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AGE, GROWTH, AND PRODUCTION OF YELLOW PERCH IN LAKE ERIE

By FRANK W. JOBES

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CONTENTS

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By FRANK W. JOBES, *Fishery Research Biologist*

The American yellow perch, *Perca flavescens* (Mitchill), is one of the most common food fishes native to the lakes and streams of the northeastern United States and southeastern Canada. It contributes heavily to the take by hook and line throughout its range and forms an important part of the catch of the modern commercial fishery in the Great Lakes.

The present study of the yellow perch is part of an extensive investigation of the Lake Erie commercial fisheries begun by the former U. S. Bureau of Fisheries and continued by the U. S. Fish and Wildlife Service. In the years 1927 through 1931 field work was carried on in cooperation with the States of Ohio, Pennsylvania, and New York, the Province of Ontario, the city of Buffalo, and the Buffalo Society of Natural Science; materials were collected also in 1932, 1934, and 1937, and in the years 1943 through 1948. This report is based primarily on the data for the specified years from 1927 to 1937 (referred to here as 1927–37) because in each of those years the materials consisted of random samples of all yellow perch taken by the nets. The 1943–48 data are from random samples of the commercial catch only (fish 8½ inches or more in total length) and will be used only where they add to the knowledge gained from the 1927–37 data.

The assistance of the officials and employees of all the agencies involved in this investigation is deeply appreciated. Without their cooperation in the collection of data and the loan of materials this study would have been much more restricted in scope, if not impossible. Special thanks are due Dr. John Van Oosten for directing the study and critically examining the manuscript, and Dr. Ralph Hile for substantial assistance in the analysis and interpretation of the data. N. H. Lagerstrom, Oberlin, Ohio, translated the Swedish and Norwegian references listed in the bibliography.

Several authors have studied the age and growth of the yellow perch without making a critical study of the validity of age determinations based on scales. Jobes (1933) and Schneberger (1935) calculated lengths from scale measurements on the assumption that the ratio of body length to scale length is constant after the first annulus is formed. Hile and Jobes (1941) determined the body-scale relation for the yellow perch in Saginaw Bay (Lake Huron) and corrected the lengths computed by direct proportion to conform to the empirically determined body-scale relation. Before a detailed study of the life history of the yellow perch in Lake Erie could be undertaken, it was necessary to demonstrate that ages read from scales are accurate and to determine the most satisfactory method of calculating growth from scale measurements.

COMMERCIAL PRODUCTION OF YELLOW PERCH IN LAKE ERIE

The earliest records of the production of yellow perch in Lake Erie are for the year 1885. The species was taken commercially before that time but was not considered important enough to warrant separate treatment in the earlier statistical reports. Table 1 gives the available figures on production for the years 1885 to 1947. The production records for United States waters, for Ontario waters, and for the entire lake are shown graphically in figure 1.

Although the record of the catch in the United States waters is not complete for the earlier years of the fishery, the annual yield appears to have been greater before 1900 than in the period immediately after. The extremes in the fluctuation in annual production during the earliest period, 1885–99, occurred in the years 1885 and 1889, when catches of 1,601,000 and 3,830,000 pounds were reported. The fragmentary statistics indicate a good production in this period; the average

TABLE 1.—*Annual production of yellow perch in Lake Erie, 1885–1947*

[In thousands of pounds]

Year	United States [1]					Canada (Ontario) [2]			Entire lake
	Michigan	Ohio	Pennsylvania	New York	Total	Western part [3]	Eastern part [4]	Total	
1885	100	1,266	225	11	1,601				
1886									
1887									
1888									
1889	96	3,204	459	70	3,830				
1890	159	2,483	209	49	2,900				
1891									
1892	138								
1893	223				2,595				
1894	115					282	281	563	
1895	255					241	156	397	
1896	202					266	208	474	
1897 [5]	147	2,604	407	95	3,253	238	263	500	3,753
1898	164					121	258	379	
1899	92	2,175	816	258	3,340	209	182	391	3,731
1900	128					398	297	695	
1901	136					255	253	508	
1902	107					373	193	566	
1903	81	625	141	27	873	218	201	418	1,292
1904	70					436	161	598	
1905	106					346	207	553	
1906	99					176	158	334	
1907	118					364	108	472	
1908	147	1,441	85	83	1,756	450	180	630	2,386
1909						428	153	581	
1910						464	210	674	
1911						681	167	847	
1912	85					913	198	1,110	
1913	66	[6] 685	[7] 114	4	870	794	161	955	1,825
1914	57	1,888	81	13	2,039	1,137	271	1,408	3,447
1915	108	1,698	105	22	1,933	809	234	1,042	2,975
1916	136	1,370	115	17	1,637	614	155	769	2,406
1917	140	866	173	79	1,259	852	143	995	2,254
1918	68	919	80	21	1,088	1,810	246	2,056	3,145
1919	37	2,573	51	114	2,775	876	221	1,097	3,872
1920	42	1,189	18	10	1,259	1,005	267	1,272	2,532
1921	41	2,053	70	28	2,192	1,676	289	1,965	4,157
1922	68	1,758	54	47	1,926	1,810	299	2,109	4,035
1923	36	1,668	98	67	1,870			2,397	4,267
1924	34	[8] 1,677	199	31	1,941	1,719	473	2,192	4,133
1925	48	2,202			2,458	1,304	756	2,060	4,518
1926	63	2,414	76	68	2,622	1,323	393	1,716	4,338
1927	32	2,468	206	40	2,748	1,888	603	2,491	5,238
1928	20	3,678	447	130	4,275	3,577	753	4,330	8,606
1929	35	5,779	177	52	6,043	4,782	907	5,689	11,733
1930	34	4,187	85	34	4,341	2,839	580	3,420	7,761
1931	72	8,455	480	55	9,062	3,466	799	4,265	13,327
1932	97	9,239	330	75	9,741	3,657	1,372	5,029	14,770
1933	87	3,024	278	45	3,434	1,474	1,255	2,729	6,163
1934	48	13,252	798	119	14,218	3,460	2,211	5,671	19,889
1935	54	8,303	542	146	9,045	3,795	1,838	5,634	14,678
1936	17	1,885	131	18	2,051	887	367	1,254	3,305
1937	16	1,596	105	34	1,750	1,298	393	1,691	3,441
1938	25	4,912	200	50	5,187	2,139	457	2,596	7,782
1939	13	1,493	80	21	1,608	956	451	1,407	3,015
1940	14	2,774	216	25	3,030	1,390	604	1,994	5,024
1941	25	3,596	163	38	3,821	1,398	652	2,050	5,871
1942	36	1,790	89	44	1,958	640	324	964	2,922
1943	24	1,178	31	20	1,253	536	175	711	1,964
1944	20	2,092	56	20	2,188	1,146	226	1,372	3,560
1945	29	1,260	58	5	1,352	982	225	1,207	2,559
1946	46	2,535	95	8	2,685	2,110	307	2,417	5,102
1947	49	1,587	97	63	1,797	1,454	798	2,252	4,049

[1] Records of production from United States waters and from entire lake for 1885–1940 are from Gallagher and Van Oosten (1943). Statistics of production from United States waters for later years were compiled originally in the Great Lakes Laboratory of the U. S. Fish and Wildlife Service from data supplied by the several States and have been published in the Commercial Fishery Statistics series of the Service.

[2] Canadian (Ontario) records for 1894–1939 are from Ford (1943). Data on the yield from Canadian waters in later years were supplied by the Ontario Department of Lands and Forests. The figures on the catch from all of the Canadian waters of Lake Erie may be found in the annual reports of the Ontario Department of Lands and Forests.

[3] West end to Port Burwell.

[4] East of Port Burwell.

[5] Fiscal year, July 1, 1896, to June 30, 1897, in United States waters, except Michigan.

[6] Fall catch only.

[7] Estimated.

[8] Fall catch of 1924 plus spring catch of 1925.

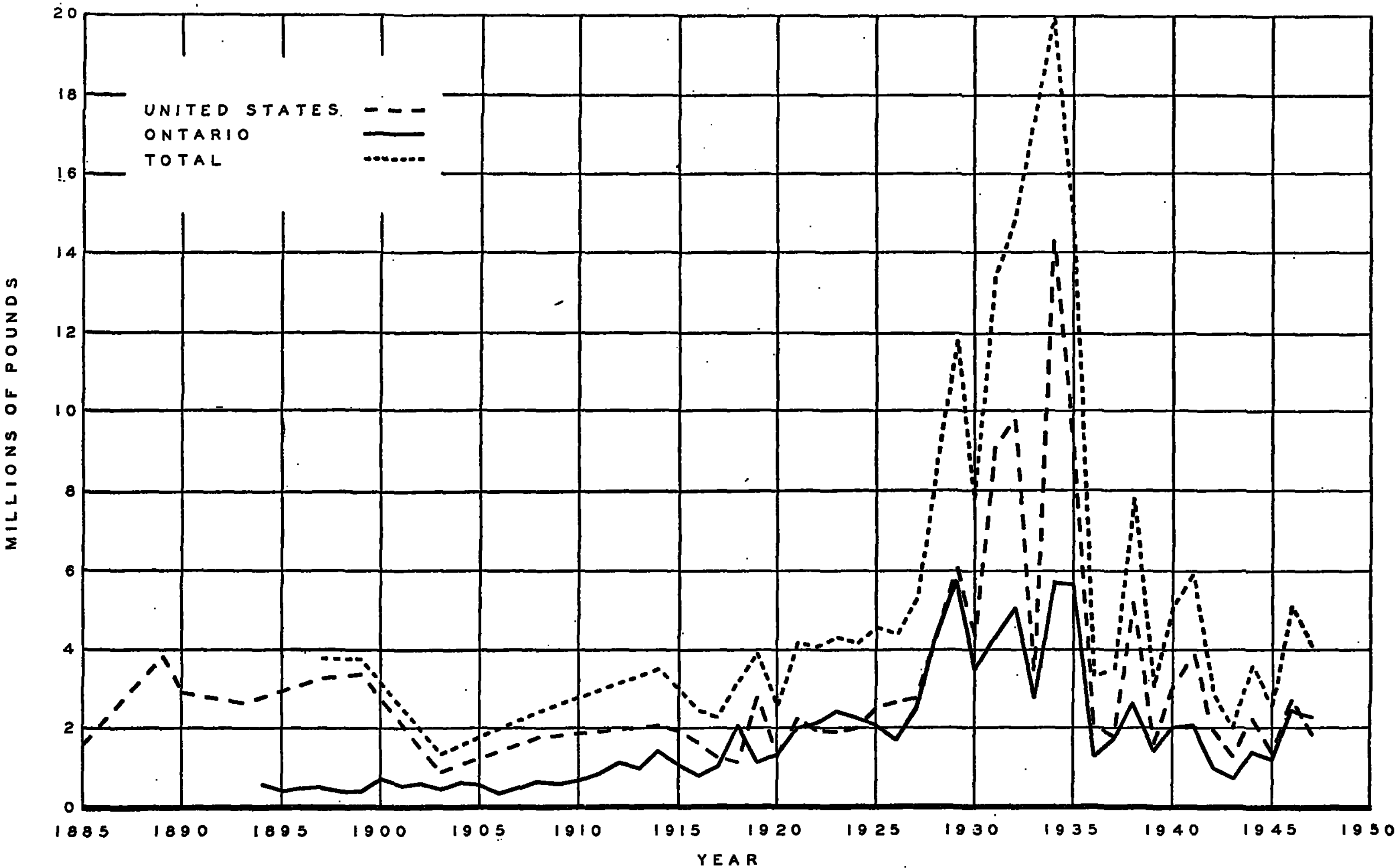

FIGURE 1.—Annual production of yellow perch in Lake Erie, 1885–1947

of the recorded yields was 2,946,000 pounds.[1] The lowest annual United States yield on record occurred in the next period, 1900–1927, when in 1903 only 873,000 pounds were reported. (No reference has been found that suggests that the statistics for 1903 are incomplete.) In only 6 years (1914, 1919, 1921, 1925, 1926, and 1927) of the 16 in this period did the annual catch from United States waters exceed 2 million pounds. The average annual yield of 1,905,000 pounds in this period was only 65 percent of the 1885–99 average. The upward trend that was to carry the yield in United States waters to the unprecedented catch of nearly 14¼ million pounds in 1934 actually began in 1925, but was relatively slight until 1928. The average of 7,520,000 pounds for the years 1928–35 was 2.55 times the average of the 1885–99 period and 3.95 times the 1900–1927 average. Not only was production high in 1928–35, but the fluctuations in annual catch were sudden and violent (for example, 9,741,000 pounds in 1932, 3,434,000 pounds in 1933, and 14,218,000 pounds in 1934). The violent fluctuations continued into the 1936–47 period, when the average annual production fell to 2,390,000 pounds. The average annual yield in these most recent years was 81 percent of that of the 1885–99 period, and only 32 percent of the 1928–35 average. The grand average for the years of recorded statistics was 3,262,000 pounds.

The Ohio production has always dominated the United States catch, and in the years for which complete data are available Ohio, on the average, has accounted for more than half of the yield of the entire lake. Furthermore, the relative importance of the Ohio catch in the United States production has shown a distinct tendency to increase. In the early period, 1885–99, Ohio produced 77.8 percent of the total United States yield. This percentage increased to 87.7 in the 1900–1927 period, to 92.9 in 1928–35, and to 93.1 in recent years. The proportion of the United States catch taken in each of the three remaining States has tended to decline.

If the Ontario statistics were to be segregated by periods independent of those of the United States, the following intervals would be selected to show the trend of production: 1894–1911, 1912–20, 1921–27, 1928–35, and 1936–47. The Ontario figures in table 1 show a progressive increase in catch with each succeeding period except the last. This trend on the Canadian side of Lake Erie, therefore, does not correspond to that on the United States side, except during the last two periods, 1928 and following years. Apparently the Canadian fishery for yellow perch began later and developed more slowly than that of the United States.

The earliest statistics of the catch in Ontario waters of Lake Erie show a relatively low yield with no extremely large variation from the average of 532,000 pounds during the period 1894–1911. The average annual catch of the next period, 1912–20, was 1,189,000 pounds or 2.23 times the 1894–1911 average; in only one year, 1918, did the take exceed 1½ million pounds. The 1921–27 period was one of relatively stable production with an average catch of 2,133,000 pounds (1.79 times the average of the preceding period). The large annual catches and increased variability of the annual yields in Ontario waters in 1928–35 were not unlike those in United States waters for the same period, except that in Ontario production did not reach such heights and the fluctuations in catch were not so violent as in the United States. The average annual Ontario yield for this period was 4,596,000 pounds, or 2.15 times that of the preceding period. Production during 1936–47 declined to an average of 1,660,000 pounds, or to 36 percent of the 1928–35 average. In only 4 of the last 12 years, 1938, 1941, 1946, and 1947, did the catch exceed 2 million pounds. The grand average for the 54 years of recorded statistics was 1,702,000 pounds.

The production from the western part of the lake (west end to Port Burwell), on the average, made up more than 60 percent of the Canadian total in each period. The percentage increased from 62 in the years 1894–1911 to 82 in 1912–20, and remained relatively constant, between 74 and 78, in the last three periods. This stabilization in the relative productivity of the two sections of the Canadian waters is in contrast to the situation in the United States waters where the western (Ohio) section increased in importance each period.

The catch in the entire lake showed variations similar to those in United States waters, except during the years 1921–27, when the total production was augmented by the increased yield in

[1] To make use of all available statistics, the averages computed from table 1 for United States waters, and for the entire lake, are the sums of the corresponding averages of the individual States and the Province of Ontario.

Ontario waters. The average total production of about 3½ million pounds during the period 1885–99 appears high only when consideration is given the low fishing intensity and the crude apparatus employed. The output of the fishery was low in 1903 but tended to increase, though irregularly, during the 1900–1920 period. The average annual yield of 2,464,000 pounds during this period was approximately 70 percent of the earlier average. The following period, 1921–27, was the steadiest one of the fishery, with but little fluctuation from an average of 4,384,000 pounds. This average was 1.78 times the average of the preceding period and about 1.29 times the 1885–99 average. The period 1928–35 was one of tremendous annual productions and violent fluctuations in yield from year to year. In every year, the catch exceeded the best of any previous period, and in 5 of the 8 years it was more than 10 million pounds. The average annual catch of 12,116,000 pounds was 4.92 times the 1900–1920 average and 2.76 times the 1921–27 average. During 1936–47, production fell off, with only one year, 1938, yielding as much as the poorest of the preceding period. Wide fluctuations in yield persisted into this last period. They were caused largely by variations in the catch in United States waters, and these in turn were due to variations in Ohio's yield. The average catch of 4,050,000 pounds in 1936–47 was only about a third of the 1928–35 average but was approximately 1.25 times the average of the earliest period, 1885–99.

The grand average production of yellow perch in all waters of Lake Erie for the years 1885 to 1947 was 4,964,000 pounds.

The tendency toward an increasing variability in the annual catch in United States waters suggests the dependence of the commercial fishery on a small number of age groups. This interpretation is supported by the observation (p. 245) that in the present-day fishery a year class is normally of major importance for little longer than a single year. Under such conditions it may be expected that production would be sensitive to variations in the strength of year classes and hence subject to sudden and wide fluctuations.

Any discussion of the factors that contributed to the changes that have occurred in the production of yellow perch in Lake Erie must be in large measure speculative. Although certain events are known to have contributed to the observed changes, their precise effects are difficult to evaluate. Brief mention may be made of the more important factors.

The early fishery in Lake Erie was conducted primarily on the inshore grounds with relatively crude gear. As production on these grounds declined, larger, faster, and seaworthier boats were built which permitted not only the extension of operations to more distant grounds but also the handling of more nets. The number of boats in operation also increased rapidly with expansion of the fishing grounds. Further increase in the amount of gear handled by each boat followed introduction of the power lifter for gill nets in the 1890's and for trap nets in the early 1930's. Efficiency of the nets was increased by reducing the size of the meshes, by using finer thread in gill nets, and by "reefing" or tying down the gill nets. Gill nets were made still more efficient by the development of the bull net, a gill net 100 meshes deep, fished in all strata of water from top to bottom. The shift from pound nets to trap nets and more recently a partial shift from gill nets to trap nets also increased exploitation, since trap nets are the most efficient gear now in use.

Although it is not possible to state precisely the extent to which fishing intensity has increased, it is valid to state that the increases in the amount and efficiency of gear just mentioned have led to a multiplication of fishing intensity in recent years over that of the early fishery.

For many years the practice has been to decrease gradually the size of mesh in the nets to compensate for diminishing yields. It was not until 1937 that the State of Ohio reversed the trend by increasing the size of mesh in trap nets to afford greater protection to the smaller fish.

In addition to these developments that have affected the fishery as a whole, there have been other circumstances that contributed more specifically to an increase in the intensity of the fishery for perch. The collapse of the cisco fishery, formerly the most productive in Lake Erie, in 1925 forced many operators, particularly the gill-netters, to turn to other species. The resulting increase in intensity of the fishing for perch was an important factor in the rise in production of this species. The yield of perch was affected also by the reduction in July 1929 of the minimum legal size from 9 to 8½ inches in the State of Ohio. The record catch of 13 million pounds in Ohio in 1934 occurred in a year when the officials failed to enforce the law on size limits.

Economic conditions doubtless have had an effect on the annual fluctuations in the yield of perch, but the relation is too obscure to point to any major change in the annual catch as the result of changes in the price of or demand for perch.

The discussion of the relation of production to fishing intensity, to fishery laws and enforcement of laws, and to market conditions, has been given in advance of the treatment of the relation between the catch and the abundance of perch, not with the intent to imply that abundance is not of great importance in determining the yield, but rather to bring out the dangers of interpreting too freely fluctuation in production as the result of fluctuation in abundance. To be sure, abundance and catch are closely related; but careful recognition also must be given to other factors that affect the annual yield.

Abundance may be considered in terms of long-period changes such as those brought about by the prosecution of the fishery or by gradual changes in the environment, or in terms of the short-period fluctuations traceable to variations from year to year in the success of natural reproduction. Both types of changes are reflected in fluctuations in the annual catch. Many of the variations in annual yield as recorded in table 1 are probably to a large extent the result of relative strength or weakness of year classes. Age determinations have shown, for example, that the increases in production in 1928 and 1929 were not exclusively the result of increased fishing intensity and the reduction of the legal size for perch, but were furthered also by the phenomenal richness of the 1926 year class.

The fluctuations in abundance that arise from variations in the strength of year classes must be accepted by fishermen as part of the natural course of events, since at present very little can be done to increase the survival of young. The environment may be improved by such measures as the control of pollution and erosion. The value of such measures to the Lake Erie fisheries is open to question, since it has been shown that no extensive areas of heavy pollution exist that would be inimical to fish life (Wright and Tidd 1933, Fish 1929), and that turbidity is not a factor in either the survival of the young or their subsequent growth in Lake Erie (Van Oosten 1948). In fact, the causes underlying annual variations in the success of natural reproduction are little understood. Although a knowledge of the fluctuations that occur in the strength of year classes may contribute to an understanding of changes in the fishery, a knowledge of the general level of abundance and of long-period trends in abundance is more pertinent to the solution of administrative problems than is information on short-period fluctuations.

The abundance of yellow perch in the early period of the United States fishery (1885–99) must have been at a relatively high level, since good production was maintained in spite of low fishing intensity and inefficient methods. On the other hand, the reduced yields of the 1900–1927 period—one of expanding fishing intensity and increasing efficiency in fishing methods—indicate a sharp reduction in the general level of abundance. The greatly increased production in 1928–35 must be considered the result, in part at least, of the increase in intensity of the fishery for perch that followed the collapse of the cisco fishery. The known abundance in 1928 and 1929 of perch of the big 1926 year class and the virtual removal of the size limit in Ohio in 1934 undoubtedly contributed to the large yields in those years. It seems unlikely, however, that a production of over 14 million pounds could have been reached in 1934, even without a size limit, unless the population had reached an enormous size that year. Likewise, the yields of more than 9 million pounds in 1931, 1932, and 1935 indicate tremendous abundance. Evidence will be presented later (p. 245) which shows that normally the perch of a year class dominate the fall fishery in their third year and the spring fishery in their fourth year of life. Thus, two year classes of perch make up the bulk of the commercial catch each calendar year. On the basis of that evidence, it may be assumed that the year classes of 1928 to 1932 or 1933, inclusive, were of exceptional strength to have been able to produce the high yields during the period 1931–35.

The statistics (table 1) suggest strongly that the abundance of yellow perch was reduced greatly during the years 1936–47. The fishing intensity may have decreased in United States waters when some of the operators quit business, but it is known also that some new outfits started operations during this period. Increase in size of the mesh in the Ohio trap nets probably did not release enough legal-sized perch to affect materially the total yield. Since Van Oosten (1932) showed that trap nets with a mesh larger than that employed in the nets at the present time did not release perch of 8½ inches (present legal size limit) and larger, the reduction in take in 1936–47 undoubtedly was largely the result of a decrease in abundance of perch rather than a decrease in fishing intensity.

A precise evaluation cannot be made of the changes in abundance of the yellow perch in Lake Erie during the period of greatest fluctuations in yield, because the data are not sufficient. An approximation of the abundance may be obtained, however, from the records of the W. D. Bates Fishery, Rondeau, Ontario, which give the number of pound nets fished and the catch each year for the period 1900–1940, and from those of Leonard Bickley, Sandusky, Ohio, which give the catch by trap nets of a 1-boat fishery during the years 1911–31. The records of number of nets fished and total pounds of fish taken published by the former Ontario Department of Game and Fisheries also are of value.

Although there are certain discrepancies among these three sets of data, they all suggest that the period 1928–35 was one in which the abundance of yellow perch in Lake Erie was high, and all data are consistent in showing that the abundance declined sharply in 1936 and has remained at a relatively low level since that time. Bickley's data, in contrast to those of Bates, suggest a slight increase in abundance in 1921–27, thus indicating that the slight rise in production in the Ohio waters in those years may, in part, reflect abundance.

It must be recognized that the yellow-perch fishery in Lake Erie is not in a prosperous condition at the present time. That the fishery has not collapsed entirely is perhaps a tribute to the fecundity of the perch. The danger exists in the absence of a reserve supply, as well as in the low abundance. The failure of only two successive year classes would lead to collapse of the fishery.

MATERIALS AND METHODS

Materials for this investigation on the age and growth of yellow perch were collected at the following Lake Erie ports: Port Clinton, Sandusky, Huron, Vermilion, Lorain, Ashtabula, and Conneaut, Ohio; Erie, Pa.; and Dunkirk, N. Y. (See fig. 2.) Originally a separate analysis was made of the data for yellow perch from the western, middle, and eastern sections of the lake; it was found, however, that a combination of the data was justifiable. It was found also that the data for trap nets and pound nets could be combined.

Table 2 shows, for each type of gear, the number of specimens on which this study has been based. The 1927–37 materials used in the growth-rate studies, a total of 3,036 fish, were random samples of the trap-net and pound-net catches taken during the latter part of the collecting period of each year. Samples from impounding nets were used because that type of net is less selective than gill nets, and because the impounding-net collections covered a greater period of years. The 1,341 fish taken from trap nets in the years 1943–48 were used in the study of annual fluctuations in growth. The ages were determined of 430 specimens taken in commercial gill nets during 1927 and 1928, and of 1,136 fish taken in the years 1943–48. The 1927–28 material consisted of random samples from shoal nets (228 fish) and from bull nets (202 fish). The data on age were used to compare the age composition of the catch in gill nets with that of impounding nets.

All specimens for which length and weight were recorded (23,158 fish) in 1927–37 were used in the study of the length-weight relation. The length-frequency data for the years 1927–37 were based on 58,665 specimens taken from random samples only and included those specimens whose ages were determined, most of those used in the study of the length-weight relation, and a large number for which lengths only were obtained. The length distribution of 1,114 yellow perch taken in 1943–48 by trap nets was used for comparison with the earlier material.

Investigation of the relation between scale length and body length was based on the examination of selected or "key" scales from 600 specimens collected in western Lake Erie as follows: September to November 1928, 188; May to August, and November 1929, 79; October 4, 1934, 207; April 1937, 60; and late autumn 1937, 66. The scale measurements from only 576 of these specimens could be used, since 24 individuals had lost the designated scale or had key scales that were regenerated, injured, or otherwise atypical. The

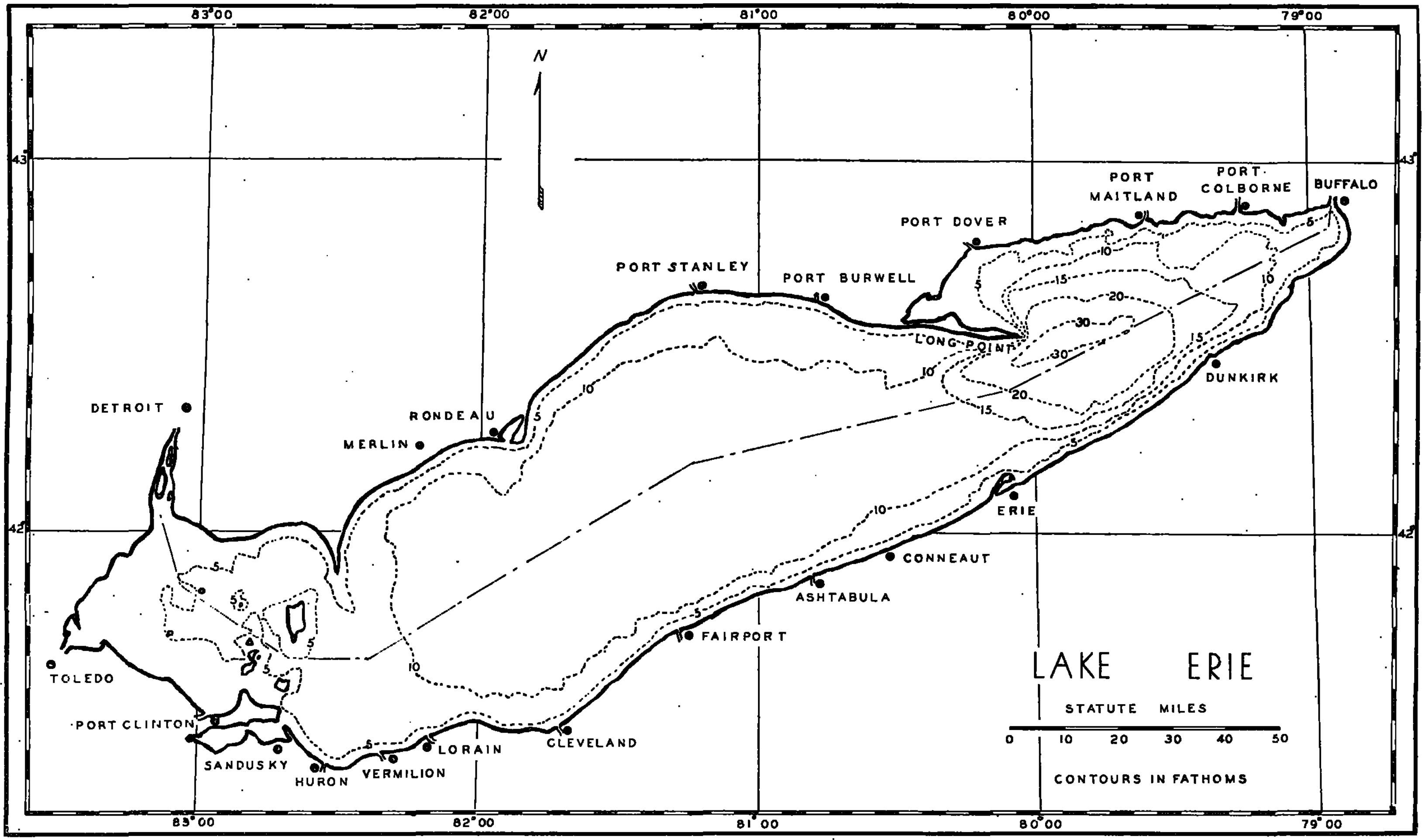

FIGURE 2.—Lake Erie.

