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FLUCTUATIONS IN THE FISHERIES OF STATE OF MICHIGAN WATERS OF GREEN BAY

By RALPH HILE, GEORGE F. LUNGER
and HOWARD J. BUETTNER

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FLUCTUATIONS IN THE FISHERIES OF STATE OF MICHIGAN WATERS OF GREEN BAY

By RALPH HILE, *Fishery Research Biologist*, and GEORGE F. LUNGER and HOWARD J. BUETTNER, *Statisticians*

Green Bay,[1] traditionally a major center of production, has assumed in recent years a position of overwhelming dominance in the commercial fisheries of the State of Michigan waters of Lake Michigan. Within the 4-year period 1945–48 the commercial take in State of Michigan waters of Green Bay increased from 3,317,000 pounds in 1945 to 7,909,000 pounds in 1948, and it was 7,782,000 pounds in 1949. At the same time the percentage contribution of Green Bay to the State total for Lake Michigan rose each year, increasing from 36.5 in 1945 to 65.4 in 1949.

The tremendous upswing in commercial production in Green Bay can be attributed to the abnormally high abundance of three important species—the lake whitefish (*Coregonus clupeaformis*), the lake herring or shallowwater cisco (*Coregonus* [=*Leucichthys*] *artedii*), and the walleye or yellow pikeperch (*Stizostedion v. vitreum*)—and to a marked rise in fishing intensity. The increase in the abundance of fish was to a great extent responsible for the rise in fishing pressure. Not only were local fishermen stimulated to greater efforts, but commercial operators from many other localities moved into Green Bay to participate in the good fishing. Most numerous, perhaps, among the newcomers were fishermen from Lake Huron who were literally driven from home by the declining productivity of their own fishing grounds. Fishermen from Wisconsin, also, purchased nonresident licenses for fishing in State of Michigan waters.

The heightened production in Green Bay has not proved an unmitigated blessing. The influx of fishermen from other localities has resulted in severe congestion of the fishing grounds. Frictions have arisen and unpleasant incidents have occurred. These difficulties are likely to be multiplied at such time as the abundance of fish approaches a more nearly normal level, for the available stocks then may prove inadequate to support profitable operations by all the fishermen now concentrated in the area.

Still another problem is offered by the greatly heightened interest of sportsmen and resort owners in the walleye. They have found the recent high abundance of walleyes greatly to their liking and wish to see it perpetuated. To that end some are willing to press for stringent limitations on commercial operations—restrictions on gear, closure of grounds, even placing the walleye on the game-fish list.

Thus we have all the elements needed to create a difficult and turbulent situation in northern Green Bay in the years ahead. The decline in abundance of fish that seems almost certain to come will prove distressing to all groups. Should these groups resort to pressures to obtain changes of regulations—either liberalized or restrictive—without first making certain that the changes are sound, the welfare of the fisheries could be gravely endangered. The best interests of the various groups are not incompatible, but their views frequently are. If the several groups are to be brought together, it will come about through a better understanding and appreciation of facts relating to the fisheries.

It is to be regretted that the available facts on the fisheries of Green Bay are few. Past studies of the biology of fishes in the area, though instructive, have been scattered. Opportunities have been lacking for the continuity of research so essential to an appreciation of the tremendous changes that take place within populations. Until better understanding of these changes is developed we shall continue at a severe disadvantage in attempting to prescribe for the welfare of the fisheries.

[1] The designation, Green Bay, as employed in this paper refers to State of Michigan waters only.

Despite the inadequacy of the biological background, we have useful information on the Green Bay fisheries. Particularly valuable are statistical data for the 21-year period 1929–49 which permit accurate description of the changes in production and good estimates of fluctuations in fishing pressure and in abundance of the principal species. True, the causes of the changes in abundance continue to be unknown; nevertheless, sounder thinking is promoted when we are in position to describe changes quantitatively. Reasonably dependable norms can be established and exceptional situations evaluated more effectively.

This paper on the Green Bay fisheries is documentary and its discussions are generally descriptive rather than analytical. Its primary purpose is to make the more significant statistical data available in concise form to investigators, conservation officials, sportsmen, industry, and others interested in the future of the fisheries. It is hoped that this review of past changes in the fishery will make possible a better understanding of the situation as it exists now and of the changes that may come about within the next few years.

Portions of the statistical data given in this paper were included in earlier publications by Hile (1937) on the artificial propagation of the walleye in Lakes Huron and Michigan; by Van Oosten, Hile, and Jobes (1946) on the whitefish fishery of Lakes Huron and Michigan; by Van Oosten (1947) on the smelt (*Osmerus mordax*) mortality of 1942–43 in the same lakes; by Hile (1950) on the recent phenomenal rise in the abundance of walleyes in Green Bay; and by Hile, Eschmeyer, and Lunger (1951a) on the decline of the fishery for lake trout (*Salvelinus namaycush*) in Lake Michigan. These earlier papers, however, dealt with special problems and undertook no review of the Green Bay fishery as a whole.

The authors wish to express appreciation to Dr. James W. Moffett for his helpful criticisms of the original manuscript; to Elmer Higgins who offered many useful suggestions on the section concerning the problem of economically sound regulations; and to Dr. Reeve M. Bailey, Curator of Fishes, Museum of Zoology, University of Michigan, for his valuable advice on the nomenclature of Green Bay fishes.

SOURCES OF DATA AND METHODS OF ANALYSIS

Data on production in 1885 were taken from Smith and Snell (1891) and those for 1891–1908 were compiled (with WPA assistance) from handwritten records turned over to the U. S. Fish and Wildlife Service by the Michigan Department of Conservation.

Statistics on production and estimates of the fluctuations in abundance of the principal species and in intensity of the fishery in 1929–49 have been based on reports of commercial fishing submitted each month to the Michigan Department of Conservation by all fishermen licensed to operate in the Great Lakes waters of the State, and subsequently released to the Fish and Wildlife Service for detailed analysis.

The methods employed in statistical analysis of the commercial fisheries of the Great Lakes have been described in earlier publications by Hile (1937), Hile and Jobes (1941), and Van Oosten, Hile, and Jobes (1946). Two points only need be stressed here. First, estimates of abundance of a particular species are derived from records of the actual catch in pounds per standard unit of fishing effort (lift of 10,000 linear feet of gill net; lift of 1 pound, trap, or fyke net; . . .). Second, estimates of the intensity of the fishery for a particular species are based only on gear lifted on days when some quantity of the species was captured by the fisherman submitting the report.

COMMERCIAL PRODUCTION IN GREEN BAY

PRODUCTION IN 1885

The earliest published review containing usable statistics on the commercial production of fish in Green Bay was that made for 1885 by Smith and Snell (1891). The catch statistics for Big Bay de Noc (including grounds in the Summer Islands area), Escanaba and vicinity, and Menominee County were combined to obtain the data of table 1.[2] (See fig. 1 for chart of area.)

[2] The figures given in table 1 represent our best judgment in the resolution of certain discrepancies in the data of Smith and Snell. The text relating to the Big Bay de Noc area mentioned 812 100-pound packages of salted walleyes but included no reference to salted lake trout. The statistics for the same area in the general tables for Lake Michigan, however, showed 81,200 pounds of salted lake trout and 2,000 pounds of salted "pike and pickerel." In our summarization we followed the table. Again, the text concerning the fisheries for Escanaba and vicinity mentioned

TABLE 1.—*Commercial production of fish, by species, in Green Bay, 1885*

[In thousands of pounds; data adapted from Smith and Snell (1891)]

Species	Production	Percentage of total
Lake trout	404	16.5
Whitefish [1]	758	31.0
Lake herring	972	39.7
Walleye [2]	91	3.7
Suckers	48	1.9
Sturgeon	131	5.3
Black bass	4	.2
Miscellaneous [3]	41	1.7
Total	2,449	----------

[1] Includes round whitefish (*Prosopium cylindraceum*) and blackfins (*Coregonus nigripinnis*). The catch of these species doubtless was small; statements by Smith and Snell concerning quantities of blackfins captured in the vicinity of Escanaba must be viewed with skepticism.
[2] Believed to have been mostly walleyes. Smith and Snell confused the terms "walleyed pike," "pike," "pickerel," and "doré" in their text.
[3] Fish mentioned specifically as having part or all of their catch included under "Miscellaneous" were black bass (*Micropterus* spp.), suckers (*Catostomus* spp. and *Moxostoma* spp.), yellow perch (*Perca flavescens*), and bullheads (*Ameiurus* spp.).

Lake herring (39.7 percent of the total of 2,449,000 pounds) and whitefish (31.0 percent) predominated in the 1885 fishery. Lake trout (16.5 percent) also was important, but among the remaining species only the lake sturgeon (*Acipenser fulvescens*) contributed as much as 5 percent of the total.

520,294 pounds of smoked fish—a poundage exactly equal to the combined totals of fresh and salt fish listed in the general tables. The tables recorded no smoked fish for the Escanaba region. Here, again, we followed the tables.

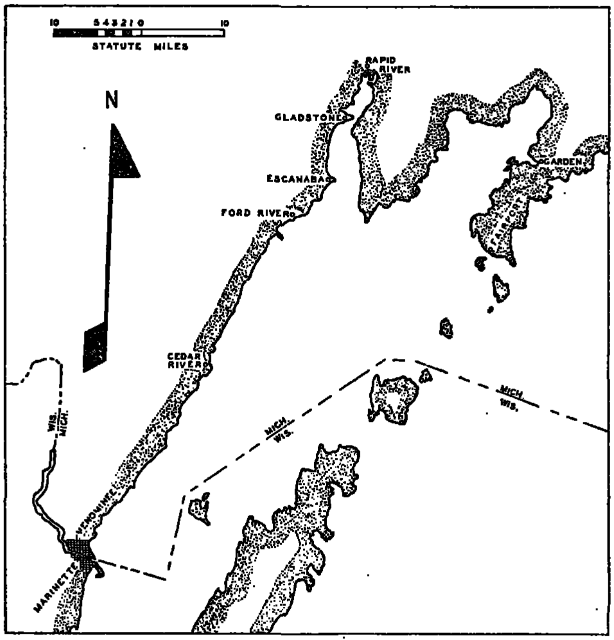

FIGURE 1.—Chart of northern Green Bay.

PRODUCTION IN 1891–1908

Outstanding features of the statistics for this 18-year period (tables 2 and 3; figs. 2 to 8) were the pronounced if irregular upward trend of production and the strong dominance of lake herring in the catch. Of significance also was the increased relative importance of yellow perch and suckers in the latter part of the period.

TABLE 2.—*Production in the commercial fisheries of Green Bay, by species, 1891–1908*

[In thousands of pounds]

Year	Lake trout	Whitefish	Lake herring	Walleye	Yellow perch	Suckers	Lake sturgeon	Miscellaneous [1]	Total catch
1891	171	78	1,515	121	----------	8	47	154	2,093
1892	35	149	1,645	214	11	19	38	129	2,241
1893	174	123	2,898	163	32	100	25	252	3,767
1894	142	89	1,956	186	41	16	30	50	2,510
1895	109	72	3,413	301	37	99	24	60	4,115
1896	119	89	3,890	300	39	38	31	52	4,558
1897	176	84	6,205	286	114	182	19	72	7,138
1898	161	85	7,164	267	78	179	24	80	8,037
1899	127	112	9,606	209	78	358	22	86	10,598
1900	90	83	5,781	183	62	387	17	157	6,762
1901	168	98	5,198	146	83	369	12	175	6,249
1902	307	140	7,169	183	131	545	14	166	8,656
1903	380	228	6,153	258	312	776	19	103	8,229
1904	363	283	8,569	120	342	582	16	53	10,327
1905	382	348	5,300	106	499	693	12	58	7,399
1906	332	292	7,526	202	355	891	12	45	9,655
1907	299	292	9,300	185	247	1,124	11	36	11,494
1908	300	222	11,850	121	367	798	17	32	13,708
Mean, 1891–1908	213	159	5,841	197	157	398	22	98	7,085
Percentage	3.0	2.3	82.4	2.8	2.2	5.6	0.3	1.4	100

[1] Includes small production of black bass, sauger (*Stizostedion canadense*), and catfish (presumably *Ictalurus punctatus*) in addition to catches not identified.

TABLE 3.—*Percentage composition of the catch, by species, in the commercial fisheries of Green Bay, 1891–1908*

Year	Lake trout	White-fish	Lake herring	Wall-eye	Yellow perch	Suck-ers	Lake stur-geon	Miscel-lane-ous
1891	8.2	3.7	72.4	5.8	------	0.4	2.2	7.3
1892	1.6	6.6	73.5	9.6	0.5	.8	1.7	5.7
1893	4.6	3.3	76.9	4.3	.8	2.7	.7	6.7
1894	5.6	3.6	78.0	7.4	1.6	.6	1.2	2.0
1895	2.6	1.8	82.9	7.3	.9	2.4	.6	1.5
1896	2.6	1.9	85.3	6.6	.9	.8	.7	1.2
1897	2.5	1.2	86.9	4.0	1.6	2.5	.3	1.0
1898	2.0	1.1	89.1	3.3	1.0	2.2	.3	1.0
1899	1.2	1.1	90.6	2.0	.7	3.4	.2	.8
1900	1.3	1.3	85.5	2.7	.9	5.7	.3	2.3
1901	2.7	1.6	83.2	2.3	1.3	5.9	.2	2.8
1902	3.6	1.6	82.8	2.1	1.5	6.3	.2	1.9
1903	4.6	2.8	74.8	3.1	3.8	9.4	.2	1.3
1904	3.5	2.7	83.0	1.2	3.3	5.6	.2	.5
1905	5.2	4.7	71.6	1.4	6.7	9.4	.2	.8
1906	3.4	3.0	78.0	2.1	3.7	9.2	.1	.5
1907	2.6	2.5	80.9	1.6	2.2	9.8	.1	.3
1908	2.2	1.6	86.5	.9	2.7	5.8	.1	.2
Mean	3.3	2.6	81.2	3.8	1.9	4.6	.5	2.1

The total catches in 1891 (a little more than 2 million pounds) and 1892 (about 2¼ million pounds) were below the 1885 level. The take rose to about 3¾ million pounds in 1893, dropped to 2½ million pounds in 1894, and then entered on a 5-year period of consistent increase which culminated in a catch of 10½ million pounds in 1899. A 4-year period, 1900–1903, of somewhat lower yield—approximately within the range of 6¼ to 8½ million pounds—was followed by a second peak of more than 10¼ million pounds in 1904. Again the take dropped sharply (nearly to 7¼ million pounds) in the year after the peak. From the relatively low 1905 value the yield increased rapidly to about 9½ million pounds in 1906, to 11½ million pounds in 1907, and to 13¾ million pounds in 1908. The last figure represents not only the maximum for the 18-year period but also the highest recorded yield for the State of Michigan waters of Green Bay.

Comparison of the statistics on the total catch with those for the lake herring reveals that the fluctuations in the take of this species were in large measure responsible for the trends of total production. Lake herring made up 82.4 percent of the 1891–1908 catch (table 2) and did not contribute less than 71.6 percent (the figure for 1905—see table 3) in any single year. The percentage was consistently above 85 in the 5 years 1896–1900 and reached 90.6 in 1899. The output of lake herring increased from the relatively low figure of 1½ million pounds in 1891 to more than 2¾ million in 1893, dropped to less than 2 million pounds in 1894, and then increased each year until a peak of more than 9½ million pounds was reached in 1899. The take varied irregularly during the next several years. Toward the end of the 18-year interval a second period of consistent increase carried the output from about 5¼ million pounds in 1905 to more than 11¾ million pounds in 1908.

Most of the other species that contributed more than 2 percent to the total 1891–1908 yield (yellow perch formed 2.2 percent of the 1891–1908 total, table 2, but had a mean percentage of only 1.9, table 3) exhibited the same upward trend of production that characterized the lake herring. The catch of lake trout, for example, did not exceed 176,000 pounds (the take in 1897) in the years 1891–1901, but was 300,000 pounds or more in 6 of the 7 years 1902–08. Similarly, in 1891–1902, the take of whitefish was greater than 100,000 pounds in only 4 years and was never as high as 150,000 pounds, but exceeded 200,000 pounds every year after 1902.

Discussion of the increase in the output of yellow perch and suckers is handicapped by the circumstance that part of the catch of both probably was included under Miscellaneous, especially during the earlier years of the 1891–1908 period. Despite this difficulty it is valid to state that the take of yellow perch and suckers did increase greatly toward the end of the period. This conclusion would hold even if we were to assume that perch and suckers made up practically all of the miscellaneous catch in the earlier years and little or none in the later ones. The increase in the production of suckers was sufficient to place that species second only to lake herring in every year after 1898 and in the 18-year average. The contribution of suckers to the annual totals exceeded 5 percent every year after 1899 and was over 9 percent in 4 years. The increase in the production of yellow perch carried that species from a position of insignificance to the point where it held third place in 1905, 1906, and 1908 and accounted for as much as 6.7 percent of the total catch (in 1905).

The walleye provides an exception to the trends just described for the other principal species. Most of the larger catches were in the earlier part of the 18-year period, with the four best years in 1895–98. The take was more than 200,000 pounds in 6 of the 9 years 1891–99, but in only 2 of the 9 years 1900–1908. The downward trend was even more pronounced in the percentage contribution of walleyes to the annual totals. This percentage was 4 or greater in every year before 1898 and was as high as 9.6 (in 1892). During the last 11 years of the period, walleyes made up more than 3 percent of the annual yield only twice and accounted for less than 2 percent in 4 years.

The production of sturgeon, a species once abundant in the Green Bay area (*cf.* Milner 1874, Smith and Snell 1891), already had fallen to a low level by 1891. The decline continued irregularly during the 1891–1908 period.

