837 Hagadorn Road
East Lansing, Michigan
48823
February 28, 1970

Dr. Robert Behnke
Cooperative Fishery Unit
Colorado State University
Fort Collins, Colorado
80521

Dear Dr. Behnke:

Here are the reprints on Menidia and I hope they prove useful. Most of the material contained in the papers from the Proceedings of the Oklahoma Academy of Science was incorporated in my thesis, but I am sending all three anyway.

Did you notice the paper in the recent AFS transactions concerning the introduction of Menidia in California? It seems they have had very good success so far.

I was sorry to hear that no positions in fisheries are available this year in Colorado, but please notify me if any openings do occur.

Sincerely yours,

James B. Mense

James B. Mense

James B. Mense

~Ph.D. Mich St. (summer 1970)

Menidia

MS thesis U. Okla. (Zool.) 1967 (C.D. Riggs) Prof. as forage in L. Texoma.

III. Publications

A. Estimating fecundity in Mississippi silversides, Menidia audens (Pisces: Atherinidae). Proc. Okla. Acad. Sci. 48:46-48. Illus. 1969.

B. Forage value of Mississippi silversides in Lake Texoma. Proc. Okla. Acad. Sci. 47:394-396. 1968.

C. Ecology of the Mississippi silversides, Menidia audens Hay, in Lake Texoma. Bull. No. 6, Oklahoma Fishery Research Laboratory, Norman, Oklahoma. 1967.

IV. Societies and honors

A. American Fisheries Society, member.

B. Wildlife Society, member.

C. President York High School Chess Club, 1960-1961.

D. Dean's List at Iowa State, twice during 1964.

E. Agriculture Council Representative from Fish and Wildlife Club at Iowa State, 1964-1965.

F. National Science Foundation Research Grant under Dr. Kenneth D. Carlander, Iowa State University, 1964-1965.

V. Courses in Ecology and Aquatics

A. Ecology

1. General Plant Ecology
2. Animal Ecology
3. Population Ecology
4. Dynamics of Biologic Populations
5. Behavior of Animal Populations
6. Physiological Plant Ecology

B. Aquatics

1. Limnology
2. Chemical Limnology
3. Behavior of Aquatic Animals
4. Taxonomy and Ecology of Aquatic Plants
5. Aquatic Insects
6. Ichthyology and Herpetology
7. Fishery Management
8. Biology of Fishes

ECOLOGY OF THE MISSISSIPPI SILVERSIDES, *MENIDIA AUDENS* HAY, IN LAKE TEXOMA

OKLAHOMA

DEPARTMENT OF WILDLIFE CONSERVATION

Oklahoma Department
of
Wildlife Conservation

ECOLOGY OF THE MISSISSIPPI SILVERSIDES, *MENIDIA AUDENS* HAY, IN LAKE TEXOMA

By

James Burr Mense

OKLAHOMA FISHERY RESEARCH LABORATORY

BULLETIN NUMBER 6

Contribution No. 167 of the Oklahoma Fishery Research Laboratory, Norman, Oklahoma. From a thesis submitted to the graduate faculty of the University of Oklahoma in partial fulfillment of the requirements for the degree of Master of Science in the Department of Zoology, 1967.

This study was conducted as part of Federal-Aid Project F-16-R

August, 1967

OKLAHOMA FISHERY RESEARCH LABORATORY
Norman, Oklahoma

Charles R. Gasaway, Acting Director

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ABSTRACT

A study of the life history, distribution, and forage value of the Mississippi silversides, *Menidia audens*, in Lake Texoma was conducted during 1965 and 1966. *Menidia* were collected predominantly in the littoral zone; a few were taken in the limnetic zone, but always within 5 feet of the surface. No differences were detected between the night and day catches with the electric shocker and seine, and it appeared that *Menidia* displayed no diurnal migration to and from the littoral zone. Adult *Menidia* were never taken after July 31, and thus it appeared that their maximum longevity was about 16 months. Unisexual aggregations of males were found in the littoral zone during April and May, and indirect evidence suggested that spawning occurred over an extended period of time, beginning in late March and extending through mid-July. *Menidia* appeared to be an important forage species for piscivorous fishes inhabiting the littoral and surface waters of Lake Texoma. They represented 78% of 290 identifiable fish taken from stomachs of young largemouth bass, *Micropterus salmoides*, collected in all seasons of the year, and were found in 72% of the stomachs containing identifiable fish.

Charles R. Gasaway

ACKNOWLEDGMENTS

I wish to express my gratitude to Dr. Carl D. Riggs for his aid throughout this study and especially for his thoughtful criticisms of the manuscript. The help of Dr. Frank Sonleitner in the statistical treatment of data is also greatly appreciated.

The project was financed with Dingell-Johnson funds through the Oklahoma Department of Wildlife Conservation; valuable assistance was provided throughout the study by Victor W. Lambou, Charles R. Gasaway, and all the members of the Oklahoma Fishery Research Laboratory; data were graciously furnished by Anthony A. Echelle on stomach contents of largemouth bass from his 1965 collections.

It is doubtful if this study could have been successful had it not been for the staff of the Oklahoma Biological Station, and especially the custodian, Mr. Clyde B. Johnson, who was of much help during my many trips to the station during the school year.

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ECOLOGY OF THE MISSISSIPPI SILVERSIDES, MENIDIA AUDENS HAY, IN LAKE TEXOMA

CHAPTER I

INTRODUCTION

The Mississippi silversides, *Menidia audens* Hay, is a freshwater atherinid closely resembling the brook silversides, *Labidesthes sicculus* Cope. Adults of the two species can be readily distinguished by the smaller scales and more pronounced beak of the brook silversides.

The Mississippi silversides was first collected in Oklahoma in 1949 from an overflow area of the Red River in Bryan County (Moore and Cross, 1950). The first specimen of Mississippi silversides from Lake Texoma was collected by Bonn in 1953; by 1959 it had become one of the most abundant species in the lake and apparently had replaced its close relative, the brook silversides (Riggs and Bonn, 1959). However, two adult brook silversides were collected by the author in the Buncombe Creek arm of the lake in October, 1965, indicating that a few specimens still exist in the lake.

A history of the Mississippi silversides in Oklahoma prior to 1959 was given by Saunders (1959), but at least two range extensions have occurred in the state since then. The species has been introduced into Boomer Lake near Stillwater, Oklahoma, and is apparently thriving, since several hundred specimens were collected there in February, 1966. An introduction was also made into Lake Lawtonka near Lawton, Oklahoma (Alfred Houser, personal communication), but the present status of the population there has not been determined.

The nearly complete replacement of the brook silversides by the Mississippi silversides in Lake Texoma suggests an important biological difference between the two species. This difference remains unknown, despite the efforts of Saunders (loc. cit.), who compared the food habits of the two species. Saunders found little difference in their food habits, although the foods of the brook silversides indicated that it may feed more commonly at the surface than the Mississippi silversides.

It is interesting, in light of the near replacement of the brook silversides by the Mississippi silversides in Lake Texoma, that both species are abundant and apparently able to exist together in Reelfoot Lake (Baker, 1939).

Hubbs (1921) and Cahn (1927) gave information on the life history of the brook silversides, but little published work is available concerning the life history of the Mississippi silversides. Comparison of these two closely related species is therefore difficult. The purposes of this study were to learn as much as possible of the life history of the Mississippi silversides, and to evaluate the contribution of the Mississippi silversides as forage for piscivorous fishes in Lake Texoma.

CHAPTER II

METHODS AND MATERIALS

Collections of Mississippi silversides were made in every month from June, 1965, through August, 1966, and preserved in ten percent formalin. All collections were made in the Buncombe Creek arm of Lake Texoma, using a seine, a boom-type electrofishing device, and a vertical gill net.

Seining was accomplished using a 20-foot, 1/8-inch ace mesh, straight seine, with one night haul and one day haul being made at each of six stations at least once each month, from June, 1965, through August, 1966. Choice of these six stations was based on differences in bottom type, vegetation, and wind exposure. Locations of these six stations are shown in Fig. 1. Station 1 faced south, near the mouth of the Buncombe Creek arm of the lake, and had a hard clay bottom which was nearly devoid of aquatic vegetation. Station 2, located on the western shore of Buncombe Creek, had a hard clay bottom interspersed with rocks, and contained inundated terrestrial shrubs during periods of high water. Station 3 was located on the eastern shore of Buncombe Creek, faced north, and had a sandy to silty bottom with a luxurient growth of *Chara*.

Stations 4, 5, and 6, located farther up the Buncombe Creek arm, all had predominantly silty bottoms. Station 4 was located far back in a cove, faced south, and had a lush growth of *Chara*. Station 6 also had a thick mat of *Chara*, and both stations 4 and 6 contained some inundated terrestrial shrubs during periods of high water. Station 5 lacked vegetation of any sort.