TABLE 2.—*Specimens used in study of Lake Erie yellow perch and gear employed in taking them*

Gear employed and year taken	Number of specimens used in study of—		
	Age and growth	Length-weight relation	Length frequency
Caught by impounding net during—			
1927	481	1,516	3,224
1928	[1] 918	3,123	5,785
1929	[2] 1,151	11,215	11,939
1930	222	269	7,118
1931	----	----	19,391
1932	133	133	133
1934	(3)	207	----
1937	[4] 131	131	131
1943	45	----	----
1944	81	----	81
1945	157	----	132
1946	225	----	204
1947	343	----	297
1948	490	----	400
Total	[5] 4,377	16,594	48,835
Caught by shoal gill net [6] during—			
1927	84	1,659	1,670
1928	144	3,386	2,754
1929	----	----	4,744
1930	----	----	----
1931	----	----	----
1932	----	----	----
1934	----	----	----
1937	----	----	----
1943	129	----	----
1944	57	----	----
1945	75	----	----
1946	204	----	----
1947	380	----	----
1948	291	----	----
Total	1,364	5,045	9,168
Caught by bull gill net [7] during—			
1927	69	116	257
1928	133	565	681
1929	----	838	838
1930	----	----	----
1931	----	----	----
1932	----	----	----
1934	----	----	----
1937	----	----	----
1943	----	----	----
1944	----	----	----
1945	----	----	----
1946	----	----	----
1947	----	----	----
1948	----	----	----
Total	202	1,519	1,776
Grand total	5,943	23,158	59,779

[1] In addition, 188 selected specimens were used in the key-scale study.
[2] In addition, 79 selected specimens were used in the key-scale study.
[3] 207 selected specimens were collected for key-scale study.
[4] In addition, 126 selected specimens were used in the key-scale study.
[5] Selected specimens used in the key-scale study and for the determination of maximum age are not included in the totals.
[6] Gill nets 22 meshes deep.
[7] Gill nets 100 meshes deep.

600 specimens collected for the key-scale study were not used for any other purpose, except the 207 collected October 4, 1934, which were employed as part of the data on the length-weight relation.

During 1927 and 1928 the lifting cribs of the trap nets from which samples were taken were made of 2-inch or 2¼-inch webbing (stretched measure as manufactured), except for the vertical middle third of the backs, where the mesh was 2⅞ inches. From 1929 to 1937 the mesh of the crib was 2¼ inches (stretched measure as manufactured) in all parts except the entire back where the mesh was 2¾ inches. Since 1937 the mesh in the back of trap nets has been 2⅞ inches, with the sides made of 2½-inch mesh. The pound-net samples (from Erie, Pa.) were from nets with meshes of $2\frac{11}{16}$ inches (stretched measure as manufactured). The gill nets, from which the 1927–28 samples were studied, were of 3-inch and $3\frac{1}{16}$-inch mesh (stretched measure as manufactured). Since the length frequencies of the perch taken in the two sizes of mesh showed no significant differences, the size of mesh was ignored in treating the gill-net data. The gill-net data, however, have been separated on the basis of depth of net because there was a difference between the length frequencies of perch taken in shoal gill nets and in bull gill nets. The shoal nets were 22 meshes deep and the bull nets 100 meshes deep. The meshes of the shoal nets from which the 1943–48 samples were taken measured 2⅞ inches.

Except in 1930–31 and 1943-48, lengths were measured with a flexible steel tape held so as to follow the curve of the body from the tip of the snout to the thickest part of the body, and then in a straight line approximately parallel to the long axis of the body. The length records of fish caught in 1930–31 and 1943–48 were obtained with a measuring board. The lengths measured on the board were converted to "tape-line lengths" by the factor 1.02. Weights were recorded to the nearest fourth of an ounce except in 1948 when they were recorded in tenths of ounces. All measurements of length and weight were obtained from fresh specimens in the field, except those of fish collected for key-scale study. Of those, the 207 used in the length-weight-relation study were shipped fresh, packed in ice, to the laboratory, where they were measured and weighed, and the rest, all preserved, were measured but not weighed. Lengths obtained from preserved specimens were corrected for shrinkage produced by the preservative; the correction factor was 1.0065.

Scales for age determinations were taken from the left side of the fish, below the lateral line and beneath the spinous dorsal fin. They were mounted on standard glass microscope slides in the gelatin-glycerin medium recommended by Van Oosten (1929).

The first examinations of the 1927 and of part of the 1928 scale collections were made by use of the projection apparatus described by Van Oosten (1923). The final examinations and the measurements of those scales, and all examinations and the measurements of the remaining scales, were made by means of the apparatus described by Van Oosten, Deason, and Jobes (1934) at magnification × 40.7. The measurements from the focus to each successive annulus and to the extreme edge of the scale were made along the most anterior interradial space. Approximately 5 percent of the scales examined were discarded because the age could not be determined with confidence.

Ages are designated in roman numerals corresponding to the number of annuli visible on the scales except for those fish taken in the early spring before growth began. An annulus was assumed to be present on the edge of the early-spring scales. Such an assumption is necessary to avoid the assignment of one age to fish of a year class whose scales were without spring growth and another age to fish of the same year class collected the same day whose scales had begun the current season's growth. Thus fish assigned to age group I were in or just ready to begin their second year of life.

DETERMINATION OF AGE AND GROWTH OF LAKE ERIE YELLOW PERCH BY THE SCALE METHOD

Since the demonstration by Hoffbauer (1898) that the age of carp could be determined by examination of their scales, the scales of fish have been used extensively for the study of growth rates and age composition of the stocks of many marine and fresh-water species. Historical summaries of the literature and discussions of the validity of age determinations from scales and of growth calculations from scale measurements already published make it unnecessary to say more here than that the major part of the evidence, obtained from a wide range of species, substantiates the general premise that age can be determined accurately from scale markings and that measurements of fields of growth in scales can be employed for the calculation of lengths at the end of the different years of life.

VALIDITY OF THE ANNULUS AS A YEAR MARK

It has been assumed by the several workers that ages may be determined accurately from an examination of the scales of the American yellow perch, since these scales showed clearly the characteristics that had been used in the accurate determination of the ages of certain other species. The data and observations of the present study, given in the following paragraphs, substantiate this assumption.

1. The collections of 1927, 1928, and 1929 were dominated by fish whose scales showed 1, 2, and 3 annuli, respectively. The corresponding average total lengths of the age groups were 7.5, 8.3, and 9.5 inches. (Most of the 1928 collections were not made as late in the autumn as were the collections of 1927 and 1929; consequently, the average length of 8.3 inches does not represent 3 full years of growth.) That the catches of succeeding years were dominated by progressively larger individuals which, in accordance with expectation, were shown by scale readings also to be progressively older, is strong evidence that one annulus is formed each year and that the scale markings can be interpreted accurately for at least the first three years of life.

2. Scales collected on December 7, 1929, showed no annulus on the edge. Samples obtained July 1, 1929, April 11 and 13, 1932, and April 29, 1937, showed an annulus forming on the edge of the scales. On July 11, 1930, the scales showed a completed annulus a short distance inside the margin. The outermost annulus was farther from the scale margin on September 25, 1930, than in July. These observed variations, especially those on the relative positions of the annulus within the scale margin at different times during the same year (1930), provide evidence that only one annulus was formed on yellow-perch scales each year.

3. There was closer agreement between the calculated and empirical lengths of fish of the same age as determined from scales than between those of different ages. This agreement indicates a constancy in the number of annuli formed each year.

Annulus formation appears to be completed between early April (1932 and 1937 collections) and the middle of July (1929 collection). There is no evidence from these data to show a relation between the time of annulus formation and sex, maturity, or spawning activity. The annulus on yellow-perch scales cannot be said to be a spawning mark despite the approximate coincidence of spawning and the completion of the annulus because (1) immature yellow perch form annuli identical in appearance with those formed by spawning fish, (2) the stage of sexual maturity appears to have no influence on the time of year the annulus is completed, and (3) the annuli do not show the typical spawning marks observed in other species of fish.

The most important characteristics of the annuli on the scales of the Lake Erie yellow perch may be stated briefly to be the "cutting over" in the lateral fields resulting from the discontinuity between scale sculpturing of the successive growth areas, and the irregular or fragmented appearance of the last circulus laid down each year. Usually there is a narrow, clear band between the outermost circulus of one growth area and the first circulus of the next.

False (accessory) annuli occurred not infrequently on the yellow-perch scales but are believed not to have affected the results seriously since all that were recognized were disregarded. Those annuli designated as false were characterized by a decreased amount of "cutting over," by less-well-defined discontinuity between the adjacent fields of growth, and, frequently, by a position that would have given inconsistent calculated lengths.

BODY-SCALE RELATION

Few calculated lengths for the American yellow perch have been published. The earliest, by Jobes (1933) and Schneberger (1935), were computed by the Dahl-Lea method of direct proportion. This method is based on the assumption that the ratio of body length to scale length is constant at all lengths beyond that at which the first year mark or annulus is formed. The age and growth of the closely related European perch, *Perca fluviatilis* L., have been studied by this method by several investigators who found that the lengths calculated by direct proportion usually were less than the empirical lengths for the early years of life.

In spite of the wide use of the direct-proportion method, numerous investigations have shown that this method frequently failed to give satisfactorily accurate results since the computed lengths obtained often did not agree with empirical lengths. Of the several methods developed to obtain a closer agreement between calculated and empirical lengths only that of Segerstråle (1933) for the European yellow perch will be mentioned here, since the calculation of lengths in the present study was by a modification of his procedure.

Segerstråle determined the average scale lengths corresponding to different body lengths through an extensive series of measurements of "key" scales, or "Normalschuppen," taken from a selected area of the body. The body-scale relation so determined, expressed either in tabular form or as a curve, served as the basis for calculating the growth histories of individual fish. On purely theoretical grounds, the method of Segerstråle is the best since it assumes no fixed mathematical relation between body length and scale length, but rather is based on the detailed examination of the actual size of scale at different body lengths. The most serious objection to the use of an empirically determined relation of body length to scale length in the calculation of growth histories is the practical difficulty of obtaining samples with adequate representation of all lengths of fish. The distribution by length of a fish population usually is such that individuals of certain sizes are difficult or impossible to obtain. Inadequate representation of these length intervals inevitably leads to inaccuracies in the calculated lengths.

The diversity of opinions expressed and of results obtained by the several investigators dealing with presumably representative collections of the same and different species leads to the conclusion that the relation of body length to scale length in fishes is not a subject for generalization. The proper method of calculation must be determined for the material at hand. Data on the yellow perch from Lake Erie made possible an analysis, for the first time,[2] of the relation of body length to scale length in a population of American yellow perch.

[2] Although circumstances prevented earlier publication of this study, Hile and Jobes (1941) were able to apply the method developed here to the determination of the body-scale relation of the yellow perch of Saginaw Bay.

Only key (selected) scales were used to determine the relation between size of scale and size of fish. The scale on the left side of the fish in the third row below the lateral line and directly beneath the sixth spine of the dorsal fin was designated the key scale. The position of the key scale approximated the center of the area from which the unselected scales were obtained for age and growth determinations. The scale occupying the designated position on the right side of the specimen was used when the one on the left side was lacking or was regenerated or malformed. Although the collections for the key-scale study were taken at widely spaced intervals of time (see p. 211), an analysis of the data failed to reveal any large or consistent differences for fish captured in different years or seasons.[3] There is no evidence of a seasonal lag between the growths of body and scale in the Lake Erie yellow perch. The data also failed to show any consistent differences in the relative sizes of scale correlated with sex or stage of maturity. Therefore, data from all fish have been combined in this study without regard for the time of capture, sex, or stage of maturity.

Table 3 shows the average standard length of the Lake Erie specimens grouped in 10-millimeter intervals, and the corresponding average total lengths in inches, together with the average scale measurement (at magnification × 40.7), and the body-scale (*L*/*Sc*) ratios of each length and age group. The *L*/*Sc* ratios of the age groups are the averages for data collected both at the end of the growing season and at various times throughout the summer (see p. 211). The data were originally grouped in 5-mm. length intervals, but careful examination revealed that condensation to 10-mm. intervals was justifiable. The average *L*/*Sc* ratios of the age groups indicate that the relative size of the scale increased during the first 3 years of life and then decreased slightly during the fourth. However, a comparison of the *L*/*Sc* ratios of fish in the same length interval but of different ages revealed that there was no consistent change in the relative size of scale with age. Consequently, the differences between the relative sizes of scales in the different age groups do not depend directly on age but rather on the length distribution of the age groups. Comparisons between fish in the same age group but of different average lengths showed that the *L*/*Sc* ratios became relatively smaller (relatively larger scales) as the fish length approached 4.3 inches (see data for age groups 0 and I); remained reasonably constant over the length range of 4.3 to 9.2 inches (age groups I, II, and III); and then established another reasonably steady but higher ratio (relatively smaller scales) over the length range of 9.2 to 10.9 inches (age groups II and III).

[3] The scales of group 0 (first year of life) yellow perch caught during late October and early November 1928 were found to be consistently somewhat smaller than the scales from fish of the same length and the same year class that were caught during September 1928 and June 1929. This unusual phenomenon cannot be explained satisfactorily at present. However, the differences were so small that the inclusion of fish caught during October and November did not change greatly the grand average ratio of body length to scale length (table 3).

TABLE 3.—*Body length to scale length ratio (L/Sc) of selected scales from western Lake Erie yellow perch by 10-mm. intervals*

[Number of specimens in parentheses]

Standard-length interval	*L*/*Sc* ratio for age group—				Grand average *L*/*Sc* ratio	Average standard length (millimeters)	Average total length (inches)	Average scale measurement (×40.7)
	0[1]	I	II	III				
41 to 50 mm	1.97 (40)				1.97 (40)	47.7	2.3	24.2
51 to 60 mm	1.74 (91)	1.64 (3)			1.74 (94)	55.5	2.7	31.9
61 to 70 mm	1.55 (37)	1.57 (27)			1.56 (64)	64.6	3.1	41.4
71 to 80 mm	1.41 (7)	1.42 (23)			1.41 (30)	74.6	3.6	52.8
81 to 90 mm	1.36 (1)	1.32 (25)			1.33 (26)	85.2	4.1	64.3
91 to 100 mm		1.16 (32)			1.16 (32)	97.2	4.6	83.5
101 to 110 mm		1.15 (15)	1.21 (1)		1.16 (16)	104.2	5.0	90.1
111 to 120 mm		1.19 (6)			1.19 (6)	116.5	5.5	98.2
121 to 130 mm		1.15 (11)	1.11 (1)		1.15 (12)	126.3	6.0	110.2
131 to 140 mm		1.14 (26)	1.22 (2)	1.20 (1)	1.14 (29)	136.7	6.3	119.8
141 to 150 mm		1.12 (23)	1.08 (6)	1.22 (2)	1.13 (31)	145.1	6.7	128.6
151 to 160 mm		1.14 (15)	1.12 (22)	1.13 (2)	[2] 1.13 (40)	156.3	7.2	138.3
161 to 170 mm		1.16 (11)	1.14 (36)	1.09 (1)	1.14 (48)	165.5	7.6	144.5
171 to 180 mm		1.18 (1)	1.19 (20)		1.19 (21)	173.9	8.0	146.7
181 to 190 mm			1.15 (8)		1.15 (8)	184.2	8.5	160.2
191 to 200 mm			1.18 (17)	1.14 (4)	1.17 (21)	196.5	8.9	167.5
201 to 210 mm			1.22 (7)	1.35 (1)	1.23 (8)	205.9	9.4	166.9
211 to 220 mm			1.20 (24)	1.22 (10)	1.20 (34)	216.8	9.9	179.9
221 to 230 mm			1.21 (7)	1.20 (6)	1.21 (13)	223.6	10.2	185.2
231 to 240 mm			1.21 (2)	1.08 (1)	1.17 (3)	234.0	10.6	200.7
Average	1.74 (176)	1.25 (218)	1.16 (153)	1.19 (28)	1.24 (576)			

[1] First year of life.
[2] The age was not determined for 1 specimen in this length interval.

These changes in the L/Sc ratio perhaps are shown more clearly in table 3 and figure 3. It is evident that the ratio of body length to scale length in the Lake Erie yellow perch is determined primarily by the length of the fish.

Figure 3 is a graphic presentation of the average total lengths and average scale measurements shown in table 3. The straight line extending upward from a fish length of 4.6 inches represents the body-scale relation of all fish with total lengths greater than 4.2 inches, on the assumption that a single average (1.16) describes the body-scale ratio satisfactorily for all these fish. The line for the average fish lengths of 2.3 to 4.6 inches was drawn freehand. The line determined by the average L/Sc ratio (1.16) fits the data closely for the fish with average total lengths of 4.6 to 8.9 inches. The scales of those fish with average lengths of 9.4 inches and more were somewhat, but not pronouncedly, smaller than would have

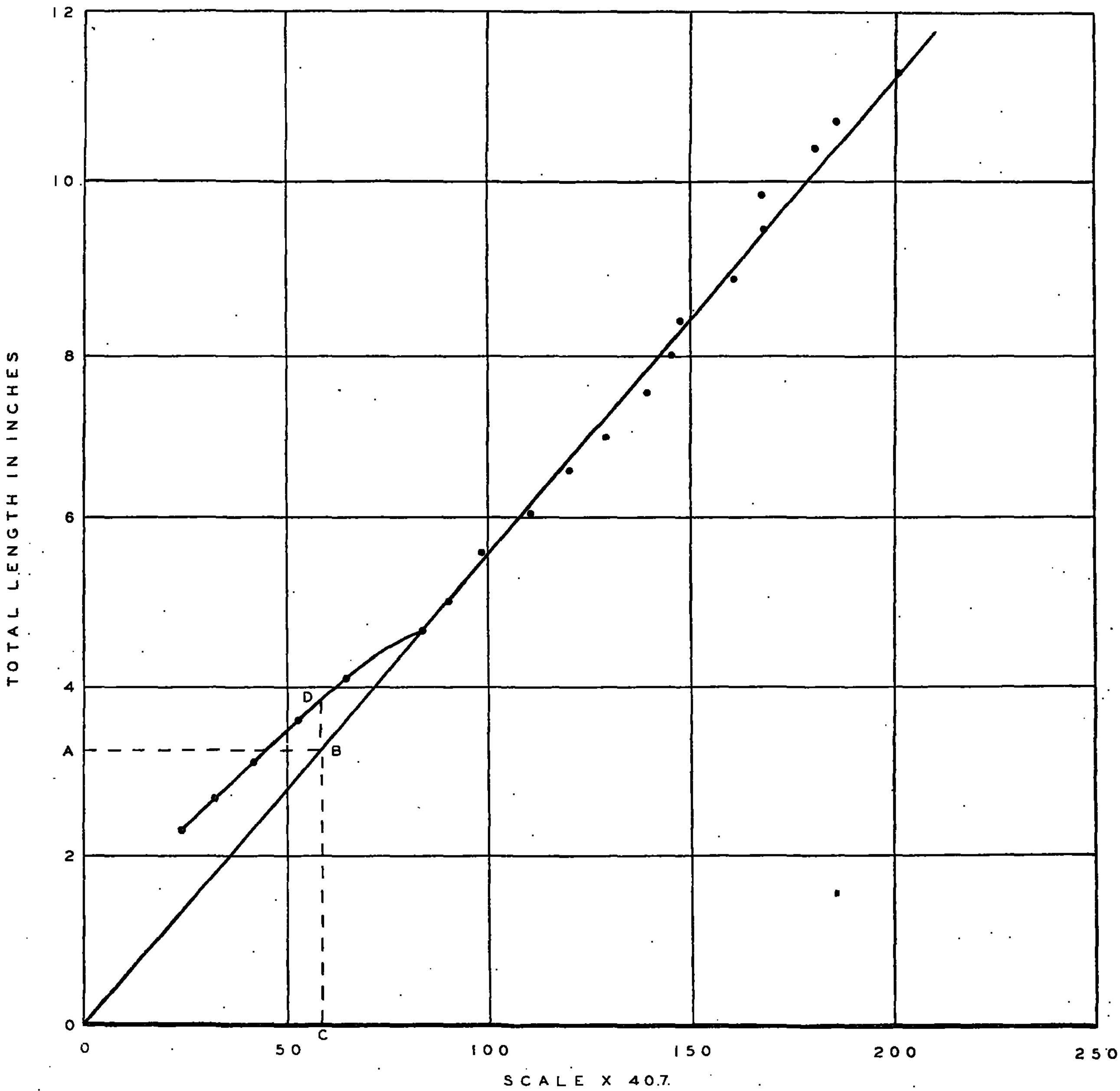

FIGURE 3.—Relation between body length and scale length in yellow perch of Lake Erie.

been expected on theoretical grounds. These rather slight discrepancies which affected only three length intervals are not believed to invalidate the conclusion that the body-scale ratio is constant beyond the average body length of 4.6 inches. The scales from the fish with average lengths of less than 4.6 inches were relatively much smaller than the scales from the larger fish. It is to be noted particularly that the relative size of the scale increased rapidly as the average length of the fish increased from 2.3 to 4.1 inches. The increase in relative size follows approximately a straight line but its slope is greater than that of the line fitted to the data for the larger fish.

The rapid increase in the relative size of the scale during early life was expected from the known facts of scale growth. The scales originate as tiny isolated platelets when the yellow perch has a total length of approximately 1 inch. The scale, then, must grow more rapidly than the body in order to attain the degree of imbrication characteristic of larger fish.

It is evident from table 3 and figure 3 that a sharp break in the series of *L/Sc* values and in the continuity of the curve occurred between the average lengths of 4.1 and 4.6 inches. A detailed examination of the *L/Sc* ratios for each millimeter length indicated that the break occurred at a length of 4.3 inches. The average ratio of the 4.2-inch individuals was comparatively high (1.34), but it fell suddenly to 1.13 in the 4.3-inch fish and continued at that level in the larger specimens. It appears, then, that the *L/Sc* ratio actually assumes constancy at a fish length of 4.3 inches rather than at 4.6 and no corrections for disproportionate growth of body and scale are necessary for calculated values greater than 4.2 inches. Since the two discontinuous portions of the curve of figure 3 were based on averages (in order to obtain a smoother curve) and (for purposes of correcting computed lengths below 4.3 inches) were connected at points of average lengths (4.1 and 4.6), any calculated values that fall between these two averages will be subject to correction. Any correction of length between 4.2 and 4.6 inches theoretically is unwarranted. However, as may be seen from table 4, the corrections for lengths between these limits are small and for all practical purposes may be ignored.

If the length of the scale were purely a function of the length of the fish, the body-scale curve for the smaller individuals would be expected to join smoothly the straight line that describes the body-scale relation for the larger ones. The pronounced discontinuity in the curve suggests that other factors must be involved. Changes in the relative size of the head with increase in fish length may have been a factor. The relative size of the head was found to decrease progressively with increase in fish length through the 71 to 80 mm. interval or up to the average length of 74.6 mm. (3.6 inches total length). Thereafter, variations in the relative size of the head were small and without any detectable trend through the 171 to 180 mm. interval (8.0 inches average total length). Although the progressive decrease in the relative length of the head may have contributed to the decrease in the values of *L/Sc* up to a fish length of 3.8 inches, it is apparent that these changes did not produce the observed sudden shift in the body-scale relation between 4.3 and 4.7 inches.

The possible effect of variations in the number of scales in linear series on the body-scale ratio also was investigated. It was found that fish with standard lengths of 81 to 90 mm. (4.1 inches average total length) averaged 54.9 (51 to 58) scales in the lateral line, and that fish with lengths of 91 to 100 mm. (4.6 inches average total length), averaged 55.1 (51 to 62). The small difference (0.2) in the averages could have had little effect on the changes in the body-scale ratio. If it is assumed that this difference could affect the body-scale ratio, then one would expect the larger fish to have relatively smaller scales, a conclusion contrary to the observed facts. It appears that the number of scales in linear series was not a factor in the sudden change in the body-scale ratio of the Lake Erie yellow perch.

Length of fish is the only factor in these data that can be demonstrated to have had an appreciable effect on the body-scale ratio. The failure of the two portions of the curve to join smoothly cannot be explained satisfactorily as yet.

CALCULATION OF GROWTH

In the preceding discussion it was indicated that because of the discontinuity of the *L/Sc* curve (change in average *L/Sc* ratios) all direct-proportion computations of length less than 4.6 inches must undergo correction, and because of the constancy in the average ratios no corrections were needed for lengths of 4.6 inches or more. The direct-proportion method was therefore employed whenever the calculated lengths exceeded 4.5 inches and the empirical curve was used only for the smaller lengths. Since the correction for 4.51 inches was less than 0.05 inch, the empirical-curve method was applied only to lengths of 4.46 inches and less.

In practice, all lengths were computed by direct proportion, and corrected lengths corresponding to calculated lengths 4.46 inches and less were read directly from table 4, which was prepared with the assistance of the empirical body-scale curve (fig. 3). The data for this curve were plotted originally on 1-mm. cross-section paper and the amount of each correction was read directly from this graph. The amount of correction required for each direct-proportion calculated length is the vertical distance between the extended straight line representing the body-scale ratio of fish with total lengths of 4.6 inches and more and the empirical line representing the ratio for the shorter fish. The procedure for obtaining the correction for a direct-proportion calculated length of 3.25 inches is illustrated in figure 3. Line *AB* is drawn horizontally from $L=3.25$ to *B* on the straight line representing the body-scale ratio of fish with total lengths of 4.6 inches and more. Line *CD* is a perpendicular that passes through *B* from the scale axis to *D* on the line representing the body-scale ratio of the smaller fish. The correction is the distance between points *B* and *D*. In the present study only the first-year lengths fell within the range that required correction.

TABLE 4.—*Calculated lengths (inches) of Lake Erie yellow perch*

[Total-length conversion of standard length in millimeters]

Direct-proportion calculated length	Corrected calculated length	Direct-proportion calculated length	Corrected calculated length
1.72	2.63	3.15	3.73
1.77	2.63	3.20	3.78
1.82	2.68	3.25	3.82
1.86	2.72	3.30	3.82
1.91	2.77	3.35	3.82
1.96	2.82	3.39	3.85
2.01	2.87	3.44	3.85
2.06	2.87	3.49	3.90
2.10	2.92	3.54	3.95
2.15	2.96	3.58	3.95
2.20	3.01	3.63	4.00
2.25	3.06	3.68	4.04
2.29	3.11	3.73	4.04
2.34	3.15	3.78	4.09
2.39	3.15	3.82	4.09
2.44	3.20	3.84	4.14
2.49	3.25	3.87	4.14
2.53	3.30	3.90	4.18
2.58	3.30	3.95	4.18
2.62	3.35	4.00	4.23
2.68	3.39	4.04	4.28
2.72	3.39	4.09	4.28
2.77	3.44	4.14	4.28
2.82	3.49	4.18	4.32
2.87	3.54	4.23	4.32
2.92	3.54	4.28	4.37
2.96	3.59	4.32	4.42
3.01	3.63	4.37	4.42
3.06	3.68	4.42	4.46
3.11	3.68	4.46	4.51

CALCULATED GROWTH HISTORIES OF THE AGE GROUPS

The average weight at capture and the calculated lengths of yellow perch taken from impounding nets in the years 1927–37 are shown by sex and age group in table 5. Combination of the data for the several years was possible because the corresponding averages varied but little from year to year and the trends in discrepancies between lengths computed from fish of different ages were the same in each of the year classes. The more rapid growth of the females in all years of life except the second was evident for each year as well as for the combined years.

The corrected calculated lengths at the end of the first year of life are seen to be 0.6 inch greater than those obtained by direct proportion for all age groups of both sexes except group I where the difference was 0.4. The smaller amount of correction for age-group-I fish is to be expected since they were the larger individuals of their year class and hence their body-scale ratio deviated less from the straight-line relation required for direct-proportion computations. In general, the same remarks may be made regarding the data for males, females, and all fish. Without exception the calculated first-year lengths of age-group-I fish were greater than those computed from older fish. The calculated lengths of fish older than age group I revealed a slight tendency for the first-year length to decrease as the fish became older. The discrepancies between the calculated first-year lengths of fish older than group I were small. Comparisons of the calculated lengths for all years of life after the first revealed not only that there was a definite tendency for the lengths to decrease as the fish became older but also that the discrepancies each year were larger than in the first year of life. It is to be noted also that, with the exception of group-II fish, the length at capture in the late fall was greater than the corresponding lengths computed from older fish.

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TABLE 5.—*Average weights and calculated lengths of Lake Erie yellow perch taken in impounding nets in late fall, 1927-37 combined*

[Number of specimens in parentheses]

Age group	Average weight at capture (ounces)	Calculated length [1] (inches) at end of year—1: Uncorrected	1: Corrected	2	3	4	5	6
Male:								
Age group I	3.15	3.6 (266)	4.0 (266)	[2] 7.5 (266)	----------	----------	----------	----------
Age group II	4.25	3.0 (532)	3.6 (532)	6.7 (532)	8.4 (394)	----------	----------	----------
Age group III	5.54	3.1 (397)	3.7 (397)	6.5 (397)	8.4 (397)	9.3 (209)	----------	----------
Age group IV	6.15	2.9 (45)	3.5 (45)	5.7 (45)	7.7 (45)	8.9 (45)	9.6 (23)	----------
Average [3]	----------	3.0 (974)	3.6 (974)	6.6 (974)	8.4 (836)	9.4 (254)	10.1 (23)	----------
Annual increment	----------	3.0	3.6	3.0	1.8	1.0	.7	----------
Female:								
Age group I	2.96	3.5 (37)	3.9 (37)	7.2 (36)	----------	----------	----------	----------
Age group II	4.66	3.1 (490)	3.7 (490)	6.9 (490)	8.7 (310)	----------	----------	----------
Age group III	6.57	3.2 (355)	3.8 (355)	6.7 (355)	8.7 (355)	9.9 (192)	----------	----------
Age group IV	7.40	2.9 (55)	3.5 (55)	5.9 (55)	7.9 (55)	9.3 (55)	10.2 (28)	----------
Age group V	8.50	2.9 (5)	3.5 (5)	6.0 (5)	7.9 (5)	9.1 (5)	10.0 (5)	10.6 (4)
Average [3]	----------	3.1 (905)	3.7 (905)	6.7 (905)	8.6 (725)	9.8 (252)	10.7 (33)	11.3 (4)
Annual increment	----------	3.1	3.7	3.0	1.9	1.2	.9	.6
All fish: [4]								
Age group I	3.02	3.6 (392)	4.0 (392)	7.4 (371)	----------	----------	----------	----------
Age group II	4.38	3.1 (1,636)	3.7 (1,636)	6.8 (1,636)	8.5 (750)	----------	----------	----------
Age group III	5.99	3.0 (895)	3.6 (895)	6.6 (895)	8.5 (895)	9.5 (409)	----------	----------
Age group IV	6.86	2.8 (108)	3.5 (108)	5.8 (108)	7.9 (108)	9.1 (108)	10.0 (51)	----------
Age group V	8.50	2.9 (5)	3.5 (5)	6.0 (5)	7.9 (5)	9.1 (5)	10.0 (5)	10.6 (4)
Average [3]	----------	3.1 (2,644)	3.7 (2,644)	6.7 (2,644)	8.5 (1,758)	9.5 (522)	10.4 (56)	11.0 (4)
Annual increment	----------	3.1	3.7	3.0	1.8	1.0	.9	.6

[1] The calculated lengths are based on all fish without regard for time of capture and usually include more specimens than used to determine the length at capture.

[2] The last length shown for each age group is the length at capture late in the fall.

[3] Age group I is not included because of selected size. Beyond the third year of life the average lengths were determined by successive addition of the average annual increments of the age groups for those years.

[4] Includes fish for which the sex was not determined.