Too much should not be made of a comparison of production in 1891–1908 with that in 1885 since we cannot be certain that conditions in the single earlier year were representative of the middle 1880's. It does appear, however, that the species composition of the catch changed markedly from 1885 to the early 1890's even though the actual total yield did not rise to a point consistently above the 1885 level until 1895. It is true that the lake herring was the principal fish taken in 1885 as it was in 1891–1908; but the percentage contribution to the total was only 39.7 in 1885 as compared with 82.4 (range, 71.6 to 90.6) in the later years. Whitefish, on the contrary, fell from 31.0 percent in 1885 to 2.3 percent (range, 1.1 to 6.6) in 1891–1908. The percentage for lake trout also declined markedly from 16.5 to 3.0 (range, 1.2 to 8.2).

PRODUCTION IN 1929–49

Data on the average take and on the percentage contribution of the leading species to the total yield have been given in tables 4 and 5 for the years 1929–43 and 1929–49. The former is the "period of reference" established for the description of fluctuations in the modern fishery of State of Michigan waters of the Great Lakes. The large discrepancies between certain figures for 1929–43 and 1929–49 suggest that in some areas an average or "normal" based on a period even as long as 15 years may have its limitations. In Green Bay the addition of only 6 years' data to those for 15 years raised the averages for the production of whitefish, lake herring, and walleyes by 297,000, 356,000, and 82,000 pounds, respectively. The corresponding percentage increases of 1929–49 over 1929–43 means for these species were: Whitefish, 71; lake herring, 50; walleyes, 161. For the remaining four principal species[8] the 1929–49 means were lower by 20,000 pounds (lake trout) to 108,000 pounds (smelt). The percentage decreases ranged from 5 for the suckers to 15 for the smelt. The average catch for all species in 1929–49 (3,582,000 pounds) was 544,000 pounds, or 18 percent greater than that for 1929–43 (3,038,000 pounds).

Of the two intervals, 1929–43 and 1929–49, the former probably represents the better reference period for the modern fishery since the high levels that have characterized the output of whitefish, lake herring, and walleyes in recent years can hardly be expected to persist indefinitely.

[8] For purposes of discussion in this paper, white and redhorse suckers (*Catostomus commersoni* and *Moxostoma* spp.) are treated as a single species. Actually, the white sucker predominates strongly in this combined catch.

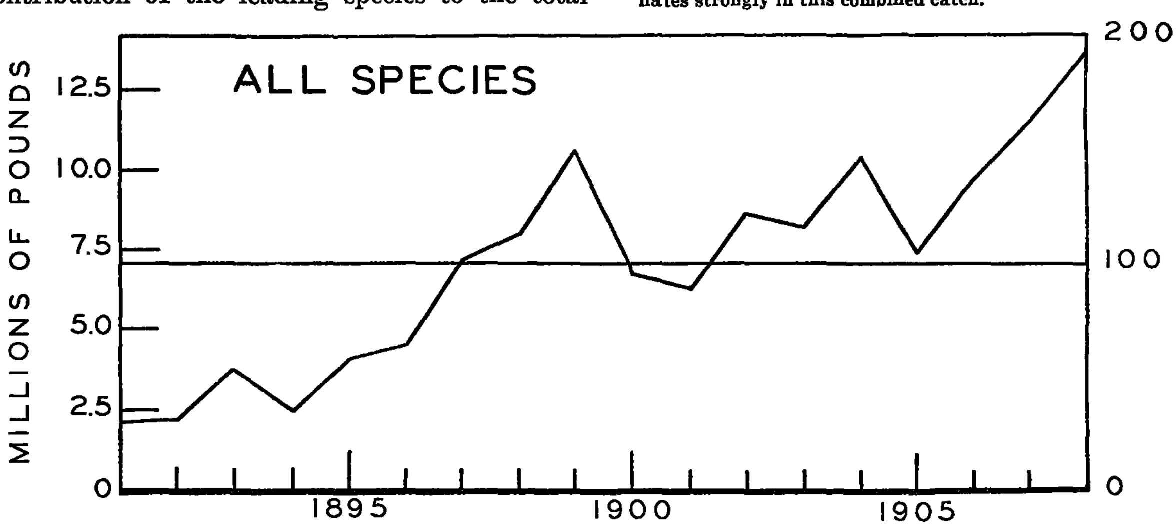

FIGURE 2.—All species: Commercial production in State of Michigan waters of Green Bay, 1891–1908, in millions of pounds and as percentages of the 18-year mean.

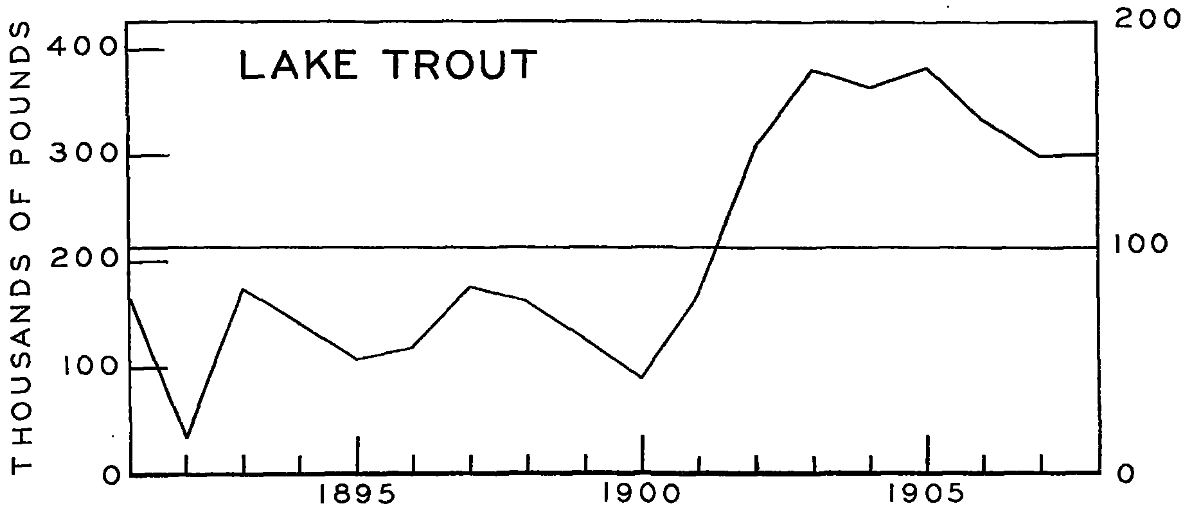

FIGURE 3.—Lake trout: Commercial production in State of Michigan waters of Green Bay, 1891–1908, in thousands of pounds and as percentages of the 18-year mean.

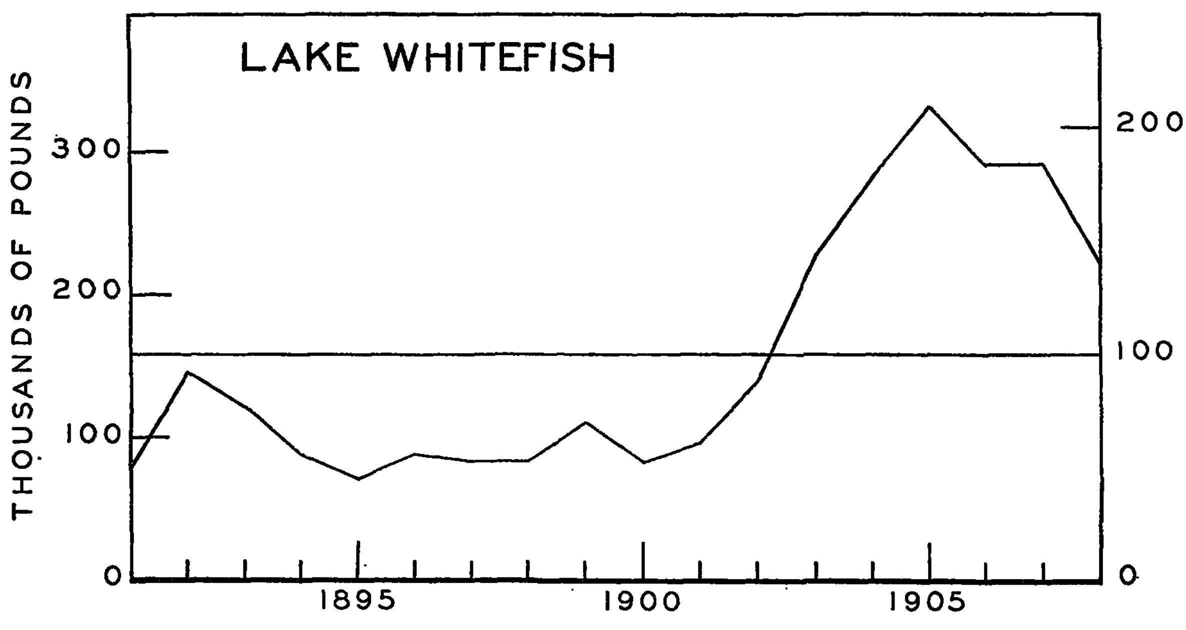

FIGURE 4.—Lake whitefish: Commercial production in State of Michigan waters of Green Bay, 1891–1908, in thousands of pounds and as percentages of the 18-year mean.

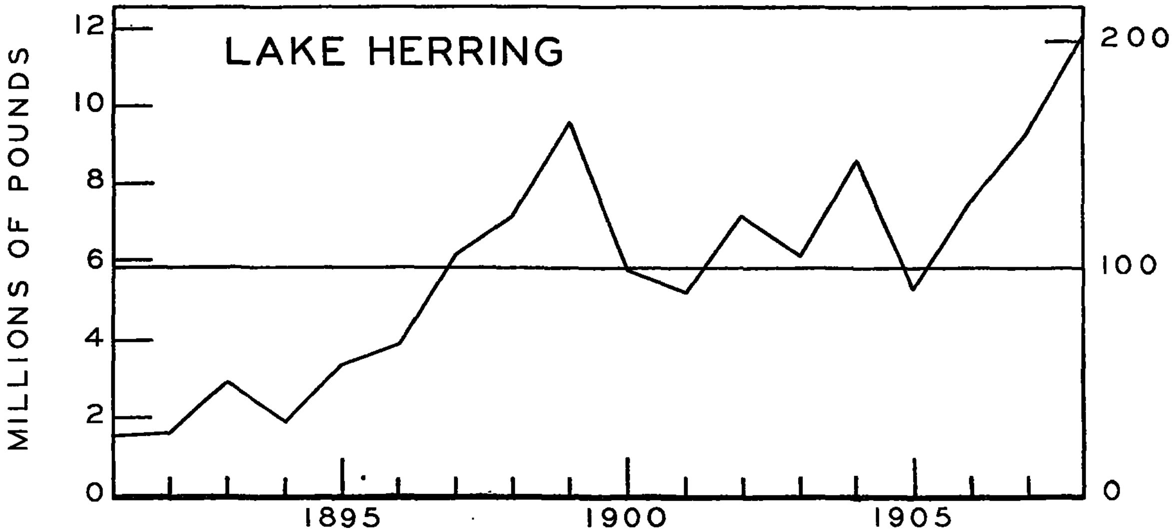

FIGURE 5.—Lake herring: Commercial production in State of Michigan waters of Green Bay, 1891–1908, in millions of pounds and as percentages of the 18-year mean.

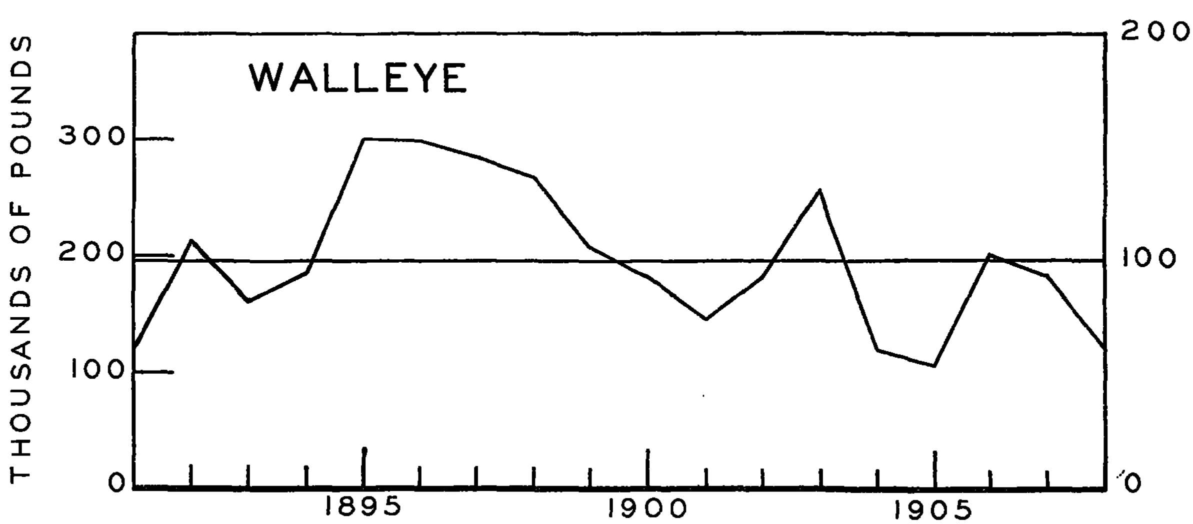

FIGURE 6.—Walleye: Commercial production in State of Michigan waters of Green Bay, 1891–1908, in thousands of pounds and as percentages of the 18-year mean.

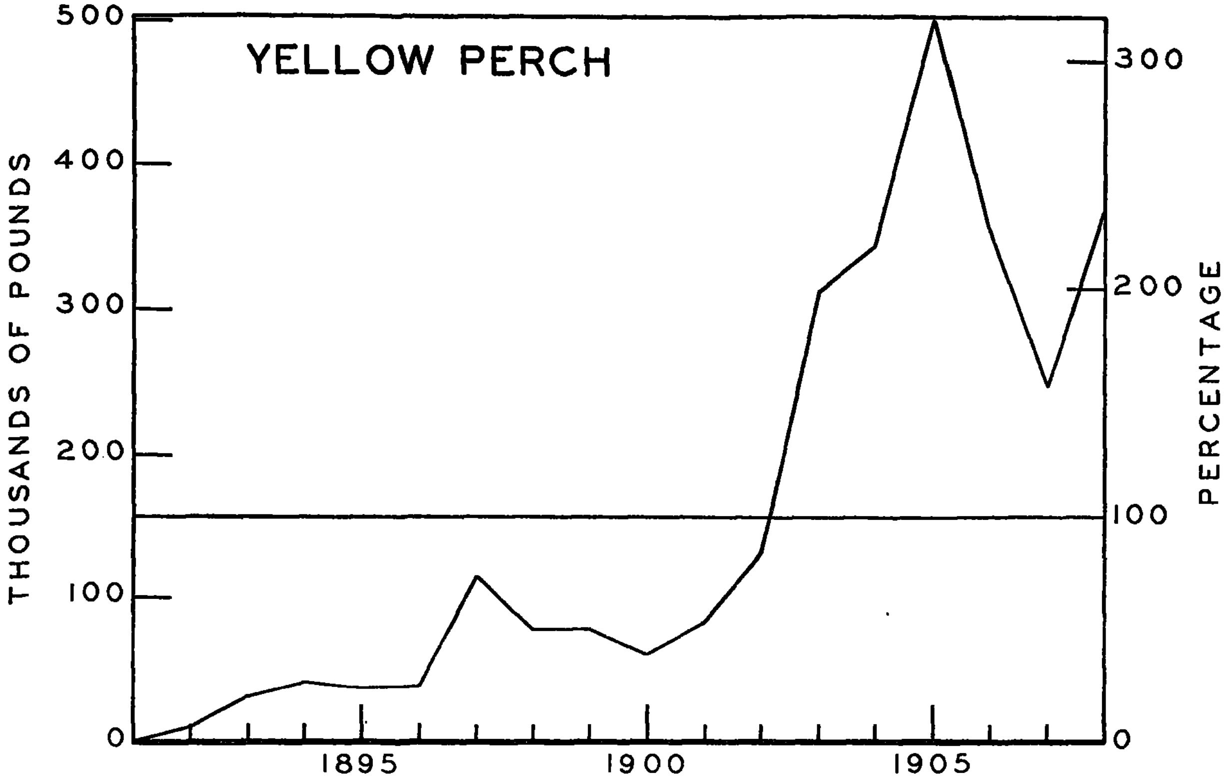

FIGURE 7.—Yellow perch: Commercial production in State of Michigan waters of Green Bay, 1891–1908, in thousands of pounds and as percentages of the 18-year mean.

