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FLUCTUATIONS IN THE POPULATION OF YELLOW PERCH, *PERCA FLAVESCENS* (MITCHILL), IN SAGINAW BAY LAKE HURON

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ABSTRACT

The average annual commercial production of Saginaw Bay yellow perch dropped from 1,961,309 pounds in 1891–1916 to 499,938 pounds in 1917–55. Since 1938 (1939–55), the catch has exceeded 500,000 pounds in only 3 years. The small catches of 1939–55 do not reflect scarcity of yellow perch. The catch of legal-sized fish per unit-of-effort has tended to increase, but fishing intensity has decreased sharply.

This paper is written around two major themes: Comparison of perch collected in 1929–30 with specimens collected in 1943–55, as to growth rate, age composition, size distribution, length-weight relation, and sex ratio; description and inquiry into the causes of fluctuations in the strength of the year classes of 1939–52, and of the growth rate during 1942–54.

The growth in length and weight of Saginaw Bay yellow perch in 1943–55 was the slowest yet reported from any Great Lakes waters. The decrease in growth rate in Saginaw Bay was believed to have resulted from a more than sevenfold increase in the population density. A "space factor" rather than competition for food may account for the decline in growth rate. Fish of the 1943–55 samples gave no evidence of a scarcity of food; on the contrary, they were heavier for their length than fish caught in 1929–30.

The weight of yellow perch in the 1943–55 samples increased as the 3.262 power of the length. Seasonal changes in the length-weight relation were small. Females lost 12.3 percent of their weight at spawning.

Age determination and growth calculation were based on the scales of 4,285 fish, 3,407 of them collected during the spawning seasons of 1943–55 and the remainder at other seasons in 1955. The average age of fish in impounding-net samples collected in the spring increased between 1929–30 (3.8 years) and 1943–55 (4.3 years), and growth declined sharply. Saginaw Bay yellow perch of the 1929–30 samples reached legal length (8½ inches) in 3 years but those taken in 1943–55 required more than 5 years to attain the same size. At the same time the modal length dropped from 8.5–8.9 to 6.5–6.9 inches and the percentage of legal-sized fish from 74 to 11 percent. In both periods, the females averaged larger than the males and grew more rapidly.

Males were relatively more plentiful in 1943–55 (62 percent) than in 1929–30 (25 percent). The percentage of males decreased with increase of age in 1929–30 but increased in 1943–55. Both males and females attained sexual maturity at a small size (nearly all males were mature at 5.0–7.5 inches; 80 percent of females at 7.0–7.4 inches).

The strongest year classes were those of 1939 and 1952. The weakest were those of 1941 and 1945. Year-class strength was correlated significantly with production 4, 5, and 6 years later, but it was not correlated with the abundance of legal-sized fish in the year of hatching or with temperature, precipitation, water level, and turbidity.

The annual fluctuation of growth (length) in the first and in later years of life were dissimilar. First-year growth was poorest in 1942 but tended strongly to improve in subsequent years. First-year growth was correlated negatively with turbidity in June but was not correlated with year-class strength or other factors investigated. Fluctuations of growth in later years of life were largely without trend. Growth in these years was not correlated with the abundance of legal-sized fish, temperature, precipitation, or turbidity, but varied inversely with the water level for May to October.

FLUCTUATIONS IN THE POPULATION OF YELLOW PERCH, *PERCA FLAVESCENS* (MITCHILL), IN SAGINAW BAY, LAKE HURON

By Salah El-Din El-Zarka, University of Michigan[1]

The yellow perch, *Perca flavescens* (Mitchill), is one of the most important and widely distributed food fishes of the northeastern United States and southeastern Canada. It inhabits the Great Lakes, inland lakes, and large streams but is never plentiful in Lake Superior. Because of this wide distribution and its frequent great abundance, the yellow perch has become important to both commercial fishermen and anglers in many localities. The commercial fishery statistics for 1954 from the United States and Canada indicate that the yellow perch fishery contributed 16,230,000 pounds or 13 percent of the total production of the lake fisheries. It was surpassed only by the lake herring which formed 18 percent of the total catch. In United States waters of the Great Lakes, the yellow perch together with the chubs and lake herring formed the largest percentage of the catch (lake herring 25.6 percent, chubs 13.5 percent, and yellow perch 10.0 percent). Statistics are not available on the sport fishery of the Great Lakes, but it is well known that in many localities the anglers annually remove more yellow perch than do the commercial fishermen. Despite the wide range of the species, the commercial production of yellow perch is mostly concentrated in Lake Erie (especially the western part of the lake), Green Bay in Lake Michigan, and Saginaw Bay in Lake Huron.

Few studies had been done on yellow perch in the Great Lakes. Jobes (1952) published a detailed account of the life history of yellow perch in Lake Erie and Hile and Jobes (1942) issued a small paper on the growth in Wisconsin waters of Green Bay and northern Lake Michigan. In Saginaw Bay, a most important center of yellow perch production in the State of Michigan, only one small paper has been published (Hile and Jobes 1941) reporting the age composition and the growth rate of fish collected in 1929 and 1930.

Since 1943 the annual visits to Saginaw Bay by the United States Fish and Wildlife Service employees indicated that the yellow perch population was undergoing a definite change in its size structure. The fish were much smaller than in previous years and the percentage of legal-sized fish ($8\frac{1}{2}$ inches) likewise was low. Thus, because of the apparent threat to this valuable fishery and hence to the economy of Saginaw Bay commercial fishermen, it was decided to collect materials that would permit the determination of possible changes in the perch stocks since earlier observations and would also throw light on various aspects of the biology not previously explored. The collections of materials which were started by the Fish and Wildlife Service staff in 1943 formed the basis of the present study. From these data it has been possible to describe the general status of the population and follow the changes in age composition, growth, and other biological characters.

This study of yellow perch in Saginaw Bay was made possible by a cooperative arrangement between the Department of Fisheries, School of Natural Resources, University of Michigan, and Great Lakes Fishery Investigations, Fish and Wildlife Service, United States Department of the Interior. I am grateful to Dr. Karl F. Lagler, Chairman of the Department of Fisheries, for recommending me to the Fish and Wildlife Service and to Dr. James W. Moffett, Chief of Great Lakes Fishery Investigations, for accepting me temporarily in his research group. As a de facto member of the Great Lakes staff I was permitted the use of past collections of fish, given

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assistance in the collection of additional materials, and granted access to all facilities necessary to the proper conduct of my research.

John E. Bardach, Chairman of my doctoral committee, planned and supervised my schedule of graduate training; Dr. Ralph Hile directed my research and the preparation of this dissertation; other members of my committee gave most useful advice and assistance.

Various staff members of the Fish and Wildlife Service were helpful in the field and laboratory. Leonard S. Joeris in particular assisted greatly when I was making a start on the preparation and examination of scales. Howard J. Buettner transferred various kinds of data to punch cards and prepared tabulations of length frequencies and length-weight records. All collections before the spring of 1955 were made by Service employees.

Cecil C. Craig, Director, Statistical Research Laboratory, University of Michigan, advised in problems of multiple correlation and regression analysis. Glenn W. Graves of the laboratory staff programmed the materials for IBM processing.

Reeve M. Bailey, Curator, Fish Division, Museum of Zoology, University of Michigan, supplied small Saginaw Bay perch from the Museum collections for the study of the body-scale relation.

Field work was greatly furthered by the cooperation of: A. J. Neering, Michigan Department of Conservation; Henry Engelhard, Bay Port Fish Co.; and John Gillingham, R. L. Gillingham Fishing Co.

MATERIALS AND METHODS

Collection of Samples

The study of the Saginaw Bay yellow perch population has been based on the determination of age and the calculation of the growth histories of 4,285 fish, 3,407 of them collected during the spawning seasons of 1943–55 (no fish were collected in 1945 and 1952). The term spawning-run sample has a degree of elasticity in its application to the 1955 collections; some tabulations included the samples of April 18, May 18, and June 7, whereas others included only the sample of May 18, the one taken nearest the height of the spawning season. The samples through 1954 were gathered by the U. S. Fish and Wildlife Service as part of a continuing study of the Saginaw Bay fisheries. In addition to the spawning-run samples, the 1955 collections included data from months outside the spawning period (table 1). All fish were caught by commercial trap nets in the Bay Port area. The actual location of the trap nets ranged from Fish Point to Charity Island (fig. 1), but most lifts were nearer Bay Port. Because no evidence of subpopulations was found, the samples all are considered to have been drawn from the same general stock.

TABLE 1.—*Collections of scales from Saginaw Bay yellow perch*

Date of collection	Number of fish	Date of collection	Number of fish
May 4, 1943	333	May 12, 1954	427
May 3, 1945	99	Apr. 18, 1955	230
June 3, 1946	155	May 18, 1955	184
May 28, 1947	199	June 7, 1955	328
May 15, 1948	200	June 22, 1955	509
May 10, 1949	263	Oct. 19, 1955	369
May 18, 1950	320		
May 1, 1951	371	Total	4,285
May 5, 1953	298		

Records for Individual Fish

The total length of fish (from tip of the head to tip of the tail, with lobes compressed to give the maximum measurement) was determined by a measuring board to the nearest 0.1 inch.

Weights were recorded either to the nearest gram or to the nearest 0.1 ounce depending on the kind of balance. Two types of balances were used: A dietary platform balance calibrated by 2-gram intervals (weight was estimated to the nearest gram); a spring balance calibrated by 0.2-ounce intervals (weight recorded to the nearest 0.1 ounce).

The sex and state of gonads were recorded for all fish except the collections of 1950 and June 7, 1955, for which information is available only on sex.

All samples of the 1943–55 period for which length and weight were recorded (4,285 fish) were used in the study of the length-weight relation.

Determination of Age

Preparation and examination of scales

Scales for age and growth studies were collected from all fish (except the 1954 collection) from below the lateral line on the left side. For the 1954 sample, scales were taken from above the lateral line. Because of this inconsistency as

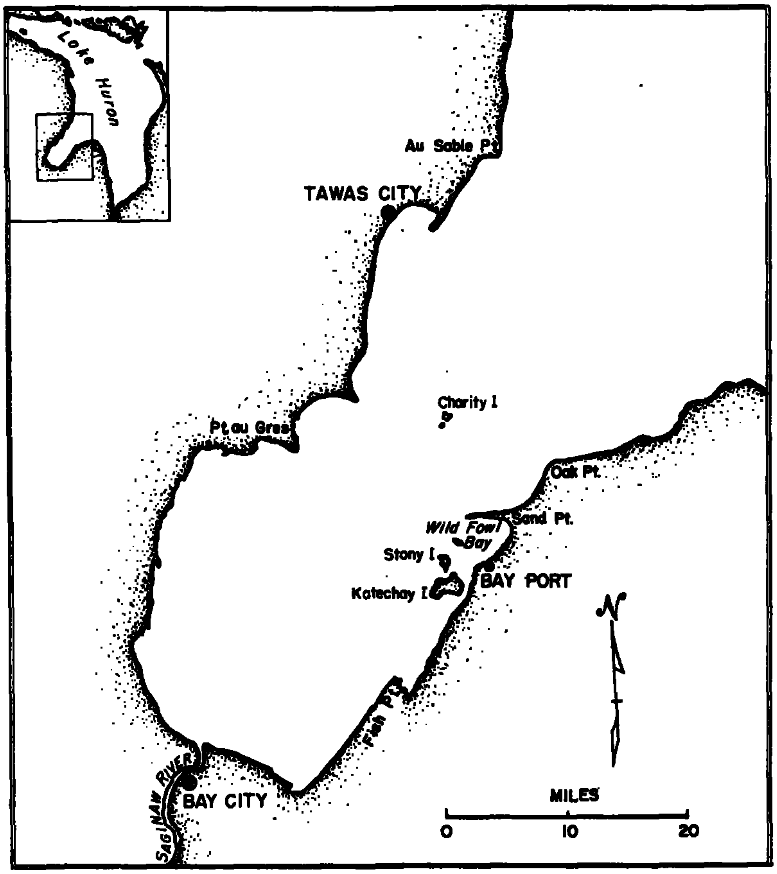

FIGURE 1.—Saginaw Bay.

to the point of scale collection, two body-scale curves were required for the calculation of growth.

The two body-scale curves were based on "key" scales taken from above and from below the lateral line of: Fish collected from trap nets on June 22, 1955 (386 fish); 80 selected (large and small) fish captured in November 1955; and 84 young-of-the-year and yearlings (caught on various dates) from the collections of the Fish Division, Museum of Zoology, University of Michigan.[2] Each key scale from below the lateral line was taken from the third row below the line on the left side of the fish and directly beneath the sixth spine of the dorsal fin. The key scale from above the lateral line also was removed from the left side and came from the second row above the line and below the insertion of the first dorsal spine. The locations of the key scales were chosen to be near the centers of the areas from which routine samples were taken.

[2] The total length of these museum specimens was increased by 2 percent for shrinkage.

Some scales (about 1,400) were mounted on glass microscope slides in a glycerin-gelatine medium described by Van Oosten (1929). The remaining scales were impressed on cellulose acetate, 0.020 or 0.040 inch thick, by a roller press similar to that described by Smith (1954). Butler and Smith (1953), demonstrated that method of preparation does not affect the measurements of scales. The examinations and the measurements of scales were made by means of a microprojector similar to the apparatus described by Van Oosten, Deason, and Jobes (1934) at the magnification × 43. The length of each scale and the distance from the focus to each annulus were measured along the interradial space most nearly collinear with the focus and recorded to the nearest millimeter.

Age analysis

Ages were determined by counting the annuli and are given in terms of completed years of life. They are expressed by Roman numerals corresponding to the number of annuli. Thus fish with one annulus belong to age group I, those with two annuli to age group II, * * *. (Young-of-the-year are assigned to age group 0.) Hile (1948) recommended for convenience and for the consistency in the relation of year of origin, year of capture, and age, that each fish be considered to pass into the next higher age group on January 1. Under this convention a "virtual" annulus is credited at the edge of the scale from January 1 until the new annulus is actually formed in spring or early summer. Year classes, identified by the year of hatching, thus can be determined by subtracting the age from the year of capture; for example, a fish of age group IV captured in 1955 belongs to the 1951 year class.

COMMERCIAL FISHERY FOR YELLOW PERCH

General Trends of the Fishery, 1891–1955

Statistics of the production of yellow perch in Saginaw Bay were available for the years 1891–1908 and 1916–55 (table 2 and fig. 2). Although production always has varied widely, almost erratically, two intervals (1891–1916 and 1917–55) can be established within which these variations showed no definite trend. The first period (1891–1916) was one of high production. The annual catch varied from 3,379,200 pounds in 1901 to 1,085,788 pounds in 1908. The average yield for the whole period (19 years) was 1,961,309 pounds. On the other hand, in the second period (1917–55), the commercial catch was far below that of the early years. The annual production was above a million pounds in only two years (1919 and 1936) and the average catch for the whole period (499,938 pounds) was 74 percent below that of the early interval. This percentage did not differ much from 72 percent recorded by Hile and Jobes (1941) for the 1917–38 period. Since 1938 (1939–55) the commercial catch has been below 500,000 pounds except in 1943, 1944, and 1945. The highest yield was in 1943 (883,087 pounds) and the lowest was reached in 1947 (250,570 pounds).

Hile and Jobes (1941) believed the low production of 1917–38 was due to a less dense yellow perch population in Saginaw Bay that had resulted from overfishing. Data for recent years (the relatively small catches of 1939–55) suggest

TABLE 2.—*Annual commercial production of Saginaw Bay yellow perch in 1891–1908 and 1916–55*

Year	Production (pounds)	Year	Production (pounds)	Year	Production (pounds)
1891	1,102,650	1920	803,725	1942	459,527
1892	1,801,600	1021	659,254	1943	883,087
1893	1,691,600	1922	461,111	1944	536,318
1894	2,013,500	1923	572,817	1945	353,102
1895	1,754,300	1924	444,064	1946	281,022
1896	1,577,300	1925	414,137	1947	250,570
1897	1,639,000	1926	314,848	1948	640,044
1898	2,187,650	1927	112,711	1949	447,456
1899	2,804,200	1928	192,008	1950	322,412
1900	3,452,800	1929	441,373	1951	306,650
1901	3,379,200	1930	611,679	1952	422,404
1902	2,394,500	1931	655,542	1953	394,454
1903	2,069,200	1932	587,532	1954	432,628
1904	1,529,200	1933	330,877	1955	488,209
1905	1,571,700	1934	398,555		
1906	1,747,900	1935	836,784		
1907	1,935,000	1936	1,073,861		
1908	1,085,877	1937	351,382		
1916	1,637,691	1938	326,824		
1917	642,840	1939	440,512	Average, 1891–1916	1,961,309
1918	789,287	1940	441,201		
1919	1,018,292	1941	331,486	Average, 1917–55	499,938

that the yellow perch recently might have become even scarcer and hence need protection even more than in 1938 and earlier. However, the records of fishing pressure and availability or abundance (table 3) show that after 1938 (1939–55), fluctuations in the abundance of yellow perch (fig. 3) were irregular but with a definite upward trend.[3] On the other hand, fishing intensity was declining though with some irregularities. The decrease of intensity was great enough that the

TABLE 3.—*Abundance, production, and fishing intensity for Saginaw Bay yellow perch fishery in 1929–55*

[Expressed as percentages of the 1929–43 average]

Year	Abundance	Production	Fishing intensity
1929	105	81	79
1930	105	112	109
1931	94	120	131
1932	115	108	96
1933	68	61	92
1934	86	73	87
1935	123	154	128
1936	130	197	155
1937	65	65	101
1938	72	60	85
1939	91	81	91
1940	92	81	90
1941	86	61	72
1942	115	84	75
1943	153	162	109
1944	115	98	88
1945	79	65	84
1946	75	52	7[illegible]
1947	86	46	5[illegible]
1948	186	118	65
1949	152	82	55
1950	109	59	56
1951	102	56	57
1952	126	78	63
1953	121	72	61
1954	143	79	57
1955	173	90	53

[3] Indices of abundance given in table 3 were derived from data on the catch per unit of effort (table 4) by the method described by Hile (1937); the method of computing the intensity index was described by Hile and Jobes (1941).

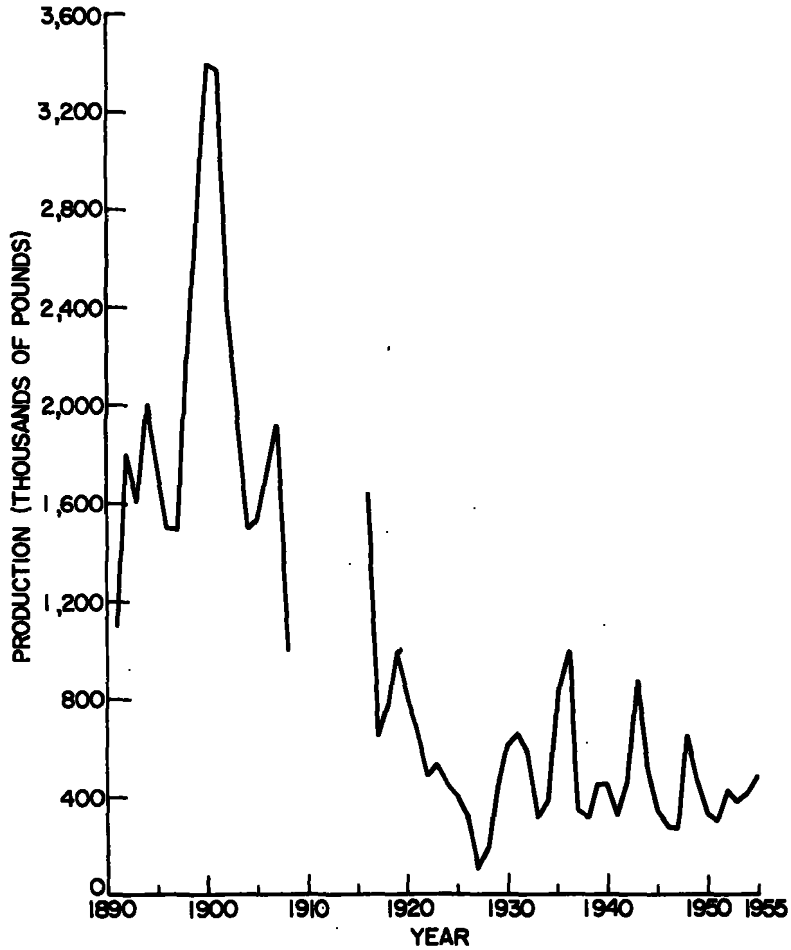

FIGURE 2.—Annual commercial production of yellow perch in Saginaw Bay, 1891–1955.

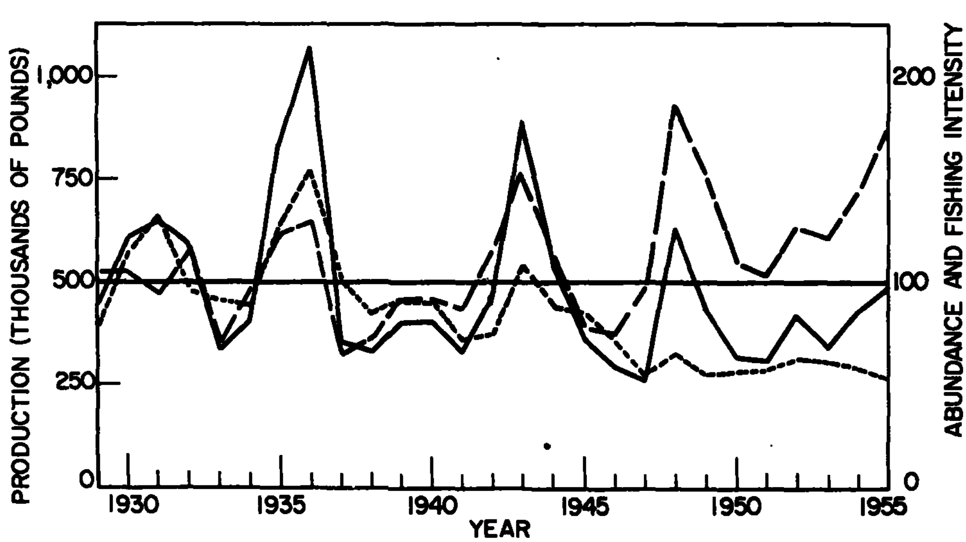

FIGURE 3.—Annual fluctuations in the production (solid lines), abundance (long dashes), and fishing intensity (short dashes), of Saginaw Bay yellow-perch fishery. Production in pounds; abundance and intensity, expressed as percentages of 1929–43 average.

TABLE 4.—*The catch of yellow perch per unit of fishing effort of 5 gears in Saginaw Bay over the period 1929–55*

[The units of effort are: Small-mesh gill nets, lift of 1,000 linear foot; pound, shallow trap, and fyke nets, lift of 1 net; seines, 1 haul of a 100-rod seine]

Year	Catch (pounds) per unit of effort in gear				
	Small-mesh gill net [1]	Pound net [1]	Shallow trap net	Fyke net	Seine
1929	46	6	18	6	30
1930	15	7	18	10	22
1931	10	7	16	10	22
1932	16	7	19	12	20
1933	9	3	12	7	15
1934	8	4	15	6	27
1935	12	4	24	12	52
1936	16	5	26	7	42
1937	5	3	11	9	44
1938	4	4	12	7	34
1939	5	5	15	8	44
1940	11	8	15	10	25
1941	6	10	13	12	38
1942	20	15	17	18	35
1943	26	100	23	20	57
1944	13	8	18	17	39
1945	6	18	12	11	26
1946	----------	13	12	8	15
1947	----------	19	14	11	18
1948	11	32	31	19	48
1949	11	33	24	20	21
1950	6	26	18	15	36
1951	9	----------	17	11	16
1952	9	43	21	12	13
1953	20	15	19	14	27
1954	23	18	23	18	28
1955	22	----------	28	24	68

[1] Based on limited data in some years; no usable data in a few years.

upward trend of abundance was more than counterbalanced, so that the annual production continued to be low. The relatively high catches of 1943 and 1948 were mainly due to high abundance and a slight increase in fishing intensity in these two years.

Catch by Gear

The trap net is the principal gear for catching yellow perch in Saginaw Bay (75.9 percent of the yellow-perch catch by trap nets; table 5). Second to this gear, the fyke net contributed 10.5 percent to the commercial yield. All other gears (small-mesh gill nets, pound nets, seines, * * *) contributed a minor percentage of the catch.

Seasonal Distribution of the Catch

The seasonal production of Saginaw Bay yellow perch (table 6; fig. 4) is concentrated in the fall; 75 percent of the catch is made in September, October, and November. The peak was reached in October (207,425 pounds; 42.9 percent of average annual total). Then followed November (91,867 pounds, 19.0 percent) and September (63,214 pounds, 13.1 percent). The catch in the

TABLE 6.—*Average monthly commercial production (pounds) of Saginaw Bay yellow perch in 1929–55*

Month	Production	Percentage
January	15, 382	3. 2
February	7, 003	1. 5
March	16, 113	3. 3
April	26, 820	5. 6
May	3, 603	. 7
June	13, 641	2. 8
July	10, 133	2. 1
August	13, 030	2. 7
September	63, 214	13. 1
October	207, 425	42. 9
November	91, 867	19. 0
December	14, 935	3. 1

TABLE 5.—*Commercial production of yellow perch in Saginaw Bay, 1929–55, according to gear*

Year	Production (pounds) by gear						Total
	Small-mesh gill net	Pound net	Shallow trap net	Fyke net	Seine	All others [1]	
1929	25, 689	54, 985	269, 132	46, 524	27, 241	17, 802	441, 373
1930	74, 171	51, 262	383, 059	63, 104	37, 332	2, 751	611. 679
1931	74, 277	47, 358	431, 454	68, 492	29, 784	4, 177	655, 542
1932	28, 351	22. 754	439, 539	64, 695	16, 269	15, 924	587, 532
1933	10, 855	16, 651	264, 937	28, 466	8, 625	1, 343	330, 877
1934	7, 096	17, 665	335, 623	16, 499	10, 965	10, 707	398, 555
1935	122, 473	17, 266	627, 040	35, 990	22, 305	11, 710	836, 784
1936	256, 970	15, 766	743, 668	25, 704	24, 307	7, 446	1, 073, 861
1937	23, 696	4, 929	254, 792	41, 231	25, 414	1, 320	351, 382
1938	4, 787	4, 963	266, 076	33, 490	16, 574	934	326, 824
1939	6, 173	8, 932	362, 429	42, 242	20, 551	185	440, 512
1940	24, 183	11, 070	361, 969	34, 578	9, 226	175	441, 201
1941	4, 026	11, 893	259, 511	35, 743	20, 262	51	331, 486
1942	20, 019	4, 913	348, 857	72, 400	13, 338	----------	459, 527
1943	197, 647	8, 096	541, 270	108, 329	23, 840	3, 905	883, 087
1944	22, 777	479	394, 408	95, 842	17, 981	4, 831	536, 318
1945	14, 200	253	273, 507	45, 901	13, 857	5, 384	353, 102
1946	3, 919	1, 064	229, 513	34, 444	9, 762	2, 320	281, 022
1947	1, 539	3, 343	208, 950	32, 903	3, 218	617	250, 570
1948	5, 964	1, 754	534, 247	76, 469	20, 504	1, 106	640, 044
1949	1. 634	3, 236	371, 006	66, 918	4, 628	34	447, 456
1950	5, 506	3, 065	271, 001	38, 577	4, 263	----------	322, 412
1951	10, 236	49	249, 699	44. 532	2, 003	131	306, 650
1952	5, 906	5, 462	348, 222	60, 920	933	961	422, 404
1953	2, 912	4, 588	323, 782	60, 624	2, 548	----------	394, 454
1954	4, 830	480	373, 696	51, 094	2, 528	----------	432, 628
1955	8, 956	----------	433, 523	41, 447	4, 187	96	488, 209
Average	35, 881	11, 936	366, 700	50, 636	14, 461	3, 478	483, 166
Percentage	7. 4	2. 5	75. 9	10. 5	3. 0	0. 7	----------

[1] Includes catches made by: Large-mesh gill nets, deep trap nets, spears, set-hooks, and handlines. Includes also a small poundage for which gear of capture is unknown.