In fish older than age group I the discrepancies just described differ from "Lee's phenomenon of apparent decrease in growth rate," as most commonly encountered, in that the wider disagreements occurred among the computed lengths for the later rather than the earlier years of life. It seems probable that the factors that produced the discrepancies in calculated lengths of the Lake Erie perch began to be effective after the first year of life had been passed.

Since an intensive study of the body-scale relation of the Lake Erie yellow perch has eliminated the possibility of large errors in computed lengths resulting from the method of calculation, the observed discrepancies in the calculated lengths must be considered real rather than apparent. In other words, the older fish in the samples actually grew more slowly than the younger ones. The demonstration that the discrepancies in computed growth were real, however, does not justify the conclusion that the data are exactly descriptive of the growth in the population from which the samples were taken. Consideration must be given to the possibility that the samples were not representative of the population as a whole.

DISCREPANCIES IN THE CALCULATED GROWTH HISTORIES OF DIFFERENT AGE GROUPS

Two explanations of the discrepancies in computed growth can be offered. It may be held that the samples were not representative of the population in the lake, and that data based on fully adequate material would not have shown a decline in the growth rate with an increase in age. Or it may be held that the samples were satisfactorily representative but that certain factors tended to bring about the gradual elimination of the more rapidly growing individuals from the yellow-perch population, and that the recorded data therefore represent a valid description of the growth of the Lake Erie perch.

SELECTION BY GEAR

The selective action of impounding nets in taking samples depends on the escape of small fish through the meshes. A rough approximation of the maximum size of escape may be obtained by determining the length of fish with a girth equal to the circumference of the largest meshes found in the lifting pot of the nets. Since the largest meshes of the impounding nets from which the yellow-perch samples were taken were approximately 2½ inches (stretched measure), no fish with a girth in excess of about 5 inches should be expected to escape from the net. Forty-two perch with an average girth of 5 inches (range, 4.72 to 5.28 inches) had an average total length of 7.9 inches.

Examination of the length-frequency distributions of the age groups (table 19) shows that only the larger of group I were retained because they were too large to escape. About one-fourth of the yellow perch in age group II were as short as the theoretical maximum size of escape; only a few of the group-III fish and none in age groups IV and V were shorter than 7.9 inches.

It is not possible to make precise estimates of the extent to which the reliability of the samples of the different age groups was affected by the selective action of the gear. However, group-I samples were unquestionably composed of individuals with the most rapid growth. Group-II samples were affected much less severely. Beyond age group II, gear selection probably had no significant effect on the reliability of the samples. It may be concluded, then, that inadequate sampling traceable to gear selectivity was an important factor in the discrepancies between the lengths calculated from group-I yellow perch and from older fish, and was a contributing factor in discrepancies between the lengths calculated from group II and from older fish. Discrepancies among age groups older than group II cannot be attributed to the selective action of the nets.

The selective action of the impounding nets serves also as the basis for the differential destruction, correlated with growth rate, that brings about an exaggeration of the discrepancies between the calculated growth histories of yellow perch of different ages. Capture in a commercial net exposes illegal-sized perch [4] to a serious risk of destruction in the fishery since a significant proportion [5] of the undersized yellow perch are dead when the nets are lifted. With a fishery as intensive as that in Lake Erie a single individual may be exposed to destruction repeatedly. Consequently, a severe mortality of the faster-growing yellow perch of the younger age groups, especially age group I, is certain to occur. It appears, then, that perch of the same year class captured at older ages show relatively slow growth not only because the samples of the younger age groups were composed of the faster-growing fish but also because some of these same fast growers were eliminated from the stock as young fish.

SEGREGATION CORRELATED WITH SEXUAL MATURITY

Any segregation of the yellow-perch population according to maturity would be in effect a segregation according to size also, since the proportion of mature individuals increased rapidly with increase in length (table 36), and it was the larger fish in the younger age groups that were mature. It will be shown later that the only evidence of a segregation of yellow perch according to maturity was found during the spawning season when the samples consisted almost entirely of mature fish—97 percent of the yellow perch in samples taken April 11 and 13, 1932, were mature.

A comparison of the percentage of mature individuals at different lengths (table 36) with the length-frequency distribution of the age groups (table 19) provides an indication of the extent to which segregation on the basis of maturity may affect the samples of each age. It is seen in table 36 that a majority of the males reached maturity at 6½ inches but that most of the females were not mature until they had passed 8½ inches. It is apparent from table 19 that of the males only group I would be affected by a segregation on the basis of maturity. Such segregation, however, would practically eliminate the group-I females, seriously affect those in age group II, and to a lesser degree disturb age group III. Because the data in tables 19 and 36 were largely from fish taken in the fall, the remarks concerning each age group may be expected to apply equally well to the next-older group in the next spawning season, since little if any intervening growth would occur. Thus, in the spawning season a segregation on the basis of sexual maturity would affect some of the males and practically all of the females in group II, a few of the males and many of the females in group III, and almost none of the fish in group IV and

[4] Since the legal size for yellow perch (8½ inches total length) is well above the maximum length of escape, the question of differential destruction dependent on gear selectivity concerns only the undersized fish.

[5] Dr. John Van Oosten, U. S. Fish and Wildlife Service, found that approximately 14 percent of the undersized yellow perch were dead in Lake Erie trap nets at the time of lifting.

older groups. The April 11 and 13, 1932, samples seem to bear out this expectation as there were no females in age group II but they accounted for 14.3 and 39.4 percent, respectively, of all fish in age groups III and IV. Although other factors no doubt affected the sex ratio in the April 1932 samples (see section on sex ratio, p. 260), segregation on the basis of maturity must have played an important part.

Inadequate sampling because of segregation according to maturity is of little importance in the present study since only one collection employed in the study of age and growth was taken from the spawning run (1932 collection). In this material the reliability of the data for the group-III females only is open to question.

Since maturity and length are closely related, it is possible that segregation according to maturity may be a source of destruction in the spawning-run fishery of fish with more rapid growth. The effects of this higher mortality of fish with rapid growth on comparisons of the growth histories of fish of different ages are similar to the effects of the selective destruction of rapidly growing fish associated with gear selectivity (p. 221).

SELECTIVE DESTRUCTION ACCORDING TO THE LEGAL SIZE LIMIT

The imposition of a minimum legal size limit does much to reduce the effect of selection by gear through the protection of the faster-growing but still illegal-sized individuals, but at the same time adherence to a legal size limit produces a similar selective effect of its own. As the fish reach the minimum legal size limit they are subject to removal by the commercial fishery. Consequently, the faster-growing individuals are exposed to this source of destruction earlier in life than are those of slower growth. In a heavily exploited fishery, successive samples of a year class, then, may be composed of fish with successively slower growth as a consequence of continued sorting according to size.

The manner and extent to which the selective destruction of yellow perch according to legal size limit may give rise to discrepancies between the calculated growth histories of different age groups are brought out by the data of table 6. Effects of the elimination of different percentages of legal-sized fish [6] on the determination of the growth histories of three age groups also are shown. From the data of table 6 it is obvious that the continued removal of legal-sized yellow perch in the commercial fishery will bring about a decrease in the calculated growth rates of an age group. The first-year computed lengths were affected the least. The exclusion of all legal-sized fish reduced the first-year length by only 0.1 inch in the 1928 group II and 0.2 inch in the 1929 group II but brought about a 0.2-inch increase in the first-year length of the 1928 group III. On the other hand, the effect of the elimination of legal-sized yellow perch on the determination of the calculated lengths at the end of the second and third years of life was pronounced. The decreases in the second-year length with all legal-sized fish excluded were as high as 0.7 inch (1929 group II); the decreases in the third-year length were as high as 0.9 inch (1928 group III). When lesser percentages of

[6] A size limit of 8½ inches was employed in the separation of legal and undersized fish in all three age groups although a 9-inch limit was actually in effect in 1928. Since most of the 1928 samples were taken in the summer before completion of the season's growth and most of the 1929 samples were taken in the fall, presumably after completion of the season's growth, it was believed that the data for all age groups would be made more nearly comparable by the use of a single size limit.

TABLE 6.—*Effect of excluding legal-sized fish in determining growth histories of Lake Erie yellow perch*

[Legal size: 8½ inches]

Proportion of legal-sized fish excluded	1928 group II			1929 group II				1928 group III			
	Number of specimens	Calculated length at end of year of life—		Number of specimens	Calculated length at end of year of life—			Number of specimens	Calculated length at end of year of life—		
		1	2		1	2	3 [1]		1	2	3
None	832	3.8	7.1	372	3.5	6.8	8.5	70	3.7	6.2	8.2
25 percent	750	3.8	7.0	323	3.5	6.7	8.4	57	3.7	6.2	8.1
50 percent	669	3.8	7.0	274	3.5	6.6	8.3	44	3.8	6.1	8.0
75 percent	588	3.7	6.9	225	3.4	6.4	8.1	31	3.8	6.1	7.9
100 percent	506	3.7	6.7	176	3.3	6.1	7.9	18	3.9	5.8	7.3

[1] Length at capture in fall (see footnote 6, above).

legal-sized fish were excluded the reductions in the calculated lengths were smaller.

It should be mentioned that the data of table 6 are based on the elimination of legal-sized fish in a single group of samples whereas the removal of legal-sized individuals by the fishery is gradual and is also progressive in the sense that continued growth during the fishing season brings more and more individuals to the legal size. The data serve, nevertheless, to illustrate the type of selective destruction that must occur in the heavily exploited yellow-perch fishery.

Comparisons of the growth data of table 6 with those of table 5, reveal that the discrepancies produced by the elimination of legal-sized fish from an age group resembled closely the discrepancies that actually occurred between the growth histories of different age groups. It is particularly striking that in both table 6 and table 5, the greatest disagreements among the calculated lengths of fish older than age group I occurred beyond the first year of life. It must be considered probable that selective destruction based on sorting according to the legal size limit was an important contributing factor in the observed discrepancies in the calculated lengths of the different age groups of Lake Erie yellow perch.

OTHER CAUSES

Differential natural mortality connected with rate of growth.—The widely observed association of slower growth with the attainment of greater age in poikilothermic animals which was also found by Hile (1936) in the ciscoes of Silver Lake, Wis., may have been a possible factor in the discrepancies in the calculated growth histories of the Lake Erie yellow perch. The effects of such a differential natural mortality among the Lake Erie perch, however, would be obscured by the more important sources of differential destruction by the fishery.

Annual fluctuations in growth rate.—The discrepancies in calculated growth cannot be traced to annual differences in growth rate since the disagreements occurred between different age groups of the same year class.

Formation of more than one annulus per year.—The validity of the use of the annulus on the Lake Erie yellow-perch scale as a true year mark has been established. Although accessory checks are not infrequent, the scales of those fish concerning whose age there was doubt were discarded. It does not appear reasonable, therefore, to assume that the number of errors in the determination of age was sufficiently great to account for the observed discrepancies in the calculated growth of different age groups.

Contraction and resorption of the scale.—Van Oosten (1929) pointed out that the nature of the structure of scales makes wholly unacceptable the assumption that a contraction of scales occurs. The examination of thousands of yellow-perch scales failed to yield any indication of resorption that would effect the calculation of growth. The limited amount of resorption or erosion observed in the lateral fields of the scales of some old fish did not affect the measurements along the anteroposterior axis of the scales.

GENERAL GROWTH CURVES

GROWTH IN LENGTH

It is not possible to determine a growth curve for the Lake Erie yellow perch that is general in the sense that it describes the growth of an individual typical of the population as a whole. The preceding discussions have brought out clearly that in general the older fish had a slower rate of growth than the younger. Consequently, the combination of the data of several age groups to determine a general growth curve involves the lumping together of heterogeneous growth material. The resulting curve is descriptive of the samples rather than of a typical individual. These limitations to the significance of the data should be kept in mind in the examination of the information on general growth contained in table 7.

The average lengths listed in table 7 have been taken from table 5 and are based on the combination of all age groups except group I, which was omitted as nonrepresentative by reason of gear selection (see p. 221). The lengths of fish taken in the fall (presumably at the end of the growing season) were combined with the corresponding calculated lengths. Beyond the third year of life the average lengths of the different age groups were determined by successive additions of the average annual increments of growth. This procedure brings about a natural smoothing of the general growth curve for the later years of life.

TABLE 7.—*Average calculated length, by age, of Lake Erie yellow perch taken by impounding nets*

Year of life	Number of specimens	Total length	Increment in length	Increase	Standard length
		Inches	*Inches*	*Percent*	*Millimeters*
Males:					
1 year	974	3.6	3.6	------	76
2 year	974	6.6	3.0	83.3	143
3 year	836	8.4	1.8	27.3	181
4 year	254	9.4	1.0	11.9	203
5 year	23	10.1	.7	7.4	220
6 year	------	------	------	------	------
Females:					
1 year	905	3.7	3.7	------	77
2 year	905	6.7	3.0	81.1	146
3 year	725	8.6	1.9	28.4	187
4 year	252	9.8	1.2	14.0	215
5 year	33	10.7	.9	9.2	234
6 year	4	11.3	.6	5.6	248
All fish:					
1 year	2,644	3.7	3.7	------	77
2 year	2,644	6.7	3.0	81.1	146
3 year	1,758	8.5	1.8	26.9	184
4 year	522	9.5	1.0	11.8	208
5 year	56	10.4	.9	9.5	228
6 year	4	11.0	.6	5.8	242

The use of the average annual increments caused the lengths of the fish in the later years of life to be higher than the corresponding average calculated lengths as determined from the individual age groups (table 5). For example, as derived from the general growth curve, the length of the females at the end of the fifth year was 10.7 inches as compared to the values of 10.2 (length at time of capture in the autumn) and 10 inches as determined from age-groups IV and V, respectively. Similarly, this length was 10.1 inches as derived from the growth curve of the males but was only 9.6 inches at time of capture in the autumn. Discrepancies occurred also in the lengths at the end of the fourth and sixth years of life. Although the successive additions of the average annual growth increments, to determine the general growth curve in the later years, introduce discrepancies, they cannot be held with certainty to represent errors in the general growth curve. On the contrary, the use of the average annual increments may tend to offset the distorting effects of the differential destruction of the more rapidly growing individuals; hence the seemingly greater lengths of the general growth curve may approximate the true typical growth of the Lake Erie yellow perch more closely than a curve based entirely on grand-average calculated lengths.

Figure 4 is a graphic presentation of the data of table 7 on length at the end of each year of life and the annual growth increment. At the end of the first year of life the females were slightly larger (0.1 inch) than the males, and they maintained this advantage in length during the second year. Beginning in the third year the females increased in length progressively faster than males of the same age until at the end of the fifth year they were 0.6 inch longer.

Of particular interest is the fact that the minimum legal size of 8½ inches, effective in the States of Michigan and Ohio, was reached at the end of the third year by all fish (sexes combined). It may be seen also (table 5) that the average length of the males captured late in the fall at the end of their third year was only slightly less (8.4 inches) and that of the females only a little more (8.7 inches) than the legal minimum. The maximum length of yellow perch examined in Lake Erie was 13.9 inches total length, sex not determined. The longest male was 11.3 inches and the longest female 12.9.

No physiological explanation can be offered for the difference in the growth of the sexes. It is rather certain, however, that the earlier attainment of sexual maturity by the males was not the primary cause of their poorer growth. The females enjoyed the greatest actual and relative advantage in growth in the fourth year of life (females 1.2 inches, males 1 inch). Yet at that size 86.1 percent of the females and 98.6 percent of the males were mature (see table 36). If the poor growth of the males was the result of their early attainment of maturity, the greatest advantage in the growth of the females would be expected to occur in the second year of life when 57.8 percent of the males and none of the females were mature.

In spite of the differences in the growth of the sexes, the same general description of the course of growth applies to the curves for the females, males, and the sexes combined. The most rapid growth in length took place in the first year of life, after which the annual increments decreased continuously.

GROWTH IN WEIGHT

The average weights of the age groups of yellow perch taken late each fall (table 5) bring out clearly that the females were heavier at each age than the males with the exception of those fish assigned to age group II in which the males also were the longer. The best-represented age group (II), which characteristically dominates the late-season

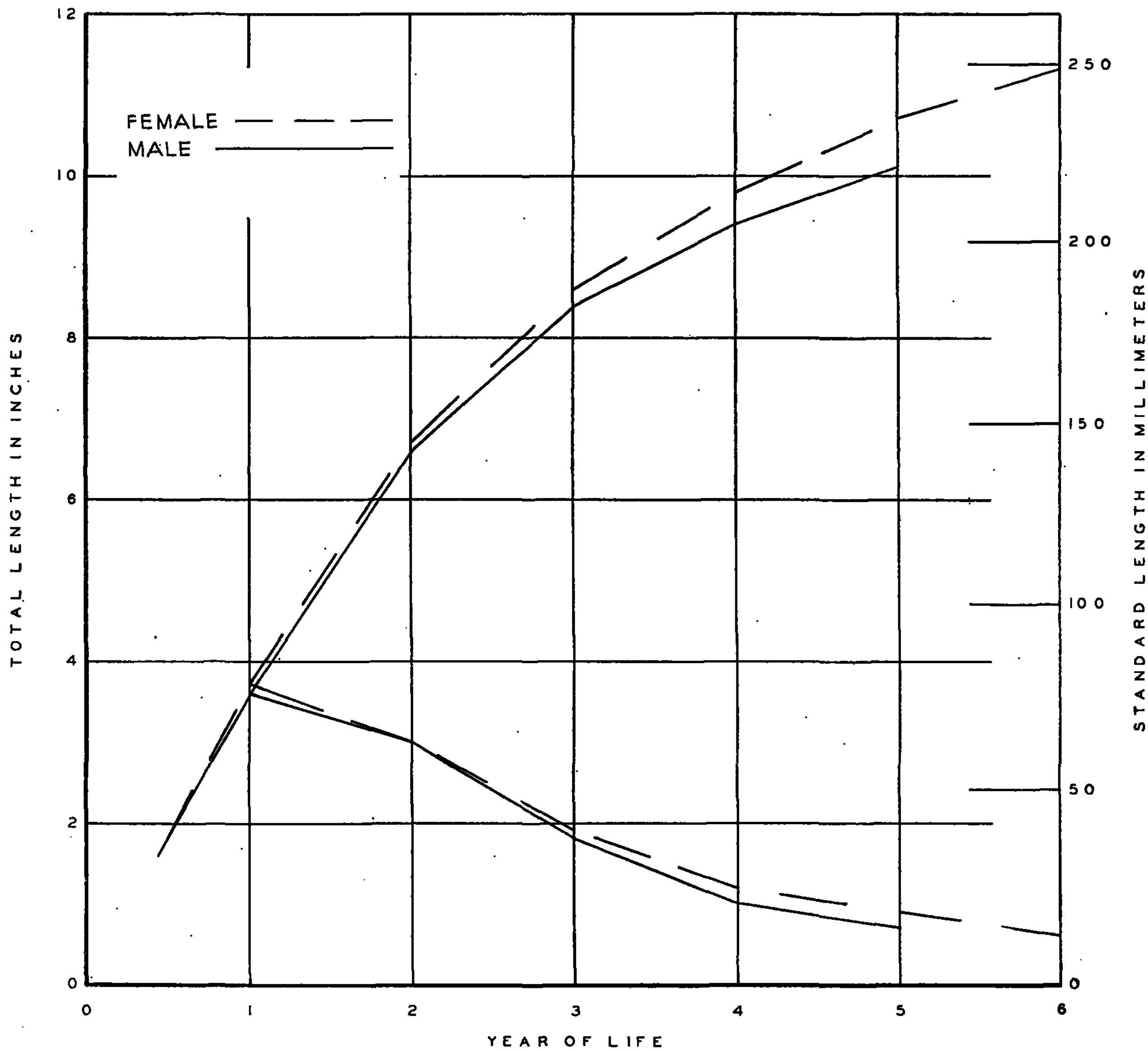

FIGURE 4.—General growth curves showing average length and average annual increments in length of Lake Erie yellow perch at end of each year of life.

catches by trap nets, had an average weight of just over 4 ounces. The only group with an average weight of over 8 ounces (V) was represented by only four fish in the late fall samples and, therefore, the reliability of the average is open to question. Although there was considerable annual variation, the values in table 5 are believed to represent rather well the average weights of yellow perch taken by trap nets from Lake Erie during the later season.

The average weights of the age groups captured late in the autumn differed considerably from the corresponding calculated weights (tables 5 and 8). The empirical weights were greater for the younger fish and smaller for the older individuals. Net selectivity, whereby only the heavier of the shorter fish were retained, no doubt accounted for the greater empirical weights of the younger fish. Perhaps the decrease in condition during October and November (p. 255) was enough to bring about the discrepancies noted among the older ages.

In order to have strictly comparable data for general growth in length and in weight, the equation for the length-weight relation of the Lake

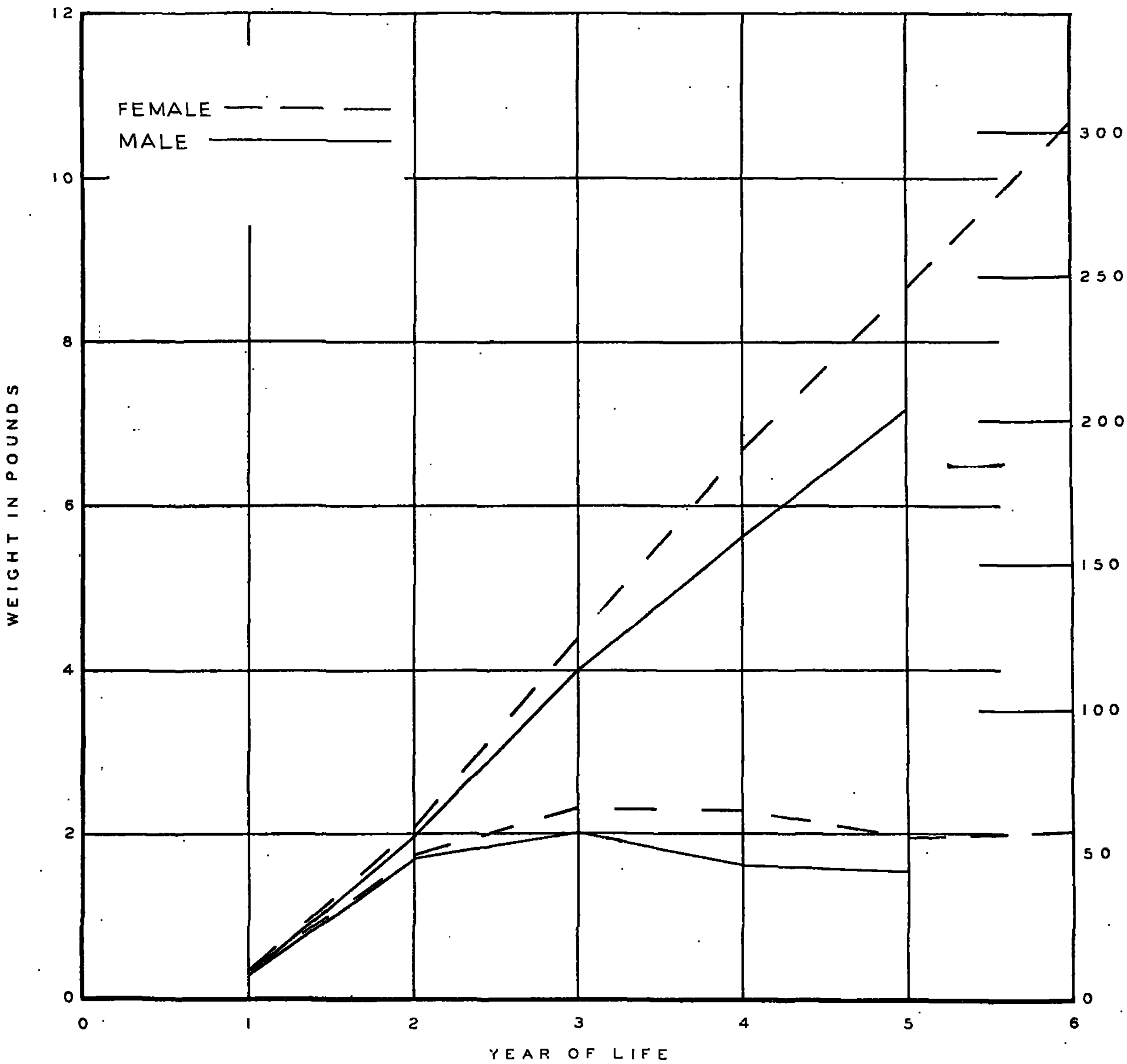

FIGURE 5.—General growth curves showing average calculated weight at end of each year of life and average annual increase in weight of Lake Erie yellow perch according to sex.

CORRECTION

For figure 5, page 226, the vertical-scale caption should read "Weight in ounces" in stead of "Weight in pounds".

TABLE 8.—*Average calculated weight, by age, of Lake Erie yellow perch*

[Collections of all years combined]

Year of life	Weight		Increment in weight	Increase
	Grams	Ounces		
Males:			*Ounces*	*Percent*
1 year	8	0.28	0.28	----
2 years	56	1.98	1.70	607.1
3 year	113	3.99	2.01	101.5
4 year	160	5.64	1.65	41.4
5 year	204	7.20	1.56	27.7
6 year	----	----	----	----
Females:				
1 year	9	.32	.32	----
2 year	59	2.08	1.76	550.0
3 year	125	4.41	2.33	112.0
4 year	190	6.70	2.29	51.9
5 year	246	8.68	1.98	29.6
6 year	303	10.69	2.01	23.2
All fish:				
1 year	9	.32	.32	----
2 year	58	2.05	1.73	540.6
3 year	119	4.20	2.15	104.9
4 year	172	6.07	1.87	44.5
5 year	224	7.90	1.83	30.1
6 year	279	9.84	1.94	24.6

Erie perch (see p. 252) has been employed to compute weights corresponding to the grand-average lengths of table 7. These calculated weights are given in table 8 which shows also the annual increments and percents of increase in weight. The data on general growth in weight are presented graphically in figure 5.

The calculated weights of the females exceeded those of the males in every year of life. The advantage of the females increased regularly from 0.04 ounce at the end of the first year of life to 1.48 ounces at the end of the fifth. The greatest advantage in the growth of the females occurred in the fourth year of life when the increment was 2.29 ounces as compared to 1.65 for the males.

For each sex and for the sexes combined the annual percent increase in weight was greatest in the second year and decreased continuously in the later years. The greatest actual increase in weight occurred in the third year of life. At the end of the third year, when the Lake Erie yellow perch attained the legal length, 8½ inches, the weight (4.2 ounces) was less than half that at the end of the sixth year (9.8 ounces). The heaviest male weighed 12¼ ounces and the heaviest female (a gravid specimen) weighed 19¾ ounces.

GROWTH OF YELLOW PERCH IN LAKE ERIE COMPARED WITH THAT IN OTHER WATERS

Comparison of the growth of yellow perch in Lake Erie with that in other waters will be based on data from the major centers of commercial production of the species. With reference to other waters, it is sufficient to say that the numerous published average lengths of the age groups show tremendous variation in the size of fish of the same age. There appears to be no correlation between geographical location of the lakes and the rate of growth of perch.

Table 9 gives the average calculated total length of yellow perch at the end of each year of life as determined in the present study;[7] by Hile and Jobes for Saginaw Bay (1941) and for the Wisconsin waters of Green Bay and northwestern Lake Michigan (1942); and by Carlander (1942) for the Minnesota waters of Lake of the Woods. The data are presented graphically in figure 6. The total lengths shown were determined where necessary from standard lengths in millimeters by use of the appropriate conversion factors. Calculated lengths at the end of each year of life are used rather than length of the age groups at capture to eliminate discrepancies caused by differences in the time of capture.

With the single exception of the first year when the growth from Lake of the Woods was the greatest (3.9 inches), the yellow perch were larger in Lake Erie and Saginaw Bay than in the other three areas. The Lake Erie yellow perch were larger than those from Saginaw Bay in the first 3 years of life. In the fourth year they averaged the same, but thereafter the Saginaw Bay

TABLE 9.—*Comparison of average calculated total lengths of yellow perch from several localities*

[Data for sexes combined]

Locality	Average calculated length (in inches) at end of year—										
	1	2	3	4	5	6	7	8	9	10	11
Lake Erie	3.7	6.7	8.5	9.5	10.4	11.0	----	----	----	----	----
Saginaw Bay	3.0	5.3	8.0	9.5	10.7	12.0	12.8	----	----	----	----
Green Bay	2.8	4.6	6.3	7.9	9.0	10.2	11.2	12.3	13.9	----	----
Northwestern Lake Michigan	2.8	4.5	6.0	7.1	8.5	9.7	----	----	----	----	----
Lake of the Woods	3.9	5.4	6.9	8.1	9.2	10.5	11.8	12.9	14.1	15.2	16.6

[7] Data on the Lake Erie yellow perch published by Harkness (1922) are not included in the table because of differences in criteria for recognizing annuli, and his estimated lengths were not computed with reference to the end of years of life. Study of these scales, which he kindly sent to me, failed to reveal any pronounced differences in the rates of growth of yellow perch collected by him in 1920 and of those collected in 1927 and used in the present study.

