SEASONAL DEPTH DISTRIBUTION OF FISH IN SOUTHEASTERN LAKE MICHIGAN

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ABSTRACT

This study is based on systematic seasonal bottom trawling between 3 and 50 fathoms (5.5 and 91.5 m.) from February to November 1964 and supplementary information from other experimental fishing at additional depths and with other gear. The seasonal depth distribution of eight common species is described, and temperature relations are discussed. Catch records for less common species are mentioned briefly.

Alewives are mostly pelagic during their first 2 years, but many young of the year are on the bottom in the fall, and yearlings occasionally descend to the bottom in substantial numbers in the spring and fall. Adults are mostly on the bottom in the winter and spring, but a significant portion of the population may be at midlevels in the summer and fall. Bloaters are in midwater during their first 2 years, but usually on the bottom thereafter. Young-of-the-year American smelt are in midwater except in the fall, yearlings are in midwater or on the bottom, and adults are mostly on the bottom.

Alewives, bloaters, smelt, spottail shiners, trout-perch, and yellow perch on the bottom moved into shallower water in the spring and into deeper water in the fall, in response to temperature changes. Slimy sculpins abandoned inshore areas as water warmed in the spring. Fourhorn sculpins showed a slight movement shoreward in the spring, but changed their depth distribution little thereafter to the end of the trawling season.

Alewives showed the greatest seasonal change in distribution. Large concentrations at 40 to perhaps 70 fathoms (73.2–128.0 m.) in mid-March had migrated to water of less than 15 fathoms (27.4 m.) by mid-April. They were in shallow water along shore or in rivers until early summer; then they began a postspawning movement back into deeper water which continued into the fall. Depth ranges in which greatest numbers of other common species occurred, considering all seasons as a whole, were as follows: bloater, 12 to 50 *fathoms* (21.9–91.5 m.); American smelt, 5 to 17 fathoms (9.1–31.1 m.); spottail shiners, 3 to 15 fathoms (5.5–27.4 m.); trout-perch, 5 to 17 fathoms (9.1–31.1 m.); yellow perch, 3 to 15 fathoms (5.5–27.4 m.); slimy sculpins, 15 to 40 fathoms (27.4–73.2 m.); fourhorn sculpins, 45 to 70 fathoms (82.2–128.0 m.).

Water temperature ranges (° C.) in which the various species were most abundant in summer were: alewife, 8 to 22; bloater, 6 to 10; smelt, 6 to 14; spottail shiner, 13 to at least 22; trout-perch, 10 to 16; yellow perch, 11 to at least 22; slimy sculpin, 4 to 6; fourhorn sculpin, 4 to 4.5. Fluctuations in inshore water temperatures in the summer caused short-term changes in depth distribution.

Published records of depth distribution of fish in the Great Lakes have been limited largely to general information included as part of other studies. Data on seasonal aspects of distribution are especially scarce, although Dryer (1966) gave considerable information on seasonal changes in bathymetric distribution of fish in the Apostle Islands region of Lake Superior. His review of current literature on the depth distribution of Great Lakes fish need not be repeated here. The present paper describes the seasonal depth distribution of eight of the most abundant species in Lake Michigan and gives information on the effect of temperature on depth distribution, especially during the summer.

METHODS AND MATERIALS

Data were obtained from bottom tows with a semiballoon trawl in 1964 off Saugatuck, Mich. This net had a 39-foot (11.9 m.) headrope, 51-foot (15.5 m.) footrope, and a cod end of ½-inch (1.3

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cm.) mesh, extension measure. Series of tows (one haul at each of 14 depths) were made from the R/V *Kaho* in mid-February and mid-March, and from the R/V *Cisco* at about 3-week intervals from April 11 to August 21, in mid-October, and in early November. A "standard" series of tows consisted of bottom tows along the contour at 3, 5, 7, 10, 12, 15, and 17 fathoms (5.5, 9.1, 12.8, 18.3, 21.9, 27.4, and 31.1 m.) and at 5-fathom (9.1 m.) intervals from 20 to 50 fathoms (36.6 to 91.5 m.). Distances from shore of the sampling depths ranged from 0.4 to 16.7 nautical miles (0.7–31.0 km.) (table 1). Ice prevented the collection of samples at 3 fathoms (5.5 m.) in February and March. All tows lasted 10 minutes except those at 3 fathoms (5.5 m.) which lasted only 5 minutes, due to limited areas of suitable trawling bottom. The catches at 3 fathoms (5.5 m.) were adjusted to 10 minutes in all tabulations. All 14 tows of each standard series were made on the same day, with two exceptions (February 13 and 14; July 7 and 9), when tows at 45 and 50 fathoms (82.3 and 91.5 m.) were made 1 or 2 days after shallower tows. The dates "February 13" and "July 7" are used here in all further references to these series.

Engine speed was the same for all tows, and the trawling speed was about 2.6 knots. Variation in speed of tows during periods of significant wind was minimized by making all tows (which, to follow the bottom contours, were always either north or south) with the wind on a stern quadrant. Currents along the shore in the study area are highly responsive to wind and ordinarily flow north or south according to the wind. We did not trawl during periods of high winds.

Bathythermograph casts were made at the beginning of each tow, and the surface water temperature was recorded continuously with a thermograph.

The catch was sorted by species and by age groups when possible. Usually total catches of all species were retained, but occasionally large catches of individual species were subsampled. Discarded fish of a species were weighed as a group and counted or, rarely, their number was estimated on the basis of their average weight in the subsample. Data were taken from some fish on the date of collection, but most specimens were stored in plastic bags in an ice chest and examined on the following day. The data for each tow included counts and total weights of each species and individual total lengths and weights of certain species.

Although this study is based primarily on catches of the "standard" series of bottom trawl tows, information has been used from other bottom trawling, midwater trawls, gill nets, and underwater television. These supplementary data, which were gathered in Lake Michigan (mostly by the R/V *Cisco*) in 1954, 1955, and 1960–67, serve primarily to extend observations into midlevels, into

TABLE 1.—*Bottom temperatures at all sampling depths during all standard series of trawl tows in southeastern Lake Michigan*