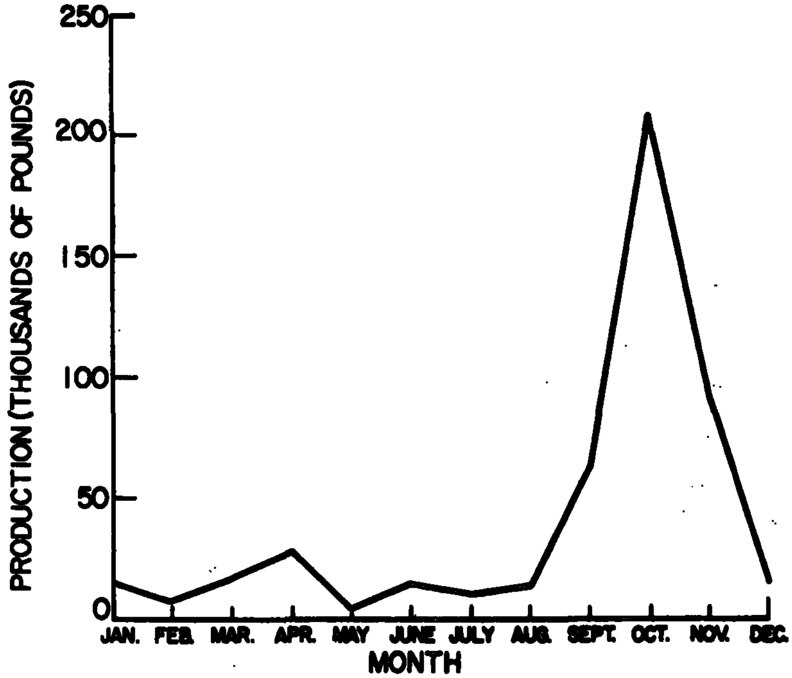

FIGURE 4.—Average monthly commercial production of yellow perch in Saginaw Bay, 1929–55.

9 other months constituted 25 percent of the perch production, varying from 0.7 percent in May to 5.6 percent in April. The take in late spring and early summer would have been greater had not closed seasons been in effect. The dates of these seasons in various years have been: 1927–33, April 15–June 15; 1933–37, April 15–May 15; 1937–47, April 15–June 1; 1947–56, April 15–May 10.

AGE COMPOSITION AND YEAR-CLASS STRENGTH

Annual and Seasonal Differences of Age Distribution

The age composition of yellow perch caught by commercial trap nets in Saginaw Bay in May or early June varied considerably from year to year (table 7; fig. 5). Because these samples came from the spawning run, they probably were biased by segregation on the basis of maturity. Hile and Jobes (1942) held that during this period the younger, immature fish were usually not highly represented. Nevertheless, samples collected in the same season throughout the whole period of study (1943–55) will, despite their bias, bring out annual changes of age distribution. Effects of gear selectivity likewise were reduced by using only fish from trap nets.

The dominant age varied between age group III and age group V. Age group III dominated the catch in only 1 year (1951) and the V group was dominant in 4 years (1945, 1948, 1949, and 1954). Age group IV dominated in the remaining 6 years (1943, 1946, 1948, 1950, 1953, and 1955). In 2 years (1949 and 1954) the percentage representations of the two most plentiful age groups (IV and V) were nearly equal (1949, 40.3 and 38.4 percent; 1954, 43.6 and 44.7 percent). The representation of other age groups, i. e., age groups II and VI–IX, during this 11-year period was consistently less than 10 percent except for the 1945 when age group VI formed 16.2 percent of the sample. In the combined 1943–55 collections age group IV constituted 48.6 percent of the total, followed by age group V (29.9 percent) and age group III (15.9 percent). The remaining age groups (II and VI–IX) together contributed only 5.6 percent.

The year-to-year change in age composition of spawning-run samples is reflected in fluctuations of the average age. The oldest fish were caught in 1945 (average age 5.1 years) and the youngest in 1951 (3.8 years). The mean age was below 4 years in 1946 and 1947 also, but in the remaining years ranged between 4.0 (1950) and 4.6 (1948). The mean of the averages for the 11 spawning-run samples was 4.3 years.

Information on the seasonal fluctuation in age composition of yellow perch from Saginaw Bay

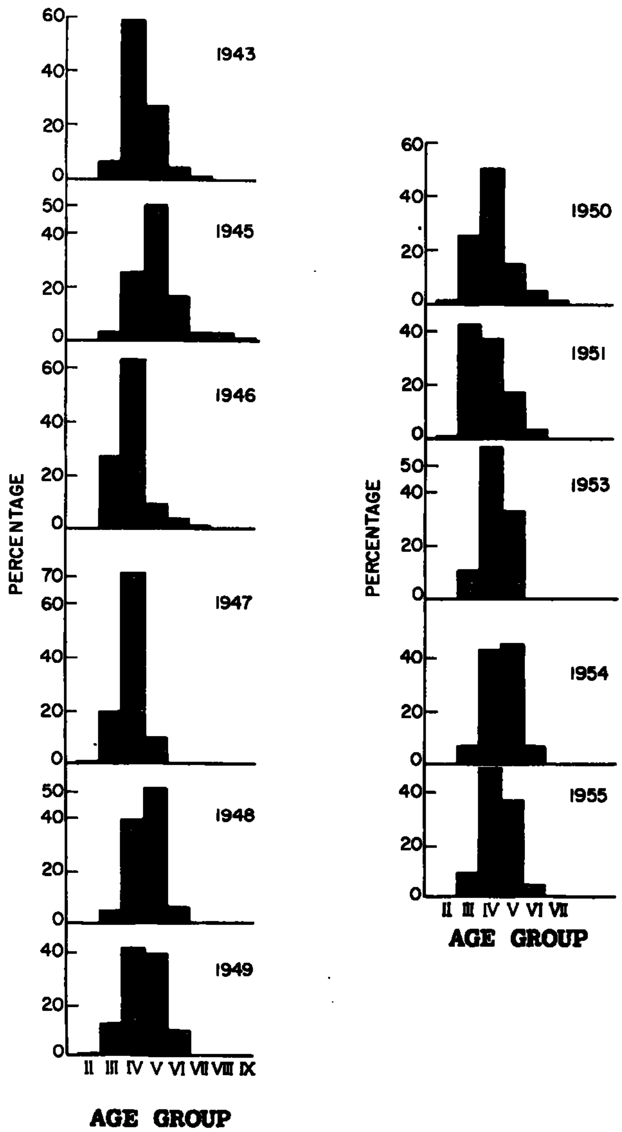

FIGURE 5.—Age composition of the spawning-run collections of Saginaw Bay yellow perch, 1943–55.

is limited to 1955 when collections were made on April 18, May 18, June 7, June 22, and October 19 (table 8; fig. 6). The data indicate no clear-cut seasonal change of age composition and average age.[4] The average age decreased from 4.8 on April 18 to 4.4 on May 18 and to 3.8 on June 7, then increased to 4.3 on June 22. On October 19, the average age decreased again to 3.7. This change in average age was accompanied by a shift in the dominance of age groups. Age group V was strongest on April 18 (45.6 percent), whereas age group IV dominated the collections of May 18, June 7, June 22, and October 19 (48.4, 47.2, 51.9, and 53.1 percent, respectively). Age group III composed as much as 32.6 and 23.8 percent, of June 7 and October 19 samples, and as little as 2.6 percent (April 18). The representation of the VI group ranged from 13.5 percent (April 18) to 1.2 percent (June 7). Members of age groups II and VII were scarce or lacking in all samples except on October 19 when age group II constituted 11.1 percent of the sample.

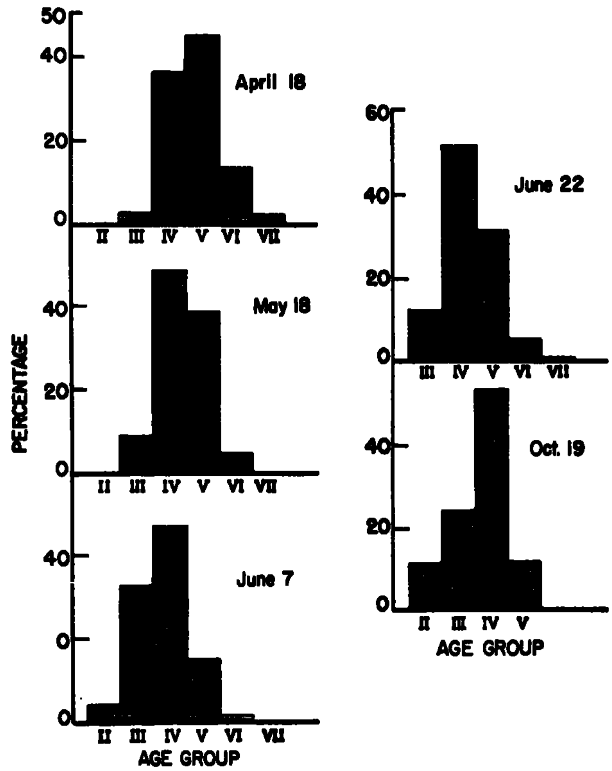

FIGURE 6.—Age composition of Saginaw Bay yellow perch on different dates in 1955.

In comparing Saginaw Bay perch with other yellow perch populations, consideration must be given only to those fish caught in similar seasons, since age composition varies within the year. A comparison of Saginaw Bay perch during the present period of study (April, May, and June collections) with those of 1929–30 (spring and early summer) discloses greater age in more recent years (table 9). In 1929–30 age groups III and IV were best represented; each made up about 39 percent of the total collection. During the 1943–55 period, age groups IV and V constituted 48.6 and 29.9 percent, respectively, of the

[4] Records in table 8 are for the sexes combined since males and females exhibited similar seasonal trends.

TABLE 7.—*Age distribution of yellow perch in May or early June collections*

[Percentages in parentheses. Asterisks indicate dominant age groups]

Date of capture	Number of fish	Number and percentage in age group								Average age[1]
		II	III	IV	V	VI	VII	VIII	IX	
May 4, 1943	333	—	21 (6.3)	*199 (59.8)	93 (27.9)	15 (4.5)	5 (1.5)	—	—	4.4
May 3, 1945	99	—	3 (3.0)	23 (25.6)	*50 (50.5)	16 (16.2)	3 (3.0)	3 (3.0)	1 (1.0)	5.1
June 3, 1946	155	—	38 (24.5)	*97 (62.6)	13 (8.4)	6 (3.9)	1 (0.6)	—	—	3.9
May 28, 1947	199	1 (0.5)	39 (19.6)	*140 (70.4)	19 (9.5)	—	—	—	—	3.9
May 15, 1948	200	—	9 (4.5)	77 (38.5)	*102 (51.0)	12 (6.0)	—	—	—	4.6
May 10, 1949	263	1 (0.4)	29 (11.0)	*106 (40.3)	*101 (38.4)	26 (9.9)	—	—	—	4.5
May 18, 1950	320	3 (0.9)	83 (25.9)	*165 (51.6)	50 (15.6)	16 (5.0)	3 (0.9)	—	—	4.0
May 1, 1951	371	1 (0.3	*157 (42.3)	139 (37.5)	63 (16.9)	11 (2.9)	—	—	—	3.8
May 5, 1953	298	—	31 (10.4)	*168 (56.4)	99 (33.2)	—	—	—	—	4.2
May 12, 1954	427	—	26 (6.1)	*182 (42.6)	*191 (44.7)	28 (6.6)	—	—	—	4.5
May 18, 1955	184	—	16 (8.7)	*89 (48.4)	71 (38.6)	8 (4.3)	—	—	—	4.4
Total	2,849	6 (0.2)	452 (15.9)	*1,385 (48.6)	852 (29.9)	138 (4.8)	12 (0.4)	3 (0.1)	1 [2](0.1)	[3]4.3

[1] Average number of annuli.
[2] Actually, less than 0.05.
[3] The unweighted mean and the weighted mean of the averages for the individual samples are the same.

TABLE 8.—*Age distribution of yellow perch on different dates in 1955*

[Percentage in parentheses. Asterisks indicate dominant age groups]

Date of capture	Number of fish	Number and percentage in age groups						Average age[1]
		II	III	IV	V	VI	VII	
Apr. 18	230	—	6 (2.6)	83 (36.1)	*105 (45.6)	31 (13.5)	5 (2.2)	4.8
May 18	184	—	16 (8.7)	*89 (48.4)	71 (38.6)	8 (4.3)	—	4.4
June 7	328	13 (4.0)	107 (32.6)	*155 (47.2)	49 (14.9)	4 (1.2)	—	3.8
June 22	509	—	61 (12.0)	*264 (51.9)	158 (31.0)	25 (4.9)	1 (.2)	4.3
Oct. 19	369	41 (11.1)	88 (23.8)	*196 (53.1)	44 (11.9)	—	—	3.7

[1] Average number of annuli. Unweighted mean of averages for individual samples is 4.2.

TABLE 9.—*Age distribution of yellow perch in Lake Michigan, Lake Erie, and Saginaw Bay*

[Sources of data: Lake Erie, Jobes (1952); southern Green Bay and northern Lake Michigan, Hile and Jobes (1942); Saginaw Bay 1929-30 samples, Hile and Jobes (1941); Saginaw Bay 1943-55 samples, present study. Percentage in parentheses]

Locality and season	Number and percentage in age groups									Total and average age[1]
	I	II	III	IV	V	VI	VII	VIII	IX	
Saginaw Bay (1929-30) spring and early summer	—	25 (3.0)	317 (38.7)	318 (38.8)	138 (16.8)	17 (2.1)	5 (0.6)	—	—	820 (3.8)
Saginaw Bay (1943-55):										
April, May, and June	—	6 (0.2)	452 (15.9)	1,385 (48.6)	852 (29.9)	138 (4.8)	12 (0.4)	3 (0.1)	1 (0.03)	2,849 (4.2)
October	—	— (11.1)	41 (23.8)	88 (53.1)	196 (11.9)	44	—	—	—	369 (3.7)
Lake Erie:[2]										
April	—	2 (1.5)	98 (73.7)	33 (24.8)	—	—	—	—	—	133 (3.2)
Late summer and fall	392 (13.5)	1,634 (56.3)	797 (27.4)	75 (2.6)	5 (0.2)	—	—	—	—	2,903 (2.2)
Southern Green Bay:[3]										
Spring	—	28 (9.1)	44 (14.3)	144 (46.8)	63 (20.4)	20 (6.5)	4 (1.3)	4 (1.3)	1 (0.3)	308 (4.1)
Fall	2 (0.9)	92 (42.2)	99 (45.4)	21 (9.6)	4 (1.8)	—	—	—	—	218 (2.7)
Northern Lake Michigan[4] fall	—	25 (9.1)	98 (35.5)	118 (42.7)	27 (9.8)	8 (2.9)	—	—	—	276 (3.6)

[1] Average number of annuli.
[2] Fish caught in commercial and experimental trap nets.
[3] Fish caught in fyke nets, pound nets, and 2⅜-inch-mesh gill nets.
[4] Fish caught in 2⅝-inch-mesh gill nets.

catch. This shift in age composition between the two periods of study in Saginaw Bay is marked by a similar change in the average age. The average age was raised from 3.8 in 1929–30 to 4.3 in 1943–55.

The Saginaw Bay yellow perch averaged older than fish of other Great Lakes stocks for which records of age have been published. The average age of Lake Erie perch was 3.2 years in April. In southern Green Bay the average age of 4.1 years in the spring was nearly equal to the average of 4.3 for Saginaw Bay in 1943–55.

The fall collection from Green Bay (average age 2.7 years), northern Lake Michigan (3.6 years), and Lake Erie (2.2 years) were likewise younger than those caught from Saginaw Bay in October 1955 (3.7 years). It should be mentioned that in all three localities from which both spring and fall collections were obtained the spring fish were considerably the older.

The effects of gear selection on the estimation of average age cannot be judged precisely. Catches of impounding nets (pound, trap, and fyke nets) are probably comparable. The fall samples from northern Lake Michigan, taken in 2⅝-inch-mesh gill nets, almost certainly were biased by selection toward the older age groups.

Relative Strength of Year Classes

Near the turn of the century, shortly after the discovery and validation of the scale method of determining the age of fish, investigators became aware of wide variations from year to year in the success of reproduction. As studies were continued on individual stocks and expanded to include new ones, it became increasingly apparent that the fluctuations in the strength of the year classes are major factors in the determination of the yield of the fisheries. It follows then that an understanding of the extent and the factors in these fluctuations can contribute fundamentally to the development of a scientific system of exploitation and management of fishery resources.

Despite the overriding importance of the subject and the considerable attention it has received, the gaining of information on the magnitude of fluctuations and the development of understanding of their causes have been painfully slow. The sampling requirements are rigorous, the analytical procedures are difficult, and the factors that must be considered are numerous and complex. Seemingly we must approach understanding through a process of slow accretion in which each new bit of evidence, though not conclusive in itself, must be welcomed.

Fishery investigators in the Great Lakes mostly have lacked the facilities for continuing studies that are so essential for inquiries into the degree and causes of fluctuations. Instead they have had to content themselves with calling attention to the occurrence of year classes of exceptional strength or weakness. Observations of this type have been made in Lake Erie for: yellow perch (Jobes 1933, 1952); walleyes, blue pike, and saugers (Deason 1933); sheepshead (Van Oosten 1938); white bass (Van Oosten 1942); whitefish (Van Oosten and Hile 1949); cisco (Scott 1951); all of the species just listed (Van Oosten 1948). In other Great Lakes waters, information on year-class strength was recorded for: South Saginaw Bay lake herring (Van Oosten 1929); Saginaw Bay yellow perch (Hile and Jobes, 1941); Saginaw Bay (Lake Huron) lake trout (Fry 1953); Green Bay walleyes, whitefish, and lake herring (Hile 1950); Green Bay lake herring (Smith 1956). In a 1954 paper, Hile attempted the ranking of 12 consecutive year classes of the Saginaw Bay walleye and commented on the strength or weakness of others.

Despite severe limitations and defects in the data (small numbers of fish in some samples; lack of collections in 1944 and 1952) it was believed that data on the age composition of yellow perch in the present study have warranted an attempt at a more precise estimate of the relative strength of year classes than has been attempted previously for Great Lakes stocks. It had been hoped originally that these estimates might be made through the application of sample data to the statistical records on catch per unit of effort in trap nets in the various years of capture, but the scarcity (even lack) of legal-sized fish in the samples forced abandonment of the idea. It was then decided to use an adaptation of the procedure employed by Hile (1941) for the estimation of annual fluctuations in growth rate. It is based on a series of comparisons in which the abundance of each year class is estimated in terms of the strength of the preceding one. From these comparisons a sequence of positions is established for each year class in the series. The procedure can be illustrated by the comparison of year classes 1943 and 1944 (table 10). The 1943 year class appeared in the collections at various ages contributing to the samples in different calendar years as follows: 1946, III group, 24.5 percent; 1947, IV group, 70.4 percent; 1948, V group, 51.0 percent; 1949, VI group, 9.9 percent; 1950, VII group, 0.9 percent. The sum of the percentages is 156.7. The 1944 year class appeared as follows: 1947, III group, 19.6 percent; 1948, IV group, 38.5 percent; 1949, V group, 38.5 percent; 1950, VI group, 5.0 percent; 1951, VII group, 0.0 percent; sum of percentages, 101.5.

The 2 sums of percentages contributed to annual samples by the 2 year classes under comparable sampling conditions are taken as representative of their relative strengths (table 11). The change of year-class strength from 1943 to 1944 is computed as

$$\frac{2\ (101.5 - 156.7)}{101.5 + 156.7} \times 100 = -42.8$$

(The use of the mean of the two percentage totals rather than the total for the earlier year as a base for the estimation of the change is essential if systematic bias is to be avoided. See Hile 1941, p. 253, footnote 23.)

TABLE 10.—*Age composition and year classes of Saginaw Bay yellow perch in 1943–55*

Date of capture	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	Average age and total
May 4, 1943:																		
Age group	VII	VI	V	IV	III													4.4
Number of fish	5	15	93	199	21													333
Percentage	(1.5)	(4.5)	(27.9)	(59.8)	(6.3)													
May 3, 1945:																		
Age group	IX	VIII	VII	VI	V	IV	III											5.1
Number of fish	1	3	3	16	50	23	3											99
Percentage	(1.0)	(3.0)	(3.0)	(16.2)	(50.5)	(25.6)	(3.0)											
June 3, 1946:																		
Age group				VII	VI	V	IV	III										3.9
Number of fish				1	6	13	97	38										155
Percentage				(0.6)	(3.9)	(8.4)	(62.6)	(24.5)										
May 28, 1947:																		
Age group							V	IV	III	II								3.9
Number of fish							19	140	39	1								199
Percentage							(9.5)	(70.4)	(19.6)	(0.5)								
May 15, 1948:																		
Age group							VI	V	IV	III								4.6
Number of fish							12	102	77	9								200
Percentage							(6.0)	(51.0)	(38.5)	(4.5)								
May 10, 1949:																		
Age group								VI	V	IV	III	II						4.5
Number of fish								26	101	106	29	1						263
Percentage								(9.9)	(38.4)	(40.3)	(11.0)	(0.4)						
May 18, 1950:																		
Age group								VII	VI	V	IV	III	II					4.0
Number of fish								3	16	50	165	83	3					320
Percentage								(0.9)	(5.0)	(15.6)	(51.6)	(25.9)	(0.9)					
May 1, 1951:																		
Age group										VI	V	IV	III	II				3.8
Number of fish										11	63	139	157	1				371
Percentage										(2.9)	(16.9)	(37.5)	(42.3)	(0.3)				
May 5, 1953:																		
Age group													V	IV	III			4.2
Number of fish													99	168	31			298
Percentage													(33.2)	(56.4)	(10.4)			
May 12, 1954:																		
Age group													VI	V	IV	III		4.5
Number of fish													28	191	182	26		427
Percentage													(6.6)	(44.7)	(42.6)	(6.1)		
May 18, 1955:																		
Age group														VI	V	IV	III	4.4
Number of fish														8	71	89	16	184
Percentage														(4.3)	(38.6)	(48.4)	(8.7)	

TABLE 11.—*Data employed in the determination of year-class fluctuation of Saginaw Bay yellow perch*

Year classes compared	Age groups included	Sum for 1st year	Sum for 2d year	Mean	Difference	Percentage difference between years
1939–40	VI, VII	16.8	3.9	10.4	−12.9	−124.0
1940–41	V, VI	54.4	8.4	31.4	−46.0	−146.5
1941–42	IV, V, VI	34.0	78.1	56.1	44.1	78.4
1942–43	III, IV, V, VI, VII	81.1	156.7	118.9	75.6	63.6
1943–44	III, IV, V, VI, VII	156.7	101.5	129.1	−55.2	−42.8
1944–45	II, III, IV, V, VI	101.5	63.8	82.6	−37.7	−45.6
1945–46	II, III, IV, V	60.9	79.5	70.2	18.6	26.5
1946–47	II, III, IV	62.6	63.8	63.2	1.2	1.9
1947–48	II, III, VI	26.3	49.8	38.0	23.5	61.8
1948–49	II, V, VI	40.7	49.3	45.0	8.6	19.1
1949–50	IV, V	101.1	81.2	91.2	−19.9	−21.8
1950–51	III, IV	53.0	54.5	53.8	1.5	2.8
1951–52	III	6.1	8.7	7.4	2.6	35.1

To obtain the relative positions of all year classes, the 1939 year class is given arbitrarily a value of 0.0 and the positions of succeeding year classes are determined by the successive addition of the "percentage" differences in the right hand column of table 11. The series so obtained is then adjusted to a mean of 0.0 to give the final ranking (table 12; fig. 7).

The year-class strength dropped from 147.4 in 1939 (highest recorded value) to –123.1 in 1941 (lowest value). The position or index value increased until it reached 18.9 in 1943 and dropped to –69.5 in 1945. From 1945 to 1952 the trend was strong toward improvement in year-class strength (only exception in 1950). The indices remained below average until 1947. From 1948 to 1952 the year-class strength was above average, reaching a value of 55.9 in 1952 (second highest value).

