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Abstract

This study was based mainly on gill-net collections of yellow perch (*Perca flavescens*) made during July and August 1971–79, in southern Lake Michigan at Grand Haven, Saugatuck, South Haven, Benton Harbor, and New Buffalo, Michigan; Michigan City and Gary, Indiana; Waukegan, Illinois; and Milwaukee, Wisconsin. Abundance of yellow perch was above the 1971–79 average in 1971 and 1972, below average in 1979, and about average or in doubt in the other years. Abundance during 1976–79 was greatest at Saugatuck and decreased more or less progressively from Saugatuck southward and around the southern end of the lake. The geographical differences in abundance were attributable partly to differences in fishing mortality. Average lengths of fish caught were greatest at Saugatuck, and generally greater in Michigan waters than in other areas; they were greater for females than for males. Fish sampled ranged in age from I to IX, but 88% of the males and 81% of the females were of ages II–V. Older perch were generally more common in State of Michigan waters, particularly at Saugatuck, than elsewhere. Females grew faster than males after the second year of life. Average lengths of males and females at the end of 3 years were 197 and 214 mm, respectively, in Michigan waters and 186 and 195 mm in Indiana–Illinois (few perch were caught in Wisconsin). The relation of weight (W) to length (L) for combined sexes was $W = 2.6761(10^{-6}) \times L^{3.2644}$. Perch in southeastern Lake Michigan spawned mainly from late May to mid June. Virtually all males were mature in their second year, but some females not until their fourth year. Perch 174 to 355 mm long contained 9,300 to 136,000 eggs. Approximate mortalities of males and females in Michigan waters were 52% and 48%, respectively; rates were higher in Indiana–Illinois.

The yellow perch (*Perca flavescens*) is an important commercial and sport species in Lake Michigan. Annual commercial production averaged 1,160 metric tons from 1889 (when records began) through 1964. In the early and mid 1960's the abundance declined severely (Smith 1970; Wells and McLain 1973; Wells 1977); commercial production averaged only 365 tons during 1965–69. The State of Michigan closed its Lake Michigan waters to commercial fishing for perch in late 1969, and did not reopen them. Several workers have inferred that perch decreased mainly because their reproduction was adversely affected by alewives (*Alosa pseudoharengus*), which were first seen in Lake Michigan in 1949 and had become exceedingly abundant by the mid 1960's (Smith 1970; Wells and McLain 1973; Wells 1977); however, an intensive and almost unregulated commercial fishery may have hastened the decline (Wells 1977). Perch reproduction improved sharply in some areas in 1968 and 1969, perhaps in response to markedly lower alewife abundance following a severe die-off that began in the winter of 1966–67 and continued into the spring (Brown 1968; Wells 1977). The comeback seemed to be most pronounced in the southeastern and extreme southwestern part of the lake proper (specifically, south of Saugatuck on the east side of the lake and south of the northern limits of Chicago on the west side); in isolated areas of the east-central part of the lake proper (e.g., near Ludington); and in Green Bay. In other areas perch numbers increased only slightly, if at all.

We sampled perch in southern Lake Michigan each year during 1971–79. The main purposes were to gather biological data and to follow trends in the abundance and age and size structure of the populations. Some of the data were used in a description of changes in perch populations in Lake Michigan during 1954–75 (Wells 1977); in a summary of the food habits of six species of fish in southeastern Lake Michigan (Wells 1980); and in a report on estimated allowable harvest of yellow perch in State of Michigan waters of southeastern Lake Michigan (Patriarche 1977; Patriarche and Wells, unpublished report). We present mainly new material in this report, although we also elaborate on certain data included in Wells (1977).

[1]Contribution 591 of the Great Lakes Fishery Laboratory.

Table 1. *Sampling dates at different index and secondary stations in southern Lake Michigan in different years.* (Dates are those on which gill nets were set; dates in italics designate the index samples that provided the primary source of data for this report.)

	Year and months[a]											
	1971	1972	1973	1974	1975	1976		1977		1978	1979	
Station	Jul	Jul	Jul	Jul	Jul	Jul	Sep	Jul	Aug	Aug	Jul	Aug
Index stations												
Grand Haven	*29*	*27*	*29*		*21*	17,*26*	10	*18*	18,29	*2*	*24*	
Saugatuck	*20*	*30*	*31*	22	8	14,*25*	19	*7*	19,27	*3*	*25*	
South Haven	*25*	*30*	*18*	*27*	9,20	*18*	14	9,17		*5*	*27*	
Benton Harbor	*25*	*31*	*19*	26	*11*	*19*	15	10,*16*	23	*14*	*28*	
New Buffalo				*19*	*12*	*21*	7	11,*15*	25	*12*	*29*	
Michigan City	*24*	*31*	20	*18*	*13*	*22*		*12*	26	*11*	*30*	
Gary	*23*				*15*	*23*		*13*		*10*		*10*
Waukegan						*24*		*14*		*9*		*9*
Milwaukee			24	*21*	*19*					*7*		*8*
Secondary stations												
Saugatuck (2 km N)			30									
Saugatuck (7 km S)						15,27	12,14					
Saugatuck (16 km S)				30				8	21	4,15	26	
South Haven (2 km N)				28					22,30	6	31	
Michigan City (5 km W)				17								
Waukegan (5 km N)	21		22	20	17							

[a]The following nine collections (none of which were index samples) are not shown: 1971—26 August at Saugatuck; 1972—2 May and 7 June at Saugatuck and 4 September at secondary station 5 km north of Waukegan; and 1976—1 May at Grand Haven, 28 April and 2 May at Saugatuck, and 29 and 30 April at South Haven.

Methods

Standardized series of samples were collected each year during 1971-79, nearly always during July and August, from the U.S. Fish and Wildlife Service R/V *Cisco*. Primary sampling sites or "index stations" were near Grand Haven, Saugatuck, South Haven, Benton Harbor, and New Buffalo, Michigan; Michigan City and Gary, Indiana; Waukegan, Illinois; and Milwaukee, Wisconsin (Fig. 1). In this report we designate the index stations by the names of the respective nearby ports. Only three of the stations were more than 5 km from the port by which they are designated: the station near South Haven was 8 km to the south (near the Palisades nuclear power plant, but clear of its thermal plume); the station near Waukegan was 10 km to the south; and the station near Gary was about 11 km to the northwest. The number of years in which individual index stations were visited varied from 4 to 9 (Table 1). Several of the stations were visited more than once in some years. For these stations we selected data from only a single visit in July (occasionally early August) in each year for detailed analysis. We believe that these data sets, designated as "index samples," best represented the populations of interest. Other samples from index stations were used only in the analysis of growth rates.

We also collected data at several secondary stations, but less regularly than at index stations (Fig. 1, Table 1). Data from the secondary stations were used only in the analysis of growth rates, and for that purpose were combined with data from the nearest index station. The secondary stations were 2 km north, 7 km south, and 16 km south of Saugatuck (data combined with those of Saugatuck); 2 km north of South Haven; 5 km west of Michigan City; and 5 km north of Waukegan.

Sampling was conducted with nylon graded-mesh gill nets that always included meshes (stretched measure) of 5.1, 6.4, and 7.6 cm and usually meshes of 3.8, 7.0, and 8.9 cm. Specifically regarding the index sampling, the nets lacked 3.8-cm mesh at all stations in 1976 and at two (Grand Haven and Benton Harbor) in 1977; 7.0-cm mesh in 1979; and 8.9-cm mesh in 1971-73. The amount of each mesh size fished varied somewhat, but in the last several years

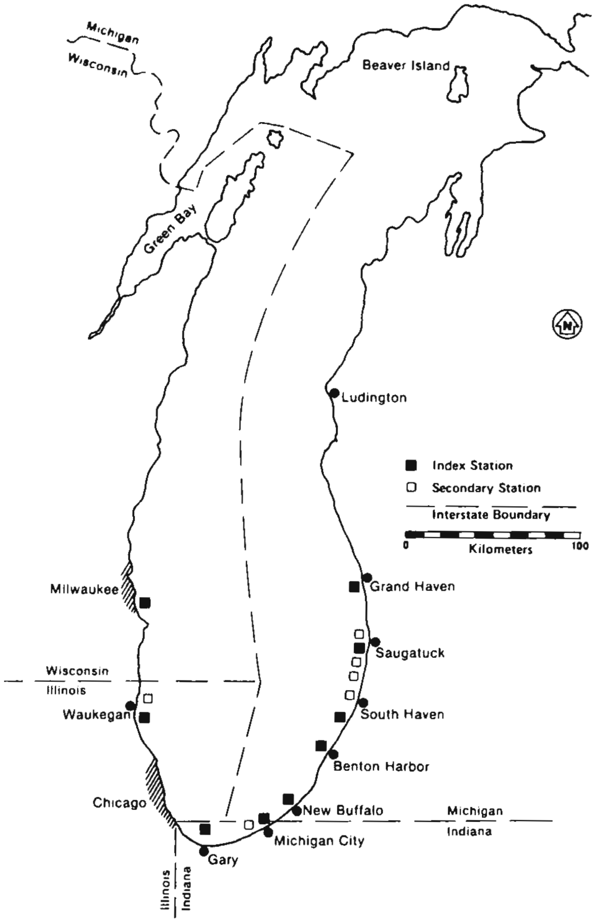

Fig. 1. Lake Michigan, showing index and secondary stations.

of the study the "standard" net included 7.6 m of 3.8-cm mesh; 15.3 m each of 5.1-, 6.4-, and 7.0-cm mesh; and 30.5 m each of 7.6- and 8.9-cm mesh. In all tabulations and computations (except those involving mesh selectivity), catches in mesh sizes that were fished in amounts other than 30.5 m were adjusted to numbers per 30.5 m of that mesh. Data from the 3.8- and 7.0-cm meshes were eliminated except in our analyses of growth rates and mesh selectivity. Catches of perch in the 3.8-cm mesh were strongly influenced by the numbers of alewives in the area in which the net was set; when alewives were abundant, they tended to "load up" this small mesh, precluding the possibility of its sampling perch in proportion to their density. The 7.0-cm mesh was an "odd" size among meshes that were otherwise graded by 1.27-cm increments.