Depth	Distance from shore		Date (1964)										
			Feb. 13	Mar. 11	Apr. 15	May 5	May 26	June 16	July 7	July 28	Aug. 21	Oct. 14	Nov. 4
Fathoms	*Nautical miles*	*Km.*	*° C.*	*° C.*	*° C.*	*° C.*	*° C.*	*° C.*	*° C.*	*° C.*	*° C.*	*° C.*	*° C.*
3	0.4	0.7	-----	-----	6.7	9.4	14.8	7.9	12.9	22.3	16.5	12.2	11.9
5	.6	1.1	0.1	0.4	6.0	9.4	13.8	5.9	10.3	22.1	14.8	12.4	11.9
7	.9	1.7	.1	.5	4.0	8.8	13.3	5.4	8.4	16.1	13.4	12.2	11.8
10	2.0	3.7	.1	1.2	3.6	6.7	11.9	4.6	5.2	13.5	10.0	12.2	11.7
12	2.4	4.5	.2	1.4	3.7	4.3	11.5	4.3	5.0	8.4	7.9	12.2	11.7
15	3.3	6.1	.3	1.3	3.3	4.0	8.1	3.9	4.7	6.5	5.7	12.3	11.2
17	3.6	6.7	.5	2.0	3.0	3.9	7.8	3.8	4.6	6.4	5.5	11.7	11.0
20	4.0	7.4	.7	2.1	2.9	3.5	6.1	3.8	4.3	4.8	4.7	11.7	10.8
25	4.9	9.1	1.0	2.1	2.4	3.6	5.1	3.8	4.1	4.8	4.4	11.5	6.1
30	5.9	11.0	2.3	2.2	2.2	3.5	4.5	3.5	4.3	4.7	4.4	6.0	5.7
35	7.2	13.4	2.2	2.5	2.0	3.2	4.3	3.9	4.1	4.3	4.1	5.0	4.9
40	8.9	16.5	2.8	2.7	2.1	3.2	3.9	3.8	3.9	4.2	4.1	4.8	4.8
45	13.5	25.1	2.9	2.9	2.2	3.2	3.9	3.9	3.9	4.2	3.9	4.5	4.3
50	16.7	31.0	3.1	2.9	2.3	3.0	3.8	3.8	3.9	4.1	4.2	4.5	4.3

bottom areas deeper than those of the standard series, and (to a limited extent) to other portions of the Lake.

Common and scientific names of the species mentioned in the text, listed below, follow the list published by the American Fisheries Society (1960).

Common name	*Scientific name*
Alewife	*Alosa pseudoharengus*
Gizzard shad	*Dorosoma cepedianum*
Bloater	*Coregonus hoyi*
Shortnose cisco	*Coregonus reighardi*
Longjaw cisco	*Coregonus alpenae*
Kiyi	*Coregonus kiyi*
Lake herring	*Coregonus artedii*
Lake whitefish	*Coregonus clupeaformis*
Lake trout	*Salvelinus namaycush*
American smelt	*Osmerus mordax*
Spottail shiner	*Notropis hudsonius*
Emerald shiner	*Notropis atherinoides*
Carp	*Cyprinus carpio*
Quillback	*Carpiodes cyprinus*
White sucker	*Catostomus commersoni*
Burbot	*Lota lota*
Ninespine stickleback	*Pungitius pungitius*
Trout-perch	*Percopsis omiscomaycus*
Yellow perch	*Perca flavescens*
Johnny darter	*Etheostoma nigrum*
Logperch	*Percina caprodes*
Slimy sculpin	*Cottus cognatus*
Spoonhead sculpin	*Cottus ricei*
Fourhorn sculpin	*Myoxocephalus quadricornis*

THERMAL CHANGES

The Lake was vertically homothermous at all sampling stations on February 13 and March 11. Bottom temperatures close to shore were near freezing (0.1° C.) and increased with depth to near 3.0° C. at 50 fathoms (table 1). Homothermous conditions continued through early May except near shore. On May 26 bottom temperatures had risen to 14.8 and 11.5° C. at 3 and 12 fathoms, respectively, and some thermal stratification had developed at depths greater than 12 fathoms. From mid-June until late August bottom temperatures of water 15 fathoms and deeper remained cold (3.9–6.5° C.), and thermal stratification became more pronounced. In water shallower than 15 fathoms (and especially at depths less than 12 fathoms) bottom temperatures in summer fluctuated and varied widely (7.9–22.3° C. at 3 fathoms). By October 15 the epilimnion had cooled and thickened so that the water was near 12° C. from surface to bottom at all stations out to 25 fathoms. Cooling progressed little from October 15 to November 4 because of unseasonably warm weather. A detailed account of seasonal thermal changes in Lake Michigan has been published by Church (1942, 1945).

DEPTH DISTRIBUTION

ALEWIFE

Alewives are the most widely distributed of any species in Lake Michigan. Depending on the time of year and life stage, they occupy all depths along the bottom and all waters above the bottom. Vertical distribution is discussed first, in general terms, then bottom distribution is described in more detail.

Young-of-the-year alewives, which hatch mostly in June and July, live at midlevels until late summer or early fall. They have been observed near the surface in early September in midlake and probably occur from shore to shore. They are always caught on the bottom in large numbers by October and have been taken in bottom trawls off Saugatuck as early as August 31. Many, however, are probably at midlevels even in the fall. Nearly all of the young on the bottom, regardless of date of capture, have been 1.5 to 3.5 inches (3.8–8.9 cm.) long, compared with an average calculated 1st-year growth of 3.7 inches (9.4 cm.). Thus, it appears that young alewives are on the bottom only at a certain size, and because the spawning season is rather long, all are not on the bottom at the same time. Possibly some alewives, particularly those which move into midlake in their earlier stages, may not go to the bottom at all in their first year. High winds and resultant turbulent conditions in the fall apparently cause most of the young on the bottom to ascend to midlevels temporarily.

Alewives after their first year tend more strongly toward a bottom existence as they grow older. Yearling alewives (age-group I) are essentially pelagic, but occasionally substantial numbers are on the bottom in the spring and fall, and a few are usually there in the summer.[1] Alewives move to the bottom in increasing numbers throughout their third year (age-group II) and make up a sizable portion of the bottom catch by late summer. Fish older than 3 years may be found on the bottom at all times, but usually are also at midlevels in varying proportions, depending on the season.

The midwater distribution of alewives, especially when the Lake is homothermous, is poorly known. When the Lake is stratified, young of the year apparently are confined to the epilimnion except in the fall. Concentrations of older fish have been found in the thermocline. Many, especially those older than yearlings, are also regularly above the thermocline and at times are probably present in large numbers a few fathoms off the bottom in areas where the bottom water is warm. In mid-August 1965, alewives older than 1 year were found in midwater from shore to shore in southern Lake Michigan.

The following discussion of bottom distribution is based almost entirely on alewives caught in standard series. Young of the year are referred to as "young" and older fish arbitrarily as "adults."

Young

Young alewives were first caught in the standard series on October 14 (table 2). At that time they were at all bottom depths to 25 fathoms at temperatures of 11.5 to 12.4° C. The temperature at the shallowest depth at which they were absent (30 fathoms) was 6.0° C. On November 4, when the cold bottom water (6.1° C.) had moved shoreward to 25 fathoms, young alewives were taken only at depths of 20 fathoms and less in bottom temperatures of 10.8 to 11.9° C. Largest catches, however, were deeper in November than in October; apparently a movement away from shore was in progress, but fish in the deepest water had moved shoreward to avoid cold water.