If the fluctuations of year-class strength are substantial, it is to be expected that their effects will be felt in later years in the abundance of fish and in the production of the commercial fishery. To test this point for Saginaw Bay yellow perch, coefficients of correlation r were computed between year-class strength and the abundance and production (see section on the commercial fishery) 4 to 6 years later (table 13; see also fig. 8). These intervals and combinations of intervals were chosen because few perch

TABLE 13.—*Correlation between estimated strength of year classes and later abundance and production of yellow perch in the commercial fishery*

Years after hatching	Coefficient of correlation		Degrees of freedom	Value of r at	
	Abundance	Production		p=0.05	p=0.01
4	0.380	0.630	11	0.553	0.684
5	.345	.658	10	.576	.708
6	–.044	.653	9	.602	.735
4 and 5	.438	.799	10	.576	.708
4, 5, and 6	.333	.904	9	.602	.735

TABLE 12.—*Index values of year-class strength of Saginaw Bay yellow perch, 1939–52*

[Adjusted to a 1939-52 mean of 0.0]

	Year class													
	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952
Deviation from mean	147.4	23.4	–123.1	–44.7	18.9	–23.9	–69.5	–43.0	–41.1	20.7	39.8	18.0	20.8	55.9

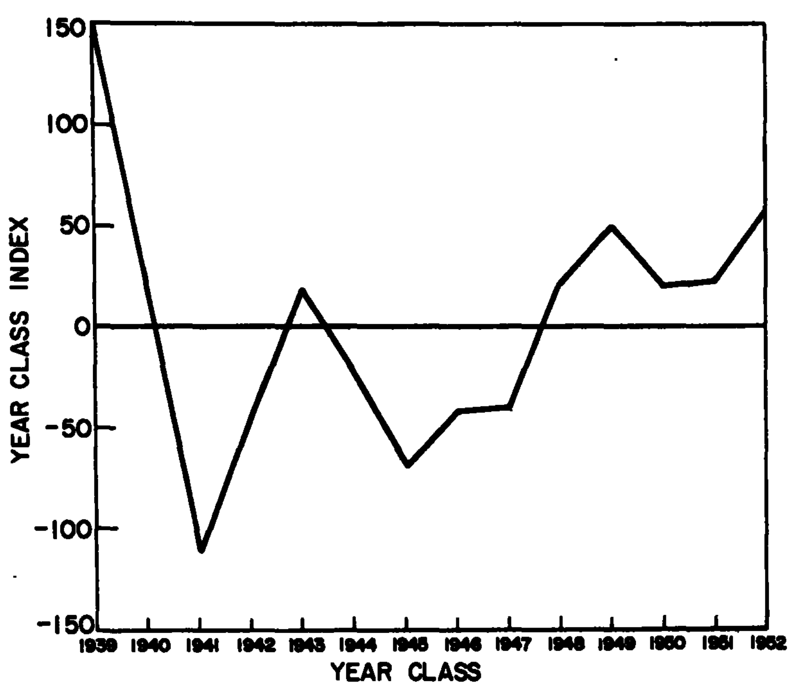

FIGURE 7.—Fluctuation in the relative strength of year classes 1939 to 1952 of Saginaw Bay yellow perch.

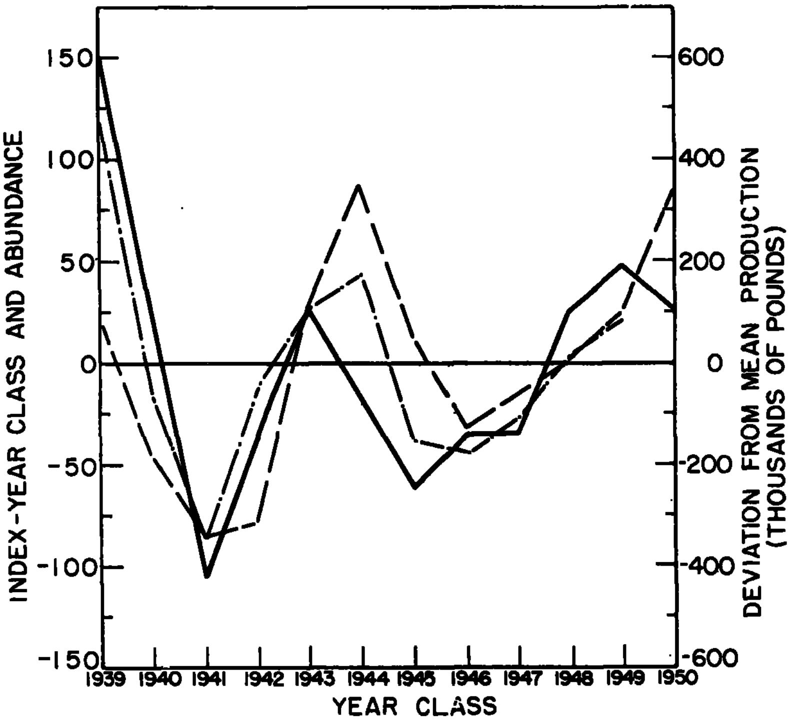

FIGURE 8.—Relation between year-class strength (solid line) and the abundance after 4 and 5 years (dashes) and production (dots and dashes) 4, 5, and 6 years later.

reach legal size in less than 4 years and fish older than the VI group are rare.

Except for the 6-year interval all coefficients of correlation between year-class strength and abundance as estimated from records of catch per unit effort were positive, but all of them were far below significant values. Correlations between year-class strength and later production, on the other hand, were all significant, three of them at the 5-percent and 2 at the 1-percent level.

Discussion of possible factors of fluctuation in year-class strength is given in a later section along with the treatment of factors of fluctuations in growth rate.

SIZE AT CAPTURE

Length Distribution of Samples

The length-frequency distribution of Saginaw Bay yellow perch during the 1943–55 period (table 14) was typically unimodal. The 1945 collection showed some tendency toward bimodality but this might be due to the accidental capture of some large fish and to the small number in the sample (only 97 fish). With the exception of 1943 and 1945, the modal lengths lay within the range of 6.0–6.9 inches total length. Most common was at 6.5–6.9 inches. In 2 years only (1947 and 1955), the modal lengths were at 6.0–6.4 inches. In 1943 and 1945, on the other hand, the modes were 7.5–7.9 and 8.0–8.4 inches. This annual variation in the length may be attributed largely to fluctuations in the age composition of the stock and to the change of growth from year to year (these fluctuations are discussed in earlier and later sections). Differences from year to year in the percentage of males and females also had a certain effect on this variation. Jobes (1952) included the selectivity of the different kinds of nets among the causes of annual variation of length. The effect of gear selectivity was minimized in the present study because all samples came from one kind of net (trap net).

The percentage of legal-sized yellow perch (total length 8½ inches or longer) of the combined samples was 11.0. This percentage varied considerably, however, from year to year. The highest value was recorded in 1945 (66 percent). In 1948 the sample included no legal-sized fish. Although it is not to be concluded that the legal-sized perch were unavailable in Saginaw Bay during that year, it is obvious that in the early season the fisherman must have had to do tedious sorting to find a marketable catch.

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TABLE 14.—*Length-frequency distribution of Saginaw Bay yellow perch from the spawning-run samples according to year of capture*

[Modes designated by asterisks]

Total length interval (inches)	Mid-point	Year of capture											Total
		1943	1945	1946	1947	1948	1949	1950	1951	1953	1954	1955	
4.5–4.9	4.7											4	4
5.0–5.4	5.2			5	3		1	1	1	1	1	46	59
5.5–5.9	5.7	7	1	24	47	5	7	19	20	7	31	144	312
6.0–6.4	6.2	12	3	31	*64	49	33	54	60	32	66	*162	566
6.5–6.9	6.7	30	1	*42	37	*55	*81	*101	*103	*53	*94	135	*732
7.0–7.4	7.2	62	4	28	26	45	71	57	99	45	*94	69	600
7.5–7.9	7.7	*71	4	12	20	39	34	49	52	*60	83	42	466
8.0–8.4	8.2	58	*20	9	1	7	18	27	24	46	35	47	292
8.5–8.9	8.7	35	6	1	1		6	10	6	23	8	41	137
9.0–9.4	9.2	25	10	2			3	1	4	15	9	28	97
9.5–9.9	9.7	14	*11				3			5	3	16	52
10.0–10.4	10.2	10	8	1			3	1	1	7	1	7	39
10.5–10.9	10.7	8	12				2		1	2	1	1	27
11.0–11.4	11.2		3						1	1	1		6
11.5–11.9	11.7	1	2				1			1			5
12.0–12.4	12.2		2								1		3
12.5–12.9	12.7		2										2
13.0–13.4	13.2		5										5
13.5–13.9	13.7		2										2
14.0–14.4	14.2												
14.5–14.9	14.7		1										1
Number of fish		333	97	155	199	200	263	320	372	298	428	742	3,407
Average length		7.97	9.59	6.72	6.46	6.91	7.17	7.00	7.02	7.60	7.12	6.80	7.16
Percentage legal		27.9	66.0	2.6	.5	0	6.8	3.8	3.5	18.1	5.6	12.5	11.0

Many of the undersized fish are destroyed in the sorting and handling. Jobes (1952) indicated that 14 percent of illegal perch taken by trap nets in Lake Erie were dead when the nets were lifted. Van Oosten (1936) also concluded that trap nets destroyed more small fish than did other kinds of nets.

The length-frequency distribution not only varies from year to year but also in the different seasons of the year (table 15). A distinct trend in the length-frequency distribution and average size of yellow perch caught in 1955 (sexes combined) can be seen. The average length dropped from 7.7 inches on April 18 to 6.1 inches on June 7. Then the length increased to 6.5 inches in early summer (June 22) and 7.6 inches in the fall (October 19). The October fish were still 0.1 inch shorter than those of the April 18 sample. Over the April 18–October 19 period the modal intervals ranged from 5.5–5.9 inches (June 7) to 7.5–7.9 inches (October 19).

TABLE 15.—*Length-frequency distribution of Saginaw Bay yellow perch on different dates in 1955*

Total length (inches)	Apr. 18	May 18	June 7	June 22	Oct. 19
4.5–4.9			4		
5.0–5.4			46	2	4
5.5–5.9	9	8	127	74	21
6.0–6.4	34	45	83	220	37
6.5–6.9	45	48	42	118	43
7.0–7.4	25	34	10	53	63
7.5–7.9	8	29	5	27	72
8.0–8.4	27	16	4	9	55
8.5–8.9	36	4	1	3	34
9.0–9.4	24		4	1	19
9.5–9.9	14		2	1	14
10.0–10.4	7			1	3
10.5–10.9	1				3
11.0–11.4					1
Number of fish	230	184	328	509	369
Average length	7.7	7.0	6.1	6.5	7.6
Percentage legal	35.6	2.2	2.1	1.2	20.0

The percentage of legal-sized yellow perch also varied seasonally. On April 18 this percentage was 35.6, but fishermen did not benefit from the relatively high value because fishing for perch is not allowed at that time (closed season, April 15–May 10). The proportion of legal-sized perch subsequently fell to barely 2 percent on May 18 and June 7 and less than 2 percent on June 22. In the fall (October 19) the percentage increased again to 20.0. This increase is due in some measure to the presence of a large number of females that typically attain larger size than males.

Length Distribution of Age Groups

In the compilation of data on the length-frequency distribution of the age groups (table 16), fish of the same age and sex in all the spawning-run samples were combined. Because of a certain amount of year-to-year variation in the length distribution, these combinations increased the range and dispersion for the individual age groups. The data serve, nevertheless, to show the general distribution and the range of length over which fish of a particular age can be expected to vary. In well-represented age groups, the range for the males varied from 4 inches in age group III to 5½ inches in age group V. The females had a slightly wider range of 4 inches

TABLE 16.—*Length-frequency distribution of spawning-run collections of Saginaw Bay yellow perch, 1943–55, according to age groups and sex*

[Modal intervals are designated by asterisks. M=male; F=female]

Total length (inches)	Age group II M	II F	III M	III F	IV M	IV F	V M	V F	VI M	VI F	VII M	VII F	VIII M	VIII F	Grand total M	Grand total F	Grand total Both	Percentage M	Percentage F	Percentage Both
4.5–4.9		2	1	1											1	3	4	0.03	0.09	0.12
5.0–5.4	3	*11	23	11	10		1								37	22	59	1.1	.6	1.7
5.5–5.9		2	*94	66	118	19	13								225	87	312	6.6	2.5	9.2
6.0–6.4		1	91	61	251	94	56	11	1						399	167	566	11.7	4.9	16.6
6.5–6.9			53	*67	*289	*128	161	22	12						*515	*217	732	15.1	6.4	21.5
7.0–7.4			14	48	173	120	*205	22	17	1					409	191	600	12.0	5.6	17.6
7.5–7.9			6	20	77	113	149	58	*40	1	2				274	192	466	8.0	5.6	13.7
8.0–8.4			2	5	31	93	64	*60	32	2	*3				132	160	292	3.9	4.7	8.6
8.5–8.9				1	10	42	31	34	16	2	1				58	79	137	1.7	2.3	4.0
9.0–9.4					5	28	16	35	7	6					28	69	97	.8	2.0	2.8
9.5–9.9					2	11	5	23	3	*7	1				11	41	52	.3	1.2	1.5
10.0–10.4						7	3	16	4	6	2	1			9	30	39	.3	.9	1.2
10.5–10.9						3	2	12	1	5	2	2			5	22	27	.15	.6	.8
11.0–11.4						1		4		1						6	6		.18	.2
11.5–11.9								3		2						5	5		.15	.2
12.0–12.4									1	2					1	2	3	.03	.06	.09
12.5–12.9										2						2	2		.06	.06
13.0–13.4										2		2		1		5	5		.15	.15
13.5–13.9												1		1		2	2		.06	.06
14.0–14.4																				
14.5–14.9														1		1	1		.03	.03
Total	3	16	284	280	966	659	706	300	134	39	11	6		3	2,104	1,303	3,407	61.8	38.2	
Average length	5.2	5.3	6.1	6.5	6.7	7.4	7.3	8.4	8.0	10.2	9.1	12.0		13.9	6.9	7.5	7.2			
Percentage legal	0	0	0	.03	1.8	14.0	8.1	42.3	23.9	89.7	54.5	100.0		100.0	5.3	20.3				
Percentage legal (both sexes)	0		0·02		7.9		25.2		56.8		72.8		100.0		11.0					

in age group III to 6 inches in age group VI. The widest ranges were mostly confined to age groups IV, V, and VI. The younger and older age groups (groups II, III, and VII) had the narrower range (in part, probably, because of the limited numbers of fish and for the young fish the inability of the nets to hold the smaller members of the age groups).

This range of length of age groups together with the distinctly slow growth led to an extensive overlap. Consequently the length of Saginaw Bay yellow perch at these ages is a poor index of age. A fish of a particular length might belong to 2 to 5 age groups (mostly 4 age groups).

The percentage of legal-sized yellow perch was nil or small at the lesser ages but increased with growth. In well-represented groups (age groups IV, V, and VI), the percentage (sexes combined) ranged from 7.9 to 56.8 percent. These three age groups are the main contributors to the commercial yellow perch fishery in Saginaw Bay. The percentage of legal-sized males was always less than that of the females. For males the value ranged from 1.8 percent for fish of age group IV to 54.5 percent in age group VII. The percentage of legal-sized females, on the other hand, rose from 14.0 percent in age group IV to 100 percent in age group VII.

Change in Length Between 1929–30 and 1943–55

The length-frequency distributions of spring collections of yellow perch from impounding nets in 1929–30 and 1943–55 (table 17; fig. 9) indicate an enormous shift in the length composition. In 1929–30 the modal length was at 8.5–8.9 inches, whereas in 1943–55 this mode was 6.5–6.9 inches, a loss of 2 inches in the modal length of the fish (2.3 inches in the mean length). In the

TABLE 17.—*Length-frequency distribution of the early-season collections of Saginaw Bay yellow perch, 1929–30 and 1943–55*

Total length (inches)	1929–30 [1] Number of fish	1929–30 [1] Percentage	1943–55 Number of fish	1943–55 Percentage
4.5–4.9			4	0.12
5.0–5.4			59	1.7
5.5–5.9	3	0.4	312	9.2
6.0–6.4	4	.5	566	16.6
6.5–6.9	9	1.1	732	21.5
7.0–7.4	10	1.2	600	17.6
7.5–7.9	47	5.8	466	13.7
8.0–8.4	90	11.2	292	8.6
8.5–8.9	139	17.3	137	4.0
9.0–9.4	109	13.6	97	2.8
9.5–9.9	105	13.1	52	1.5
10.0–10.4	111	13.8	39	1.2
10.5–10.9	101	12.6	27	.8
11.0–11.4	39	4.8	6	.2
11.5–11.9	20	2.5	5	.15
12.0–12.4	9	1.1	3	.09
12.5–12.9	7	.9	2	.06
13.0–13.4			5	.15
13.5–13.9			2	.06
14.0–14.4				
14.5–14.9			1	.03
Total or average	803	9.4	3,407	7.2

[1] Data adapted from table 7, Hile and Jobes (1941).

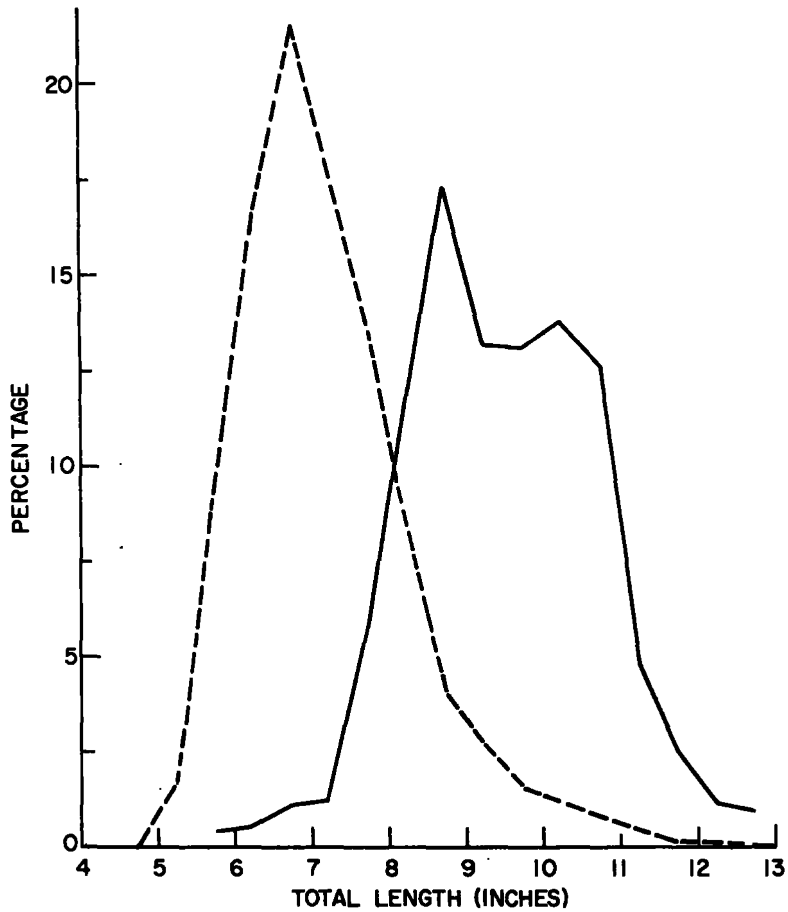

FIGURE 9.—Length-frequency distribution of Saginaw Bay yellow perch in 1929–30 (solid lines) and 1943–55 (short dashes).

two periods the mesh size of the fishing gears did not change appreciably, if at all, and thus the effect of net selectivity could be excluded.

This change of length is reflected in the percentage of legal-sized fish ($8\frac{1}{2}$ inches) in the two periods. In 1929–30 the legal-sized yellow perch comprised 73.9 percent of the catch. In 1943–55 this percentage dropped to only 11.0 percent.

LENGTH-WEIGHT RELATION

The length-weight relationship of fish has sometimes been described by the "cube law," $W = CL^3$ (where W = weight, C = a constant, and L = length). This law, however, can be applied only if the form and the specific gravity of fish remain constant throughout life. These requirements are so rarely met, that the more general equation $W = cL^n$ (c and n are determined empirically) is usually the more suitable in the study of length-weight relationship. Hile (1936) demonstrated that the exponent n can vary widely (he showed values from 1.34 to 3.68 for various samples and stocks of ciscoes). Hile (1936) and Le Cren (1951) discussed many of the questions and controversies involved in the application of this relationship. The cube relationship serves best in the study of "condition" since the value of C, the condition factor, measures "plumpness" or degree of well-being regardless of the actual length-weight relationship. Some have advocated the use of c in $W = cl^n$ in the study of condition, but this application is beset with many difficulties (Hile 1936).

The equation $W = cL^n$ was proved by several authors to describe the general length-weight relationship of yellow perch adequately (Hile and Jobes, 1941 and 1942; Jobes 1952; and Le Cren 1951 for the European perch).

General Length-Weight Relation

The determination of the length-weight relationship of Saginaw Bay yellow perch of 1943–55 collections was based on the combined data for all fish regardless of time of capture, sex, and state of maturity (table 18). This procedure gives the most practical curve for conversions between length and weight. The fitting of a straight line (by least squares) to the logarithms of lengths and weights of table 18 led to the equation: $\log W = -2.3982 + 3.2620 \log L$, where W = weight in ounces and L = total length in inches. This equation may be written also in the form $W = 3.9975 \times 10^{-3} L^{3.2620}$.

TABLE 18.—*Length-weight relationship of Saginaw Bay yellow perch of the combined collections of 1943–55*

Number of fish	Total length (inches)	Weight (ounces)		Standard length (millimeters)	Calculated weight (grams)
		Empirical	Calculated		
1	4.6	0.70	0.58	100	16
2	4.8	.70	.66	102	19
1	4.9	.60	.76	105	22
7	5.0	.76	.76	108	22
10	5.1	.84	.81	111	23
18	5.2	.86	.86	113	24
15	5.3	.91	.98	114	28
15	5.4	.99	.98	116	28
57	5.5	1.03	1.04	119	29
38	5.6	1.12	1.10	121	31
97	5.7	1.13	1.20	123	34
99	5.8	1.21	1.23	124	35
116	5.9	1.26	1.31	127	37
156	6.0	1.35	1.38	129	39
144	6.1	1.44	1.46	132	41
184	6.2	1.54	1.54	135	44
176	6.3	1.59	1.62	136	46
163	6.4	1.67	1.70	138	48
194	6.5	1.78	1.79	140	51
171	6.6	1.88	1.88	143	53
191	6.7	1.91	1.98	144	56
168	6.8	2.02	2.08	145	59
169	6.9	2.16	2.18	148	62
165	7.0	2.29	2.28	151	65
131	7.1	2.39	2.39	154	68
170	7.2	2.54	2.50	156	71
130	7.3	2.56	2.62	157	74
120	7.4	2.74	2.74	159	78
144	7.5	2.90	2.86	162	81
122	7.6	3.09	2.98	164	84
97	7.7	3.01	3.12	166	88
116	7.8	3.25	3.25	168	92
86	7.9	3.30	3.39	170	96
98	8.0	3.59	3.53	172	100
81	8.1	3.72	3.68	178	104
74	8.2	3.97	3.82	180	108
51	8.3	3.87	3.82	183	108
52	8.4	4.26	4.14	185	117
36	8.5	4.50	4.30	187	122
42	8.6	4.56	4.47	189	127
31	8.7	4.69	4.64	191	132
36	8.8	5.06	4.82	194	137
29	8.9	5.01	5.00	196	142
39	9.0	5.27	5.18	198	147
26	9.1	5.83	5.37	200	152
19	9.2	5.85	5.57	202	158
13	9.3	5.72	5.77	205	164
20	9.4	6.17	6.00	207	170
24	9.5	6.23	6.18	209	175
12	9.6	6.69	6.40	211	181
6	9.7	6.50	6.62	213	188
16	9.8	6.62	6.84	216	194
9	9.9	6.98	7.07	218	200
13	10.0	7.38	7.31	220	207
6	10.1	7.87	7.55	222	214
10	10.2	7.66	7.79	224	221
5	10.3	8.76	8.05	227	228
9	10.4	8.50	8.30	229	235
12	10.5	8.92	8.57	231	243
5	10.6	8.58	8.84	233	251
6	10.7	9.25	9.11	235	258
3	10.8	8.60	9.39	240	266
4	10.9	9.38	9.68	243	274
3	11.0	10.23	9.97	245	283
1	11.1	10.90	10.27	247	291
1	11.2	11.10	10.58	249	300
1	11.3	10.80	10.89	252	309
1	11.4	9.00	11.09	254	314
4	11.5	11.40	11.52	256	327
1	11.6	12.20	11.87	258	336
1	12.0	13.50	13.23	267	375
1	12.1	12.50	13.61	269	386
1	12.3	14.00	14.35	274	407
1	12.5	16.10	15.13	278	429
1	12.6	13.50	15.53	281	440
1	13.0	15.80	17.19	290	487
1	13.1	17.50	17.64	292	500
2	13.2	17.40	18.08	294	512
1	13.3	18.50	18.54	296	526
1	13.6	21.00	19.92	303	565
1	13.8	28.80	20.90	307	592
1	14.9	24.50	26.84	332	761

In the graphical representation of the length-weight relation (fig. 10) the smooth curve represents the calculated weights and the dots the empirical ones. The agreement of the calculated and empirical weights (table 18) was satisfac-

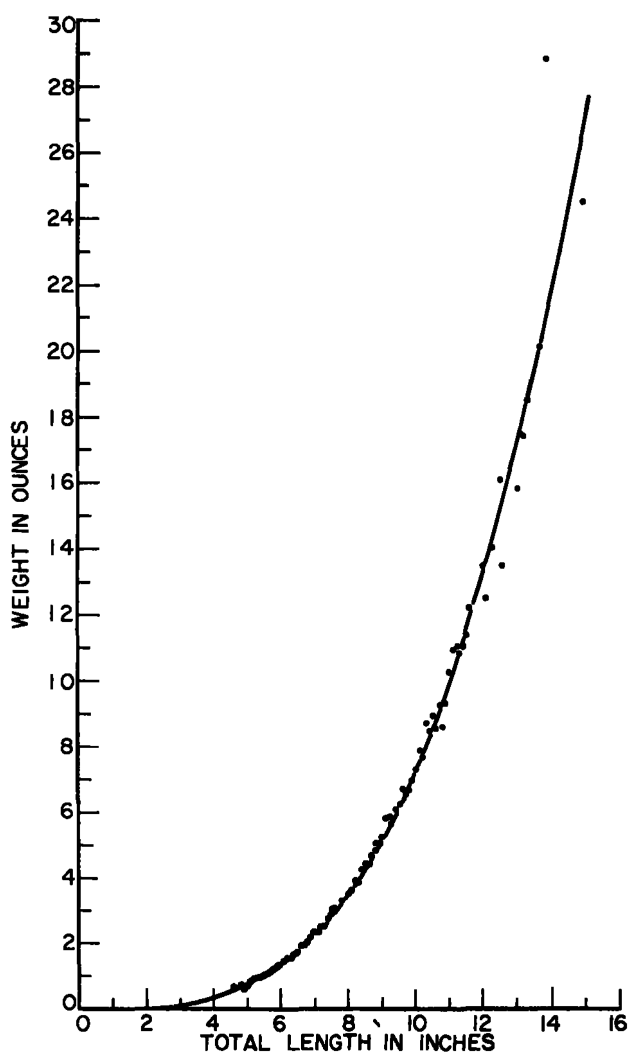

FIGURE 10.—Length-weight relation. The smooth curve represents the calculated weights and the dots represent the empirical weights.

tory. The discrepancies were more pronounced among larger fish, but on the whole, distribution of the disagreements had no particular trend. Jobes (1941) noticed that disagreements were very large for Lake Erie perch beyond 11.8 inches total length, but attributed them to the small number of fish. In addition, the heterogenity of the sample must be considered as the cause of some disagreements because collections of different years were combined in the determination of the length-weight relation.