Each time a station was visited, except in 1971, single standard gill nets were fished along the contour at depths of 5.5 and 11 m; they were also fished at 16 m in 1976–79 (and at Milwaukee in 1973) and at 22 m in 1978–79. In 1976, a few sets were made at 22 and 27 m in non-index sampling. Except on a few occasions during non-index sampling, nets at a given station were set at all sampling depths on the same day. In 1971, nets were fished at only a single depth – either 5.5, 7.3, or 9.1 m – at each station; for convenience we state depths at all stations in 1971 as 7.3 m. The *Cisco*'s 2.4-m draft prevented our fishing gill nets safely in water shallower than 5.5 m, although we were aware that large numbers of perch sometimes occupy such shallower depths. All nets were left in the water for a single night, with a few exceptions when bad weather prevented their retrieval until the second day; we then simply halved the catches to adjust them to a catch-per-night basis. A bathythermograph cast was made at the sampling site each time a net was set or retrieved.

Although samples of perch were not always processed in exactly the same way, the procedure did not vary greatly. Data were recorded separately for fish taken in each mesh size in each net. Total numbers of perch caught were always recorded. Samples of scales (for aging) were generally removed from some or all of the fish, depending on the size of the catch. We usually removed scales from all fish caught at a station when the total (meshes and depths combined) was less than about 150, and typically took scales from about 150 fish when the total catch exceeded that number substantially. Scales were taken from directly below the sixth dorsal spine, in the area of the second, third, and fourth row of scales below the lateral line. Total length (mm), weight (g), and sex were recorded for each specimen from which scales were taken. Except for a few instances in the earlier years, length and sex of the rest of the fish were recorded. In our age analyses, done separately by sex for each index sample, the age frequencies of fish from which scales were not removed were estimated on the basis of the length frequencies of these fish and the length frequencies of fish of different ages from which scales were taken. Stomachs for food analysis were removed from some of the fish collected in 1974 (see Wells 1980).

Abundance

Although catches from stationary gear do not lend themselves well to computation of absolute abundance, they nevertheless provide a basis for some general conclusions regarding relative abundances in different localities and years. Precise assessment of relative population sizes is not feasible because the catches were influenced not only by abundance but by other factors as well. The most important of these factors was probably water temperature, although the relation between temperature and catch was highly inconsistent. Wells (1968), basing his observations on catches in trawls fished periodically during February–November at rather closely spaced depth intervals, wrote that when a wide range of temperatures was available to yellow perch in southeastern Lake Michigan, they were

Table 2. *Numbers of yellow perch caught in gill nets (30.5 m each of 5.1-, 6.4-, and 7.6-cm mesh) fished overnight at selected localities in different years.* (Numbers represent averages of catches at depths of 5.5 and 11 m except in 1971, when they represent the catch from a single set at 7.3 m.)

	Year								
Locality	1971	1972	1973	1974	1975	1976	1977	1978	1979
Saugatuck	73	293	50	136	884	107	262	55	108
South Haven	238	401	252	227	280	199	231	57	80
Benton Harbor	380	326	133	120	322	186	164	61	95
Michigan City	132	42	63	65	100	55	36	2	14
Average	206	266	125	137	397	137	173	44	74

usually in water warmer than 11°C and were sometimes abundant at temperatures as high as 22°C, but were occasionally found in substantial numbers in water as cold as 8°C. The present study confirmed these observations; we cannot offer anything more specific. On a few occasions, when very cold hypolimnial waters upwelled into even our shallowest sampling depths, the catches obviously greatly underrepresented the populations. During these periods the perch probably sought warmer water close to shore in areas shallower than our minimum sampling depth. Perhaps many of them also escaped the upwelled water by moving offshore into warm upper water levels. Although perch are not generally regarded as a pelagic species, they have been observed in the epilimnion in Lake Michigan far from shore (Wells 1968).

For analyses of relative abundance according to year and locality, we used only certain segments of the data from the index samples.[2] In comparisons of year-to-year abundance, we included the data from Saugatuck, South Haven, Benton Harbor, and Michigan City, from 5.1-, 6.4-, and 7.6-cm meshes; and from 5.5 and 11 m (7.3 m in 1971). These were the only stations (all in southeastern Lake Michigan), mesh sizes, and depths from which we obtained data every year. The three meshes seemed to sample all but the very largest adult perch fairly representatively, although they obviously took disproportionately small numbers of immature fish. Probably the sets at 5.5 and 11 m usually (but certainly not always) provided a reasonable index of abundance; they normally took most of the perch when the series included deeper sets (1976–79). For example, considering only the catches in 5.1-, 6.4-, and 7.6-cm meshes, the combined sets at 5.5 and 11 m in index sampling always took at least 67% (often more than 80%) of the total from all depths, except for two notable exceptions in 1979, when they captured only 3% of the totals at Grand Haven and 31% at Saugatuck. In comparisons of relative abundance between stations, we considered only the data collected in 1976–79, because several stations frequently were not included in the sampling in earlier years. (We did not sample at Milwaukee in 1976 or 1977, but the catches at Milwaukee in 1978 and 1979 provided us a suitable indication of the relative abundance there.) We included data from 5.1-, 6.4-, 7.6-, and 8.9-cm meshes, and from depths of 5.5, 11, and 16 m, because we had data from all these mesh sizes and depths in each year from 1976 to 1979.

After the general resurgence of yellow perch in the late 1960's, abundance as measured in the southeastern part of the lake appeared to decline, but not steadily, after 1972 (Table 2). Catches in 1971 and 1972 were above average for the period of the study; many of the fish in these years were of the very strong 1969 year class (Brazo et al. 1975; Wells 1977). A definite decline was evident in 1973, and catches changed little in 1974. Abundance in 1975 is in doubt, because the catches almost surely overrepresented the populations; spawning appears to have been later than usual and when our sampling was conducted (somewhat earlier than usual), large numbers of freshly spent males were still concentrated in the shallow spawning areas. Most adult females had abandoned the shallow water, but fairly large numbers of immature females were present at some of the sampling localities. Catches of males were especially large at Saugatuck, where sampling was conducted on a known rocky spawning ground. Catches in 1976 and 1977 suggested that abundance had not changed appreciably since 1974. Abundance in 1978 is in question because the small catches in that year were due at least in part to abnormal thermal conditions. Although the nets were not fished during periods of pronounced upwelling, they were nevertheless set in water that was colder than in most years. Owing to the extreme severity of the winter of 1977–78, and slow warming the following spring, the epilimnion did not reach as great a thickness as usual in summer 1978, and consequently bottom water temperatures were seldom favorable for perch except perhaps in limited areas shallower than our minimum sampling depth. The small

[2]Detailed data supporting this work are given in three tables, available on request from the Great Lakes Fishery Laboratory. The tables show catches of yellow perch in index and non-index sampling by year, locality, date, depth, and mesh size (water temperatures are also given); age structure of yellow perch caught in gill nets at combined depths, by locality and sex in different years; and calculated total lengths at the end of each year of life of male and female yellow perch, by locality and year of capture.

catches in 1979 probably represent a real decline in abundance from 1977, since sampling was carried out under favorable thermal conditions. However, abundance at Saugatuck seems to have been high in 1979, contrary to the impression given by the modest catches there at 5.5 and 11 m. These catches obviously underrepresented the populations, because most of the perch were at depths greater than 11 m, as indicated by the large catches at 16 and 22 m, which made up 69% of the total.

Among the index stations, abundance during 1976–79 appeared to decrease progressively from Saugatuck to Milwaukee; it was also much lower at Grand Haven (the only station north of Saugatuck) than at Saugatuck (Table 3).

We believe that the differences in abundance among the sampling localities resulted in part from differences in fishing mortality. Age structures of the catches (discussed later) indicated that mortality of older fish was much lower in Michigan than in the other States. We also suspect that the geographical differences in abundance are related in part to other factors (e.g., reproductive success), but we have no quantitative data relating to such factors.

Length–Frequency Distribution

The length–frequency distribution of perch in the samples varied somewhat with year of capture, and considerably with locality and sex. We made between-year comparisons for two areas: Michigan (Table 4) and Indiana–Illinois (Table 5). (Samples at Milwaukee were too small to support a sound analysis of length distribution.) To maintain consistency through all years, we included data from only the 5.5- and 11-m depths (7.3 m in 1971), and from only the 5.1-, 6.4-, and 7.6-cm meshes. To make between-station comparisons (Table 6), we included data from 1976–79; from 5.5-, 11-, and 16-m depths; and from 5.1-, 6.4-, 7.6-, and 8.9-cm meshes. Sexes were considered separately, except in 1972, when sex was determined for only a small portion of the fish caught. Data for 1975, although included in Tables 4 and 5, are ignored in the following discussion because (as mentioned earlier) they were not considered to be representative of the populations.