Water temperature and approximate wind direction and velocity at each station were recorded, both night and day, and starting and ending times for both night and day sampling periods were also recorded. A Hellige Aqua Analyzer was used to measure the turbidity of a water sample taken from each station during the day. Stations were sampled in numerical

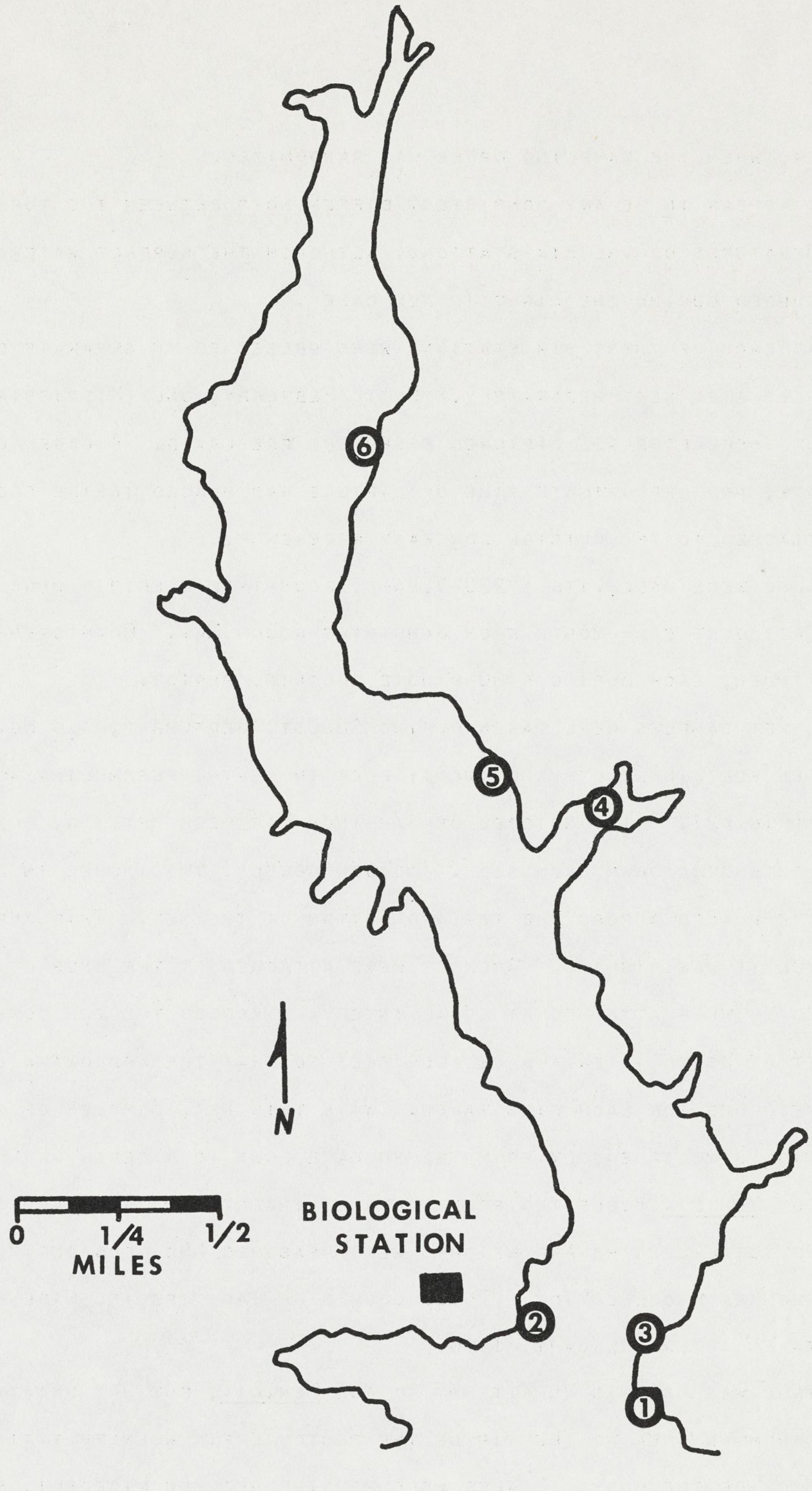

Fig. 1. Seining stations located in the Buncombe Creek arm of Lake Texoma.

order until October, when the sampling order was randomized.

There did not appear to be any consistent differences between the turbidities or surface water temperatures of the six stations, although the surface water temperatures of all stations dropped during the night in all cases.

Fish caught at each of these six stations were preserved in separate glass jars, with night and day samples also kept separately. Until February, only Mississippi silversides were preserved, but thereafter all captured fish were preserved. A label giving the station number, date, and approximate time of capture was placed inside each jar; a similar label was later attached to the outside for easy reference.

Collections also were made with a 220-V, a-c, boom-type electric shocker, described by Ming (1964), at least once each month from January through May. Both open-water and shoreline samples were taken, each during a 30-minute shocking period.

Vertical gill net samples were taken during August, September, and November, 1965. The net measured ten feet in length and twenty feet in depth, resembling an ordinary gill net turned on end (Fig. 2). It consisted of 3/8-inch bar mesh netting, hung on a 1/2 basis along lines extending down each side. Wooden dowels, two inches in diameter and ten feet in length, were placed across the top and bottom of the net. This arrangement kept the net spread while it was fishing. Anchors were attached at the ends of the bottom dowel, and five floats were attached at equal intervals across the top dowel. Marks were made across the net at depth intervals of four feet so that the approximate depth of capture could be recorded for each fish taken. With this net, samples of fish could be taken at one location simultaneously from the surface down to a depth of 20-feet.

Total counts of Menidia collected from each seining station and each shocker collection were made, and total-lengths and weights were measured and recorded for each fish in subsamples taken from each collection. Total counts of each species were made for each seine collection taken after February, 1966.

The scale method was used in an attempt to age Menidia, but was unsatisfactory. Scales were taken from an area at the tip of the pectoral fin when that fin was pressed back against the side of the body. Scales were mounted between microslides and examined under a 45X scale projector. Although both wet and dry mounts of scales taken from fish collected in every month of the year were tried, no definite annuli were detected. Saunders (loc. cit.) examined Menidia scales for possible annulus formation, but did not mention if annuli were observed.

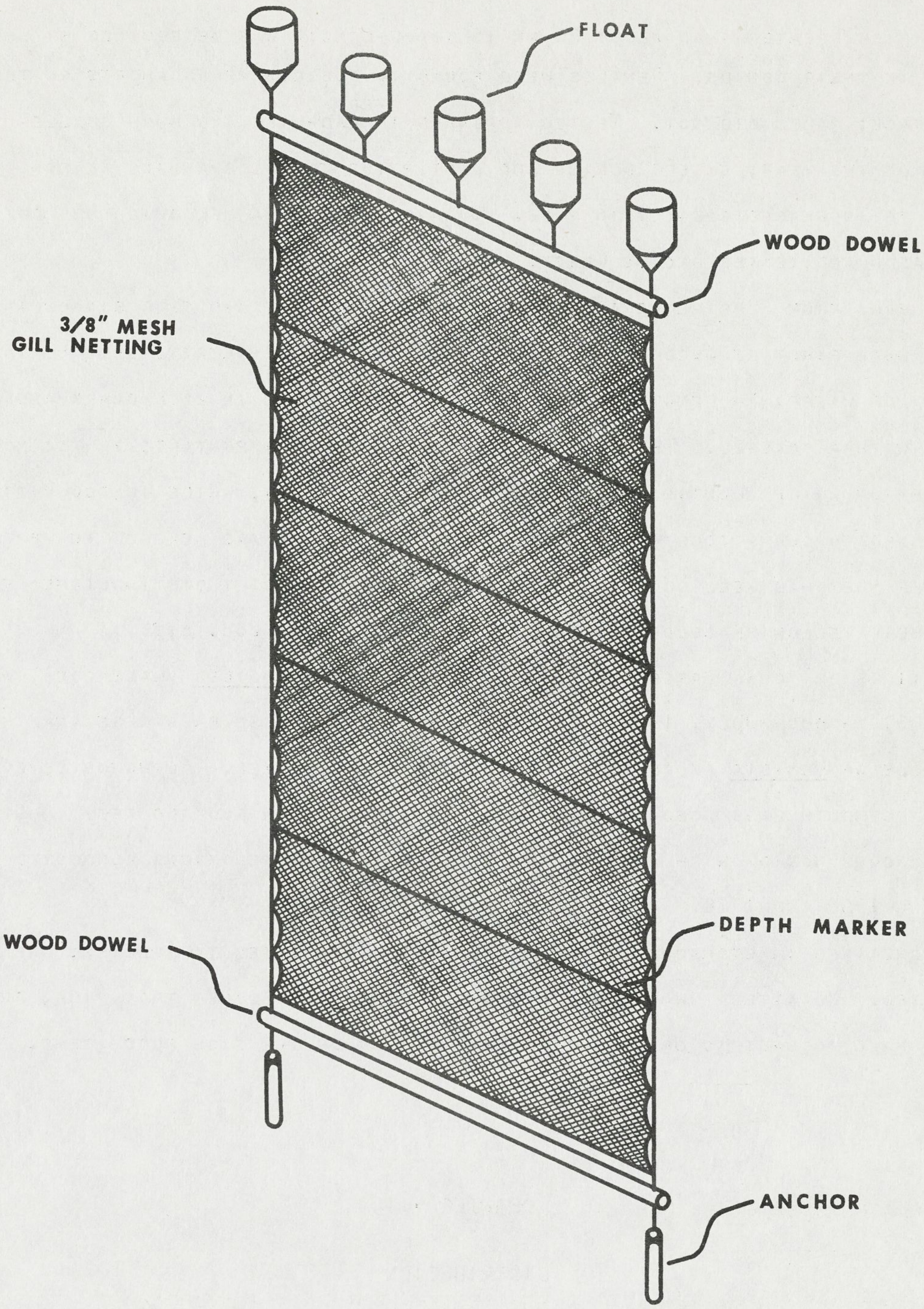

Fig. 2. Small-mesh vertical gill net.

Sex of fish greater than about 35 mm in total-length was determined by superficial differences in their gonads. Females were found to possess melanophores on the outer gonadal surface; males did not. Testes appeared thread-like and much smaller than ovaries during most of the year, except during and just prior to the spawning season, when the gonads of both increased greatly in size. Ovaries took on a yellowish hue during the spawning season and testes became white.