Weight in Relation to Condition of Gonads

Information on the state of the gonads was, unfortunately, not available for all the spawning-run samples. For this reason, only those for 1949, 1951, 1953, 1954, and 1955 could be used for the study of the relation of weight to the condition of the gonads. Annual variations of weight in the 5 years were so small among fish of the same length, sex, and the state of the organs that the data were combined in the preparation of table 19. The insignificant difference of weight between ripe and spent males justified their combination as adult males. On the other hand, the differences between ripe and spent females indicated a large percentage loss of weight at spawning. The loss exhibited no clear-cut trend with increase of length. This observation agreed with the finding of Jobes (1952) that no relation exists between the percentage loss of weight and the length of fish.

The loss of weight of females at spawning varied between 8.5 and 22.2 percent (a gain was indicated at 5.5–5.9 inches but the comparison was based on only 2 fish). Over the length interval in which both unspent and spent fish were represented by 9 or more fish in each comparison (6.5–9.4 inches) the values ran from 8.5 to 16.7. The average percentage loss for the whole sample was 12.3 percent, much less than the 16.1 percent recorded by Jobes (1952) for Lake Erie yellow perch.

The weights of the immature fish of both sexes, of adult males, and of spent females all were closely similar, and as noted, substantially below those of ripe females of corresponding length.

Seasonal Change in Weight

Information on seasonal variation in weight can be studied only for 1955, the 1 year with collections outside the spawning season. Because of their relatively greater weight, ripe females are listed separately in the data on the length-weight relation of spawning-run fish (table 20). In later collections, however, the difference in weight between the sexes was too small to warrant separate presentation.

TABLE 19.—*Length-weight relation of Saginaw Bay yellow perch according to sex and state of organ*

[Based on spawning-run collections of 1949, 1951, 1953, 1954, and 1955. Number of fish in parentheses]

Total length (inches)	Male		Female				
	Immature	Adult [1]	Immature	Ripe or nearly ripe [2]	Spent	Loss at spawning	Percentage loss
5.0–5.4		0.8 (2)	0.9 (2)				
5.5–5.9		1.2 (64)	1.2 (7)	1.3 (1)	1.5 (1)	−0.2	−15.4
6.0–6.4	1.5 (5)	1.5 (192)	1.5 (22)	1.8 (2)	1.4 (5)	.4	22.2
6.5–6.9	1.7 (6)	1.9 (284)	1.9 (46)	2.4 (18)	2.0 (18)	.4	16.7
7.0–7.4	2.4 (2)	2.4 (248)	2.4 (16)	2.7 (28)	2.4 (32)	.3	11.1
7.5–7.9		3.0 (155)	3.0 (12)	3.3 (26)	2.9 (40)	.4	12.1
8.0–8.4		3.7 (74)	3.5 (1)	4.2 (27)	3.7 (47)	.5	11.9
8.5–8.9		4.5 (35)		5.2 (9)	4.6 (35)	.6	11.5
9.0–9.4		5.4 (17)		5.9 (11)	5.4 (27)	.5	8.5
9.5–9.9		6.1 (5)		7.1 (3)	6.2 (17)	.9	12.7
10.0–10.4		7.4 (2)		9.2 (2)	7.6 (13)	1.6	17.4
10.5–10.9		8.4 (1)		9.8 (1)	8.8 (4)	1.0	10.2
Total or average	13	1,079	106	128	239		[3] 12.3

[1] All mature fish combined (nearly ripe fish omitted).
[2] Ripe and nearly ripe fish combined.
[3] In the computation of this average, each percentage was weighed by the sum of the number of fish in the 2 groups whose weights were compared to obtain the percentage.

TABLE 20.—*Length-weight relation of Saginaw Bay yellow perch in the different seasons of 1955*

[Number of fish in parentheses]

Total length (inches)	Spawning season [1]: Males and spent females [2]	Spawning season [1]: Ripe females	Spawning season [1]: All fish	June 22 [3]	Oct. 19 [3]
5.0–5.4	----------	----------	----------	1.1 (2)	1.1 (3)
5.5–5.9	1.2 (11)	2.1 (2)	1.3 (13)	1.2 (74)	1.3 (15)
6.0–6.4	1.4 (39)	1.7 (1)	1.4 (40)	1.5 (219)	1.7 (31)
6.5–6.9	2.0 (47)	3.6 (2)	2.1 (49)	1.9 (118)	2.1 (40)
7.0–7.4	2.4 (29)	2.5 (1)	2.4 (30)	2.4 (53)	2.6 (61)
7.5–7.9	2.9 (9)	3.0 (4)	2.9 (13)	3.0 (27)	3.1 (69)
8.0–8.4	3.7 (23)	3.8 (10)	3.7 (33)	4.0 (9)	3.8 (54)
8.5–8.9	4.5 (30)	4.8 (9)	4.6 (39)	4.8 (3)	4.7 (33)
9.0–9.4	5.5 (17)	5.8 (9)	5.6 (24)	6.5 (1)	5.6 (19)
9.5–9.9	6.1 (11)	7.1 (3)	6.3 (14)	8.0 (1)	6.7 (13)
10.0–10.4	6.6 (4)	9.2 (2)	7.5 (6)	9.5 (1)	7.1 (3)
10.5–10.9	8.4 (1)	----------	8.4 (1)	----------	8.5 (3)
11.0–11.4	----------	----------	----------	----------	11.6 (1)

[1] Based on samples of Apr. 18 and May 18. The June 7 sample was excluded because of the lack of records as to the state of gonads in some fish.
[2] Ripe and spent males and spent females combined; no immature fish.
[3] Mature fish, sexes combined.

The differences in weight among the different seasons were so slight that it is not possible to speak of a seasonal trend. Nevertheless, some differences could be detected. The males and spent females of the spawning-run sample, for example, usually were lighter than perch caught June 22 and October 19, and ripe females had a somewhat weaker tendency to be heavier than fish caught later in the year. The fall fish (October 19) were a little heavier than the June 22 sample for lengths between 5.0 and 7.9 inches, but for larger sizes (8.0 to 10.4 inches) yellow perch tended to be heavier in summer. In his study of the length-weight relation of Lake Erie perch, Jobes (1952) found the fish to be lighter in June than later in the season. He recorded the following coefficients of conditions for different months: June, 1.80; July, 1.97; August, 1.98; September, 1.92; October, 1.87. No other studies have been made of the seasonal trends of weight in perch in the Great Lakes.

Comparison with Length-Weight Relation in 1929–30 and with other Great Lakes Populations

Data on the length-weight relation (table 21) of the yellow perch from Green Bay, Lake Michigan, Lake Erie, and Saginaw Bay (1929–30) are from records published by Hile and Jobes (1941,

TABLE 21.—*Length-weight relation of yellow perch populations in the different Great Lakes waters*

[Data adapted from publications as follows: Green Bay and Lake Michigan' Hile and Jobes (1942); Lake Erie, Jobes (1952); Saginaw Bay in 1929–30. Hile and Jobes (1941)]

Total length (inches)	Calculated weights (ounces): Green Bay	Lake Michigan	Lake Erie	Saginaw Bay (1929–30)	Saginaw Bay (1943–55)
5.0	0.7	1.0	0.8	0.8	0.8
5.5	1.0	1.4	1.1	1.0	1.0
6.0	1.4	1.8	1.4	1.3	1.4
6.5	1.7	2.2	1.9	1.6	1.8
7.0	2.2	2.7	2.3	2.0	2.3
7.5	2.8	3.4	2.9	2.7	2.9
8.0	3.4	4.0	3.5	3.4	3.5
8.5	4.1	4.8	4.1	4.0	4.3
9.0	4.9	5.6	5.0	4.9	5.2
9.5	5.8	6.6	6.1	6.1	6.2
10.0	7.0	7.7	7.0	7.2	7.3
10.5	8.1	8.9	8.3	8.1	8.6
11.0	9.4	10.1	9.4	9.5	10.0
11.5	10.8	11.4	10.9	11.0	11.5
12.0	12.2	12.8	12.3	12.5	13.2
12.5	13.9	14.4	14.1	13.3	15.1
13.0	15.8	16.0	15.8	16.0	17.2
13.5	17.8	17.9	17.6	17.8	19.4
Exponent value (n)	3.133	2.811	3.015	3.117	3.262

1942) and Jobes (1952). The table was arranged to facilitate the comparison of weights of fish of the same length in the different Great Lakes populations. The following length-weight equations from which weights were derived will clearly show the different degrees of deviation from the cube relationship between weight and length.

Lake Erie:

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

Green Bay:

$$W = 0.9319 \times 10^{-5} L^{3.133}$$

Lake Michigan:

$$W = 5.8405 \times 10^{-5} L^{2.811}$$

Saginaw Bay (1929–30):

$$W = 0.9826 \times 10^{-5} L^{3.1174}$$

In all the above equations W = weight in grams and L = standard length in millimeters.

The length-weight relations (weights calculated from length-weight equations) of the different Great Lakes yellow-perch populations (table 21) did not differ greatly. Most important differences, perhaps, were in the values of the exponent n which measures the ratio of the instantaneous rates of increase in weight and length. The value of n in the equation for Saginaw Bay samples of 1943–55 (3.262) shows the most rapid rate of increase in weight with increase in length yet reported for a Great Lakes stock of perch. Thus these Saginaw Bay perch, though substantially lighter than Lake Michigan fish at the shorter lengths, were able to overtake and then surpass in weight the Lake Michigan population at greater lengths. On the other hand, although Lake Michigan yellow perch had the lowest exponent value (2.811), they were so heavy at the shorter lengths that the other Great Lakes populations (Green Bay, Lake Erie, and Saginaw Bay 1929–30) were unable to reach their weights even at the greatest lengths.

The unusually low value of n (2.811) in the equation for yellow perch of northern Lake Michigan probably can be attributed to the selective action of the commercial gill nets (2⅝-inch mesh) by which they were captured. Gill nets have been shown to take the relatively heavier of the shorter fish and the relatively lighter of the longer ones (Farran 1936; Deason and Hile, 1947; Le Cren 1951).

The rapid rate of increase of weight with length in Saginaw Bay collections of 1943–55 also gave them a weight advantage over fish collected in 1929–30. Differences between the two groups were nil or slight at the shorter lengths, but among larger fish the 1943–55 collections had substantially greater weights. At 10.5 to 13.5 inches the advantage ranged from 0.5 to 1.6 ounces.

CALCULATED GROWTH

Body-Scale Relation

Most workers who have published on the growth of yellow perch have given only the average size of age groups, or, if they published calculated lengths have assumed that the body-scale ratio is constant at all lengths of fish. Studies have been made, however, of the body-scale relation of perch in Saginaw Bay (Hile and Jobes, 1941), Lake Erie (Jobes 1952) and Lake of the Woods (Carlander 1950). Particulars on the findings for the two Great Lakes stocks are given later in this section. Carlander described the body-scale relation in yellow perch of Lake of the Woods by two conic-section parabolas, one fitted to data for fish 50 to 150 mm. long and the other to data for smaller (down to 19 mm.) and larger (up to 289 mm.) fish.

Inasmuch as the curve of regression of fish length on the radius of the key scale below the lateral line, presented by Hile and Jobes (1941), was based on plentiful materials, its use in the present study for the calculation of growth from measurements of scales from the same general area of the body could be considered valid. Through a misunderstanding on the part of the field collectors, however, the scale samples of the 1954 collections were removed from above the lateral line, which made necessary a study of the body-scale relation for scales from that part of the body. Because the assembling of materials for a body-scale study was necessary it was decided to extend the study and make a redetermination of the relation for the key scale below the lateral line. This extension permitted the comparison of two regression lines determined independently for the same key scale and also the comparison of the growth of the same fish as estimated independently by regression lines for scales from two positions on the body. (The exact positions of both key scales are stated in the section on materials and methods.)

Key scales below the lateral line

The graphic presentation of the body-scale data from below the lateral line (fig. 11) indicated that for fish over 70-mm. standard length the body-scale relation could be represented by a

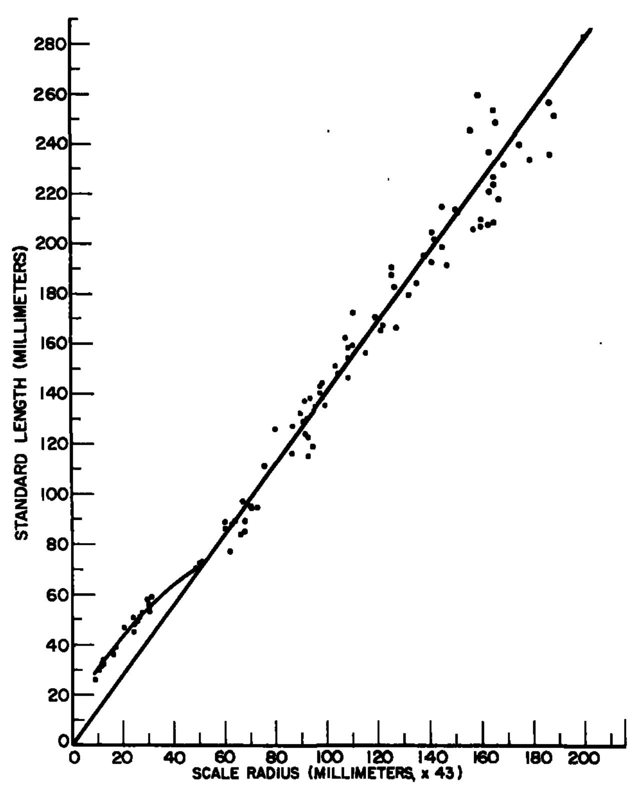

FIGURE 11.—Relation between body length and scale length of Saginaw Bay yellow perch (key scales from below the lateral line).

straight line passing through the origin. This view was supported by the fact that the values of the body-scale ratio, L/S (table 22), did not show any trend with change of length. The straight line of figure 11, therefore, was drawn through the origin at a slope equal to the average L/S value of 1.40. For these lengths above 70 mm., the direct-proportion computations were valid as calculated. For lengths less than 70 mm., however (body-scale curve drawn freehand in fig. 11) the direct-proportion calculation always gave an underestimate of length. The amount of correction required at a particular length can be obtained by measuring the vertical distance between the straight line and the empirical curve. Table 23 was set up to show the correction for each direct-proportion calculated length.

Similar body-scale relations were determined for the same key scale by Hile and Jobes (1941) for Saginaw Bay and by Jobes (1952) for Lake Erie. In both studies the relation for the larger

TABLE 22.—*Relation between body length (L) and the anterior interradial measurement (S) of key scales of yellow perch from above and from below the lateral line*

Standard length interval	Number of fish	Average standard length	Average scale radius (x43)		Average L/S ratio	
			Below lateral line	Above lateral line	Below lateral line	Above lateral line
25–30	5	28.4	8.8	4.6	3.23	6.17
31–35	13	32.3	11.4	6.6	2.83	4.89
36–40	6	37.2	16.2	9.6	2.30	3.88
41–45	2	43.0	22.2	14.2	1.94	3.03
46–50	11	48.0	23.9	15.5	2.01	3.10
51–55	8	52.2	27.8	17.7	1.88	2.95
56–60	5	57.0	30.3	18.6	1.88	3.06
61–65	4	63.5	39.5	21.1	1.61	3.01
66–70	8	67.6	44.4	23.0	1.52	2.94
71–75	8	73.2	49.8	28.2	1.47	2.60
76–80	1	77.0	61.5	34.5	1.25	2.23
81–85	3	84.0	65.8	36.0	1.28	2.33
86–90	8	87.6	63.4	37.2	1.38	2.35
91–95	1	95.0	69.5	38.5	1.37	2.47
96–100	1	97.0	67.0	41.0	1.45	2.36
111–115	2	113.0	84.8	52.8	1.33	2.14
116–120	4	116.8	89.2	71.6	1.31	1.63
121–125	22	122.7	88.5	61.4	1.39	2.00
126–130	19	128.3	89.7	59.4	1.43	2.16
131–135	14	133.3	92.8	65.3	1.44	2.04
136–140	40	138.2	94.3	64.4	1.46	2.14
141–145	22	143.4	98.2	70.5	1.46	2.03
146–150	17	147.3	106.3	71.6	1.38	2.06
151–155	30	152.5	106.4	76.2	1.43	2.00
156–160	45	157.6	112.1	76.6	1.40	2.06
161–165	30	163.2	113.8	78.1	1.43	2.09
166–170	48	167.5	124.0	79.9	1.35	2.10
171–175	19	172.0	110.6	79.8	1.56	2.16
176–180	7	179.0	132.9	89.7	1.35	2.00
181–185	35	182.4	128.8	90.9	1.42	2.01
186–190	14	188.5	126.0	84.0	1.50	2.24
191–195	21	192.0	144.7	95.0	1.33	2.02
196–200	7	198.0	145.8	99.1	1.36	2.00
201–205	11	203.1	149.7	105.2	1.36	1.93
206–210	9	208.3	160.6	112.4	1.30	1.85
211–215	8	212.8	150.8	108.5	1.41	1.96
216–220	6	218.5	166.0	115.7	1.32	1.90
221–225	2	223.0	165.5	118.8	1.35	1.88
226–230	9	227.0	165.5	125.6	1.37	1.81
231–235	9	232.6	177.2	133.5	1.31	1.74
236–240	4	238.2	173.0	141.5	1.38	1.68
241–245	3	245.0	157.0	107.9	1.56	2.27
246–250	2	248.0	166.8	127.0	1.49	2.00
251–255	4	252.0	178.2	133.0	1.41	1.89
256–260	2	257.5	173.8	135.0	1.48	1.91

TABLE 23.—*Amount of correction to be added to direct-proportion calculated standard lengths of yellow perch from Saginaw Bay and Lake Erie*

[Scales from below the lateral line]

Direct-proportion calculated length (millimeters)	Amount to be added (millimeters)		
	Saginaw Bay (1955)	Saginaw Bay [1] (1929–30)	Lake Erie [2]
15–21	16		
22–30	15		
31–35	14		
36	14		19
37	13		18
38–39	13	16	18
40	12	16	18
41–42	12	15	18
43–45	11	15	17
46–47	11	14	17
48–49	10	14	17
50	10	13	16
51–53	9	13	16
54–56	8	12	15
57	8	12	14
58	7	12	14
59	7	11	14
60	6	11	14
61	6	10	13
62–63	5	10	13
64	4	10	13
65	4	9	12
66–67	3	9	12
68	2	8	12
69	1	8	12
70	0	8	11
71–72	0	8	10
73–75	0	7	9
76–78	0	6	8
79	0	6	7
80	0	5	7
81–83	0	5	6
84–86	0	4	5
87	0	4	4
88	0	4	3
89	0	3	3
90–91	0	3	2
92	0	2	2
93–95	0	2	1
96–101	0	1	0

[1] Data taken from table 5 of Hile and Jobes (1941).
[2] Data adapted from table 4 of Jobes (1952.)

fish could be described by a straight line through the origin but direct-proportion calculations gave underestimates at the smaller lengths. The amount of correction differed, however, between Lake Erie and Saginaw Bay and between the Hile and Jobes sample and the recent one from Saginaw Bay. Without exception the corrections determined in the present study were smaller than those published for Saginaw Bay by Hile and Jobes; furthermore, the 1955 samples indicated no need for corrections beyond 70 mm. whereas Hile and Jobes listed corrections through 101 mm. Differences between corrections at corresponding lengths averaged 4.5 mm. over the range, 38–101 mm. The corrections of direct-proportion calculations at the smaller lengths of fish for Lake Erie yellow perch were greater at most lengths than those given by Hile and Jobes for Saginaw Bay perch and were much larger than those determined in the present study. The average differences in the two comparisons were

1.9 mm. (absolute values employed) and 7.2 mm.

It is not possible at this time to state to what extent the difference between the Hile and Jobes curve and the one determined in the present study represent a true change in the population or to what extent they reflect random variation. Unpublished data on body-scale curves derived from different samples of Great Lakes fish (from a single lake) do indicate a considerable sample-to-sample variability, but the possibility of a real change is not to be discounted. At any rate, it was obviously proper to apply the more recently derived curve to the 1943–55 collections.

Key scales above the lateral line

The graph of body-scale data (fig. 12) indicated a linear relation between the standard length and the scale radius for fish longer than

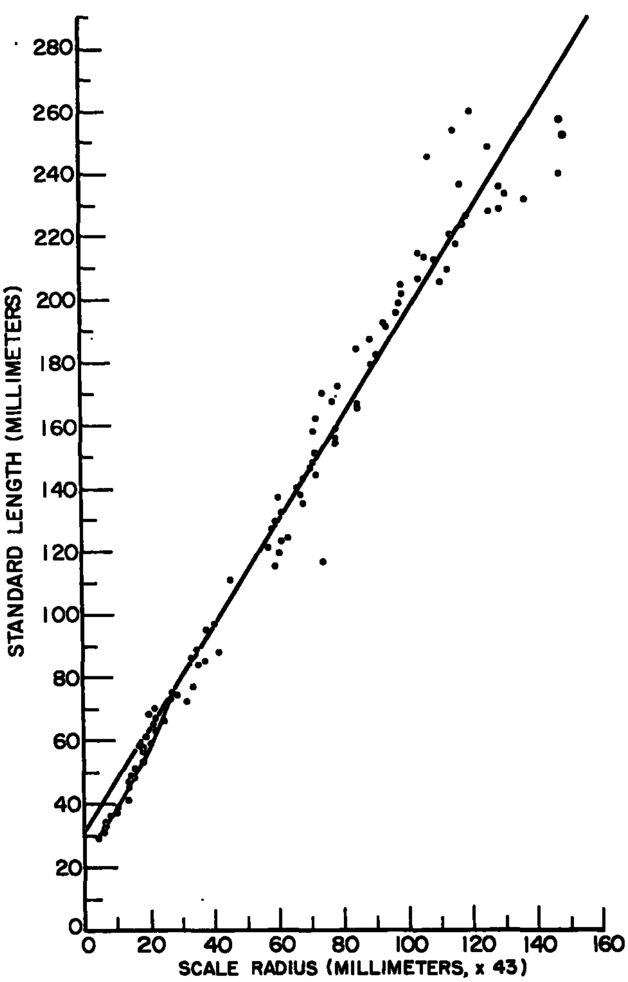

FIGURE 12.—Relation between body length and scale length of Saginaw Bay yellow perch (key scales from above the lateral line).

75 mm. The straight line fitted by least squares to data for fish longer than 75 mm. had the equation:

$$L = 30.5 + 1.63\,S$$

where

L = standard length in mm.,

and

S = scale radius (×43) in mm.

For practical use the intercept was taken to be 30 mm.

Calculated lengths greater than 75 mm. were computed by the formula:

$$L_n = 30 + \frac{(L_t - 30)}{S_t} S_n,$$

where

L_n = calculated length at the end of n years,

L_t = standard length at capture,

S_n = scale radius to the nth annulus,

and

S_t = total scale radius.

Calculated lengths less than 75 mm. obtained by this formula are overestimates. Corrections for these overestimates (table 24) were determined from the body-scale curve (fig. 12). They are the vertical distance between the empirically fitted body-scale curve for fishes below 75 mm. and the extension of the straight line.

TABLE 24.—*Correction to be subtracted from standard lengths of Saginaw Bay yellow perch calculated by formula*

[Scales from above the lateral line]

Calculated length interval (millimeters)	Correction to be subtracted (millimeters)	Calculated length interval (millimeters)	Correction to be subtracted (millimeters)
29–45	9	66–67	4
46–53	8	68–70	3
54–61	6	71–73	2
62–65	5	74	1

Comparison of lengths calculated from different scales of the same fish

Inasmuch as the two body-scale curves were determined from selected or key scales it should be expected that nearly identical estimates of growth of fish in the sample would be obtained from the two sets of scales. The comparison of the growth histories of the same fish as computed from measurements of scales from above and below the lateral line (table 25) supports this expectation with the exception of calculated lengths at the end of the second year of life. At this age the scales above the lateral line consistently gave the higher calculated lengths; the discrepancies ranged from 1 to 6 mm. and averaged 3.6 mm. There is no information now from which to determine the cause of this bias. Fortunately, the discrepancies affect principally a single year of life and are not excessive.

Implications as to procedure in the calculation of growth

The differences in body-scale relation between stocks and between two scale positions on the body of the same fish emphasize the importance of an exact knowledge of the body-scale relation of the population under study and a high degree of consistency in the field as to the point from which scale samples are removed. Not only must the body-scale relation be known for a particular key area; routine samples of scales must be taken from that area.

Even with these precautions, precision may not be so great as would be desired. The differences between the body-scale curves derived for Saginaw Bay perch by Hile and Jobes (1941) and in the present study, and discrepancies between lengths calculated for the same fish from measurement of scales above and below the lateral line indicate a certain amount of variability that cannot yet be explained.

TABLE 25.—*Calculated standard length (millimeters) of the same yellow perch from key scales above and below the lateral line*

Age group and position of scales	Number of fish	Calculated length at end of year					
		1	2	3	4	5	6
Male:							
Age group III	10						
Above		61	111	[1] 142			
Below		61	110	142			
Discrepancy		0	1	0			
Age group IV	30						
Above		58	94	115	[1] 133		
Below		59	90	114	133		
Discrepancy		1	4	1	0		
Age group V	58						
Above		57	92	115	132	[1] 151	
Below		58	88	113	132	151	
Discrepancy		1	4	2	0	0	
Age group VI	12						
Above		59	86	104	124	142	[1] 160
Below		61	92	109	127	143	160
Discrepancy		2	6	5	3	1	0
Female:							
Age group III	31						
Above		63	110	[1] 155			
Below		60	109	155			
Discrepancy		3	1	0			
Age group IV	58						
Above		63	103	134	[1] 169		
Below		62	100	134	169		
Discrepancy		1	3	0	0		
Age group V	138						
Above		59	93	119	144	[1] 175	
Below		60	88	119	145	175	
Discrepancy		1	5	0	1	0	
Age group VI	32						
Above		58	92	112	134	156	[1] 181
Below		60	87	109	133	157	181
Discrepancy		2	5	3	1	1	0

[1] Size of fish at capture.

Growth in Length

Growth in length of the age groups

In the presentation of average calculated lengths for yellow perch collected from Saginaw Bay during the spawning season of 1943–55 (tables 26 and 27) sexes are kept separate because of the more rapid growth of the females. Data for the calculated growth histories of age groups from different years are combined to give a best estimate of average conditions.