The average length of females generally exceeded that of males. The difference was conspicuous in State of Michigan waters, where females were substantially larger in every year for which we had sex data (Table 4); where the (unweighted) average length of females for all years combined — 250 mm — exceeded that of males by 25 mm; and where about 20% of the females, but less than 1% of the males, were longer than 279 mm (years combined). The size advantage of females was not as great in Indiana–Illinois (Table 5): average lengths of females and males for years combined (no samples of fewer than 10 fish considered), were 222 and 212 mm; and virtually no males, and only about 6% of the females, were longer than 279 mm. The size advantage of females resulted mostly from faster growth but also to some extent from greater longevity (discussed later).

In the different years under consideration, the average lengths of perch (sexes combined) ranged from 224 to 249 mm in Michigan and from 203 to 236 mm in Indiana–Illinois (Tables 4 and 5). Lengths in both areas were appreciably greater in 1974 than in earlier years, but then dropped considerably by 1976. Average lengths approached the levels of 1974 in 1977–79 in Michigan waters, but increased little in Indiana–Illinois after 1976.

Among the different localities, the average lengths of perch during 1976–79 were greatest at Saugatuck (partly as a result of the presence in the samples of a high percentage of females), and next greatest at Grand Haven, to the north; they decreased more or less progressively at localities increasingly distant southward from Saugatuck and around the south end of the lake (Table 6). The average length of fish (sexes combined) was 277 mm at Saugatuck, compared with only 201 mm at Gary. Very large perch were much more common at Saugatuck than elsewhere. For example, the average number of fish 300 mm long or longer in the 4 years was 154 at Saugatuck, compared with only 8 to 19 at the other localities in Michigan waters, and nil at stations in Indiana–Illinois (Table 6). The variations in size of perch among the different localities were related largely to age structure.

Age Structure

Among the combined index samples from all localities, depths, meshes (except 3.8 cm), and years (except 1972, when few fish were aged, and 1975, when collections did not represent populations closely), perch ranged in age from I to IX, but 88% of the males and 81% of the females were of ages II to V (Table 7). Yearlings were scarcely represented in the catches because they were almost completely invulnerable to the sampling gear, and 2-year-olds were surely underrepresented to some extent. At most localities a greater proportion of females than of males were of age II, probably because more females became vulnerable to the gear at this early age, owing to their faster growth. The overall proportion of age-II fish was 17% among the females, compared with only 9% among the males. Females also were more strongly represented than males among the older fish; e.g., 10% of the females were age VII and older, compared with only 3% of the males.

Age structure, besides differing according to sex, also varied considerably from place to place and year to year. For comparing age structures between localities and years, we analyzed the same data sets as those used for the respective comparisons of length frequencies (again disregarding 1975 data other than in tabulations), except that data for 1972 were not considered in comparing ages in different years.

Table 3. *Numbers of yellow perch caught in gill nets (30.5 m each of 5.1-, 6.4-, 7.6-, and 8.9-cm mesh) fished overnight at different localities in 1976–79.* (Numbers represent averages of catches at depths of 5.5, 11, and 16 m.)

	Locality								
Year	Grand Haven	Saugatuck	South Haven	Benton Harbor	New Buffalo	Michigan City	Gary	Waukegan	Milwaukee
1976	41	98	160	181	173	41	42	20	
1977	50	246	161	114	20	30	2	5	
1978	21	73	45	42	16	3	0	1	0
1979	8	197	54	68	13	10	15	14	1
Average	30	154	105	101	56	21	15	10	1

Table 4. *Length frequency distribution in different years of male and female yellow perch caught in gill nets (30.5 m each of 5.1-, 6.4-, and 7.6-cm mesh) fished overnight at depths of 7.3 m in 1971 and 5.5 and 11 m in 1972–79 at Grand Haven, Saugatuck, South Haven, Benton Harbor, and New Buffalo.*[a]

	Year, sex, and total number of fish																
	1971		1972[b]	1973		1974		1975		1976		1977		1978		1979	
Total length (mm)	M 162	F 214	524	M 138	F 117	M 164	F 197	M 531	F 119	M 139	F 152	M 148	F 160	M 55	F 31	M 46	F 73
70–79						1											
110–119						1					T						
120–129											T		T				
130–139										T	1		T				
150–159								T	T								
160–169								1	T	1	1		1				
170–179	1	3	2	1			1	1	2	3	8		1				
180–189	17	9	18	4	1	1	3	4	8	12	19	3	2	T			T
190–199	30	38	66	14	2	2	10	11	24	27	17	10	5	1		1	
200–209	25	44	98	29	4	11	8	21	17	41	10	17	11	10	1	7	5
210–219	26	23	70	36	12	20	10	28	5	18	10	14	9	11	3	11	10
220–229	18	15	71	23	11	26	13	55	4	8	11	17	15	8	7	12	6
230–239	15	10	84	13	10	48	22	133	7	4	12	15	10	7	3	6	7
240–249	15	15	50	10	11	31	17	137	6	10	13	22	14	4	2	2	6
250–259	7	9	23	4	16	15	18	89	4	10	10	24	14	7	2	6	10
260–269	4	14	12	2	11	4	14	35	4	3	9	17	16	3	2	1	7
270–279	5	15	9	1	13	3	19	11	5	2	3	5	9	3	2	T	6
280–289	1	9	4	1	9	T	16	4	7	T	4	2	12	1	2	T	4
290–299	T	5	6	T	6	1	16	1	6		5	1	7	T	3	T	4
300–309		3	4		3	T	13	T	9		5	1	10	T	T		3
310–319		1	4	T	4		6	T	4		5		9		1		2
320–329		1	1		3		5		4		4		7		2		1
330–339		T	1		1		3		2		4		5		T		1
340–349			1		T		2		1		1		2		1		T
350–359			T				1		T		T		1				1
360–369							T						T				
370–379																	T
Average length	219	227	224	218	256	232	259	239	240	213	235	236	261	231	257	227	254
Average length, sexes combined	224		224	234		247		239		224		249		240		244	

[a]Entries for 1972–79 are the averages per station of the catches from the combined depths; for 1971 they are averages per station at the single depth, times a factor of 2. No samples from New Buffalo in 1971–73, or from Grand Haven in 1974; no fish collected were in any of the following length groups: 80–89, 90–99, 100–109, and 140–149. T = trace (less than 0.5).

[b]Sexes combined. Sex not recorded for most fish.

Table 5. *Length frequency distribution in different years of male and female yellow perch caught in gill nets (30.5 m each of 5.1-, 6.4-, and 7.6-cm mesh) fished overnight at depths of 7.3 m in 1971 and 5.5 and 11 m in 1972–79 at Michigan City, Gary, and Waukegan.*[a]

	Year, sex, and total number of fish																
	1971		1972[b]	1973		1974		1975		1976		1977		1978		1979	
Total length (mm)	M 41	F 113	83	M 69	F 56	M 28	F 101	M 19	F 126	M 65	F 34	M 24	F 3	M 3	F 0	M 24	F 7
120–129																	1
130–139																T	
140–149																1	T
150–159	1															1	1
160–169								1	1							T	T
170–179	1	1	2	2					4	2							
180–189	1	14	6	8	2		2	2	15	14	6			1		1	
190–199	11	36	20	16	2	2	22	4	57	18	9	5		1		4	T
200–209	7	25	19	22	2	2	14	1	28	21	5	6	1			6	2
210–219	11	12	12	10	8	8	2	3	4	7	4	7				3	2
220–229	4	10	10	7	15	2	8	1	2	2	2	1	1			5	1
230–239	3	5	9	2	12	6	4	3	6		3	3		1		1	T
240–249	2	3	1	1	6	2	6	2	1		3	1	1			1	
250–259	T	2	T		4	6	6	2	3	1	1	1				1	
260–269	T	2	1	1	1		13		1		1						
270–279	T	T	1		1		8										T
280–289		2	1				5										
290–299		T	1		1		7		1								T
300–309		1			1		4		1								
310–319			T				T		1								
320–329									1								
330–339					1												
340–349			T														
Average length	210	208	212	205	233	229	238	216	203	199	211	214	220	203		216	191
Average length, sexes combined	208		212	218		236		205		203		215		203		210	

[a]Entries for 1972–79 are the averages per station of the catches from the combined depths; for 1971 they are averages per station from the single depth, times a factor of 2. No samples from Gary in 1973 and 1974, or from Waukegan in 1971–75. T = trace (less than 0.5).
[b]Sexes combined. Sex not recorded for most fish.

Old perch (i.e., those age VI and older) were less abundant in the earlier years of the study than in later years, at least in State of Michigan waters. For example, few fish of age VI and no older ones were in the Michigan catches of 1971 and 1973, whereas many of age VI and VII, and a few of VIII and IX, were in the catches of 1976–79 (Table 8). Fish older than VI were predominantly females. The average age of males climbed from 3.0 in 1971 to 3.6 in 1974 and 4.5 in 1979; the average ages of females increased similarly. The scarcity of old perch in the early 1970's probably was related to the poor reproduction in the mid 1960's, and to the cropping of large fish by the commercial fishery that continued through 1969; also, their increased numbers in the mid and late 1970's probably reflected (aside from reduced fishing mortality) improved reproduction that began in the late 1960's (Wells 1977). The increases in old fish over the years were far less conspicuous in Indiana–Illinois than in Michigan (Table 9).

Old perch were considerably more common at Saugatuck than at other localities, and were generally more common in Michigan than in Indiana and Illinois (Table 10). At Saugatuck, 42% of the males and 52% of the females were age VI and older; corresponding percentages were 8 and 12 for State of Michigan waters exclusive of Saugatuck and 3% and nil for Indiana–Illinois. The mean ages were 5.2 for males and 5.5 for females at Saugatuck, compared with (unweighted) average means of 3.8 (both sexes) at Michigan localities exclusive of Saugatuck, and 3.4 and 2.9 at localities in Indiana–Illinois.