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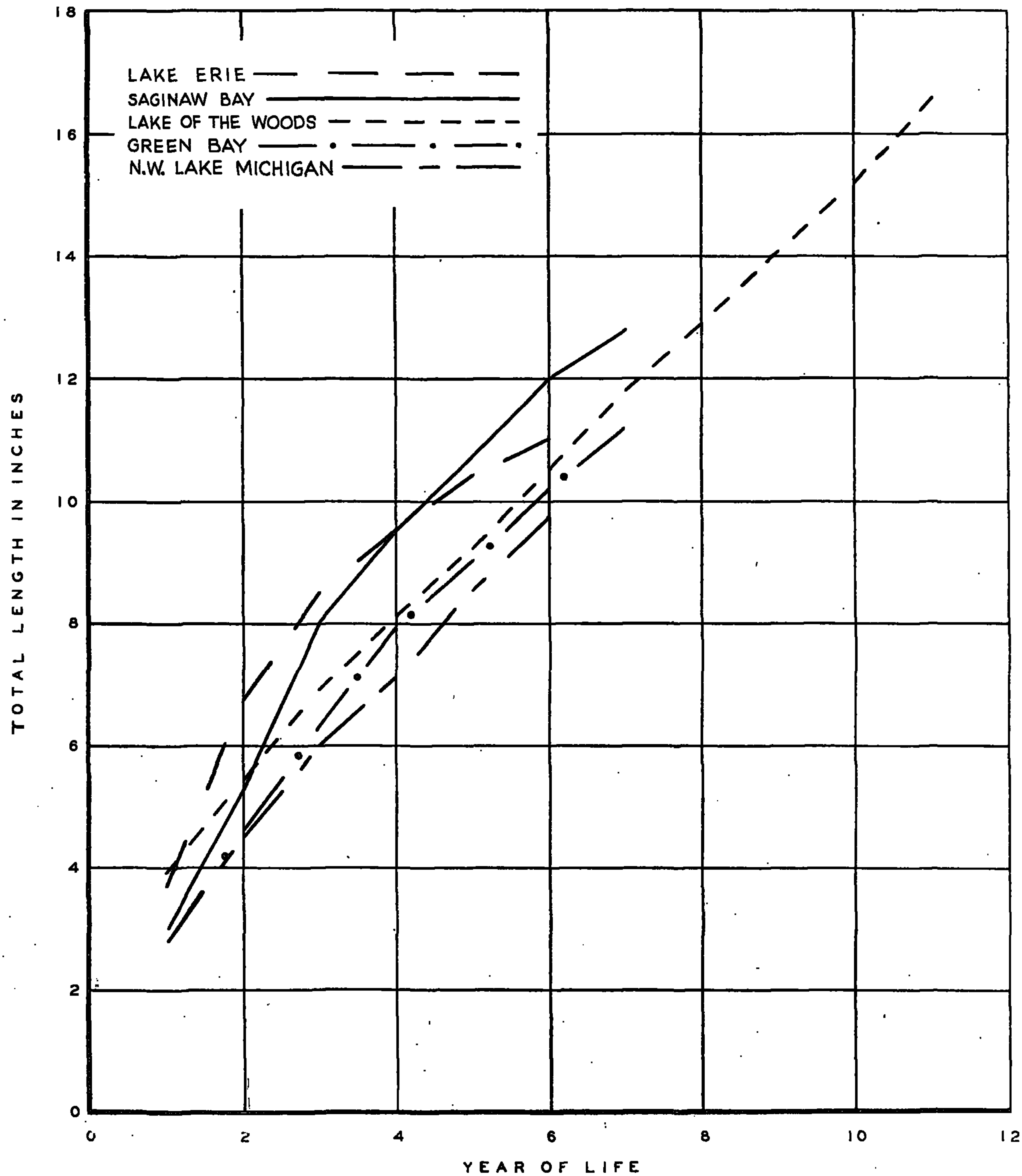

FIGURE 6.—Average calculated total length in inches at end of each year of life of yellow perch from different waters of the Great Lakes and Lake of the Woods. Sexes combined.

fish averaged the larger. There is a striking similarity in the growth curves of the other three populations (fig. 6). The yellow perch from Lake of the Woods averaged about 1 inch longer than those from Green Bay and northwestern Lake Michigan at the end of the first year, and after this year the individuals from northwestern Lake Michigan averaged somewhat shorter than those from the other two areas.

Although each of these growth rates compares favorably with those from other waters, slow growth does occur in the Great Lakes. Van Oosten (1944) reported a sample of yellow perch taken from Presque Isle Bay (Lake Erie) that averaged only 6.7 inches total length as age-group-IV fish. Apparently these slow-growing fish do not frequent Lake Erie proper as none was found among the thousands examined in the course of the present study. The largest yellow perch taken from Lake Ontario by Greeley (1940) had a total length of just more than 6.5 inches in its fifth summer of life.

GROWTH COMPENSATION

Two types of relation between early size and subsequent growth have been observed: (1) That in which the individuals with greater growth in the first year retain or add to that advantage in later growth; and (2) that in which the individuals with greater growth in the first year grow relatively more slowly each subsequent year so that a reduction in range of size occurs. This latter relation is known as growth compensation. No attempt will be made to review the literature on the subject, but it may be stated that the phenomenon of growth compensation has been observed in so many species of fish, both marine and fresh-water, that its occurrence may be considered general.

Age groups II and III of the 1929 collection, both of which contained large numbers of specimens, have been selected for a study of the relation between the first-year length and the later growth in length of the Lake Erie yellow perch. The data have been restricted further to those fish collected late in the autumn, when it could be assumed that the year's growth was complete. Table 10 shows the growth histories of the different yearling-size classes (sexes separately) of each of these age groups.

The first-year difference of 0.99 inch between the average lengths of the largest and smallest group-II males was increased to 1.38 inches in the second year. The maximum difference was reduced by compensatory growth in the third year to 1.05 inches, but nevertheless remained above the original difference. In the group-II females the original 0.94-inch advantage of the largest yearlings over the smallest was increased slightly to 0.97 inch in the second year. The maximum difference was reduced by compensatory growth in the third year to only 0.68 inch.

TABLE 10.—*Relation between calculated length of Lake Erie yellow perch at end of first year and growth in subsequent years, based on 1929 collections of age groups II and III*

Calculated length at end of first year of life	Number of specimens	Length (inches) at end of year—				Increment (inches) for year—			
		1	2	3	4	1	2	3	4
Age group II:									
Males:									
3.35 inches and under	59	3.15	6.24	8.22	----	3.15	3.09	1.98	----
3.36 to 3.82 inches	77	3.58	6.88	8.56	----	3.58	3.30	1.67	----
3.83 inches and over	29	4.14	7.62	9.27	----	4.14	2.58	1.65	----
Maximum difference	----	.99	1.38	1.05	----	----	----	----	----
Females:									
3.35 inches and under	49	3.15	6.28	8.27	----	3.15	3.13	1.99	----
3.36 to 3.82 inches	64	3.58	6.88	8.63	----	3.58	3.30	1.75	----
3.83 inches and over	27	4.09	7.25	8.95	----	4.09	3.16	1.70	----
Maximum difference	----	.94	.97	.68	----	----	----	----	----
Age group III:									
Males:									
3.35 inches and under	40	3.11	5.50	7.48	8.86	3.11	2.39	1.98	1.38
3.36 to 3.82 inches	68	3.58	6.42	8.27	9.27	3.58	2.84	1.85	1.00
3.83 inches and over	70	4.09	7.21	8.81	9.73	4.09	3.12	1.60	.92
Maximum difference	----	.98	1.71	1.33	.87	----	----	----	----
Females:									
3.35 inches and under	40	3.20	5.97	7.99	9.46	3.20	2.77	2.02	1.47
3.36 to 3.82 inches	57	3.63	6.38	8.50	9.73	3.63	2.75	2.12	1.23
3.83 inches and over	58	4.18	7.58	9.32	10.33	4.18	3.40	1.74	1.01
Maximum difference	----	.98	1.61	1.33	.87	----	----	----	----

The relation between first-year length and later growth in length of both sexes of age group III resembled that of the group-II males. The largest yearlings of both the males and females added materially to their first-year advantage over the smallest yearlings during the second year of life. The maximum difference was reduced by compensatory growth during the third year, but remained greater than the original difference. In the fourth year further growth compensation reduced the maximum difference below the first-year value.

It appears to be characteristic of the growth of the Lake Erie yellow perch that a first-year advantage in size is increased in the second year. Growth compensation occurs in the third and fourth years of life.

PROPORTION OF SEASON'S GROWTH COMPLETED AT TIME OF CAPTURE

TABLE 11.—*Increment of growth completed by Lake Erie yellow perch at certain dates in 1927*

Age group and sex	For fish captured— Oct. 24	Oct. 31 to Nov. 21
Season's growth (increment of standard length) to date of capture:	*Mm.*	*Mm.*
Age group I:		
Males	76	80
All fish [1]	75	79
Age group II:		
Females	46	50
Males	38	47
All fish [1]	39	47
Age group III:		
Females	21	28
Males	27	29
All fish [1]	19	29
Proportion of season's growth completed to date of capture:	*Percent*	*Percent*
Age group I:		
Males	95	100
All fish [1]	95	100
Age group II:		
Females	92	100
Males	81	100
All fish [1]	83	100
Age group III:		
Females	75	100
Males	93	100
All fish [1]	66	100
Average (weighted) percentage	88	100
Specimens:	*Number*	*Number*
Age group I:		
Males	28	136
All fish [1]	40	195
Age group II:		
Females	3	46
Males	15	95
All fish [1]	22	170
Age group III:		
Females	2	15
Males	2	21
All fish [1]	8	39

[1] Includes fish whose sex was not determined.

TABLE 12.—*Increment of growth completed by Lake Erie yellow perch at certain dates in 1928*

Age group and sex	For fish captured— July 17 and 23	Aug. 4 and 8	Aug. 23	Sept. 5	Oct. 16 and Nov. 20
Season's growth (increment of standard length) to date of capture:	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
Age group I: All fish [1]			52		74
Age group II:					
Female			26	29	37
Male			20	27	34
All fish [1]	15	18	26	29	37
Age group III:					
Female			20	26	24
Male			20	23	22
All fish [1]	16	21	19	24	24
Proportion of season's growth completed to date of capture:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Age group I: All fish [1]			70		100
Age group II:					
Female			70	78	100
Male			59	79	100
All fish [1]	40	49	70	78	100
Age group III:					
Female			83	108	100
Male			91	104	100
All fish [1]	67	88	79	100	100
Average (weighted) percentage	45	50	71	80	100
Specimens:	*Number*	*Number*	*Number*	*Number*	*Number*
Age group I: All fish [1]			7		4
Age group II:					
Female			104	68	77
Male			40	70	86
All fish [1]	107	151	242	148	184
Age group III:					
Female			2	5	18
Male			3	5	7
All fish [1]	21	5	9	10	25

[1] Includes fish whose sex was not determined.

Although the dates of collection of the Lake Erie yellow perch were not distributed in such a manner as to permit a thoroughgoing study of the progress of growth during the season, scattered data based on samples taken after June 30 do provide a certain amount of information. The calculated increments of growth added in the year of capture and the percentages of these increments of the year's total growth are shown in tables 11, 12, and 13 for three age groups collected in 1927, 1928, and 1929. The growth increments of perch from late-season collections have been considered to represent the total season's growth and hence have been assigned the percentage of 100. The selection of these late-season samples was not arbitrary, but was based on a careful study of the growth increments of fish in the collections of single days. For example, detailed data for 1928 (not given here) demonstrated that the growth increments of perch captured on October 16 were as large as those of fish taken on November 20. It was assumed, therefore, that no growth occurred after October 16 in that year, and consequently the sample of that date was included as part of the "late-season" collection. In 1927, on the other hand, the growth increments of perch captured on October 24 were noticeably smaller than those of fish taken on October 31 and on various dates in November. Accordingly, the October 24 sample was excluded in the computation of the

TABLE 13.—*Increment of growth completed by Lake Erie yellow perch at certain dates in 1929*

Age group and sex	For fish captured—			
	July 1	Aug. 29 and Sept. 5	Sept. 23	Nov. 12 to Dec. 7
Season's growth (increment of standard length) to date of capture:				
Age group I:	*Mm.*	*Mm.*	*Mm.*	*Mm.*
Females	---------	---------	67	64
Males	---------	---------	---------	72
All fish [1]	---------	62	67	70
Age group II:				
Females	9	---------	42	39
Males	8	---------	38	39
All fish [1]	9	41	40	39
Age group III:				
Females	3	---------	26	27
Males	1	---------	21	22
All fish [1]	2	20	24	25
Proportion of season's growth completed to date of capture:				
Age group I:	*Percent*	*Percent*	*Percent*	*Percent*
Females	---------	---------	105	100
Males	---------	---------	---------	100
All fish [1]	---------	89	96	100
Age group II:				
Females	23	---------	108	100
Males	20	---------	97	100
All fish [1]	23	105	102	100
Age group III:				
Females	11	---------	96	100
Males	4	---------	95	100
All fish [1]	8	80	96	100
Average (weighted) percentage	9	90	96	100
Specimens:				
Age group I:	*Number*	*Number*	*Number*	*Number*
Females	---------	---------	1	17
Males	---------	---------	---------	53
All fish [1]	---------	12	1	70
Age group II:				
Females	8	---------	6	140
Males	5	---------	3	168
All fish [1]	13	42	9	308
Age group III:				
Females	96	---------	44	155
Males	35	---------	60	178
All fish [1]	131	64	104	333

[1] Includes fish whose sex was not determined.

full-season increments of growth.[8] Other combinations of collections, as for example, that of the samples of July 17 and 23, 1928, were made only after examination proved the combinations to be warranted.

The data of tables 11, 12, and 13 were presented in considerable detail to bring out the fact that neither sex nor age appeared to affect the course of the season's growth. Females did not show consistently lower or higher percentages than males taken on the same day or days; neither did the percentages vary consistently among samples of different age groups captured on the same dates. It appears valid, therefore, to employ the weighted percentages (given in each table) as measures of the proportion of season's growth completed at different dates.

In order to obtain a more definite idea of the course of growth through the season, the weighted percentages of tables 11, 12, and 13 were plotted as functions of time within the season (fig. 7). The smooth curve appearing in figure 7 was fitted by inspection to the percentages for 1928 and 1929. For reasons to be brought out presently the single percentage available for 1927 (that of growth up to October 24) was held to represent exceptional conditions and was disregarded in the fitting of the curve.

If the curve of figure 7 is accepted as descriptive of the normal course of growth of the yellow perch during the season, the following estimates are obtained:

For month of—	*Percent of total growth end of month*	*Percent of total growth within month*
June	15	15
July	50	35
August	80	30
September	100	20

According to these estimates relatively little growth was completed before July 1 (only 15 percent of the total). The greatest increase in length in a single month occurred in July (35 percent). Growth dropped slightly in August (to 30 percent) and sharply in September (to 20 percent), and appears to have ceased toward the end of September. The small percentage completed on July 1 suggests that growth began some time in June, although it is not possible to be certain on that point.

The preceding description of the course of the growth of the yellow perch during the season must be recognized as merely an approximation since it was based on rather limited and scattered data. The data for 1927 indicate that with exceptional conditions the percentage of total growth completed at different times within the growing season may vary considerably. Perch collected on October 24, 1927, were found to have completed only 88 percent of the estimated total growth for the season. Although the indicated growth of 12 percent of the season's total between October 24 and October 31 does seem to be too high, the data provide evidence, nevertheless, that growth was proceeding actively in October.

[8] Estimates of the progress of growth during the season of capture made by Hile, for the cisco (1936) and for the rock bass (1941) in the lakes of northeastern Wisconsin, were based on comparisons of the growth increments up to the time of capture with the full-season growth as calculated from samples of the same year class in collections of later years. The severe discrepancies between the calculated growth histories of different age groups of the same year class of the Lake Erie yellow perch prohibit the use of the same procedure in the present study.

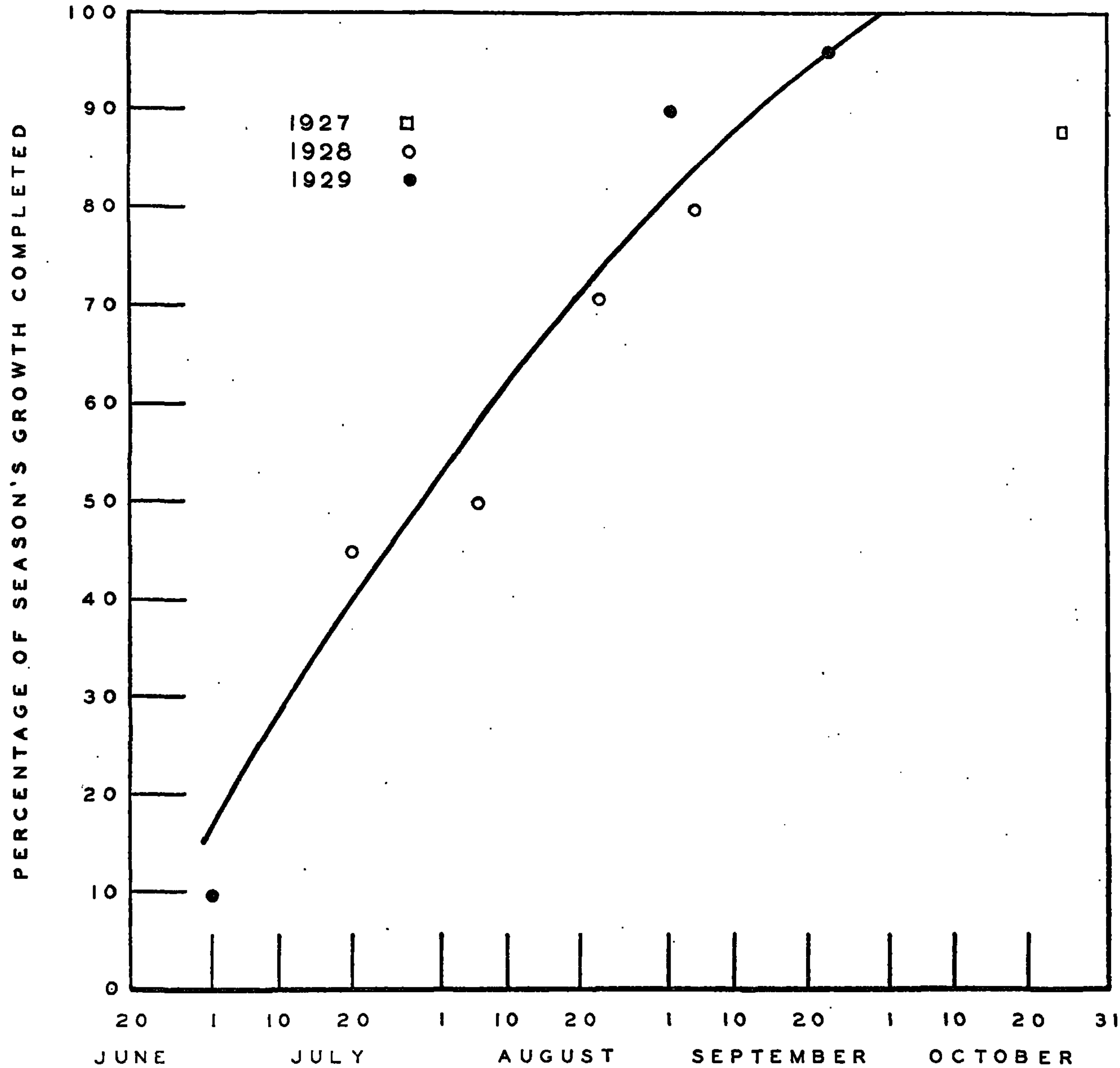

FIGURE 7.—Percentage of season's growth completed at different dates by Lake Erie yellow perch. Curve fitted to 1928–29 data by inspection.

Exceptional conditions may be expected also to affect the course of growth in the early season (earlier onset or more rapid early-season increase in some years).

ANNUAL FLUCTUATIONS IN GROWTH

Data are available for the analysis of fluctuations in the growth of the yellow perch taken by impounding nets in Lake Erie in the two periods, 1927–29 and 1943–48. Although the annual increments of growth in the years 1924–29 were computed from samples of the entire take by the nets, whereas the growth in 1940–48 was determined only from the legal-sized fish (8½ inches and larger), the average annual increments did not differ greatly. The fluctuations in growth were determined separately for each period and represent deviations from the average of the period to

TABLE 14.—*Calculated annual growth increments according to calendar year and year of life of Lake Erie yellow perch taken by impounding net, 1927–29*

[Data for sexes shown separately]

Year of life	Calculated growth increments (inches) in—					
	1924	1925	1926	1927	1928	1929
Males:						
Age group III:						
Fourth year				1.2	0.9	0.9
Third year			1.9	1.9	1.8	
Second year		2.3	2.6	2.9		
First year	3.6	3.6	3.8			
Age group II:						
Third year				2.1	1.4	1.7
Second year			2.7	3.3	3.2	
First year		3.6	3.8	3.6		
Females:						
Age group III:						
Fourth year				1.2	1.0	0.9
Third year			1.9	2.3	2.0	
Second year		2.4	2.7	3.0		
First year	3.7	3.5	3.8			
Age group II:						
Third year				2.3	1.3	1.7
Second year			2.9	3.4	3.2	
First year		3.5	3.8	3.6		

which the individual years belong. The analysis has been confined to the growth of age groups II and III since other age groups contained too few fish to give reliable averages in all years.

The calculated annual increments of age groups II and III taken in 1927–29 are shown for each sex in table 14 and those for the fish taken in 1943–48 are given in table 15. The data in both tables are arranged so that the horizontal rows show the growth in different calendar years of fish in the same year of life. The vertical columns show the growth in a single calendar year of fish in different years of life. The growth histories of the individual age groups are shown in rows running diagonally from the bottom to the right.

The method of estimating annual fluctuations in growth may be illustrated by the 1925 and 1926 data for the females in table 14. The 1926

TABLE 15.—*Calculated annual growth increments according to calendar year and year of life of Lake Erie yellow perch taken by impounding net, 1943–48*

[Data for sexes combined]

Year of life	Calculated growth increments (inches) in—								
	1940	1941	1942	1943	1944	1945	1946	1947	1948
Age group III:									
Fourth year				1.2	1.3	1.1	1.1	1.3	1.4
Third year			2.1	1.6	1.9	1.6	2.0	1.7	
Second year		2.4	2.5	2.8	3.1	2.5	2.4		
First year	3.7	3.9	3.6	3.9	3.5	3.8			
Age group II:									
Third year				1.8	1.9	1.9	2.1	1.9	2.4
Second year			3.1	3.4	3.3	3.3	3.6	3.0	
First year		4.1	3.9	3.7	3.8	3.5	3.8		

growths of 2.7, 3.8, and 3.8 inches of age group III in the first and second years of life and of age group II in the first year of life totaled 10.3 inches or 0.9 inch more than the total (9.4) of the corresponding increments in 1925 (2.4, 3.5, and 3.5). The average of the two totals is 9.85 inches. Compared with this average, the total growths in 1926 showed an improvement of 9.1 percent. A continuation of this procedure shows the percentage change in growth from each year to the next. The position of each year's growth with respect to that of 1924 is obtained by the successive addition of the percentages of change. For example, the growth of the group-III females decreased 5.6 percent from 1924 to 1925 as determined by this method of computation, but as indicated above, that of the group-II and group-III females increased 9.1 percent from 1925 to 1926. Hence, the growth in 1926 may be said to have been $-5.6+9.1$, or 3.5 percent better than in 1924. In order to make the percentage deviations describe the changes with respect to average growth over the period 1924–29, rather than only to growth in 1924, the mean of the deviations as computed by the above procedure was subtracted from the individual deviation of each year. The same procedure was used to determine the annual fluctuations in growth in 1940 to 1948 (table 15). The method just described for obtaining the percentage deviations from average growth is that employed by Hile (1941) to determine the annual fluctuations in growth of the Nebish Lake (Wisconsin) rock bass.

The annual percentage deviations of the growth of the Lake Erie perch from the 1924–29 and 1940–48 means are shown in table 16 for the sexes separately, where possible, and for the sexes combined. Particularly noteworthy is the very close agreement between the percentage deviations of the sexes. The coefficient of correlation between the annual deviations in the growth of the sexes has the high value of 0.959. This close correlation may be construed as a strong argument for the reliability of the percentages in table 16 as true measures of the annual fluctuations in growth.

The annual variations in the growth of the Lake Erie yellow perch were fairly large. The ranges for the percentages in the period 1924–29 were 23.2 percent for the females, 15.2 percent for the males, and 18.3 percent for the sexes combined. The range in the percentage variation of the sexes

TABLE 16.—*Deviations in growth rate of Lake Erie yellow perch and in mean air temperatures at Sandusky, Ohio, from 1924–29 and 1940–48 averages*

Year	Deviation from average growth			Deviations of mean temperatures					
	Male	Female	Average	May	June	July	August	September	October
	Percent	*Percent*	*Percent*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
1924	−4.8	−10.2	−7.5	−3.9	−0.7	−1.9	0.3	−4.5	3.0
1925	−4.8	−4.6	−4.7	−1.6	5.5	−1.1	.6	3.3	−8.3
1926	2.3	4.5	3.4	1.8	−1.5	.0	2.8	.1	−1.4
1927	8.5	13.0	10.8	1.2	−1.9	.2	−4.2	3.3	4.4
1928	−6.7	−7.4	−7.0	2.1	−2.1	2.1	2.8	−2.6	3.6
1929	5.5	4.8	5.2	.6	.5	.6	−2.1	.3	−1.0
1940			−3.1	−2.0	.2	1.1	−.3	−2.5	−.9
1941			2.2	4.4	1.0	1.3	−.9	2.9	2.2
1942			−1.7	3.0	.4	1.1	−.9	−1.3	−.1
1943			−.4	−.4	4.0	.8	.1	−3.3	−2.4
1944			1.8	5.4	2.8	.5	1.5	−.1	−1.5
1945			−4.2	−5.0	−2.8	−2.1	−.1	1.1	−2.3
1946			3.4	−1.0	−1.0	−.7	−4.1	.7	3.5
1947			−7.4	−2.9	−3.2	−2.5	4.7	.8	6.5
1948			9.7	−1.9	−1.4	.6	−.3	1.7	−4.7
Correlation (r) between growth and temperature (sexes combined)				.346	−.030	.347	−.605	.504	−.117

combined during the 1940–48 period was 17.1 or a little less than in the 1924–29 period. Growth was below average in 1924 but improved each year until the maximum was reached in 1927. The sharp decline in 1928 was followed by an improvement in 1929. Growth in 1940 was below the average for the period 1940–48. The increase in 1941 was followed by a 3-year period in which the growth fluctuated but little; the variations were greater in 1945–48. The poorest growth in the 1940–48 period was in 1947 and the best in 1948.

Neither a detailed discussion of all the probable factors that contributed to the annual fluctuations observed in the growth of the Lake Erie yellow perch nor a review of the literature on fluctuations in the growth of fish seems desirable. It may be stated, however, that chief among the factors that previous investigators found associated with annual fluctuations in growth rate were changes in the density of the population and fluctuations in weather conditions (temperature and precipitation).[9]

It is not possible to state definitely whether fluctuations in the density of the yellow-perch population affected the growth of the species in Lake Erie. Three years in which growth was above average (1926, 1927, and 1929) and a year of poor growth (1928) occurred when members of the strong year class of 1926 were abundant. This situation suggests that fluctuations in the density of the population may have little or no effect on the growth rate of the Lake Erie perch.

In the study of the relation between meteorological conditions and the growth rate of the Lake Erie yellow perch, detailed records of rainfall, the percentage of possible sunshine, mean wind velocity, and temperature were consulted. Preliminary analyses of the data demonstrated that no correlation existed between growth rate and the first three of the meteorological factors. Seemingly, variations in the amount of sunshine did not affect the production of food sufficiently to influence the growth of the perch. The influence of rainfall which would affect turbidity and the chemical content of the water, and of variation in wind velocity which would affect turbidity, appeared to be too small to detect, or was obscured by other factors.

Investigation of the relation between annual fluctuations in temperature and in the growth rate of the Lake Erie yellow perch yielded suggestive results. The annual deviations of the air temperatures at Sandusky, Ohio,[10] from the 1924–29 and 1940–48 averages in each month from May to October, and the coefficients of correlation between the annual deviations of growth and of temperature in each month are shown in table 16. Included in the table are data not only for the four months, June through September, that were held to constitute the normal growing season (p. 231), but also for May and October. Evidence was brought out that under exceptional conditions growth may continue through October (p. 230), and it is believed possible that temperatures in May can

[9] Hile (1936) and Van Oosten (1944) have reviewed the literature on the causes of fluctuations in the growth rate of fish.

[10] These data on air temperatures were taken from Climatological Data of the United States by Sections, Weather Bureau, U. S. Department of Agriculture.

affect the time at which the season's growth begins. It is recognized that air temperatures do not provide an exact measure of water temperatures, but air temperatures averaging exceptionally high or low over the period of a month probably have a significant effect on the average water temperatures, especially in such shallow water as in western Lake Erie. Doan (1942) concluded that either air or water temperatures may be used to indicate monthly variations from normal, as the two fluctuate similarly.

Of the six coefficients of correlation between annual fluctuations in growth rate and in the air temperatures of individual months listed in table 16, only that for August ($r=-0.605$) may be termed "significant" ($r=\pm 0.514$ when $p=0.05$). The coefficient for September ($r=0.504$) fell just short of the significant value and those for July ($r=0.347$) and May ($r=0.346$), though moderately high were far from significant. The extremely low values for October ($r=-0.117$) and June ($r=-0.030$) offer not the slightest suggestion of any correlation between annual fluctuations in growth rate and temperatures in those months.

Even if temperature were known to be a major factor in the determination of annual fluctuations in growth rate, high correlations between growth and temperature in individual months could hardly be anticipated, since, as has been demonstrated previously, the growing season of the Lake Erie perch includes all or part of several months. It was with this in mind that the following coefficients of correlation (r) were computed between annual fluctuations in growth and the combined temperatures for several groupings of months:

May to October (inclusive)	−0.124
June to September (inclusive)	.036
May and June	.218
May, June, and July	.268
May, June, and September	.416
May, June, and October	.104
May, June, September, and October	.352
May and July	.371
May, July, and September	.562
May and September	.550
May and October	.116
May, September, and October	.327
June, July, and August	−.289
June and August	−.461
June, August, and October	−.537
June and September	.328
June and October	−.176
June, September, and October	.202
July and August	−.384
July, August, and September	−.289
July and September	.651
August and October	−.420
September and October	.180

A detailed discussion is unnecessary, but attention is called to the following points:

1. There is no evidence of correlation between annual fluctuations in growth rate and in temperature during the season as a whole. The coefficients for the 6- and 4-month periods May-October and June-September were both low (−0.124 and 0.036).

2. Combinations of data for the 3 months, May, July, and September, which exhibited positive though statistically insignificant correlations of temperature and growth yielded evidence that a real correlation may exist. The coefficient for the three months combined was 0.562, and both of the groupings of two that included September—May and September ($r=0.550$), and July and September ($r=0.651$)—also showed significant positive correlation between temperature and growth. Only the coefficient for May and July ($r=0.371$) was below the significant value. It is to be noted also that the combinations of still other months with any of these three, or groupings of them, diminished the correlation below the significant level.

3. The negative coefficient of correlation between annual fluctuations in growth and the combined temperatures during the three months, June, August, and October, that exhibited negative values individually was significant ($r=-0.537$) but was less than the figure for August alone ($r=-0.605$). Furthermore, not one of the coefficients for the three pairings of these months—June and August ($r=0.461$), June and October ($r=-0.176$), and August and October ($r=-0.420$)—was significant. This behavior of the data suggests that any true negative correlation between growth and temperature during the growing seasons probably holds for August alone.

Inasmuch as earlier investigations have demonstrated that correlations among meteorological factors themselves can obscure true relations between those factors and growth (Hile 1941) or even render the data highly ambiguous (Van Oosten and Hile 1949), the possibility of similar interference was checked in the present data. This work was carried out with special reference to the relation between the annual fluctuations of temperatures in June and in August and those of other months.

The lack of correlation between June temperatures and growth appears to be somewhat anomalous in view of the evidence of a positive correlation between growth and temperatures in May and July. Since the absolute temperature in June normally is intermediate between those of May and July a similar relation would be expected for all 3 months. The coefficients of correlation between temperatures in June and those in certain other months listed below are too small, however, to support any belief that a true relation between growth and June temperatures has been concealed by correlations with temperatures of other periods of the growing season.