Mature eggs from 32 ripe females were counted with the aid of a binocular microscope. The ovaries were first removed from each fish and placed in petri dishes containing a small amount of water. A lengthwise incision was then made in each ovary and the eggs scraped out with a scalpel. The amount of water used was important; if too much was used, agitation set up while counting the eggs confused the count, while if too little was used, the eggs tended to clump together. A squeeze-bulb pipette was helpful in removing groups of eggs after they had been counted. Mature eggs were readily distinguished from all others by their yellowish color and larger size (Saunders, loc. cit.).

Collections of young largemouth bass, _Micropterus salmoides_ (Lacepede), were made from October, 1965, through July, 1966. Stomach contents of these bass were analysed to determine the value of _Menidia_ as forage for young of this species. Although several of the 536 young largemouth bass used in this study were caught on rod and reel, most were collected in conjunction with seining and electrofishing operations conducted in Lake Texoma during 1965 and 1966.

Fish contained in stomachs of these bass were identified to species, when possible, and enumerated. No attempt was made to analyse food items other than fish, and no attempt was made to make volumetric or weight determinations of the fish food items.

CHAPTER III

DISTRIBUTION

Vertical Distribution

The vertical gill net was used to gather data on vertical distribution of _Menidia_ over a four-month period in 1965 (Table I). These limited data indicate that _Menidia_ is a surface dwelling species, since 38 of the 39 captured specimens were caught in the upper four-foot section of the net. The one exception was caught approximately six inches below the four-foot depth marker. In contrast, the catch of shad, Dorosoma spp., was relatively uniform to a depth of 16 feet.

Menidia catches were contagiously distributed, with numbers of fish being found together in the same area of the net and facing the same direction, indicating a tendency toward schooling or aggregation.

The vertical gill net was effective only during the part of the year when Menidia were relatively abundant, active, and of a catchable size. Seventeen Menidia caught in the net on August 18, ranged from 61 to 79 mm, total-length, with a mean of 67.2; 635 specimens taken by seine on August 21, ranged from 27 to 89 mm, with a mean of 55.1 mm. Thus, apparently only the larger specimens in the August population were in the catchable size range of the gill net.

Not only were these Menidia moving near the surface when captured, but since the gill net was set in water 16 to 20 feet deep on each occasion, the fish were also moving at the surface in deep water. Menidia were often observed swimming at the surface in the open-water region of the lake, and Saunders (loc. cit.) stated that he, too, had observed Menidia at the surface where the water was deep.

Table 1. Vertical gill net catches at four-foot intervals during August, September, and November, 1965.

Depth in feet	August		September		November	
	Menidia	Shad	Menidia	Shad	Menidia	Shad
0 - 4	33	13	3	0	1	0
4 - 8	0	12	1	0	0	0
8 - 12	0	15	0	2	0	0
12 - 16	0	7	0	0	0	0
16 - 20	0	0	-	-	-	-

Lateral Distribution

Since vertical gill net data indicated that *Menidia* could be found at the surface in deep water, an electric shocker with boom-suspended electrodes was employed to compare the relative densities of *Menidia* in the open-water zone and in the littoral zone (Table 2). Both night and day shoreline catches were markedly higher than open-water catches, although some specimens of *Menidia* were collected in the open-water region of the lake in every month sampled. Although *Menidia* were often seen swimming at the surface in the open-water zone in all seasons of the year, their numbers never appeared to be as great as in the littoral zone. Thus it appears that *Menidia* is concentrated in the littoral zone of Lake Texoma during most of the year.

The electric shocker was effective only on larger fish, and for this reason was of limited seasonal use in catching *Menidia*. By May, numbers of larger, adult *Menidia* in the lake were very low, resulting in low catch per unit effort even though young-of-year were abundant. These young-of-year could be seen throughout the summer, swimming around the electrodes and seemingly unaffected by the electricity.

Table 2. Comparisons of Mississippi silversides catches during five months, January through May, 1966, using a 220 V, a-c, electric shocker.

	January		February		March		April		May		Total
	s[1]	o[2]	s[1]	o[2]	s[1]	o[2]	s[1]	o[2]	s[1]	o[2]	
Day											
Number	1	-	0	-	50	2	18	-	2	0	73
Catch per unit effort	0.3	-	0.0	-	25.0	1.0	18.0	-	1.0	0.0	5.62
Night											
Number	42	17	34	6	107	40	18	-	19	5	288
Catch per unit effort	42.0	17.0	34.0	6.0	107.0	40.0	18.0	-	9.5	2.5	26.18
Total											
Number	43	17	34	6	157	42	36	-	21	5	
Catch per unit effort	10.8	17.0	17.0	6.0	52.3	14.0	18.0	-	5.2	1.2	

[1] shoreline sample
[2] open-water sample

Distribution Within the Littoral Zone

Possible differences in the littoral distribution of Menidia were analysed by comparisons of catches from the six seining stations.

The two-way analysis of variance test was used to compare catches of night and day samples for station I on each sample date (Table 3). Tukey's additivity test yielded no significant differences at the .05 level and thus the assumption of additivity for this model was satisfied (Steel and Torrie, 1960). Since only one replicate for either day or night on each date was made, no test of normality could be made, however Snedecor (1956) felt that additivity was the most essential requirement of the analysis of variance. Values of F for both dates and time of day were non-significant at the .05 level, and since station I contained the greatest differences between night and day catches of any of the six stations, no further tests of this nature were deemed necessary.

Table 3. Analysis of variance of night and day catches of *Menidia audens* at station I on various dates in 1965 and 1966.

Source	Sum of squares	DF	Mean square	F
Date	10,093,763.06	18	560,764.61	1.07 N.S.
Day and night	1,933,662.74	1	1,933,662.74	3.71 N.S.
Error	9,369,971.26	18	520,553.96	
Additivity	931,280.50	1	931,280.50	1.88 N.S.
Residual	8,438,690.80	17	496,393.60	
Total	21,397,397.05	37		

It thus appears likely that Menidia have no nocturnal shoreward migration as has been supposed to occur in populations of Labidesthes (Cahn, 1927). Saunders (loc. cit.) proposed such a migration for Menidia because of their "greater ease" of capture with a seine at night.

Since no differences were detectable between catches of night and day samples, the two were combined for each station and for each date and their means calculated. A two-way analysis of variance was then computed comparing these means for each station and for each date. Tukey's additivity test was applied to these data and the resulting F value of 15.51 for 1 and 90 degrees of freedom was highly significant, indicating that the assumption of additivity was not satisfied.

To attempt to correct for non-additivity, a logarithmic transformation was performed on the data as follows (Steel and Torrie, 1960):

$$Y_{IJ} = \text{Log}(X_{IJ} + 1)$$

where Y_{IJ} = the transformed value of X_{IJ},
and X_{IJ} = the mean catch of <u>Menidia</u> on the Ith date at the Jth station.

After transformation to this new scale the data were analysed with a two-way analysis of variance in the same manner as was previously described (Table 4). Tukey's additivity test yielded a non-significant F value and the transformation was deemed successful in removing non-additive effects. The variation among sampling dates was very highly significant, as was variation due to station differences. Sampling dates and mean catches of <u>Menidia</u> for each station on each of these dates are shown in Table 5.

Duncan's new multiple range test was applied to these station grand means to determine where significant differences existed (Steel and Torrie, 1960). Results of this test are contained in Table 6.

These results indicate that <u>Menidia</u> were found more abundantly at those stations displaying some sort of protection from the prevailing southerly winds, and having relatively sandy bottoms with some sort of submergent vegetation such as <u>Chara</u>.

Table 4. Analysis of variance of mean catches of <u>Menidia audens</u> for all stations on various dates in 1965 and 1966.

Source	Sum of squares	df	Mean square	F
Date	74.95	18	4.16	19.81**
Station	10.57	5	2.11	10.05**
Error	18.93	90	0.21	
Additivity	0.63	1	0.63	3.00 n.s.
Residual	18.30	89	0.21	
Total	104.45	113		

*P <.05
**P <.01

Table 5. Mean seine catches of Menidia audens from six stations located in the Buncombe Creek arm of Lake Texoma during 1965 and 1966.

Date	Station number 1	2	3	4	5	6
July 10 1965	50.5	310.5	234.0	777.0	109.0	65.0
July 24 1965	100.0	132.0	310.5	4.0	0.0	5.0
Aug. 7 1965	34.0	59.5	218.0	91.0	32.0	365.0
Aug. 21 1965	6.5	44.0	150.5	67.5	48.0	70.5
Sept. 4 1965	8.0	12.0	160.0	49.5	35.5	66.5
Oct. 16 1965	11.5	1.0	53.0	30.0	10.0	50.5
Nov. 20 1965	33.0	1.5	17.5	10.5	2.0	77.0
Dec. 11 1965	1.0	1.0	18.0	24.5	2.5	18.0
Feb. 5 1966	0.5	0.0	16.0	3.5	1.0	23.5
Mar. 19 1966	7.5	3.0	0.5	1.5	1.0	18.5
April 2 1966	0.0	0.0	24.0	10.0	0.0	18.0
April 30 1966	3.0	0.0	4.0	4.0	0.0	0.5
May 28 1966	6.5	1.0	533.5	38.0	3.5	167.5
June 12 1966	313.0	1087.0	1765.5	717.5	42.5	218.5
June 26 1966	1007.0	1781.0	2270.0	2717.0	1087.5	2169.5
July 11 1966	95.5	181.0	1006.5	623.5	459.5	632.5
July 25 1966	381.0	405.0	834.0	229.5	65.5	851.0
Aug. 7 1966	2094.0	108.0	224.0	224.5	96.5	443.0
Aug. 23 1966	828.5	34.0	122.5	179.5	34.5	291.0

Table 6. Comparisons of mean catches of *Menidia* at six stations during 1965 and 1966 using Duncan's new multiple range test.