Young alewives in the November series were larger in deeper water. The average length ranged from 2.0 to 2.2 inches (5.1 to 5.6 cm.) in the tows at 3 to 10 fathoms and 2.6 to 2.9 inches (6.6 to 7.4 cm.) at 12 to 20 fathoms. This size-depth relation was not apparent in the October series, but was pronounced in sampling off several ports in southeastern Lake Michigan in 1967.

[1] Large numbers of yearling alewives were concentrated between the breakwalls at the mouth of the Kalamazoo River at Saugatuck in early July 1967. Commercial fishermen, who trawl for adult alewives between breakwalls in the spring and early summer, reported that such large numbers of small ones had not appeared before.

TABLE 2.—*Numbers of young-of-the-year (0 group) alewives and young-of-the-year smelt taken in 10-minute trawl tows at various depths, October 14 and November 4, 1964*

[No young-of-the-year alewives or smelt were caught at 30, 35, 40, 45, and 50 fathoms on either date; none were taken in standard series on Feb. 13, Mar. 11, Apr. 15, May 5, May 26, June 16, July 7, July 28, and Aug. 21]

Depth	Alewives		American smelt	
	Oct. 14	Nov. 4	Oct. 14	Nov. 4
Fathoms	*Number*	*Number*	*Number*	*Number*
3	6,658	1,714	0	0
5	2,985	1,478	0	0
7	1,701	2,599	10	0
10	312	107	313	564
12	780	319	673	247
15	525	1,591	145	89
17	75	1,989	85	37
20	602	5,863	47	3
25	302	0	14	0

Adults

Adult alewives showed a more striking seasonal migration than any other species. In February they were concentrated in deep water (table 3). They were taken at 30 to 50 fathoms in the standard series of February 13. The catches increased sharply with depth; 74 were caught at 30 fathoms and 11,267 at 50 fathoms. (Other catches by the R/V *Kaho* and reports from commercial fishermen indicate that concentrations in winter may extend at least to 70 fathoms.) By March 11 the beginning of a shoreward movement was evident. A few alewives were as shallow as 15 fathoms, but concentrations were still at the greatest depths. Movement toward shore was rapid after March 11; by April 15 the largest concentration was at 10 fathoms, and relatively few were taken at depths greater than 17 fathoms. The shoreward movement was probably greatest in the latter portion of the March 11 to April 15 period. Commercial fishermen reported heavy concentrations of alewives at 35 fathoms on April 7; on April 11 the R/V *Cisco* took few at 35 fathoms but large numbers at 20 fathoms. Adult alewives were present in large numbers at 3 fathoms on May 5 and 26. Concentrations probably extended into still shallower water. Catches also were large at 12 and 15 fathoms on May 5 and at 15 to 20 fathoms on May 26. Most alewives on the bottom remained in shallow water throughout the

TABLE 3.—*Number of adult alewives (I group and older) taken per 10-minute trawl tow at various depths, February 13 to November 4, 1964*

Depth	Date										
	Feb. 13	Mar. 11	Apr. 15	May 5	May 26	June 16	July 7	July 28	Aug. 21	Oct. 14	Nov. 4
Fathoms	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
3	(1)	(1)	938	3, 172	3, 506	466	736	0	90	88	9
5	0	0	594	652	917	107	126	11	63	144	176
7	0	0	1, 589	531	234	10	505	296	209	36	28
10	0	0	4, 201	372	998	38	0	358	208	104	198
12	0	0	1, 841	1, 113	708	57	0	162	188	115	238
15	0	5	1, 330	1, 019	1, 089	49	1	18	17	346	308
17	0	9	636	173	1, 125	40	1	7	8	327	204
20	0	28	192	74	1, 416	61	0	0	1	164	396
25	0	42	13	26	686	40	0	5	0	224	106
30	74	88	13	56	12	6	0	0	0	32	34
35	614	824	42	5	2	4	0	0	0	67	52
40	3, 326	5, 083	15	0	0	5	0	1	0	8	56
45	6, 201	9, 524	85	1	4	0	0	0	0	42	49
50	11, 267	7, 494	12	1	0	0	0	0	0	25	28

[1] No data.

summer. Some shift away from shore was evident in late July and August, however, and adult alewives were taken at all sampling depths on October 14 and November 4. Greatest numbers in the fall were at 5 to 25 fathoms.

Catches were considerably smaller in summer and fall than those made earlier. Several factors could account for this decline. In early summer large numbers had moved into the rivers for spawning and many others probably were along the Lake shore in water shallower than 3 fathoms. A substantial die-off in late spring and summer may have reduced the population enough to affect the trawl catches. It is possible also that the larger alewives at midlevels in summer represented a major segment of those which had moved back out into the Lake after spawning. These fish might well have remained at midlevels in the fall.

The size-depth relation of adult alewives changed with the seasons. Larger fish led the migration to shore during late winter and early spring. In February the average lengths at 30, 40, and 50 fathoms were 6.9, 6.6, and 5.5 inches (17.5, 16.8, and 14.0 cm.), respectively; in March at 20, 30, 40, and 50 fathoms the lengths were 7.0, 7.0, 6.6, and 5.9 (17.8, 17.8, 16.8, and 14.0 cm.). Size did not change with depth in April and early May, but after that the average size increased with depth (except in early July, when alewives were concentrated close to shore). The unweighted average length of alewives caught in the shallowest and deepest tows of the seven standard series after May 5 was 6.0 inches in the shallowest tows and 6.8 inches in the deepest (only tows that took 10 or more alewives were included).

The seasonal migration of adult alewives observed by Graham (1956) in the Port Credit and Bay of Quinte areas of Lake Ontario closely resembled that in Lake Michigan. Adults began to move from deep water toward shore in April, and numbers were greatest inshore in about middle or late June. Soon after spawning (mostly mid-June to early July) they began to move into deeper water. They appeared in numbers in deep water (25–50 fathoms) about mid-September and were abundant there from December through March.

BLOATER

Bloaters live at midlevels in Lake Michigan until their third year. Few less than 7 inches (17.8 cm.) long are on the bottom. The larvae are in the hypolimnion in deep water (Wells, 1966), but the exact distribution of juveniles at middepths is unknown. The few that have been caught were taken in the thermocline or in upper levels when the water was cool. A few adult bloaters (2 years old or older) are frequently taken at midlevels, almost invariably in or below the thermocline, but the proportion off the bottom is usually small (largest catches in gill nets set obliquely from the surface to the bottom are characteristically near the bottom).