The calculated lengths of the males and females through age group VI for the different years of life show a definite tendency to decrease as the fish grow older. This discrepancy in calculated length is more pronounced in the later years of life, particularly after the second year. Among the first-year calculated lengths the values for different age groups beyond the II group are nearly the same.

TABLE 26.—*Calculated total length at the end of the different years of life for male yellow perch collected during the spawning seasons of 1943–55*

[The figures in this table were rounded from original records carried to the nearest 0.01 inch, hence the discrepancy between the 5th-year grand average increment and the 4th- and 5th-year lengths derived from summation of the increments. Increments in parentheses]

Age group	Number of fish	Length (inches) at end of year						
		1	2	3	4	5	6	7
II	3	3.1	5.1 (2.0)					
III	284	2.7	4.6 (1.9)	6.2 (1.6)				
IV	963	2.6	4.2 (1.6)	5.5 (1.3)	6.7 (1.2)			
V	706	2.6	4.0 (1.4)	5.4 (1.4)	6.3 (.9)	7.3 (1.0)		
VI	134	2.6	3.9 (1.3)	5.2 (1.3)	6.2 (1.0)	7.1 (.9)	8.0 (.9)	
VII	6	2.5	3.5 (1.0)	4.7 (1.2)	6.0 (1.3)	7.0 (1.0)	8.0 (1.0)	8.8 (.8)
Grand average calculated length		2.6	4.2	5.5	6.5	7.3	8.0	8.8
Increment of average		2.6	1.6	1.3	1.0	.8	.7	.8
Grand average increment of length		2.6	1.6	1.4	1.1	1.0	.9	.8
Sum of average increments		2.6	4.2	5.6	6.7	7.6	8.5	9.3

TABLE 27.—*Calculated total length at the end of the different years of life for female yellow perch collected during the spawning seasons of 1949–55*

[Increments in parentheses]

Age group	Number of fish	Length (inches) at end of year								
		1	2	3	4	5	6	7	8	9
II	15	2.9	5.0							
			(2.1)							
III	281	2.7	4.5	6.6						
			(1.8)	(2.1)						
IV	660	2.7	4.3	5.8	7.5					
			(1.6)	(1.5)	(1.7)					
V	300	2.6	4.1	5.6	7.0	8.3				
			(1.5)	(1.5)	(1.4)	(1.3)				
VI	39	2.7	4.1	5.5	7.3	8.6	10.0			
			(1.4)	(1.4)	(1.8)	(1.3)	(1.4)			
VII	6	2.9	4.7	6.6	8.2	9.8	10.8	11.8		
			(1.8)	(1.9)	(1.6)	(1.6)	(1.0)	(1.0)		
VIII	3	3.2	5.3	7.7	9.6	10.8	12.4	13.3	13.9	
			(2.1)	(2.4)	(1.9)	(1.2)	(1.6)	(.9)	(.6)	
IX	1	2.5	4.8	8.1	10.5	12.4	13.2	13.7	14.1	14.5
			(2.3)	(3.3)	(2.4)	(1.9)	(.8)	(.5)	(.4)	(.4)
Grand average calculated length		2.7	4.3	5.9	7.4	8.4	10.3	12.4	14.0	14.5
Increment of average		2.7	1.6	1.6	1.5	1.0	1.9	2.1	1.6	.5
Grand average increment of length		2.7	1.6	1.6	1.6	1.3	1.4	.9	.6	.5
Sum of average increments		2.7	4.3	5.9	7.5	8.8	10.2	11.1	11.7	12.2

Most of the calculated lengths of age groups VII–IX of the females, on the other hand, were greater than the corresponding calculated lengths of younger age groups. That these discrepancies can be attributed to erroneous interpretation of the difficult scales of old fish seems unlikely since the trend toward higher calculated lengths among the older perch is present in the earlier as well as in the later years of life. Ordinarily the first 3 or 4 annuli are easy to locate and measure even on the scales of old fish. Inasmuch as age groups VII–IX were represented by only 10 fish it can hardly be concluded that the survivors to advanced ages are regularly the more rapidly growing individuals, but the possibility of such a selective survival should not be ignored.

The discrepancies shown in tables 26 and 27, for yellow perch other than the older females, exhibit a different pattern from that of "Lee's phenomenon of apparent decrease in growth rate" as defined by that author (Lee 1920). In Lee's phenomenon the discrepancies among calculated lengths are greatest in the early years of life and become less and less in later years. In the Saginaw Bay perch, on the contrary, the disagreements affect the later years of life most severely. A similar situation has been reported earlier for Saginaw Bay by Hile and Jobes (1941) and also for perch of Lake Erie (Jobes 1952) and Green Bay (Hile and Jobes 1942) and for certain species of deep-water ciscoes (Jobes 1949a, 1949b, and 1943; Deason and Hile 1947).

A change in calculated lengths occurred also between samples of the same age group caught in spring and fall (tables 28 and 29). Among males the disagreements were generally smaller between the calculated lengths of any age group caught in the fall and the next higher age group caught in the spring than were the differences

TABLE 28.—*Calculated lengths of spring and fall samples of 3 age groups of male yellow perch, 1955*

Age group and time of capture	Number of fish	Length (inches) at end of year					
		1	2	3	4	5	6
III							
Spring	72	2.9	4.8	[1] 6.0			
Fall	30	2.7	4.2	5.3	[1] 6.2		
IV							
Spring	179	2.7	4.1	5.4	[1] 6.3		
Fall	58	2.7	4.1	5.2	6.1	[1] 7.0	
V							
Spring	149	2.6	3.9	5.1	6.1	[1] 7.1	
Fall	12	2.7	4.0	4.8	5.8	6.6	[1] 7.4

[1] Size at capture.

TABLE 29.—*Calculated lengths of spring and fall samples of 3 age groups of female yellow perch, 1955*

Age group and time of capture	Number of fish	Length (inches) at end of year					
		1	2	3	4	5	6
III							
Spring	57	2.8	4.6	[1] 6.3			
Fall	58	2.9	4.6	6.2	[1] 7.8		
IV							
Spring	148	2.7	4.1	5.8	[1] 7.3		
Fall	139	2.8	4.1	5.5	6.7	[1] 8.0	
V							
Spring	76	2.6	4.0	5.0	6.3	[1] 7.7	
Fall	32	2.8	4.0	5.0	6.2	7.3	[1] 8.2

[1] Size at capture.

between members of the same age group. Although the same observation does not hold well for the females the data offer evidence that much of the disagreement among calculated lengths of different age groups is established between the spring and fall during the time of active growth in length and when fishing intensity is high.

Jobes (1952) discussed the possible causes of these discrepancies among calculated lengths in full detail. The present comments will be limited, therefore, to those factors believed to be most important in Saginaw Bay perch.

Much of the disagreement in calculated lengths of Saginaw Bay perch can be attributed to biased samples and to the progressive elimination of the more rapidly growing individuals from the population. These two sources of discrepancy are interrelated.

Selection according to legal size: Although this factor was mentioned in the preceding paragraph, it is given a special listing because of its great importance. The mortality of legal-sized fish caught in commercial nets is 100 percent. Inasmuch as the commercial fishery is supported principally by age groups whose length distributions cross the legal minimum of 8½ inches this selective destruction, particularly if the fishery is intensive, has a profound effect on the growth characteristics of the survivors.

Selective action of gears: The mesh sizes of the commercial trap nets by which the samples were taken (about 2½ inches, extension measure) were large enough to permit the escape of the smaller individuals of the younger age groups (the older the fish the higher the percentage held by the nets). As a result, the size at capture and calculated lengths of the younger age groups were overestimates of their growth.[5] Furthermore, these larger members of the younger age groups, as a result of being caught, were subjected to certain mortality hazards. The few that had reached legal size (8½ inches) all were killed. Those shorter than 8½ inches were returned to the water but they experienced some mortality from handling and sorting (nearly all fish are dead in gill nets). The extent of the mortality of small fish is not known, but Jobes (1952) estimated that in Lake Erie 14 percent of the perch were dead when the trap nets were lifted. This selective destruction of the more rapidly growing fish surely affects the growth characteristics of samples from the same year classes taken in subsequent years at older ages.

Selection due to segregation by sexual maturity and size: Segregation according to maturity can be significant in the present study since the principal samples were taken in the spawning season during which time small, immature fish tend to avoid the spawning grounds. Data from our samples (see Size at Maturity, p. 408) gave no evidence of this type of segregation, although other investigators have reported it frequently. A scarcity of immature fish can mean a segregation according to size because the fast-growing individuals usually mature earlier. Selective destruction of the mature fish during the spawning season is of limited consequence since most or all of the spawning is covered by the closed season during which all perch must be returned to the water.

Segregation according to sex and size can lead to biased sampling and selective mortality at all times of year. Evidence is strong for a segregation of sexes in various months outside the spawning season (Eschmeyer 1937, Weller 1938, Jobes 1952). It is well known also that perch of different size inhabit different regions of a lake, but the nature of this segregation apparently differs among populations (Hile and Juday, 1941). Data are lacking for a description of segregation by sex and by size in Saginaw Bay, but undoubtedly it occurs. This segregation can lead both to biased samples and selective mortality since fishermen can be expected to concentrate their efforts on grounds occupied by the larger fish.

Greater natural mortality rate for fish with rapid growth: Hile (1936) found a higher natural mortality rate among the rapidly growing ciscoes of Silver Lake (northern Wisconsin) than among the slow-growing ones. Whether a similar differential mortality occurs in the Saginaw Bay yellow perch is not known. Indeed, it would be most difficult to obtain information on the question in view of the known selective destruction of rapidly growing individuals in the fishery.

Evidence that the discrepancies of calculated lengths among the age groups of Saginaw Bay yellow perch are of the type that would result from the selective mortality of fish with the more rapid growth is given in table 30 which contains

[5] The selective action of such other gears as pound nets, fyke nets, and seines is similar to that of trap nets. Gill nets are even more selective as both the smallest and largest fish escape capture.

TABLE 30.—*Effect of the elimination of fish with the more rapid growth on the determination of the calculated lengths of female yellow perch of group IV, collected on Oct. 19, 1955*

[Age group V is included for comparison]

Age group	Sample	Number of fish	Length at capture	Calculated length (inches) at end of year					
				1	2	3	4	5	6
IV	All fish included	138	8.0	2.8	4.1	5.5	6.7	[1]8.0	----
IV	Fish longer than 7.9 inches excluded.	68	7.3	2.8	4.0	5.3	6.3	[1]7.3	----
V	All fish included	32	8.2	2.8	4.0	5.1	6.2	7.3	[1]8.2

[1] Size at capture.

three sets of calculated lengths (all for fish collected Oct. 19, 1955): Age group IV, entire sample; age group IV, with the more rapidly growing fish excluded; age group V. It is seen that exclusion of the larger IV-group fish results in a growth curve closely similar to that of the full sample of age group V.

From the previous discussion it is apparent that various factors bias sampling and change the growth characteristics of yellow perch in Saginaw Bay but that it is not possible to rank these factors as to their relative importance. The factors doubtless operate together to bring about these consistent discrepancies among the calculated lengths of the different age groups.

General growth rate

Two estimates of general growth are given in the bottom section of tables 26 and 27. One is based on the grand average calculated lengths and the second on the summation of the grand average annual increments of length. The grand average calculated lengths serve best to show the regression of size on age in an exploited stock, and the sum of the increments is believed to indicate approximately the average growth that yellow perch might have if the stock were not subjected to selective destruction of individuals with the more rapid growth. The present discussion is based on the sums of increments since this curve is held to be the more descriptive of biological growth potential. The selection of these data was mainly due to the discrepancies in calculated length of the age groups. This view agrees with that of earlier investigators who made similar use of average annual increments to show the general growth of yellow perch in Saginaw Bay (Hile and Jobes, 1941), Green Bay (Hile and Jobes, 1942) and Lake Erie (Jobes 1952). Comments on general growth and a comparison of the growth of the sexes are best made from table 31 which was prepared from data of tables 26 and 27 (see also fig. 13).

The lengths of the sexes were closely similar in the first and second years of life (a difference of 0.1 inch). Then, the curves started to diverge (with the females the longer). The advantage of the females increased from 0.3 inch at the end of the third year to 1.8 inches at the end of the seventh (no males older than age-group VII in

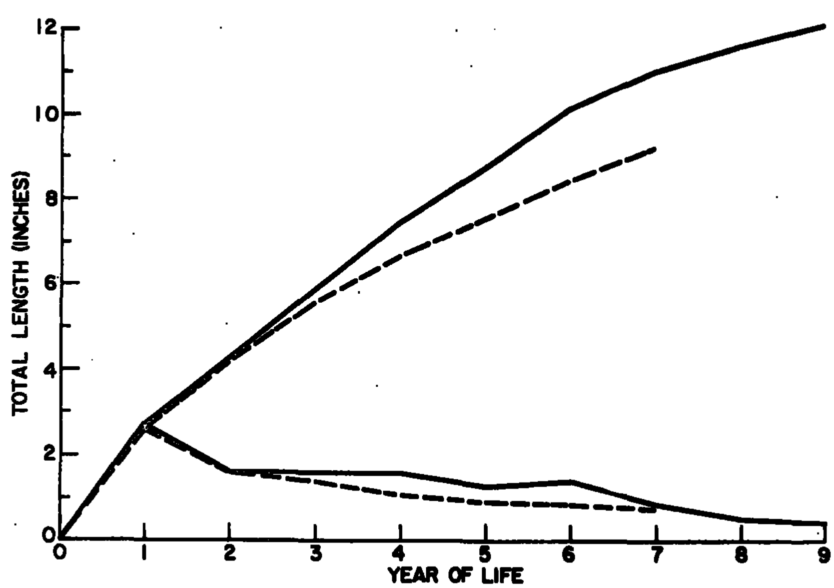

FIGURE 13.—General growth in length and annual increments in length of Saginaw Bay yellow perch of the 1943–55 spawning-run samples. Males, broken line; females, solid line.

TABLE 31.—*Calculated total lengths (inches) and length increments of male and female yellow perch of Saginaw Bay in different years of life*

[Data from tables 26 and 27]

Year of life	Males		Females		Size advantage of females
	Calculated length	Increment	Calculated length	Increment	
1	2.6	2.6	2.7	2.7	0.1
2	4.2	1.6	4.3	1.6	.1
3	5.6	1.4	5.9	1.6	.3
4	6.7	1.1	7.5	1.6	.8
5	7.6	[1]1.0	8.8	1.3	1.2
6	8.5	.9	10.2	1.4	1.7
7	9.3	.8	11.1	.9	1.8
8			11.7	.6	
9			12.2	.5	

[1] See caption of table 29.

the samples). This difference in growth rate between male and female fish affected the age at which the legal size (8½ inches) was reached. The male perch took 6 years to reach this legal size and the female more than 4½ years.

The greatest increase in length for both sexes took place during the first year of life (2.6 inches for the males and 2.7 inches for the females). The amount of growth dropped sharply during the second year (1.6 inches for both sexes). The decrease continued for the males through the seventh year but the females made nearly the same amount of growth every year (1.3 inches to 1.6 inches) through the sixth year of life. After the sixth year annual growth increments dropped continuously.

A divergence of growth curves of the sexes surely is characteristic of the yellow perch and may be of the perch family. It has been observed in the three Great Lakes stocks of perch that have been studied and was reported for the Saginaw Bay walleye by Hile (1954).

Annual fluctuation of growth in length

Data on the annual fluctuation of growth in length of Saginaw Bay yellow perch (tables 32 and 33) are so arranged as to facilitate the comparison of the growth increments. The growth in a particular year of life in the different calendar years can be read from the horizontal rows. The columns show the increments for the different years of life in a particular calendar year. The growth histories of individual age groups can be traced from the diagonal rows. Records are given separately by sex and age because of sex differences in growth and systematic discrepancies among calculated lengths of fish of different ages. Age groups represented by fewer than 10 fish have been omitted from the tables.

It is readily apparent from tables 32 and 33 that growth increased or decreased sharply in some years, whereas for other years no trend can be detected. A comparison of the growth of males in 1945 and 1946, for example, reveals a consistent increase of the increments from 1945 to 1946 for all the years of life for the different age groups (table 32). On the other hand, the

TABLE 32.—*Annual increments of growth in length of male Saginaw Bay yellow perch, spawning-run collections of 1943–55*

[Each diagonal gives the growth history of an age group, belonging to the year class indicated by the year of 1st-year growth and captured in the spring of the calendar year following the one for which the last increment is given. Number of fish in sample of each age group in parentheses immediately below 1st-year increment]

Age groups and years of life	Increment of standard length (millimeters) in calendar years																
	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Age group VI:																	
6										19	20	23	24			19	20
5									20	18	15	18			16	20	
4								20	24	20	18			21	23		
3							22	26	27	23			26	30			
2						23	22	24	32			35	29				
1					55	55	53	57			55	55					
Number of fish					(12)	(17)	(16)	(10)			(27)	(34)				(27)	(34)
Age group V:																	
5					29		28	22	24	18	25	24	22		19	20	21
4				26		33	30	24	24	22	23	20		27	21	22	
3			34		33	33	22	28	29	23	24		33	26	24		
2		32		28	27	31	26	27	30	35		29	38	30			
1	58		56	58	55	54	54	55	58		55	54	55				
Number of fish	(32)		(14)	(10)	(14)	(66)	(85)	(41)	(56)		(56)	(183)	(149)				
Age group IV:																	
4					37			24	26	28	30	24	27		25	22	20
3				32			26	30	31	28	33	25		31	24	27	
2			32			35	27	28	32	33	38		35	39	31		
1		61			58	54	53	56	56	59		56	56	58			
Number of fish		(112)			(48)	(75)	(51)	(77)	(102)	(98)		(70)	(146)	(179)			
Age group III:																	
3					45				33		43	36	40		30	31	26
2				36				34		36	46	41		42	40	40	
1			55				58		59	58	58		57	58	63		
Number of fish			(14)				(17)		(18)	(50)	(73)		(10)	(17)	(72)		

TABLE 33.—*Annual increments of growth in length of female Saginaw Bay yellow perch, spawning-run collections of 1943–55*

[Each diagonal gives the growth history of an age group, belonging to the year class indicated by the year of 1st-year growth and captured in the spring of the calendar year following the one for which the last increment is given. Number of fish in sample of each age group in parentheses immediately below 1st-year increment]

Age groups and years of life	Increment of standard length (millimeters) in calendar years																
	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Age group VI																	
6							28										
5						38											
4					57												
3				38													
2			37														
1		60															
Number of fish		(10)															
Age group V																	
5					31		31			19	26				33		31
4				31		52			29	23				37		27	
3			34		44			33	34				39		22		
2		31		34			24	28				30		29			
1	62		55			54	54				56		56				
Number of fish	(61)		(36)			(36)	(16)				(43)		(76)				
Age group IV																	
4					48		41	31	34	25	37	33	38		37	37	35
3				34		50	27	32	35	30	39	27		38	27	35	
2			32		45	34	26	34	34	33	42		42	38	30		
1		60		59	58	55	55	58	58	61		56	59	58			
Number of fish		(87)		(18)	(49)	(65)	(26)	(29)	(63)	(41)		(98)	(36)	(148)			
Age group III																	
3								41	38		57	42	48		47		37
2							34	36		32	47	42		39		39	
1						55	56		57	59	60		58		60		
Number of fish						(29)	(22)		(11)	(33)	(84)		(21)		(57)		

growth in 1944 was less than that of 1943. In 1948 and 1949 change of growth was irregular for the different age groups. In 1949, growth of all years of life of age group VI were higher than that of 1948, whereas in age groups V, IV, and III growth was less than that of 1948. Similar comparisons for the females can be made from table 33.

The comparison of growth increments in tables 32 and 33 is instructive but gives only a rough quantitative picture of the changes that occurred. Hile (1941) suggested the use of the actual percentage changes in growth to obtain more precise data on growth fluctuations. This method has been applied to several fish populations (Hasler and Farner, 1942; Carlander 1945a and 1945b; Van Oosten and Hile, 1949; Jobes 1952; Hile 1954). Procedural details for estimating the percentage changes in growth are not discussed here since a complete account was given by Hile (1941).

The percentage deviations of growth from average for the first year and for later years of life (tables 34 and 35) indicate dissimilar growth fluctuations during the two periods. A like situation was noticed by Hile (1941) for the rock bass and by Van Oosten (1929) for the Saginaw Bay lake herring. In the Saginaw Bay walleye, on the contrary, the fluctuations of growth in the first and in the later years were closely similar (Hile 1954).

Fluctuation in first-year growth

Although the range of percentage deviations of first-year growth from the 1942–51 average was much greater for females than for males, the trends were similar (table 34). The coefficient of correlation between the annual deviations of the sexes was highly significant (r = 0.850). Therefore, the unweighted means of the percentages for the sexes (bottom row of table 34) can

TABLE 34.—*Percentage deviation of growth in length for the 1st year of life of Saginaw Bay yellow perch from the 1942–51 average*

Sex	Percentage deviation from average growth in calendar year									
	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951
Male	−1.9	−4.9	−6.7	−1.8	0.9	2.6	2.6	1.5	2.6	5.2
Female	−16.5	−11.2	−10.6	−5.3	−.5	3.7	[1] 5.4	8.8	14.0	12.3
Average	−9.2	−8.1	−8.6	−3.6	.2	3.2	4.0	5.2	8.3	8.8

[1] Percentage obtained by linear interpolation.

describe the fluctuations in first-year growth very satisfactorily.

The poorest first-year growth (9.2 percent below average) was made in 1942 (fig. 14). In subsequent years a strong trend toward improvement of growth is apparent. The first-year growth in length remained below average until 1946. From 1946 to 1951 growth was continually above average reaching the maximum of 8.8 percent in 1951.

Fluctuation of growth in later years of life

The data used in the analysis of fluctuations of growth of later years of life covered the 1944–54 period only. The records for earlier calendar years, particularly those for females, are believed to be inadequate. In the later years of life, as with first-year growth, the annual percentage deviations of sexes (table 35) agreed very well (coefficient of correlation, 0.942) and thus the average percentage was used to describe the fluctuation of growth. Data for the two periods agreed further in showing a greater range of fluctuations in the females.

Contrary to the first-year growth which exhibited a consistent trend, fluctuations in growth in the later years of life were largely without trend, indeed were almost erratic (fig. 15). Growth in years later than the first was slightly below average in 1944 (–1.4 percent). Growth improved to 2.2 percent above average in 1945 and 8.2 percent above in 1946, dropped to 4.2 percent below average in 1947, and then jumped to the 11-year maximum of 16.8 in 1948. Following a drop in 1949 (to 0.3) and an increase in 1950 (12.4, second highest value) 2 sharp decreases carried the percentage to the 11-year minimum (–16.2) in 1952. Growth improved in 1953 (–8.4 percent) but 1954 was the second poorest year of the period (–14.0 percent).

The difference in growth fluctuations between the first year of life and those for later years was discussed by past investigators. Van Oosten (1929) showed that lake herring in their first year of life spend a larger part of the growing season inside Saginaw Bay than do older fishes (which seem to move into Lake Huron) and thus are affected more by any changes that might happen in the Bay. Hile (1941) explained this difference in the Nebish Lake rock bass on the basis that conditions controlling the first year of growth and that of later years are not the same. In the Saginaw Bay perch, the factors that determine first-year and later growth obviously are dissimilar. In 1948, for example, first-year growth was only slightly above average (4.0 per-

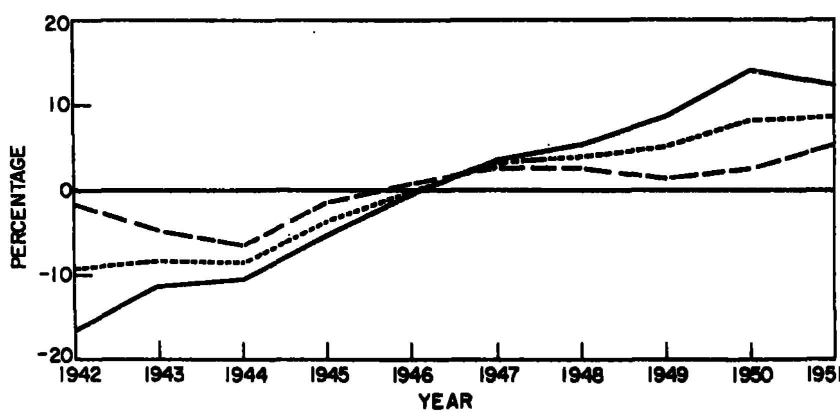

FIGURE 14.—Annual fluctuations in the growth in length of Saginaw Bay yellow perch in the first year of life. Males, broken line; females, solid line; both sexes, dots and dashes.

TABLE 35.—*Percentage deviation of the growth in lengths in the 2d and later years of life of Saginaw Bay yellow perch from the 1944–54 average*

Sex	Percentage deviation from average growth in calendar year										
	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Male	–4.0	–2.6	7.2	–0.2	10.2	–0.6	9.8	4.4	–8.8	–4.9	–10.5
Female	1.1	6.9	9.2	–8.1	23.4	1.2	14.9	3.9	–23.7	–11.9	–17.5
Average	–1.4	2.2	8.2	–4.2	16.8	.3	12.4	4.2	–16.2	–8.4	–14.0

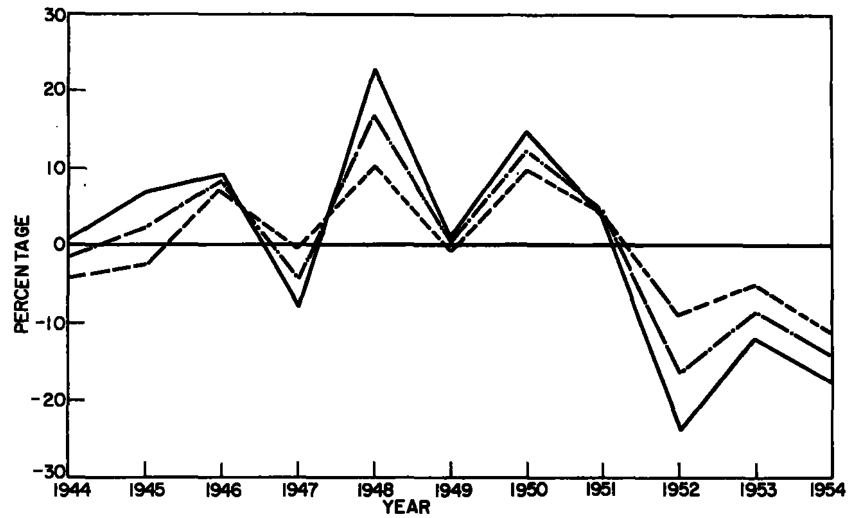

FIGURE 15.—Annual fluctuations in the growth in length of Saginaw Bay yellow perch in the second and later years of life. Males, broken line; females, solid line; both sexes, dots and dashes.

cent) whereas that in later years of life was at the maximum (16.8 percent). Other calendar years show similar disagreements; furthermore, the trends were entirely different (cf. figs. 14 and 15).