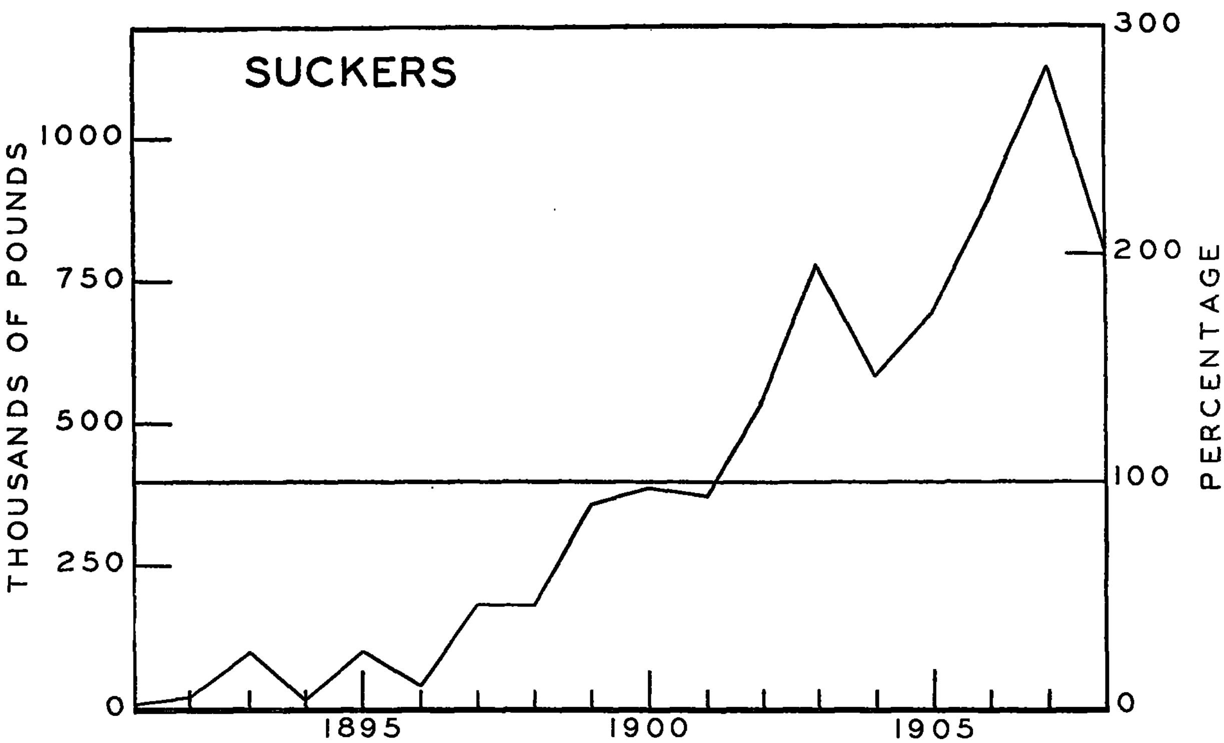

FIGURE 8.—Suckers (all species): Commercial production in State of Michigan waters of Green Bay, 1891–1908, in thousands of pounds and as percentages of the 18-year mean.

TABLE 4.—*Production in the commercial fisheries of Green Bay, by species, 1929–49*

[In thousands of pounds]

Year	Lake trout	Whitefish	Lake herring	Walleye	Yellow perch	White and redhorse suckers	Smelt	Others [1]	Total catch
1929	182	1,140	396	27	95	393	----------	86	2,319
1930	203	1,076	484	27	129	566	----------	163	2,648
1931	220	1,195	521	41	111	714	(2)	121	2,924
1932	194	910	170	85	130	858	23	119	2,489
1933	134	238	160	108	129	588	9	51	1,418
1934	72	263	16	108	172	763	17	73	2,384
1935	77	175	1,054	57	156	1,181	45	52	2,797
1936	158	90	1,271	74	142	982	114	56	2,888
1937	236	105	1,834	59	261	1,015	186	39	3,736
1938	248	354	1,552	38	361	718	672	61	4,004
1939	157	238	697	30	256	635	607	82	2,703
1940	83	123	668	28	170	719	2,392	26	4,209
1941	75	116	297	26	191	591	2,976	48	4,319
1942	56	93	285	16	203	665	2,212	44	3,574
1943	91	141	402	36	125	611	1,723	22	3,153
Mean, 1929–43	146	417	714	51	175	733	732	70	3,038
Percentage	4.8	13.7	23.5	1.7	5.8	24.1	24.1	2.3	----------
1944	47	232	419	43	49	564	(2)	25	1,379
1945	29	234	2,193	21	151	593	43	54	3,317
1946	11	514	2,367	72	116	505	66	41	3,692
1947	46	2,427	1,881	262	70	499	336	49	5,570
1948	178	3,066	2,668	572	66	634	626	99	7,909
1949	149	2,263	2,230	1,063	65	878	1,050	84	7,782
Mean, 1929–49	129	714	1,070	133	150	699	624	66	3,582
Percentage	3.5	19.9	29.9	3.7	4.2	19.5	17.4	1.9	----------

[1] Includes chubs, or ciscoes (*Coregonus* spp.), carp (*Cyprinus carpio*), round whitefish, burbot (*Lota lota*), bullheads, catfish, northern pike (*Esox lucius*), saugers, longnose suckers (*Catostomus catostomus*), sheepshead, or freshwater drum (*Aplodinotus grunniens*), white bass (*Morone chrysops*), rock bass (*Ambloplites rupestris*), bowfin (*Amia calva*), and garfish (probably *Lepisosteus osseus*).

[2] Less than 500 pounds.

TABLE 5.—*Percentage composition of the catch in the commercial fisheries of Green Bay, by species, 1929–49*

Year	Lake trout	Whitefish	Lake herring	Walleye	Yellow perch	White and redhorse suckers	Smelt	Others
1929	7.8	49.2	17.1	1.2	4.1	16.9	-------	3.7
1930	7.7	40.6	18.3	1.0	4.9	21.4	-------	6.1
1931	7.5	40.9	17.8	1.4	3.8	24.4	0.0	4.2
1932	7.8	36.6	6.8	3.4	5.2	34.5	.9	4.8
1933	9.5	16.8	11.3	7.6	9.1	41.5	.6	3.6
1934	3.0	11.1	38.4	4.5	7.2	32.0	.7	3.1
1935	2.7	6.3	37.7	2.0	5.6	42.2	1.6	1.9
1936	5.5	3.1	44.0	2.6	4.9	34.0	4.0	1.9
1937	6.3	2.8	49.1	1.6	7.0	27.2	5.0	1.0
1938	6.2	8.8	38.8	1.0	9.0	17.9	16.8	1.5
1939	5.8	8.8	25.8	1.1	9.5	23.5	22.5	3.0
1940	2.0	2.9	15.9	.7	4.0	17.1	56.8	.6
1941	1.7	2.7	6.9	.6	4.4	13.7	68.9	1.1
1942	1.6	2.6	8.0	.4	5.7	18.6	61.9	1.2
1943	2.9	4.5	12.8	1.1	4.0	19.4	54.6	.7
Mean, 1929–43	5.2	15.8	23.3	2.0	5.9	25.6	19.6	2.6
1944	3.4	16.8	30.4	3.1	3.6	40.9	0.0	1.8
1945	.9	7.1	66.1	.6	4.5	17.9	1.3	1.6
1946	.3	13.9	64.1	2.0	3.1	13.7	1.8	1.1
1947	.8	43.6	33.8	4.7	1.2	9.0	6.0	.9
1948	2.3	38.8	33.7	7.2	.8	8.0	7.9	1.3
1949	1.9	29.1	28.6	13.7	.8	11.3	13.5	1.1
Mean, 1929–49	4.2	18.4	28.8	2.9	4.9	23.1	15.5	2.2

Catch records for the principal species in the individual years reveal a wide range of fluctuation in the take of all species and a strong tendency toward cyclic fluctuations in some. The trends of production for the different kinds and for the total catch are summarized briefly in the paragraphs that follow.

Lake trout: After increasing from 182,000 pounds in 1929 to 220,000 pounds in 1931, the take declined to a low of 72,000 pounds in 1934, rose to a second peak of 248,000 pounds in 1938, declined again (except for an irregularity in 1943) to a minimum of 11,000 pounds in 1946, jumped to 178,000 pounds in 1948, and dropped to 149,000 pounds in 1949.[4] (See fig. 9.)

Whitefish: Production exceeded a million pounds in each of the 3 years 1929–31, but from the high figure of 1,195,000 pounds in 1931 decreased (with an irregularity in 1934) to the 21-year minimum of 90,000 pounds in 1936 (fig. 10). A recovery to the relatively low peak of 354,000 pounds in 1938 was followed by another decline to 93,000 pounds in 1942. Successive increases in each of the next 6 years carried the take to the all-time recorded high of 3,066,000 pounds in 1948. The catch dropped to 2,263,000 pounds in 1949.

[4] See Hile, Eschmeyer, and Lunger (1951a) for a discussion of the cause of the sharp recovery in the production of lake trout in 1948 and 1949.

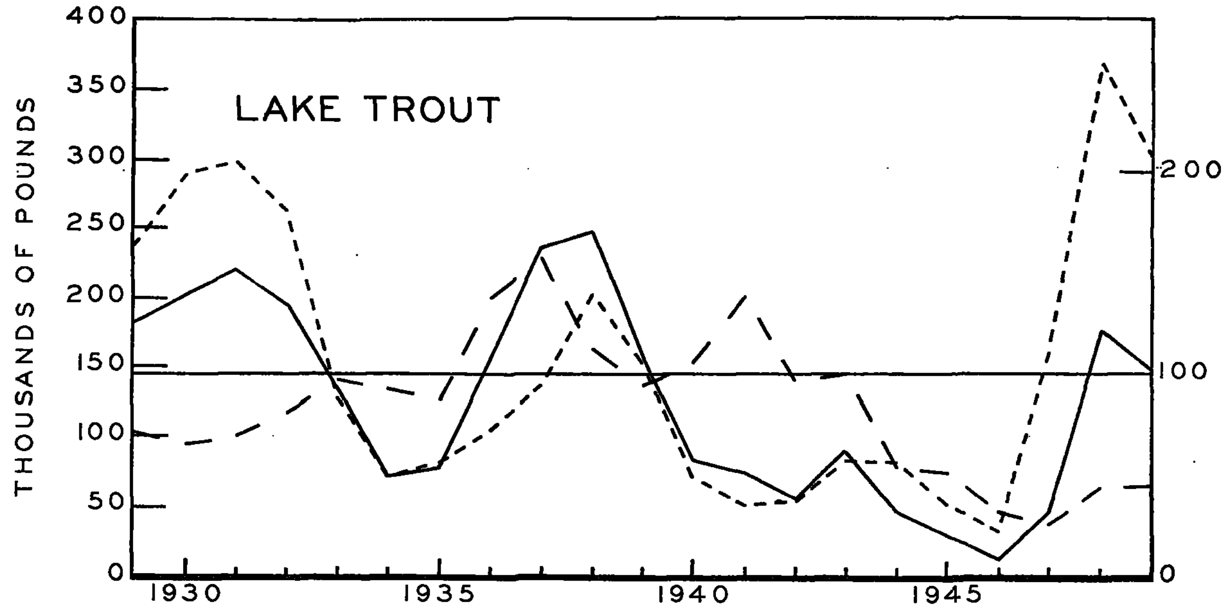

FIGURE 9.—Lake trout: Production (solid line), abundance (long dashes), and intensity of the fishery (short dashes) in State of Michigan waters of Green Bay, 1929–49, as percentages of the 1929–43 mean. Production is also given in pounds on scale at the left.

Lake herring: From a level of 396,000 pounds in 1929 the yield rose to 521,000 pounds in 1931, dropped to the 21-year minimum of 160,000 pounds in 1933, and then increased to 1,834,000 pounds in 1937 (fig. 11). A second decline, to a low of 285,000 pounds in 1942, was followed by yet another upward trend (interrupted by a decrease in 1947) which culminated in an output of 2,668,000 pounds, the 21-year maximum, in 1948. The 1949 yield was 2,230,000 pounds.

Walleye: The take rose from 27,000 pounds in 1929 and 1930 to 108,000 pounds in 1933 and 1934, and then declined irregularly to the minimum of 16,000 pounds in 1942 (fig. 12). Production continued to be relatively low during the next 3 years, but 1946 saw the start of an upswing that led to a record yield of 1,063,000 pounds in 1949.

Yellow perch: Production statistics for perch exhibit little indication of the cyclic fluctuations that characterized the lake trout, whitefish, lake herring, and to some extent, the walleye (fig. 13). Except for the high production of 1937–39 (catch more than 250,000 pounds in all 3 years and 361,000 pounds in 1938) and a tendency toward small yields in recent years (output below 100,000 pounds in 4 of the last 6 years and only 49,000 pounds in 1944) the fluctuations in the take of yellow perch can be described as erratic.

White and redhorse suckers: The catch of suckers, much like that of perch, varied erratically. (See fig. 14.) The principal features aside from this irregular fluctuation were the rise from the low catch of 393,000 pounds in 1929 to 714,000 pounds (near the mean level for 1929–43 and 1929–49) in 1931 and the high output in 1935–37 when the take was approximately a million pounds in three consecutive years.

Smelt: This introduced species (see Van Oosten 1937, for an account of its introduction and spread in the Great Lakes) first entered the commercial fishery in 1931 (less than 500 pounds caught). The take did not exceed 100,000 pounds until 1936 or 500,000 pounds until 1938 but large increases in 1940 and 1941 carried the output to nearly 3 million pounds in the latter year. From this 1941 peak the catch dropped to less than 500 pounds in 1944. The declines in 1943 and 1944 were the result of the 1943 epidemic that all but exterminated the stock (Van Oosten 1947). Production recovered slowly in the ensuing years and exceeded a million pounds in 1949.

Total production: The combined catch of all species (fig. 15) rose from 2,319,000 pounds in 1929 to 2,924,000 pounds in 1931, declined to 1,418,000 pounds in 1933 and then increased five consecutive years to 4,004,000 pounds in 1938. A drop to

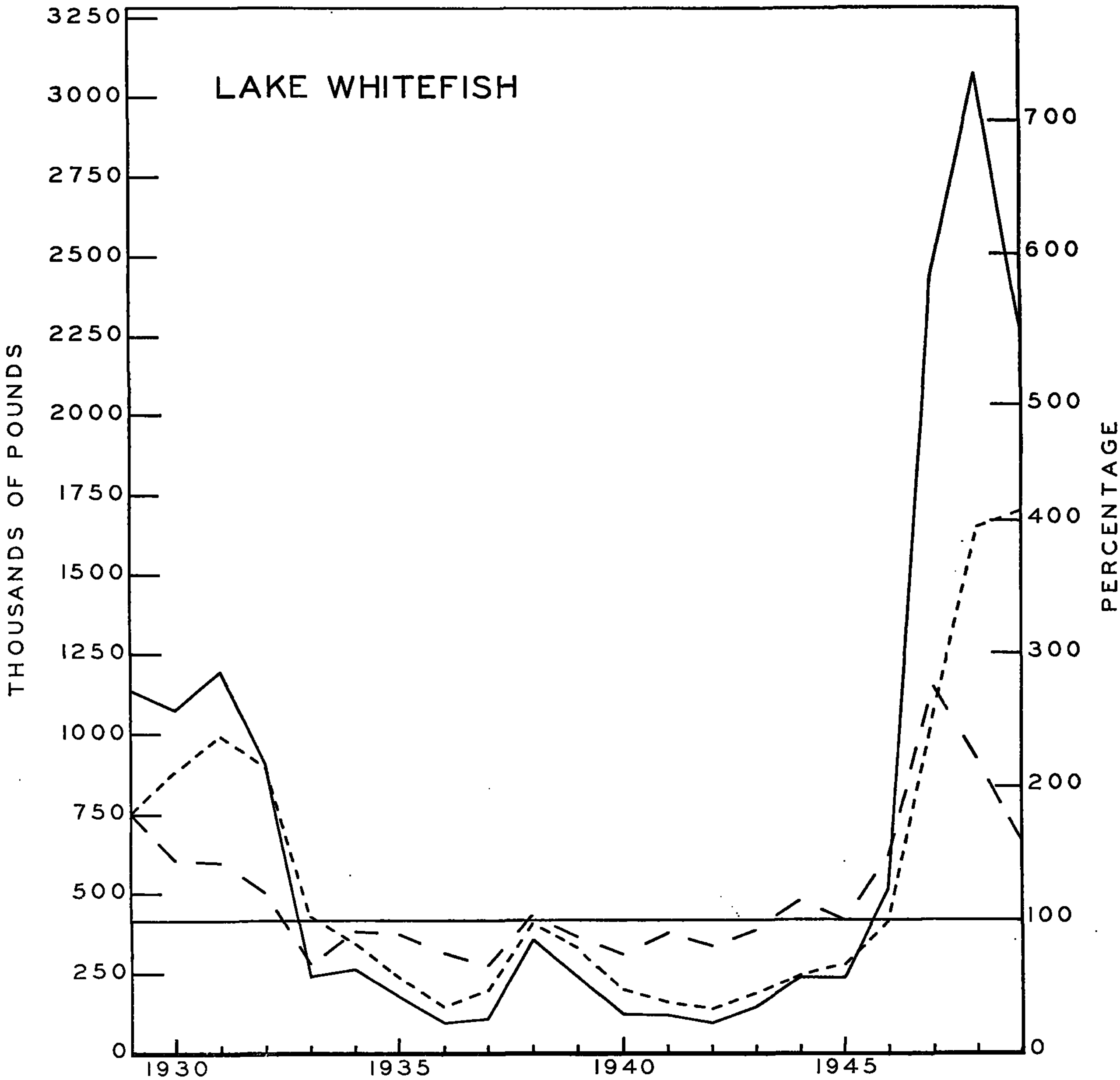

FIGURE 10.—Lake whitefish: Production (solid line), abundance (long dashes), and intensity of the fishery (short dashes) in State of Michigan waters of Green Bay, 1929–49, as percentages of the 1929–43 mean. Production is also given in pounds on scale at the left.

2,703,000 pounds in 1939 was followed by two more years in which the take exceeded 4 million pounds. From a peak of 4,319,000 pounds in 1941 the catch declined rapidly to the 21-year low of 1,379,000 pounds in 1944 only to rise in 4 years to the 21-year high of 7,909,000 pounds in 1948. The output was still high in 1949 (7,782,000 pounds).