Bloaters on the bottom inhabit intermediate and deep areas, but are sometimes in shallow water. In February, March, and April the largest numbers taken in the standard series were at 25 fathoms and deeper; few were caught during this period at depths less than 20 fathoms, and none were taken in less than 12 fathoms (table 4). A shoreward movement began in May, and by July the greatest numbers were at depths shallower than 20 fathoms. Bloaters avoided warm inshore water, but in the July 7 series, when the inshore water was cooled during an upwelling, the largest catches were at 5 to 12 fathoms and two bloaters were taken at 3 fathoms. Movement into deeper water was pronounced in the fall. On October 14 and November 4 few bloaters were shallower than 17 and 20 fathoms, respectively, and the largest catches were at 35 fathoms.

The above discussion based on the catches of the standard series is, of course, limited to seasonal distribution at depths of 50 fathoms and less. Other experimental fishing indicates that the number of bloaters decreases progressively at depths beyond 50 fathoms. Numbers are occasionally substantial at 60 fathoms but not often at 70 fathoms or deeper. A few bloaters, however, are present in the deepest portion of the southern basin (90 fathoms) and at depths of at least 140 fathoms in the northern basin. (One bloater was taken at 200 fathoms in a gill net fished from the R/V *Cisco* in Lake Superior in 1953.)

The length of bloaters varied little with depth and season. Bloaters in the three shallowest depths at which they were caught in each series, however, usually averaged about 0.2 to 0.4 inch (0.5–1.0 cm.) longer than those in deeper tows. The average length of all bloaters was 8.4 inches (21.3 cm.); 97.1 percent were between 7.0 and 9.9 inches (17.8–25.1 cm.).

Jobes (1949) reported the greatest abundance of bloaters in Lake Michigan at 20 to 59 fathoms. He suspected a movement toward shore in summer and a return to deeper water in fall.

Distribution of bloaters in southeastern Lake Michigan is shallower than in the Apostle Islands region of Lake Superior where largest numbers were usually taken at 40 to 59 fathoms (Dryer, 1966). The shoreward movement in summer and fall in Lake Superior was later and less pronounced than that in Lake Michigan. None were taken at depths less than 10 fathoms, and catches at 10–29 fathoms were never greater than at 40–49 fathoms.

AMERICAN SMELT

American smelt in Lake Michigan move in increasing numbers from a pelagic to a bottom exist-

TABLE 4.—*Number of bloaters taken per 10-minute trawl tow at various depths, February 13 to November 4, 1964*

Depth	Date										
	Feb. 13	Mar. 11	Apr. 15	May 5	May 26	June 16	July 7	July 28	Aug. 21	Oct. 14	Nov. 4
Fathoms	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
3	(1)	(1)	0	0	0	0	2	0	0	0	0
5	0	0	0	1	0	8	177	0	0	0	0
7	0	0	0	1	0	59	301	1	3	0	0
10	0	0	0	4	0	198	164	14	188	1	1
12	0	0	1	12	3	170	119	178	146	4	1
15	0	6	0	23	53	144	80	172	137	8	11
17	2	9	5	31	95	134	57	207	226	95	12
20	13	25	31	39	80	124	59	72	162	75	47
25	58	94	71	74	16	102	53	62	98	95	33
30	158	63	57	77	30	39	59	66	148	208	94
35	145	165	172	63	36	87	47	65	169	391	131
40	92	483	300	150	62	148	64	39	89	121	68
45	35	132	77	71	46	38	67	58	56	84	77
50	98	126	151	103	81	66	53	27	12	33	68

[1] No data.

ence as they grow older. First-year fish (0 group) live in the upper levels until the fall (or very late summer) when at least some move to the bottom. In their second year (I group) they may be either at midlevels (commonly in the thermocline) or on the bottom. After their second year (II group and older) they are mostly on the bottom. Ferguson (1965) reported a diurnal vertical migration of adult smelt in eastern Lake Erie. In the discussion below "young" refers to young of the year and "adults" (arbitrarily) to older fish.

Young

Appreciable numbers of young smelt were caught in the trawls on October 14 and November 4, mostly at 10 to 15 fathoms (table 2). No change in distribution appeared between the two periods. None had been taken prior to October 14, but the nearly 2-month span since the immediately preceding series on August 21 precludes a statement of the exact time they first appear on the bottom. Most young smelt in the Apostle Islands region of Lake Superior were caught at less than 10 fathoms and seldom were deeper than 19 fathoms (Dryer, 1966). In eastern Lake Erie they frequented the shallow epilimnial waters and at times were highly concentrated near shore (Ferguson, 1965).

Adults

Adult smelt on the bottom occupy shallow and intermediate depths in southeastern Lake Michigan. They were caught consistently during standard series but never in large numbers (table 5). They were widely scattered from 7 to 35 fathoms on February 13, but most had abandoned the deeper water by March 11, when greatest numbers were at 10 to 17 fathoms. Most older smelt had moved into very shallow spawning areas by April 15, when few were caught. Smelt reappeared in the catches on May 5, at depths of 3 to 10 fathoms. They had extended their range to 20 fathoms by May 26. Thereafter none were taken deeper than 20 fathoms but they avoided warm water near shore.

The length of smelt varied with depth. In spring and summer (except during the spawning season) those in shallow water were largely yearlings (which averaged 3.2 inches or 8.1 cm.) and those in deeper water were mainly older fish (average 5.3 inches or 13.5 cm.). In the fall, yearlings and older fish could not be separated readily by size, but the larger fish still preferred deeper water. The average length on November 4 was 5.4 inches (13.7 cm.) at 5 to 7 fathoms and 6.8 inches (17.3 cm.) at 10 to 20 fathoms.

Adult smelt in northern Lake Michigan, where they are far more abundant than in the southeastern portion of the Lake, extend their summer range into deeper water than in southeastern Lake Michigan. They were commonly taken in the northern area by the R/V *Cisco* in 1961 at 25 to 35 fathoms and occasionally in small numbers at 50 fathoms. The largest catches were at 15 fathoms (usually the shallowest water fished).

TABLE 5.—*Number of adult American smelt taken per 10-minute trawl tow at various depths, February 13 to November 4, 1964*

Depth	Date										
	Feb. 13	Mar. 11	Apr. 15	May 5	May 26	June 16	July 7	July 28	Aug. 21	Oct. 14	Nov. 4
Fathoms[1]	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
3	(2)	(2)	0	2	0	10	0	0	0	0	0
5	0	0	2	54	0	7	33	0	0	0	3
7	2	1	0	44	4	7	12	0	17	0	8
10	1	6	0	16	6	11	4	11	0	3	5
12	2	6	0	0	14	7	0	2	2	8	1
15	1	10	0	0	17	2	0	4	3	6	6
17	1	9	0	0	11	1	1	0	1	5	6
20	1	0	0	0	1	0	1	1	0	0	5
25	5	1	0	0	0	0	0	0	0	0	0
30	3	0	0	0	0	0	0	0	0	0	0
35	1	0	0	0	0	0	0	0	0	0	0

[1] No adult smelt were caught deeper than 35 fathoms. [2] No data.