Growth in Weight

Growth in weight of the age groups: general growth

Data on calculated growth in weight (tables 36 and 37) were obtained by applying the calculated lengths of tables 26 and 27 to the length-weight equation. Thus the length and weight at a particular age derived by this equation are exactly comparable. (The mean weight of a group of fish in which both length and weight vary is higher than the normal weight of a fish of average length.)

The discrepancies among the calculated weights of the different age groups are so similar to those previously described for the calculated lengths that they may be summarized briefly and with very little comment. Among the males and in age groups III–VI of the females growth rate generally decreased with increase of age. The discrepancies were small in the earlier years of life, but became larger with increase in the year of life for which the calculations were made. In age-groups VII–IX of the females this downward trend of growth rate was reversed and growth in weight was relatively fast. The previous discussion of factors of discrepancies in calculated lengths applies, of course, to the calculated growth in weight.

With growth in weight as with growth in length, the general growth (table 38; fig. 16) is based on the sums of the grand average incre-

TABLE 36.—*Calculated weights at the end of the different years of life for male yellow perch collected during the spawning season of 1943–55*

[Increments in parentheses]

Age group	Number of fish	Weight (ounces) at end of year						
		1	2	3	4	5	6	7
II	3	0.16	0.78 (.62)					
III	284	.11	.68 (.57)	1.56 (.88)				
IV	963	.13	.42 (.29)	1.05 (.63)	2.01 (.96)			
V	701	.08	.37 (.29)	.90 (.53)	1.65 (.75)	2.68 (1.03)		
VI	134	.08	.34 (.26)	.88 (.54)	1.60 (.72)	2.39 (.79)	3.55 (1.16)	
VII	6	.08	.24 (.16)	.67 (.43)	1.46 (.79)	2.32 (.86)	3.65 (1.33)	5.37 (1.72)
Grand average calculated weight		0.11	0.43	1.06	1.84	2.63	3.55	5.37
Increment of average		.11	.32	.63	.78	.79	.92	1.82
Grand average increment of weight		.11	.33	.62	.86	.99	1.17	1.82
Sum of average increments		.11	.44	1.06	1.92	2.91	4.08	5.90

TABLE 37.—*Calculated weights at the end of the different years of life for female yellow perch collected during the spawning seasons of 1943–55*

[Increments in parentheses]

Age group	Number of fish	Weight (ounces) at end of year								
		1	2	3	4	5	6	7	8	9
II	12	0.13	0.82 (.69)							
III	281	.11	.58 (.47)	1.90 (1.32)						
IV	660	.10	.45 (.35)	1.28 (.83)	2.94 (1.66)					
V	300	.10	.39 (.29)	1.09 (.70)	2.36 (1.27)	4.23 (1.87)				
VI	39	.10	.40 (.30)	1.08 (.68)	2.76 (1.68)	4.89 (2.13)	7.69 (2.80)			
VII	6	.18	.70 (.52)	2.01 (1.31)	4.08 (2.07)	6.60 (2.52)	10.55 (3.95)	13.82 (3.27)		
VIII	3	.18	.98 (.80)	3.12 (2.14)	6.51 (3.39)	9.53 (3.02)	14.93 (5.40)	18.54 (3.61)	21.14 (2.60)	
IX	1	.08	.71 (.63)	3.75 (3.04)	8.18 (4.43)	14.74 (6.56)	18.08 (3.34)	20.65 (2.57)	22.42 (1.77)	24.85 (2.43)
Grand average calculated weight		.10	.47	1.37	2.78	4.42	8.70	15.91	21.46	24.85
Increment of average		.10	.37	.90	1.41	1.64	4.28	7.21	5.55	3.39
Grand average increment of weight		.10	.36	.91	1.56	1.93	3.11	3.30	2.39	3.39
Sum of average increments		.10	.46	1.37	2.93	4.86	7.97	11.27	13.66	17.05

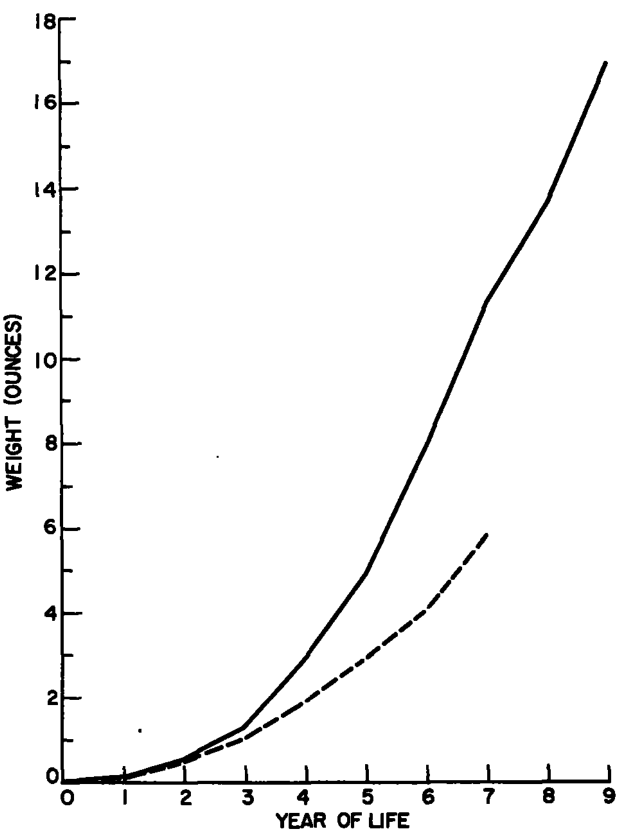

FIGURE 16.—General growth in weight for Saginaw Bay yellow perch of the 1943–55 spawning-run samples. Male, broken line; female, solid line.

ments. The calculated weights of the females were higher than those of the males in all years of life except the first. At the end of their second year the females were only a little heavier than the males (a difference of 0.02 ounce) but

TABLE 38.—*Calculated weights (ounces) and weight increments of male and female yellow perch of Saginaw Bay in different years of life*

[Data from tables 36 and 37]

Year of life	Males		Females		Growth advantage of females		
	Calculated weight	Increment	Calculated weight	Increment	Difference in weight	Ratio of weight	Ratio of increments
1	0.11	0.11	0.10	0.10	−0.01	0.91	0.91
2	.44	.33	.46	.36	.02	1.04	1.09
3	1.06	.62	1.37	.91	.31	1.29	1.47
4	1.92	.86	2.93	1.56	1.01	1.53	1.81
5	2.91	.99	4.86	1.93	1.95	1.67	1.95
6	4.08	1.17	7.97	3.11	3.89	1.95	2.66
7	5.90	1.82	11.27	3.30	5.37	1.91	1.81
8			13.66	2.39			
9			17.05	3.39			

in subsequent years the weights of the sexes were widely separated. The growth advantage of females can be clearly shown from the ratios of weights of females to those of males (table 38). These ratios increased steadily from the second to later years of life (slight decrease in seventh year). At the end of the sixth and seventh years the weights of the females were nearly double those of the males (ratios 1.95 and 1.91 for the sixth and seventh years, respectively).

The annual increments of weight for both sexes increased almost continuously after the first year of life (only exception, eighth year of life of females). The females attained their greatest advantage in annual increase over the males in the sixth year when they had added more than $2\frac{1}{2}$ times the weight gained by the males (ratio 2.66). The sharp drop in growth increment in the eighth year of life might be due to the inadequacy of the sample.

Annual fluctuation of growth in weight

The annual increments of growth in weight (tables 39 and 40) are arranged in the same manner as those of length presented in an earlier section. Likewise, the percentage deviations of the growth in weight for the first and later years of life (tables 41 and 42) were determined separately because of the different pattern of growth in the two periods. The fluctuations of growth of males and females during their later years of life agreed well except for 1944; if that year is excluded, the coefficient of correlation for the percentages is 0.867. For the first year of life agreement between males and females was poor ($r = 0.113$); here the percentages for the sexes were arbitrarily combined for the sake of consistency with the treatment of other data on growth.

Since the calculated weights were based on the calculated lengths, it was to be expected that the trends of the annual fluctuation of growth in weight would show certain similarities to those of growth in length (figs. 17 and 18). However,

TABLE 39.—*Annual increment of growth in weight of male Saginaw Bay yellow perch, spawning-run collections of 1943–55*

[See table 32 for explanation of arrangement]

Age groups and years of life	Increment of weight (ounces) in calendar years																
	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Age group VI:																	
6										0.94	0.97	1.13	1.37			1.19	1.10
5									0.67	0.77	0.52	0.81			0.60	0.84	
4								0.49	0.60	0.56	0.56			0.76	0.68		
3							0.32	0.45	0.45	0.44			0.56	0.64			
2						0.18	0.18	0.19	0.32			0.34	0.26				
1					0.08	0.18	0.07	0.10			0.08	0.08					
Number of fish					(12)	(17)	(16)	(10)			(27)	(34)				(27)	(34)
Age group V:																	
5					1.54		0.45	1.21	0.97	0.77	1.16	1.02	1.08		0.94	1.06	0.88
4				1.01		1.22	1.14	0.66	0.70	0.68	0.66	0.65		0.97	0.73	0.68	
3			0.85		0.67	0.69	0.39	0.48	0.48	0.39	0.55		0.67	0.58	0.42		
2		0.32		0.25	0.25	0.29	0.20	0.22	0.29	0.36		0.26	0.35	0.28			
1	0.10		0.09	0.10	0.08	0.08	0.08	0.08	0.10		0.08	0.08	0.08				
Number of fish	(32)		(14)	(10)	(14)	(66)	(85)	(41)	(56)		(56)	(183)	(149)				
Age group IV:																	
4					1.57			0.91	0.85	0.93	1.12	0.98	1.03		1.03	0.78	0.64
3				0.80			0.61	0.51	0.51	0.63	0.75	0.63		0.69	0.49	0.58	
2			0.31			0.36	0.22	0.23	0.29	0.31	0.41		0.32	0.43	0.30		
1		0.12			0.10	0.08	0.07	0.09	0.09	0.11		0.09	0.09	0.10			
Number of fish		(112)			(48)	(75)	(51)	(77)	(102)	(98)		(70)	(146)	(179)			
Age group III:																	
3					1.13				0.85		1.18	1.08	1.14		0.82	0.86	0.67
2				0.33				0.32		0.41	0.61	0.46		0.46	0.46	0.57	
1			0.08				0.10		0.11	0.10	0.10		0.10	0.10	0.14		
Number of fish			(14)				(17)		(18)	(50)	(73)		(10)	(17)	(72)		

TABLE 40.—*Annual increment of growth in weight of female Saginaw Bay yellow perch, spawning-run collections of 1943–55*

[See table 32 for explanation of arrangement]

Age groups and years of life	Increment of weight (ounces) in calendar years																
	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Age group VI:																	
6							3.40										
5						3.57											
4					3.11												
3				1.06													
2			0.44														
1		0.12															
Number of fish		(10)															
Age group V:																	
5					1.79		2.74			0.95	1.31				2.05		1.58
4				1.37		2.72			0.98	0.76				1.59		0.78	
3			0.85		1.10			0.55	0.67				0.90		0.39		
2		0.33		0.32			0.18	0.23				0.28		0.28			
1	0.13		0.08			0.08	0.08				0.09		0.09				
Number of fish	(61)		(36)			(36)	(16)				(43)		(76)				
Age group IV:																	
4					2.33		2.48	1.21	1.27	1.00	1.59	1.48	1.83		1.99	1.57	1.45
3				0.84		1.63	0.61	0.58	0.85	0.72	0.97	0.71		0.98	0.69	0.85	
2			0.31		0.60	0.36	0.20	0.30	0.33	0.31	0.59		0.47	0.43	0.28		
1		0.12		0.11	0.10	0.08	0.08	0.10	0.10	0.12		0.09	0.11	0.10			
Number of fish		(87)		(18)	(49)	(65)	(26)	(29)	(63)	(41)		(98)	(86)	(148)			
Age group III:																	
3								1.02	0.99		1.71	1.37	1.57		1.46		1.06
2							0.32	0.34		0.32	0.65	0.54		0.42		0.44	
1						0.08	0.09		0.10	0.11	0.12		0.10		0.12		
Number of fish						(29)	(22)		(11)	(33)	(84)		(21)		(57)		

TABLE 41.—*Percentage deviation of the growth in weight for the 1st year of life of Saginaw Bay yellow perch from the 1942–52 average*

Sex	Percentage deviation from average growth in calendar year										
	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952
Male	−13.9	12.8	−30.0	−9.2	1.9	2.4	2.4	2.4	2.4	2.9	26.2
Female	21.0	−1.2	.8	−23.0	−23.0	−0.4	[1] −8.5	1.9	21.9	20.9	----------
Average	3.6	5.8	−14.6	−16.1	−10.6	−3.5	−3.0	2.2	12.2	11.9	----------

[1] Percentage obtained by linear interpolation.

TABLE 42.—*Percentage deviation of the growth in weight in the 2d and later year of life of Saginaw Bay yellow perch from the 1944–54 average*

Sex	Percentage deviation from average growth in calendar year										
	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Male	−17.3	−5.5	−3.5	−3.0	10.6	7.5	15.9	17.5	−5.8	−0.10	−16.8
Female	27.7	−7.3	4.2	−16.3	26.8	8.6	26.2	17.3	−19.6	−29.8	−37.8
Average	5.2	−6.4	.4	−9.6	18.7	8.0	21.0	17.4	−12.7	−15.0	−27.3

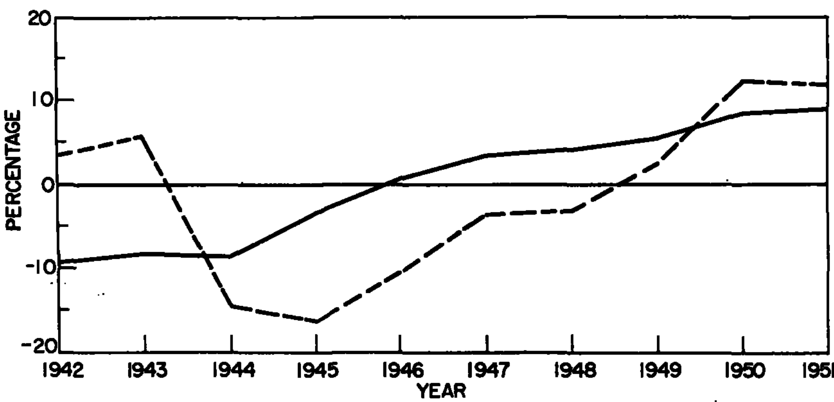

FIGURE 17.—Annual fluctuations of growth in length (solid line) and growth in weight (broken line) in the first year of life of Saginaw Bay yellow perch (sexes combined).

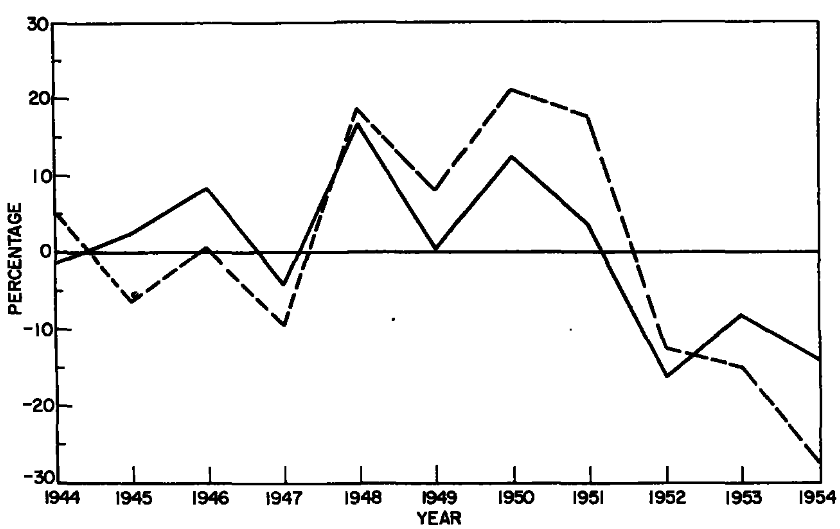

FIGURE 18.—Annual fluctuations of growth in length (solid line) and growth in weight (broken line) in the second and later years of life of Saginaw Bay yellow perch (sexes combined).

the range of fluctuation of annual increments in weight was greater than that of length and the curves disagree in certain details. Hile (1954) showed a similar situation in the fluctuation of growth of the walleye in Saginaw Bay. This difference between the annual fluctuations of growth in length and weight depends partly on the nature of the length-weight relation (weight varies approximately as the cube of the length). Thus the growth in weight in a particular year varies both according to the amount of increase in length made in that year and with the actual length of the fish at the time the increase is made. In other words, when two groups of fish in a particular year of life have equal increments of length, their weight increments will differ if the lengths were not equal at the start of that year of life. This influence of length when the growth is made on the value of weight increments can be shown clearly in the fluctuation of first-year growth of Saginaw Bay perch. Here, the growth in weight, as that of length, followed the same strong trend toward improvement in 1942–51 (fig. 17). Yet the slow growth in length during the years 1942–45 had reduced the length of perch to an extent that the improved growth in length (1946–51) did not bring growth in weight above average until 1949.

The annual fluctuations of growth in weight in later years of life followed those of length more closely than did those for the first year (fig. 18). Here again, however, the slow growth in length in 1947 reduced the size of the fish enough to delay the attainment of the maximum growth in weight. Although the maximum growth in length was attained in 1948, the highest value for weight was reached in 1950.

Still another factor contributing to the discrepancies between curves of fluctuations of growth in length and in weight in the second and later years is the difference in the years of life that predominate in controlling the course of the curves. A curve of fluctuation of growth in length (especially for males) is influenced most strongly by the data for the earlier years of life when growth in length is most rapid. Curves of fluctuation of growth in weight, on the other hand, are affected most by the data for later years when growth in weight is most rapid. Although no differences of trend of annual fluctuations in growth could be detected beyond the first year, the percentage changes in different years of life were not identical. Only random variation in these changes can be a source of discrepancy between curves of fluctuations of growth in length and weight.

Difference in Growth Rate in 1929–30 and 1943–55 and Comparison with Growth from other Great Lakes Waters

Hile and Jobes (1942) and Jobes (1952) offered detailed comparisons of the growth rate of Saginaw Bay yellow perch (collected in 1929–30) with that of perch in Lake Erie, southern Green Bay, and northern Lake Michigan. Since this previous discussion need not be repeated, the present section emphasizes the changes that occurred in the growth of Saginaw Bay yellow perch population between the 1929–30 and 1943–55 collections.

The calculated lengths (table 43, fig. 19) reveal a pronounced change in the growth of Saginaw Bay perch between 1929–30 and 1943–55. Saginaw Bay yellow perch of the 1929–30 samples were second longest or longest for their age, but those collected in 1943–55 had the slowest growth in length yet reported from the Great Lakes. The legal size (8½ inches) which was reached by 1929–30 fish during the fourth growing season was not attained by 1943–55 perch until the sixth growing season.

The change in growth of Saginaw Bay perch between 1929–30 and 1943–55 is shown even more

TABLE 43.—*Growth in length of yellow perch from different localities of the Great Lakes*

[Sources of data: Lake Erie, Jobes (1952); southern Green Bay and northern Lake Michigan, Hile and Jobes (1942); Saginaw Bay 1929–30 samples, Hile and Jobes (1941); Saginaw Bay 1943–55 samples, present study]

Locality and sex	Average calculated length (inches) at end of year						
	1	2	3	4	5	6	7
Lake Erie:							
Male	3.6	6.6	8.4	9.4	10.1	------	------
Female	3.7	6.7	8.6	9.8	10.7	------	------
Sexes combined [1]	3.6	6.6	8.5	9.6	10.4	------	------
Southern Green Bay:							
Male	2.9	4.6	6.0	7.4	8.4	9.6	10.3
Female	2.8	4.6	6.4	8.0	9.0	10.4	11.3
Sexes combined [1]	2.8	4.6	6.2	7.7	8.7	10.0	10.8
Northern Lake Michigan [2]	2.8	4.4	5.9	7.1	8.3	9.6	------
Saginaw Bay (1929–30):							
Male	3.0	5.3	7.7	9.3	10.6	11.6	12.3
Female	3.0	5.4	8.1	9.6	10.7	12.1	13.2
Sexes combined [1]	3.0	5.4	7.9	9.4	10.6	11.8	12.8
Saginaw Bay (1943–55):							
Male	2.6	4.2	5.6	6.7	7.6	8.5	9.3
Female	2.7	4.3	5.9	7.5	8.8	10.2	11.1
Sexes combined [1]	2.6	4.2	5.8	7.1	8.2	9.4	10.2

[1] Unweighted means.
[2] No data for sexes separately.

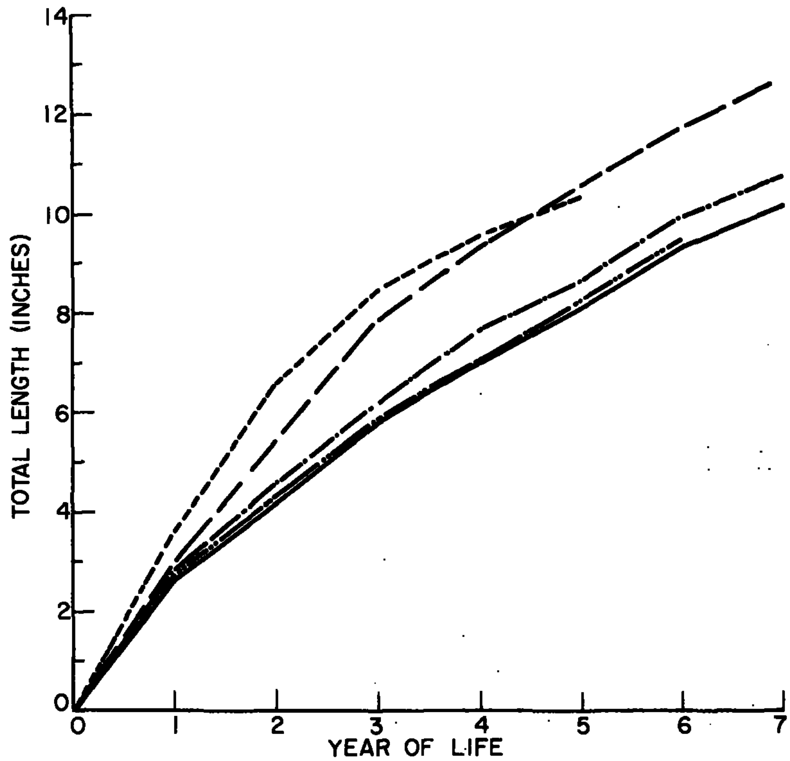

FIGURE 19.—Average calculated lengths at the end of each year of life for yellow perch from different Great Lakes waters (sexes combined). Lake Erie, short dashes; Green Bay, dots and dashes; northern Lake Michigan, two dots and dashes; Saginaw Bay, 1929–30, long dashes; Saginaw Bay, 1943–55, solid line.

forcefully by the comparison of calculated weights for the various samples (table 44, fig. 20). The growth of the earlier collection of Saginaw Bay perch, for weight as well as length, ranked second or first among the Great Lakes stocks. It was surpassed by the Lake Erie perch during the first 4 years of life, but in the fifth and later years (no data for Lake Erie beyond the fifth year), Saginaw Bay perch were the heaviest for their age of all perch populations. In the 1943–55 period, the situation was completely reversed; the growth of Saginaw Bay perch was inferior to that of all other Great Lakes perch populations. This sharp drop in the growth in weight affected all years of life. The ratios of calculated weights of 1929–30 fish to those of perch collected in 1943–55 follow:

Year of life	Ratio	Year of life	Ratio
1	1.4	5	2.2
2	2.1	6	2.0
3	2.6	7	1.9
4	2.4		

From these ratios, it is apparent that in most years Saginaw Bay yellow perch caught in 1929–30 were more than twice as heavy as those in the 1943–55 samples.

TABLE 44.—*Growth in weight of yellow perch from different localities of the Great Lakes*

[Sources of data: Lake Erie, Jobes (1952); southern Green Bay and northern Lake Michigan, Hile and Jobes (1942); Saginaw Bay 1929–30 samples, Hile and Jobes (1941); Saginaw Bay 1943–55 samples, present study]

Locality and sex	Average calculated weight (ounces) at end of year						
	1	2	3	4	5	6	7
Lake Erie:							
Male	0.28	1.98	3.98	5.64	7.20	------	------
Female	.32	2.08	4.41	6.70	8.68	------	------
Sexes combined [1]	.30	2.03	4.20	6.17	7.94	------	------
Southern Green Bay:							
Male	.14	.60	1.38	2.57	4.16	6.28	7.90
Female	.14	.60	1.62	3.39	5.08	8.01	10.83
Sexes combined [1]	.14	.60	1.50	2.98	4.62	7.14	9.36
Northern Lake Michigan [1 2]	.21	.78	1.73	2.93	4.73	7.16	------
Saginaw Bay (1929–30):							
Male	.14	.88	2.89	5.50	8.22	11.57	13.93
Female	.14	.95	3.35	6.10	8.64	13.16	17.00
Sexes combined [1]	.14	.92	3.12	5.80	8.43	12.36	15.46
Saginaw Bay (1943–55):							
Male	.09	.43	1.10	1.98	2.98	4.30	5.77
Female	.10	.46	1.31	2.86	4.82	7.79	10.27
Sexes combined [1]	.10	.44	1.20	2.42	3.90	6.04	8.02

[1] Unweighted means.
[2] No data for sexes separately.

