups combined.

20. Lengths at which 50 percent of the walleyes had reached sexual maturity were about 15½ inches for the males and 17 inches for the females.

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