The 1929–49 production statistics were characterized by the tendency for first one and then another of the four principal species of fish to dominate the catch. This dominance usually lasted 2 to 4 years. Whitefish, for example, contributed more than any other species to the catch during the 4 years, 1929–32, and the 3 years, 1947–49; the lake herring during the 4 years, 1936–39, and the 2 years, 1945–46; and the smelt during the 4 years, 1940–43. The only examples of dominance for a single year were provided by the lake

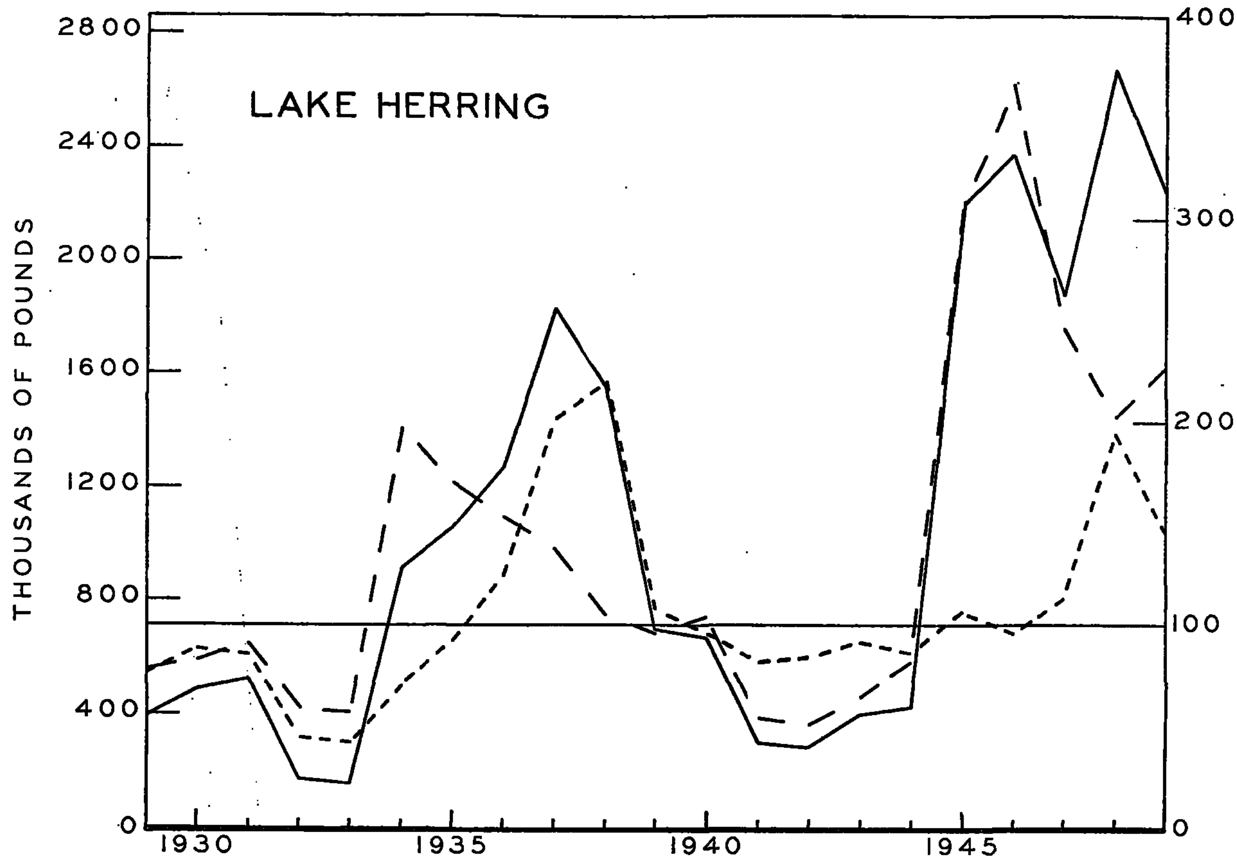

FIGURE 11.—Lake herring: Production (solid line), abundance (long dashes), and intensity of the fishery (short dashes) in State of Michigan waters of Green Bay, 1929–49, as percentages of the 1929–43 mean. Production is also given in pounds on scale at the left.

herring in 1934 and by the suckers in 1933, 1935, and 1944. These shifts of dominance were accompanied by relatively wide ranges in the percentage contribution of whitefish, lake herring, and smelt and can be related to the fluctuations of production described earlier. (It is to be noted that suckers, which exhibited no periodicity in production but rather showed erratic variations, failed to dominate the catch in consecutive years.)

Comparisons of production data for 1891–1908 and 1929–49 (tables 2, 4, and 6) reveal a much lower level of total yield in the latter period. The average annual output of 3,582,000 pounds for all species combined in 1929–49 was 3,503,000 pounds less than the 1891–1908 mean of 7,085,000 pounds—a decrease of 49.4 percent. Examination of the statistics for individual species shows that the decline in the production of lake herring alone more than accounted for this decrease. The catch of this species fell from 5,841,000 pounds in 1891–1908 to 1,070,000 pounds in 1929–49—a drop of 4,771,000 pounds, or 81.7 percent. For species other than lake herring the combined yield increased from 1,244,000 pounds in 1891–1908 to 2,512,000 pounds in 1929–49—an increase of 1,268,000 pounds, or 102.9 percent. Even if we exclude the smelt, an exotic variety not present in 1891–1908, the 1929–49 catch of fish other than lake herring was 52.5 percent greater than that of the earlier period. The greatest increase of production, aside from the introduced smelt, was that of whitefish (from 159,000 pounds in 1891–1908 to 714,000 pounds in 1929–49—a rise of 555,000 pounds, or 349.1 percent). The increase was large also for suckers (398,000 pounds in 1891–1908 and 699,000 pounds in 1929–49—a rise of 301,000 pounds, or 75.6 percent). These increases more than compensated the declines in the output of the remaining species (herring excluded) which were all less than 100,000 pounds (largest drop, lake

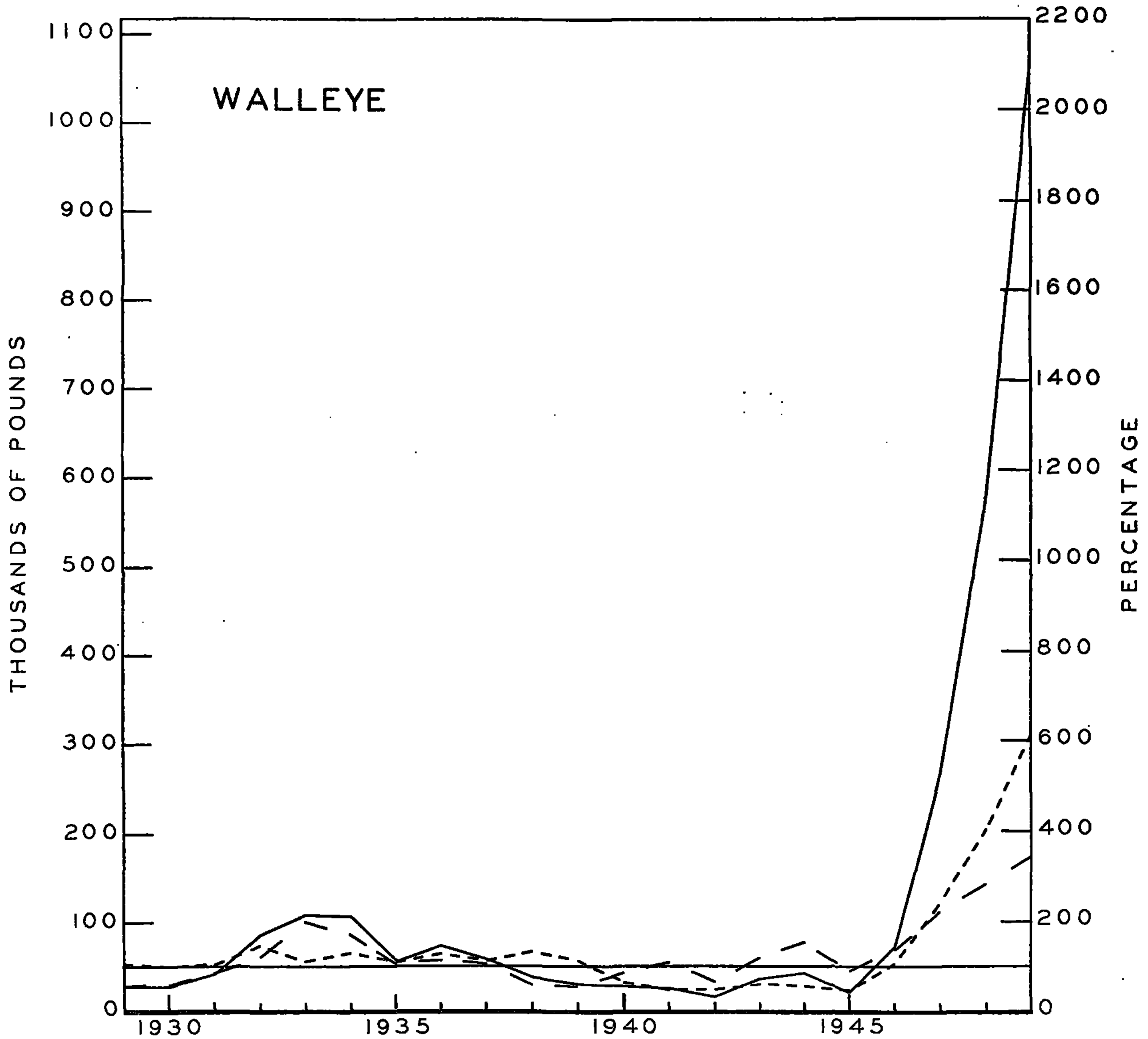

FIGURE 12.—Walleye: Production (solid line), abundance (long dashes), and intensity of the fishery (short dashes) in State of Michigan waters of Green Bay, 1929–49, as percentages of the 1929–43 mean. Production is also given in pounds on scale at the left.

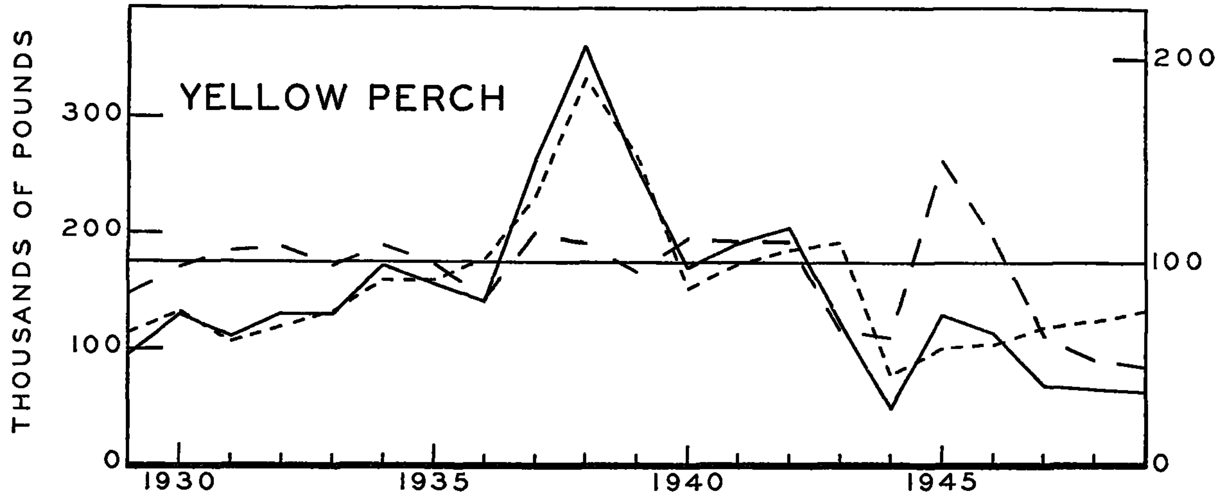

FIGURE 13.—Yellow perch: Production (solid line), abundance (long dashes), and intensity of the fishery (short dashes) in State of Michigan waters of Green Bay, 1929–49, as percentages of the 1929–43 mean. Production is also given in pounds on scale at the left.

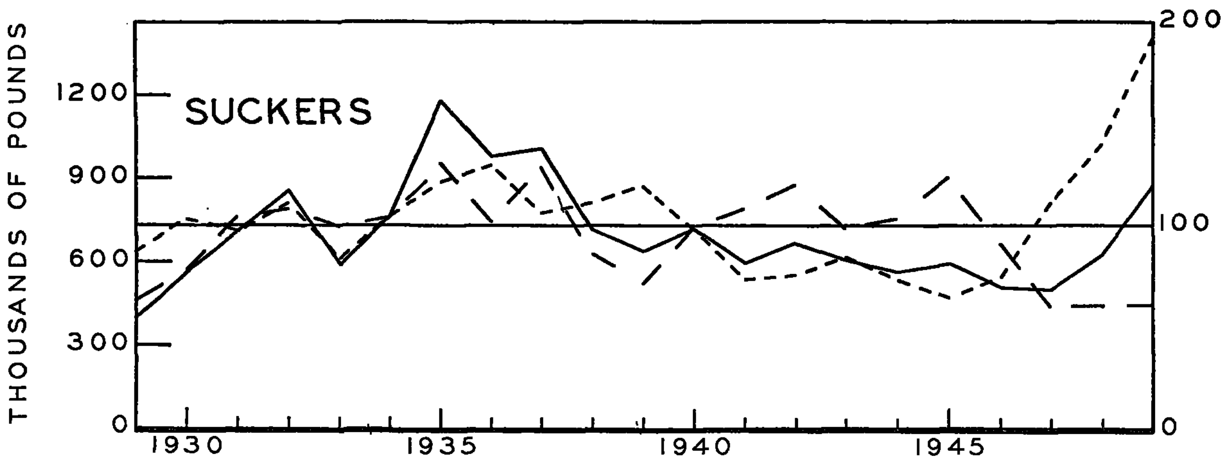

FIGURE 14.—White and redhorse suckers: Production (solid line), abundance (long dashes), and intensity of the fishery (short dashes) in State of Michigan waters of Green Bay, 1929–49, as percentages of the 1929–43 mean. Production is also given in pounds on scale at the left.

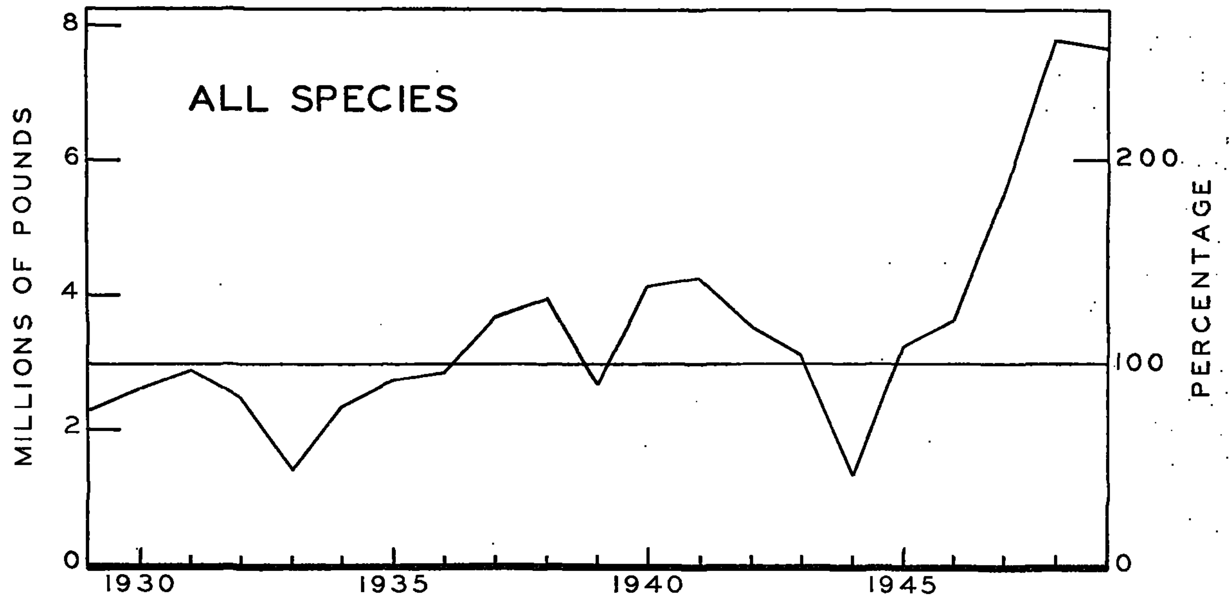

FIGURE 15.—All species: Commercial production in State of Michigan waters of Green Bay, 1929–49, in millions of pounds and as percentages of the 1929–43 mean.

trout—87,000 pounds), and except for the sturgeon[5] did not exceed 40.8 percent (the figure for the lake trout).

TABLE 6.—*Comparison of production in the commercial fisheries of Green Bay, by species, 1891–1908 and 1929–49*

Species	Production in 1891–1908		Production in 1929–49		Change from 1891–1908 to 1929–49		
	Thousands of pounds	Percentage of total	Thousands of pounds	Percentage of total	Thousands of pounds	Percentage of total	Percentage change in production
Lake trout	213	3.0	126	3.5	−87	0.5	−40.8
Whitefish	159	2.3	714	19.9	555	17.6	349.1
Lake herring	5,841	82.4	1,070	29.9	−4,771	−52.5	−81.7
Walleye	197	2.8	133	3.7	−64	.9	−32.5
Yellow perch	157	2.2	150	4.2	−7	2.0	−4.5
Suckers [1]	398	5.6	699	19.5	301	13.9	75.6
Smelt			624	17.4	624	17.4	
Lake sturgeon	22	.3			−22	−.3	
Others [2]	98	1.4	66	1.9	−32	.5	−32.7
All	7,085	100	3,582	100	−3,503	100	−49.4
All, except herring	1,244	17.6	2,512	70.1	1,268	52.5	102.9

[1] All suckers in 1891–1908; white and redhorse suckers in 1929–49.
[2] See tables 2 and 4 for list of species included.

The changes from 1891–1908 to 1929–49 in total production, in the take of the individual species, and in the species composition of the catch offer wide fields for speculation but the theories that can be advanced in explanation of these changes are mostly without supporting evidence. The shifts in production—increases of yield for some species and decreases for others—give prima facie evidence of changes in the conditions affecting the population as a whole, but we have little knowledge of the mechanisms whereby these changes came about. Fishing surely played an important role; however, it must have placed different degrees of pressure on different species and in turn the several species must have exhibited varying degrees of resistance to fishing pressure. Similarly, the effects of physical-chemical changes brought about by sawdust, bark, and other debris from the earlier lumbering period, by the varied industrial waste of the present era, by the fertilizing action of domestic sewage and of drainage from agricultural lands must have been significant and must have varied with the species of fish.