$S_{\bar{x}}$ = (error MS)/r = 0.21/19 = 0.105

where r = the number of observations per mean

error degrees of freedom = 90

Number of means involved, P	2	3	4	5	6
SSR	2.80	2.95	3.05	3.12	3.18
LSR	0.29	0.31	0.32	0.33	0.33

Station* number					
5	2	1	4	6	3

*Stations encompassed within a line are similar.

CHAPTER IV

LIFE HISTORY

Age and Growth

Growth of *Menidia* was determined by measurement of fish taken by seining only, because of the selectivity of the electric shocker and the gill net for certain sizes of fish. Fig. 3 shows the average length and range in length of fish samples plotted against sampling dates in 1965 and 1966. The growth of *Menidia* apparently stopped in October--as indicated by the tendency of the line to assume a slope of zero--and resumed again in March.

Adult *Menidia* were never taken after July 31, which suggests a maximum longevity of about 16 months. The maximum size of *Menidia* captured in Lake Texoma, as shown by length-frequency distributions in Fig. 4, was 119 mm, total-length; however, a 130 mm specimen weighing 9.65 g was taken from Boomer Lake in February, 1966. The length-frequency distributions also show both the 1964 and 1965 year-classes disappearing in late July of the year following the year of hatching. The distributions are approximately normally distributed

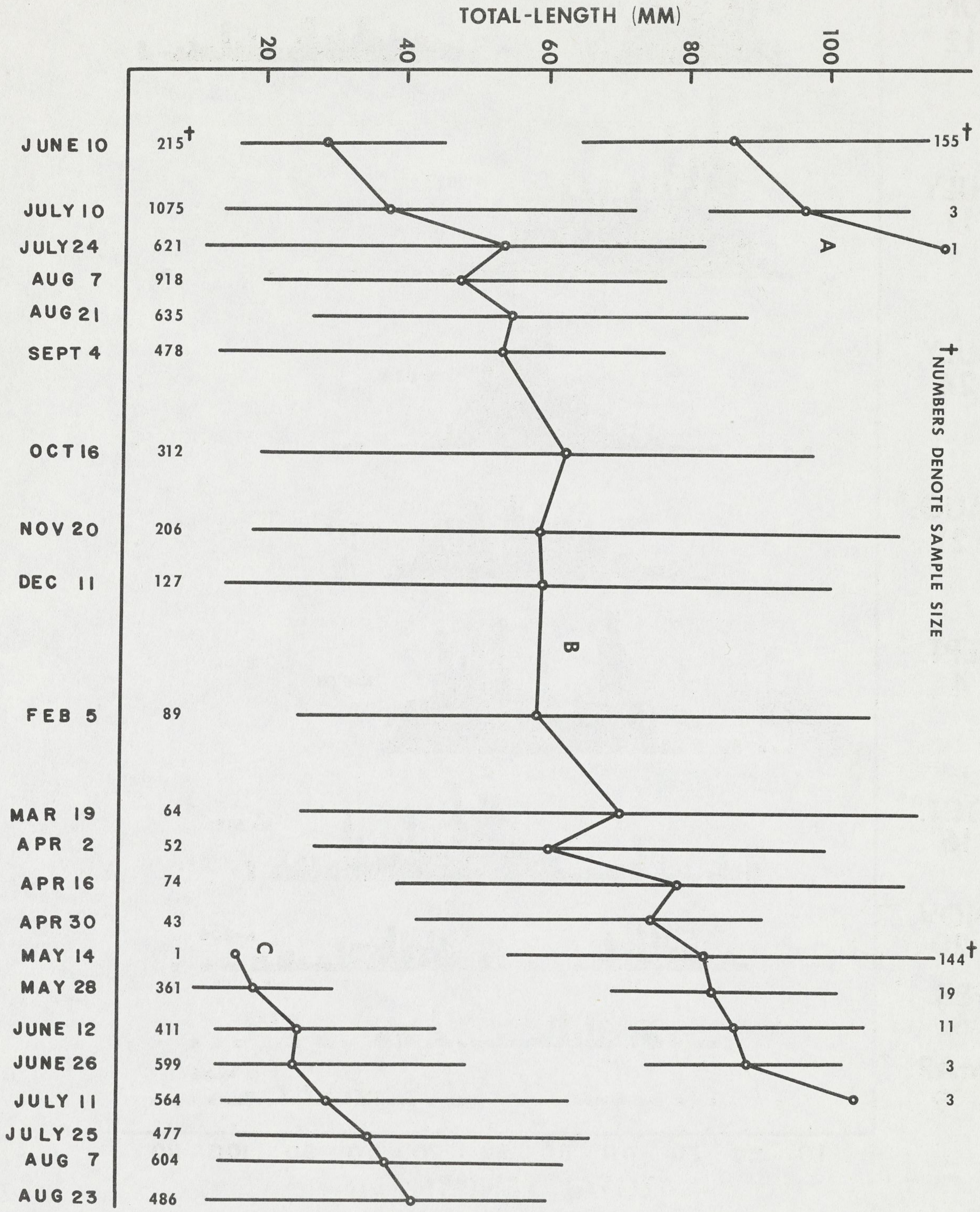

Fig. 3. Means and ranges in total length of the 1964, (A); 1965, (B); and 1966, (C); year-classes of Menidia audens taken from Lake Texoma during 1965 and 1966.

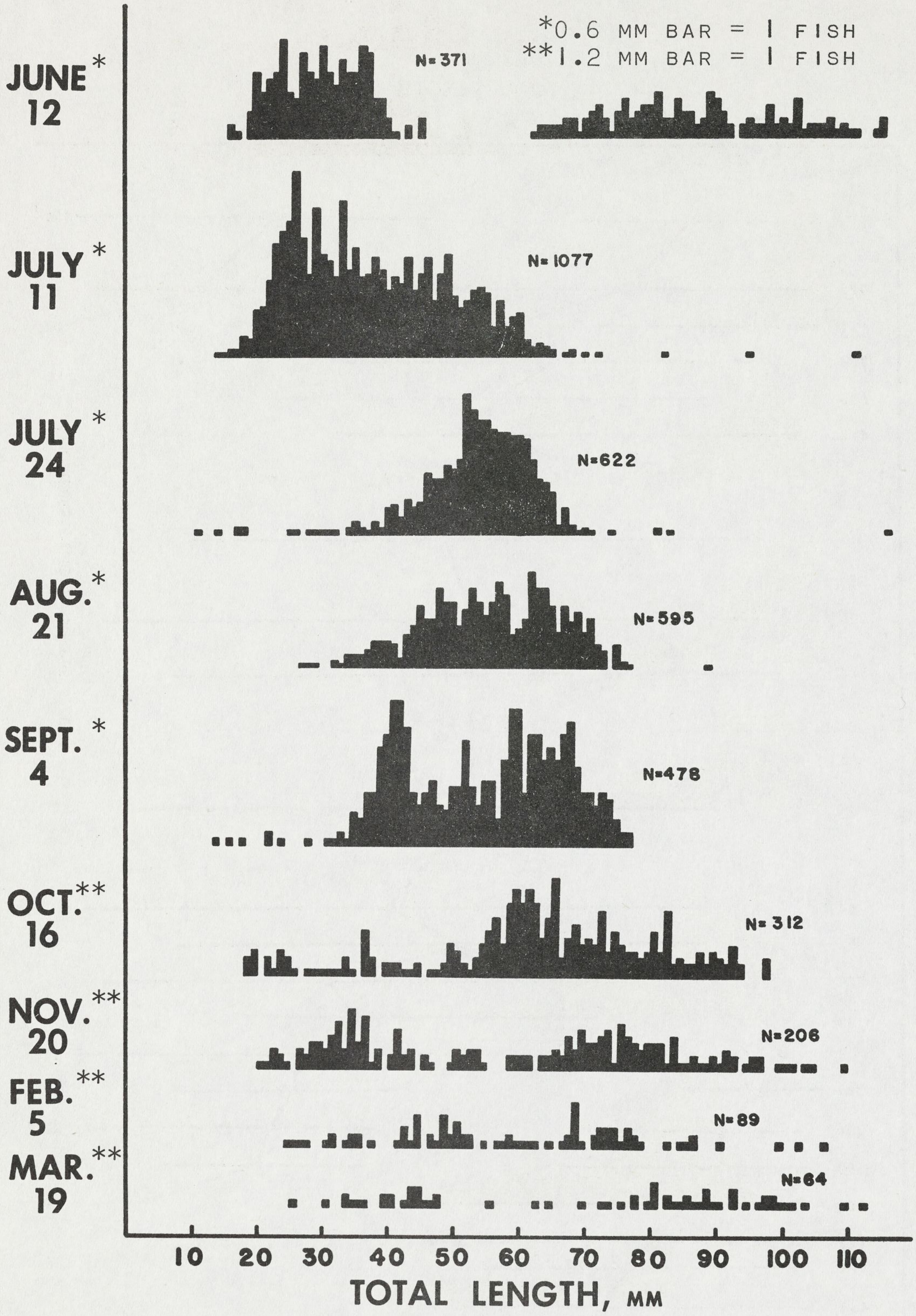

Fig. 4. Length-frequency distributions of Menidia audens taken by seine from Lake Texoma during 1965 and 1966.