Between June temperature and temperature in—	Correlation
May and July	0.291
May and September	.214
May, July, and September	.246
July and September	.124
August	.083

The high negative value of *r* for growth and August temperatures cannot be termed anomalous since water temperatures reach their maximum in that month in most years[11] and the concept that a high maximum might exert a depressing effect on growth is not unreasonable. It was considered desirable, nevertheless, to determine the possible effects on the interpretation of the data of correlations between August temperatures and those of months that exhibited significant positive correlations between temperature and growth. The following coefficients, including one for May and July in which temperature was not correlated significantly with growth, were computed.

Between August temperature and temperature in—	Correlation
May and July	−0.086
May and September	−.186
July and September	−.339
May, July, and September	−.205

Again none of the correlations between temperatures in different periods was sufficiently close to conceal possible relations.

The data presented in this section may be taken as strong evidence that temperatures exert a significant effect on the annual fluctuations in growth of the yellow perch in Lake Erie, with high temperatures in May, July, and September (especially September) accelerating growth, and high temperatures in August retarding it.

Any attempt at a biological interpretation of the observed correlations would, with our present knowledge, be of little value. Conceivably, temperatures may affect growth directly, as through the control of the instantaneous rate of increase or of the length of the growing season, or indirectly, as through the control of the distribution or abundance of food organisms. Until more is learned of the natural history of the perch, the mechanism of the apparently significant correlation between growth and temperature must remain unknown.

[11] This statement is supported by records of Lake Erie water temperatures at the intake of the Chestnut Street Water Plant at Erie, Pa. (published in the Annual Reports of the Commissioner of Water Works of that city). According to those records the maximum monthly average water temperature occurred in August in 23 of the 25 years, 1923–47; furthermore, August temperatures of the period averaged 2.3° and 3.7° F. higher than those of July and September. The crib of the intake is located 5,100 feet north of the Presque Isle Peninsula and is covered by 22 feet of water at low-water level. Although Erie is located well to the east of the centers of greatest abundance of the yellow perch, water temperatures off that port may be taken to indicate monthly trends.

LENGTH-FREQUENCY DISTRIBUTION

The catches of impounding nets and gill nets differed in the actual form of the frequency distribution as well as in the size of fish taken (table 17). The length distribution of yellow perch caught in trap nets and pound nets was unimodal each year. The shoal-net collections, on the other hand, showed definite bimodal length distributions for 1927 and 1929, but gave no indication of bimodality in 1928. The fairly large number of small perch taken by the shoal nets during 1927 is probably explained by the presence of the abundant year class of 1926, then in their second year of life (age group I). The bimodal length distribution of the bull-net samples in 1927 was the result of the accidental capture of a large school of small fish on a single day. These smaller individuals ordinarily were not gilled in the true sense, but rather, were captured by tangling the webbing of the net in the marginal bones of the mouth or in the fins.

It will be noticed that there was considerable annual variation in the length of the modal fre-

TABLE 17.—*Length frequencies of Lake Erie yellow perch by year of capture and type of gear*

[An asterisk designates the modal interval in each frequency distribution]

Standard-length interval	Total length equivalent to midpoint	Taken by impounding nets								Taken by shoal gill nets [1]				Taken by bull gill nets [2]			
		1927	1928	1929	1930	1931	1932	1937	Total	1927	1928	1929	Total	1927	1928	1929	Total
	Inches																
41 to 50 mm	2.2										1		1				
51 to 60 mm	2.7										2		2				
81 to 90 mm	4.0											2	2				
91 to 100 mm	4.5			1					1	1		5	6		1		1
101 to 110 mm	5.0	4	1	31					36	9	1	13	23	4			4
111 to 120 mm	5.4	21	5	73	7				106	37	1	8	46	27	1		28
121 to 130 mm	5.9	46	19	61	40	14			180	64		5	69	*49			49
131 to 140 mm	6.3	108	94	108	158	108	1		577	49	4	4	57	35	1		36
141 to 150 mm	6.7	272	477	291	529	568	3	3	2,143	47	15	1	63	17	9	1	27
151 to 160 mm	7.2	380	1,143	553	1,016	1,167	1	10	4,270	26	11	1	38	4	14		18
161 to 170 mm	7.6	495	*1,531	1,021	*1,541	2,508	10	24	7,130	14	30	4	48	1	30	3	34
171 to 180 mm	8.1	*509	1,090	1,692	1,364	4,524	28	*35	9,242	13	84	27	124	3	40	5	48
181 to 190 mm	8.6	414	612	2,553	1,126	*4,963	*46	24	*9,738	31	241	165	437	6	79	15	100
191 to 200 mm	9.0	375	411	*2,632	759	3,608	27	19	7,831	130	708	987	1,825	13	136	78	227
201 to 210 mm	9.4	317	253	1,765	376	1,399	10	6	4,126	397	*866	*1,750	*3,013	40	*173	252	465
211 to 220 mm	9.9	164	98	775	121	381	6	6	1,551	*545	529	1,214	2,288	36	130	*300	*466
221 to 230 mm	10.3	82	29	263	44	103		4	525	237	200	443	880	16	46	150	212
231 to 240 mm	10.7	16	14	83	22	29	1		165	51	47	88	186	3	16	30	49
241 to 250 mm	11.2	17	2	28	10	8			65	16	12	24	52	1	4	4	9
251 to 260 mm	11.6	3	3	3	4	4			17	2	2	3	7	1	1		2
261 to 270 mm	12.1		2	2	1	3			8								
271 to 280 mm	12.5					1			1								
281 to 290 mm	13.0			4		3			7	1			1	1			1
291 to 300 mm	13.4		1						1								
301 to 310 mm	13.9	1							1								
Total		3,224	5,785	11,939	7,118	19,391	133	131	47,721	1,670	2,754	4,744	9,168	257	681	838	1,776
Average standard length (mm.)		177	170	187	174	182	186	181	180	201	203	207	205	167	200	212	201
Average total length (inches)		8.17	7.85	8.64	8.04	8.41	8.59	8.36	8.32	9.22	9.32	9.50	9.41	7.72	9.18	9.73	9.22
Percentage illegal (less than 8½ inches)		61.1	78.8	38.1	69.8	53.4	43.6	61.1	55.6	15.9	7.4	2.0	6.2	54.9	17.0	1.4	15.1

[1] Gill nets 22 meshes deep.

[2] Gill nets 100 meshes deep.

quency group in each gear. The modal frequency intervals of perch caught in impounding nets varied from 161–170 mm. (7.6 inches total length) in 1928 and 1930 to 191–200 mm. (9.0 inches total length) in 1929, or over a range of 30 mm. (1.4 inches). Annual fluctuations in the percentage occurrence of individuals in the several length intervals of the trap-net and pound-net catches of 1927–29, inclusive, are shown graphically in figure 8, which includes only the length range over which the representation was continuous. The years 1927 to 1929 were selected for graphic presentation because the year class of 1926 dominated the collections for each of those three years. The mode of the 1927 specimens caught in impounding nets was at a length 10 mm. greater than the mode of the 1928 collections. Since collections of both years were dominated by fish of the 1926 year class, one would expect the length of the modal frequency in 1928 to be greater than that in 1927. However, this discrepancy can be explained readily. It may be seen in table 21 that two age groups were well represented in the 1927 collections; age group I made up 48.9 percent and age group II made up 39.9 percent of the total. The 1928 collections were made up almost entirely (90.6 percent) of group-II fish. Approximately 95 percent of the 1927 specimens were taken in October and November whereas some 72 percent of the 1928 individuals were taken by the end of June. Thus, the 1926 year class (group I of 1927), had only a small part of a growing season in which to increase their lengths before the 1928 collections (in which the year class appeared as age group II) were made. Furthermore, the occurrence of large numbers of group-II fish in 1927 caused the length at maximum abundance in the combined collections of that year to be greater than that of the dominant age group (see table 19). Thus, the reduced abundance of fish older than the 1926 year class in 1928 and the short period of time intervening between the dates of collection of the 1927 and 1928 samples no doubt account for the shorter modal length in 1928.

The large modal length in 1929 may be attributed in great measure to the dominant 1926 year class which had completed approximately 2 full years' growth subsequent to the collection of the 1927 material. Even so, the length of the modal frequency in 1929 was somewhat less than the modal length of the 1926 year class (age group III) in that year because of the strong representation of the 1927 year class (age group II). In general, the position of the modal frequency each year can

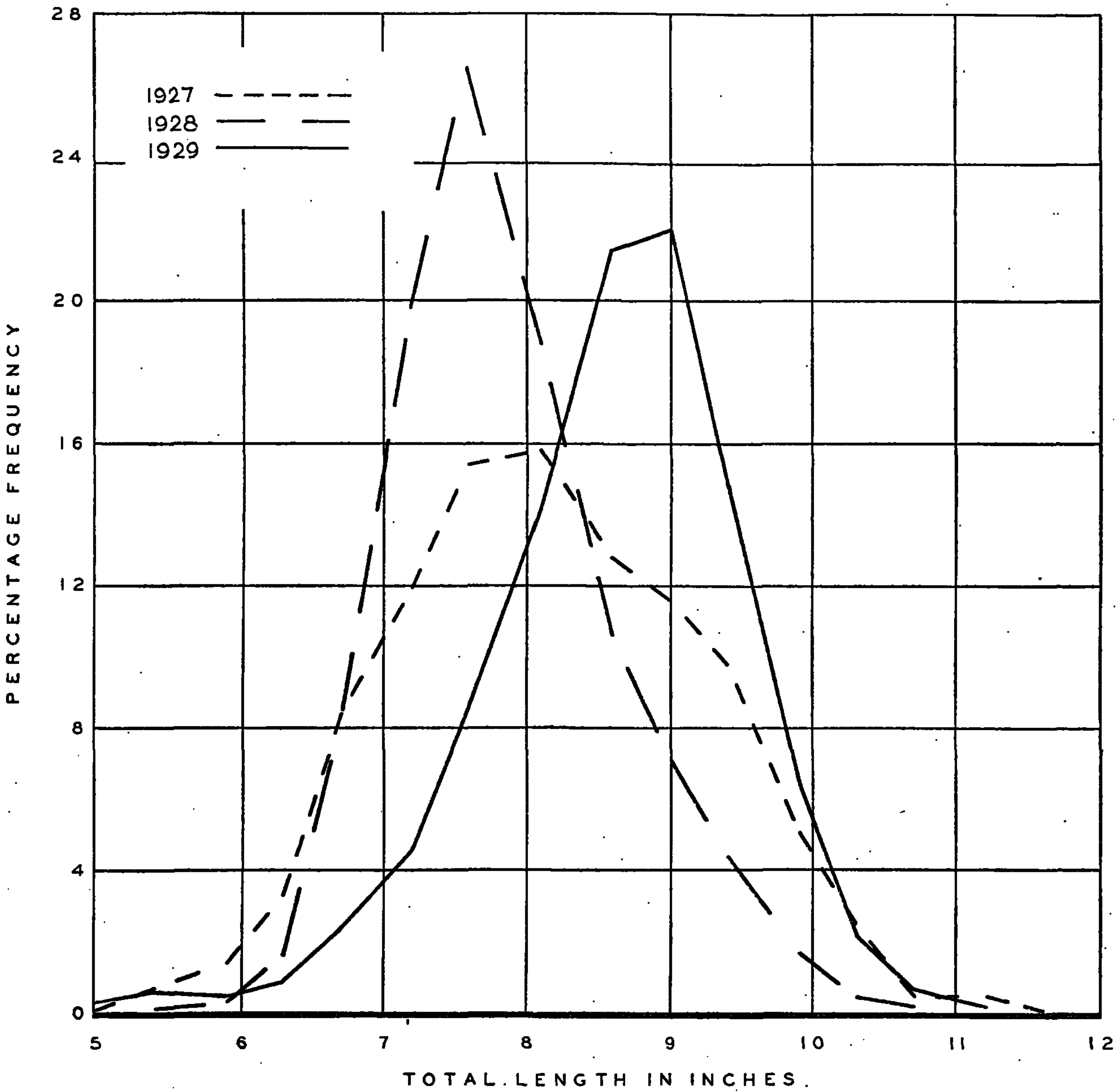

FIGURE 8.—Percentage frequency distribution of total length of Lake Erie yellow perch in 1927, 1928, and 1929 collections from impounding nets. Curves extend only over length range where representation was continuous.

be explained by the known age composition of the stock and the time of year when the collections were obtained. A similar explanation may account for the shifts in the modal frequency of the years 1930 to 1932 and 1937.

The gill-net collections showed trends in the annual fluctuation of the length at maximum abundance similar to those of the impounding nets, but the total range of variation of the length of the modal frequencies of the fish actually gilled was reduced. The modal frequency interval of the shoal-net samples varied only from 201–210 mm. (9.4 inches total length) in 1928 and 1929 to 211–220 mm. (9.9 inches total length) in 1927, or extended over a range of 10 mm. as compared with a range of 30 mm. in impounding-net samples. The modes of the yellow perch actually gilled by the bull net were at the 201–210 mm. (9.4 inches total length) interval in 1927 and 1928, and at the 211–220 mm. (9.9 inches total length) level in

1929. The reduction in the annual fluctuation of the position of the modal length intervals of the gilled fish in the gill-net collections as compared with the impounding-net samples can be ascribed to the greater selectivity of gill nets.

The lengths of the modal frequencies of fish gilled in both shoal and bull nets were without exception greater than those of fish caught in impounding nets in the same year. The general differences between the length distribution of the fish from impounding, shoal, and bull nets (all collections combined) are shown graphically in figure 9. The curves are based on the totals of table 17, expressed as percentage frequencies. The graph includes only the length range over which representation was continuous. As mentioned in the preceding paragraph, the much more compact distributions and the greater average size of perch in the gill-net collections may be attributed to net selectivity. The occurrence of small

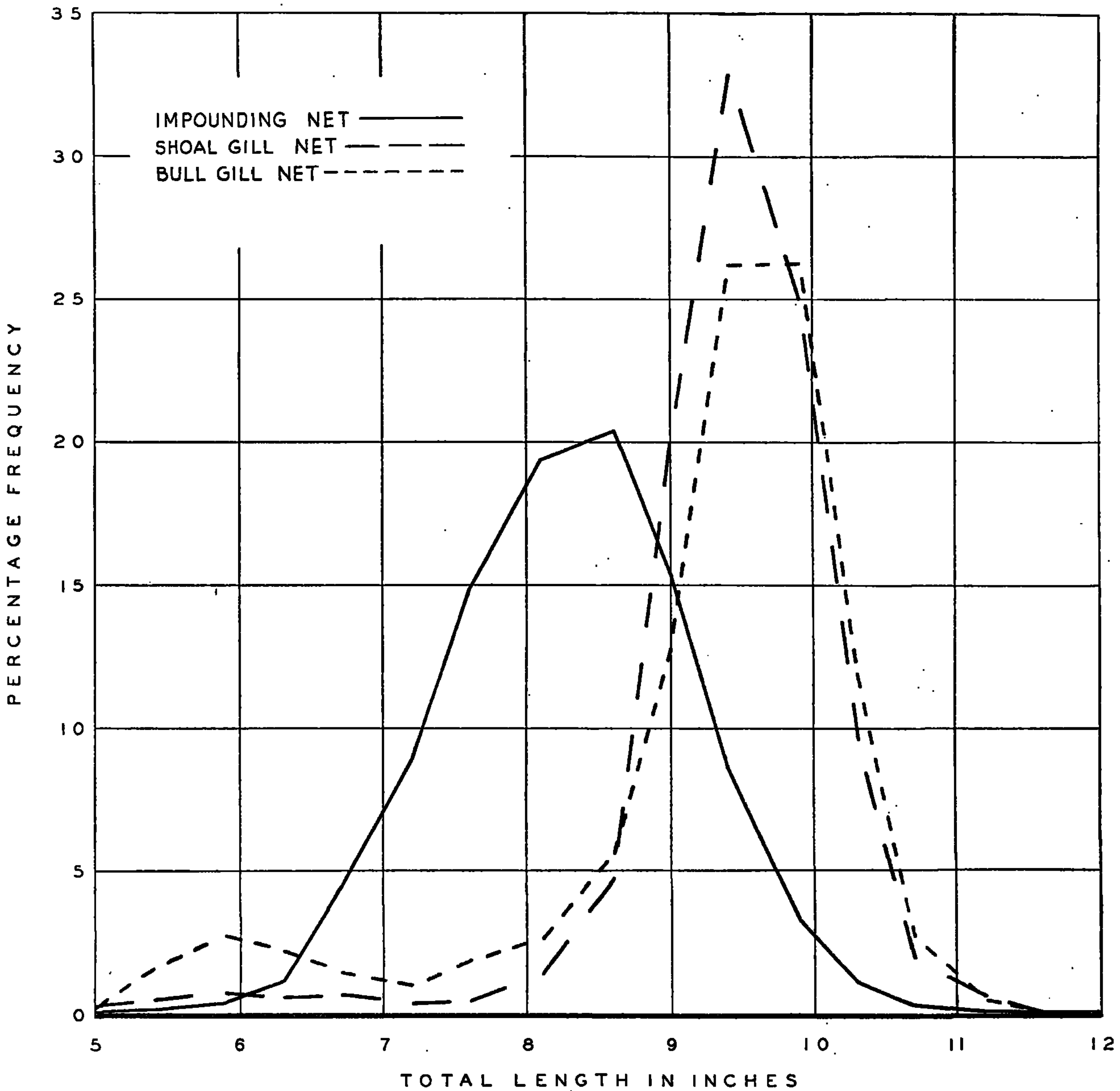

FIGURE 9.—Percentage frequency distribution of total lengths of Lake Erie yellow perch in collections from each kind of gear. Curves extend only over length range where representation was continuous.

perch in the gill-net collections does not represent gilling but, as stated earlier, is the result of the entanglement of the marginal bones of the mouth or of the fins in the gill-net webbing.

The occurrence of illegal-sized yellow perch in impounding-net samples (table 17) varied from a maximum of 78.8 percent in 1928 when the collections were dominated by the 1926 year class as age group II to a minimum of 38.1 percent in 1929 when the same year class was dominant as age group III. Had the computation for 1928 been made on the basis of the then-effective size limit of 9 inches instead of the current 8½ inches, the proportion of undersized yellow perch would have been even greater—89.6 percent. The 1927 collection which was dominated by the 1926 year class as age group I nevertheless had relatively fewer illegal-sized yellow perch (61.1 percent computed from a size limit of 8½ inches and 76.2 percent from a size limit of 9 inches) than the 1928 collection. An explanation of this discrepancy was given on page 237. Perch under the legal size limit were in the minority in the impounding-net samples in only 2 of 7 years (1929 and 1932). The percentage of undersized perch in the collections of all years combined, computed from a size limit of 8½ inches, was 55.6.

Illegal-sized yellow perch were relatively much less abundant in the gill-net than in the impounding-net catches, except in the 1927 bull-net samples which contained a high proportion of small, accidentally captured fish. Undersized individuals in shoal-net samples varied from a maximum of 15.9 percent in 1927 to a minimum of 2 percent in 1929 and amounted to 6.2 percent for the 3 years' collections combined. Computed from the then-effective size limit of 9 inches, the 1927 and 1928 percentages would have been higher—20.3 and 23.4. The percentages of undersized yellow perch in bull nets were 54.9 in 1927, 17.0 in 1928, and 1.4 in 1929. On the basis of the then-effective size limit of 9 inches these would have been increased to 59.1 and 33.2 percent in 1927 and 1928. For all years combined the percentage of illegal-sized yellow perch in the bull nets was 15.1 as compared with 6.2 in the shoal-net collections. The percentage of illegal-sized fish in all gill nets was 7.6.

The proportion of illegal-sized yellow perch in gill-net catches provides a fairly precise measure of the destruction of undersized individuals by this type of gear, as practically all individuals are dead at capture or are killed in the process of removal from the nets. It should be noted, however, that on the average the percentage of undersized fish in gill-net samples usually fell well below Ohio's legal allowance of 10 percent in the commercial catch, especially since the allowance is based on weight rather than on numbers of fish.

The destruction of illegal-sized yellow perch can be determined less accurately for impounding nets than for gill nets because the trap-net and pound-net fishermen are required to return all illegal-sized fish to the water. It is relatively certain that an unknown portion of these fish die as the result of handling. It is known that on the average 14 percent of the illegal-sized perch taken by Lake Erie trap nets are dead at the time of lifting. (See footnote 5, p. 221.) Since 55.6 percent of the yellow perch from impounding nets were undersized, it may be computed that for every 1,000 yellow perch taken, 76 illegal-sized fish were destroyed. This value was well below the 151 determined for bull nets but was above the 62 for shoal nets, and equaled the 76 from all gill nets. However, the computed number of illegal-sized yellow perch destroyed by impounding nets must be considered as the minimum since it does not include those fish that are killed during the sorting of the catch to conform to the legal-size limit. Further, impounding nets took many more fish during the year than did the gill nets and therefore destroyed many more individuals. The data seem to offer good support to Van Oosten's (1936) conclusion that more fish are destroyed by trap nets than by gill nets.

The importance of the destruction of small yellow perch by trap nets is emphasized when it is remembered that in recent years this gear has accounted for approximately 61 percent of all perch taken in the United States waters of Lake Erie (65 percent of those taken in Ohio waters).[12]

Table 18 contains a summary of the length frequencies (total lengths) by half-inch intervals, the percentage frequencies, and the cumulative percentages for Lake Erie yellow perch taken in different types of gear, with all years' collections combined. Practical considerations make such

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[12] Percentages were computed from data for the calendar years 1930, 1931, 1932, 1934, 1936, 1937, and 1938 contained in the former U. S. Bureau of Fisheries publication, "Fisheries Industries of the United States," Report of the Commissioner of Fisheries, for 1931, 1932, 1933, 1935, 1937, 1938, and 1939.

TABLE 18.—*Length frequencies of Lake Erie yellow perch taken in different types of gear*

[Collections of all years combined]

Total-length interval [1]	Trap and pound nets			Shoal gill nets			Bull gill nets		
	Number of specimens	Percentage	Cumulative percentage	Number of specimens	Percentage	Cumulative percentage	Number of specimens	Percentage	Cumulative percentage
2.0 to 2.5 inches				1	0.01	0.01			
2.5 to 3.0 inches				2	.02	.03			
3.0 to 3.5 inches						.03			
3.5 to 4.0 inches						.03			
4.0 to 4.5 inches	1	(2)	(2)	4	.04	.07			
4.5 to 5.0 inches	7	0.01	0.01	14	.15	.22	2	0.11	0.11
5.0 to 5.5 inches	98	.21	.22	46	.50	.72	18	1.01	1.12
5.5 to 6.0 inches	130	.27	.49	54	.59	1.31	40	2.25	3.37
6.0 to 6.5 inches	664	1.39	1.88	85	.93	2.24	51	2.87	6.24
6.5 to 7.0 inches	1,872	3.92	5.80	57	.62	2.86	33	1.86	8.10
7.0 to 7.5 inches	5,182	10.86	16.66	48	.52	3.38	22	1.24	9.34
7.5 to 8.0 inches	8,109	16.99	33.65	62	.68	4.06	40	2.25	11.59
8.0 to 8.5 inches	10,473	21.95	55.60	194	2.12	6.18	63	3.55	15.14
8.5 to 9.0 inches	11,346	23.78	79.38	1,004	10.95	17.13	156	8.78	23.92
9.0 to 9.5 inches	6,189	12.97	92.35	2,947	32.14	49.27	399	22.47	46.39
9.5 to 10.0 inches	2,634	5.52	97.87	3,156	34.42	83.69	594	33.45	79.84
10.0 to 10.5 inches	751	1.57	99.44	1,248	13.61	97.30	297	16.72	96.56
10.5 to 11.0 inches	174	.36	99.80	193	2.11	99.41	50	2.82	99.38
11.0 to 11.5 inches	65	.14	99.94	50	.56	99.97	8	.45	99.83
11.5 to 12.0 inches	11	.02	99.96	2	.02	99.99	2	.11	99.94
12.0 to 12.5 inches	6	.01	99.97			99.99			
12.5 to 13.0 inches	3	.01	99.98			99.99			
13.0 to 13.5 inches	4	.01	99.99	1	.01	100.00	1	.06	100.00
13.5 to 14.0 inches	2	(2)	100.00						

[1] Each ½-inch interval contains lengths up to but not including the greater value.
[2] Specimens occurred in the samples but made up less than 0.005 percent of the total.

a tabulation desirable since legal-size limits for yellow perch are expressed in terms of the total length in inches. It may be seen at a glance, for example, that with a size limit of 8½ inches, 55.6 percent of the yellow perch taken in trap nets were under legal length, whereas 79.38 percent were undersized with a 9-inch limit; or it may be seen that almost 98 percent of the yellow perch in trap-net catches were less than 10 inches long. The tabulation also permits ready comparisons of the catches by different types of gear.

The length distributions by age for impounding-net samples are shown in table 19. The collections of 1930, 1932, and 1937 are omitted from the table because the number of specimens whose ages were determined was too small in each of those years to give reliable results. The length range of fish of the same age did not vary greatly in the better-represented age groups during the 3 years 1927 to 1929. The range in length of the age groups was sufficiently great to cause considerable overlapping between these groups. Because of this overlap, length cannot be held a reliable indication of age. Age groups IV and V were represented by too few individuals to give an accurate idea of the range in either group. The distinctly unimodal distribution within each well-represented age group and the great amount of overlapping in length probably accounted for the unimodal length distribution in the yearly collections from impounding nets.

Additional data obtained from impounding nets each year in the period 1944–48 (table 20) make possible a comparison of the length distribution of the legal-sized yellow perch in the commercial catch of those years with the legal-sized fish included in the biological samples collected from the same type of nets in the 3 years 1927 to 1929. Only age groups II and III will be compared since younger and older fish contributed but little to the commercial catch.

The length distribution of the legal-sized (8½ inches total length and larger) yellow perch assigned to age group II exhibited a striking difference between the two periods, 1927–29 and 1944–48. The minimum legal size of 8½ inches was near, or above, the modal length of all group-II fish in each of the 3 years 1927 to 1929. The length distribution of group-II fish in each year of the period 1944–48 gave strong reason to believe that the 8½-inch size limit was below (less than) the modal length each year with the possible exception of 1945 when the small sample agreed more nearly with the data of the earlier period. Also in each year except 1945 of the recent period, age group II contained longer fish than in any year of the earlier period. Further, the number of the longer group-II fish tended to

TABLE 19.—*Length frequencies of Lake Erie yellow perch by age and year of capture, taken by impounding nets from western and middle Lake Erie*

[An asterisk designates the modal interval in each frequency distribution]

Standard-length interval	Total length equivalent to midpoint	Age group I			Age group II			Age group III			Age group IV			Age group V		All age groups
		1927	1928	1929	1927	1928	1929	1927	1928	1929	1927	1928	1929	1927	1929	
	inches															
106 to 110 mm	5.1		1	1												2
111 to 115 mm	5.3		2													2
116 to 120 mm	5.5			1		1										2
121 to 125 mm	5.8			1												1
126 to 130 mm	6.0	1	2	3	2											8
131 to 135 mm	6.1	3	1	3												7
136 to 140 mm	6.4	7		6			1									14
141 to 145 mm	6.6	16		13	3	3	3									38
146 to 150 mm	6.8	18	2	*16	5	11	2			1						55
151 to 155 mm	7.1	23		5	4	29	7									68
156 to 160 mm	7.3	25		11	8	41	20	1								106
161 to 165 mm	7.5	32		7	14	58	21	1	1							134
166 to 170 mm	7.8	*52	1	9	14	80	34	2	3	4						199
171 to 175 mm	8.0	37	2	6	*27	99	35	3	4	10						*223
176 to 180 mm	8.2	13		1	21	*122	27	3	6	18						211
181 to 185 mm	8.5	5			*27	108	*42	3	6	31	1					*223
186 to 190 mm	8.7	2			20	100	39	5	4	31		1	2			204
191 to 195 mm	8.9	1			18	77	33	*8	3	52			5			197
196 to 200 mm	9.1				10	49	39	2	10	70		1	8			189
201 to 205 mm	9.3				11	28	27	5	*11	72	2		7			163
206 to 210 mm	9.5				3	15	21	5	8	*75			5		1	133
211 to 215 mm	9.8				3	7	16	5	4	68			3			106
216 to 220 mm	10.0				2	3	4		4	68			7			88
221 to 225 mm	10.1					1	1	3	2	51		1	*12			71
226 to 230 mm	10.4							1	1	36			2		1	41
231 to 235 mm	10.6								2	15	1	1	5		1	25
236 to 240 mm	10.8									16		1	4			21
241 to 245 mm	11.1									10	1		1			12
246 to 250 mm	11.3									2				2		4
251 to 255 mm	11.5									2						2
256 to 260 mm	11.7								1							1
Total		235	11	83	192	832	372	47	70	632	5	5	61	2	3	2,550
Average standard length (mm.)		162	138	152	181	179	182	195	198	207	214	217	214	250	223	186
Average total length (inches)		7.5	6.4	7.0	8.4	8.3	8.4	9.0	9.1	9.5	9.8	10.0	9.8	11.4	10.1	8.6
Percent illegal (less than 184 mm.)		97.9	100.0	100.0	59.4	61.2	47.0	25.5	25.7	8.2	20.0	0	0	0	0	47.2

TABLE 20.—*Length frequencies of legal-sized yellow perch taken commercially and as biological samples in impounding nets in western and middle Lake Erie*

Total-length interval [1]	Standard-length interval	1927 [2]	1928 [2]	1929 [2]	1944 [3]	1945 [3]	1946 [3]	1947 [3]	1948 [3]	Years combined	
										1927–29	1944–48
Age group II:	*Millimeters*										
8.50 to 8.75 inches	184 to 189	28	119	44	6	13	8	13	19	191	59
8.75 to 9.00 inches	190 to 195	20	104	43	10	13	8	22	37	167	90
9.00 to 9.25 inches	196 to 201	11	54	45	17	6	34	50	65	110	172
9.25 to 9.50 inches	202 to 206	11	28	26	15	6	53	24	48	65	146
9.50 to 9.75 inches	207 to 211	2	12	18	12	8	26	32	62	32	140
9.75 to 10.00 inches	212 to 217	4	7	16	6	1	17	9	28	27	61
10.00 to 10.25 inches	218 to 224	1	3	3	2		7	9	29	7	47
10.25 to 10.50 inches	225 to 230						1	2	3		6
10.50 to 10.75 inches	231 to 236				1			2	7		10
10.75 to 11.00 inches	237 to 241								1		1
Total number		77	327	195	69	47	154	163	299	599	732
Average total length (inches)		8.95	8.86	9.07	9.37	9.10	9.45	9.28	9.39	8.94	9.36
Age group III:											
8.50 to 8.75 inches	184 to 189	3	5	41		1		2	1	49	4
8.75 to 9.00 inches	190 to 195	11	4	58		6		11	1	73	18
9.00 to 9.25 inches	196 to 201	4	12	84	4	17	2	30	20	100	73
9.25 to 9.50 inches	202 to 206	4	12	69	5	18	5	21	20	85	69
9.50 to 9.75 inches	207 to 211	5	5	75	1	17	16	32	28	85	94
9.75 to 10.00 inches	212 to 217	4	6	93	2	14	12	14	16	103	58
10.00 to 10.25 inches	218 to 224	2	3	68		7	9	15	9	73	40
10.25 to 10.50 inches	225 to 230	2	2	51		2	3	4		55	9
10.50 to 10.75 inches	231 to 236		2	21		3	1	4	2	23	10
10.75 to 11.00 inches	237 to 241			12			2		1	12	3
11.00 to 11.25 inches	242 to 247			8				1		8	1
11.25 to 11.50 inches	248 to 252			3						3	
11.50 to 11.75 inches	253 to 258		1	1					3	2	3
Total number		35	52	584	12	85	50	134	101	671	382
Average total length (inches)		9.29	9.45	9.63	9.46	9.63	9.95	9.51	9.63	9.60	9.62

[1] Each interval contains lengths up to but not including the greatest value. [2] From biological samples. [3] From commercial samples.

increase in the later years of the 1944-48 period. The average total length of the legal-sized group-II yellow perch was considerably larger in each year except 1945, of the period 1944–48, than in any year of the period 1927–29.