Most yearling (I group) smelt in the Apostle Islands region of Lake Superior were caught at less than 10 fathoms, and older ones were most common at 10 to 39 fathoms (Dryer, 1966).

SPOTTAIL SHINER

The spottail shiner was more strongly limited to shallow water than other common species; it was the only species caught in the shallowest tows of every series (table 6). The range was extended into intermediate depths, however, in winter and fall. Shiners were irregularly distributed from the shallowest depths to 20 or 25 fathoms in February–April; numbers were greatest at 3 to 17 fathoms. A definite shoreward movement was evident by May 5. None were caught deeper than 7 fathoms from May 26 to August 21. For each of the six series in May to August the average percentages of the total catch that were taken at 3, 5, and 7 fathoms were 42.5, 48.2, and 9.3 percent, respectively. In other years, however, spottail shiners have occurred in appreciable numbers as deep as 12 fathoms in summer, when very warm water extended on the bottom to that depth. Catches in shore seines near the trawling area indicated that they also may be common at depths less than 3 fathoms. By October 14 spottail shiners had scattered into water as deep as 17 fathoms; largest catches were at 12 and 15 fathoms. They were caught at depths of 3 to 15 fathoms on November 4, except for one taken at 25 fathoms; largest numbers were at 5 fathoms, but all catches were small.

Larger spottail shiners tended to be at the deeper end of the distribution throughout the year. The average weight from tows which contained at least 10 individuals was 0.37 ounce (10.5 g.) in the shallowest tow and 0.51 ounce (14.5 g.) from the deepest (unweighted mean of average for each series). Spottail shiners taken on October 14 averaged 4.0, 4.4, and 4.7 inches (10.2, 11.2, and 11.9 cm.) at 10, 12, and 17 fathoms, respectively.

TROUT-PERCH

Trout-perch were restricted to shallow and intermediate depths. Most fish in the small catches of February-April were at 12 to 17 fathoms, but they were scattered from 5 to 30 fathoms (table 7). Trout-perch were concentrated nearer shore in May, when most were at 5 and 7 fathoms, and none were caught deeper than 17 fathoms. The depth of greatest abundance of trout-perch continued to be 5 to 7 fathoms in summer, and the maximum depth at which they were taken was only 10 fathoms. In the summer of other years, however, they have been caught in appreciable numbers as deep as 15 fathoms when epilimnial waters reached the bottom at that depth. Trout-perch had moved back into deeper water by October 14, when they were at 10 to 20 fathoms, and largest numbers were at 12 fathoms. On November 4 a few trout-perch were caught at 3 and 5 fathoms, but most were at 10 to 20 fathoms.

Average weights of trout-perch in each catch suggest some segregation by size, but no clear-cut size-depth relation.

TABLE 6.—*Number of spottail shiners taken per 10-minute trawl tow at various depths, February 13 to November 4, 1964*

Depth	Date										
	Feb. 13	Mar. 11	Apr. 15	May 5	May 26	June 16	July 7	July 28	Aug. 21	Oct. 14	Nov. 4
Fathoms [1]	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
3	(2)	(2)	16	88	44	70	626	2	62	4	18
5	11	45	16	1, 046	299	11	15	80	421	5	24
7	12	11	5	158	178	0	0	10	25	0	1
10	21	28	22	3	0	0	0	0	0	12	1
12	33	39	39	0	0	0	0	0	0	75	2
15	82	19	24	0	0	0	0	0	0	74	3
17	13	30	4	3	0	0	0	0	0	7	0
20	1	8	1	0	0	0	0	0	0	0	0
25	0	1	0	0	0	0	0	0	0	0	1

[1] No spottail shiners were caught deeper than 25 fathoms.

[2] No data.

TABLE 7.—*Number of trout-perch taken in 10-minute trawl tows at various depths, February 13 to November 4, 1964*

Depth	Date										
	Feb. 13	Mar. 11	Apr. 15	May 5	May 26	June 16	July 7	July 28	Aug. 21	Oct. 14	Nov. 4
Fathoms [1]	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
3	(2)	(2)	0	6	0	46	16	0	18	0	2
5	1	0	1	134	117	74	186	0	648	0	1
7	0	0	3	31	185	39	2	11	18	0	0
10	4	5	5	2	8	1	0	22	1	12	7
12	3	15	6	1	28	0	0	0	0	44	3
15	12	15	10	1	2	0	0	0	0	4	2
17	12	9	9	2	2	0	0	0	0	3	14
20	9	3	2	0	0	0	0	0	0	2	6
25	2	1	4	0	0	0	0	0	0	0	0
30	1	1	1	0	0	0	0	0	0	0	0

[1] No trout-perch were caught deeper than 30 fathoms.

[2] No data.

Dryer (1966) reported that trout-perch in the Apostle Islands region of Lake Superior were widely distributed down to 49 fathoms, were most abundant at 10 to 19 and 30 to 39 fathoms, and exhibited no seasonal changes in distribution.

YELLOW PERCH

Yellow perch in their first 2 years of life in southeastern Lake Michigan are in water shallower than 3 fathoms, as indicated by their presence in shore seines and scarcity in trawls fished as shallow as 3 fathoms. No young-of-the-year (O group) yellow perch and only 23 yearlings (I group), distinguished by size, were caught in the 11 standard series. Extensive trawling off Grand Haven, Mich. (23 nautical miles north of Saugatuck), in 1954 and 1960 produced only one large catch of young-of-the-year perch (4 fathoms, November 20, 1954) and two of yearlings (5 and 7 fathoms, June 20, 1960). The yearlings were caught during a mild upwelling. The depth distribution of small yellow perch in southeastern Lake Michigan contrasts strikingly with that in Lake Erie, where research vessels of the Bureau of Commercial Fisheries regularly have found large numbers of young of the year (as small as 1.2 inches or 3.0 cm.) in depths to 6 fathoms and yearlings commonly to 17 fathoms. Young-of-the-year perch in Saginaw Bay (Lake Huron) strongly preferred water shallower than 2 fathoms in summer, but many moved several fathoms deeper in October (R/V *Cisco* trawling and shore-seining records, 1956). Yearlings were distributed at least as deep as 7 fathoms in summer.