The differences from species to species in the direction of change in production from 1891–1908 to 1929–49 make any attempt to appraise the effects of fishing on the stocks especially difficult. Statistics on lake herring and whitefish illustrate the nature of the problem. It is inviting, for example, to explain the enormous drop in the production of lake herring from nearly 6 million pounds to barely 1 million pounds as depletion resulting from overexploitation. If this explanation is accepted, however, we are confronted at once with the problem

[5] The taking of sturgeon became illegal in 1929.

of accounting for the simultaneous increase (from 159,000 pounds to 714,000 pounds) in the average annual take of whitefish—a species much higher priced than the lake herring, always in market demand, and continually subject to intensive fishing.

Seemingly paradoxical situations such as the one just described become less perplexing if we admit the concept that in mixed stocks of the type found in Green Bay and other shallow-water areas of the Great Lakes (that is, stocks in which several species not closely related and of different habits are present in number) the effects of fishing should be considered in terms of the entire population rather than individual species, and recognize that a major effect of fishing lies in the disturbance of ecological relations among the fishes. Thus, fishing pressure to which the species are subject in common may give one a competitive advantage and place another at a disadvantage. Differences of fecundity, growth, and longevity, . . . that lead to a particular species composition at one level of fishing intensity may bring about a greatly different composition at another. Changes of this origin can be accentuated if fishing pressures, relative to the actual stock, differ from species to species. Furthermore, the generally lower level of commercial production in the modern period suggests the possibility that fishing pressure on commercially exploited species may have operated so much to the advantage of the smaller, noncommercial species that the latter now make up an increased percentage of the total biological production.

SEASONAL TRENDS OF PRODUCTION AND COMPOSITION OF THE CATCH ACCORDING TO GEAR

The statistics on seasonal trends of production (tables 7 and 8) and on the gear composition of the catch (table 9) of the principal species in State of Michigan waters of Green Bay were based on the records for 1929–49. The presentation of these data for the 1929–43 base period would be little to the point since we are concerned here with average conditions and not with trends of annual fluctuation about a norm. Seasonal trends and gear composition both varied considerably from year to year, but the expansion of the tabular material to show these variations is not justified.

SEASONAL DISTRIBUTION OF THE CATCH

The data on monthly and quarterly trends of production for five of the seven species listed in tables 7 and 8 were affected materially by closed seasons. These seasons as presently defined by

TABLE 7.—*Percentage distribution, by month and quarter, of the average annual catch of the principal species of fish in Green Bay, 1929–49*

Period of time	Lake trout	Whitefish	Lake herring	Walleye	Yellow perch	White and redhorse suckers	Smelt
Month:							
Jan.	3.6	5.6	5.3	6.4	6.8	11.9	12.0
Feb.	4.1	6.2	11.5	3.9	4.6	7.9	33.2
Mar.	6.1	4.1	8.4	6.2	3.5	10.1	46.2
Apr.	26.2	8.4	.4	.3	2.8	11.7	6.7
May	16.5	16.4	3.9	14.6	2.3	11.9	.2
June	7.3	12.0	12.3	19.7	3.3	9.9	.4
July	5.7	6.3	6.5	5.7	3.3	6.8	.2
Aug.	9.8	5.1	2.5	5.5	5.4	5.7	.1
Sept.	8.7	8.8	1.8	12.1	11.1	7.0	.2
Oct.	5.6	14.9	7.7	13.4	22.1	5.0	.2
Nov.	4.2	5.3	29.9	6.4	20.1	3.2	.3
Dec.	2.2	6.9	9.8	5.8	14.7	8.9	.3
Quarter:							
First	13.8	15.9	25.2	16.5	14.9	29.9	91.4
Second	50.0	36.8	16.6	34.6	8.4	33.5	7.3
Third	24.2	20.2	10.8	23.3	19.8	19.5	.5
Fourth	12.0	27.1	47.4	25.6	56.9	17.1	.8

TABLE 8.—*Distribution, by month and quarter, of the average catch of the principal species of fish in Green Bay, 1929–49*

[In thousands of pounds]

Period of time	Lake trout	Whitefish	Lake herring	Walleye	Yellow perch	White and redhorse suckers	Smelt
Month:							
Jan.	4.5	40.0	56.9	8.5	10.3	83.4	74.7
Feb.	5.2	44.2	123.4	5.2	6.8	55.5	207.3
Mar.	7.7	29.4	89.2	8.2	5.2	70.2	288.1
Apr.	33.0	59.7	4.7	.4	4.2	81.9	41.9
May	20.8	116.9	41.8	19.5	3.5	83.1	1.0
June	9.2	85.9	131.5	26.2	4.9	69.2	2.3
July	7.2	45.4	69.7	7.6	4.9	47.5	1.3
Aug.	12.4	36.4	26.2	7.3	8.1	39.8	.9
Sept.	11.0	62.6	18.9	16.1	16.7	48.9	1.3
Oct.	7.1	106.2	82.8	17.9	33.2	34.6	1.2
Nov.	5.2	37.9	319.7	8.5	30.1	22.6	1.6
Dec.	2.7	49.3	105.1	7.7	22.0	61.9	2.1
Quarter:							
First	17.3	113.6	269.5	21.8	22.3	209.1	570.1
Second	63.0	262.5	178.0	46.0	12.6	234.3	45.3
Third	30.6	144.4	114.8	31.1	29.7	136.2	3.6
Fourth	15.1	193.3	507.5	34.1	85.3	119.1	4.9
Total	126.0	713.9	1,069.8	133.0	149.9	698.7	623.7

Michigan State law [6] are as follows (seasons open and close at noon on the dates indicated): Lake trout, October 10–November 10; whitefish, November 5–December 10; walleye, April 1–May 20;

[6] Some adjustments have been made in the closed seasons since 1928, but a detailed account of these changes does not seem desirable.

yellow perch, April 15–May 20; suckers, April 15–May 15. The depressing effects of these closed seasons is especially strong because they cover approximately the spawning periods of the several species and prevent capture of the fish at a time when they are particularly easy to take. Lake herring and smelt are not subject to a closed season in State of Michigan waters of the Great Lakes.

TABLE 9.—*Average annual production and composition of the catch, by gear, of the principal species of fish in Green Bay, 1929–49*

[In thousands of pounds]

Species	Gill nets [1]			Pound nets	Shallow trap nets	Fyke and hoop nets	Set hooks	Other [2]	Tota
	Bait	Small-mesh	Large mesh						
Lake trout:									
Production	----------	0.1	104.4	7.1	0.1	[3] 0	11.5	2.8	126.0
Percentage	----------	.1	82.9	5.6	.1	[4] 0	9.1	2.2	----------
Whitefish:									
Production	----------	0	438.7	245.1	4.1	1.0	----------	25.0	713.9
Percentage	----------	0	61.5	34.3	.6	.1	----------	3.5	----------
Lake herring:									
Production	0.3	516.3	3.3	534.1	10.3	3.8	----------	1.7	1,069.8
Percentage	[4] 0	48.2	.3	49.9	1.0	.4	----------	.2	----------
Walleye:									
Production	----------	.2	32.7	25.3	49.1	23.9	[3] 0	1.9	133.0
Percentage	----------	.1	24.6	19.0	36.9	18.0	[4] 0	1.4	----------
Yellow perch:									
Production	[3] 0	92.1	.2	4.2	32.5	20.0	.2	.7	149.9
Percentage	[4] 0	61.5	.1	2.8	21.7	13.3	.1	.5	----------
White and redhorse suckers:									
Production	[3] 0	1.2	151.9	64.1	394.0	80.8	----------	6.6	698.7
Percentage	[4] 0	----------	21.7	9.2	56.4	11.6	----------	.9	----------
Smelt:									
Production	100	6.9	3.4	503.1	.3	5.1	----------	4.4	623.7
Percentage	16.1	1.1	.6	80.7	[4] 0	.8	----------	.7	----------

[1] Mesh sizes, extension measure: Bait nets, mostly 1½–1⅝ inches; small-mesh nets, 2¼–2¾ inches; large-mesh nets, 4½ inches and larger.
[2] Includes catches by deep trap nets (not fished after 1935), dip nets, hand lines, and trolling; also catches for which records of gear were lacking (no catches in this category after 1937).
[3] Less than 50 pounds.
[4] Less than 0.05 percent.

Inasmuch as seasonal trends are of principal interest in this section (actual production of the important species was discussed in the preceding section), the following brief comments on the monthly and quarterly distribution of the catch are based on the percentages of table 7.

Lake trout: The contribution to the average annual total exceeded 10 percent in only 2 months—April (26.2 percent) and May (16.5 percent). The percentages were less than 5.0 during January and February and November and December and ranged from 5.6 to 9.8 in the remaining months. The figures by quarters show that half (50.0 percent) of the annual production took place in the spring[7] and a little less than a fourth (24.2 percent) in the summer. Production was lowest in the first (13.8 percent) and fourth (12.0 percent) quarters.

Whitefish: The monthly and quarterly distributions of the catch were more nearly even in the whitefish than in the lake trout. The maximum percentage for any single month was 16.4 (May) and in only one month did the percentage fall below 5 (4.1 in March). The spring quarter was the most productive (36.8 percent) and the winter quarter the poorest (15.9 percent). Values for the third (20.2 percent) and fourth (27.1 percent) quarters did not deviate greatly from the expected figure of 25.

Lake herring: The percentage for November (29.9), the month in which much of the spawning occurs, was far greater than that for any other month. Among the remaining 11 months the percentage exceeded 10 in only 2 (12.3 in June and 11.5 in February), and fell below 5 in 4 (lowest value, 0.4 in April). The most productive quarter by far was the fourth (47.4 percent) and the poorest was the third (10.8 percent).

Walleye: The most productive months were June (19.7 percent) and May (14.6 percent), with October (13.4 percent) and September (12.1 percent) not far behind. If April, which in recent years has been completely closed to walleye fishing, is excluded the figures for the remaining months range from 6.4 percent in January and November to 3.9 percent in February. The best quarter was the second (34.6 percent) and the least

[7] In this section, winter, spring, summer, and autumn are treated as synonymous with the first, second, third, and fourth quarters.

productive was the first (16.5 percent). The percentages for both the summer (23.3) and autumn (25.6) quarters were near the 25-percent level.

Yellow perch: The three most productive months (October, 22.1 percent; November, 20.1 percent; December, 14.7 percent) fell in the autumn. Production was good in September also (11.1 percent), but in the remaining months the percentage did not exceed 6.8 (the figure for January) and was as low as 2.3 (May). More than half (56.9 percent) of the average annual total was produced in the fourth quarter and more than three-fourths (76.7 percent) in the second half of the year. The winter (14.9 percent) and spring (8.4 percent) quarters together accounted for less than a fourth (23.3 percent) of the annual take.

White and redhorse suckers: With the exception of November which contributed only 3.2 percent of the average annual total, the percentages for the individual months did not fall below 5.0 (the figure for October) or exceed 11.9 (the value for January and May). Most productive quarters were the second (33.5 percent) and first (29.9 percent), but contributions of the summer and autumn quarters (19.5 and 17.1 percent, respectively) were nevertheless substantial.

Smelt: The major production of smelt comes from the winter ice fishing. March alone accounted for 46.8 percent of the 1929–49 commercial take, and February for almost a third (33.2 percent). The combined percentage for the three winter months was 91.4. The percentage was 6.7 for April but in none of the remaining 8 months did the value exceed 0.4 (the figure for June).

Actually, large catches of smelt dipped from tributary streams during the spawning period (mostly in April) and not recorded in fishing reports find their way into commercial channels. No exact measure of the quantities of smelt taken during the spawning run is available but a good idea of the magnitude of the catch is provided by the estimate of the Michigan Department of Conservation that dippers took more than 5½ million pounds from State of Michigan waters in 1942 (Van Oosten 1947). A large portion of this catch was taken in the Green Bay area, which is the center of greatest abundance of smelt. By no means all of the smelt captured by dippers are sold. Much of the catch is consumed by the dippers, their families, and friends and a certain amount is wasted, but enough is sold to bring about a complete collapse of the market in years of high abundance.

GEAR COMPOSITION OF THE CATCH

The data of table 9 on the composition of the catch of the important species according to gear bring out two major points: All species were produced in quantity by more than one kind of gear, and most of the principal gears produced significant amounts of more than one species of fish.

For the different species the most important gears and the percentage contribution of each to the average annual total for the species were as follows (no percentages less than 5.0 listed):

Lake trout: Large-mesh[8] gill nets, 82.9; set hooks, 9.1; pound nets, 5.6.

Whitefish: Large-mesh gill nets, 61.5; pound nets, 34.3.

Lake herring: Small-mesh gill nets, 48.2; pound nets, 49.9.

Walleye:[9] Shallow trap nets, 36.9; large-mesh gill nets, 24.6; pound nets, 19.0; fyke and hoop nets, 18.0.

Yellow perch: Small-mesh gill nets, 61.5; shallow trap nets, 21.7; fyke and hoop nets, 13.3.

White and redhorse suckers: Shallow trap nets, 56.4; large-mesh gill nets, 21.7; fyke and hoop nets, 11.6; pound nets, 9.2.

Smelt: Pound nets, 80.7; bait nets,[10] 16.1.

Average annual production of important species in thousands of pounds by the principal gears was as follows (except for fyke nets and set hooks no catches less than 25.0 listed):

Bait nets: Smelt, 100.6.

Small-mesh gill nets: Lake herring, 516.3; yellow perch, 92.1.

Large-mesh gill nets: Whitefish, 438.7; suckers, 151.9; lake trout, 104.4; walleye, 32.7.

Pound nets: Lake herring, 534.1; smelt, 503.1; whitefish, 245.1; suckers, 64.1; walleye, 25.3.

Shallow trap nets: Suckers, 394.0; walleye, 49.1; yellow perch, 32.5.

Fyke and hoop nets: Suckers, 80.8; walleye, 23.9; yellow perch, 20.0.

Set hooks: Lake trout, 11.5.

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[8] See footnote 1 to table 9 for statement of mesh sizes for the different types of gill nets.

[9] The sudden rise in production of walleyes to unprecedentedly high levels in recent years was accompanied by a pronounced shift in gear composition of the catch as the following percentages for the 1929–43 base period prove: Fyke and hoop nets, 50.2; pound nets, 24.9; shallow trap nets, 20.2; large-mesh gill nets, 3.6.

[10] The term "bait net" derives from the traditional use of the gear for the capture of small chubs and lake herring as bait for set hooks fished for lake trout.

FLUCTUATIONS IN ABUNDANCE OF THE PRINCIPAL SPECIES OF GREEN BAY, 1929–49

The abundance, or availability, indices [11] of table 10 were derived from the records of catch per unit of effort of tables 11 to 16 by methods described in publications listed in the introduction of this paper (Hile, 1937, gave an example of the actual computations). Information on the catch per unit of effort is given for smelt in table 17, but no attempt has been made to compute abundance percentages for the species. The comparatively recent development of the smelt fishery and the disruption occasioned by the 1943 mortality have prevented the establishment of satisfactory norms.

TABLE 10.—*Abundance indices of six commercially important fish in Green Bay, 1929–49*

[Expressed as percentages of the 1929–43 mean]

Year	Lake trout	White-fish	Lake herring	Walleye	Yellow perch	White and red-horse suckers
1929	71	180	78	54	84	63
1930	65	145	83	57	97	78
1931	69	143	91	83	105	104
1932	80	120	58	121	107	108
1933	97	66	57	198	98	99
1934	92	91	197	171	108	104
1935	87	89	170	106	99	131
1936	137	75	153	115	82	102
1937	157	65	138	105	114	129
1938	112	104	105	57	109	86
1939	94	86	96	54	98	71
1940	105	74	104	86	112	99
1941	138	90	54	108	110	108
1942	96	80	51	66	110	120
1943	100	92	65	119	67	98
1944	53	114	82	152	63	103
1945	51	100	306	89	150	124
1946	32	148	367	136	112	91
1947	26	275	247	[1] 220	64	60
1948	44	221	203	[1] 282	53	61
1949	45	158	228	[1] 344	49	61

[1] Probably too high; see text, p. 22.

[11] In using the terms "abundance" and "availability" interchangeably in references to our indices we follow Hile, Eschmeyer, and Lunger (1951a), rather than Marr (1951), when they stated:

Arguments about which of the two words should be employed would constitute a futile quibbling over terminology. These estimates are based on the fishing experience of the fishermen—the records of their catch of legal-sized lake trout per standard unit of fishing effort. They offer no information on the abundance of undersized lake trout and are affected by such factors as meteorological conditions, annual differences in the time of spawning in relation to the fixed closed season, and annual differences in the distribution of fish. Yet, for all these obvious weaknesses they offer the best estimates of abundance to be had at the present time. Accordingly, we do not hesitate to use "availability" and "abundance" interchangeably.

TABLE 11.—*Catch, in pounds, of lake trout per unit of effort in Green Bay, by gear, 1929–49*

[Per lift of 10,000 linear feet of large-mesh gill nets, of one pound net, and of 1,000 set hooks]

Year	Large-mesh gill nets	Pound nets	Set hooks
1929	66	14	223
1930	57	15	253
1931	63	13	201
1932	78	18	151
1933	106	16	197
1934	73	29	247
1935	79	23	237
1936	168	8	165
1937	189	13	154
1938	121	16	129
1939	96	12	138
1940	118	8	129
1941	134	13	----------
1942	91	----------	102
1943	94	2	----------
Mean, 1929–43	102	[1] 14	[1] 184
1944	50	4	----------
1945	48	----------	----------
1946	30	----------	----------
1947	24	9	----------
1948	42	8	----------
1949	44	5	----------

[1] When data were lacking for one or more years the 15-year average was estimated by dividing the mean of the available annual averages by the mean of the abundance percentages for the same years. See Van Oosten, Hile, and Jobes (1946) for comments on the estimation of a normal catch when data are not available for all years.