The totals for the two periods place the modal length of the legal-sized fish in the 8.50 to 8.75 inch interval in 1927–29 and in the 9.00 to 9.25 inch interval in 1944–48. The weighted-average total lengths for the two periods were 8.94 and 9.36 inches, respectively. The use of unweighted means of the annual average total lengths to eliminate the distorting effects of the differences in size of samples changes the averages for the periods only slightly, to 8.96 and 9.32 inches. Both methods of computation show that the age-group-II fish of legal size taken in 1944–48 averaged about 0.4 inch longer than those taken in 1927–29.

The general pattern of the length distribution of the legal-sized yellow perch assigned to age group III failed to show as great differences between the 1927–29 and 1944–48 periods as were exhibited by group-II fish. The modal frequency interval was well above the 8½-inch size limit in all years. The average total length was greater each year in the 1944–48 period than in either 1927 or 1928 but agreed rather well with that of 1929. The weighted-average length was almost identical in both periods because the best represented year in the earlier period included fish with the longest average length while the best represented of the later years included specimens with the shortest average for the period. The unweighted means of the annual averages in the two periods were 9.46 and 9.64 inches. The more reliable unweighted means thus show the legal-size yellow perch assigned to age group III to have averaged approximately 0.2 inch longer in 1944–48 than in 1927–29.

Although these data do not constitute proof, they do offer strong evidence that yellow perch in Lake Erie were growing at a faster rate in 1944–48 than in 1927–29.

AGE COMPOSITION AND ABUNDANCE OF YEAR CLASSES

In the study of the age and year-class composition of the Lake Erie yellow perch it should be remembered that the samples must be considered truly descriptive, not of the stock, but rather of the catch of commercial gear. Trap-net and pound-net collections were employed in the biological study of the relative abundance of age groups and year classes because those nets are less selective than gill nets. Although samples from impounding nets in a single year may not give dependable information as to the relative abundance of the year classes represented, the persistent abundance or scarcity of a year class at different ages, that is, in different years' collections, offers a reasonably trustworthy method for the detection of exceptionally strong or weak year classes. Of course, a knowledge of the age composition in both gill nets and impounding nets is of importance in the practical problem of determining the effects of these types of gear on the stock.

The number of specimens and the percentage occurrence of each age group in the yearly collections of biological samples from impounding nets for the years 1927–37 are shown in table 21. Age group I dominated the samples in one (1927) of the six years in which collections were made, although the percentage of abundance of this age group was also high in 1937. Age group II dominated in three years (1928, 1930, and 1937), and group III was dominant in the remaining two years (1929 and 1932). However, the fact that the 1932 samples were taken from the spawning run in April, when the fish were comparable in size and maturity to those in the next younger age group in the previous fall, throws doubt on the validity of comparisons between the data for this and other years. The spawning run consists almost entirely of mature individuals; consequently, those age groups containing high percentages of immature fish were not represented adequately in the 1932 collections. The 1932 data serve, however, to show the age composition of the catch in the spawning-run fishery.

It will be brought out later (p. 251) that unusual conditions made possible the dominance of age group I in 1927 and of age group III in 1929. Dominance of age group II in the late-season catch of yellow perch in impounding nets may be considered the normal condition.

The preceding remarks were based on the total catch of impounding nets including both legal-

TABLE 21.—*Distribution by age groups of yellow perch in the different years' collections from impounding nets*

[Percentages in parentheses]

Year	Month of capture	Number of specimens	Number and percentage in age group—				
			I	II	III	IV	V
1927	October and November	481	235 (48.9)	192 (39.9)	47 (9.8)	5 (1.0)	2 (0.4)
1928	July, August, September, October, and November	918	11 (1.2)	832 (90.6)	70 (7.6)	5 (0.5)	
1929	July, August, September, November, and December [1]	1,151	83 (7.2)	372 (32.3)	632 (54.9)	61 (5.3)	3 (0.3)
1930	July and September	222	1 (0.4)	172 (77.5)	45 (20.3)	4 (1.8)	
1932	April	133		2 (1.5)	98 (73.7)	33 (24.8)	
1937	November	131	62 (47.3)	66 (50.4)	3 (2.3)		
	All collections	3,036	392 (12.9)	1,636 (53.9)	895 (29.5)	108 (3.6)	5 (0.2)

[1] The 1929 data may be considered as representative of autumn conditions since 66 percent of the specimens were collected in November and December.

sized and illegal-sized fish. It is of practical value to know also the representation of these two size groups separately as well as the age groups in the marketable catch, that is, legal-sized fish. Data on these subjects are contained in table 22 which shows the number and percentage of legal and undersized yellow perch in each age group represented in the total catch and in table 23 which gives the numerical and percentage composition of the marketable catch in each year's collection. From the former table it may be seen that legal-sized yellow perch constituted an unimportant proportion of age group I. This age group dominated the catch of impounding nets in 1927 but apparently contributed nothing to the commercial yield. The highest percentage of legal-sized perch in any group I was 8.1 in 1937. The majority of all group-II perch captured were undersized—60.3 percent as determined from a size limit of 8½ inches. In only two years (1929 and 1937) did the percentage of undersized perch in age group II fall below 50. Thus it may be seen that the age group that normally dominated the catch of impounding nets (the spawning-run fishery excepted) consisted largely of yellow perch that could not be retained and sold by the fisherman. The percentage of undersized perch in all group-III fish combined was small (15.1). In two years

TABLE 22.—*Distribution by age groups of legal- and illegal-sized yellow perch in the different years' collections from impounding nets*

[Percentages in parentheses]

Year	Minimum legal-size limit (inches)	Number of specimens	Number of legal in all ages	Number of illegal in all ages	I		II		III		IV		V	
					Legal	Illegal	Legal	Illegal	Legal	Illegal	Legal	Illegal	Legal	Illegal
1927	9	481	56 (11.6)	425 (88.4)	0 (0)	235 (100.0)	29 (15.1)	163 (84.9)	21 (44.7)	26 (55.3)	4 (80.0)	1 (20.0)	2 (100.0)	0 (0)
	8½	481	123 (25.6)	358 (74.4)	4 (1.7)	231 (98.3)	77 (40.1)	115 (59.1)	35 (74.5)	12 (25.5)	5 (100.0)	0 (0)	2 (100.0)	0 (0)
1928	9	918	151 (16.4)	767 (83.6)	0 (0)	11 (100.0)	103 (12.4)	729 (87.6)	44 (62.7)	26 (37.1)	4 (80.0)	1 (20.0)		
	8½	918	384 (41.8)	534 (48.2)	0 (0)	11 (100.0)	327 (39.3)	505 (60.7)	52 (74.3)	18 (25.7)	5 (100.0)	0 (0)		
1929	8½	1,151	843 (73.2)	308 (26.8)	0 (0)	83 (100.0)	195 (52.4)	177 (47.8)	584 (92.4)	48 (7.6)	61 (100.0)	0 (0)	3 (100.0)	0 (0)
1930	8½	222	54 (24.3)	168 (75.7)	0 (0)	1 (100.0)	9 (5.2)	163 (94.8)	41 (91.1)	4 (8.9)	4 (100.0)	0 (0)		
1932	8½	133	74 (55.6)	59 (44.4)			0 (0)	2 (100.0)	45 (45.9)	53 (54.1)	29 (87.9)	4 (12.1)		
1937	8½	131	50 (38.2)	81 (61.8)	5 (8.1)	57 (91.9)	42 (63.6)	24 (36.4)	3 (100.0)	0 (0)				
Total:														
Effective limits [1]	([1])	3,036	1,228 (40.4)	1,808 (59.6)	5 (1.3)	387 (98.7)	378 (23.1)	1,258 (76.9)	738 (82.5)	157 (17.5)	102 (94.4)	6 (5.6)	5 (100.0)	0 (0)
8½-inch limit [2]	8½	3,036	1,528 (50.3)	1,508 (49.7)	9 (2.3)	382 (97.7)	650 (39.7)	986 (60.3)	760 (84.9)	135 (15.1)	104 (96.3)	4 (3.7)	5 (100.0)	0 (0)

[1] The number and percentage of legal- and illegal-sized fish in the various age groups of all years' collections combined as determined for the size limit effective in each year.

[2] As determined for 8½-inch limit for all years.

(1927 and 1932), however, this percentage exceeded 50. The proportion of undersized perch in age group IV may be considered unimportant, and all group-V perch were of legal size.

The effects of the varying percentages of legal and undersized yellow perch in the different age groups, and of the varying abundance of the age groups themselves, on the age composition of the marketable catch may be seen in table 23. Age group II dominated the commercial catch in all years' samples except four, 1929, 1930, 1932, and 1945, when group-III fish were most numerous. The data in table 23 give strong indication that the time of capture within the season may have an important effect on the age composition of the marketable catch. The April 1932 (spawning-run) sample contained no legal-sized yellow perch younger than age group III. The midsummer collection of 1930 (most of the fish were taken in July) was dominated by age group II when both legal and undersized yellow perch were included

TABLE 23.—*Distribution by age groups of legal-sized yellow perch in the different years' collections from impounding nets*

[Percentages in parentheses]

Year	Legal size limit [1] (inches)	Number of specimens	Number and percentage in age group—				
			I	II	III	IV	V
1927	9	56	0 (0)	29 (51.8)	21 (37.5)	4 (7.1)	2 (3.6)
	8½	123	4 (3.2)	77 (62.6)	35 (28.5)	5 (4.1)	2 (1.6)
1928	9	151	0 (0)	103 (68.2)	44 (29.1)	4 (2.7)	0 (0)
	8½	384	0 (0)	327 (85.2)	52 (13.5)	5 (1.3)	0 (0)
1929	8½	843	0 (0)	195 (23.1)	584 (69.3)	61 (7.2)	3 (0.4)
1930	8½	54	0 (0)	9 (16.7)	41 (75.9)	4 (7.4)	0 (0)
1932	8½	74	0 (0)	0 (0)	45 (60.8)	29 (39.2)	0 (0)
1937	8½	50	5 (10.0)	42 (84.0)	3 (6.0)	0 (0)	0 (0)
1943	8½	28	6 (21.4)	16 (57.1)	5 (17.9)	1 (3.6)	0 (0)
1944	8½	81	0 (0)	69 (85.2)	12 (14.8)	0 (0)	0 (0)
1945	8½	153	0 (0)	47 (30.7)	85 (55.6)	19 (12.4)	2 (1.3)
1946	8½	213	0 (0)	154 (72.3)	50 (23.5)	7 (3.3)	2 (0.9)
1947	8½	320	1 (0.3)	163 (50.9)	134 (41.9)	19 (6.0)	3 (0.9)
1948	8½	420	7 (1.7)	299 (71.2)	101 (24.0)	13 (3.1)	0 (0)
Total	([1])	2,443	19 (0.8)	1,126 (46.1)	1,125 (46.0)	161 (6.6)	12 (0.5)
Average (unweighted) percentage:							
Effective limits.[1]	([1])	----------	(2.8)	(50.9)	(38.0)	(7.7)	(0.6)
8½-inch limit.[2]	8½	----------	(3.0)	(53.3)	(36.0)	(7.3)	(0.4)

[1] Minimum legal size 9 inches in 1927 and 1928 and 8½ inches in all other years.
[2] As determined for 8½-inch limit for all years.

(table 22). However, such a small proportion (5.2 percent) of the age group had attained legal size (table 22) that age group III became strongly dominant (75.9 percent) when only legal-sized fish were considered (table 23). Of the 10 years in which all or most of the yellow perch were taken in autumn (1927, 1928, 1929, 1937, 1943–48), after the continued growth of group-II perch had brought a greater proportion of them to legal length, this group dominated the commercial catch in all but 1929 and 1945. Since the conditions are known to have been abnormal in 1929, and perhaps also in 1945, it appears valid to conclude that age group II normally dominates the late-season commercial catch. Members of the same year class dominate the fishery as age group III the following spring and during the summer up to the point that the growth of the incoming group II makes it possible for fish of that age to assume a dominant position in the commercial catch.

The conclusion about the change in the age composition of the marketable catch within a single season finds further support in data of the 1928 and 1929 collections. Scales were collected in both summer and autumn of each of these years. Comparisons of the percentage age composition of legal-sized perch in different months of capture in the two years may be found in table 24. Analyses were made for the 1928 data with respect to the then-effective 9-inch size limit and the current 8½-inch limit. The data of table 24 cannot be considered descriptive of the typical seasonal changes in the age composition of legal-sized yellow perch since age group II was abnormally abundant in 1928 and group III was exceptionally strong in 1929. The percentages serve, nevertheless, to show clearly the tendency for group II to replace group III in the marketable catch as the season progresses. In 1928, age group III was dominant among legal-sized yellow perch in July (41.7 percent) but age group II was dominant in the later months of the season. Had an 8½-inch limit been in force, age group II would have dominated the catch in July as well as in late season, but its relative importance would have increased, nevertheless, from 69.1 percent in July to 91.1 percent in August to November. The great abundance of group-III yellow perch in 1929 made it possible for that age group to maintain its dominance in the marketable catch

TABLE 24.—*Percentage age composition of legal-sized yellow perch in Lake Erie in different months of capture in 1928 and 1929*

Size limit and month of capture	Age group			
	II	III	IV	V
1928:				
9-inch size limit:				
July	33.3	41.7	25.0	0
August through November	71.6	27.7	.7	0
8½-inch size limit:				
July	69.1	21.4	9.5	0
August through November	91.1	8.6	.3	0
1929: 8½-inch size limit:				
July	.8	85.5	12.9	.8
August and September	14.4	85.6	0	0
November and December	31.6	59.4	8.6	.4

to the end of the season. The representation of age group II increased, however, from 0.8 percent in July to 14.4 percent in August and September and to 31.6 percent in November and December. At the same time the corresponding percentage representations of age group III changed from 85.5 to 85.6 to 59.4.

The legal-sized fish of the combined samples for all years' collections belonged very largely (92.1 percent) to age groups II and III which were represented almost equally—46.1 and 46 percent (table 23). However, the relatively high representation of age group III can be traced to the large 1929 collection in which it was dominant. A more reliable estimate of the age composition of the marketable catch may be had from the unweighted averages of the percentages for the different years. At the bottom of table 23 these averages are given as computed from the size limits actually in effect in the different years (that is, from a size limit of 9 inches in 1927 and 1928 and of 8½ inches in the later years) and as computed from a size limit of 8½ inches for all years. The percentages computed from both the effective and the 8½-inch size limits showed dominance of age group II.

Yellow perch older than age group V were not found in the samples, but are known to have been present in Lake Erie. Specimens selected because of their large size revealed no males older than age group IV, but did include one female of age group VII and two fish of undetermined sex assigned to age group VIII.

The data on the age composition of gill-net catches (shoal and bull nets) contained in tables 25, 26, and 27 correspond to those already given for trap nets. The data for 1927 and 1928 included both legal- and illegal-sized fish while those for later years represented only the commercial sizes. Comparisons between the catches of trap nets and gill nets bring out sharply the strongly selective action of the latter gear. Age group III dominated three of the four gill-net collections obtained in 1927 and 1928 (table 25). The fourth (the bull-net collection of 1928) was dominated by age group II, but age group III was only slightly less abundant. This distribution of the age groups bears little resemblance to the age composition of the less-selective impounding nets (table 21) where the 1927 samples were dominated by age group I (48.9 percent), and 90.6 percent of the yellow perch in the 1928 collections were members of age group II. The 1927 gill-net samples do not give the slightest indication of the great abundance of age group I. Possibly the dominance of age group II in the 1928 bull-net collection was due to the great abundance of group-II fish in that year. However, the shoal-net collection failed to reveal such dominance and abundance. On the whole, the age composition of gill-net catches appears to be in large measure independent of the relative strength of the age groups in the population. Characteristically, age group III was dominant, with age group II regularly well represented and occasionally dominant. The tendency for gill nets to take older fish than do trap nets may be seen also in the greater abundance of group-IV yellow perch in the gill-net samples.

A second difference between gill-net and impounding-net collections lies in the greater proportion of legal-sized yellow perch in the age groups from the former gear (table 26). For example, the percentages of legal yellow perch of group II, in the impounding-net collections for 1927 and 1928, were only 15.1 and 12.4, computed from a 9-inch size limit (table 22). Group II in the gill-net collections for these years, on the other hand, contained from 30.2 to 79.2 percent of such perch and showed an average for the 2-year period (bull and shoal nets combined) of 47.9 percent. If the percentages of legal-sized yellow perch in age group II are computed from a size limit of 8½ inches, the values are 39.7 for impounding-net samples and 76.3 for gill-net collections. A similar though less pronounced difference existed between the percentages of group III legal-sized

TABLE 25.—*Distribution by age groups of yellow perch from gill nets*

[Percentages in parentheses]

Year	Month of capture	Number of specimens	Number and percentage in age group—				
			I	II	III	IV	V
Taken in shoal nets:							
1927	August	84	2 (2.4)	29 (34.5)	40 (47.6)	11 (13.1)	2 (2.4)
1928	July and August	144	----	53 (36.8)	73 (50.7)	17 (11.8)	1 (0.7)
Total		228	2 (0.9)	82 (36.0)	113 (49.6)	28 (12.3)	3 (2.9)
Taken in bull nets:							
1927	August	69	----	24 (34.8)	38 (55.1)	5 (7.2)	2 (2.9)
1928	July and August	133	1 (0.8)	63 (47.4)	56 (42.1)	13 (9.8)	----
Total		202	1 (0.5)	87 (43.1)	94 (46.5)	18 (8.9)	2 (1.0)
Take of shoal and bull nets combined:							
1927	August	153	2 (1.3)	53 (34.6)	68 (51.0)	16 (10.5)	4 (2.6)
1928	July and August	277	1 (0.4)	116 (41.9)	129 (46.6)	30 (10.8)	1 (0.4)
Total		430	3 (0.7)	169 (39.3)	207 (48.1)	46 (10.7)	5 (1.2)

TABLE 26.—*Distribution by age groups of legal- and illegal-sized yellow perch from gill nets*

[Percentages in parentheses]

Year and minimum legal size	Number of specimens	Number legal size	Number illegal size	Number and percentage in age group—									
				I		II		III		IV		V	
				Legal	Illegal	Legal	Illegal	Legal	Illegal	Legal	Illegal	Legal	Illegal
Taken in shoal nets:													
1927:													
9 inches	84	72	12	0 (0)	2 (100.0)	19 (65.5)	10 (34.5)	40 (100.0)	0 (0)	11 (100.0)	0 (0)	2 (100.0)	0 (0)
8½ inches	84	78	6	0 (0)	2 (100.0)	25 (86.2)	4 (13.8)	40 (100.0)	0 (0)	11 (100.0)	0 (0)	2 (100.0)	0 (0)
1928:													
9 inches	144	101	43	----	----	24 (45.3)	29 (54.7)	60 (82.2)	13 (17.8)	16 (94.1)	1 (5.9)	1 (100.0)	0 (0)
8½ inches	144	135	9	----	----	44 (83.0)	9 (17.0)	73 (100.0)	0 (0)	17 (100.0)	0 (0)	1 (100.0)	0 (0)
Total, 1927–28:													
9 inches	228	173	55	0 (0)	2 (100.0)	43 (52.4)	39 (47.6)	100 (88.5)	13 (11.5)	27 (96.4)	1 (3.6)	3 (100.0)	0 (0)
8½ inches	228	213	15	0 (0)	2 (100.0)	69 (84.1)	13 (15.9)	113 (100.0)	0 (0)	28 (100.0)	0 (0)	3 (100.0)	0 (0)
Taken in bull nets:													
1927:													
9 inches	69	64	5	----	----	19 (79.2)	5 (20.8)	38 (100.0)	0 (0)	5 (100.0)	0 (0)	2 (100.0)	0 (0)
8½ inches	69	68	1	----	----	23 (95.8)	1 (4.2)	38 (100.0)	0 (0)	5 (100.0)	0 (0)	2 (100.0)	0 (0)
1928:													
9 inches	133	75	58	0 (0)	1 (100.0)	19 (30.2)	44 (69.8)	43 (76.8)	13 (23.2)	13 (100.0)	0 (0)	----	----
8½ inches	133	101	32	0 (0)	1 (100.0)	37 (58.7)	26 (41.3)	51 (91.1)	5 (8.9)	13 (100.0)	0 (0)	----	----
Total, 1927–28:													
9 inches	202	139	63	0 (0)	1 (100.0)	38 (43.7)	49 (56.3)	81 (86.2)	13 (13.8)	18 (100.0)	0 (0)	2 (100.0)	0 (0)
8½ inches	202	169	33	0 (0)	1 (100.0)	60 (69.0)	27 (31.0)	89 (94.7)	5 (5.3)	18 (100.0)	0 (0)	2 (100.0)	0 (0)
Take of shoal and bull nets combined:													
9 inches	430	312	118	0 (0)	3 (100.0)	81 (47.9)	88 (52.1)	181 (87.4)	26 (12.6)	45 (97.8)	1 (2.2)	5 (100.0)	0 (0)
8½ inches	430	382	48	0 (0)	3 (100.0)	129 (76.3)	40 (23.7)	202 (97.6)	5 (2.4)	46 (100.0)	0 (0)	5 (100.0)	0 (0)

TABLE 27.—*Distribution by age groups of legal-sized yellow perch from gill nets, 1927–28 and 1943–48*

[Percentages in parentheses]

Year and minimum legal size	Total number	Number and percentage in age group—				
		I	II	III	IV	V
Period 1927–28:						
1927:						
9 inches	136	0	38	78	16	4
		(0)	(27.9)	(57.4)	(11.8)	(2.9)
8½ inches	146	0	48	78	16	4
		(0)	(32.9)	(53.4)	(11.0)	(2.7)
1928:						
9 inches	176	0	43	103	29	1
		(0)	(24.4)	(58.5)	(16.5)	(0.6)
8½ inches	236	0	81	124	30	1
		(0)	(34.3)	(52.6)	(12.7)	(0.4)
Total, 1927–28:						
9 inches	312	0	81	181	45	5
		(0)	(26.0)	(58.0)	(14.4)	(1.6)
8½ inches	382	0	129	202	46	5
		(0)	(33.8)	(52.9)	(12.0)	(1.3)
Average percentage: [1]						
9 inches	----------	(0)	(26.1)	(58.0)	(14.1)	(1.8)
8½ inches	----------	(0)	(33.6)	(53.0)	(11.8)	(1.6)
Period 1943–48:						
1943: 8½ inches	114	6	64	34	8	2
		(5.3)	(56.1)	(29.8)	(7.0)	(1.8)
1944: 8½ inches	56	0	42	13	1	0
		(0)	(75.0)	(23.2)	(1.8)	(0)
1945: 8½ inches	74	1	35	35	3	0
		(1.3)	(47.3)	(47.3)	(4.1)	(0)
1946: 8½ inches	207	1	148	48	9	1
		(0.5)	(71.5)	(23.2)	(4.3)	(0.5)
1947: 8½ inches	389	9	74	235	71	0
		(2.3)	(19.0)	(60.4)	(18.3)	(0)
1948: 8½ inches	291	0	170	103	18	0
		(0)	(58.4)	(35.4)	(6.2)	(0)
Total, 1943–48:						
8½ inches	1,131	17	533	468	110	3
		(1.5)	(47.1)	(41.4)	(9.7)	(0.3)
Average percentage: [1]						
8½ inches	----------	(1.6)	(54.5)	(36.5)	(7.0)	(0.4)
Total, all years [2]	1,443	17	614	649	155	8
Average percentage: [1]						
Effective limits	----------	(1.2)	(47.4)	(41.9)	(8.8)	(0.7)
8½-inch limit	----------	(1.2)	(49.3)	(40.6)	(8.2)	(0.7)

[1] Unweighted mean.
[2] Minimum legal size was 9 inches in 1927 and 1928 and 8½ inches in all later years.

yellow perch in impounding-net and gill-net collections. The small numbers of specimens do not warrant detailed comparisons of the remaining age groups. Attention should be called to the fact that in both 1927 and 1928 the samples taken by gill nets did not contain fish caught as late in the season as did those taken by impounding nets. Consequently, the yellow perch taken by gill nets may be expected to have completed less of the season's growth. Had the collections from both types of gear been made at the same time within the season, the advantage of the gill-net samples with respect to the percentage of legal-sized yellow perch in the age groups would probably have been even greater.

Differences in the age composition of collections from the two types of gill nets were not great, although there was a slight tendency for bull nets to take more of the younger fish (table 25). The only dominant group II occurred in the 1928 bull-net collection, and when the data for 1927 and 1928 are combined, bull nets may be seen to have taken relatively more fish of age group II than did shoal nets and relatively fewer of the older age groups. Likewise, the differences in the proportion of legal-sized yellow perch in corresponding age groups of shoal-net and bull-net collections were not large. The best represented age groups (II and III) of the shoal-net samples contained slightly higher percentages of legal-sized fish than the same age groups in bull-net samples.

The data on numerical and percentage age composition of the legal-sized yellow perch taken by gill nets are presented in table 27 with the catches of shoal and bull nets combined. Added to the 1927 and 1928 data are those obtained from samples of the commercial catch by gill nets in 1943–48. Age group III dominated the samples in both 1927 and 1928 and made up 58 percent of the total at the then-effective size limit of 9 inches (53 percent at the present 8½-inch size limit). Age groups II and IV made up 26.1 and 14.1 percent (33.6 and 11.8 percent at the 8½-inch limit) and formed the only other well-represented groups in the catches. Age group I was not represented at all. The 1943–48 data differed from those of the earlier years in that age-group-II fish dominated in 4 years, age groups II and III were equally represented in one, and age group III was dominant in only 1 year. The averages for the 6 years (comparable to the averages at the 8½-inch size limit in 1927–28) showed that group II made up 54.5 percent of the total, group III 36.5 percent, group IV 7 percent, and group I 1.6 percent. Thus it is seen that there was not only a shift in dominance from group III in 1927–28 to group II in 1943–48 but also an accompanying decrease in the relative abundance of the fish in groups IV and V and an increase in the number of those in group I.

Explanation of the difference in age composition of the legal-sized yellow perch taken by gill nets in 1927–28 and 1943–48 probably lies in the time of year the fish were captured. All of the 1927–28 samples were collected in July and August while those for 1943–48 were taken from late September to early November. The samples obtained in July and August (1927–28) unquestionably were made up of fish that had not completed the season's growth, whereas those taken later in the year (1943–48) could be expected to have completed, or nearly completed, growth for the year. The continued growth, especially of the age group just entering the commercial fishery in large numbers (group II) can be expected to increase the relative abundance of the younger individuals among the legal-sized fish. The belief that the time of capture in a year explains the shift of dominance from group III to group II is supported by the strikingly similar changes found in the impounding-net data.

If the data for impounding and gill nets are considered together, it may be stated that the fishery is supported chiefly by age groups II and III. Age group III dominated the commercial catch of gill nets in late summer of both 1927 and 1928. The same age group is in all probability usually dominant in the early-season catches also. The late-season (late September to early November) commercial catches by gill nets were dominated by age group II in 4 of the 6 years 1943–48. Age group III dominated the late-season gill-net catches only once (1947) and age groups II and III were of equal abundance in 1945. The commercial catch of impounding nets appeared to be dominated by age group III in the spring and during at least part of the summer. As growth during the summer brings an increasing percentage of age group II to legal size this age group assumed a more important position in the catch. Dominance by age group II seems to be characteristic of late-season impounding-net catches, although there may be exceptions, as in 1929 and 1945, when age group III may be the stronger.

The dependence of the fishery on two age groups renders the abundance of the Lake Erie perch very sensitive to natural fluctuations in the strength of year classes and vulnerable to overfishing. The small quantity of fish of commercial size that is carried over from one year to the next makes the maintenance of protective measures to ensure an adequate stock of spawners at all times highly imperative.

The percentage representation of the year classes in each year's collection of yellow perch from impounding nets in Lake Erie is recorded in table 28. The data for the 1937 collection have been omitted because of the long time interval separating this sample from the earlier collections. Discussion of the year-class composition of the 1937 samples will be based on the age-composition data of table 21. No tabulation has been presented of the year-class composition of gill-net samples because of the highly selective action of that gear.

The inability of impounding nets to retain representative samples of the younger age groups, and the rapid rate at which year classes disappear from the fishery owing to the short life span, combine to make interpretation of data on the year-class composition of the samples most difficult. Age group 0 (first year of life) is of course absent from all collections, and normally group-I fish occur

TABLE 28.—*Occurrence of year classes of yellow perch in the catch of impounding nets of Lake Erie*

Asterisk designates dominant year class each year; roman numerals show age at capture]

PART I—PERCENTAGE BASED ON ALL FISH TAKEN

Year of capture	Year class of—								
	1922	1923	1924	1925	1926	1927	1928	1929	1930
1927	0.4 V	1.0 IV	9.8 III	39.9 II	*48.9 I				
1928			.5 IV	7.6 III	*90.6 II	1.2 I			
1929			.3 V	5.3 V	*54.9 III	32.3 II	7.2 I		
1930					1.8 IV	20.3 III	*77.5 II	0.4 I	
1932							24.8 IV	*73.7 III	1.5 II

PART II—PERCENTAGE BASED ON COMMERCIAL CATCH

Year of capture	Year class of—								
	1939	1940	1941	1942	1943	1944	1945	1946	1947
1943	3.6 IV	17.9 III	*57.1 II	21.4 I					
1944			14.8 III	*85.2 II					
1945		1.3 V	12.4 IV	*55.6 III	30.7 II				
1946			.9 V	3.3 IV	23.5 III	*72.3 II			
1947				.9 V	6.0 IV	41.9 III	*50.9 II	0.3 I	
1948						3.1 IV	24.0 III	*71.2 II	1.7 I

only in small numbers. Age group II is affected less by the selective action of the gear although many fish of this age seem to be too small to be retained in the nets in spring and early summer (p. 221). It appears, then, that estimates of the relative abundance of the year classes of the Lake Erie perch must be based chiefly on the representation of the older fish in the different years' samples. The relative strength of age group II may be considered significant only if the sample was taken late in the season. The scarcity of group-I fish cannot be held to indicate a weak year class, although a great abundance of yellow perch of this age may be considered evidence of a strong one.