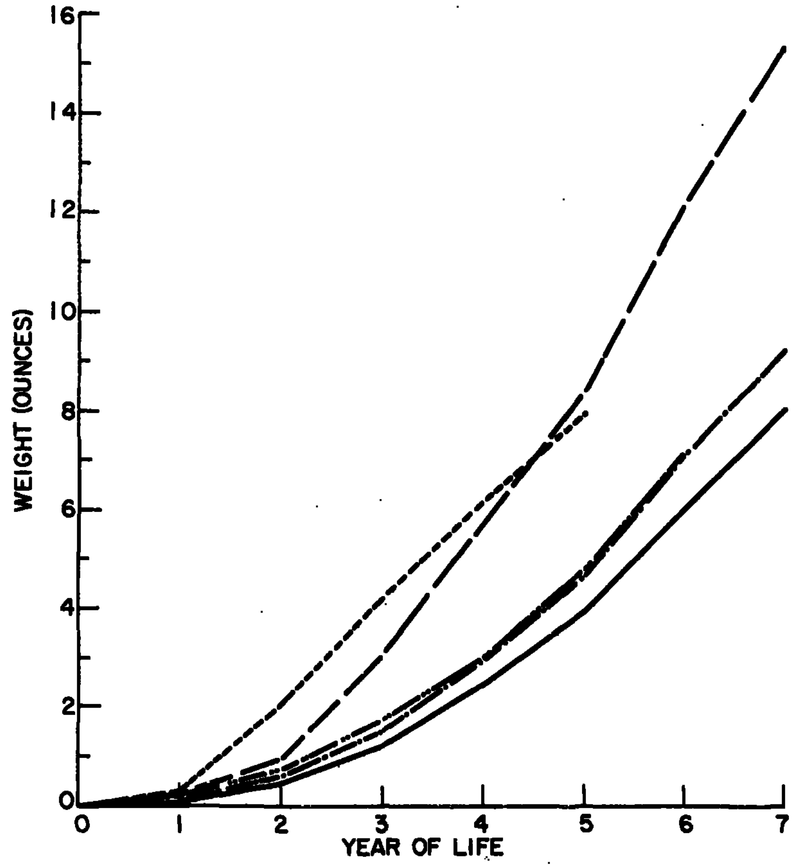

FIGURE 20.—Average calculated weights at the end of each year of life for yellow perch from different Great Lakes waters (sexes combined). Lake Erie, short dashes; Green Bay, dots and dashes; northern Lake Michigan, two dots and dashes; Saginaw Bay, 1929–30, long dashes; Saginaw Bay, 1943–55, solid line.

Probable Factors of the Decrease in Growth Rate

The extensive decrease in the growth rate of the Saginaw Bay yellow perch as indicated by the records for the 1929–30 and 1943–55 samples offers convincing evidence that the species is living now in a greatly changed situation. Many factors might contribute to this change: Limnological conditions including production of food; pollution; meteorological conditions; changes within populations of associated species and of the yellow perch itself.

Limnological factors are omitted in this study because of lack of data. The first limnological observations on Saginaw Bay of consequence were made in 1956.

With pollution also we are in poor position to offer quantitative estimates of differences between the periods. Even if we had full knowledge of sources, kinds, and quantities of pollutants, interpretation would be difficult because of the wide variety of substances and their equally varied and largely unknown effects on the several species of fish and fish-food organisms. (For a survey of conditions in 1935 and 1936, see the Saginaw Valley Report, Adams 1937.) Although changes in the pollution situation in Saginaw Bay cannot be described quantitatively, it appears most probable that conditions in recent years are less adverse than formerly. Construction of sewage-disposal plants in cities and great advances in the treatment of industrial wastes surely have decreased the total load. Evidence of lessening of industrial pollution comes from the decrease in complaints about tainted fish.

Although certain meteorological conditions appear to show a degree of correlation with limited annual fluctuations in growth rate (p. 404) there is no evidence for a major climatic change of the proportions that would have to be postulated if the large drop in growth rate were to be attributed to weather.

The changes within the populations of fish in Saginaw Bay are somewhat better understood, and for some species quantitative estimates of annual abundance are available from the statistics of the commercial fishery. Before these changes are discussed, however, comments are needed on the "degree of association" between perch and other species in Saginaw Bay.

According to the experimental trawling from the research vessel *Cisco* in the summer and fall of 1956 the two species taken in greatest numbers along with yellow perch were smelt (*Osmerus mordax*) and the alewife (*Pomolobus pseudoharengus*). The *Cisco* was able to do only limited fishing in the shallow inner part of the Bay, which includes many of the more productive commercial grounds. On the outer, deeper grounds where bottom suitable for trawling was not extensive, association among the three species seems to be well established. In the larger-meshed commercial gears which take relatively few smelt or alewives the principal species captured along with perch are suckers (most of them *Catostomus commersoni*, a few *C. catostomus* and some *Moxostoma* spp.), catfish (*Ictalurus punctatus*), walleye (*Stizostedion v. vitreum*), and carp (*Cyprinus carpio*). The preceding have been arranged in the estimated order of degree of association as judged from records of commercial catch and from observations of lifts. With all species the degree of association is subject to seasonal variation. Walleyes, for example, move farther offshore in summer than do perch, whereas carp and catfish remain in relatively shallower waters. Still another important component of the catch in Saginaw Bay, the lake herring (*Coregonus artedi*) is rarely taken in quantity in the same nets as yellow perch. Lake trout (*Salvelinus namaycush*) and whitefish (*Coregonus clupeaformis*), two formerly plentiful species in the Saginaw Bay area, taken mostly in the outer Bay and in immediately adjacent waters of Lake Huron, likewise were little associated with perch.

The commercial fishery for smelt, one of the two principal associates of the yellow perch in Saginaw Bay has been too limited and too erratically prosecuted to provide quantitative information on the development and fluctuations of the stock. Yet, interest in the species as a sport fish has been such that a fairly dependable account can be offered. The first record of the capture of a smelt in Saginaw Bay is for 1928 (Van Oosten 1937). The population developed during the 1930's, reaching a high level toward the end of that decade and in the early 1940's. In the fall of 1942 an epidemic all but exterminated the entire stock (Van Oosten 1947). Smelt were extremely scarce during the next few years, and no significant catch was listed until 1950 when the take was 112,000 pounds. In the next 5 years the catch ranged from 138,000 to 218,000 pounds.

Possibly some idea of the rate of recovery of the smelt stock in Saginaw Bay can be gained by statistics on the stock of northern Green Bay where a brisk commercial fishery has existed since the late 1930's. The Green Bay population was nearly destroyed in the late winter of 1943 by the same epidemic that had struck Saginaw Bay the preceding fall (Van Oosten 1947). According to records of the catch of smelt per unit effort (gill nets and pound nets) published by Hile, Lunger, and Buettner (1953) smelt were extremely scarce in 1944–46 and despite steady improvement the catches did not approach the "premortality" level until 1949 and 1950.

The information on the smelt in Saginaw Bay leads to two important conclusions. First, smelt were too scarce to have been of any consequence in the ecology of the fast-growing yellow perch collected in 1929–30. Second, they were present throughout the period covered by growth data for the 1943–55 samples, but the abundance varied enormously. Smelt were plentiful up to the mortality of 1942, then were scarce for several years and finally became abundant again about 1950. The growth of perch of the 1943–55 samples, despite certain annual fluctuations, was consistently below that of the 1929–30 samples regardless of the abundance of smelt. An assumption that the addition of smelt to the fish fauna of the Bay was the cause of the poor growth of perch in the later years, therefore, cannot be supported.

Even though the smelt cannot be established as a causative agent in the slow growth of yellow perch of the 1943–55 collections, the mere fact of their close association dictates that the two species should have effect on each other. Formal studies of the food of smelt and perch have not been made in Saginaw Bay, but such information as is available on the feeding habits in other Great Lakes waters (Allin 1929, Ewers 1933, Schneberger 1927, Turner 1920) suggests that they are food competitors at the smaller sizes.

The opening of stomachs of the larger Saginaw perch in samples of the present study indicated smelt to be an important, possibly the principal, item of diet. Perch sometimes take smelt of surprising size (often the tail of the smelt protrudes from the perch's mouth).

Total length of perch (inches)	Total length of smelt (inches)
6.6	5.0
7.3	5.0
7.7	5.8
8.9	6.2

The alewife can be dismissed as a significant factor in the slow growth of yellow perch of the 1943–55 samples because it has become plentiful too recently. The current great abundance of alewives in Saginaw Bay is new. It is to be questioned whether alewives were present in consequential numbers before 1954 or even 1955. Should alewives continue to be plentiful, they could supply additional forage for the larger perch. The degree of food competition with small perch is not known.

The abundance indices for other associates of the yellow perch in Saginaw Bay (table 45) are

TABLE 45.—*Average abundance and production of yellow perch and associated species in Saginaw Bay in 1929–30 and 1943–55*

Species	1929–30		1943–55		Ratio of indices
	Abundance index	Production [1]	Abundance index	Production [1]	
Yellow perch	105	526	125	443	1.19
Sucker	128	1,440	152	881	1.19
Catfish	89	124	146	271	1.64
Walleye	60	818	44	383	.73
Carp	52	598	200	1,267	3.85
Lake herring	52	2,552	104	988	2.00

[1] In thousands of pounds.

based on records of the commercial catch per unit of fishing effort and were computed by the procedure described by Hile (1937); the base of 100 is the mean abundance for 1929–43. It should be understood that the indices are based on the catch of only the legal- or marketable-sized fish and that they have been biased to some degree by changes of regulations. In the most recent years the abundance of suckers and carp probably was underestimated because of the failure of fishermen to land their entire catch (weak market conditions). Despite their defects, these indices are our best information on the changes in population level of the several species, except perch for which additional information is given later.

The mean abundance index of yellow perch and of all its associates except the walleye increased from 1929–30 to 1943–55. The average index for perch in 1943–55 was 1.19 times that for 1929–30. For the other species the ratio ranged from 0.73 (walleyes—only value below 1.00) to 3.85 (carp). These changes of the index, the addition of smelt as an important member of the population, and the recent great abundance of alewives all point toward a substantial rise in the fish population of Saginaw Bay.

The records of sizes of yellow perch in random samples from commercial gear in 1929–30 and 1943–45 makes possible a more discriminating estimate of the change in the population density of that species. The nature of the computations can be illustrated with the data for 1929–30. From the length-frequency distribution published by Hile and Jobes (1941) and from their length-weight equation it was determined first that the 640 legal-sized fish (then 9 inches or longer) in their sample had a total weight of 239.5 pounds. In the same 2 years the average catch of yellow perch per lift of one trap net was 17.83 pounds. It is then calculated that the lifting of 100 trap nets in 1929–30 yielded $640 \times \frac{17,830}{239.5}$ or 4,765 legal-sized fish. The same sample, however, contained also 302 undersized perch which correspond to a rate of capture of 2,248 per 100 lifts. The same procedure applied to the size distribution of all samples and the average catch per trap net for 1943–55 leads to an estimated take of 5,062 legal (now 8½ inches or longer) and 42,502 undersized perch per 100 trap nets.

The comparison of the estimates of numbers of legal- and undersized yellow perch taken per 100 trap-net lifts in 1929–30 and 1943–55 (table 46) brings out the enormous change that has

TABLE 46.—*Estimated numbers of legal-sized and undersized yellow perch captured in Saginaw Bay per lift of 100 shallow trap nets in 1929–30 and 1943–55*

[Minimum legal size: 1929–30, 9 inches; 1943–55, 8½ inches]

Years	Legal-sized	Undersized	Total
1929–30	4,765	2,248	7,013
1943–56	5,062	42,502	47,564
Ratio	1.06	18.91	6.78

taken place in the yellow perch population of Saginaw Bay. The numbers of legal-sized perch in the two periods were closely similar but this similarity is largely the result of the decline in growth rate that permitted so few perch to reach 8½ inches in 1943–55. In total numbers of fish taken, the rate of capture in 1943–55 was nearly 7 (6.78) times that of 1929–30. The actual increase in numbers was surely even higher than the ratio indicates. Because of their slow growth rate many fish of the 1943–55 population could escape from the nets at ages which were adequately sampled in 1929–30. A ratio of 10 rather than 6.78 might be much nearer the truth.

Despite the possibility that other factors may have been of some consequence, it is believed that the increase in population density of Saginaw Bay yellow perch is in itself sufficient to explain the observed decrease of growth rate.

The status of rate of growth of fish as a density-dependent variable is too well established to require presentation of argument or any extensive review of the voluminous literature on the subject. Evidence in the matter has come mainly from two sources: Changes in growth following transplantation from densely to thinly populated areas; changes in growth accompanying change of population density within a stock. Changes of population density that have been accompanied by change of growth rate have included fluctuations resulting from fluctuations in rate of exploitation or in the strength of year classes, from destruction of a considerable portion of the stock by a catastrophe, such as an epidemic or a winterkill, and by a deliberate, experimental destruction of the stock. A single example of each type of observation should provide adequate illustration.

The classic example of results from moving fish from crowded to thinly populated grounds is provided by plaice (*Pleuronectes platessa*) of the North Sea area. These experiments started early in the present century. Borley (1912) reported on the improved growth of plaice transferred from inshore waters to the Dogger Bank in 1904–08. These and later studies proved benefits to growth to be so substantial that the Danes developed an economically profitable enterprise in the transfer of young from the crowded nursery grounds to the broads of the Limfjord. A comprehensive review of the plaice transplantation experiments was published by Blegvad (1933).

The plaice also provided an early clear-cut illustration of change of growth rate with fluctuation in the density of the stocks. Prior to World War I excessive exploitation had greatly thinned the stock but during the war the drastic curtailment of operations permitted a substantial accumulation of fish on the grounds, and with it came not only an increase of average age but also a sharp decline in growth rate. The resumption of heavy fishing in post-war years led in turn to a thinning of the plaice, a decrease of average age, and an increase in growth rate. A thorough discussion of various aspects of the problem of population density and growth, centered largely about observations on plaice, was given by Bückmann (1932), Russell (1932), and other contributors to volume 80 of Rapports et Procès-Verbaux, Conseil Permanent International pour l'Exploration de la Mer.

Evidence on the effects of destruction of a large segment of the population by catastrophe was provided by Beckman's (1950) study of the growth of fishes in four Michigan Lakes that suffered severe winterkill in early 1945. With the exception of a single species in a single lake, all stocks exhibited an immediate marked improvement of growth. The rapid growth was soon lost, however, as reproduction restored population density to a high level.

The effects of an experimental reduction of population size was demonstrated by Beckman (1941 and 1943) for the rock bass (*Ambloplites rupestris*) of Standard Lake (Mich.). The destruction of the entire stock of fish in one basin of this hourglass-shaped lake in 1937 produced an immediate sharp improvement in growth. This good growth was still largely maintained at least as late as 1942, the year of the last sampling.

Critical reviews of the literature and references to publications on the relation between population densities and growth rates of fishes have been given by Hile (1936), Van Oosten (1944), and Watt (1956).

Changes of growth rate with increase or decrease of population density have mostly been related to the availability of food. In many situations, as notably with the plaice, evidence in support of this view is good. Some authors have suggested, however, that space available per individual may in itself affect growth, independently of food conditions. The possibility of an influence of space on growth was recognized many years ago. Semper (1880) demonstrated a strong positive correlation between water volume per individual and the growth of snails (*Lymnaeus stagnalis*) reared from the same batch of eggs. Willer (1929) applied the term "Raumfaktor" to this influence of space on growth and offered the view that it is important in determining growth rate in natural populations as well as under experimental conditions. Numerous authors since have mentioned the space factor as of possible importance in observed correlations between growth rate and population density, but have not been able to separate its effects from those of food competition (see Hile 1936).

The sevenfold or greater increase from 1929–30 to 1943–55 in the numbers of yellow perch in Saginaw Bay suggests at once that competition for food has greatly increased, for we can hardly assume that food production has increased in a corresponding ratio. On the other hand, we are quite without evidence that an actual scarcity of food for perch has existed in recent years. Furthermore, the fish give no indication of starvation. They lack altogether, the large-headed, thin-bodied appearance of the stunted perch described and figured by Eschmeyer (1937), but, on the contrary, appear plump and healthy. This impression as to the well-being of fish of the 1943–55 samples is supported by the facts, for the earlier data on the length-weight relation proved them to be heavier, length for length, than the rapidly growing perch of the 1929–30 samples. The evidence, then, supports the conclusion that crowding in itself, not a scarcity of food, was the principal factor in the decline in growth.

POSSIBLE FACTORS OF FLUCTUATIONS IN YEAR-CLASS STRENGTH AND GROWTH RATE

The literature on the relation between environmental factors and the fluctuation of year-class strength and growth in fishes is extensive. No general review of this subject is undertaken here since excellent and detailed reviews were given by Hile (1936 and 1941), Van Oosten (1944), and more recently by Watt (1956).

Evidence from the literature suggests that factors not only vary, but conditions that control growth and success of reproduction are not the same for any particular species in different waters. It appears also that under natural conditions, the year classes and growth rate are not controlled by single factors, but by a number of interacting ones, some of which may be beneficial while others are harmful. The interrelations among these complex factors are unknown and indeed it is to be suspected that some important factors have not been discovered or tested. Most work done on this subject has been only exploratory.

The present inquiry is also exploratory and not conclusive. It is limited to possible effects of population density and to certain environmental factors about which information was available; temperature, precipitation, water level, and turbidity. The study is restricted also to growth in length. More intensive study must await the accumulation of information covering a greater span of calendar years.

Data on precipitation and on monthly air temperatures at Bay City (Mich.) published by the United States Weather Bureau, were taken as indicative of fluctuations of rainfall and the water temperature of the Bay itself. Doan (1942) showed a significant correlation between average temperatures of the air and water for Lake Erie. Similar correlations were determined between average air temperature and the temperature of water, for April through October 1939 to 1950. The data were collected at the intake (3,400 feet from shore) of the Bay City filtration plant. The values of r for the different months are as follows:

Month	r	Month	r
April	0.748	August	0.607
May	.887	September	.640
June	.846	October	.781
July	.599		

The preceding values of r are statistically significant at the 1-percent level except for July, August, and September which are significant at the 5-percent level.

Data on the average monthly turbidity were obtained from the Bay City water plant for the years 1939–52 (after 1952 the intake was changed to a different location) and expressed as parts per million (table 47).

TABLE 47.—*Turbidity of the raw water from the intake of the municipal water plant Bay City, Mich.*

Month	Turbidity (p. p. m.) in year													
	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952
January	5	5	7	8	24	5	5	15	5	5	7	43	7	2.3
February	5	5	3	3	7	6	5	6	5	5	7	11	8	1.5
March	11	5	4	17	42	18	7	27	6	61	7	15	15	4
April	7	14	6	62	79	73	22	26	78	94	43	81	21	27
May	15	16	17	32	57	20	30	26	39	32	20	43	38	16
June	12	21	18	38	59	27	39	16	21	15	14	13	15	10
July	14	12	21	23	40	25	27	17	24	17	31	16	16	10
August	13	19	21	15	29	25	18	15	35	17	40	25	20	15
September	14	11	13	23	22	25	20	8	21	21	13	23	20	[1] 24
October	11	12	16	13	27	19	22	9	19	11	21	17	22	17
November	10	31	16	23	14	14	22	5	12	10	15	22	19	17
December	10	18	25	16	9	13	13	5	7	8	13	14	7	12

[1] New intake.

Records of water level were taken from charts and from monthly report sheets issued by United States Lake Survey, Army Corps of Engineers.

Environmental Factors and Fluctuation in Year-Class Strength

The first environmental factor checked as possibly having an effect on the strength of the year classes was the density of the population. The coefficients of correlation between the indexes of abundance and production of Saginaw Bay yellow perch and the year-class strength for the period 1939–52 had insignificant values (r = 0.321 and 0.272 for abundance and production, respectively). This result indicates that the number of legal-sized fish did not affect the brood strength.

The correlation coefficients of table 48 also did not indicate any significant relation between year-class strength and the environmental factors. The coefficients for precipitation in April ($r = 0.462$) and September ($r = 0.492$) although moderately high, were far from significant. Likewise the different multiple correlations (table 49) failed to reveal any relation between the year-class strength and environmental factors. No values of R^2 or of the regression coefficients were significant. Jobes (1952) similarly failed to establish a relation between certain environmental factors and year-class strength of Lake Erie yellow perch.

Failure to establish a relation between the year-class strength and the abundance of yellow perch or any of four environmental factors is not surprising. Unquestionably, we shall need a much broader and more detailed knowledge of limnological conditions within Saginaw Bay before we can hope for even a modest measure of success. We need particularly to know conditions during embryological development, at hatching, and during the early larval stages. It has long been believed that the strength of a year class is determined very early in its history (Hjort 1914), and many feel that the success of reproduction is determined by conditions over

TABLE 48.—*Coefficients of correlation between year-class strength and temperature precipitation, water level, and turbidity*

[Values of r at the 5-percent and 1-percent levels of significance are: 0.532 and 0.661]

Month	Temperature	Precipitation	Water level	Turbidity
April	−0.377	0.462	0.063	−0.045
May	.233	−.364	.135	−.116
June	.319	.158	.125	−.298
July	.290	.030	.143	−.282
August	.004	−.230	.199	−.092
September	−.167	−.493	.196	.010
October	−.202	−.255	.138	−.115

TABLE 49.—*Coefficients in regression equation and R^2 in the study of the relation between environmental factors and year-class strength of Saginaw Bay yellow perch*

[When regression coefficient is not given, that variable was not considered in the determination of the equation]

Number of variables and *months*	Constant term (a)	Temperature (b_1)	Precipitation (b_2)	Water level (b_3)	Turbidity (b_4)	R^2
4 variables:						
April–June	−6608.35	0.42	9.92	11.35	−0.86	0.060
May–June	−10857.47	9.03	12.38	17.73	−1.70	.186
April-May	−4481.54	−6.30	−8.59	9.23	−.47	.064
May	−5989.02	.28	−13.68	10.38	−.13	.154
June	−15540.36	10.85	23.82	25.47	−3.02	.476
3 variables:						
Various [1]	−16469.42	−9.35	17.09	29.05	-------	.323
Various [2]	−9024.83	−7.28	−51.36	16.17	-------	.184
Various [3]	−4913.22	−6.39	5.27	9.07	-------	.093
Various [4]	−1569.80	−8.27	1.14	3.52	-------	.080
2 variables:						
Various [5]	−6454.96	-------	8.39	11.08	-------	.046
Various [6]	−2385.52	-------	.25	4.11	-------	.004
Various [7]	−8115.53	-------	8.94	13.94	-------	.059
Various [8]	−4183.38	-------	−.53	7.22	-------	.010
April	−6739.39	−6.75	-------	12.16	-------	.172
Various [9]	−8003.88	−6.82	-------	14.35	-------	.183

[1] Temperature, April; precipitation, June; water level, April.
[2] Temperature, April; precipitation, July; water level, April.
[3] Temperature, September-October; precipitation, June; water level, April-May.
[4] Temperature, September-October; precipitation, July; water level, April-May.
[5] Precipitation, June; water level, April.
[6] Precipitation, July; water level, April.
[7] Precipitation, June; water level, April-May.
[8] Precipitation, July; water level, April-May.
[9] Temperature, April; water level, April-May.

a very brief period of time. For the yellow perch Jobes (1952) and Pycha and Smith (1954) agreed that the availability and kind of food organisms had an important effect on the survival of newly hatched fish.

Environmental Factors and Fluctuation in Growth Rate

In the attempt to uncover possible relations between the four environmental factors and the fluctuations of growth special emphasis was placed on the environmental factors in the months April to October. The months include and probably exceed the growing season for Saginaw Bay yellow perch. In samples collected on June 7 and June 22, the percentages of individuals exhibiting new (current-season) growth were 28.4 percent and 42.6 percent, respectively. Jobes (1952) found that 15 percent of the total growth of Lake Erie perch had taken place in June. In the present study, although little or no growth occurs before June, the months of April and May were included because it is possible that the conditions in these two months might have some influence on the growth of fish later in the season. There are no good data on the time the growing season ends in Saginaw Bay but Jobes (1952) showed that in Lake Erie growth appeared nearly to have ceased toward the end of September (his 1927 data indicated that growth was still active in October). Accordingly, to take into account any exceptional growth later in the season, environmental conditions in October were included in the present study.

As a matter of general procedure simple correlations first were computed between annual fluctuations in growth rate and each of the 4 environmental factors for each month in the 7-month period considered, and for certain arbitrarily selected combinations, a number of multiple correlations were computed to evaluate the importance of combinations of the factors on growth.

First-year growth

In view of repeated observations on the relation between population density and growth rate (see preceding section on factors of change in growth rate from the 1929–30 to the 1943–55 collections), it is logical to assume that first-year growth may be good in years producing weak year classes and poor in years producing strong year classes. The coefficient of correlation between the year-class strength and the fluctuation in the first-year growth of Saginaw Bay yellow perch for the years 1942–51 ran contrary to such an assumption. The relatively high value of the correlation coefficient ($r = 0.507$; $r = 0.632$ at the 5-percent level) suggests that good growth and a strong year class occur in the same calendar year.

The correlation coefficients of table 50 indicate no correlation between the annual fluctuations in growth rate and the fluctuations of different environmental factors except for turbidity in June ($r = -0.799$). The value was fairly high for July also ($r = -0.555$) but was not significant. Other values of r were very low except those for rainfall in May (−0.617) and temperature in October (0.565). The possible association between first-year growth and turbidity in June and July was further indicated from the several multiple correlations shown in table 51. Although no multiple correlation involving turbidity and 2 or 3 other factors was significant, all that involved 1 other factor were significant when turbidity in June (or June and July) was included. The regression coefficients for turbidity likewise were significant in three of these two-factor equations. The only other indication of significance lay in the regression coefficient for precipitation in the combination: Temperature, July and August; precipitation, May. The multiple correlation, however, was not significant. Thus it appears that among the environmental factors an argument can be made for turbidity alone as possibly influencing first-year growth.