TABLE 12.—*Catch, in pounds, of whitefish per unit of effort in Green Bay, by gear, 1929–49*

[Per lift of 10,000 linear feet of large-mesh gill nets, of one pound net, and of one deep trap net]

Year	Large-mesh gill nets	Pound nets	Deep trap nets [1]
1929	183	113	----------
1930	150	89	132
1931	• 131	104	100
1932	116	74	118
1933	71	41	55
1934	100	56	75
1935	105	42	91
1936	77	48	----------
1937	72	38	----------
1938	120	54	----------
1939	74	63	----------
1940	83	44	----------
1941	125	39	----------
1942	92	39	----------
1943	102	43	----------
Mean, 1929–43	107	59	[2] 87
1944	123	60	----------
1945	110	52	----------
1946	158	84	----------
1947	280	170	----------
1948	208	171	----------
1949	156	106	----------

[1] Became illegal during the 1935 season.
[2] Estimated. See footnote 1, table 11.

TABLE 13.—*Catch, in pounds, of lake herring per unit of effort in Green Bay, by gear, 1929–49*

[Per lift of 10,000 linear feet of small-mesh gill nets and of one pound net]

Year	Small-mesh gill nets [1]	Pound nets
1929	614	88
1930	632	92
1931	622	113
1932	483	59
1933	507	54
1934	1,312	259
1935	1,241	208
1936	1,118	185
1937	926	205
1938	723	150
1939	651	143
1940	838	86
1941	437	26
1942	479	26
1943	343	146
Mean, 1929–43	728	123
1944	349	123
1945	154	498
1946	378	591
1947	1,526	329
1948	1,865	183
1949	2,062	195

[1] About 2¼ to 2¾ inches, extension measure.

TABLE 14.—*Catch, in pounds, of walleye per unit of effort in Green Bay, by gear, 1929–49*

[Per lift of one pound net, of one shallow trap net, and of one fyke net]

Year	Pound nets	Shallow trap nets	Fyke nets
1929	11	4	15
1930	7	5	20
1931	11	10	27
1932	20	10	37
1933	33	19	57
1934	32	9	59
1935	35	5	31
1936	62	7	23
1937	20	10	30
1938	8	4	20
1939	8	2	23
1940	10	8	28
1941	9	11	32
1942	9	4	23
1943	11	7	54
Mean, 1929–43	19	8	32
1944	13	13	58
1945	6	17	20
1946	8	21	23
1947	17	30	48
1948	28	40	66
1949	27	56	57

TABLE 15.—*Catch, in pounds, of yellow perch per unit of effort in Green Bay, by gear, 1929–49*

[Per lift of 10,000 linear feet of small-mesh gill nets, of one shallow trap net, and of one fyke net]

Year	Small-mesh gill nets	Shallow trap nets	Fyke nets
1929	262	6	18
1930	273	8	17
1931	239	20	17
1932	233	21	17
1933	212	18	14
1934	241	17	22
1935	298	13	16
1936	205	12	13
1937	309	17	16
1938	306	12	17
1939	308	8	16
1940	378	7	18
1941	302	11	14
1942	281	14	19
1943	170	7	17
Mean, 1929–43	268	13	17
1944	191	5	7
1945	404	6	22
1946	339	4	17
1947	198	5	11
1948	186	4	17
1949	185	4	8

TABLE 16.—*Catch, in pounds, of white and redhorse suckers per unit of effort in Green Bay, by gear, 1929–49*

[Per lift of 10,000 linear feet of large-mesh gill nets, of one pound net, of one shallow trap net, and of one fyke net]

Year	Large-mesh gill nets	Pound nets	Shallow trap nets	Fyke nets
1929	102	45	59	46
1930	156	51	63	54
1931	167	68	108	55
1932	232	61	96	61
1933	251	80	69	65
1934	434	46	68	96
1935	431	63	117	62
1936	420	43	85	49
1937	723	47	98	73
1938	365	36	73	44
1939	338	36	56	40
1940	398	31	83	61
1941	504	16	86	75
1942	400	7	110	81
1943	404	28	74	149
Mean, 1929–43	355	44	83	67
1944	387	35	73	116
1945	378	27	104	95
1946	175	36	86	91
1947	140	30	51	71
1948	159	28	50	71
1949	170	17	55	59

TABLE 17.—*Catch, in pounds, of smelt per unit of effort in Green Bay, by gear, in each of the months, January to April, 1938–49*

[Per lift of 1,000 linear feet of small-mesh gill nets (bait nets) and of one pound net]

Year	Small-mesh gill nets [1]				Pound nets			
	Jan.	Feb.	Mar.	Apr.	Jan.	Feb.	Mar.	Apr.
1938	67	68	117	214	233	175	182	------
1939	50	76	128	223	267	207	474	1,173
1940	45	60	74	110	347	365	544	1,252
1941	68	59	95	233	353	378	472	391
1942	------	57	88	------	225	313	447	869
1943	67	62	37	------	374	211	34	------
1944	------	------	------	------	------	------	------	------
1945	------	------	------	------	13	23	50	68
1946	29	43	58	------	6	20	43	40
1947	------	37	56	204	83	66	104	659
1948	43	39	48	158	139	114	102	594
1949	28	54	52	125	157	182	347	1,129

[1] Mesh sizes mostly 1½ to 1⅝ inches, extension measure.

Comparison of the annual fluctuations in the catch of a particular species per unit effort of different gears reveals that major improvements or declines in the success of fishing commonly were shared by the principal types of nets [12] but that certain discrepancies occurred. Numerous examples can be found in which the catch per lift of one gear increased over that of the previous year while the catch of another gear exhibited a decline. Furthermore, the relative increases or decreases of different gears were often dissimilar even when there was agreement as to direction of change. Some of these discrepancies doubtless reflect inadequacies (and to some extent inaccuracies) of the original data. On the other hand, extremely close agreement between the annual fluctuations in the catch per unit of effort of a species in different gears was not to be expected.

One important source of discrepancies between trends in the catch of different gears most probably lies in annual differences in the distribution of fish as related to hydrographic and other ecological conditions. One year these conditions may tend to concentrate the fish on grounds fished principally by one gear and cause them to be scarce on the major grounds of another, whereas the next season the situation may be reversed. We are not in position to offer quantitative information on this point, but we do know from general observations on the fishery and from statements of fishermen that different gears fished on different grounds do not share equally increases or decreases in the abundance of fish.

A second factor contributing to the discrepancies between trends in the catch of different gears is that some gears operate most effectively over certain size ranges. Thus a progressive change in the size composition of the stock may operate to the advantage of first one and then another type of net. Records for the lake herring (table 13) provide a good example of this type of disagreement. From 1929 through the middle 1930's, fluctuations in the catch of herring per unit effort of small-mesh gill nets and pound nets, although by no means identical, were generally similar. This situation changed during the late 1930's and early 1940's with the development and widespread use of pound nets with extremely small meshes (about 1½ inches extension measure, as manufactured, and still smaller after treatment with preservative). This new type of pound net was designed for smelt but proved so efficient at taking small or "pin" herring, that with its general use changes in the abundance of that species became detectable in the pound-net catches before they were noticed by gill netters who take larger fish. The relatively poor pound-net lifts of 1940–42, for example, were followed by poor gill-net fishing in 1943–46. Again, the rich 1943 year class led to large catches of "pins" as early as 1945 whereas the catch per unit effort of gill nets did not rise sharply until 1947. In this situation both gears probably offered fair indication of the abundance of fish of the size they took but they fished different size groups within the general population.

From the considerations of the preceding two paragraphs it appears first, that discrepancies between gears in the annual fluctuations in the catch per lift of a particular species do not necessarily mean weakness of the data; and second, that the procedure followed in our statistical studies of pooling the data from different gears to obtain our abundance index probably gives the best estimate of abundance of fish of commercial size to be had at the present time.

The abundance percentages for all six species listed in table 10 exhibited rather wide fluctuations and in some species these fluctuations tended to be periodic. The following brief statements concerning trends for the different species can be

[12] The terms "gear" and "nets" are used interchangeably in this section since all fishing apparatus with which we are concerned fall under the category of "nets" except the set hooks formerly fished for lake trout.

followed more easily if reference is made to figures 9 to 14.

Lake trout: During earlier years of the 1929–49 period, abundance was generally below the 15-year (1929–43) mean but the trend was irregularly upward (fig. 9). Sharp increases in 1936 and 1937 carried the index to the 21-year maximum of 157 in 1937. A decline to 94 in 1939 was followed by a rise to a second peak of 138 in 1941. The succeeding years saw a pronounced downward trend which culminated in an index of only 26 in 1947. The rise to 44 in 1948 and 45 in 1949 still left the abundance far below average. The recent decline of the lake trout can be attributed primarily to the depredations of the sea lamprey (Hile, Eschmeyer, and Lunger 1951a).

Whitefish: Van Oosten, Hile, and Jobes (1946) believed that 1929 represented the peak year of a period during which whitefish were abnormally plentiful in Lake Michigan. In Green Bay the 1929 index stood at 180 (fig. 10). From this value the abundance declined to 66 in 1933, recovered somewhat in 1934 (91), and then declined to the 21-year low (65) in 1937. After this year the availability of whitefish entered on a definite, though slightly irregular, upward trend. Large increases from 100 in 1945 to 148 in 1946 and the 21-year maximum of 275 in 1947 were followed by substantial declines to 221 in 1948 and 158 in 1949.

Lake herring: The abundance was consistently below average in 1929–33 (range from 57 in 1933 to 91 in 1931—see fig. 11). A sharp increase to 197 in 1934 was followed by a long decline (interrupted by a small rise in 1940) that led to the 21-year low of 51 in 1942. Small increases in 1943 and 1944, a phenomenal jump from 82 to 306 in 1945, and yet another increase to 367 in 1946, raised the level of abundance to the 21-year high. The subsequent downward trend which carried the percentage to 203 in 1948 was halted by a rise to 228 in 1949.

Walleye: From the 21-year minimum of 54 in 1929 the abundance of walleyes (fig. 12) rose to 198 in 1933 and then fell away to the same minimum of 54 in 1939 (interruption to the decline in 1930). The following years saw a highly irregular but definite upward trend. The increases were so large after 1946 that a level of 344 was reached by 1949.

The data on the catch of walleyes per lift (table 14) together with our knowledge of changes that have taken place in the types of trap nets fished in Green Bay give us reason to suspect that the abundance of walleyes during the last few years, particularly in 1947–49, may have been overestimated. The catches per lift of fyke nets in these 3 years indicate a great abundance of walleyes (catches from 150 to 206 percent of the 1929–43 mean) and the pound-net records for 1948 and 1949 support a similar view (lifts 147 and 142 percent of 1929–43 mean). These 1947–49 figures were relatively far lower, however, than those for trap nets in which the average lift ranged from 30 to 56 pounds as compared with a 15-year average of 8. To some extent this relatively greater increase in the catch of trap nets may have reflected especially heavy concentrations of fish on trap-net grounds (as compared with pound-net and fyke-net grounds) during the years of high abundance of walleyes. Much of the exceptional success of trap nets, however, is believed to have resulted from the introduction (especially by Lake Huron fishermen who moved into the area) of larger nets better suited to the taking of walleyes than the gear employed by local operators in earlier years.

Yellow perch: During the years 1929–42, fluctuations in the abundance of yellow perch (fig. 13) were largely without trend and relatively limited (ranged from 82 in 1936 to 114 in 1937), but during the later years the variations were wide. After dropping from 110 in 1942 to 63 in 1944 the abundance index jumped suddenly to the 21-year peak of 150 in 1945 only to fall away to the 21-year low of 49 in 1949.

White and redhorse suckers: The fluctuations in abundance of suckers (fig. 14), much like those of yellow perch, were without clear-cut trends. The index was low (63) in 1929, but during the next 17 years it varied irregularly within the range of 71 (1939) to 131 (1935). The level of availability was again low (60 or 61) during the last 3 years, 1947–49.

Smelt: As stated earlier, late development of the fishery and the effects of the 1943 epidemic have prevented the establishment of "normal" standards from which to estimate annual fluctuations in the abundance of smelt; nevertheless, a good idea of the extent of these fluctuations is to be had from the records of the catch per unit effort for the months January to April (table 17). Particular attention should be given to the figures for January, February, and March, the 3 months of highest production (tables 7 and 8). Annual fluctuations in the catch per net during these months exhibited no pronounced trend prior to 1943. In that year the January-February catches of gill nets and the January catches of pound nets gave no inkling of the unusual events to come, but in February the catch of smelt per pound net was the lowest since 1939. This decrease is to be associated with the mortality which Van Oosten (1947) believed to have started about the middle of February. By March 1943 the fishery was in a state of collapse. Almost no smelt were taken in 1944 and production (table 4) and catch per net (table 17) both were low in 1945 and 1946. In 1947–49 both production and the catch per unit effort exhibited an upward trend that bids fair to carry the fishery soon to the premortality level.

Examination of table 10 gives strong indication that the annual fluctuations in availability of certain species tended to be similar, whereas with others the trends were distinctly opposite. To bring out these relationships more clearly coefficients of correlation (r) between abundance percentages have been computed for all pairings of the six species (table 18). In these calculations all coefficients involving lake trout were restricted to the 15-year period, 1929–43, since it is believed that the abundance of that species has not followed "natural" fluctuations in recent years but rather has been controlled by depredations of the sea lamprey. All other coefficients were based on the 21-year interval.

Of the 15 coefficients listed in table 18, 7 were significant at the 5-percent level of probability (p); 6 of these 7 were "highly significant" ($p<0.01$). Thus we have strong evidence that the fluctuations in abundance of several of the species were in fact correlated. It would be futile at this time to speculate how these relationships came about—whether they represent interreactions between species, similar or opposite reactions to changing ecological conditions . . . Before we can hope to improve greatly our understanding of the changes within the fish populations in northern Green Bay we must increase our knowledge of the biology of the various species; nevertheless, data of the type given in table 18 can be most helpful by suggesting lines of attack in the general research program.

TABLE 18.—*Correlations between fluctuations in abundance of lake trout and five other species, 1929–43, and among species other than lake trout, 1929–49*

[Absolute values of r corresponding to probabilities (p) of 0.1, 0.05, 0.02, 0.01, and 0.001, respectively, are 0.369, 0.433, 0.503, 0.549, and 0.665 for the 21-year interval and 0.441, 0.514, 0.592, 0.641, and 0.760 for the 15-year period]

Species	Lake trout	White-fish	Lake herring	Walleye	Yellow perch	White and red-horse suckers
Lake trout	--------	−0.690	0.205	0.187	0.181	0.426
Whitefish	−0.690	--------	.383	.459	− .534	−.726
Lake herring	.205	.383	--------	.402	.056	−.118
Walleye	.187	.459	.402	--------	− .645	−.582
Yellow perch	.181	−.534	.056	−.645	--------	.642
White and redhorse suckers	.426	−.726	−.118	−.582	.642	--------

Still further useful information can be had through an investigation of the correlations between abundance percentages for intervals shorter than the entire period for which data are at hand or after the establishment of a time lag of one or more years. This latter procedure can be justified logically since fish of different species hatched in the same year commonly do not enter the fishery simultaneously, and an abundance of large fish of a predator species may reduce stocks of prey species, . . . Examples of the results obtained from this type of analysis (table 19) bring out some interesting relationships. We have evidence, for example, that the correlation between the fluctuations in availability of whitefish and walleyes was negative in 1929–38, but that this situation was reversed in 1939–47 over which period the correlation was strongly positive. Equally striking are the data for the lake herring. Fluctuations in the abundance of this species were not correlated with those of other species when indices for the same calendar year were paired but exhibited significant positive correlations with the abundance of walleyes 1, 2, or 3 years later or 1 or 2 years earlier, and significant negative correlation with the abundance of suckers 1 year later. Again, the expansion of the type of analyses illustrated in table 19 and the inquiry into the possible causes underlying the observed relationships must await further investigation of the natural histories of the various species.

TABLE 19.—*Correlations between annual fluctuations in abundance of fishes of northern Green Bay during specified intervals of time*

Abundance indices correlated	Period of time	*r*	*p*
Whitefish: Walleye	1929–38	−0.670	0.05>*p*>0.02
Whitefish: Walleye	1939–47	0.886	0.01>*p*>0.001
Whitefish: Yellow perch (1 year later)	1929–49	−0.533	0.02>*p*>0.01
Lake herring: Whitefish (1 year later)	1929–49	0.716	0.001>*p*
Lake herring: Walleye (1 year later)	1929–49	0.468	0.05>*p*>0.02
Lake herring: Walleye (2 years later)	1929–49	0.615	0.01>*p*>0.001
Lake herring: Walleye (3 years later)	1929–49	0.603	0.01>*p*>0.001
Lake herring: Suckers (1 year later)	1929–49	−0.467	0.05>*p*>0.02
Walleye: Lake herring (1 year later)	1929–49	0.481	0.05>*p*>0.02
Walleye: Lake herring (2 years later)	1929–49	0.567	0.02>*p*>0.01

As part of recent statistical studies of the lake trout fisheries of the Great Lakes, inquiries have been made into the dependability of production statistics as indicators (but not as measures) of fluctuations in abundance. Because of its bearing on the use of past data on production for judging changes of abundance that may have taken place, the accumulation of information on the dependability of estimation of abundance from production statistics is desirable. For no other waters of the Great Lakes are statistics on fishing intensity and, hence, on catch per unit effort available for a period as long as that in the State of Michigan (for all Great Lakes waters of the State beginning with 1929) and for certain States the collection of data on intensity of fishing began as recently as 1950. Analyses made to date support the general view that fluctuations of abundance are reflected in statistics of production but the exceptions bring out the need for caution in the interpretation of catch data and for a constant alertness to detect disturbing factors that may render those data useless or misleading.[13]

In northern Green Bay, fluctuations in production and abundance were correlated positively at significant levels (table 20) for four of six species (the value of *r* for yellow perch fell short of the 5-percent level in 1929–43 but was highly significant in 1929–49). For those fish, production served reasonably well as an indicator of changes in abundance. The lack of significant correlation in the data for lake trout (to be traced to a negative correlation between fishing intensity and the abundance of that species, see p. 25) demonstrates once more the need for caution in this use of catch statistics.