We believe that the differences we have described in size

Table 6. *Length frequency distribution at different localities of male and female yellow perch caught in gill nets (30.5 m each of 5.1-, 6.4-, 7.6-, and 8.9-cm mesh) fished overnight at depths of 5.5, 11, and 16 m during 1976–79.*[a]

	Locality, sex, and total number of fish															
	Grand Haven		Saugatuck		South Haven		Benton Harbor		New Buffalo		Michigan City		Gary		Waukegan	
Total length (mm)	M 45	F 50	M 167	F 300	M 156	F 164	M 196	F 115	M 97	F 89	M 42	F 24	M 39	F 8	M 28	F 6
110–119								1								
120–129						1		1						T		
130–139						T		1	T	T			T			
140–149													1	T		
150–159													1	T		
160–169					1	1		1	1				1	T		
170–179		2		1	2	5	2	5	1	1	1		1	T	1	
180–189	3	1	1	2	6	10	5	8	7	8	3	3	7	1	3	1
190–199	6	3	2	5	8	8	25	5	18	12	9	4	9	2	6	2
200–209	8	2	8	5	29	11	38	9	27	12	12	5	9	1	8	1
210–219	5	1	13	8	26	14	26	13	14	11	10	2	4	2	3	2
220–229	5	3	18	10	21	21	20	15	8	6	3	2	2	1	3	
230–239	4	3	15	8	16	18	21	12	6	8	2	2	2	1	1	
240–249	5	4	19	16	20	18	22	7	5	5	1	4	2		1	
250–259	6	4	35	15	19	15	21	9	7	7	1	1			2	
260–269	2	3	25	22	7	13	11	8	3	3		1				
270–279	1	5	16	16	1	4	4	4	1	1				T		
280–289		4	7	19		3	1	3	1	2						
290–299		3	5	20		3	T	3		2				T		
300–309		2	3	23		6		3		2						
310–319		3		31		5		3		3						
320–329		3	T	39		4		1		3						
330–339		2		27		3		2		2						
340–349		1		20		1		1		1						
350–359		1		10		T				1						
360–369				3						T						
370–379				T												
Average length	223	268	248	293	225	241	224	234	215	235	209	217	200	208	209	201
Average length, sexes combined	247		277		233		228		225		212		201		208	

[a]Entries are the annual averages of the combined catches from all depths. T = trace (less than 0.5).

and age of perch in Indiana–Illinois as compared with Michigan related mainly to selective cropping of large fish by the commercial fishery in Indiana–Illinois. Among these differences were the scarcity of large and old fish in Indiana–Illinois relative to Michigan; the near absence of a size advantage of females over males in Indiana–Illinois (despite the faster growth of females) as contrasted with Michigan; the lower average age of females than males in Indiana–Illinois but not in Michigan; and the less conspicuous increase in size and age of fish in Indiana–Illinois than in Michigan in the last 4 years of the study.

The particularly strong representation of large, old fish at Saugatuck may have resulted at least in part from a movement of some of these fish into the sampling area, perhaps because food was especially plentiful there. Sampling at Saugatuck was conducted on a rocky reef that harbored an abundance of crayfish, a prime food of large perch in southeastern Lake Michigan (Wells 1980). Possibly exceptional longevity contributed to the conspicuous abundance of old perch in the Saugatuck sampling area, but such fish were too heavily represented in the catches to be accounted for by that factor alone. Above-average abundance of large perch was not confined to the immediate area of the index station at Saugatuck. Catches at secondary stations 7 and

Table 7. *Numbers of male and female yellow perch, and percentages of total for each sex, in each age group taken in gill nets from combined depths, meshes, localities, and years except 1972 and 1975.*[a]

	Sex			
	Male		Female	
Age	Number	Percent	Number	Percent
I	5	T	9	T
II	443	9	847	17
III	1,880	38	1,149	23
IV	1,292	26	1,268	25
V	753	15	768	15
VI	388	8	451	9
VII	120	2	343	7
VIII	35	1	109	2
IX	3	T	42	1
Total	4,919		4,986	

[a]Entries are based on 30.5 m each of 5.1-, 6.4-, 7.6-, and 8.9-cm mesh (no 8.9-cm mesh in 1971 and 1973) fished at depths of 7.3 m in 1971; 5.5 and 11 m in 1973–74; 5.5, 11, and 16 m in 1976–77; and 5.5, 11, 16, and 22 m in 1978–79. T = trace (less than 0.5).

16 km south of Saugatuck (4 and 13 km south of the index station) also usually included rather large proportions of old fish, although not as large as at the index station. We do not know the character of the bottom at either secondary station, except that neither is on a reef.

Sex Ratio

Although sex ratios of perch in different collections varied considerably, neither sex consistently outnumbered the other at any locality, except in Indiana and Illinois, and then only in the later years of the study. The ratio in combined catches from all years (except 1972 and 1975), localities, depths, and meshes was remarkably close to unity—4,919 males to 4,986 females (Table 7). Highly imbalanced sex ratios that occasionally occurred among samples from individual depths at a locality (tabulated only for 1976–79—Table 11), and that sometimes resulted in serious imbalances for the combined catches of all depths at a locality, suggested that, in summer, perch in Lake Michigan often are at least partly segregated by sex. The data do not indicate any appreciable difference in depth distribution of the sexes, except for limited evidence that males were more inclined than females to occupy the deepest areas we fished. In 1976 and 1977, when we sampled at 5.5, 11, and 16 m, the numbers of males and females taken at a given depth (localities combined) were not widely different (Table 11). In 1978 and 1979, the only years in which we extended our sampling to a depth of 22 m, 278 of the 290 perch caught at that depth (years combined) were males; however, inconsistencies in sex ratios at the other depths cause some doubt that the ratio at 22 m was typical for fish at that depth. Although catches at 5.5 m contained about equal numbers of males and females in both 1978 and 1979, those at 11 m consisted predominantly of males in 1978 and females in 1979; and those at 16 m contained about the same number of each sex in 1978, but were mostly males in 1979.

Table 8. *Age frequency distribution in different years of male and female yellow perch caught in gill nets (30.5 m each of 5.1-, 6.4-, and 7.6-cm mesh) fished overnight at depths of 7.3 m in 1971 and 5.5 and 11 m in 1973–79, at Grand Haven, Saugatuck, South Haven, Benton Harbor, and New Buffalo.*[a]

	Year and sex															
	1971		1973		1974		1975		1976		1977		1978		1979	
Age	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
I					1				T	1		1				
II	53	122	29	6	6	22	14	57	18	52	7	10				T
III	67	35	70	44	61	26	55	15	90	42	51	45	20	10	4	20
IV	33	34	30	50	78	66	218	14	11	24	28	61	17	8	25	28
V	11	21	7	14	15	68	210	20	17	12	44	14	7	7	10	16
VI	1	5	T	1	1	12	34	13	7	12	16	18	10	3	5	6
VII						2	1	3	T	8	3	10	2	3	3	2
VIII								T		T		2	T	1		1
IX										T				T		1
Total[b]	165	217	136	115	162	196	532	122	143	151	149	161	56	32	47	74
Average age	3.0	2.9	3.1	3.7	3.6	4.1	4.2	3.3	3.4	3.4	4.1	4.1	4.3	4.5	4.5	4.4

[a]Entries for 1973–79 are the averages per station of the catches from the combined depths; for 1971 they are the averages per station at the single depth, times a factor of 2. No samples from New Buffalo in 1971 and 1973, or from Grand Haven in 1974. T = trace (less than 0.5).
[b]Totals are not always identical with those in Table 4, due to rounding.

Table 9. *Age frequency distribution in different years of male and female yellow perch caught in gill nets (30.5 m each of 5.1-, 6.4-, and 7.6-cm mesh) fished overnight at depths of 7.3 m in 1971 and 5.5 and 11 m in 1973–79, at Michigan City, Gary, and Waukegan.*[a]

	Year and sex															
	1971		1973		1974		1975		1976		1977		1978		1979	
Age	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
I																1
II	5	50	15	7		36	4	107	3	17	6	1			8	5
III	28	47	43	34	14	14	7	11	59	13	13	1	2		12	8
IV	5	12	9	12	4	21	3	4	1	5	5	1	1		35	5
V	5	2	2	2	10	26	4		1		1				13	4
VI		2		1		5	2	2							9	
VII								1								
Total[b]	43	113	69	56	28	102	20	125	64	35	25	3	3	0	77	23
Average age	3.4	2.8	3.0	3.2	3.9	3.6	3.7	2.3	3.0	2.7	3.0	3.0	3.2	–	4.0	3.2

[a]Entries for 1973–79 are the averages per station of the catches from the combined depths; for 1971 they are averages per station at the single depth, times a factor of 2. No samples from Gary in 1973 and 1974, or from Waukegan in 1971, 1973, and 1974.
[b]Totals are not always identical with those in Table 5, due to rounding.

Males almost always outnumbered females in catches at individual depths and localities in Indiana and Illinois during 1976–79; combined catches for the four years contained 408 males and 146 females (Table 11). On the other hand, in Michigan waters during the same period, males and females each were the more numerous about equally often, and contributed about equally to the combined catches: 2,883 males and 2,812 females. (Few fish were taken in Wisconsin during this period.) We cannot explain the preponderance of males in the samples from Indiana–Illinois in 1976–79. Entry into the commercial fishery of females at an earlier age than males, due to the females' faster growth, could account for such an unbalanced sex ratio; however, McComish (1981) reported sex ratios near 1:1 in samples collected near Michigan City, Indiana, in the same series of years.