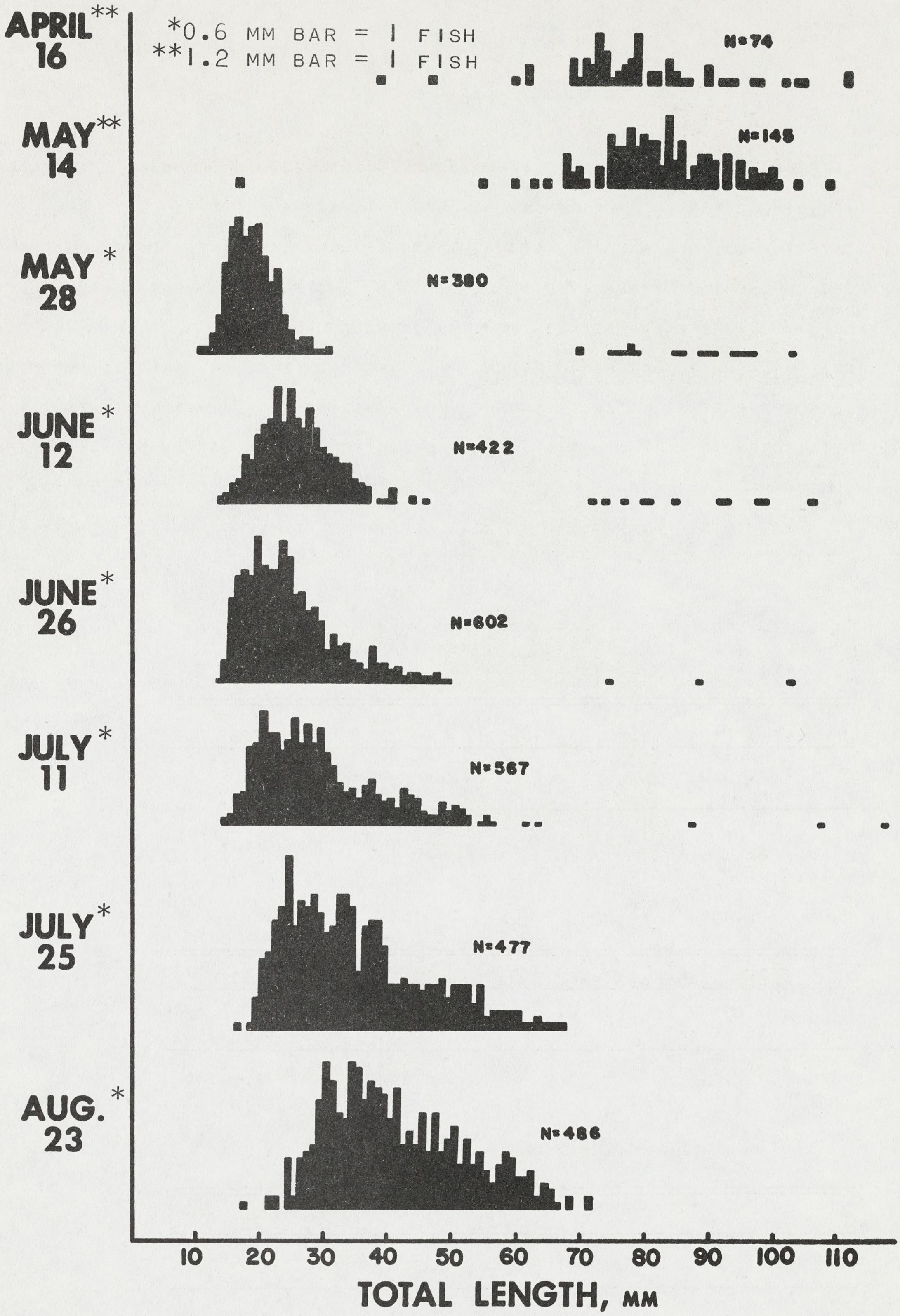

Fig. 4. (continued)

during the early life of the fish, but by October a more contagious or bimodal pattern can be detected, possibly indicating a differential growth rate of male and female fish.

To test this hypothesis, one-way analyses of variance were calculated comparing lengths of males and females of the 1964 year-class in June, 1965, and the 1965 year-class throughout the year (Table 7). Differences between lengths of males and females of the 1965 year-class were non-significant until October. After this date the level of significance tended to become greater, except for the December sample, which was non-significant. This one exception may be attributed to chance deviation resulting from small sample size. Difference between lengths of male and female fish of the 1964 year-class in June, 1965, was very highly significant. From these data it can be concluded that females grow at a faster rate than males.

Table 7. Analyses of variance of differences in lengths of male and female Menidia taken from Lake Texoma in various months of 1965 and 1966.

June 1965 (1964 year-class)		N = 148	(59 ♂♂; 89 ♀♀)	
Source	DF	Sum of squares	Mean squares	F
Among	1	6,473.75	6,473.75	60.78**
Within	146	15,550.33	106.51	
Total	147	22,024.08		
August 1965 (1965 year-class)		**N = 76**	**(15 ♂♂; 61 ♀♀)**	
Source	DF	Sum of squares	Mean squares	F
Among	1	17.52	17.52	3.58 n.s.
Within	74	372.20	5.03	
Total	75	389.72		
September 1965		**N = 33**	**(9 ♂♂; 24 ♀♀)**	
Source	DF	Sum of squares	Mean squares	F
Among	1	1.14	1.14	0.05 n.s.
Within	31	748.86	24.16	
Total	32	750.00		

*P <.05
**P <.01

Table 7. (continued)

October 1965 N = 75 (28♂♂; 47♀♀)

Source	df	Sum of squares	Mean squares	F
Among	1	606.90	606.90	6.99*
Within	73	6,339.90	86.80	
Total	74	6,946.80		

November 1965 N = 37 (14♂♂; 23♀♀)

Source	df	Sum of squares	Mean squares	F
Among	1	408.00	408.00	7.93**
Within	35	1,801.00	51.46	
Total	36	2,209.00		

December 1965 N = 36 (16♂♂; 20♀♀)

Source	df	Sum of squares	Mean squares	F
Among	1	9.61	9.61	0.13 n.s.
Within	34	2,530.39	74.42	
Total	35	2,540.00		

January 1966 N = 57 (25♂♂; 32♀♀)

Source	df	Sum of squares	Mean squares	F
Among	1	1,176.50	1,176.50	6.61*
Within	55	9,792.50	178.05	
Total	56	10,969.00		

February 1966 N = 90 (42♂♂; 48♀♀)

Source	df	Sum of squares	Mean squares	F
Among	1	2,836.50	2,836.50	10.09**
Within	88	24,731.50	281.04	
Total	89	27,568.00		

*P <.05
**P <.01

Table 7. (continued)

March 1966			N = 174 (78 ♂♂; 96 ♀♀)	
Source	df	Sum of squares	Mean squares	F
Among	1	3,371.2	3,371.2	30.76**
Within	172	18,860.1	109.6	
Total	173	22,231.3		

April 1966			N = 182 (155 ♂♂; 27 ♀♀)	
Source	df	Sum of squares	Mean squares	F
Among	1	2,145.0	2,145.0	10.20**
Within	180	37,849.0	210.3	
Total	181	39,994.0		

May 1966			N = 208 (153 ♂♂; 55 ♀♀)	
Source	df	Sum of squares	Mean squares	F
Among	1	4,753.5	4,753.5	39.71**
Within	206	24,651.4	119.7	
Total	207	29,404.9		

*$P < .05$
**$P < .01$

Sex Ratios

Sex ratios of fish from the 1965 year-class were compared using Chi-square tests and the assumption of a 50:50 ratio (Table 8). Only seine-caught fish were used in analyses of sex ratios because the shocker was found to be selective for larger fish, and since males, on the average, were found to be smaller than females, the use of fish caught with the shocker would introduce bias into sex ratio data for this species. Since fish smaller than about 35 mm, total-length, could not be sexed positively by superficial examination of their gonads, only larger fish were used in determining sex ratios.

Table 8. Results of sex ratio analyses of samples of *Menidia audens* taken in various months of 1965 and 1966, assuming a 50:50 ratio.

Month of capture	Sample size	Males per 100 females	Chi-square
August	78	26	27.12**
September	33	38	5.92*
October	75	60	4.82*
November	38	58	2.64 n.s.
December	34	79	0.48 n.s.
February	57	97	0.02 n.s.
March	41	71	1.20 n.s.
April	137	879	86.72**
May	165	511	74.68**
June	170	65	7.62**
July	16	60	1.00 n.s.

*P <.05
**P <.01

Chi-square values were significant for August, September, and October samples, indicating a predominance of females. Chi-square values were non-significant throughout the rest of the fall and winter until a difference was again detected in April and May samples. These significant differences, however, indicated a predominance of males in the littoral zone population during these months. A possible explanation of this apparent increase in males was the tendency of males to form unisexual aggregations in the spring. Thus, the capture of one male in a seine haul increased the probability of others being caught in the same seine haul. Most samples of fish taken at this time of year contained only male fish, while those few samples containing females usually also contained males. It is also possible that the increased catch of male fish resulted from the movement of female fish out of the littoral zone.

The Chi-square value calculated for fish caught in June was again significant, but this time indicated a predominance of females. This may have resulted from a dispersal of male aggregations. Saunders (loc. cit.) found females to outnumber males 20 to 1 in June and July samples.