TABLE 20.—*Correlation between production and abundance indices for the principal commercial species in Green Bay, 1929–43 and 1929–49*

Species	1929–43		1929–49	
	r	*p*	*r*	*p*
Lake trout	−0.028	*p*>0.10	0.337	*p*>0.10
Whitefish	0.924	0.001>*p*	0.892	0.001>*p*
Lake herring	0.707	0.01>*p*>0.001	0.856	0.001>*p*
Walleye	0.869	0.001>*p*	0.878	0.001>*p*
Yellow perch	0.471	0.10>*p*>0.05	0.566	0.01>*p*>0.001
White and redhorse suckers	0.743	0.01>*p*>0.01	0.501	0.05>*p*>0.02

FLUCTUATIONS IN INTENSITY OF THE FISHERY FOR THE PRINCIPAL SPECIES OF GREEN BAY, 1929–49

An outstanding feature of the statistics on the 1929–49 fluctuations in the intensity of the fishery for the principal species (table 21 and figs. 9 to 14) is the high level attained by most of the species during the later years of the period. For four of the six species (lake trout, lake whitefish, walleye,[14] and suckers), the 21-year maximum intensity was reached in 1948 or 1949, and for a fifth (lake herring) the intensity of the fishery in those 2 years was well above the 1929–43 mean. The intensity of the fishery for yellow perch was higher in 1948 and 1949 than in the years immediately preceding but was still below the 15-year average.

There is good evidence that the recent increase of fishing pressure on whitefish, lake herring, and walleye is to be associated with the nearly simultaneous rise in the abundance of those species (*cf.* tables 10 and 21). The increases in fishing intensity for lake trout and suckers, on the contrary, came about during periods of relatively low availability. These two exceptions indicate that a positive correlation between abundance and fishing intensity may not be the rule; such a view finds support in the data of table 22.

[13] See Hile, Eschmeyer, and Lunger (1951a) for comments on the relation between fluctuations of abundance and production in Great Lakes fisheries.

[14] In the preceding section evidence was given that the estimates of abundance of walleyes were probably too high for recent years notably 1947–49. Our method of analysis is such that when abundance is overestimated, fishing intensity is underestimated correspondingly. Consequently the 1947–49 figures on fishing intensity for walleyes in table 21 are probably too low. It is not believed, however, that these underestimates impair the general validity of remarks in this section based on the intensity indices for walleyes.

TABLE 21.—*Fluctuations in fishing intensity for the principal commercial species in Green Bay, 1929–49*

[Expressed as percentages of the 1929–43 mean]

Year	Lake trout	Whitefish	Lake herring	Walleye	Yellow perch	White and redhorse suckers
1929	162	180	76	104	65	87
1930	198	211	88	98	75	103
1931	204	238	85	102	61	97
1932	155	215	44	144	68	111
1933	88	102	42	111	75	83
1934	49	82	70	129	91	104
1935	56	56	92	108	91	121
1936	72	34	124	127	101	129
1937	94	46	197	112	132	106
1938	139	97	220	132	190	111
1939	105	78	108	112	152	119
1940	49	47	96	64	87	97
1941	35	37	82	48	99	73
1942	37	33	84	48	106	75
1943	57	44	92	61	107	84
1944	56	58	76	56	45	73
1945	36	66	107	46	58	64
1946	22	99	96	105	60	74
1947	111	251	113	[1] 236	63	111
1948	253	395	195	[1] 403	72	140
1949	207	407	145	[1] 615	77	194

[1] Probably too low; see footnote 14.

TABLE 22.—*Correlation between indices of abundance and of fishing intensity for six principal species in Green Bay, 1929–43 and 1929–49*

Species	1929–43		1929–49	
	r	p	r	p
Lake trout	−0.553	$0.05>p>0.02$	−0.316	$p>0.10$
Whitefish	0.819	$0.001>p$	0.761	$0.001>p$
Lake herring	0.310	$p>0.10$	0.270	$p>0.10$
Walleye	0.198	$p>0.10$	0.844	$0.001>p$
Yellow perch	0.152	$p>0.10$	0.184	$p>0.10$
White and redhorse suckers	0.005	$p>0.10$	−0.464	$0.05>p>0.02$

Over the base period 1929–43 only whitefish exhibited a significant positive correlation between abundance and fishing intensity. The correlation for lake trout was significant but negative, and among the remaining species the values of r, all positive, were far below the level of significance ($r=\pm 0.514$ at $p=0.05$ and $df=13$). The addition to the base period of 6 years' data brought about several changes in the relationship. In 1929–49 the value of r for whitefish continued to be positive at a high level of significance, but the correlation between abundance and fishing intensity for lake trout, although still negative, was no longer significant. At the same time a highly significant positive correlation for the walleye and a significant negative correlation for suckers appeared. In lake herring and yellow perch the values of the coefficient continued to fall short of significance.

Although an abundance of fish normally would be expected to stimulate fishing operations [15] and a scarcity to depress them, those studies that have been made of the relation between availability and fishing pressure for individual species have failed to reveal a consistent relation between the two (Van Oosten, Hile, and Jobes 1946; Hile 1949; Hile, Eschmeyer, and Lunger 1951 a and 1951 b). Even where the data have favored the assumption of a cause-and-effect relationship, the correlation has at times been negative. In State of Michigan waters of Lake Superior, for example, the evidence indicates that fishermen increased fishing pressure as the abundance of lake trout declined in order to maintain production at an economically satisfactory level (Hile, Eschmeyer, and Lunger 1951b). In shallow-water fisheries where several species are usually taken together the situation becomes extremely complicated, for it is the total catch of a number of species that determines the financial returns to the fishermen. Our understanding of the economic, biological, and other factors that may influence fluctuations of fishing intensity does not justify a detailed consideration of the problem at this time. The remainder of this section will be restricted, therefore, to comments on certain relationships between abundance and fishing intensity in northern Green Bay for which satisfactory explanations can be advanced.

The fluctuations in the intensity of the fishery for lake trout in the Michigan waters of Green Bay were treated by Hile, Eschmeyer, and Lunger (1951a) who explained the negative correlation between fishing pressure and the abundance of lake trout on the basis of the following points: Lake trout and whitefish are commonly taken together in large-mesh gill nets, with the whitefish normally making up the bulk of the catch; the fishing intensity for whitefish has been correlated closely with the availability of that species and the fishing pressure on lake trout accordingly has tended to fluctuate with the availability of whitefish; the abundance indices of lake trout and whitefish have been correlated negatively, however, and as a result a negative correlation has existed between abun-

[15] Excessively high abundance can lead to a glutting of the market with an accompanying collapse of prices and thus depress fishing intensity. Severe market gluts are not common with most Great Lakes species, and when they do occur they usually are so short-termed as to have no great effect on the total annual fishing intensity.

dance and fishing intensity for lake trout. Those authors published detailed statistical data in support of their conclusions.

An analogous explanation is believed to hold for the negative correlation between abundance and intensity of the fishery for white and redhorse suckers in 1929–49, with the walleye as the "principal associated species" responsible for the high level of fishing at a time of low abundance of suckers. The 1929–43 data do not indicate a significant correlation between abundance and fishing intensity for either species. (The fluctuations of intensity for walleyes and suckers, however, were positively correlated at a highly significant level—value of $r=0.737$ for the 15 years.) The rise in abundance of walleyes to the unprecedentedly high level of 1947–49 changed the situation for that fish. Walleyes which normally had been taken only incidentally became the primary object of extensive operations. The simultaneous sharp rise of abundance and of fishing intensity increased the correlation coefficient from 0.198 in 1929–43 to 0.844 in 1929–49. Part of the increased fishing for walleyes resulted also in the capture of suckers.[16] Consequently, the intensity of the fishing for suckers rose considerably. Since the level of availability of suckers was low (the abundance indices for suckers in 1947–49 were all below the minimum for 1929–46) a negative correlation between abundance and fishing intensity resulted.

THE PROBLEM OF ECONOMICALLY SOUND REGULATION OF THE FISHERIES

From the preceding discussion it can be seen that the increase which carried the commercial production in Green Bay from the 1929–49 minimum of 1,379,000 pounds in 1944 to nearly 8 million pounds in 1948 and 1949 was largely the result of the exceptionally high abundance of whitefish, lake herring, and walleyes and of greatly increased fishing pressure. This pressure, no doubt, was directed primarily toward the capture of the highly abundant species but those below average abundance (lake trout and suckers) felt its effects. The recovery of the smelt population from the 1943 epidemic also contributed substantially to the heightened production in the late years of the 1929–49 period.

[16] It must be stressed here that fishing intensity is estimated separately for each species. Nets lifted by a fisherman on a particular day are charged against a species only if some quantity of that species is taken.

At the end of 1949 the fishing industry of northern Green Bay had enjoyed three consecutive years of production far above the catch in any of the preceding 18 years. During the years of high productivity the market was generally strong and prices, aside from normal seasonal fluctuations, were good. Yet, for all this prosperity, a troublesome situation has developed and, as explained earlier, the groundwork has been laid for possible disaster in the years ahead. The industry may yet pay dearly for these few years of good fishing.

The present difficult situation will become critical at such time as the abundance of fish returns to a more nearly normal level. As was mentioned earlier, numbers of fishermen have moved into Green Bay from other areas. Much of the increase in fishing intensity recorded in the preceding section can be attributed to their activities. Although this increased fishing was desirable in that it made possible the cropping and use of an unusually plentiful supply of fish, the congestion on the grounds and the competition between the newcomers and local fishermen led to some strained relations even when all were making good catches. These relations surely will deteriorate further at such time as the abundance of fish decreases to the point where the available stocks are insufficient to provide profitable fishing for all commercial operators in the area. To be sure, congestion may be relieved somewhat by the return of some of the "migrant" fishermen to their former ports or by their transfer to yet other grounds outside Green Bay;[17] nevertheless, fishing intensity out of proportion to the supply is anticipated. The situation in Green Bay is complicated further by the activities of sportsmen and resort owners who have a strong interest in the sport fishery, especially for walleyes.

The quality of fishing that accompanies fishing intensity of a high level and stocks of only normal abundance will provide a painful contrast with conditions of the past few years, and a loud clamor for protection of the fishery resource is certain to arise. Unless sound judgment prevails, numerous restrictive measures highly detrimental to the industry are almost certain to be enacted. We had

[17] At the time of preparation of this paper (summer of 1951) we received reports that some fishermen had left Green Bay.

a foretaste of this with the introduction of a bill during the 1950–51 session of the Michigan State Legislature to regulate commercial fishing in Delta County (the greater part of the State of Michigan waters of Green Bay lies within its boundaries). Introduced for the stated purpose of protecting the walleye and barely failing of passage, this proposed legislation contained a series of restrictive provisions that would have crippled the industry sadly. Staff members of the Great Lakes Fishery Investigations, when asked to offer an opinion, opposed this legislation on the grounds that it would deprive the community unnecessarily of valuable production and impose severe hardships on commercial operators. Opposition to this measure was not against the principle of a rational control over fishing intensity in a heavily exploited area, but rather against the means proposed for bringing about that control.

Realistic consideration of the means whereby we can best achieve the goal of a productive and economically sound fishery in the Great Lakes is badly needed. That a fishery, to be of maximum benefit to the community, should be productive would appear axiomatic. Mere abundance of fish, no matter how high it may be, is of no value. It is not the fish that are in the water but the fish that are taken out of the water that provide food and revenue. Yet this axiom often has been disregarded. For the "protection" of fish, productive grounds have been closed, unsound size limits established, species placed on the "game fish" list, and other regulations imposed that serve principally to limit production and create unused stocks.

It may be held axiomatic further that an economically sound fishery not only must show a good level of production with a high dollar value but also must provide the average operator a reasonably good chance for adequate financial returns on his investment and labor. To a large extent the protective regulations in effect in the United States waters of the Great Lakes—size limits that prohibit the capture and sale of fish of a size at which they are plentiful and in demand, closed seasons that forbid operations at a time when fish are easiest to take, closure of grounds to all commercial fishing or the limitation of certain gears to the less productive areas or depths, structural specifications on gears that reduce their effectiveness . . .—limit the income of fishermen by forcing on them inefficient methods of production. The resulting increase in production costs narrows the margin of profit on the one hand and raises the price to the consumer on the other.

It lies outside the scope of this paper to inquire into the actual protective value of the many restrictions on fishing in the Great Lakes or into the soundness of the speculation and theory on which they are based. We are largely without facts to form a judgment. Some may have averted disaster in certain fisheries, others may have had no significant effect either on the stocks or on the conduct of fishing, and still others have, no doubt, been detrimental. A few, such as certain closures of productive areas for the alleged protection of sport fisheries, are indefensible. Although the extent and nature of protection needed and the degree to which present regulations have provided that protection may be debatable, these restrictions unquestionably have served to reduce fishing pressure. The point at issue is the economic expediency of reducing fishing pressure by reducing efficiency of operation.

If the productive capacity of an area is limited, it follows that regulation of fishing pressure may be essential to the economic welfare of the fishery. As the number of units of gear increases, the share available for each unit becomes smaller, and the catch per unit of effort declines—in short, fishing becomes poor. The common remedy for such a situation is to impose restrictions that lessen efficiency of operation and aggravate economic distress by reducing further the catch per unit of effort, and thus add to the cost of production. Fishing pressure may be reduced as some operators are forced out of business or transfer their activities to other grounds, but the control comes from economic hardship, not rational management.

A sounder approach would appear to lie in limiting the units of gear to a number that would assure opportunity for profitable returns per unit of fishing effort. Restricting the number of nets per fisherman or per boat to accomplish this would be of limited value, since with the number of fishermen remaining the same, the share available to each would be unchanged. More effective would be the gradual reduction in the number of licenses (through the retirement of licenses not renewed) until the point is reached at which a reasonably enterprising fisherman can be assured of as great economic stability as is possible in the business he follows. The most modern and efficient methods of capture could be employed and restrictions relaxed, with a resulting decrease in the cost of production and a more dependable profit margin. Without control over the number of licenses issued we can look forward to further legally imposed inefficiency of operation and a continuation of economic instability.

The preceding paragraphs offer a most sketchy treatment of a highly intricate problem; however, the purpose of this discussion is not to undertake a critical analysis of problems of regulation, but merely to point out that economic as well as biological considerations must enter into the framing of a sound program for the utilization of the fishery resources.[18]

SUMMARY

In 1885, the first year for which we have production statistics for the commercial fisheries of the State of Michigan waters of Green Bay, lake herring made up 972,000 pounds, or 39.7 percent, of the total catch of 2,449,000 pounds. Other important species taken were whitefish (31.0 percent), lake trout (16.5 percent), and sturgeon (5.3 percent).

The dominance of lake herring in the catch was much stronger in 1891–1908, the next period for which there are production records. During that period lake herring contributed from 71.6 percent (1905) to 90.6 percent (1899) of the catch in the individual years and had an average take of 5,841,000 pounds or 82.4 percent of the average annual total of 7,085,000 pounds for all species. The mean annual catch and the percentage contribution to the total 1891–1908 production for other important species were: Suckers—398,000 pounds, 5.6 percent; lake trout—213,000 pounds, 3.0 percent; walleyes—197,000 pounds, 2.8 percent; whitefish—159,000 pounds, 2.3 percent; yellow perch—157,000 pounds, 2.2 percent. Despite certain irregularities and possibly some cyclic fluctuations the trends of production in 1891–1908 were decidedly upward for all leading species except walleyes (which were taken in greater quantities in the early than in the late years of the period). The total output (all species) rose from 2.1 million pounds in 1891 to 3.8 million pounds in 1893, dropped to 2.5 million pounds in 1894, and then started on an upward trend that culminated in a take of 10.6 million pounds in 1899. From this high value the catch fell to 6.2 million pounds in 1901, rose (with an irregularity in 1903) to 10.3 million pounds in 1904, dropped suddenly to 7.4 million pounds in 1905, and finally entered on a period of increase that led to the 18-year maximum—in fact, the all-time recorded high—of 13.7 million pounds in 1908. The fluctuations in total yield followed closely those of the dominant lake herring.

Records of production in State of Michigan waters of Green Bay are lacking for 1909–28. When the tabulation of these statistics was resumed in 1929 the species composition of the stock and the level of take had changed markedly. The mean annual yields of the principal species in 1929–49 and their percentage contributions to average annual total of 3,582,000 pounds were: Lake herring—1,070,000 pounds, 29.9 percent; whitefish—714,000 pounds, 19.9 percent; white and redhorse suckers—699,000 pounds, 19.5 percent; smelt (an introduced species)—624,000 pounds, 17.4 percent; yellow perch—150,000 pounds, 4.2 percent; walleyes—133,000 pounds, 3.7 percent; lake trout—126,000 pounds, 3.5 percent.