Growth

An analysis of scales from 5,421 males and 4,374 females showed that growth of yellow perch in southern Lake

Table 10. *Age frequency distribution at different localities of male and female yellow perch caught in gill nets (30.5 m each of 5.1-, 6.4-, 7.6-, and 8.9-cm mesh) fished overnight at depths of 5.5, 11, and 16 m during 1976–79.*[a]

	Locality and sex															
	Grand Haven		Saugatuck		South Haven		Benton Harbor		New Buffalo		Michigan City		Gary		Waukegan	
Age	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
I						1		1	T	T				T		
II	5	5	T	8	4	22	14	18	7	34	6	10	4	3		2
III	14	10	20	31	67	55	80	46	54	23	23	7	26	5	15	3
IV	12	15	31	62	35	51	45	23	15	15	11	5	4	1	6	1
V	7	7	45	40	40	16	34	13	12	5	2		3	1	3	
VI	5	6	42	59	8	12	19	5	6	3			1		2	
VII		5	21	61		5	3	2	T	7	T					
VIII		1	5	25		1		1	T	1						
IX			1	10												
Total[b]	43	49	165	296	154	163	195	109	94	83	42	22	38	10	26	6
Average age	3.8	4.4	5.2	5.5	3.9	3.7	3.9	3.5	3.5	3.6	3.2	2.8	3.2	3.0	3.7	2.8

[a]Entries are the annual averages of the combined catches from all depths. T = trace (less than 0.5).
[b]Totals are not always identical with those in Table 6, due to rounding.

Table 11. *Numbers of yellow perch caught in gill nets each year 1976–79, by locality, sex, and depth.*[a]

Year and depth (m)	Grand Haven M	Grand Haven F	Saugatuck M	Saugatuck F	South Haven M	South Haven F	Benton Harbor M	Benton Harbor F	New Buffalo M	New Buffalo F	Michigan City M	Michigan City F	Gary M	Gary F	Waukegan M	Waukegan F	Total M	Total F
1976																		
5.5	0	43	52	119	152	160	152	89	82	85	20	51	44	6	40	16	542	569
11	14	30	38	43	23	75	77	56	117	139	24	16	64	14	4	0	361	373
16	16	20	21	21	23	48	130	41	49	57	4	8	0	0	0	0	243	195
Total	30	93	111	183	198	283	359	186	248	281	48	75	108	20	44	16	1,146	1,137
1977																		
5.5	24	9	35	299	253	212	186	133	40	46	48	6	4	0	0	0	590	705
11	48	41	113	157	4	3	16	0	24	0	16	2	2	0	4	0	227	203
16	6	23	46	88	10	2	6	0	10	0	17	0	0	0	10	0	105	113
Total	78	73	194	544	267	217	208	133	74	46	81	8	6	0	14	0	922	1,021
1978																		
5.5	4	11	48	96	54	55	50	7	24	20	0	0	0	0	4	0	184	189
11	22	10	10	10	6	0	60	7	3	0	4	0	0	0	0	0	105	27
16	15	1	10	42	19	0	2	0	0	0	4	0	0	0	0	0	50	43
22	0	0	36	0	0	0	0	0	0	0					0	0	36	0
Total	41	22	104	148	79	55	112	14	27	20	8	0	0	0	4	0	375	259
1979																		
5.5	0	0	18	62	52	85	82	94	20	7	18	4	14	6	36	4	240	262
11	0	2	16	154	18	6	15	2	10	2	6	0	4	10	0	0	69	176
16	22	0	252	88	2	0	2	0	0	0	2	0	13	3	2	0	297	91
22	52	0	185	12	5	0	0	0	0	0					0	0	242	12
Total	74	2	471	316	77	91	99	96	30	9	26	4	31	19	38	4	848	541

[a]Entries are based on 30.5 m each of 5.1-, 6.4-, 7.6-, and 8.9-cm mesh, fished overnight. Not shown (but included in totals) are two females caught in 1979 at 16 m off Milwaukee.

Michigan varied considerably according to sex and somewhat according to locality and year. Although a tabulation of calculated lengths at the end of each year of life by locality and sex for each year of capture would be too lengthy for presentation here, the averages for all years combined are shown in Table 12.

Table 12. *Calculated total lengths at end of each year of life of male and female yellow perch taken at different localities, 1971–79.* (Entries are unweighted averages of the values for all years.)

Locality	Number of fish M	Number of fish F	1 M	1 F	2 M	2 F	3 M	3 F	4 M	4 F	5 M	5 F	6 M	6 F	7 M	7 F	8 M	8 F	9 M	9 F
G. Haven	351	364	81	81	158	163	200	221	227	254	249	282	258	306	275	321	270	340		
Saugatuck	1,604	2,084	85	85	162	167	207	227	235	261	255	288	267	310	279	326	285	343	298	353
S. Haven	795	1,057	85	85	159	164	202	222	229	256	247	283	254	310	266	328	284	344		357
B. Harbor	686	572	86	84	161	164	203	220	229	254	248	279	258	302	273	323		331		
New Buffalo	318	572	82	83	154	160	193	216	217	252	240	283	251	310	281	323	282	340		
Mich. City	260	542	82	80	154	158	192	208	214	253	235	279	267	302	284	315	295	341		350
Gary	153	148	83	79	153	152	188	197	214	227	226	253	243	289						
Waukegan	185	76	79	74	146	142	189	199	213	226	221		237							
Milwaukee	22	6	81	81	152	156	187	217	211	246										

Body–Scale Relation

The body–scale relation was derived from scales of 461 yellow perch, 143 to 342 mm long, collected at Saugatuck in 1975. Only a single scale from each fish was measured. The relation between anterior scale lengths and total fish length, at least in the range of sizes in our sample, appeared to be linear. Fitted by simple least squares, the equation of the line was $L = 26.8 + 1.71\ (S)$, where L = total length of fish (mm) and S = anterior scale radius (mm × 42). The value for the intercept (26.8) was rounded to 27 for back-calculation of lengths. Computations based on 20 young-of-the-year perch caught in trawls in southeastern Lake Michigan suggested that the equation for body–scale relation shown above applied only to fish longer than about 100 mm, and that the relation for smaller fish was best described by a straight line intercepting the L-axis at about 21 mm. If we had used an intercept of 21 for fish lengths of 100 mm or less in our back-calculations, the calculated lengths would have been reduced by 3 to 5 mm at the end of the first year of life, but would have been unchanged for later years.

Differences in Growth According to Sex

Female perch grew considerably faster than males, at least after the second year. Growth of the sexes was usually about the same in the first year. Females nearly always gained a slight size advantage over males in the second year; however, the opposite was true in 1979 at localities from Benton Harbor clockwise around the south end of the lake, and (as judged from scanty data) also in some years before 1979 at Gary and Waukegan. An example of the difference in growth of the sexes is provided by a comparison of average back-calculated lengths at the ends of each of the first four years, for males and females taken at Saugatuck: for males the lengths were 85, 162, 207, and 235 mm, and for females they were 85, 167, 227, and 261 mm (Table 12).

Differences According to Locality

Among the different localities, growth was fastest at Saugatuck, but was only slightly slower at Grand Haven, South Haven, and Benton Harbor; it became progressively slower at stations increasingly distant from Benton Harbor around the south end of the lake. These differences are apparent from the data in Table 12, but to illustrate them more precisely we used the combined growth data (through age VI) for just two years — 1976 and 1979 (Table 13). Those years were selected because samples collected in each of them were at least reasonably large at each of the stations, with only two exceptions: in 1976 we did not collect data at Milwaukee, and since the samples there were small in other years, we eliminated the station from consideration; and in 1979 the sample of females at Grand Haven was extremely small, and we substituted 1978 data from that station instead. Perhaps the best impression of the geographical differences in growth is obtained from a comparison of the combined data for Michigan waters with those of Indiana–Illinois (Table 13). Although the differences were not great at the end of the first year of growth, by the end of the third year males in Michigan were 11 mm longer than those in Indiana–Illinois (197 vs. 186 mm), and females were 19 mm longer (214 vs. 195 mm). The slower growth in Indiana–Illinois probably resulted largely from the generally colder nearshore water present in that area during

Table 13. *Calculated total lengths at end of each year of life of male and female yellow perch taken at different localities in 1976 and 1979.*[a] (Entries represent unweighted averages of the values for the two years.)

	Year of life, and sex											
	1		2		3		4		5		6	
Locality	M	F	M	F	M	F	M	F	M	F	M	F
Michigan												
Grand Haven	78	78	154	160	198	214	227	248	246	278	258	299
Saugatuck	83	81	158	162	202	222	227	258	245	286	259	308
South Haven	82	81	155	159	197	215	223	250	240	279	255	308
Benton Harbor	84	83	157	157	196	212	222	246	241	269	255	299
New Buffalo	83	81	154	157	191	209	216	241	235	275	250	
Indiana–Illinois												
Michigan City	83	76	150	148	189	207		229				
Gary	81	74	149	145	186	194	209		219			
Waukegan	80	76	139	140	183	184						
Average, Michigan	82	81	156	159	197	214	223	249	241	277	255	304
Average, Indiana–Illinois	81	75	146	144	186	195	209	229	219			

[a]1976 and 1978 at Grand Haven.

Table 14. *Calculated total lengths at end of each year of life of male and female yellow perch taken in different years at Saugatuck, South Haven, and Benton Harbor.* (Entries represent unweighted averages of the values for the three localities.)