Adult yellow perch (defined here as those older than 2 years) in southeastern Lake Michigan inhabit shallow and intermediate depths. Most are on the bottom, but appreciable numbers may be at midlevels in summer. Greatest numbers in February to early May were at 10 to 12 fathoms, and the extreme depth range was 5 to 25 fathoms (table 8). A movement into shallower water was in progress by May 26. Yellow perch congregate in middle and late May for spawning at depths less than 8 fathoms on rocky bottom about 2 miles south of the trawling area. Most adult yellow perch were at 7 fathoms or less during summer. Substantial numbers probably were often shallower than 3 fathoms; the maximum depth was 10 to 12 fathoms. Perch have been abundant as deep as 12 to 17 fathoms during occasional periods in August of other years when warm water reached unusual depths. Adult yellow perch moved into deeper water in fall. None were taken at depths shallower than 10 fathoms in the October 14 and November 4 standard series. The largest catch on November 4 was at 20 fathoms, but no fish were caught deeper. The fall movement of yellow perch into greater depths in Lake Michigan can be more pronounced than the catches of the standard series indicate. An extremely heavy catch was made off Charlevoix, Mich., on October 17, 1955 in a gill net at 25 fathoms (bottom temperature 15.1° C.), where none had been taken in several sets in spring and summer.

TABLE 8.—*Number of yellow perch, II group and older, taken per 10-minute trawl tow at various depths, February 13 to November 4, 1964*

Depth	Date										
	Feb. 13	Mar. 11	Apr. 15	May 5	May 26	June 16	July 7	July 28	Aug. 21	Oct. 14	Nov. 4
Fathoms [1]	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
3	(2)	(2)	0	0	24	138	1,082	240	108	0	0
5	18	76	0	28	48	114	46	978	157	0	0
7	14	9	8	23	85	240	110	6	72	0	0
10	70	28	55	422	22	7	2	25	1	7	3
12	42	194	35	46	16	0	0	22	0	27	23
15	29	26	16	5	2	0	0	0	0	35	9
17	4	12	0	1	0	0	0	0	0	5	3
20	0	4	0	0	1	0	0	0	0	2	53
25	0	0	0	1	0	0	0	0	0	1	0

[1] No yellow perch caught deeper than 25 fathoms.

[2] No data.

In the summer, appreciable numbers of yellow perch follow warm upper strata farther out into the Lake than their normal range on the bottom. They have been taken on several occasions from the upper portions of gill nets set obliquely from top to bottom at a bottom depth of 26.7 fathoms along the eastern shore of Lake Michigan. About 90 percent were from the epilimnion (usually about the upper 10 fathoms); all were from the upper 17 fathoms.

Yellow perch, usually in poor condition, occasionally have been taken on the bottom at great depths in Lake Michigan. The deepest recorded by the R/V *Cisco* was a fish taken at 140 fathoms off Frankfort, Mich. (June 29, 1955); another was caught at 100 fathoms in Grand Traverse Bay (June 3, 1955).

Size of adult yellow perch varied somewhat with depth. Larger ones were inclined to be in shallower water in February, March, and April; among tows in which at least 10 perch were taken the average length was 8.8 inches (22.4 cm.) for the shallowest tow and 7.7 inches (19.6 cm.) for the deepest (unweighted means of averages for each of the three series). The size-depth relation was reversed in May to August when average lengths for fish from the shallowest and deepest tows were 7.2 and 8.0 inches (18.3 and 20.3 cm.), respectively. Size did not change with depth in the fall.

SLIMY SCULPIN

Larval slimy sculpins are at midlevels, mostly in the hypolimnion. Little else is known of the O group, except that some apparently appear on the bottom in the fall. Most slimy sculpins caught in the standard series were between 2 and 4 inches (5.1 and 10.2 cm.) long and probably included yearlings and older fish. In the series of November 4, however, the catches at 25 and 30 fathoms contained 72 and 5 individuals, respectively, between 1.0 and 1.5 inches (2.5 and 3.8 cm.) long. Studies of age and growth by Rottiers [2] suggest that these fish were young of the year. They are not included in the following discussion.

The depth range of slimy sculpins extends beyond the maximum depth of the present standard series of collections. Limited trawling data for greater depths indicate that in summer slimy sculpins are present in small numbers at least to 71 fathoms but are rare or absent at 85 fathoms. Deason (1939) found them in stomachs of lake trout and burbot caught in Lake Michigan as deep as 70 fathoms, but concluded that they were usually between the shore and 50 fathoms.

The slimy sculpin is distributed over a wide depth range in winter, but abandons shallow areas in spring as soon as warming is significant and continues a gradual movement away from shore through summer and fall. Greatest numbers of slimy sculpins on February 13 were at 10 to 35 fathoms (table 9). They were in all catches except at 45 and 50 fathoms (where an occasional specimen might have been overlooked because of the

[2] Rottiers, Donald V. Some aspects of the life history of *Cottus cognatus* in Lake Michigan. Master's thesis, University of Michigan. 1965. 49 pp.

TABLE 9.—*Number of slimy sculpins taken per 10-minute trawl tow at various depths, February 13 to November 4, 1964*

Depth	Date										
	Feb. 13	Mar. 11	Apr. 15	May 5	May 26	June 16	July 7	July 28	Aug. 21	Oct. 14	Nov. 4
Fathoms	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
3	([1])	([1])	14	0	0	0	0	0	0	0	0
5	10	2	15	4	0	0	0	0	0	0	0
7	5	10	43	8	0	1	0	0	0	0	0
10	51	22	97	4	0	5	0	0	0	0	0
12	109	61	90	6	2	4	0	0	0	0	0
15	117	118	115	44	2	29	37	1	0	1	2
17	107	121	91	161	19	36	72	0	4	0	1
20	117	97	122	48	54	101	100	41	44	3	1
25	106	146	35	32	187	122	133	132	124	58	68
30	171	293	42	11	138	170	100	88	97	73	139
35	74	126	14	60	75	65	86	75	86	81	97
40	9	43	9	38	41	46	139	79	119	105	140
45	0	28	29	41	46	31	42	36	66	14	36
50	0	6	8	46	38	21	29	31	12	15	15

[1] No data.

great quantities of alewives). Small numbers appeared in the catches at 45 and 50 fathoms on March 15, but distribution had not changed significantly. In every later series, slimy sculpins were found at all depths greater than 17 fathoms. A slight shift shoreward was evident on April 15, when greatest numbers were at 7 to 30 fathoms. They had started to move away from shallow water by May 5, when relatively few were at 12 fathoms or shallower, and none were at 3 fathoms. A general trend away from shore continued thereafter until fall. On May 26 the shallowest depth of capture was 12 fathoms, and on August 21 it was 17 fathoms; largest numbers in the period May 26–August 21 were at 20 to 40 fathoms. On October 14 and November 4 most were at 25 to 40 fathoms, and few were at 20 fathoms or shallower.

Slimy sculpins beyond the earlier growth stages ordinarily are considered strict bottom dwellers, but at times larger ones may ascend several fathoms above the bottom in Lake Michigan. On May 20, 1955, 20 (probably slimy sculpins, but possibly spoonhead sculpins) were caught at night (about 2000 e.s.t.) in a trawl fished by the R/V *Cisco* 6 fathoms above the bottom where total depth was 23 fathoms; another was taken at night on November 18, 1954, 27 fathoms above the bottom at a 40-fathom depth. On June 20, 1967, 31 slimy sculpins were caught during daytime by the Bureau's R/V *Siscowet* 3 to 9 fathoms above the bottom in turbid water 13 to 14 fathoms deep in western Lake Superior (Merryll Bailey, personal communication).