Reproduction

Although spawning of *Menidia* was never observed, indirect evidence indicates that spawning began in late March or early April and extended over a wide range of time in 1965 and 1966. Saunders (loc. cit.) felt that *Menidia* spawned from late March through mid July in Lake Texoma, and that spawning occurred in "pulses". He found that small specimens could be caught throughout the summer, and believed that the young could be placed in several length groups. Fig. 4 indicates that an almost perfect gradation occurs between lengths of early hatched and late hatched young, and therefore while spawning of individuals may occur in "pulses", the spawning of the population, as a whole, occurs more smoothly than Saunders suspected.

The lower limit of the length ranges for young-of-year fish collected in this study remained relatively constant throughout the summer (Fig. 3). Those individuals representing the lower limit of the range approximated the smallest catchable size for the 1/8-inch mesh seine. From Fig. 3 it can be seen that although the lower limit of the range remained relatively constant throughout the summer, fall, and winter, for the 1965 year-class, it went up quite rapidly as growth resumed in the spring. Fluctuation in the range is known to be due to the sensitivity of the range to fluctuations in sample size, and since sample size varied considerably from sample to sample in the 1965 collections, some fluctuation in the range is to be expected. In the summer of 1966, sizes of samples were more constant and fluctuations in the range were minimal. Additional evidence for an early and prolonged spawning period was obtained by examination of ovaries.

Gonads of females taken in early March were well developed, and some contained nearly mature eggs. All ripe females examined throughout the summer were found to contain additional immature eggs, and no completely spent female was ever found. Saunders (loc. cit.) also found that many immature eggs remained in the ovaries of female *Menidia* after stripping and concluded from this that females may spawn more than once. Cahn (1927) found no eggs of any kind remained in ovaries of female *Labidesthes* captured immediately after spawning. Thus, *Menidia* may have a higher total fecundity than *Labidesthes* if the number of mature eggs spawned at one time does not differ for the two species.

Fecundity

Fecundity of *Menidia* was determined by making total counts of mature eggs from 31 females collected during the summers of 1965 and 1966. One additional female was excluded when a count showed that the number of mature eggs found in this fish were far below the numbers found in other individuals of nearly the same size. This indicated that she may have been partially spent at time of capture.

Mean number of mature eggs per female was 984, with a standard deviation of 358.6 and a range from 384 to 1699. Saunders (loc. cit.) found that he could remove only between 10 and 200 eggs by stripping, however.

Four measurements were compared with numbers of mature eggs per female to determine the best technique for estimating fecundity: (1) total-length, (2) total weight, (3) ovary weight, (4) body weight. Body weight was considered as the weight of the fish after removal of its ovaries, while ovary weight was obtained indirectly by subtracting body weight from total weight.

The data for these four relationships, with fitted regression lines, are shown in Fig. 5; statistics are contained in Table 9. All four relationships show a high degree of correlation. Total weight and body weight had the highest correlation with mature egg numbers, while the correlation of total-length with mature egg numbers was somewhat lower. The correlation of mature egg numbers and ovary weight was the lowest.

Table 9. Statistics for comparisons of total-length, total weight, body weight, and ovary weight with mature egg numbers in *Menidia audens*.

	Total-length	Total weight	Body weight	Ovary weight
Correlation coefficient, r	0.872	0.913	0.912	0.775
95% confidence interval for r	0.748 to 0.937	0.826 to 0.958	0.825 to 0.957	0.578 to 0.886
Regression:				
slope, b	23.29	192.84	846.75	165.90
intercept, a	-1278.18	126.99	153.10	83.90
95% confidence interval for b	18.34 to 28.24	156.41 to 175.39	181.27 to 204.40	764.76 to 928.73

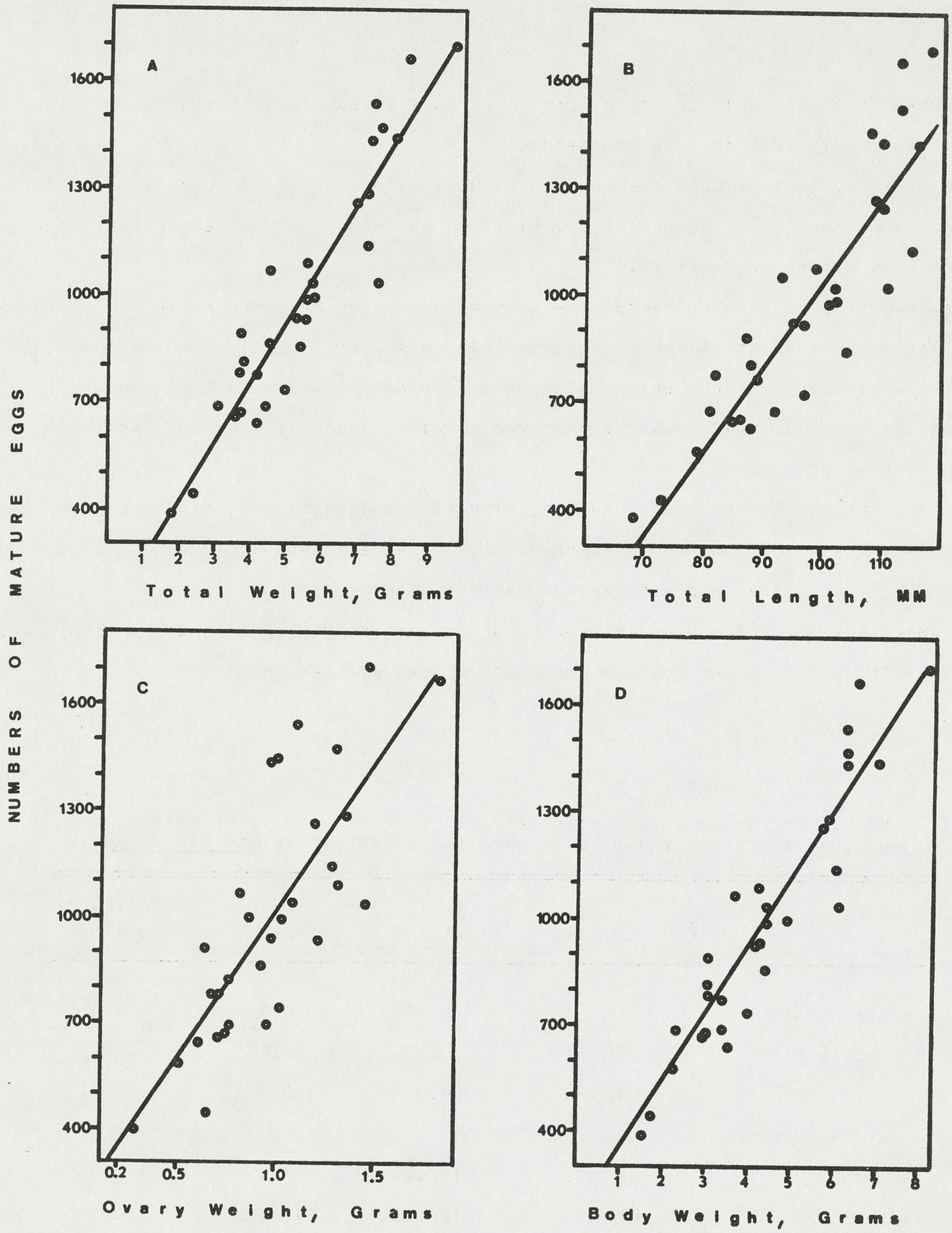

FIG. 5. RELATIONSHIPS OF VARIOUS MEASUREMENTS TO NUMBERS OF MATURE EGGS FOUND IN THE OVARIES OF *MENIDIA AUDENS*.

It is apparent that the correlation between length and numbers of mature eggs is the most practical method from which to estimate numbers of mature eggs in the field, although correlations of both total weight and body wieght with numbers of mature eggs are more reliable. The reason for the poorer correlation between mature egg numbers and ovary weight could be due to variability in numbers of immature eggs contained in each individual pair of ovaries.

Length-weight Relationships

Length-weight relationships for *Menidia* taken in each season of the year were calculated using the formula:

$$\text{Log } w = \text{Log } a + b \text{ Log } L$$

where W = total weight in grams,

a = the intercept of L on W,

b = slope due to regression,

and L = total-length in millimeters.

Slopes and elevations of regression lines calculated for males and females were compared using F tests. To test elevations it was necessary to adjust mean weights as in the analysis of covariance (Lux and Porter, 1966). Results of these computations are contained in Table 10.

Table 10. Seasonal length-weight relationships for *Menidia audens* taken from Lake Texoma during 1965 and 1966.

	Sex	N	(Log 10^2L) b	a	$s_{y.x}$	Slope F	Elevation F	Range in total-length
Summer 1965								
Adults	M	61	3.2011	-3.6369	0.0265	0.075 n.s.	0.875 n.s.	62-101
	F	95	3.2831	-3.8004	0.0300			64-115
Young-of-year	M	12	2.7037	-2.7009	0.0529	0.07 n.s.	7.07*	62-69
	F	34	2.8972	-3.0865	0.0300			51-89
Fall 1965								
Young-of-year	M	43	2.6912	-2.6921	0.0361	0.11 n.s.	0.33 n.s.	58-93
	F	79	2.7257	-2.7534	0.0265			60-110
Winter 1965-6								
Adults	M	51	2.9446	-3.2036	0.0283	3.11 n.s.	1.11 n.s.	49-105
	F	67	3.0574	-3.4131	0.0300			51-111
Spring 1966								
Adults	M	293	2.8859	-3.0486	0.0283	0.72 n.s.	15.22**	43-107
	F	119	2.8364	-2.9403	0.0316			44-120

*P <.05
**P <.01

Differences in slopes were non-significant in every season of the year, but the elevations of the lines differed significantly for young-of-year fish in summer and for adults in spring. In the first case, males of a given length were heavier than females of the same length, while in the second case, females were heavier than males. It thus appears that in the first months of life, male *Menidia* outweigh their female counterparts, while development of eggs in adult females in spring increases their weight relative to that of males of the same length. In summer, the loss of eggs in spawning, combined with the gradual loss of energy required for the production of more eggs, may act to decrease the weight of females. Observation of gonad development throughout the year indicate that eggs begin development in early spring and very little difference in gonads of male and female fish exists over the winter. Although gonads of young-of-year fish began to develop in the fall, they soon regressed and remained in that condition until development began anew toward the end of winter.