Year of capture	Year of life, and sex									
	1		2		3		4		5	
	M	F	M	F	M	F	M	F	M	F
1971	90	88	164	171	208	226	237	254	256	274
1973	88	86	166	164	209	226	239	263	262	293
1974	89	88	164	169	209	230	235	263	257	288
1975	86	86	162	169	206	229	232	264	249	290
1976	83	82	157	161	202	220	230	257	247	286
1977	83	83	159	162	201	221	230	261	247	291
1978	84	80	157	161	198	216	222	249	239	275
1979	83	82	157	158	193	215	226	249	239	272

the perch growing season. Southwesterly winds that are so prevalent during the summer tend to push epilimnial waters away from the western and extreme southern shores, leaving nearshore waters there colder than on the east side of the lake. The slower average growth of the sample fish from Indiana–Illinois may also have been related to some unknown extent to removal by the commercial fishery of disproportionate numbers of the faster growing individuals.

Differences According to Year of Capture

Perch grew slightly slower in the later than in the earlier years of the study. Although the decline in growth obviously occurred in all areas, the best data for showing the changes were from Saugatuck, South Haven, and Benton Harbor; at least reasonably large numbers of fish were aged from each of these localities in each year of the study except 1972 (when age data were collected only at Saugatuck), a year that we ignored in the analysis. To make the year-to-year comparisons, we computed the averages of the back-calculated lengths for five age groups for the three localities (Table 14).

The decline in growth did not occur until after 1975, and even then was rather gradual and irregular. However, by 1979 the differences in length for fish of a given age had become appreciable. In 1979, as compared with 1975, males at ages I, III, and V were shorter by 3, 13, and 10 mm, respectively, and females by 4, 14, and 18 mm. (We did not make the comparisons for fish older than 5 years, because data were scanty for those ages in the earlier years.) McComish (1977, 1981) reported a steady, marked decline in growth of yellow perch in the Michigan City area between 1975 and 1979. As an example of the extent of the decline that he described, males at the end of 3 years of growth were 36 mm shorter, and females 45 mm shorter, in 1979 than in 1976. Our data did not indicate a decrease in growth at Michigan City as striking as that reported by McComish, although it was greater there than in the Saugatuck–Benton Harbor area. We offer no explanation for the slower growth after 1975 except to speculate that in 1978 and 1979 it might have been related at least in part to the cold winters (followed by slow warming in spring) in 1977–78 and 1978–79.

Comparisons with Other Studies

Several previous studies of growth of yellow perch in Lake Michigan are available (Table 15), some of which were conducted within the time period of our study and in parts of our study area. The findings of Keller et al. (1974) relative to growth rates of perch at South Haven in the early 1970's agree closely with ours. However, McComish (1977, 1981) reported growth rates at Michigan City that were faster in 1975 and 1976, and slower (except in the first year of life) in 1979, than our data indicated. Although our samples from Michigan City were sometimes smaller than ideal (McComish's were larger), we do not believe that larger samples would have greatly affected our results. We suspect that the differences in results between the two studies stem from differences in interpretation of year marks on the scales.

Investigators working in Lake Michigan outside our study area have reported a rather wide range of growth rates for yellow perch. At Ludington (100 km north of Grand Haven) in 1972, perch grew faster, at least through the third year (Brazo et al. 1975), than at any of our stations in any year; whereas in Green Bay and in northern Lake Michigan near Beaver Island in 1932–38 (Hile and Jobes 1942) and at Grand Haven in 1954 (Wells 1977) they grew much slower than the fish we examined. Wells (1977) described a marked increase in yellow perch growth in the Grand Haven area between 1954 and 1970, and attributed the change to an abrupt decline in perch abundance. We suspect that the slow growth rates reported by Hile and Jobes (1942) related more to the abundance of the perch than to the geographical area of the lake that they inhabited.

Table 15. *Total lengths of yellow perch at end of each year of life in different areas of Lake Michigan.*[a]

		Year of life, and sex													
		1		2		3		4		5		6		7	
Area and reference	Year	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Green Bay (Hile and Jobes 1942)	1932–38	73	72	117	117	154	162	186	203	217	231	246	266	264	292
Northern (Beaver Is.)[b] (Hile and Jobes 1942)	1937	72		114		152		180		214		247			
Grand Haven (Wells 1977)	1954			128	126	154	163	179	189	188		193			
Ludington (Brazo et al. 1975)	1972			186	190	213	241	250	262	274	294	288	339	294	365
South Haven (Keller et al. 1974)	Early 1970's			163	175	203	229	236	267	249	284				
South Haven (Present study)	1971	88	90	161	173	205	230	238	255	254	271				
Michigan City (McComish 1977)	1975	106	108	178	188	210	235	240	266	255	292		318		
Michigan City (Present study)	1975	82	82	157	161	196									
Michigan City (McComish 1981)	1976	102	107	162	168	209	219	216	243		273		297		
Michigan City (Present study)	1976	82	77	153	158	189									
Michigan City (McComish 1981)	1979	100	100	134	134	173	174	198	202	212	216	250	239		
Michigan City (Present study)	1979	83	74	147	138	188	201	205		215					
Saugatuck (Present study)	1971–79	85	85	162	167	207	227	235	261	255	288	267	310	279	326

[a]The values for Green Bay, northern Lake Michigan, and Ludington were originally given in standard lengths. We converted these values to total lengths, using factors from Hile and Jobes (1942). For standard lengths 149 mm and less, the factor was 1.185; for lengths 150–209 mm it was 1.172; and for lengths greater than 209 mm it was 1.167.
[b]Lengths given only for sexes combined.

Weight–Length Relations

The relation of weight to length of yellow perch in the study area varied according to sex, year, and locality. These conclusions were based on covariance analysis of the differences in variables a (intercept) and b (slope) in the equation Log_{10} weight (g) = $\text{Log}_{10}\, a + b\ \text{Log}_{10}$ length (mm), derived for each sex for each year (localities combined) and locality (years combined). The analyses showed that both constants were nearly always significantly different between sexes and that either or both sometimes differed with year or locality. In deriving the equations, we used only data collected in July, to minimize possible differences relative to time of year. Consequently, the 1978 data, all of which were collected in August, were disregarded. We also eliminated the data for 1972, because weights of individual fish were not recorded at most localities, and those for 1975 because inclusion in the samples of some fish that had just completed spawning may have added another variable to the comparisons. We included data only from Saugatuck, South Haven, Benton Harbor, and Michigan City. Collections at other localities either were not made in all of the years under consideration, or were too small for meaningful analysis (or both). We do not present the equations for the separate years and localities, but rather show calculated weights at selected lengths between 100 and 350 mm, based on the equations (Tables 16 and 17).

Growth in weight with increase in length was faster among females than males, at least at lengths above 150 mm. Females generally were slightly lighter than males, or of about the same weight, at lengths up to 150 mm, but were nearly always heavier than males at a length of 200 mm, and always conspicuously heavier at 250 mm (Tables 16 and 17). Little of the females' faster

Table 16. *Calculated weights (g) of male and female yellow perch of selected lengths in different years, based on equations derived from combined data for Saugatuck, South Haven, Benton Harbor, and Michigan City.*

	Total length (mm) and sex																			
	100		150		175		200		225		250		275		300		325		350	
Year	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1971	10	12	38	41	60	65	91	99	131	142	183	197	246	264	324	345	415	441	525	555
1973	11	9	38	34	60	57	91	88	129	131	178	186	237	256	309	342	374	446	491	572
1974	10	9	35	33	56	56	85	87	122	129	169	184	227	253	297	338	381	442	479	566
1976	9	9	35	34	57	57	87	89	125	133	173	189	233	261	306	350	392	458	494	588
1977	11	10	36	36	57	59	84	90	120	130	163	181	216	244	279	321	354	412	440	521
1979	10	9	34	34	54	56	81	85	113	125	155	175	205	237	265	313	336	405	419	513
All years	11	10	36	36	57	59	86	90	122	132	168	186	223	253	290	335	369	433	460	551

growth in weight with length resulted from greater increases in gonadal tissue, because gonads were poorly developed in July.

Some general decline in robustness occurred among perch of both sexes from the earlier years of the study to the more recent ones (Table 16). For example, the computed weights of males and females 250 mm long were 183 and 197 g, respectively, in 1971, compared with 155 and 175 g in 1979. The downward trend in the relation of weight to length was generally fairly steady, except for a rather distinct increase in 1976. We cannot explain the general tendency toward somewhat poorer condition in the later years of the study.

The relation of weight to length varied little among localities in fish of either sex, even when the constants for intercept and slope in the weight–length equation were significantly different statistically (Table 17). For example, although both constants were significantly different ($P < 0.05$) for males at Saugatuck and South Haven, the differences at these localities relative to weights of males of given lengths between 100 and 350 mm never exceeded 19 g as computed from the equation. Among all four localities, the computed weight of fish 300 mm long covered a range of only 4 g (291 to 295) for males and only 12 g (330 to 342) for females.

The weight–length equations of males and females derived from the combined data for all years and localities follow.

Males: $\log_{10} W = -4.9777 + 3.0034 \log_{10} L$, or
$W = 1.0527(10^{-5}) \times L^{3.0034}$

Females: $\log_{10} W = -5.4739 + 3.2290 \log_{10} L$, or
$W = 3.3581(10^{-6}) \times L^{3.2290}$

Weights for selected lengths between 100 and 350 mm, as computed from these equations, are shown in the bottom line of Table 16.

Because weight–length equations for yellow perch presented in the literature nearly always refer to sexes combined, we considered it advisable to derive such an equation. It is given here, based on the combined data for all years and localities.