Slimy sculpins were concentrated in deeper water in the Apostle Islands region of Lake Superior than in southeastern Lake Michigan; they were most common in the Apostle Islands at depths greater than 40 fathoms, and probably the greatest numbers were at 50 to 59 fathoms (Dryer, 1966).

The depth distribution of slimy sculpins in southeastern Lake Michigan varied noticeably with size in winter and early spring, but not thereafter. Sculpins at intermediate depths were smaller than at other depths in February to May. In the five series of February 13 to May 26, the average weights of sculpins taken at depths less than 30 fathoms were 0.36, 0.34, 0.32, 0.24, and 0.23 ounce (10.2, 9.6, 9.1, 6.8, and 6.5 g.) respectively; at 30 to 40 fathoms the averages were 0.27, 0.27, 0.14, 0.12, and 0.16 ounce (7.7, 7.7, 4.0, 3.4, and 4.5 g.); and at 45 and 50 fathoms (no data for February 13 and March 11) the weights were 0.30, 0.21, and 0.25 ounce (8.5, 6.0, and 7.1 g.). No obvious size-depth relation existed after May, but some tendency existed for the larger fish to be in intermediate depths in August–November—the opposite of the situation in early season.

FOURHORN SCULPIN

Fourhorn sculpins (also called deepwater sculpins) are confined to deep water much more than any of the other species. They were uncommon in the catches shallower than 40 fathoms in the standard series. Data from additional trawling of the R/V's *Cisco* and *Kaho* indicate that fourhorn sculpins are present in the deepest part of the southern basin (90 fathoms) and are abundant to at least 70 fathoms. They are found at least as deep as 140 fathoms in northern Lake Michigan, where their range does not appear to extend into as shallow water as in the southern basin. Deason (1939) estimated the depth of greatest abundance of fourhorn sculpins in Lake Michigan as 40 to 75 fathoms on the basis of their occurrence in stomachs of lake trout and burbot. Fourhorn sculpins in the Apostle Islands region of Lake Superior were seldom shallower than 50 fathoms (Dryer, 1966); they were fairly abundant in R/V *Cisco* trawl catches at 200 fathoms in eastern Lake Superior in 1953.

Larval fourhorn sculpins are in the hypolimnion in deep areas. No other information is available on distribution in the first year.

Although the standard series did not cover a large enough portion of the depth range of fourhorn sculpins to give a good indication of seasonal distribution, certain features are evident from the data. The species was always abundant at 45 and 50 fathoms, but was never numerous at other depths (table 10). It extended its range slightly shoreward in spring. None were shallower than 45 fathoms on February 13, but a few were as shallow as 35 fathoms on March 11 and 17 fathoms on April 15. Numbers which had been considerably larger at 50 fathoms than at 45 fathoms in February–May were usually larger at 45 fathoms afterwards. Distribution showed no obvious change in summer and fall.

The shallowest water in which a fourhorn sculpin was caught in the standard series was 7 fathoms (May 26), but one specimen, seemingly in good condition, was taken at 4 fathoms off Saugatuck in August 1965.

The segment of the depth range of fourhorn sculpins sampled in the standard series was too small for an evaluation of the size-depth relation. The average individual weight in most catches was 0.8 to 1.0 ounce (22.7–28.3 g.). Fourhorn sculpins in the standard series were not measured, but 80 percent of those from identical trawling off Saugatuck in 1965 were 4.5 to 5.5 inches (11.4–14.0 cm.) long, and few fell outside the length range 4.0 to 6.0 inches (10.2–15.2 cm.).

OTHER SPECIES

Several species were caught in such small numbers in the standard series that their depth distribution could not be determined accurately. The limited data available are discussed briefly.

Shortnose ciscoes (18 collected) were taken at 5 to 50 fathoms, mostly 40 to 50 fathoms. One longjaw cisco was caught at 15 and another at 50 fathoms, and individual kiyis were taken at 45 and 50 fathoms. Lake herring (62 collected) were taken at 5 to 50 fathoms; they were most common at 15 to 25 fathoms, especially on February 13 and March 11. In the mid-1950's, when this species was more abundant in Lake Michigan, it was frequently caught in nets of the R/V *Cisco* at midlevels, occasionally near the surface. Studies by Smith (1956) and Dryer (1966) indicated that lake herring in the Great Lakes are essentially pelagic during the warm months, but may be

TABLE 10.—*Number of fourhorn sculpins taken per 10-minute trawl tow at various depths, February 13 to November 4, 1964*

Depth	Date										
	Feb. 13	Mar. 11	Apr. 15	May 5	May 26	June 16	July 7	July 28	Aug. 21	Oct. 14	Nov. 4
Fathoms [1]	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
17	0	0	1	0	0	0	0	0	0	0	0
20	0	0	1	0	0	0	1	0	1	0	0
25	0	0	1	0	0	0	1	0	0	0	0
30	0	0	2	2	1	2	1	0	1	1	1
35	0	7	2	3	4	3	3	3	4	3	0
40	0	22	13	35	25	13	22	12	30	38	25
45	105	85	235	303	356	324	494	264	732	454	228
50	279	876	580	508	500	289	425	381	275	286	250

[1] No fourhorn sculpins caught at depths shallower than 17 fathoms, except for one at 7 fathoms on May 26.

abundant on the bottom at other times. The ranges of all the ciscoes mentioned here, especially the kiyi, extend into water deeper than 50 fathoms in southeastern Lake Michigan.

Lake whitefish (5 collected) were taken at 3 to 20 fathoms. Seven carp were caught at 5 to 7 fathoms. Ninespine sticklebacks (3 collected) were at depths of 20 to 50 fathoms. This species is more common in bottom catches in most other parts of the Lake and is occasionally taken at midlevels. Johnny darters (19) were collected at 7 to 35 fathoms (mostly 12–17) and logperch (12) at 5 to 12 fathoms. Single individuals of gizzard shad, white sucker, and quillback were caught at 3, 5, and 15 fathoms, respectively.

EFFECTS OF TEMPERATURE ON DISTRIBUTION

Temperature was the most obvious factor in the depth distribution of fish in this study. Even in winter, temperature influenced the distribution of some of the species. Alewives and bloaters, for example, congregate in the deeper areas to avoid the colder inshore waters. Numbers of both species increased significantly at 15 to 20 fathoms between February 13 and March 11 as bottom temperatures rose from 0.3–0.7° C. to 1.3–2.1° C. The movement toward shore in the spring of all species except the sculpins is closely correlated with a warming of inshore waters. The shift of all species except the fourhorn sculpin into deeper water in the fall also is obviously related to temperature. As warm water steadily encroaches on deeper bottom areas warm-water species spread with it, and cold-water forms move deeper to avoid it. The control of temperature over depth distribution is best seen in summer when thermal changes are most pronounced.