Fluctuations in Seine Catches

Fig. 6 shows mean catch per seine haul of *Menidia* in night, day, and combined night and day samples. Catch per haul of the 1965 year-class underwent a relatively constant rate of decrease from early summer until May, when the rate of decrease increased until this year-class disappeared from the samples in late July. Catch per haul for the 1966 year-class, as represented by specimens large enough to be caught with the seine, reached peak numbers in early July and began a relatively constant rate of decline through August, when the study was terminated.

Since *Menidia* appears to be a surface dwelling fish with a marked preference for the littoral zone, catch per seine haul may represent a fair index of survival and mortality. Either a seasonal change in distribution or an increased escapement as the fish became larger, would modify the significance of this curve as an index of these population parameters. For this reason, more work on the seasonal distribution patterns of *Menidia* needs to be done before any conclusions can be made.

The mean catch of the 1966 year-class in late August was 248, approximately equal to the mean catch of 258, representing the 1965 year-class during early July, 1965. The mean catches of the 1966 year-class during July and August, 1966, were consistently higher than the mean catches of the 1965 year-class over the same period in 1965. These comparisons indicate either a later initiation of spawning for *Menidia* in 1966, a greater hatch of *Menidia* in 1966, or a greater mortality of *Menidia* in the summer of 1965.

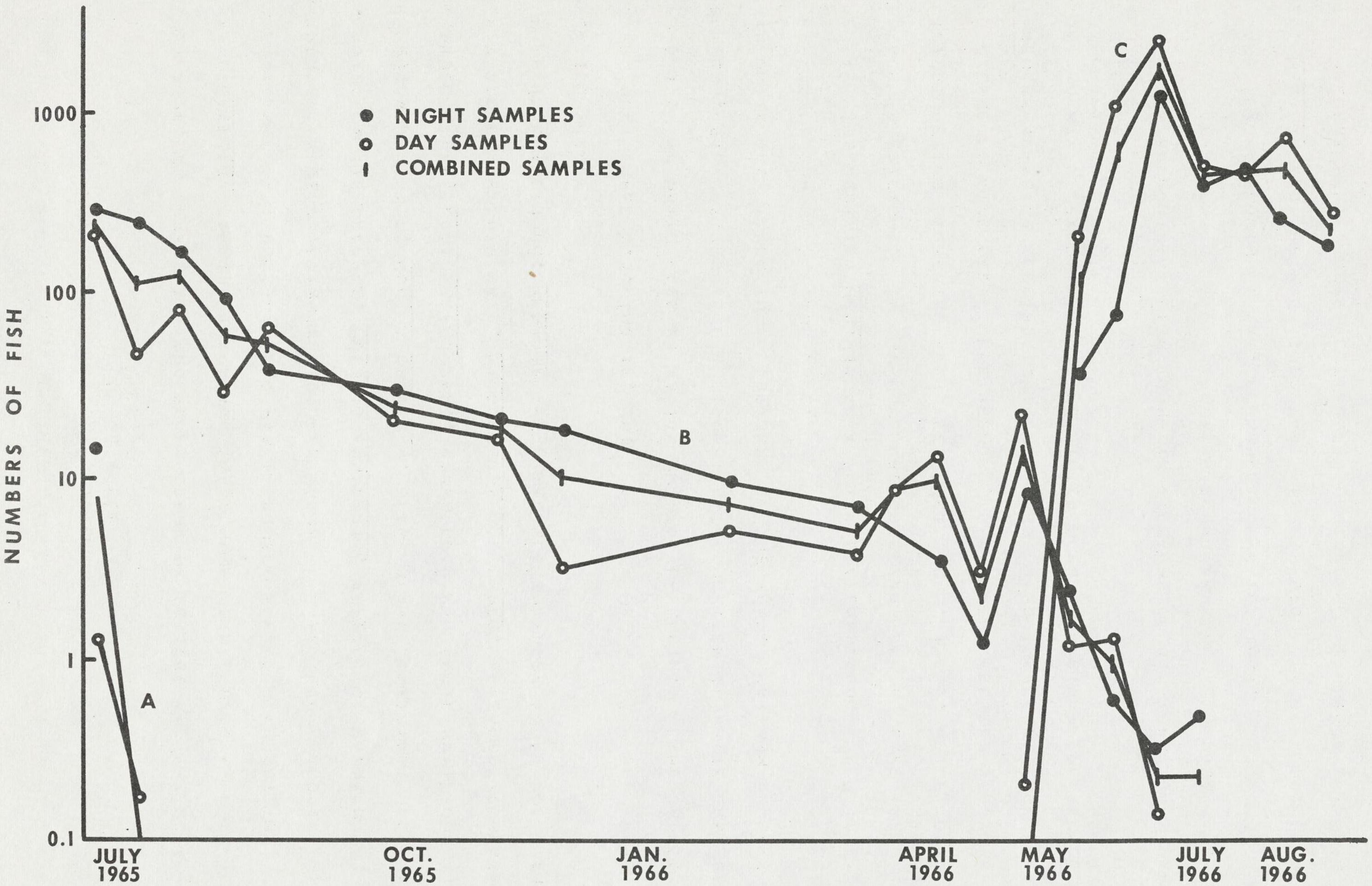

FIG. 6. MEAN SEINE CATCHES OF THE 1964, (A); 1965, (B); AND 1966, (C); YEAR-CLASSES OF MENIDIA AUDENS TAKEN FROM LAKE TEXOMA DURING 1965 AND 1966.

CHAPTER V

FORAGE VALUE

Small adult size, an apparently prolonged spawning period, and the relatively high total fecundity of *Menidia* combine in making large numbers of these fish available as forage for adult as well as young-of-year piscivorous fishes throughout the year.

Menidia apparently begin spawning in late March in Lake Texoma and continue through early summer. Since white crappie, *Pomoxis annularis*, appear to spawn in May and June (Whiteside, 1962); white bass, *Roccus chrysops*, spawn during the first half of May in Lake Texoma (Riggs, 1955); gar, *Lepisosteus* spp., spawn from mid April until June in Lake Texoma (Echelle, 1967); and largemouth bass, *Micropterus salmoides*, appeared to begin spawning in late April during 1965 and 1966; *Menidia* are available to these young sport fishes in their initial fish-eating stages.

B. B. Moser (unfinished M.S. Thesis, University of Oklahoma) found *Menidia* to be the predominant food item in white bass 38 to 148 mm, total-length. Although less important in larger specimens, silversides were a significant food item in white bass of all sizes, and occurred in white bass taken in all seasons of the year. Maximum numbers occurred in stomachs of fish taken during May and June.

Whiteside (1962) classified *Menidia* as a "miscellaneous food item" in stomachs of 719 white crappie from Lake Texoma. In the Buncombe Creek arm of the lake the white crappie occurs primarily at depths exceeding four feet (Grinstead, 1965), while *Menidia* rarely reaches depths exceeding five feet. Furthermore, during the present study, white crappie were rarely taken by seine or electrofishing devices. The infrequent occurrence of *Menidia* in crappie stomachs may be explained by the differences in habitat preferences of the two species in Lake Texoma.

Menidia were the predominant fish found in stomachs of 386 young gars examined by Echelle (1967), and represented 54% of the fish found in adult longnose gar, *Lepisosteus osseus*, from Lake Texoma (Edwin B. May, personal communication).

By number, *Menidia* was the most important fish in stomachs of young largemouth bass examined in the present study, representing 78% of the 290 fish identified to genus and occurring in 72% of stomachs containing identifiable fish (Table 11). The number of bass analysed and their months of capture, as well as the number of stomachs found to contain fish, are included in Table 12.

Table 11. Seasonal occurrence of fishes found in stomachs of 536 young largemouth bass taken from Lake Texoma in 1965 and 1966.

	Menidia audens	Dorosoma	Lepomis	Micropterus	Cyprinus carpio	Pimephales vigilax	Unidentified
Winter							
frequency	1	3	1	-	-	-	4
number	1	8	1	-	-	-	
Spring							
frequency	24	4	1	-	1	-	16
number	116	4	1	-	1	-	
Summer							
frequency	45	13	6	2	1	2	38
number	107	31	10	2	4	2	
Fall							
frequency	1	-	-	-	-	-	2
number	1	-	-	-	-	-	
Total							
frequency	71	20	8	2	2	2	60
% frequency	72	20	8	2	5	2	
number	225	43	12	2	5	2	
% of identified fishes	78	15	4	1	2	1	

Table 12. Frequency of fish in stomachs of 536 young largemouth bass taken from Lake Texoma during 1965 and 1966.

Month of capture	Total stomachs	Empty stomachs	Stomachs with fish
January	5	2	2
February	6	0	5
March	8	5	0
April	31	16	12
May	150	35	33
June	231	14	67
July	34	6	12
August	41	16	13
September	19	7	1
October	7	3	2
November	4	1	0
Total	536	105	147

Menidia occurred in largemouth bass as small as 24 mm, total-length, and represented 90% of the 146 fish identified from largemouth bass less than 50 mm.