Ordinarily the estimate of the strength of a year class is based on a knowledge of its relative abundance in the collections of several successive years. In the Lake Erie yellow perch, however, the great scarcity of all fish older than age group III, together with the unreliability of data on the abundance of the younger age groups, makes the application of this method very difficult. Further complications arise from the failure to obtain data in 1938 and 1939, and the fact that only the legal-sized fish were sampled in 1943–48.

Because of the limitations just outlined it is not possible to make a precise arrangement of the year classes of the Lake Erie yellow perch in the order of their abundance. In fact it is possible to speak with certainty concerning only one of them—the year class of 1926. This year class was without doubt one of exceptional strength. It dominated the impounding-net collections of three successive years, 1927, 1928, and 1929. Dominance of this year class as group I and as group III is particularly significant. The only dominant group I of the collections occurred in the 1927 samples. In the remaining collections, age group I made up no more than 7.2 percent of the samples except in 1937 and 1943. Age group III was dominant in the late-season collections of both 1929 and 1945. It should be pointed out further than in 1928 the 1926 year class provided relatively the strongest group II in any of the collections (90.6 percent of the total).

Three other year classes appeared to have been of more than ordinary strength. The 1936 year class as group I made up 47.3 percent of the entire 1937 sample (table 21). The only other collection with such an abundance of group-I fish was made in 1927 when the 1926 year class dominated the catch of impounding nets. Unfortunately, no samples were obtained in either 1938 or 1939 and, as a consequence, nothing is known of the strength of the 1936 year class at the ages when they would contribute most to the fishery. However, production increased from 3,305,000 pounds in 1936 to 7,782,000 pounds in 1938 when the 1936 year class would have entered the commercial fishery in greatest numbers. A large increase in yield is to be expected when a strong year class enters the fishery, and the 236-percent increase from 1936 to 1938 in the catch of yellow perch may be taken as evidence, if not proof, that the 1936 year class was of more than ordinary strength. The sharp decline to 3,015,000 pounds in 1939 in the take of yellow perch could mean the exhaustion of an abundant year class by an intense fishery.

Despite the fact that the evaluation of the strength of year classes in the 1943–48 period is handicapped by lack of knowledge of the abundance of group-I fish in those years, it seems evident that the 1942 year class was one of considerable size. It comprised 21.4 percent of the 1943 samples as age group I. The same year class was strongly dominant as group-II fish in 1944 (85.2 percent) and continued to dominate the commercial samples as age group III in 1945 (55.6 percent). The strong representation of the 1942 year class as group-I fish in the commercial yield in 1943 and the dominance of the group in the two succeeding years could have been accomplished only by remarkably good survival.

Evidence, less convincing but nevertheless strongly suggestive, points to 1944 as having produced a year class that was stronger than that of either 1943 or 1945. The 1944 year class as group-II fish made up 72.3 percent of the 1946 commercial samples and contributed heavily (41.9 percent) to the 1947 take when they were in age group III.

The 1943–48 data from gill nets (table 27) provide some evidence of the relative strength of year classes despite the fact that these nets are highly selective and the samples were taken from the legal-sized yellow perch. Age group III made up 47.3 percent of the legal-sized fish in 1945 and equaled the abundance of group II. This high relative abundance of age group III supports the conclusion reached from the trap-net data that the 1942 year class was of more than ordinary strength. Although the fish assigned to age group III dominated the late-season commercial catch of yellow perch by gill nets in 1947, the evidence that the 1944 year class was exceptionally strong is not conclusive. As group-II fish the 1944 year class strongly dominated (71.5 percent) the commercial catch in 1946 and exhibited the second-strongest dominance in the 6-year period 1943–48, but the class appeared sparingly (1.3 percent) as age group I in 1945. Data from the gill nets add strength to the suggestion based on trap-net catches that the year class of 1944 was stronger than that of either 1943 or 1945.

The occurrence of rather wide fluctuations in the abundance of year classes has been observed in a large number of species, both marine and fresh-water. Despite the extensive studies that have been made of the fluctuations in abundance of year classes, relatively little is known concerning the underlying causes. It is agreed rather generally, however, that the fluctuations "have their origin in certain conditions prevailing at a very early period in the life of the fish" (Hjort 1914). The belief is general also that fluctuations depend on variations in meteorological-hydrographical conditions, although biological conditions (for example, competition for food among the young and increase in predators) may at times be important.[13]

Under conditions of a stabilized fishing intensity, it is believed that the causes of fluctuations in the abundance of year classes in the fishes of Lake Erie are most probably to be found in the meteorological-hydrographical conditions. It is recognized that overfishing and other factors also may be involved. The simultaneous occurrence in 1926 of a strong year class in seven species strongly suggests that competition for food among the young is not normally a limiting factor. The comparatively low yield of the fishery in 1926, a year that produced a strong year class, indicates that as long as the population is maintained at a reasonable strength the number of spawners may not be the primary determining factor.

The weather records from the Sandusky, Ohio, station of the U. S. Weather Bureau (1919–48) have been examined in an effort to detect a possible correlation between weather conditions and the strength of the year classes. It has been assumed that conditions in 1926 and 1942 and probably in 1936 and 1944 were exceptional as those years produced the strongest year classes of yellow perch found within the data, and that the causes for the strength of those year classes should be found in the extent and manner in which the meteorological conditions of those years differed from other years. It was expected further that conditions would be more comparable in the years 1926 and 1942 than in any other years.

Because of the previously mentioned impossibility of evaluating accurately the strength of each year class it is possible to speak only in general terms concerning the effects of weather, hence detailed weather data will not be presented. The temperature data that were examined referred to air temperatures. As mentioned previously, trends in air temperature no doubt indicate approximate trends in water temperature, especially in such shallow water as is found in western Lake Erie. It was found that the winter of 1925–26 (November to February) was cold and that the following prespawning period (March and April) was the coldest for the years 1919 to 1948. However, both the winter of 1941–42 and the prespawning period in 1942 were warmer than average. The 2 years probably producing strong year classes (1936 and 1944) differed in that the winter of 1935–36 was exceptionally cold and that of 1943–44 was warmer than average. The prespawning period in 1936 had above average temperatures but in 1944 temperatures were below average. In other months of the year temperature exhibited no relation to the strength of the year classes.

Although all of the 4 years that apparently produced strong year classes had less than average rainfall in May and June, the total precipitation in both 1942 and 1944 was only slightly below normal and amounted to between two and three times that in either 1926 or 1936. Wind velocities and percentage of possible sunshine appear to bear even less relation to the strength of year classes than the other factors considered. Van Oosten (1948) pointed out that there was no relation between turbidity and strength of year classes.

The contradictory evidence of the effects of temperature during the winter and prespawning period and total precipitation during May and June on the strength of year classes makes it appear that no simple relation exists. Although

[13] Jensen (1933) gave a detailed review of the literature and a critical discussion of the causes of fluctuations in the abundance of marine fish of the North Sea and neighboring waters.

extremely high or low temperatures and severe storms may lead to catastrophic destruction of eggs and small fish, the strength of a year class is believed to depend normally on the sum of the effects of many factors. It seems entirely reasonable to suppose that the controlling factors have to do with the coincidental occurrence of early feeding by the newly hatched fish and the appearance of suitable food organisms in adequate amounts.

LENGTH-WEIGHT RELATION

The mathematical relation between length and weight of the yellow perch of Lake Erie in 1927–37 was determined by fitting the equation $W=cL^n$ to the average empirical length and weight of each 5-mm. standard-length frequency interval over the range 106 to 250 mm. (5.0 to 11.4 inches total length). Length intervals both longer and shorter than this range contained less than 28 fish each and were not employed in the fitting of the equation because of possibly unreliable averages. The data represent all yellow perch with standard lengths of 106 to 250 mm. that were measured and weighed without regard for locality, sex, season and year of capture, or gear employed. Data on the length and weight of Lake Erie yellow perch in 1943–48 are not included because analysis of these later data showed them to be similar in every respect to those obtained during the earlier years. The equation derived from the 1927–37 data applied equally well to the 1943–48 material.

The equation that best describes the length-weight relation of the Lake Erie yellow perch is:

$$W=1.766\times 10^{-5}L^{3.015},$$

in which W=weight in grams, and L=standard length in millimeters. Since n=3.015, it may be said that the weight of the yellow perch in Lake Erie increased approximately as the cube of the length (n=3.0).

Table 29 shows the actual and calculated weights for each 5-mm. interval of standard length of the yellow perch of Lake Erie from 1927 to 1937. Weights were computed both from the cube relationship and from the more general equation ($W=cL^n$). It was found that weights calculated by the general equation agreed closely with those computed by the equation $W=1.91\times 10^{-5}L^3$. (The weighted grand average K for all Lake Erie yellow perch was 1.91.) Weights calculated by the two equations were in complete agreement for all but 6 of the 31 frequency intervals for fish with standard lengths of less than 236 mm., and in no interval differed by more than 1 gram. The weights computed by the two equations agreed at no lengths greater than 235 mm. The weights of these larger yellow perch calculated from the cubic relationship were always less than those computed from the more general equation but at no length was the difference between the two calculated weights greater than 4 grams. It is true also that the differences between the two corresponding calculated weights tended to increase progressively as

TABLE 29.—*Actual and calculated weights of Lake Erie yellow perch by 5-millimeter length intervals*

[Data based on all fish weighed during the investigation]

Standard-length interval [1]	Total length	Number of fish	Average actual weight	Average weight calculated from equation—	
				$W=cL^n$	$W=K\times 10^{-5}L^3$
	Inches		*Grams*	*Grams*	*Grams*
83 mm	3.9	1	7	11	11
88 mm	4.1	----------	----------	13	13
93 mm	4.4	1	21	15	15
98 mm	4.6	1	21	18	18
103 mm	4.8	8	21	21	21
108 mm	5.1	28	24	24	24
113 mm	5.3	52	26	27	28
118 mm	5.5	53	29	31	31
123 mm	5.8	58	35	35	36
128 mm	6.0	76	40	40	40
133 mm	6.2	93	45	45	45
138 mm	6.4	144	51	50	50
143 mm	6.6	281	58	56	56
148 mm	6.8	431	64	62	62
153 mm	7.1	513	69	68	68
158 mm	7.3	751	77	75	75
163 mm	7.5	992	83	82	83
168 mm	7.8	1,161	91	90	91
173 mm	8.0	1,275	98	99	99
178 mm	8.2	1,463	108	108	108
183 mm	8.5	1,633	117	116	117
188 mm	8.7	1,844	126	127	127
193 mm	8.9	1,997	137	137	137
198 mm	9.1	2,252	149	148	148
203 mm	9.3	2,124	162	160	160
208 mm	9.5	1,845	174	172	172
213 mm	9.8	1,531	186	185	185
218 mm	10.0	1,066	200	198	198
223 mm	10.2	681	213	212	212
228 mm	10.4	399	227	227	226
233 mm	10.6	166	240	242	242
238 mm	10.8	113	255	258	257
243 mm	11.1	66	266	275	274
248 mm	11.3	34	282	292	291
253 mm	11.5	5	304	310	309
258 mm	11.7	7	334	329	328
263 mm	12.0	1	312	349	347
268 mm	12.2	5	349	369	368
273 mm	12.4	1	404	390	389
278 mm	12.6	----------	----------	412	410
283 mm	12.9	3	418	435	433
288 mm	13.1	2	524	459	456
293 mm	13.3	----------	----------	483	480
298 mm	13.6	1	475	508	505
303 mm	13.8	----------	----------	535	531
308 mm	14.0	----------	----------	562	558

[1] In 5-mm. intervals.

the standard length of the fish increased above 270 mm.

A comparison of the average actual weights with the calculated weights shows that there was excellent agreement over most of the length range for which there were large numbers of fish.[14] Over the standard length range of 103 to 238 mm. the actual weights at no point disagreed with either of the computed weights by more than 3 grams. It is apparent also that calculated weights obtained by the two equations agreed almost equally well with the average actual weights over this length range. The lack of agreement between the observed weights and the computed weights of perch with standard lengths less than 103 mm. may be due to the small number of specimens of that size. The empirical weights were somewhat less than either calculated weight at all but three of the lengths greater than 238 mm. (intervals with midpoints at 258, 273, and 288 were the exceptions). Over this range, the weights calculated on the basis of the cubic relationship were ordinarily closer to the observed weights than were those calculated from the more general equation. The fact that the actual weights of the larger fish were usually less than the computed weights may indicate that both equations fail to fit the data exactly for standard lengths greater than 238 mm., or it may be due to the small number of individuals in most of the frequency intervals. Another possible explanation of the lower actual weights at lengths greater than 238 mm. is that the gill nets selected only the lighter of the longer fish.

The weights calculated from the length-weight equation, $W=1.766\times10^{-5}L^{3.015}$, are shown graphically in figure 10. The use of two scales permits ready conversion from metric to English units of weights and measures. The factors needed most frequently for conversions between standard, fork, and total lengths are shown in table 30. It was mentioned (p. 252) that intervals of standard length that contained less than 28 fish were not used in the determination of the general length-weight equation. Hence, the points on the curve that lie below 106 mm. and above 250 mm. are outside the range to which the curve was actually fitted. However, the closeness with which the extrapolated portions of the curve (shown by broken lines) fit the average actual weights based on few specimens indicates that, in spite of the discrepancies already mentioned, the curve is for practical purposes applicable to the length-weight relation over the entire range represented.

COEFFICIENT OF CONDITION (*K*)

The condition of fishes and fluctuations in the values of the coefficient of condition (*K*) involve problems that are distinctly different from the description of the general length-weight relation (see Hile 1936, for detailed discussion). Condition, or relative heaviness, is influenced by those physiological and environmental factors that affect the general well-being of the individuals. The present data permit a description of the fluc-

[14] The average actual weights are the averages of all fish in each 5-mm. interval. Only the midlength of each interval is shown in the table.

TABLE 30.—*Factors for conversions between standard, fork, and total lengths of Lake Erie yellow perch*

[Number of specimens employed to determine values of the factors are shown in parentheses]

Conversion of—	Factors to be employed for standard lengths of—				
	80 mm. and under	81 to 130 mm.	131 to 190 mm.	191 to 220 mm.	221 mm. and over
Standard length to total length (same unit of measurement)	1.215 (87)	1.193 (112)	1.174 (648)	1.165 (1,267)	1.156 (513)
Standard length in millimeters to total length in inches	.0478 (87)	.0470 (112)	.0462 (648)	.0459 (1,267)	.0455 (513)
Standard length to fork length (same unit of measurement)	---------- (0)	1.141 (5)	1.132 (285)	1.125 (591)	1.119 (131)
Standard length in millimeters to fork length in inches	---------- (0)	.0449 (5)	.0446 (285)	.0443 (591)	.0441 (131)
Total length to standard length (same unit of measurement)	.823 (87)	.838 (112)	.852 (648)	.858 (1,267)	.865 (513)
Total length in inches to standard length in millimeters	20.904 (87)	21.285 (112)	21.641 (648)	21.793 (1,267)	21.971 (513)
Total length to fork length (same unit of measurement)	---------- (0)	.956 (5)	.964 (285)	.966 (591)	.968 (131)
Fork length to standard length (same unit of measurement)	---------- (0)	.876 (5)	.883 (285)	.889 (591)	.894 (131)
Fork length in inches to standard length in millimeters	---------- (0)	22.250 (5)	22.428 (285)	22.581 (591)	22.708 (131)
Fork length to total length (same unit of measurement)	---------- (0)	1.046 (5)	1.037 (285)	1.035 (591)	1.033 (131)

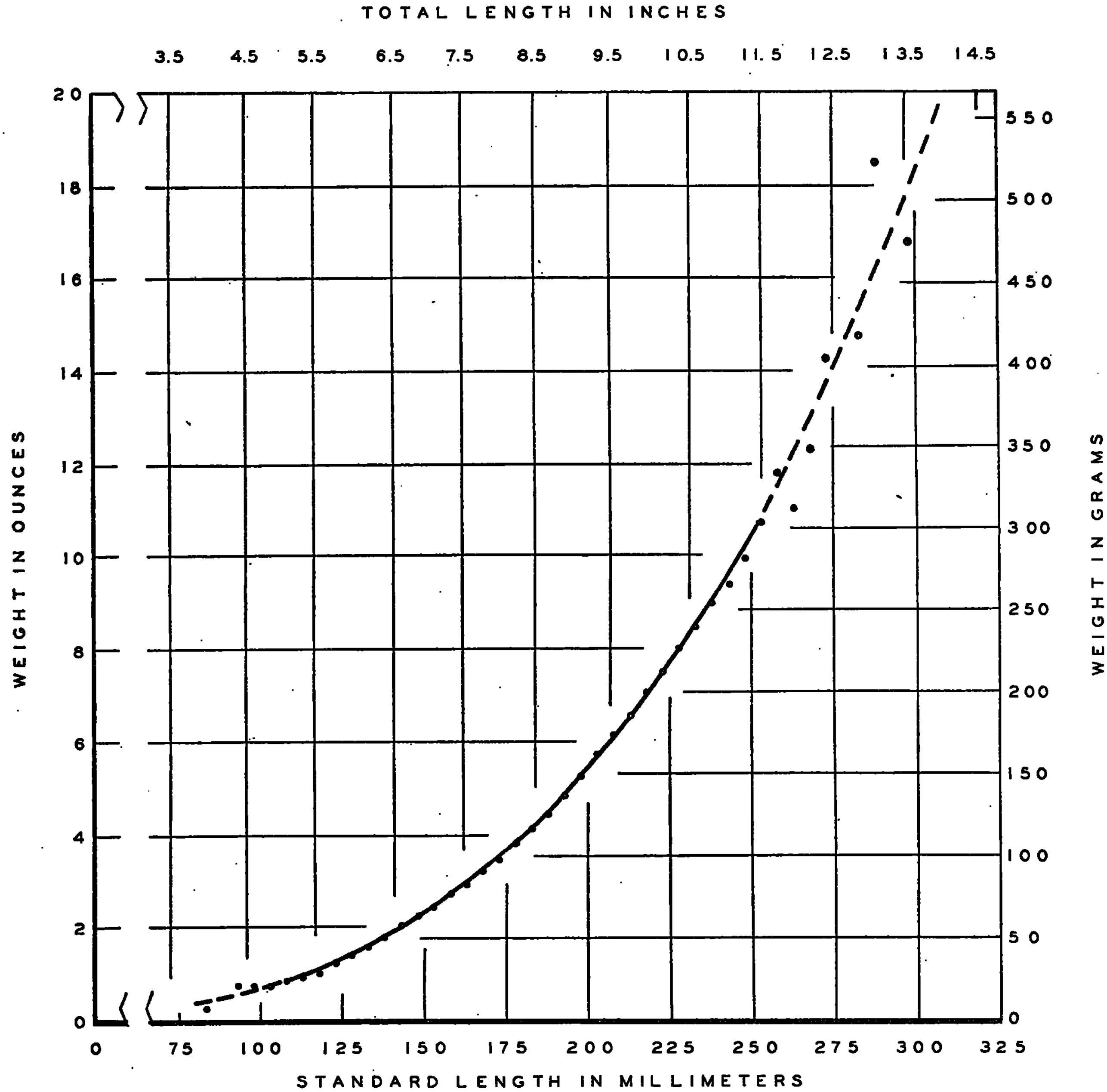

FIGURE 10.—Relation between length and weight in yellow perch of Lake Erie. Solid portion of the curve represents length range to which equation $W=cL^n$ was fitted; broken lines represent the curve in length ranges not well represented in the data. Dots show averages of empirical data grouped into 5-mm. length intervals.

tuations in the coefficient of condition (K) of the Lake Erie yellow perch according to month of capture, sex and maturity, state of gonads, age, length, and type of gear employed. The data obtained from samples taken in the period 1943–48 will be omitted from this discussion since they contribute nothing new and would bring about no important changes in the conclusions.

Monthly and annual fluctuations in the value of *K*

Among the factors that might be expected to influence monthly variations in K are food, degree of activity, and stage of sexual maturity. Spawning, and the preparatory sexual development, may be expected to produce the greatest changes in condition. Description of the monthly and annual fluctuations in the value of K in the Lake

Erie yellow perch is based entirely on specimens taken from impounding nets since, as will be shown later (p. 258), the type of gear employed influences the average value of K and gill nets are particularly selective in this respect.

Sex and stage of maturity were shown by separate analyses to have had very little effect on the value of K except in the spawning period. The data in table 31 showing the monthly fluctuations in condition of Lake Erie yellow perch according to year of capture therefore, include individuals for which sex or stage of maturity was not recorded. The data from samples obtained during April 1932, October 1934, and November 1937 are not shown in the table because each of those years was represented by only 1 month. The values of K for these 3 months were 2.24 (133 fish), 2.24 (207 fish), and 2.18 (131 fish), respectively.

TABLE 31.—*Monthly values of* K *(condition) of Lake Erie yellow perch taken in impounding nets, 1927–30*

Month	1927		1928		1929		1930	
	Number of specimens	Average value of *K*	Number of specimens	Average value of *K*	Number of specimens	Average value of *K*	Number of specimens	Average value of *K*
April	------	------	429	1.78	------	------	------	------
May	------	------	664	1.76	3,122	1.84	41	1.85
June	------	------	504	1.81	1,841	1.78	5	1.81
July	------	------	132	2.06	2,747	1.88	173	2.31
August	------	------	510	2.04	1,820	1.92	25	2.34
September	125	1.87	162	2.00	451	1.93	25	2.33
October	895	1.91	458	1.99	126	1.86	------	------
November	496	2.01	264	1.96	691	1.78	------	------
December	------	------	------	------	417	1.88	------	------
Average, all months	1,516	1.94	3,123	1.89	11,215	1.85	269	2.24
Average, excluding April and May	1,516	1.94	2,030	1.96	8,093	1.86	228	2.30

Annual fluctuations in condition and differences with respect to the months represented in the various years' collections place limitations on the conclusions to be drawn from the data of table 31. Nevertheless, certain trends can be detected. It is obvious, for example, that perch tend to be in better condition in midsummer and late summer than in June. This is brought out by the following tabulation of the unweighted averages of K for corresponding months of 1928 and 1929:

	Average K		*Average* K
June	1.80	September	1.96
July	1.97	October	1.92
August	1.98	November	1.87

The monthly averages for the 2 years show a great improvement in condition from June to July. Condition remained good in August and September. The average K decreased slightly in September and underwent a greater decrease in October and November. The averages in table 31 show that the October-November decline was much more pronounced in 1929 than in 1928.

The averages for September, October, and November, 1927, suggest that loss of condition in the autumn may not be typical for the Lake Erie perch. In 1927 the value of K increased in both October and November. The averages for the 1930 collection, on the other hand, agreed with the trend of the 1928–29 averages. In 1930 the value of K increased markedly in July and remained at a high level in August and September. The only available comparisons of the averages of K for November and December (1929) indicate an improvement in condition in the latter month. Three comparisons are available of condition in May and June and one of condition in April and May. However, the possible disturbing effects of variations in the relative abundance of gravid and spent fish in the various April and May collections make it inadvisable to draw conclusions concerning monthly changes in condition from April to May and from May to June.

The grand averages for K in the different years' collections are not strictly comparable because of differences from year to year in the months represented. A more reliable estimate of the annual fluctuations in condition may be had from comparisons of averages for corresponding months. Comparisons of the averages for September, October, and November indicate that condition was slightly better in 1928 than in 1927. The large 1928 advantages in September and October overshadowed the 1927 advantage in November. Condition was poorer in 1929 than in 1928. The K averages were lower in 1929 in every month except May. The condition of the Lake Erie perch in 1929 was also probably poorer than in 1927. The September average was higher in 1929 than in 1927, but the October and November averages were both higher in 1927. The best condition of the 4 years occurred in 1930. With the exception of June which had the same K averages in 1928 and 1930, the monthly averages in 1930 were consistently greater than the corresponding averages in any other year. From the data just discussed it would appear that the probable order of the 4 years with respect to condition of the Lake Erie yellow perch from best to poorest condition is: 1930, 1928, 1927, and 1929.

The *K* averages of 2.24 in April 1932 and October 1934, and 2.18 in November 1937 (p. 255), suggest that the condition of the Lake Erie yellow perch in these 3 years was excellent—probably superior to that in 1927, 1928, and 1929.

Fluctuations in value of *K* with stage of maturity

Great differences in value of *K* associated with stage of maturity were found in the comparison of the gravid and spent females taken in May. (Unfortunately, gravid and spent males were not recorded separately in the field records.) The detailed information on the loss of weight by the females at spawning is presented in table 32 where the data have been arranged to show the average weight in grams and the average *K* before and after spawning for each 5-mm. standard-length interval. For both gravid and spent females the changes of *K* with increase in length appeared to be random rather than to exhibit a progressive increase or decrease. Consequently, there was no obvious relation between the percentage loss of weight and the length of the specimens. The loss of weight varied from 3.4 to 24.6 percent. The average of the percentages computed from the best-represented intervals, those in which both gravid and spent fish were represented by seven or more specimens, showed a weight loss of 16.1 percent at spawning. A slightly lower estimated loss of weight (15.5 percent) was obtained from the weighted-average coefficient of condition.

Fluctuations in value of *K* with age

Data for the study of the variations of *K* with age are given in table 33. To avoid the distorting effects of monthly and annual variations in condition, averages are given for each month's collection of each year. Since sex and stage of maturity have little influence on the value of *K* in the summer and autumn, the data include all the fish whose ages were determined. The data of table 33 do not point toward any dependence of condition on age. It is true that in 7 of 10 comparisons fish of age group II had lower average coefficients of condition than those of age group I. This difference can be explained, however, as the result of gear selectivity. Since the group-I fish were near the smallest size that could be retained by the impounding nets it is readily conceivable that only the heavier individuals of that age group were retained. There is less indication that gear selectivity affected the *K* values of age groups II and III although numbers of the group-II yellow perch were below the theoretical maximum length of escape (170 mm.). Gear selection possibly may account for the fact that group II had the larger average *K* in 9 of 10 comparisons for months earlier than October (see p. 221). In the later months, after group II has practically completed the third season of growth, age group III had the higher *K* values in all 7 comparisons (October, November, and December). Comparisons of age groups III and IV reveal that the former had the higher average *K* 6 times whereas the latter had the higher value 2 times. The two age groups

TABLE 32.—*Comparison of average weights and condition* (K) *of gravid and spent female yellow perch taken by impounding nets in Lake Erie, May 1929*

[Number of specimens in parentheses]

Standard-length interval	Average total length	Gravid females		Spent females		Loss of weight at spawning
		Average weight	*K*	Average weight	*K*	
	Inches	*Grams*		*Grams*		*Percent*
166 to 170 mm	7.8	89 (3)	1.89	86 (10)	1.82	3.4
171 to 175 mm	8.0	122 (5)	2.36	92 (20)	1.78	24.6
176 to 180 mm	8.2	115 (10)	2.05	99 (24)	1.75	13.9
181 to 185 mm	8.5	128 (29)	2.08	109 (52)	1.77	14.8
186 to 190 mm	8.7	138 (58)	2.08	118 (75)	1.78	14.5
191 to 195 mm	8.9	148 (82)	2.06	125 (101)	1.74	15.5
196 to 200 mm	9.1	161 (90)	2.08	135 (107)	1.74	16.2
201 to 205 mm	9.3	172 (100)	2.05	147 (92)	1.76	14.5
206 to 210 mm	9.5	186 (90)	2.06	157 (77)	1.75	15.6
211 to 215 mm	9.8	200 (40)	2.07	167 (48)	1.73	16.5
216 to 220 mm	10.0	211 (42)	2.04	175 (39)	1.69	17.1
221 to 225 mm	10.2	232 (26)	2.09	181 (7)	1.63	22.0
226 to 230 mm	10.4	246 (14)	2.08	214 (5)	1.81	13.0
231 to 235 mm	10.6	261 (6)	2.06	232 (3)	1.83	11.1
236 to 240 mm	10.8	291 (1)	2.16	230 (4)	1.71	20.7
Weighted average *K*			2.07 (596)		1.75 (664)	
Average loss in weight [1]						16.1

[1] Unweighted mean, based on those length intervals in which both gravid and spent fish are represented by at least 7 individuals.

had the same values in November 1927. Only three comparisons were available between age groups IV and V, and in each the older age group had the lower *K*. In general, fluctuations of *K* with age may be considered random among all age groups in which gear selectivity is absent or unimportant, although there was a tendency for a progressive decrease with age during the period April to September. It may be justified to conclude, however, that generally condition is independent of age in the Lake Erie yellow perch. No computation was made of average values of *K* for all data combined since the combined effects of monthly variations and of variations in the numbers of specimens would cause these averages to be of little significance.

TABLE 33.—*Coefficient of condition* (K) *of Lake Erie yellow perch according to age, month, and year of capture*

[Number of specimens in parentheses]

Month and year	Age group I	II	III	IV	V
April: 1932	----------	2.35 (2)	2.26 (98)	2.23 (33)	----------
July:					
1928	----------	2.05 (107)	1.85 (21)	1.93 (4)	----------
1929	----------	2.00 (13)	1.90 (131)	1.82 (16)	1.72 (1)
1930	----------	2.51 (128)	2.16 (40)	2.13 (4)	----------
August:					
1928	2.61 (7)	2.07 (393)	2.14 (14)	----------	----------
1929	2.05 (7)	1.91 (29)	1.86 (32)	----------	----------
1930	----------	2.32 (23)	2.14 (2)	----------	----------
September:					
1928	----------	2.00 (148)	1.94 (10)	----------	----------
1929	2.01 (6)	2.16 (22)	2.05 (136)	----------	----------
1930	2.38 (1)	2.41 (21)	2.12 (3)	----------	----------
October:					
1927	1.90 (74)	1.89 (61)	1.93 (28)	1.96 (4)	1.91 (2)
1928	----------	1.96 (61)	2.05 (9)	2.02 (1)	----------
November:					
1927	2.01 (161)	1.92 (129)	2.08 (19)	2.08 (1)	----------
1928	1.99 (4)	1.99 (123)	2.02 (16)	----------	----------
1929	1.87 (28)	1.79 (170)	1.84 (218)	1.80 (33)	1.78 (2)
1937	2.30 (62)	2.07 (66)	2.15 (3)	----------	----------
December: 1929	1.93 (42)	1.91 (138)	1.94 (115)	1.93 (12)	----------

The range of fluctuation of *K* for the age groups of Lake Erie yellow perch extended from 1.72 to 2.61. The individual yellow perch were found to have values of *K* ranging from 1.13 to 3.23, with the average 1.91. Comparisons of these values of *K* with those found in other waters of the Great Lakes reveal that the yellow perch of Lake Erie were a little heavier than the ones in Saginaw Bay (Hile and Jobes 1941), about equal to those in Green Bay, and somewhat more slender than the yellow perch in northwestern Lake Michigan (Hile and Jobes 1942).