It is difficult to judge the effects of turbidity on ecological conditions in Saginaw Bay or the manner in which turbidity might affect the first-year growth of yellow perch. The literature on

TABLE 50.—*Coefficients of correlation between annual fluctuation of growth in the first year of life and temperature, precipitation, water level, and turbidity*

[Asterisk indicates significance at the 5-percent level. Absolute values for r at 5- and 1-percent levels of significance are: 0.632 and 0.765]

Month	Temperature	Precipitation	Water level	Turbidity
April	−0.159	0.313	−0.096	−0.126
May	.013	−.617	.012	.015
June	−.226	−.297	−.175	*−.799
July	−.092	.258	−.138	−.555
August	−.274	−.338	−.105	.217
September	.080	−.042	−.080	−.288
October	.565	−.124	−.091	−.097

TABLE 51.—*Coefficients in regression equation and R^2 in the study of the relation between environmental factors and growth in length in the first year of life of Saginaw Bay yellow perch*

[When regression coefficient is not given, that variable was not considered in the derivation of the equation. Values significant at the 5-percent level are indicated by an asterisk]

Number of variables and months	Constant term (a)	Temperature (b_1)	Precipitation (b_2)	Water level (b_3)	Turbidity (b_4)	R^2
4 variables:						
May–October	175.24	−0.45	−1.60	−0.23	−0.38	0.219
June–September	286.70	−.52	−.21	−.41	−.60	.381
July–August	532.63	−1.51	−1.78	−.72	.05	.125
April–May	925.18	−.89	−2.76	−1.50	−.01	.197
3 variables:						
Various [1]	−7.35	.31	−.66		−.27	.663
Various [2]	39.48	−.39	−.39		−.43	.581
Various [3]	73.18	−.88	−.80		−.29	.688
2 variables:						
Various [4]	10.15		−.50		−.33	*.646
Various [5]	13.08		−1.00		−.39	*.610
Various [6]	57.32	−.68			*−.35	*.667
Various [7]	−5.12	.25			*−.33	*.650
Various [8]	61.98	−.74			*−.36	*.670
Various [9]	−35.11	.79	−2.05			.541
Various [10]	107.71	−1.38	*−2.68			.493

[1] Temperature, October; precipitation, May; turbidity, June.
[2] Temperature, June–August; precipitation, May–June; turbidity, June–July.
[3] Temperature, July–August; precipitation, May; turbidity, June.
[4] Precipitation, May; turbidity, June.
[5] Precipitation, May; turbidity, June–July.
[6] Temperature, June–August; turbidity, June.
[7] Temperature, October; turbidity, June.
[8] Temperature, July–August; turbidity, June.
[9] Temperature, October; precipitation, May.
[10] Temperature, July–August; precipitation, May.

relations between turbidity and fish is voluminous, controversial, and inconclusive. Arguments have been particularly lively as to effects on fish of turbidities at levels encountered in the Great Lakes, especially Lake Erie. Langlois (1941) held that siltation and turbidity resulting from land erosion in the watershed were the cause of the decreasing abundance of the more choice species of fish in Lake Erie, and Doan (1942) supported the same general view. Van Oosten (1948), however, held the Langlois "turbidity theory" to be invalid and offered extensive data and detailed argument in support of his belief. He pointed out in particular that: Recent trends of turbidity in Lake Erie had been downward, not upward as Langlois had argued; turbidity levels encountered in Lake Erie and other Great Lakes waters are too low to have a significant effect on fish; no relation can be established for Lake Erie species between annual fluctuations of turbidity and of growth or year-class strength. Van Oosten (1948) included an exhaustive review of the literature on turbidity.

If the observed negative correlation between turbidity and the first-year growth of yellow perch in Saginaw Bay is accepted as a cause-and-effect relation, three possible explanations suggest themselves: The reduced light penetration may affect the photosynthetic action in phytoplankton and thus lower the biological productivity; lowered visibility in the water may impede the feeding activities of the small perch; under turbid conditions the availability of food may be lessened by the concentrations of zooplankton near the surface (Doan 1942) while perch remain near the bottom.

Growth in later years of life

The first approach to the study of factors affecting growth beyond the first year was the determination of correlations between the fluctuation of growth and of abundance and production of yellow perch in the same year (p. 368). Both values of the coefficient were insignificant (r = 0.049 and 0.112 for abundance and production, respectively). This result indicates that growth was not affected by fluctuations in the numbers of legal-sized fish within the range of variation of the stock during the present study.

The coefficient (r) of table 52 show no correlation between the annual fluctuation in growth rate and the different environmental factors in single months except for water level. The coefficients for water level were negative and significant for May to October, but insignificant for April. It is to be noticed also that the values of r had an upward trend during the season. Other moderately high but insignificant correlation coefficients were those for turbidity in April (r = 0.405), May (r = 0.555), and October (r = −0.429) and temperature in June (r = −0.498).

TABLE 52.—*Coefficients of correlation between annual fluctuation of growth in the second and later years of life and temperature, precipitation, water level, and turbidity*

[Asterisk indicates significance at the 5-percent level. Absolute value for r for turbidity at 5- and 1-percent levels of significance are 0.666 and 0.798; for temperature, precipitation, and water level they are 0.602 and 0.735]

Month	Temperature	Precipitation	Water level	Turbidity
April	−0.050	−0.127	−0.589	0.405
May	−.001	−.007	*−.612	.555
June	−.498	−.004	*−.664	−.017
July	−.260	−.234	*−.681	.015
August	−.293	.091	*−.681	−.132
September	−.080	.022	*−.710	−.258
October	.103	−.210	*−.701	−.429

The possible relation between growth in the second and later years of life and water level was further revealed from the selected multiple correlations in table 53. When all the variables were included in the regression equation, only

TABLE 53.—*Coefficient in regression equation and R^2 in the study of the relation between environmental factors and growth in length in the second and later years of life of Saginaw Bay yellow perch*

[When regression coefficient is not given that variable was not considered in the derivation of the equation. Values significant at the 5-percent level are indicated by an asterisk]

Number of variables and months	Constant term (a)	Temperature (b_1)	Precipitation (b_2)	Water level (b_3)	Turbidity (b_4)	R^2
4 variables:						
May–October	4145.74	−8.06	−13.48	6.23	1.21	0.766
June–September	4102.51	−2.89	−3.20	−6.69	.40	.668
July–August	5984.74	−.63	−2.10	−10.18	.84	.785
Various [1]	1436.48	*−3.06	*−5.51	−2.08	.20	*.891
Various [2]	2225.78	−.98	−2.56	−3.72	.45	.782
3 variables:						
Various [3]	3246.18	−1.29	--------	−5.44	.32	.619
Various [4]	2148.65	−2.62	--------	−3.39	.26	.679
May–October	4759.44	−4.63	−6.59	*−7.65	--------	*.707
June–September	3917.67	−3.74	−5.35	*−6.27	--------	*.671
July–August	4343.16	−1.30	−.28	−7.31	--------	.511
June–August	4086.74	−2.30	−1.28	−6.75	--------	.603
Various [5]	4256.61	−1.32	−.81	−7.16	--------	.550
2 variables:						
Various [6]	212.55	−3.12	--------	--------	.339	.611
June–September	4147.70	−1.89	--------	*−6.92	--------	*.554
July–August	4372.78	−1.29	--------	*−7.37	--------	.511
Various [7]	4365.95	−1.36	--------	*−7.35	--------	*.535

[1] Temperature, June–Aug.; precipitation, July–Aug.; water level, June–Aug.; turbidity, April–May.
[2] Temperature, July–Aug.; precipitation, July; water level, June–Sept.; turbidity, May.
[3] Temperature, July–Aug.; water level, June–Sept.; turbidity, May.
[4] Temperature, July–Aug.; water level, July–Aug.; turbidity, April–May.
[5] Temperature, July–Aug.; precipitation, July; water level, June–Sept.
[6] Temperature, July–Aug.; turbidity, April–May.
[7] Temperature, July–Aug.; water level, June–Sept.

one combination was significant (temperature, June–Aug.; precipitation, July–Aug.; water level, June–Aug.; turbidity, April–May). In this combination, regression coefficients were not significant for water level and turbidity, but were significant for both temperature and precipitation. When three variables were used in the multiple correlation, only two combinations, neither of which included turbidity, gave significant correlation (temperature, precipitation, and water level for May–Oct., and for June–Sept.). In these two regressions, the only significant regression coefficients were those of water level. With 2 variables, 2 of the 3 correlations that included water level were significant (temperature and water level for June–Sept.; temperature for July–Aug., and water level for June–Sept.), and all three regression coefficients for water level also were significant. In the combination, temperature and water level for July and August, the regression coefficient for water level was significant but the multiple correlation was not.

These correlations offer strong evidence that the growth of Saginaw Bay yellow perch in the second and later years of life has fluctuated inversely with the water level. Despite this apparent relation, it is not possible to offer an ecological explanation as to how water level might affect growth. Possibly the adverse effects of deeper water over the usual shallows is greater than beneficial effects from the creation of new shallows along the shore. Limnological studies are needed on the food production of inshore areas.

The regressions also provide some but much less convincing evidence that growth has been correlated negatively with temperature in June through August and with precipitation in July and August. Jobes (1952) showed a similar negative but insignificant correlation between fluctuation in growth and the combined temperature of June to August for Lake Erie yellow perch.

SEX AND MATURITY

Size at Maturity

The spawning-run samples are considered by many investigators as almost entirely mature fish. Van Oosten (1929) showed that immature fish were not represented in the spawning-run collection of Saginaw Bay lake herring and hence concluded that these samples were not suitable for the estimation of size at first sexual maturity. A similar conclusion was expressed in studies on Great Lakes yellow perch (Hile and Jobes, 1941, 1942; Jobes 1952).

In the present investigation, the comparison of the spawning-run samples for the period 1943–55 with the 1955 collections made outside the spawning season (summer and fall) revealed no significant difference in the percentage of mature yellow perch at corresponding lengths. Consequently, the data on the percentage of mature fish in the collections from all seasons were combined in the preparation of table 54 (in the collections of 1950 and June 7, 1955, records of maturity were not available).

TABLE 54.—*Relation between length and sexual maturity of Saginaw Bay yellow perch in 1943–55*

[All perch longer than those recorded in the table were mature]

Total length (inches)	Male			Female		
	Immature	Mature	Percent mature	Immature	Mature	Percent mature
5.0–5.4	----------	10	100	7	----------	0
5.5–5.9	7	165	96	45	35	44
6.0–6.4	8	393	98	70	170	71
6.5–6.9	8	430	98	86	174	67
7.0–7.4	2	376	99	46	183	80
7.5–7.9	----------	247	100	29	182	86
8.0–8.4	----------	120	100	8	179	96
8.5–8.9	----------	57	100	2	100	98
9.0–9.4	----------	27	100	1	84	99
9.5–9.9	----------	9	100	----------	55	100

Nearly all the males were mature including the smallest size captured (100 percent at 5.0–5.4 inches; 96 to 99 percent at lengths of 5.5–7.4 inches). All males more than 7½ inches long were mature.

Females attain sexual maturity at a slightly greater length than do males. No females were mature at 5.0–5.4 inches and fewer than half (44 percent) were mature at 5.5–5.9 inches. At all greater lengths, however, the majority of the females were mature. The 80-percent level was reached at 7.0–7.4 inches and the 95-percent figure passed at 8.0–8.4 inches. All females more than 9 inches long were mature.

The evidence in table 54 on the small size of Saginaw Bay yellow perch at first maturity indicates that the protection of immature fish to preserve a spawning stock needs little consideration in the management of the fishery. The present size limit of 8½ inches permits the capture of almost no immature fish and destruction of nonspawners would be unimportant even at 7 inches. The double protection from the 8½-inch size limit and a closed season during spawning seems unnecessary. Indeed, under present fishing conditions the imposition of either a size limit or a closed season must be justified on economic grounds.

The size at first maturity of Saginaw Bay yellow perch in 1943–55 appears to be closely similar to that in the same stock in 1929–30 and in Green Bay. Hile and Jobes (1941) published no details on the state of the gonads of the perch in their Saginaw Bay samples, but their comment that 96 percent of their specimens were mature and the published length frequencies give strong evidence of maturity at small size. For Green Bay perch Hile and Jobes (1942) stated that males were predominantly mature down to a length of 5 inches. A majority of females were immature at lengths below 7 inches but 59 percent were mature at 7–7½ inches and all were mature at lengths above 7½ inches.

Yellow perch mature at a greater length in Lake Erie than in Saginaw Bay and Green Bay. The 50-percent level of maturity is first exceeded by the males in Lake Erie at 6½–7 inches and by the females at 8½–9 inches (Jobes 1952).

Sex Ratio

The present study of the sex composition of Saginaw Bay yellow-perch population has served principally to confirm the findings of earlier investigators concerning the extreme variability of the sex ratio in samples of the species (Schneberger 1935; Weller 1938; Eschmeyer 1937, 1938; Hile and Jobes 1941, 1942; Jobes 1952; Alm 1946, European perch). Jobes (1952) showed that the sex ratio of Lake Erie yellow perch varied erratically even in day-to-day collections. He concluded that the best estimate of the sex ratio in the population could be obtained from the unweighted means of the percentages of males and females, determined for several individual samples.

Eschmeyer (1938) attributed this wide sample-to-sample fluctuation in the sex ratio to a persistent segregation of the sexes in nonspawning fish and during the spawning season. He based his conclusion on the stomach contents of fish that had been killed in the poisoning of an entire population. Females had consumed items characteristic of the surface and of shallow water, whereas males had eaten deep-water forms.

Sex ratio of individual samples

The data on sex ratio of Saginaw Bay yellow perch from the spawning runs in 1943–55 (right column, table 55) show pronounced year-to-year variability. The percentage of males varied from 26 percent in 1945 to 87 percent in 1954. In 4 years (1943, 1946, 1947, 1953) the sexes were nearly equally represented. For all the collections combined, the males were more abundant than the females (62 percent males).

Wide fluctuation in the sex composition was observed not only from year to year but also in collections of the same year (table 56). The males were most plentiful at the beginning and at the end of spawning season (April 18, 70 percent; June 7, 65 percent). On the other hand, females predominated strongly in the collections of June 22 (33 percent males) and October 19 (30 percent males). Males and females were represented equally in the remaining sample (May 18).

A high percentage of males in spawning-run samples has been observed commonly and among many species of fish. Different explanations of the phenomenon have been offered. Numerous investigators believe that males ripen sooner, move to the spawning grounds earlier, and remain there longer than do females. Deason and Hile (1947) showed that this explanation did

TABLE 55.—*Sex composition of Saginaw Bay yellow perch in spawning-run samples of 1943–55, expressed as percentage of males*

[Number of fish in parentheses, males at left, females at right]

Date of capture	Percentage of males in age group								All ages
	II	III	IV	V	VI	VII	VIII	IX	
May 4, 1943		67 (14–7)	56 (112–87)	34 (32–61)	40 (6–9)	40 (2–3)			50 (166–167)
May 3, 1945		33 (1–2)	22 (5–18)	28 (14–36)	37 (6–10)	0 (0–3)	0 (0–3)	0 (0–1)	26 (26–73)
June 3, 1946		24 (9–29)	49 (48–49)	77 (10–3)	100 (6–0)	100 (1–0)			48 (74–81)
May 28, 1947	0 (0–1)	44 (17–22)	54 (75–65)	74 (14–5)					53 (106–93)
May 15, 1948		33 (3–6)	66 (51–26)	65 (66–36)	100 (12–0)				66 (132–68)
May 10, 1949		62 (18–11)	73 (77–29)	84 (85–16)	65 (17–9)				75 (197–65)
May 18, 1950	0 (0–3)	60 (50–33)	62 (102–63)	82 (41–9)	100 (16–0)	100 (3–0)			66 (212–108)
May 1, 1951	0 (0–1)	46 (73–84)	70 (98–41)	89 (56–7)	91 (10–1)				64 (237–134)
May 5, 1953		32 (10–21)	42 (70–98)	71 (56–43)					46 (136–162)
May 12, 1954		65 (17–9)	80 (146–36)	96 (183–8)	96 (27–1)				87 (373–54)
Apr. 18, May 18, and June 7, 1955	23 (3–10)	56 (72–57)	55 (179–148)	66 (149–76)	79 (34–9)	100 (5–0)			61 (442–300)
Total	17 (3–15)	50 (284–281)	59 (963–660)	70 (706–300)	77 (134–39)	85 (11–6)	0 (0–3)	0 (0–1)	[1] 62 (2,101–1,305)

[1] The unweighted mean for the collections is 58.

TABLE 56.—*Sex composition of Saginaw Bay yellow perch in different seasons of 1955, expressed as percentage of males*

[Number of fish in parentheses, males at left, females at right]

Date of capture	Percentage of males in age group						All ages	Average age of females
	II	III	IV	V	VI	VII		
Apr. 18		50 (3–3)	66 (55–28)	70 (74–31)	77 (24–7)	100 (5.0)	70 (161–69)	4.2
May 18		12 (2–14)	25 (22–67)	58 (41–30)	88 (7–1)		50 (72–112)	4.2
June 7	23 (3–10)	63 (67–39)	66 (103–53)	69 (34–15)	75 (3–1)		65 (210–118)	3.6
June 22		29 (18–43)	30 (79–185)	38 (61–98)	32 (8–17)		33 (166–343)	4.2
Oct. 19	24 (10–31)	34 (30–58)	30 (58–138)	27 (12–32)			30 (110–259)	3.7

not hold for their data on the sex ratio of kiyi (*Coregonus* [*Leucichthys*] *kiyi*) and suggested that the great activity of males during spawning led to their capture in numbers out of proportion to their true abundance. Possibly both the actual abundance and differential activity affect the estimates of the sex ratio of spawning-run samples of perch.

Change of sex ratio with increase in age

The tendency toward a decrease in the percentage of males with advancing age has been repeatedly shown for many species. Hile (1936) who reviewed the subject of change of the sex ratio with age concluded with the suggestion that this condition might be characteristic among fish. A decrease in the percentage of males with increase of age has been observed also in a number of yellow perch populations (Schneberger 1935; Weller 1938; Hile and Jobes 1941, 1942; Jobes 1952). Exceptions to this trend were recorded, however, by Eschmeyer (1937 and 1938) and by Alm (1946) for populations of stunted perch. Thus the possibility suggests itself that the change in growth rate of Saginaw Bay yellow perch from 1929–30 to 1943–55 may be associated with a reversal in the change of the sex ratio with age. In the earlier years males grew scarcer with increasing age whereas in most of the 1943–55 samples (tables 55 and 56) the percentage of males increased with age (oldest age groups excepted).

In all of the 1943–55 samples, except for the spawning-run collections of 1943 and 1945 and the sample of June 22, 1955, the males became more plentiful with increase of age. This trend toward increase was so strong in some years (1948, 1950, 1954) that fish in age group VI were almost all males. Beyond age group VI, the change in the sex ratio could not be considered as descriptive because of the small number of fish. In the 1943 collection, the females were more plentiful in age group V–VII than in age groups III–IV and in the 1945 data and the June 22, 1955, sample no trend is apparent. For all spawning-run collections combined (bottom of table 55), the percentage of males increased continuously from 17 percent in age group II to 77 percent in age group VI and then dropped slightly to 65 in the VII group. The 4 older fish were all females.

It is difficult to judge the degree to which the trends of tables 55 and 56 are actually descriptive of the sex ratio of the Saginaw Bay stock of yellow perch. Samples of perch from commercial gear are biased, and this bias, in turn, leads to differential destruction in the fishery. Because of sex differences of growth rate (more rapid growth of females), the younger males are much less easily captured than are females. Even before fish of either sex attain legal size, this differential rate of capture leads to a greater mortality of females since numbers of undersized fish are killed in the handling and sorting of the catch. As the fish reach legal size this differential destruction is intensified, since females grow to 8½ inches in about 4½ years, as compared with 6-years for males.

SUMMARY

(1) The yellow perch is an important fish for both commercial fishermen and anglers because of its wide distribution and its frequent great abundance.

(2) In Saginaw Bay, the average commercial catch of yellow perch has decreased from 1,961,309 pounds in 1891–1916 to 499,938 pounds in 1917–55. Since 1938 the commercial production of yellow perch has been below 500,000 pounds except in 1943, 1944, and 1945. Statistics of the commercial fishery prove that the recent low output has resulted from reduced fishing intensity, not from a scarcity of fish.

(3) The trap net is the principal gear for catching yellow perch in Saginaw Bay (75.9 percent of the catch). Production is concentrated in the fall (75 percent of the catch in September, October, and November).

(4) The present study of age and growth was based on the determination of age and the calculation of growth histories of 4,285 fish, 3,407 of them collected during the spawning seasons of 1943–55 (no collections, 1945 and 1952). In 1955 additional collections were made outside the spawning periods.

(5) In the combined 1943–55 spawning-run collections, age group IV contributed 48.6 percent of the total, followed by age group V (29.9 percent) and age group III (15.9 percent). The remaining age groups (II and VI–IX) together contributed only 5.6 percent. The mean of the average ages for the 1943–55 spawning-run samples was 4.3 years.

(6) In 1955 the age composition changed seasonally. Average ages on various dates were: April 18, 4.8 years; May 18, 4.4 years; June 7, 3.8 years; June 22, 4.3 years; October 19, 3.7 years.

(7) Saginaw Bay yellow perch collected in 1943–55 averaged older than fish from the same Bay collected in 1929–30 and from other Great Lakes stocks (southern Green Bay, northern Lake Michigan, and Lake Erie).

(8) The estimation of year-class strength for 1939–52 was based on a series of comparisons of the percentage representation at various age groups. The strongest year classes were those of 1939 and 1952. The weakest were those of 1941 and 1945. The estimated year-class strength was correlated significantly with production 4, 5, and 6 years later, but the corresponding correlation with later commercial availability was not significant.

(9) It was not possible to establish a relation between year-class strength and the abundance of legal-sized fish in the year of hatching or with temperature, precipitation, water level, and turbidity.

(10) Length frequencies of the spawning-run samples were typically unimodal. The modal lengths (½-inch intervals) fluctuated from year to year but mostly lay within the range 6.0–6.9 inches, total length. The length-frequency distribution also varied seasonally in 1955. From April 18 to October 19 the modal intervals ranged from 5.5–5.9 inches (June 7) to 7.5–7.9 inches (October 19).

(11) The length distributions of successive age groups overlapped extensively. Fish of a particular length might belong to 2 to 5 age groups (mostly 4 age groups). The overlap made the length of Saginaw Bay perch a poor index of age.

(12) The length composition of the spring collections of Saginaw Bay yellow perch changed enormously between 1929–30 (modal length 8.5–8.9 inches) and 1943–55 (mode at 6.5–6.9 inches). At the same time the percentage of legal-sized fish (8½ inches and more) dropped from 73.9 percent in 1929–30 to 11.0 percent in 1943–55.

(13) The relation between the total length in inches (L) and the weight in ounces (W) of the 4,285 Saginaw Bay yellow perch in the combined collections was described satisfactorily by the equation:

$$W = 3.9975 \times 10^{-3} L^{3.260}$$

The value of the exponent in this equation was greater than that determined for Saginaw Bay fish in 1929–30 or for any other Great Lakes stock of perch.

(14) The annual variations of weight were so small among fish of the same length, sex, and condition of the gonads that the data for different years were combined in the study of the relation between weight and sexual condition. No significant difference of weight existed between ripe and spent males. On the other hand, the females showed an average loss of 12.3 percent of their weight at spawning.

(15) The seasonal differences of weight were so slight that it is not possible to speak of a seasonal trend. The males and spent females of the spawning-run sample usually were lighter than fish caught on June 22 and October 19. Ripe females had a somewhat weaker tendency to be heavier than fish caught later in the year.

(16) Because in 1954 scales were taken from above the lateral line rather than from below, as in other collections, it was necessary to establish two body-scale curves for the calculation of growth. These curves were based on "key" scales from above and below the lateral line of 520 fish.

(17) For scales collected from below the lateral line, the direct-proportion method was valid for the calculation of growth to the end of various years of life for standard lengths of 70 mm. and greater. Direct-proportion calculated lengths below 70 mm. were underestimates and had to be corrected on the basis of the empirical body-scale curve.

(18) The relation between fish length (standard length in millimeters) and the scale radius for scales above the lateral line was a straight line with a 30-mm. intercept on the length axis. Lengths computed from this relation were overestimates at values of 75 mm. and shorter. Corrections were determined from the empirical body-scale curve.

(19) Growth histories of the same fish as computed from measurements of scales from above and from below the lateral line were nearly identical except for the calculated lengths at the end of second year of life (discrepancies at this age averaged 3.6 mm.).

(20) The calculated lengths for a particular year of life tended to decrease as the fish grew older. These discrepancies in calculated length were most pronounced in the later years of life, particularly after the second year. They differed from "Lee's phenomenon" of apparent decrease in growth rate in which earlier years are affected most.

(21) The principal causes of discrepancies among calculated lengths are: Biased sampling from selective action of gears and from segregation by sexual maturity and size; higher mortality of the faster growing fish in the fishery. A higher natural mortality rate in faster growing fish also may be possible.

(22) The lengths of the sexes were similar in the first and second year of life. In later years the females were the longer; 0.3 inch at the end of the third year of life to 1.8 inches at the end of the seventh. The annual increments of growth in length decreased progressively with age among males and irregularly among females. Males reached the legal length of 8½ inches in about 6 years and females in a little more than 4½ years.

(23) The annual fluctuations of growth in length the first year and in the later years of life were dissimilar.

(24) The poorest first-year growth (9.2 percent less than the 1942–51 average) was made in 1942. In subsequent years a strong trend toward improvement of growth was apparent. The best first-year growth was 8.8 percent above average in 1951.

(25) No correlation could be demonstrated between first-year growth and: Year-class strength in year of growth; temperature; precipitation; water level. Significant negative correlation was found between first-year growth and turbidity in June (and possibly July). Possible explanations

of apparent effects of turbidity on fluctuation of growth were given.

(26) Fluctuations in growth in the later years of life were largely without trend. The maximum value (1948) was 16.8 percent above the 1944–54 average and the minimum (1952) was 16.2 percent below average.

(27) Little or no evidence was discovered of a correlation between growth in the second and later years of life and: Commercial production; abundance of legal-sized fish; temperature; precipitation; turbidity. Evidence was strong that growth had fluctuated inversely with the water level for May to October. No ecological explanation could be offered as to how water level might affect growth.

(28) The calculated weights of the females were higher than those of the males in all years of life except the first year where the increments were nearly equal. At the end of the second year of life and in subsequent years, the females were consistently heavier than the males. In the sixth and seventh years of life the weights of the females were nearly double those of males.

(29) The annual increments of weight for both sexes increased throughout life. The females attained their greatest advantage in annual increase over the males in the sixth year of life when they added more than 2½ times the weight gained by the males.

(30) The annual fluctuations of growth in weight were similar to those of growth in length but covered a wider range.

(31) The Saginaw Bay yellow perch collected in 1943–55 had grown much more slowly than fish collected from the Bay in 1929–30 and from other Great Lakes waters. Possible factors of the decrease in growth rate in Saginaw Bay were discussed. It was concluded that the increase in population density (about sevenfold or greater) was probably the cause.

(32) Male yellow perch in Saginaw Bay matured at a smaller size than females. Nearly all the males were mature at the length of 5.0 to 7.5 inches. All males more than 7½ inches long were mature. Among females 44 percent were mature at 5.5–5.9 inches, 80 percent at 7.0–7.4 inches; 95 percent at 8.0–8.4 inches. All females more than 9 inches long were mature.

(33) The sex ratio of Saginaw Bay yellow perch from the spawning runs in 1943–55 varied widely from year to year. The percentage of males ranged from 26 percent in 1945 to 87 percent in 1954. For all the collections combined the males constituted 62 percent. The sex ratio also varied seasonally (from 70 percent males on April 18 to 30 percent on October 19 in the 1955 samples).

(34) In 1929–30 the males grew scarcer with increasing age whereas in most of the 1943–55 samples the percentage of males increased with age. For the combined spawning-run collections the percentage of males rose from 17 percent in age group II to 77 percent in age group VI and then dropped to 65 percent in the VII group. The 4 older fish, however, were all females. The fact that a rise in the percentage of males with increase of age has been shown by other authors for populations of stunted perch suggests that the change in growth rate of Saginaw Bay yellow perch in recent years was also the cause of this reversal in the changes of the sex ratio with age.

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