$\log_{10} W = -5.5725 + 3.2644 \log_{10} L$, or
$W = 2.6761(10^{-6}) \times L^{3.2644}$

Spawning Season, Age and Size at Maturity, and Fecundity

We had to rely largely on incidental data collected during other studies, mostly at Saugatuck, for information on spawning season, maturity, and fecundity and some of our

Table 17. *Calculated weights (g) of male and female yellow perch of selected lengths at different localities, based on equations derived from combined data for 1971, 1973, 1974, 1976, 1977, and 1979.*

	Total length (mm) and sex																			
	100		150		175		200		225		250		275		300		325		350	
Locality	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Saugatuck	9	10	33	37	53	60	81	99	118	134	165	188	223	255	293	337	377	436	477	553
S. Haven	11	10	38	37	59	60	88	92	124	132	170	185	225	250	291	330	368	424	458	538
B. Harbor	11	9	36	36	58	56	86	87	124	128	170	181	227	249	295	332	377	433	471	553
Mich. City	11	9	36	36	57	58	86	91	123	133	169	188	225	257	293	342	373	444	467	567

conclusions must therefore be rather general. Most of the data gathered routinely for the study were deficient for the present purposes because no fish were collected immediately before or during the spawning season, and because the sampling gear was not suitable for sampling small fish.

Spawning Season

Yellow perch in southeastern Lake Michigan spawned mainly from late May to mid June, and occasionally in late June; the data do not permit precise bracketing, for any year, of the range of spawning dates or the period of peak spawning. Males moved into spawning areas well in advance of the females, and remained there for perhaps a week or more after all females had spawned and most had departed. (Perch spawning sites in southeastern Lake Michigan are not fully known, but may include any shallow water—probably mainly less than 15 m deep—where the bottom is not smooth. The rocky reef south of Saugatuck, where our index station was situated, is a well-known, heavily used spawning ground; however, a bottom of such extreme irregularity is certainly not required.) It is difficult to determine by field examination when males begin spawning, because, as judged by shipboard observation of sample fish, some milt can be expressed from the testes before their appearance has changed significantly. Therefore, the seasonal progress of spawning is best determined through examination of female gonads, which change in appearance suddenly and conspicuously when the eggs are released.

Following are limited data concerning spawning dates in several years, derived from the examination of gonads of females collected on the spawning grounds near Saugatuck (except as noted). In 1966, spawning had begun by 25 May when 1 of 16 females was spent, and was well along by 29 May when 27 of 67 had spawned (at Michigan City). In 1971, when spawning apparently had not begun by 29 May, 58 of 72 females (81%) taken on 13–15 June were spent. In 1972, only 11 of 47 (23%) were spent on 8 June, but on the same date in 1974, 170 of 177 (96%) had spawned. As mentioned earlier, our index samples collected at Saugatuck and several other stations during 8–15 July 1975, contained large numbers of freshly spent males and a few spent females, suggesting that spawning was not over until the end of June or perhaps early July.

Yellow perch usually seem to spawn in about mid June in Illinois waters of Lake Michigan (B. Muench, Illinois Conservation Department, personal communication). Perhaps spawning is somewhat later on the west side of the lake as a result of slower warming of nearshore waters in spring. Prevailing winds tend to move epilimnial waters away from the west shore. Brazo et al. (1975) stated that spawning in east-central Lake Michigan near Ludington in 1972 extended from mid May through the end of June; however, they did not actually observe a spent female in May or early June. Patriarche (1975) reported that about one-third of the female perch caught in the heated effluents of the Palisades power plant on 8 May 1973 were spent, but he believed that the warm water had advanced spawning by 3–4 weeks.

Age and Size at Maturity

Our data provided some insight into the age and size at maturity of yellow perch in southeastern Lake Michigan, but nothing highly quantitative. They indicated that at least some males reached maturity in their first year (i.e., spawned at an age of about 1 year), and nearly all the rest in their second year. It appeared that few males less than 85 mm long at the time of the spawning season were mature (the smallest mature male observed in late fall, presumably after growth cessation, was 79 mm), but that most longer than 100 mm and virtually all longer than 130 mm were mature. A few females attained maturity in their second year, but most not until their third year, and a few not until their fourth. Although we observed gravid females as short as 148 mm (in April), it appeared that few spawned at a length under 180 mm; however, most females as long as 210 mm in the spring spawned.

McComish (1977) reported that in the vicinity of Michigan City, 77–96% of the males captured in July–August 1975 and 1976 were mature in their second year, and all in their third year. Among females, about one-half to two-thirds were mature in their third year, and all in their fourth year.

Fecundity

Based on an examination of the ovaries from 49 females collected at Saugatuck on 4–7 May 1972 and 16 April 1979, yellow perch 174–355 mm long and weighing 78–760 g contained an estimated 9,300 to 136,000 eggs. The estimates were based on actual counts of the eggs in known proportions by weight of the ovaries. The subsamples consisted of segments removed from 5 to 10 widely distributed areas of the ovaries and contained from 1,102 to 6,807 eggs (average 2,447). Although, as would be expected, the number of eggs generally increased with the size of the fish, they occasionally differed widely among fish of similar lengths. For example, the numbers varied from 60,000 to 102,000 among four fish in the narrow length range of 300–319 mm (Table 18).

The mathematical relation between number of eggs (E) and length of fish in millimeters (L), calculated from individual data points, is described by the curvilinear regression $E = 1.023\ (10^{-4}) \times L^{3.56}$ ($r = 0.96$). This regression is similar to that obtained by Brazo et al. (1975) for yellow perch in east-central Lake Michigan. The number of eggs computed from our equation, as compared with the num-

Table 18. *Estimated fecundity of yellow perch of different lengths, based on gravid females taken off Saugatuck on 4–7 May 1972 (23 specimens), and 16 April 1979 (26).*

Total length (mm)		Number	Number of eggs (thousands)	
Range	Average	of fish	Range	Average
160–179	174	1	9.3	9.3
180–199	194	3	15–22	17
200–219	212	6	14–24	19
220–239	227	10	20–31	26
240–259	251	8	21–38	30
260–279	264	3	38–45	41
280–299	287	4	62–71	67
300–319	307	4	60–102	76
320–339	328	4	103–120	110
340–359	351	6	89–136	110

ber calculated from the equation of Brazo et al., is 6.9% fewer for fish 200 mm long, but becomes more closely similar with increasing length, and is virtually the same for fish 350 mm long.

The relation between number of eggs (E) and weight of fish in grams (W) is described by the linear regression $E = 5{,}169 + 183\ W$ ($r = 0.97$). The number of eggs for fish of a given weight are smaller when computed from this equation than from an equation developed by Brazo et al. (1975) for perch in east-central Lake Michigan. For example, fish weighing 100 g contained 30% fewer eggs when estimated from our equation; the difference decreases with increasing weight of fish, but even at a weight of 600 g the fish in our study contained 6.9% fewer eggs. Considering that the regression of egg count on length of fish did not differ greatly in the two studies, the results relative to egg count on weight suggest that the perch in our samples from southeastern Lake Michigan were more robust than the perch at Ludington; i.e., for fish of a given weight, ours were shorter and consequently would contain fewer eggs. However, we suspect that such differences in egg count with weight of fish, at least with respect to the smaller (i.e., lighter) fish, did not actually exist between the perch populations in the two areas under consideration, and that the variations were in some way related partly to sampling error or methods of analysis.

Mortality

Although the catch data do not provide a basis for highly accurate estimates of mortality of yellow perch in southern Lake Michigan, we believe it is possible to obtain by catch-curve analysis an approximation of total mortality, at least in State of Michigan waters. The analyses (sexes separate) are based on the age distributions of the average annual catches during 1976–79; data considered are those from the 5.1-, 6.4-, 7.6-, and 8.9-cm meshes, fished at 5.5, 11, and 16 m (see Table 10). Mortality estimates were derived for the combined data for all Michigan localities, excluding Saugatuck. We disregarded the data for Saugatuck because the large proportion of older fish there seemed to provide an age structure that represented the populations in only a relatively small (uniquely rocky) portion of the Michigan waters within our study area, and inclusion of the data probably would have resulted in estimates of mortality that were too low. Any overestimation of mortality caused by this exclusion should have been slight. The age distributions of the mean catch on which we based our mortality estimates follow:

	I	II	III	IV	V	VI	VII	VIII
Male		30	215	107	93	38	3	
Female	2	79	134	104	41	26	19	4

To make the calculations, we used the method described by Robson and Chapman (1961). This method is intended for analysis of the catch curve of a single year's catch, with the assumption that the recruitments of the year classes involved are about equal. We averaged data from several years with the hope of reducing the effects of any differences in year-class strength.

As estimated from the age distributions tabulated, the mortalities of male and female yellow perch after age III (the age at which both sexes were assumed to reach full vulnerability to the gear) in State of Michigan waters were 52 and 48%, respectively.

Data on which to base mortality estimates for yellow perch in Indiana–Illinois are scant, although they seem sufficient to indicate that mortality in this area was higher than in Michigan. Somewhat more data are available for males than for females. The estimated mortality of males after age III was 71%, as judged from the combined data from Michigan City, Gary, and Waukegan in 1976–79 (in which frequencies for ages II through VI were 10, 64, 21, 8, and 3, respectively). The sparse information on females suggested that their mortality was even higher than that of males.