Influence of rate of growth on value of K

The possibility that the values of *K* of the age groups were influenced by varying proportions of faster or slower growing individuals has been investigated. Table 34 permits comparisons of *K* for yellow perch of the same length but of different ages and for fish of different lengths but of the same age. All comparisons have been limited to fish collected in the same year and month. The data have been limited further to the 1927 and 1929 collections from trap nets since those collections had the most suitable distribution of the age groups, that is, contained adequate samples from more than one age group. It may be seen that there were no consistent differences between the values of *K* for fish of the same length but different age. In other words, neither the older (slow growing) nor the younger (rapid growing) yellow perch maintained a consistent advantage. This indication that individual growth rate did not influence individual condition is supported by the fact that the longer (more rapid growing) indi-

TABLE 34.—*Comparison of condition* (K) *in Lake Erie yellow perch at different ages and lengths taken by trap nets*

[Number of specimens in parentheses]

Standard-length interval	Average total length	Value of *K* in— October 1927, I	October 1927, II	November 1927, I	November 1927, II	November 1929, II	November 1929, III	December 1929, II	December 1929, III
	Inches								
121 to 130 mm	5.9	----------	1.67 (1)	1.96 (1)	3.23 (1)	----------	----------	----------	----------
131 to 140 mm	6.3	1.71 (4)	----------	1.98 (6)	----------	----------	----------	----------	----------
141 to 150 mm	6.7	1.79 (7)	1.71 (3)	2.02 (27)	2.03 (5)	1.83 (2)	----------	1.93 (2)	----------
151 to 160 mm	7.2	1.95 (17)	1.96 (3)	1.99 (31)	1.95 (9)	1.81 (9)	----------	1.85 (11)	----------
161 to 170 mm	7.6	1.87 (25)	1.91 (12)	2.01 (59)	1.97 (16)	1.70 (19)	1.73 (1)	1.86 (21)	2.02 (1)
171 to 180 mm	8.1	1.87 (16)	1.82 (10)	1.96 (34)	2.00 (38)	1.76 (23)	1.70 (4)	1.87 (30)	1.87 (11)
181 to 190 mm	8.6	1.80 (5)	1.88 (14)	1.91 (2)	1.99 (33)	1.76 (42)	1.72 (13)	1.88 (29)	1.83 (14)
191 to 200 mm	9.0	----------	1.81 (11)	1.94 (1)	2.04 (17)	1.75 (43)	1.73 (34)	1.81 (18)	1.86 (21)
201 to 210 mm	9.4	----------	1.85 (6)	----------	2.01 (8)	1.73 (24)	1.78 (52)	1.85 (19)	1.88 (25)
211 to 220 mm	9.9	----------	1.81 (1)	----------	2.02 (4)	1.81 (8)	1.78 (48)	1.85 (7)	1.93 (23)
221 to 230 mm	10.3	----------	----------	----------	----------	----------	1.83 (36)	1.76 (1)	1.93 (15)
231 to 240 mm	10.7	----------	----------	----------	----------	----------	1.87 (18)	----------	2.01 (5)
241 to 250 mm	11.2	----------	----------	----------	----------	----------	1.93 (10)	----------	----------
251 to 260 mm	11.6	----------	----------	----------	----------	----------	1.78 (2)	----------	----------

viduals of an age group did not differ in condition from the shorter, slower-growing fish of the same group.

The conclusion concerning the independence of growth rate and condition disagrees with Van Oosten's (1937) observation that the slower-growing individuals of the Lake Superior longjaw (*Leucichthys zenithicus*) were in the better condition. The same author (Van Oosten 1938) found, however, that growth rate and condition were not correlated in the Lake Erie sheepshead (*Aplodinotus grunniens*).

Effect of type of gear on determining value of *K*

The study of condition in the preceding sections was confined entirely to data from collections taken by trap and pound nets. Gill-net samples were excluded because of the effect of the selective action of that gear on the determination of *K*. The extent to which gill-net selection affects the determination of the value of the coefficient of condition may be seen from the data of table 35 which show the average *K* for each centimeter-length interval of the Lake Erie yellow perch taken from trap and gill nets in the same month and calendar year. Only five series were available for comparisons. The consistency with which the value of *K* was greater for fish caught in gill nets than in trap nets each month leaves little doubt that gill nets capture relatively heavier yellow perch than do impounding nets. In no single month did yellow perch taken in trap nets have average coefficients of condition as great as those of fish taken in gill nets.

The unweighted averages given in the two columns at the extreme right of table 35 give further information on the general influence of the type of net on the value of *K*. These averages were computed only for those lengths that were represented in the samples in all the months for which comparisons are given. An examination reveals that fish taken in gill nets had consistently higher average values of *K*. The averages also reveal a difference between gill- and trap-net samples with respect to the variation of *K* with length. Except for the relatively high figures at 141 to 150 mm. and 161 to 170 mm., the values of *K* tended to be constant at all lengths in the trap-net samples. The cause of the high values of *K* in these shorter fish taken in impounding nets has been discussed previously (p. 256). The nearly constant value of *K* over the interval 171 to 220 mm. is probably descriptive of true condition in the population. In the gill-net samples, on the contrary, *K* decreased consistently with each increase in length over the entire interval of 171 to 240 mm. In other words, the gill nets selected the heavier short fish and the slenderer long fish. At lengths below 171 mm. the captures of perch by gill nets were probably in large measure "accidents," that is, the fish were tangled in the meshes by their fins or the marginal bones of the mouth. The selective action of gill nets with

TABLE 35.—*Effect of type of gear on determination of the coefficient of condition* (K) *in Lake Erie yellow perch*

[Number of specimens in parentheses]

Standard-length interval	Average total length	September 1927		October 1927		July 1928		August 1928		November 1928		Average[1] K	
		Trap nets	Gill nets	Trap nets	Gill nets	Trap nets	Gill nets	Trap nets	Gill nets	Trap nets	Gill nets	Trap nets	Gill nets
	Inches												
91 to 100 mm.	4.5						2.23 (1)						
101 to 110 mm.	5.0							2.78 (1)					
111 to 120 mm.	5.4							2.86 (3)	2.13 (1)				
121 to 130 mm.	5.9		1.96 (3)	1.67 (4)	2.31 (1)			2.53 (2)					
131 to 140 mm.	6.3	1.90 (2)	1.90 (5)	1.70 (16)	1.90 (1)		2.70 (1)	2.72 (1)			1.90 (1)		
141 to 150 mm.	6.7	1.76 (1)	1.86 (9)	1.87 (38)	1.95 (2)	2.36 (5)	2.30 (8)	2.11 (12)	2.08 (2)	1.97 (2)	1.97 (1)	2.01	2.03
151 to 160 mm.	7.2	1.80 (1)	1.97 (7)	1.95 (67)	1.98 (1)	2.22 (18)	2.14 (13)	2.10 (65)	2.04 (3)		1.79 (1)		
161 to 170 mm.	7.6	1.76 (7)	1.80 (1)	1.93 (98)	2.00 (3)	2.14 (25)	2.16 (24)	2.04 (123)	2.19 (20)	2.12 (2)	2.12 (1)	2.00	2.05
171 to 180 mm.	8.1	1.89 (19)	2.64 (1)	1.91 (115)	2.02 (2)	1.98 (33)	2.11 (32)	2.01 (146)	2.19 (70)	2.00 (17)	1.94 (5)	1.96	2.18
181 to 190 mm.	8.6	1.82 (23)	2.16 (6)	1.90 (132)	2.16 (2)	2.06 (32)	2.18 (51)	2.03 (99)	2.18 (209)	1.99 (35)	2.10 (11)	1.93	2.16
191 to 200 mm.	9.0	1.93 (22)	2.05 (39)	1.90 (153)	2.02 (11)	1.90 (10)	2.17 (74)	2.00 (42)	2.14 (499)	1.98 (43)	2.09 (52)	1.94	2.09
201 to 210 mm.	9.4	1.88 (21)	2.05 (168)	1.91 (140)	2.08 (29)	1.50 (4)	2.06 (79)	1.97 (9)	2.08 (468)	1.96 (27)	2.05 (116)	1.94	2.06
211 to 220 mm.	9.9	1.88 (13)	2.00 (261)	1.94 (71)	1.97 (51)	1.94 (2)	2.02 (49)	2.01 (3)	2.01 (212)	1.96 (15)	1.95 (101)	1.95	1.99
221 to 230 mm.	10.3	1.87 (12)	1.99 (99)	1.94 (49)	1.96 (32)		1.91 (24)	2.11 (2)	1.96 (43)	1.89 (2)	1.91 (59)		1.95
231 to 240 mm.	10.7	1.92 (3)	1.91 (20)	1.92 (4)	1.83 (5)		1.86 (9)	1.68 (1)	1.91 (11)	2.25 (1)	1.88 (10)		1.88
241 to 250 mm.	11.2	1.73 (1)	1.85 (6)	1.90 (5)	1.90 (4)		1.68 (3)		1.78 (4)				
251 to 260 mm.	11.6			1.96 (2)			1.94 (1)	2.06 (1)					
261 to 270 mm.	12.1												
271 to 280 mm.	12.5				1.99 (1)								
Average[2]		1.87 (125)	2.01 (625)	1.91 (894)	1.99 (145)	2.06 (129)	2.10 (369)	2.04 (510)	2.10 (1,542)	1.98 (144)	2.00 (358)	1.96	2.04

[1] Unweighted mean, computed only for length intervals that were represented in all samples.
[2] Unweighted mean.

respect to condition would not be expected to operate on these accidental captures. The selection by gill nets of yellow perch according to the condition of the fish is similar to the action of drift (gill) nets on marine herring (Farran 1936) and supports the previous conclusion of a like action among the smaller perch by impounding nets.

From the preceding discussion it appears not only that gill nets tend to take relatively heavier yellow perch in Lake Erie than trap nets but that in gill-net samples K decreased with increases in length. The resulting distortion of the data justifies the exclusion of gill-net material from the study of condition.

SIZE AT MATURITY

A knowledge of size at sexual maturity has its practical application in the determination of the minimum legal size that may be needed to protect an adequate spawning stock. Data on the relation between total length and the percentage of maturity of the yellow perch taken in 1927–37 are given for the sexes separately and combined in table 36. The males matured at a much smaller size than the females: 47.4 percent of the males were mature or maturing at 6 to 6.5 inches and 48.4 percent of the females were mature or maturing at 8 to 8.5 inches. Any minimum legal size for the Lake Erie yellow perch, therefore, must be based on the maturity of females.

The shortest ½-inch total-length interval that contained a large percentage of mature females was 8 to 8.5 inches. At that length 48.4 percent were mature. At lengths of 8.5 to 9 inches 86.1 percent were mature, and at 9 to 9.5 inches 97 percent were mature. All females 9.5 inches and longer were mature. These data show that 86.1 percent of the females were mature in the shortest ½-inch total-length interval (8.5 to 9) available to the commercial fishery operating under the 8½-inch minimum legal size now effective in the Michigan and Ohio waters of Lake Erie (no size limit on yellow perch in Pennsylvania and New York waters). The samples collected in 1947–48 showed an even greater proportion of mature female yellow perch since 51 of 53 individuals (96.2 percent) in the 8.5- to- 9-inch interval were mature.

On the basis of the data in table 36 it is apparent that the great majority of female yellow perch in Lake Erie mature at total lengths between 8 and 9 inches. Reference to table 19 reveals that most of the fish with these lengths belonged to age group II (174 mm. standard length is equivalent to 8 inches total length, and 196 mm. equals 9 inches). It thereby becomes apparent that the majority of the female yellow perch reach maturity in Lake Erie during their third year of life and spawn for the first time early in their fourth year (as age-group-III fish). The average calculated length of the females at the end of the third year of life was 8.6 inches (table 7).

Although the data in tables 36 and 19 are from fish taken late in the fall one would expect little, if any, growth in winter or until spawning time in the spring. The percentages of maturity at the different sizes determined from fall samples, therefore, may be applied reasonably well to the spawning-season population. The small sample

TABLE 36.—*Relation between length of Lake Erie yellow perch and proportion of mature individuals, 1927–37*

Total-length interval [1]	Fork-length interval [1]	Standard-length interval	Sexes combined			Female			Male		
			Number mature	Number immature	Percentage mature	Number mature	Number immature	Percentage mature	Number mature	Number immature	Percentage mature
Less than 6.0 inches	Less than 5.7 inches	Less than 127 mm.	0	38	0	0	15	0	0	23	0
6.0 to 6.5 inches	5.7 to 6.3 inches	127 to 140 mm.	10	17	37.0	1	7	12.5	9	10	47.4
6.5 to 7.0 inches	6.3 to 6.7 inches	141 to 149 mm.	26	50	34.2	0	31	0	26	19	57.8
7.0 to 7.5 inches	6.7 to 7.2 inches	150 to 161 mm.	82	154	34.7	7	95	6.9	75	59	56.0
7.5 to 8.0 inches	7.2 to 7.7 inches	162 to 172 mm.	216	189	53.3	30	131	18.6	186	58	76.2
8.0 to 8.5 inches	7.7 to 8.2 inches	173 to 183 mm.	521	137	79.2	103	110	48.4	418	27	93.9
8.5 to 9.0 inches	8.2 to 8.7 inches	184 to 195 mm.	901	64	93.4	348	56	86.1	553	8	98.6
9.0 to 9.5 inches	8.7 to 9.2 inches	196 to 206 mm.	737	15	98.0	423	13	97.0	314	2	99.4
9.5 to 10.0 inches	9.2 to 9.7 inches	207 to 218 mm.	426	0	100.0	290	0	100.0	136	0	100.0
10.0 inches and over	9.7 inches and over	219 mm. and over	236	0	100.0	190	0	100.0	46	0	100.0

[1] Fish included within each total-length and fork-length interval had lengths equal to the lowest and up to, but not including, the greatest length of the interval.

obtained during the breeding season suggests that spawning in itself may protect immature females since only 3 of 27 females (11.1 percent) in the entire sample were immature. The largest of the immature females in this sample was 8¼ inches total length.

SEX RATIO

The number of specimens, the sex ratio expressed as the percentage of males in the total for the daily collections, and the ratios for the combined collections of each month are shown in table 37 for samples containing 50 or more fish. All samples were obtained from commercial impounding nets. The sex ratio of the individual samples fluctuated rather widely within each month except August, September, and December, 1929, and April 1932. This wide fluctuation points to a segregation of the sexes throughout much of the year. A segregation may occur, however, in a month in which the sex ratio is not highly variable (as the predominance of males in April 1932).

The wide daily variation in the relative abundance of females and males in the samples makes it difficult to determine a truly reliable sex ratio for the perch of Lake Erie. The data in table 37 suggest that a large number of relatively small samples, preferably distributed throughout the season, will permit a more accurate estimate of the relative abundance of the sexes than may be obtained from a few large samples. Table 37 reveals that the average ratio for all samples combined, except those taken in April, was 96 females to 100 males (50.9 percent). The April samples were omitted from the computation because the sex ratio obviously was distorted by the presence of disproportionately large numbers of males.

The April (1928 and 1932) collections were consistent in the strong preponderance of males. The males predominated also in both samples obtained late in May 1929. On the other hand, the females were relatively more abundant in the samples obtained May 9 and 10, 1929. One sample collected during June 1929 indicated that the sexes were segregated, whereas the other showed no marked preponderance of either sex. The data obtained during July 1929 showed an increasing proportion of males as the month advanced. The males were somewhat more abundant than the females in each sample taken during August, but on no date, with the possible exception of August 6, were they strongly predominant. No strong dominance of either sex was evident in the material taken in September. The single October collection contained nearly 70 percent males. Only two of seven samples taken during November (November 26, 1929, and November 7, 1937) showed sufficiently disproportionate representation of the sexes to be interpreted as indicative of segregation. There was little evidence of segregation on the two dates in December. In general, then, it appears that the sexes were segregated during April and May, and probably to some extent during part of June, July, August, October, and November. There is no evidence of any distinct segregation during September and December; however, only two samples were taken in each of these months.

TABLE 37.—*Percentage of males in the daily samples of Lake Erie yellow perch*

Date	Number of specimens	Percentage of males	Date	Number of specimens	Percentage of males
1928: Apr. 30	94	95.7	1929:		
1929:			Nov. 2	72	51.4
May 9	110	30.9	Nov. 12	251	47.0
May 10	147	26.5	Nov. 16	114	57.9
May 15	228	74.6	Nov. 22	51	54.9
May 25	132	69.7	Nov. 26	86	72.1
May, all samples	617	54.3	November, all samples	574	54.2
June 20	563	37.1	Dec. 4	136	55.1
June 29	90	54.4	Dec. 7	171	57.3
June, all samples	653	39.5	December, all samples	307	56.4
July 1	202	30.7	1932:		
July 6	65	36.9	Apr. 11	70	75.7
July 13	447	48.1	Apr. 13	63	84.1
July 20	114	60.5	April, all samples	133	79.7
July 30	68	64.7	1937:		
July, all samples	896	46.2	Nov. 3	65	47.7
Aug. 6	252	61.1	Nov. 7	66	68.2
Aug. 17	87	56.3	November, all samples	131	58.0
Aug. 22	86	52.3	Grand total, April excluded	4,313	50.9
Aug. 26	178	55.6			
Aug. 31	133	52.6			
August, all samples	736	56.7			
Sept. 3	216	47.2			
Sept. 23	114	55.3			
September, all samples	330	50.0			
Oct. 26	69	69.6			

The reasons for the apparent segregation of the sexes of the Lake Erie yellow perch are largely unknown. The segregation during April and May perhaps was due to the spawning-season habits of the species. A segregation associated with sex differences in feeding habits during the summer months, such as was found by Eschmeyer (1938), may occur. Materials for study of the food of the Lake Erie perch were not available. Another possible factor in the fluctuating sex ratios during the summer is age. The females tend to increase in relative abundance with advancing age; consequently, variation in the age composition of the samples would contribute to an apparent segregation of the sexes. However, this explanation can account for only part of the variation in the sex ratio since the ratios varied widely in samples of fish of the same age but taken on different days of the same month (table 38).

Age determinations of certain of the above materials permit the examination of the relation between the proportional representation of the sexes and age. Table 38 shows the sex ratio of Lake Erie yellow perch in a number of samples, expressed as the percentage of males in the total, by age group. Because of the daily fluctuations in sex ratio the data have been presented for daily catches as well as by the month and for all months combined. In spite of certain exceptions, it may be said that there was a progressive decrease in the proportion of males as the age increased. It is apparent that either the relative abundance of males in the stock was progressively less with each yearly increase in age, or that the females were progressively more available to the fishery.

TABLE 38.—*Percentage of male Lake Erie yellow perch by age groups, according to date of capture*

[Total number of specimens in parentheses]

Date	Age group				
	I	II	III	IV	V
1929:					
July 1	----------	38.5(13)	26.7(131)	12.5(16)	0(1)
Sept. 23	0(1)	33.3(9)	57.7(104)	----------	------
Nov. 12	83.3(18)	49.4(83)	43.8(121)	33.3(27)	0(2)
Nov. 16	80.0(5)	55.8(52)	57.4(54)	66.7(3)	------
Nov. 26	80.0(5)	74.3(35)	67.4(43)	100.0(3)	------
November, all samples	82.1(28)	56.5(170)	51.8(218)	42.4(33)	0(2)
Dec. 4	83.3(6)	52.7(55)	56.1(66)	44.4(9)	------
Dec. 7	69.4(36)	51.8(83)	59.2(49)	66.7(3)	------
December, all samples	71.4(42)	52.2(138)	56.5(115)	50.0(12)	------
1932:					
Apr. 11	----------	100.0(2)	83.3(48)	55.0(20)	------
Apr. 13	----------	----------	88.0(50)	69.2(13)	------
April, all samples	----------	100.0(2)	85.7(98)	60.6(33)	------
1937:					
Nov. 3	71.4(28)	31.4(35)	0(2)	----------	------
Nov. 7	73.5(34)	61.3(31)	100.0(1)	----------	------
November, all samples	72.6(62)	45.5(66)	33.3(3)	----------	------
Grand total, April excluded	73.7(133)	52.0(396)	48.0(571)	36.1(61)	0(3)

Sex differences in the age of entry into the fishery can produce an "apparent" change in the sex ratio with increase in age. The earlier attainment of maturity by the males, together with their apparent tendency to remain on the spawning grounds longer than the females, doubtless accounted for the great preponderance of males in age groups I and II and their abundance in age group III of the spawning-run (April 1932) collection. Consequently, the decrease in relative abundance of males with increase in age in that collection cannot be accepted as descriptive of the general population. Significance must be ascribed, however, to the fact that a similar, if less pronounced, change in the sex ratio occurred in the collections of other months when there is no reason to believe that a segregation on the basis of maturity existed. In a majority of the samples taken in months other than April the males exhibited a tendency to decrease in relative abundance with increase in age. It may be concluded that this tendency of the males is a real and not an apparent characteristic of the Lake Erie yellow perch.

The acceptance of a shifting sex ratio with age as characteristic of the Lake Erie yellow perch population carried with it the assumption of a differential mortality of the sexes. This difference in death rate may have its origin in a selective destruction in the fishery or it may depend on sex differences in the natural mortality rate.

It would appear that a differential destruction of the sexes by the fishery is the most plausible explanation of the changes in sex ratio with age of the Lake Erie yellow perch. The males mature at a younger age, and consequently, are taken by the nets during the spawning season earlier in life than are the females. Furthermore, the apparent tendency for the males to arrive earlier and stay longer than the females on the spawning grounds increases the chances of capture for any particular male, and presumably would result in effect in a more intensive fishery for that sex. The monthly records of the Ohio Division of Conservation for the years 1930, 1931, 1939, and 1940 [15] reveal that during those years the spawning-season fishery (April and May) produced 28.3 percent of the perch caught during the entire year in Ohio waters. Fishing intensity during the spawning season, when the males predominate in the catches, is therefore sufficiently great to account for an important differential destruction of the sexes. The apparent preponderance of females during early May would reduce, but probably not eliminate, the effect of the spawning-season fishery on the changes in the sex ratio. It seems impossible to escape the conclusion that the changes in sex ratio with age of the Lake Erie yellow perch were caused in large measure by a differential destruction by the fishery chiefly during the spawning season.

It should be mentioned that the minimum legal size operates to reduce the effect of the differential destruction of the males in the spawning-run fishery. Large numbers of mature but illegal-sized males on the grounds are captured but returned to the lake. However, it is known that about 14 percent of the illegal-sized yellow perch are destroyed, or seriously injured, when the nets are lifted. It is not improbable that the total destruction of illegal-sized males during a spawning season is considerable, in spite of the fact that none enters the commercial catch.

Other factors that might have had an influence on the changes in sex ratio with age will be mentioned briefly. Geiser (1923, 1924a, 1924b) concluded that the females (of fishes, as of many other animals) are inherently more viable than the males under adverse conditions. Hile (1936) stated that a differential natural mortality was the most probable cause of the changes in sex ratio of the cisco, *Leucichthys artedi*, with age. There is no fishery for the cisco in the Wisconsin lakes whose populations he studied. Hile pointed out further that there was no basis for any assumption of a differential destruction of the sexes by predatory forms. Any possible effect of a differential natural mortality of the sexes would be obscured in the Lake Erie yellow perch because of the differential destruction by the fishery.

SUMMARY

1. The annual production of yellow perch from the United States waters of Lake Erie fluctuated about an average of 3 million pounds in the early (1885–99) period of the fishery. The average declined to about 2 million pounds in 1900–1927, increased to over 7½ million pounds in 1928–35, and fell to about 2½ million pounds in 1936–47. There was a definite tendency for the variability in annual production to increase in each succeeding period except the most recent one (1936–47). The trend in average annual production from the Ontario waters was similar to that in United States waters only in the last two periods, 1928–35 and 1926–47. The factors of fishing intensity (increases in the number of nets, and improvements in nets, boats, and methods of lifting gear), changes in fishery laws and the administration of the laws, and abundance were considered in evaluating both the long- and short-period trends in the annual production of Lake Erie yellow perch.

2. In this study, age determinations and growth calculations were made from examination and measurement of the scales of 4,377 yellow perch taken by trap nets from Lake Erie. In addition, ages were determined of 576 specimens employed in a special study of the relation between body length and scale length, and of 1,566 fish taken by gill nets. Analysis of the length-weight relation was based on 23,158 specimens, and the length frequencies were compiled from the measurements of 59,779 individuals. The materials were collected during the years 1927 to 1930, and in 1932, 1934, 1937, and 1943 to 1948. Data from the different sections of the lake were combined after preliminary examinations revealed the combination justifiable.

3. Validity of the use of annuli on the scales of the yellow perch as year marks was established for the first time on the basis of the following observations: (a) The 1927, 1928, and 1929 collections were dominated by the same year class that was represented by larger and, according to scale readings, older fish in each succeeding year; (b) the annulus was on the margin of the scale in the early season but was progressively farther from the margin in mid-July, September, and December; (c) the lengths calculated from scale measurements for different years of life agreed

[15] These four years are the only ones close to the period during which sex data were obtained for which monthly records of catch are available.

rather closely with the empirical lengths of fish shown by scale readings to have completed the same number of years of life, and lengths calculated for the same year of life agreed more closely with each other than with lengths computed for any other year regardless of the age of the fish employed in the calculations.

4. The more important criteria employed to determine the presence of an annulus were the discontinuity between successive growth fields which resulted in well-defined "cutting over" of the circuli, particularly in the lateral region of the scale, and the fragmented, irregular appearance of the last circulus laid down in each growing season. False annuli occurred but it is believed they usually could be detected by the lack of cutting over, their generally indefinite appearance, and their position with respect to true annuli. About 5 percent of the scales were discarded as unfit for age determinations.

5. Annulus formation may be completed as late as July 1 in some years. In spite of the apparent coincidence of spawning and the completion of the annulus in some years, the annulus cannot be considered as a spawning mark since immature individuals form annuli identical in appearance with those formed by mature fish, and the characteristics of a typical spawning mark as found on the scales of other fish are absent from yellow perch scales.

6. Detailed data are provided on the relation between body length and scale length of the American yellow perch.

7. The Dahl-Lea method of calculating lengths by direct proportion was applicable to the yellow perch when the calculated standard lengths were 96 mm. (4.5 inches total length) or greater. When these lengths were less than 4.5 inches they were corrected by use of a table containing the corrected length corresponding to each length computed by direct proportion. These corrected calculated lengths, derived from an empirical curve of the body-scale relation, were always greater than the uncorrected lengths. Correction of the computed lengths failed, however, to eliminate the discrepancies between corresponding lengths calculated for different age groups.

8. Discrepancies occurred between corresponding calculated lengths in all years of life. The computed lengths for any one year of life decreased progressively as the fish for which the computations were made became older. Discrepancies in first-year calculated lengths were small among age groups older than group I.

9. The discrepancies in calculated lengths were shown to represent real rather than "apparent" differences in growth since large errors could not result from the method of calculation.

10. It was concluded that the selective action of gear, selection according to maturity at the time of the spawning run, and selection according to legal-size limit, all of which doubtless produced a selective destruction of the more rapidly growing individuals in the fishery, were the chief causes of the discrepancies in the calculated growth of the Lake Erie yellow perch, but that a differential natural mortality, correlated with rate of growth, was a possible supplementary factor. The presence of discrepancies between corresponding calculated lengths of different age groups of the same year class proved that annual fluctuations in growth rate were not an important source of the discrepancies in calculated lengths.

11. The females grew in length a little more rapidly than the males during the first year of life, at the same rate in the second year, and more rapidly in all later years.

12. The annual increments of growth in length decreased progressively with age in both sexes.

13. Growth compensation occurred in the Lake Erie yellow perch, but usually did not appear before the third year of life. The difference in average length between the largest and smallest yearlings was maintained or increased in the second year.

14. It was estimated that the proportions of growth completed at the end of the different months of the 1928 and 1929 seasons were 15 percent for June, 50 percent for July, 80 percent for August, and 100 percent for September. However, growth continued through October in 1927.

15. Significant correlations could not be demonstrated between annual fluctuations in growth rate and precipitation, percentage of possible sunshine, and mean wind velocity. Significant positive correlations were determined, however, between growth and mean air temperatures for the following combinations of months: May, July, and September; May and September; July and September. Mean air temperatures in August exhibited significant negative correlation with annual fluctuations in growth rate.

16. The yellow perch of Lake Erie grew more rapidly than did most of the perch of other waters with which comparisons were made.

17. Scales of Lake Erie yellow perch used by Harkness (1922) were compared with those in the present study, and the annual increments of calculated length indicated no pronounced change in the growth rate of 1927 from that of 1920.

18. Length frequencies of the impounding-net collections had a unimodal distribution each year, but gill-net collections showed both unimodal and bimodal distributions.

19. The position of the mode in the length frequencies fluctuated from year to year, and was influenced to a considerable extent by the average length of the dominant age group. The modal frequency fluctuated over a wider range in the impounding-net collections than in the gilled fish from gill nets because of the greater selectivity of the latter gear.

20. The coefficient of condition *K* of individual Lake Erie yellow perch ranged from 1.13 to 3.23, and averaged 1.91. The state of the gonads affected the coefficient of condition of the females during the spawning season, at which time they lost approximately 16 percent of their prespawning weight. There are no data on the loss of weight of males at spawning. At other periods condition was not related to sex or state of maturity.

21. The coefficient of condition increased sharply from June to July and remained at a high level in August and September. In two of three years condition declined in the autumn, but in the third year it improved.

22. Weight of the Lake Erie yellow perch increased at a rate slightly greater than the cube of the length. Over the interval of length to which the equation was fitted the empirical and calculated weights agreed closely.

23. The year class of 1926 was unusually strong and dominated the impounding-net catches of 1927, 1928, and 1929. There is evidence from the samples of legal-sized yellow perch that the 1942 year class also was one of exceptional strength. The year classes of 1936 and 1944 are believed to have been of more than ordinary size.

24. No relation between strength of year classes and meteorologic conditions could be demonstrated.

25. The commercial catch (legal size) of both impounding and gill nets was dominated by age group III in the spring and early summer. Dominance by group-II fish was characteristic of the late-season catches of both types of gear, although there are exceptions when age group III may be dominant in both gears during the autumn.

26. The sex ratio was determined to be 96 females to 100 males in the combined data from all samples except those obtained in April, when the ratio was obviously distorted. Evidence was obtained of segregation according to sex in all months from April to November, inclusive, except September. It was pointed out that the number of samples employed, as well as the number of individuals examined, was important in the accurate determination of the sex ratio. The relative abundance of females in a year class increased with age.

27. Male yellow perch in Lake Erie matured at an earlier age and at a smaller size than females. Practically all males were mature or maturing at a total length of 8 inches. Proportions of females mature or maturing at different total lengths were 48.4 percent at 8 to 8½ inches, 86.1 percent at 8½ to 9 inches, and 97 percent at 9 to 9½ inches.

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