After thermal stratification, bottom temperatures in water shallower than 12 or 15 fathoms in southeastern Lake Michigan are seldom stable for any length of time. Direction and speed of wind influence water temperatures strongly. Onshore winds thicken the epilimnion near shore and increase the depth to which warm water extends on the bottom; offshore winds have the opposite effect. Exceptionally strong, persistent northeast or north winds cause extensive upwellings along a large portion of the east shore of the Lake and hypolimnial water of 5 to 6° C. may replace water of 20° C. in 1 or 2 days. At such times cold water from surface to bottom may extend from shore several miles out into the Lake, and no warm bottom water is available to the fish.

Catches of the standard series illustrate the influence of thermal conditions on the depth distribution of fish in summer. A comparison may be made between the catches of July 7, when epilimnial waters near shore were relatively cool and the hypolimnion extended into shallow water, and July 28, when epilimnial waters were much warmer and reached the bottom to greater depths. The thermal conditions of July 28 were more common for summer; those of July 7, though less frequent, were by no means unusual. Species in the shallowest water had a deeper distribution on July 28. Bloaters and slimy sculpins showed changes only in the shallow extremity of their depth range because the temperature in the remainder of their range was unchanged. The fourhorn sculpin was too deep to be affected.

The standard series were too infrequent to show the rapidity of movement in response to temperature change; however, evidence from other trawling indicates that appreciable movement may occur in a few hours, and that major redistribution may take place in 2 or 3 days. On August 24, 1963, tows were made in the morning (0807–1001 e.s.t.) and afternoon (1344–1541 e.s.t.) at 7, 10, and 12 fathoms off Saugatuck during a period of rather rapidly changing bottom temperatures. The temperature remained steady at 16.5° C. at 7 fathoms but rose from 12.6 to 14.0° C. at 10 fathoms and from 12.4 to 13.3° C. at 12 fathoms (table 11). At the same time several species moved into deeper water. Spottail shiners decreased drastically at 7 fathoms and increased greatly at 10; several appeared in the afternoon catch at 12 fathoms where none had been taken in the morning. Catches of yellow perch decreased slightly at 7 fathoms and strongly at 10 fathoms and increased drastically at 12. No other species were present in significant numbers at 7 fathoms in either period. Trout-perch decreased appreciably at 10 fathoms and increased correspondingly at 12. Bloaters decreased at both 10 and 12 fathoms. Smelt showed only a slight change at 10 fathoms and none at 12. Alewives did not change significantly. Sculpins were not caught in any of the tows. These changes do not necessarily indicate that individual fish

TABLE 11.—*Trawl catches in identical morning (0807–1001 e.s.t.) and afternoon (1344–1541 e.s.t.) tows at various depths off Saugatuck, Mich., August 24, 1963*

[Bottom temperatures (° C.) with each tow are in parentheses]

Species	7 fathoms		10 fathoms		12 fathoms	
	a.m. (16.5)	p.m. (16.5)	a.m. (12.6)	p.m. (14.0)	a.m. (12.4)	p.m. (13.3)
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
Alewife	12	3	39	51	39	34
Bloater	0	1	49	23	184	65
American smelt	1	3	193	246	92	87
Spottail shiner	36	1	5	113	0	5
Trout-perch	9	3	254	146	5	92
Yellow perch	97	76	233	113	34	246

traveled a great distance (e.g., the 0.5 nautical mile from 10 to 12 fathoms), but may reflect a more modest shift of the entire populations of various species.

A pronounced shift in depth distribution of fish during a few days occurred between August 14 and 17, 1962, when trawl tows were made at 7, 10, 12, and 15 fathoms off Saugatuck. Bottom temperatures in this period rose from 7.9 to 17.7° C. at 7 fathoms and from 5.9 to 11.2° C. at 15 fathoms. Spottail shiners were rare as deep as 7 fathoms at the cooler temperatures on the earlier date, but were common out to 12 fathoms when the water warmed. Trout-perch were caught only at 7 fathoms on August 14, but were concentrated at 15 fathoms on the 17th. Yellow perch, bloaters, and smelt moved similarly. Alewives, which characteristically responded less to sudden temperature changes than other species, showed little movement. Sculpins were not in the catches.

Shifts in the depth distribution of fish in shallow water in summer, although not usually as abrupt as the examples cited, are frequent if not almost continuous in southeastern Lake Michigan (and probably along other exposed shorelines of the Lake as well) as bottom temperatures fluctuate. During upwellings, however, warm-water species may suddenly be exposed to temperatures much colder than those preferred from which they cannot escape. Such conditions can occur at crucial times, such as the spawning season or during hatching. It would seem then that temperatures for these species would be much more suitable in terms of growth rates and spawning success in smaller bodies of water or protected bays, where thermal stability is greater.

TEMPERATURE PREFERENCES

Certain generalities regarding temperature preferences of the various species are possible from the standard series and other trawling at Saugatuck, although unstable thermal conditions and other factors prevented any determination of either exact temperature preferences or "final preferenda" (see Fry, 1947). These observations apply to adult fish during periods when the range of temperatures on the bottom was wide.

All species except fourhorn sculpins were in water with a temperature range of several degrees. Alewives apparently had the least temperature specificity. At times they were simultaneously in water from 5° C. or less to 20° C. or more, but most were in water warmer than 8° C. Evidence suggests that they tend to shun temperatures greater than 22° C., although in some spawning streams they must occasionally endure temperatures of 25° C. or more. Bloaters generally inhabited water from 4 to 11° C., although a few usually were present at temperatures several degrees higher; greatest concentrations often were at 6 to 10° C. Smelt were mostly in water of intermediate temperatures, about 6 to 14° C. Spottail shiners with few exceptions were in water from 13° C. to the warmest available. Trout-perch were mainly in water of 10 to 16° C. Yellow perch were usually in water above 11° C. and were occasionally abundant in water as warm as 22° C.; substantial numbers, however, were found at temperatures as low as 8° C. Slimy sculpins were seldom taken in water above 10° C., and most were at 4 to 6° C. Occasionally in fall overturns, however, when moderately warm water reached bottom at greater depths, large numbers of slimy sculpins were taken from water as warm as 13° C. Fourhorn sculpins with rare exceptions were restricted to water colder than 4.5° C. Factors other than temperature must exert a strong influence on the depth distribution of fourhorn sculpins because they did not move into shallow water in numbers even where temperatures were under 4.5° C.

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