Mesh Selectivity

Although the objectives of the study did not include an analysis of the sizes of yellow perch taken by each of the mesh sizes in the sampling nets, a brief consideration of this subject might be useful. The perch populations in State of Michigan waters provided an opportunity to observe mesh selectivity that is perhaps unique among Great Lakes perch populations in that they contain a wide range of sizes in large numbers, mainly because size distribution has not been truncated by an intensive size-selective commercial fishery. Thus our results, which pertain to State of Michigan waters only, probably give a more accurate indication

Table 19. *Length frequencies (percentages) of male and female yellow perch from State of Michigan waters arranged according to mesh size in which captured.* (Entries based on combined catches from all localities and depths in 1976–79.)[a]

	Mesh size (cm), sex, and number of fish											
	3.8		5.1		6.4		7.0		7.6		8.9	
	M	F	M	F	M	F	M	F	M	F	M	F
Total length (mm)	114	104	896	571	482	381	168	298	122	499	5	410
110–119				T								
120–129				T		T						
130–139				T					1			
140–149										T		
150–159	11	14										
160–169	16	23	T	1			1		1	T		T
170–179	18	25	1	4	T			1	1	T		
180–189	22	20	5	10			1			T		
190–199	11	6	13	11	T							T
200–209	5	4	25	13	T	T						
210–219	6	1	20	16	1				1			
220–229	3	4	17	18	3	2				T	20	T
230–239	2		10	11	8	8	2	1			20	T
240–249	4		5	7	24	15	14	3	4	1		
250–259	1	2	3	4	34	19	21	11	7	1		T
260–269	1	1	1	3	19	19	33	16	11	4		T
270–279		1	1	1	7	10	19	16	34	7	20	1
280–289			T	1	2	8	9	13	20	11		1
290–299				T	T	4	1	8	15	15		3
300–309				1	T	6		8	7	12	20	6
310–319						4		7		16	20	17
320–329				T		3		10	1	14		26
330–339				T		2		3		10		19
340–349				T		T		2		5		16
350–359				T		T		2		2		7
360–369										1		2
370–379										T		
Average length	187	180	215	218	254	267	263	286	275	306	267	327
Average age	2.8	2.2	3.6	3.2	5.3	4.5	5.5	5.1	6.2	5.8	5.5	6.7

[a]T = trace (less than 0.5).

of the size selectivity of the different meshes than would ordinarily be obtained.

Each mesh size in our sampling gill nets was rather selective in the size of perch it captured. For quantitative consideration we examined the length distributions by sex in each mesh size, for the combined catches of 1976–79 from all depths and localities (Table 19). Catches were not adjusted to equal amounts of each mesh size, and thus are not useful for comparing the relative efficiency of the different meshes in terms of total numbers caught; in any case, the relative numbers caught in each mesh varied in different years and localities, according to the existing size structure of the population being sampled. Within the length distributions of males and females for individual mesh sizes, most fish were always in four consecutive 10-mm length intervals (i.e., within a 40-mm interval), except for males in 8.9-cm mesh. Obviously, males large enough to be gilled in 8.9-cm mesh were rare, and some of the few that were caught were small fish that had become entangled in the webbing by their spines or other protuberances; data regarding males in 8.9-cm mesh are disregarded in this discussion. The tight grouping of lengths within a mesh size was more conspicuous in males than in females. Depending on the mesh, 67 to 87% (average, 79%) of males fell within a 40-mm bracket, whereas corresponding percentages for females were 56 to 82 (average 66).

Successively larger meshes took increasingly larger fish, most obviously so among the females. The average length of males increased progressively from 187 mm in the 3.8-cm mesh to 275 mm in the 7.6-cm mesh; and the average length of females increased steadily from 180 mm in the 3.8-cm mesh to 306 mm in the 7.6-cm mesh and 327 mm in the

8.9-cm mesh. The greater average length of females than males in the larger meshes must have resulted from the much better representation of large females in the population (as evidenced by their much better representation in the catches of the larger meshes) – i.e., the proportion of gilled to entangled fish was greater among females. If the length distributions of the two sexes in the populations had been similar, a given mesh size should have taken, on the average, somewhat shorter females than males, since females of a given girth were somewhat the shorter.

McComish (1981), examining size selectivity relative to perch of 5.1-, 6.4-, and 7.6-cm gill-net meshes fished off Michigan City during 1976–79, found (as we did in our combined data from Michigan waters) that the average lengths of males and females were not greatly different in the 5.1-cm mesh but that females were definitely the larger in the 6.4-cm mesh; the comparison cannot be made for the 7.6-cm mesh, because few males in McComish's study were taken in it. The average size of fish for a given mesh size was less in McComish's study than in ours. For example, the length of females caught in the 7.6-cm mesh averaged about 263 mm in his study as compared with 306 mm in ours. The difference is probably due to the generally greater abundance of larger fish in Michigan than in Indiana waters.

Although we did not compute age distribution by mesh size, our data show that the average ages of both sexes increased progressively with mesh size and that the average age of males was slightly greater than that of females in each mesh (Table 19). Average ages of males and females from the 3.8-cm mesh were 2.8 and 2.2 years, respectively; and from the 7.6-cm mesh, 6.2 and 5.8 years. The average age of females caught in the 8.9-cm mesh was 6.7 years.

Outlook

After the severe decline in the early and mid 1960's and partial comeback in the late 1960's, yellow perch in Lake Michigan failed to regain their former abundance in the 1970's. (The statements in this section relative to perch abundance outside the study area during the 1970's are based on unpublished data collected by the U.S. Fish and Wildlife Service and natural resource agencies of States bordering the lake.) On the contrary, it appears that populations decreased during the 1970's, although neither steadily nor drastically. It is doubtful that at any time during the 1970's perch were at the pre-1960 levels anywhere but in the most favorable habitat; they were probably farthest below the pre-1960 levels in areas other than Green Bay and the region from Saugatuck around the south end of the lake to Chicago. Removal by commercial fisheries (and to a lesser extent the sport fisheries) in Indiana, Illinois, and Wisconsin were almost surely affecting the abundance of perch appreciably, particularly of the older ones. However, in Michigan's waters, where commercial fishing was not permitted and where the sport fishery was not intense in many areas, it seems improbable that fishing mortality was seriously influencing the populations, except in isolated areas.

We suspect that the failure of yellow perch in Lake Michigan to increase during the 1970's was due at least partly to interference with their reproduction by alewives – the same factor held by some workers to have caused the precipitous decline in the 1960's. Although alewives were not as abundant as in the early and mid 1960's, they were nevertheless exceedingly common in the 1970's (E. Brown, Great Lakes Fishery Laboratory, unpublished manuscript). Probably yellow perch in Lake Michigan will never regain their abundance of the pre-1960's, at least lakewide, as long as the alewife remains a major component of the fish population.

References

Brazo, D. C., P. I. Tack, and C. R. Liston. 1975. Age, growth, and fecundity of yellow perch, *Perca flavescens*, in Lake Michigan near Ludington, Michigan. Trans. Am. Fish. Soc. 104: 726–730.

Brown, E. H., Jr. 1968. Population characteristics and physical condition of alewives, *Alosa pseudoharengus*, in a massive dieoff in Lake Michigan, 1967. Great Lakes Fish. Comm. Tech. Rep. 13. 20 pp.

Hile, R., and F. W. Jobes. 1942. Age and growth of yellow perch, *Perca flavescens* (Mitchill), of Saginaw Bay and northern Lake Michigan. Pap. Mich. Acad. Sci. Arts Lett. 27:241–266.

Keller, M., M. H. Patriarche, and R. W. Rybicki. 1974. Status of selected fish stocks in Lake Michigan and recommendations for commercial harvest. Pages 69–150 *in* J. D. Bails and M. H. Patriarche, eds. Status of selected fish stocks in Michigan's Great Lakes waters and recommendations for commercial harvest. Fishery Division, Michigan Department of Natural Resources.

McComish, T. S. 1977. Yellow perch (*Perca flavescens*) population characteristics in Lake Michigan. Ball State University, final report, Federal Aid Proj. 3-217-R. 34 pp.

McComish, T. S. 1981. Yellow perch population characteristics in Indiana waters of Lake Michigan, 1976–79. Ball State University, final report, Federal Aid Proj. 3-283-R. 97 pp.

Patriarche, M. H. 1975. Reaction of nearby Lake Michigan fish stocks to a heated discharge at the Palisades Site. Mich. Dep. Nat. Resour., Fish. Div., Fish. Res. Rep. No. 1820. 38 pp.

Patriarche, M. H. 1977. Quota recommendations for Great Lakes stocks. Michigan Department of Natural Resources Dingell-Johnson Annual Report, July 1, 1976–September 30, 1977. Proj. F-35-R-3, Study No. VII:259–265.

Robson, D. S., and D. G. Chapman. 1961. Catch curves and mortality rates. Trans. Am. Fish. Soc. 90:181–189.

Smith, S. H. 1970. Species interactions of the alewife in the Great Lakes. Trans. Am. Fish. Soc. 99:754–765.

Wells, L. 1968. Seasonal depth distribution of fish in southeastern Lake Michigan. U.S. Fish Wildl. Serv., Fish. Bull. 67:1–15.

Wells, L. 1977. Changes in yellow perch (*Perca flavescens*) populations of Lake Michigan, 1954–75. J. Fish. Res. Board Can. 34: 1821–1829.

Wells, L. 1980. Food of alewives, yellow perch, spottail shiners, trout-perch, and slimy and fourhorn sculpins in southeastern Lake Michigan. U.S. Fish Wildl. Serv., Tech. Pap. 98. 12 pp.

Wells, L., and A. L. McLain. 1973. Lake Michigan: Man's effects on native fish stocks and other biota. Great Lakes Fish. Comm., Tech. Rep. 20. 55 pp.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1983—679 – 975.

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