The 1929–49 fluctuations in production were large for all principal species and tended to be cyclic in some. The ranges in the annual take were: Lake herring—160,000 to 2,668,000 pounds; whitefish—90,000 to 3,066,000 pounds; smelt—nil (no reported commercial catch of this introduced species before 1931) to 2,976,000 pounds; white and redhorse suckers—393,000 to 1,181,000 pounds; yellow perch—49,000 to 361,000 pounds; walleyes—16,000 to 1,063,000 pounds; lake trout—11,000 to 248,000 pounds. These wide fluctuations together with differences in their timing from species to species led to dominance of the total catch first by one variety and then by another. Because of tendencies toward periodicity, domi-

[18] Higgins (1938) pointed out certain economic problems in the management of marine fisheries. Nesbit (1943) discussed the question of control of fishing pressure through limitation of the number of licenses. Taylor, et al. (1951) made an exhaustive analysis of the economics of fisheries.

nance by whitefish, lake herring, and smelt lasted 2 to 4 years (lake herring once held first rank for only 1 year). White and redhorse suckers which exhibited little tendency toward periodic fluctuations were dominant three times but never in consecutive years.

The total production (all species) stood at 2.3 million pounds in 1929, rose to 2.9 million pounds in 1931, dropped to 1.4 million pounds in 1933, and then increased to 4 million pounds in 1938. The take continued to exceed 4 million pounds in 2 of the next 3 years (it was only 2.7 million pounds in 1939) but 1942 saw the start of a decline that carried the yield to the 21-year minimum of 1.4 million (1,379,000) pounds in 1944. Production increased rapidly during the next 4 years, reaching the 21-year peak of 7.9 million pounds in 1948. The catch was only slightly below this figure in 1949 (7.8 million pounds). The sharp rise to high levels of production in recent years can be traced largely to phenomenal increases in the take of whitefish, lake herring, and walleyes. Production attained the all-time recorded high for whitefish in 1948 and for walleyes in 1949. The catch of lake herring reached the 21-year maximum in 1948, but still was far below the output for certain years in 1891–1908. Also contributing to the increase was the recovery of the smelt stock from the disastrous 1943 mortality; the commercial take of this species increased from less than 500 pounds in 1944 to 1,050,000 pounds in 1949.

The average annual production of 3,582,000 pounds for all species combined in 1929–49 was 3,503,000 pounds or 49.4 percent less than the 1891–1908 mean of 7,085,000 pounds. Decline in the take of lake herring alone (from 5,841,000 pounds in 1891–1908 to 1,070,000 pounds in 1929–49—a drop of 4,771,000 pounds) more than accounted for the difference. For species other than the lake herring the combined average output increased from 1,244,000 pounds in 1891–1908 to 2,512,000 pounds in 1929–49—a rise of 1,268,000 pounds or 102.9 percent. Comparisons of 1891–1908 and 1929–49 production figures throw doubt on the validity of the commonly held belief that most or all major declines in the production of individual species have been the result of overfishing. If we hold, for example, that the huge drop in the average annual catch of lake herring was caused by overexploitation, we are sorely pressed to account for the increase in the output of whitefish, a more valuable species always in high demand, from an annual mean of 159,000 pounds in 1891–1908 to 714,000 pounds in 1929–49. The suggestion is offered that the principal effects of fishing may lie in the disturbance of ecological relationships among species, and that fishing pressure on commercially exploited varieties may have operated so much to the advantage of the smaller, noncommercial species that the latter now make up an increased percentage of the total biological production of fish.

Statistics on distribution of the catch by month and by quarter revealed pronounced differences among the principal species with respect to seasonal trends. Data on the catch by gear demonstrated that all species were taken in quantity by more than one type of gear and that the catches of most gears are made up of several species. The principal gears are gill nets (of three groupings with respect to mesh size), pound nets, shallow trap nets, and fyke and hoop nets.

The fluctuations of abundance (as estimated from the records of catch per unit fishing effort) were considerable for all principal species. Least variable were the abundance indices of yellow perch and white and redhorse suckers. The abundance of lake trout could have been described as moderately steady were it not for the tremendous decline after 1943 (believed to have been caused by the sea lamprey). The most extensive fluctuations in abundance occurred in the whitefish, lake herring, and walleyes. The abundance indices of these species were particularly high during the last 3 (whitefish, walleyes) or 5 (herring) years of the period. Maximum levels attained (indices expressed as percentages of the average 1929–43 abundance) were: Whitefish—275 in 1947; lake herring—367 in 1946; walleyes—344 in 1949 (this last figure may be an overestimate, see p. 22). The available evidence indicates that the attainment of these high values was made possible by the phenomenal strength of the 1943 year class of all three species. The late development of the smelt fishery and the disruption occasioned by the 1943 mortality have prevented the establishment of suitable norms for the estimation of fluctuations in the abundance of that species.

Of the 15 coefficients of correlation that could be computed between abundance percentages among the 6 principal species, 7 were significant (5 were negative and 2 were positive). Additional significant coefficients were obtained when time lags of 1 to 3 years were established. With the whitefish and walleyes a significant negative correlation for 1929–38 was followed by a highly significant positive correlation in 1939–47. Only a greatly expanded knowledge of the natural history of Green Bay fish can explain these interrelationships.

Correlations between annual fluctuations in abundance and production indicated that production would have served as a reasonably dependable indicator of the major changes of availability in 1929–49 for whitefish, lake herring, walleyes, yellow perch, and suckers, but would have been highly misleading for lake trout.

The abundance of fish and the intensity of fishing exhibited highly significant positive correlation for whitefish in the 1929–43 base period and in 1929–49, and for walleyes in 1929–49. Our knowledge of the fishery prompts us to view these correlations as reflecting a true cause-and-effect relation. The remaining coefficients fell short of significance or had significant negative values (lake trout in 1929–43; white and redhorse suckers in 1929–49). These negative coefficients were explained as the result of heavy fishing for whitefish and walleyes in which lake trout and suckers were taken as incidental parts of the catch during periods of low abundance of the latter two species.

An outstanding feature of the data on fishing intensity was the extremely great pressure directed against most species during the last 2 or 3 years of the 1929–49 period. The maximum levels (indices give as percentages of the average 1929–43 intensity) attained for the different varieties in recent years were: Lake trout—253 in 1948; whitefish—407 in 1949; lake herring—195 in 1948; walleyes—615 in 1949 (possibly an underestimate); yellow perch—77 in 1949; white and redhorse suckers—194 in 1949. Higher levels of fishing intensity were reached in earlier years by only two species: Lake herring—220 in 1938; yellow perch—190 in 1938.

The upswing of production that carried the annual take from the 21-year low of 1.4 million pounds in 1944 to nearly 8 million pounds in 1948 and 1949 was made possible to a large degree by the phenomenal increase in the abundance of whitefish, lake herring, and walleyes and by an enormous expansion of fishing activity (much of it to be traced to fishermen who moved in from other areas). Although the cropping of this large supply of fish was desirable a dangerous situation has been created. At such time as the abundance of fish returns to a more nearly normal level the available supply may be inadequate to support profitable operations for all the fishermen in the bay. Not only will the fishermen experience financial difficulties, but there is a real threat of the enactment of "protective" legislation that could all but destroy the fishing industry.

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SUPPLEMENT—THE FISHERY OF GREEN BAY IN 1950

After completion of the main body of the present paper on fluctuations in fish populations and take in the Green Bay fisheries through 1949, statistics became available for 1950, and are presented here. The following comments are concerned principally with comparisons of 1949 and 1950 levels of yield, abundance, and fishing intensity for the principal species (table 23). Records of the catch per lift on which estimates of abundance were based are given in table 24 and detailed figures on production are included in table 25. Understanding of these tables will be furthered by references to earlier tables in the text giving corresponding data for 1929–49.

Lake trout: A decline in abundance from 45 in 1949 to 23 (the 1929–50 low) in 1950 and a drop in fishing intensity from 207 to 40 combined to reduce the take from 149,000 pounds (102 percent of the 1929–43 mean) in 1949 to 15,000 pounds (10 percent) in 1950. With the exception of the 11,000-pound catch in 1946, the 1950 take was a record low.

Whitefish: Abundance changed little from 1949 (158) to 1950 (156) but fishing intensity dropped from 407 to 272. The take accordingly fell more than three-quarters of a million pounds—from 2,263,000 pounds to 1,494,000 pounds. Even so, the 1950 yield exceeded 3½ times the 1929–43 average.

TABLE 23.—*Levels of production, abundance, and fishing intensity for the principal species in Green Bay, 1949 and 1950*

[In thousands of pounds; index figures as percentages of the 1929–43 mean]

Species	Production		Production index		Abundance index		Fishing intensity index	
	1949	1950	1949	1950	1949	1950	1949	1950
Lake trout	149	15	102	10	45	23	207	40
Whitefish	2,263	1,494	543	358	158	156	407	272
Lake herring	2,230	3,249	312	455	228	222	145	218
Walleyes	1,063	1,294	2,093	2,547	344	(1)	615	(1)
Yellow perch	65	107	37	61	49	52	77	119
White and redhorse suckers	878	729	120	99	61	63	194	155
Smelt	1,050	1,624	144	222	------	------	------	------
All species	7,782	8,578	256	282	------	------	------	------

1 Estimates not attempted for 1950; abundance index in 1949 probably too high and intensity index too low; see text, p. 22.

TABLE 24.—*Catch, in pounds, of principal species of fish per unit of effort in Green Bay, by gear, 1950*

[Figures, except for smelt, are based on annual totals of production and gear lifted]

Species	Gill nets [1]			Pound nets [4]	Shallow trap nets [4]	Fyke and hoop nets [4]
	Bait [2]	Small-mesh [3]	Large-mesh [3]			
Lake trout	--------	--------	23	2	--------	--------
Whitefish	--------	--------	167	88	--------	--------
Lake herring	--------	2,081	--------	187	--------	--------
Walleyes	--------	--------	--------	21	74	56
Yellow perch	--------	133	--------	--------	6	23
White and redhorse suckers	--------	--------	170	18	53	48
Smelt:						
January	28	--------	--------	41	--------	--------
February	27	--------	--------	171	--------	--------
March	21	--------	--------	286	--------	--------
April	73	--------	--------	450	--------	--------

1 Mesh sizes, extension measure: bait nets, mostly 1¼–1⅝ inches; small-mesh nets, 2¼–2¾ inches; large-mesh nets, 4½ inches and larger.
2 Unit of effort: lift of 1,000 linear feet.
3 Unit of effort: lift of 10,000 linear feet.
4 Unit of effort: lift of one net.

Lake herring: The rise of more than a million pounds in the output of lake herring, from 2,230,000 pounds (312 percent of the 15-year average) in 1949 to 3,249,000 pounds (455 percent) in 1950 can be traced entirely to an increase in fishing intensity from an index value of 145 to one of 218. The availability of lake herring declined (from 228 to 222) but was extremely high in both years.

Walleye: The production which amounted to 1,063,000 pounds, or 2,093 percent of the 1929–43 mean, in 1949 was increased further to the all-time recorded high of 1,294,000 pounds, or 2,547 percent, in 1950.

We are, unfortunately, without basis for a good estimate of the relative importance of the abundance of walleyes and of fishing intensity in this record output. The difficulty in estimating abundance and fishing intensity originates in uncertainty as to whether the catch per lift of shallow trap nets in the most recent years is in fact comparable with the "normal" established for that gear for the base period 1929–43. When discussing the 1929–49 fluctuations in abundance, we called attention to the fact that during the later years of that period, particularly 1947–49, the catch per lift was relatively much more above the 15-year mean in trap nets than in pound nets or fyke nets, the other two gears employed in the estimation of abundance.[19] Much of the relatively greater success of the trap nets, it was explained, probably resulted from the introduction of larger nets capable of taking more walleyes per lift at a given population level than were taken by the gear formerly employed. Any increases in the catch per net that resulted from change of gear rather than from increased abundance, of course, contributed to an overestimate of the index of abundance and an underestimate of the index of fishing intensity.

The discrepancies between the data for trap nets and those for pound nets and fyke nets that were troublesome in the 1947–49 statistics became excessive in 1950, as is seen from the following tabulation:

	Catch per lift (pounds)		*1950 catch as percentage of*
	1929–43	*1950*	*average*
Pound nets	19	21	111
Shallow trap nets	8	74	925
Fyke nets	32	56	175

Although the discrepancies indicated above are so large as to make the computation of general indices of abundance and fishing intensity undesirable, the original data do provide some useful information. There can be little doubt, for example, that in 1950 the abundance of walleyes continued to be substantially above the 1929–43 average. The lowest estimate for a single gear was 111 percent (pound nets) and the other gear for which we have no reason to suspect biased records (fyke nets) yielded the higher figure of 175. Furthermore, we cannot overlook the possibility that the high figure for trap nets resulted from a heavy concentration of walleyes on the trap-net grounds as well as from the introduction of more efficient nets. Hence, on those fishing grounds the relative abundance may have been in fact at a level higher than that indicated by the data for either pound nets or fyke nets.

The continued high (if not precisely measured) abundance and the enormous yield of walleyes in 1950 are a tribute to the phenomenal strength of the 1943 year class. That group, according to Robert F. Balch,[20] strongly dominated the commercial catch in State of Michigan waters of Green Bay in 1950; furthermore, an early 1951 sample indicated that walleyes hatched in 1943 would form the main support of the 1951 fishing.

Yellow perch: The year 1950 saw an end to the downward trend that had carried the index of abundance from a high of 150 in 1945 to 49 in 1949. The improvement to 52 in 1950 was, of course, small, but it does lend hope that a recovery of the stocks may be under way. The increase in the catch of yellow perch from 65,000 pounds (37 percent of the 1929–43 average) in 1949 to 107,000 pounds (61 percent) in 1950 came principally from the upswing in fishing intensity from an index value of 77 in the former year to one of 119 in the latter.

White and redhorse suckers: With the suckers as with the yellow perch a slight rise in the abundance index (from 61 in 1949 to 63 in 1950) gives us hope that a period of low availability may be nearing its end. Despite the small improvement in abundance the production of suckers fell from 878,000 pounds (120 percent of the 15-year normal) in 1949 to 729,000 pounds (99 percent) in 1950. The decline can be traced to a drop in fishing intensity from 194 to 155.

Smelt: The recovery of production following the mortality of 1943 continued in 1950 when the catch of 1,624,000 pounds (222 percent of the 1929–43 mean) was 574,000 pounds greater than the 1949 yield of 1,050,000 pounds (144 percent). Comparisons of the catch per lift in 1950 (table 24) with those of 1949 (table 17) prove that the increase in the take resulted from an upswing in fishing pressure. With the exception of the equal catches of 28 pounds per 1,000 feet of bait nets in January of both years, the production per unit of fishing effort was consistently higher in 1949 than in the same month and with the same gear in 1950.

Total production: The take of 8,578,000 pounds (282 percent of the 1929—43 average) constituted a new high in the modern period which began with 1929. The principal contributors to the rise from 7,782,000 pounds (256 percent) in the previous year were lake herring, smelt, and walleyes with

[19] Data from large-mesh gill nets, a major gear in the production of walleyes in 1947–50, cannot be used for the estimation of abundance since we have been unable to establish a long-term normal catch per lift. In 1929–46, the production of walleyes by this gear was too small to yield dependable data on the take per unit effort. The annual take averaged only 1,946 pounds over that period, and in 7 of the 18 years the catch was less than 1,000 pounds.

[20] Unpublished manuscript submitted to the Wisconsin Conservation Department.

increases of 1,019,000, 574,000, and 231,000 pounds, respectively. These increases, together with those of yellow perch and of certain minor species, exceeded by 796,000 pounds the decreases in the take of whitefish (769,000 pounds), white and redhorse suckers (149,000 pounds), lake trout (134,000 pounds), and other varieties.

Pound nets, which took 3,157,000 pounds, or 36.8 percent of the total, were the most productive gear in 1950 (table 25). Next in importance were large-mesh gill nets (1,998,000 pounds, 23.3 percent), small-mesh gill nets (1,996,000 pounds, 23.3 percent), and shallow trap nets (1,330,000 pounds, 15.5 percent). No other method of fishing contributed as much as 1 percent of the total.

The 1950 production of 8,578,000 pounds in Green Bay constituted 70.2 percent of the State of Michigan total of 12,223,000 pounds for Lake Michigan. The corresponding percentage was 65.4 in 1949.

TABLE 25.—*Production of each species of fish in Green Bay, by gear, 1950*

[In pounds]

Species	Gill nets [1]			Pound nets	Shallow trap nets	Fyke and hoop nets	Seines	Hand line and trolling	Total	Percentage
	Bait	Small-mesh	Large-mesh							
Lake trout	----------	5	14,455	249	----------	----------	----------	----------	14,709	0.2
Whitefish	----------	207	1,007,323	470,993	15,041	----------	----------	----------	1,493,564	17.4
Lake herring	313	1,893,512	16,929	1,007,941	330,456	121	----------	----------	3,249,272	37.9
Walleyes	----------	129	559,714	99,110	624,279	10,230	----------	51	1,293,513	15.1
Yellow perch	----------	68,732	285	5,603	27,153	4,759	----------	293	106,825	1.2
White and redhorse suckers	----------	1,948	359,820	38,458	321,748	7,308	----------	----------	729,282	8.5
Smelt	69,104	8,922	11,551	1,534,228	----------	----------	----------	----------	1,623,805	18.9
Others [2]	----------	22,634	27,446	683	11,621	1,901	2,717	----------	67,002	.8
Total	69,417	1,996,089	1,997,523	3,157,265	1,330,298	24,319	2,717	344	8,577,972	----------
Percentage	0.8	23.3	23.3	36.8	15.5	0.3	[3] 0.0	[3] 0.0	----------	----------

[1] Mesh sizes, extension measure: Bait nets, mostly 1½–1⅝ inches; small-mesh nets, 2¼–2¾ inches; large-mesh nets, 4½ inches and larger.

[2] Includes (catches in pounds of all gears combined): Chubs, 21,784; carp, 18,880; longnose suckers, 10,260; northern pike, 8,570; bullheads, 3,908; rock bass, 1,630; round whitefish, 1,373; saugers, 220; sheepshead, 137; burbot, 121; catfish, 103; bowfin, 8; white bass (actually not a commercial species), 8.

[3] Less than 0.05.