Often several *Menidia* were found in a stomach, and in one case, a 30 mm bass was found to contain 49 sac fry. These cases could have been consequences of the schooling or aggregating behavior of *Menidia*. One peculiar case of a bass feeding on a *Menidia* too long for its digestive tract was discovered. The bass, an 89 mm specimen apparently in good condition, had swallowed a 58 mm silverside. The tail of this fish protruded from the mouth of the bass, while the anterior portion was partially digested. Since the bass was preserved immediately after capture, it was improbable that it had swallowed the silversides accidentally while trying to escape the seine.

The percentages of *Menidia* and *Dorosoma* in the total seine catch, approximated the percentages that these genera made up of the identifiable fish in the stomachs of largemouth bass (Tables 11 and 13). The correlation does not seem to hold for the other forage species, probably because of low numbers resulting in relatively high chance deviations. These data indicate that the value of *Menidia* as forage for young largemouth bass lies in its abundance in the littoral zone rather than any selective preference toward it by the bass.

Table 13. Catch per unit effort of fishes taken by seine from Lake Texoma in 1966.

	Winter	Spring	Summer	% of total catch
Menidia	7.4	34.3	713.8	71.1
Dorosoma	0.2	5.3	265.4	25.9
Lepomis	0.2	1.1	17.4	1.8
Pimephales	4.9	0.5	5.4	0.6
Notropis	0.3	1.0	2.0	0.3
Micropterus	0.0	0.4	1.0	0.1
Gambusia	0.0	0.0	1.4	0.1
All other	0.0	0.2	0.9	0.1

Based on available information and the results of this study, *Menidia* appears to be an important forage species to those piscivorous fishes feeding at the surface or in littoral areas of Lake Texoma.

CHAPTER VI

SUMMARY

1. A study of the life history; vertical, lateral, and littoral distribution; and the forage value of the Mississippi silversides, *Menidia audens*, in Lake Texoma was conducted during 1965 and 1966. Collections of fish were made using a small-mesh, vertical gill net; boom-type electric shocker; and a small seine.

2. *Menidia* were never collected at depths greater than five feet with the vertical gill net during late summer and fall, and were seen swimming at the surface in all seasons of the year. Thus, it appeared that the vertical distribution of *Menidia* was restricted to the upper five feet of the lake throughout the year.

3. *Menidia* were collected predominantly in the littoral zone with the electric shocker during the winter and spring, but a few were also taken near the surface in the open-water region of the lake. Observations during all seasons of the year also indicated a greater abundance of *Menidia* in the littoral zone than near the surface in the open-water zone.

4. Within the littoral zone, *Menidia* were most abundantly found over relatively sandy bottoms possessing a mat of *Chara* and protected from the prevailing southerly winds. No differences were detected between night and day catches, and it appeared likely that *Menidia* displayed no diurnal migration to and from the littoral zone.

5. Growth of *Menidia* stopped in October in Lake Texoma and began again in March during 1965-66. The largest specimen of *Menidia* taken from Lake Texoma during this study was 119 mm, total-length, but a 130 mm specimen was collected from Boomer Lake in February, 1966. Adult *Menidia* were never taken after July 31, and thus it appeared that their maximum longevity was about 16 months. The scale method was unreliable for aging *Menidia* from Lake Texoma.

6. Females were found to grow at a faster rate than males, and females significantly outnumbered males in samples taken by seine during the summer and early fall. The sex ratio did not deviate significantly from 50:50 for samples collected throughout the winter and early spring, but the sex ratios of samples of fish taken in April and May suggested a great preponderance of males in the littoral zone population. This can be most likely attributed to the unisexual aggregations of males found in the littoral zone at this time of year. In June, a significantly greater number of females was again found, which

may have resulted from a breakup of male aggregations.

7. Gonads developed somewhat in early fall, but became regressed, and remained in that condition until the following spring when development began again.

8. Indirect evidence suggested that spawning occurred over an extended period of time, beginning in late March and extending through mid-July. Small *Menidia* could be taken throughout the summer, and ripe females contained many immature eggs. No completely spent female was ever collected.

9. Mean number of mature eggs per female was 984, with a standard deviation of 358.6 and a range from 384 to 1699. Numbers of mature eggs were most closely correlated with the weight of the females. The poor correlation between mature egg numbers and ovary weight was probably due to the varying numbers of immature eggs contained in the ovaries.

10. Tests of slopes and intercepts of regression lines of length-weight relationships of male and female *Menidia* taken during each season of the year indicated that young males outweighed their female counterparts in late summer. In spring, however, adult females outweighed males, possibly as a result of egg development.

11. Mean catch of *Menidia* per seine haul underwent a relatively constant rate of decline throughout summer, fall and winter of 1965-66. The rate of decline of the mean catch of the 1965 year-class increased in May and remained at this higher rate of decline until the last adult was taken in late July. The mean catch of the 1966 year-class began to decline in July and continued this decline until the study was terminated at the end of August.

12. *Menidia* appeared to be an important forage species for piscivorous fishes inhabiting the littoral and surface waters of Lake Texoma. They have been found to be an important item in the diet of white bass, *Roccus chrysops*, and are especially important as forage for young of this species. *Menidia* represented 78% of 290 identifiable fish taken from stomachs of young largemouth bass, *Micropterus salmoides*, collected in all seasons of the year, and were found in 72% of the stomachs containing identifiable fish. Shad, *Dorosoma* spp., was next in importance, representing 15% of the identifiable fish, and occurring in 20% of the largemouth bass stomachs containing identifiable fish.

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Developmental Rates of *Menidia audens* with Notes on Salt Tolerance

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ABSTRACT

Fertilized eggs of *Menidia audens* were incubated at temperatures from 10.2 to 36.4 C, normal development occurred between 13.2 and 34.2 C, high survival was between 17.0 and 33.5 C, and optimal development seemed to be between 20 and 25 C. Cold lethality was associated with depletion of yolk supply prior to hatching. Eggs in ¼ sea water did as well as those in fresh water; development through eye pigmentation was normal even in full strength sea water. Adults were more salt tolerant with critical salinities being near full sea water.

INTRODUCTION

Reservoir construction and enlargement has placed large bodies of quiet water in biogeographic areas in which natural lakes are rare or absent; therefore, balanced and integrated lacustrine biotas are not locally available. Unfortunately, we can not wait until this fauna evolves. In the interim a species can become excessively abundant; many exotics have been introduced to control the pests, sometimes with the result that a second pest must also be controlled.

The control of pest organisms by carefully selected predators has been advocated by Train *et al.*, (1970). Biological control seldom results in extermination of the pest but may reduce the problem to manageable proportions. Cook and Moore (1970) have advocated the use of the Mississippi silversides, *Menidia audens*, to control the pestiferous gnat, *Chaoborus astictopus*, in Clear Lake, California. The availability of the Mississippi silversides as forage for game fish contributes to its desirability. If this fish is to be considered as a biological control agent, its life history must be fully understood so that reasonable predictions can be made.

This investigation was designed to determine tolerances of Mississippi silverside eggs and young to thermal and salinity stress. Several other items were observed that apply to the life history of *Menidia audens*. Some agreed with the published reports, some supplemented the available information, and others that were discordant were checked to confirm the validity of our observations which are reported below.

MATERIALS AND METHODS

Stocks of adult *Menidia audens* were obtained at several localities on the north shore of Lake Texoma, most notably at Mayfield Flat, Willis Bridge, and Willis Island, and returned to the University of Oklahoma Biological Station. The adults were placed in styrafoam coolers as soon as possible. Those left in the seine more than 10 seconds after beach-

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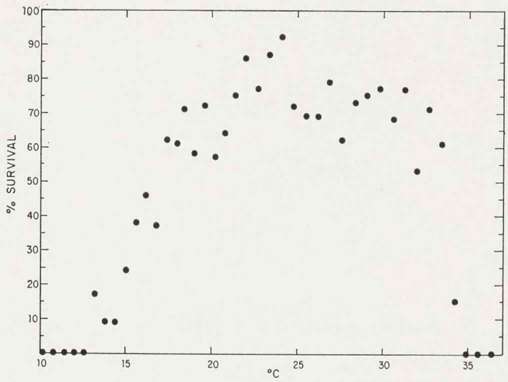

FIGURE 1.—Survival percentages of fertilized *M. audens* eggs incubated at constant temperatures. A successful test is one in which the larva depletes its yolk after previously free swimming.

ing suffered severe mortality as did those in slightly crowded coolers. Transfer between coolers and/or checking for gametes had to be done with extreme care to avoid 100% mortality. Gametes were mixed in petri dishes and inoculated into individual screwcapped culture tubes (20 × 125 mm), which were placed in the temperature gradient blocks described by Hubbs, Peden, and Stevenson (1969).

The eggs were checked daily for developmental stage; the 4 intervals used had patterns typical of the others. Gastrulation was considered to be equivalent to Oppenheimer (1937) Stage 19; eye pigmentation equivalent to Oppenheimer Stage 28; and hatching equivalent to Oppenheimer Stage 34. The fourth stage, starvation death, was thought to reflect rates of yolk consumption (or general metabolism). Eggs were considered to have been successful if the young were normal and died with small or absent yolk sacs. Those that were abnormal (usually with the tail curled ventrally) often were quiet when examined and lived longer than their active siblings at the same temperature. The number of days required to reach each stage was recorded for each egg, and the days were averaged for each temperature station. After one to four days of free swimming, normal young sank to the bottom and did not move but had a visible heart beat. Such young were allocated a half day survival as they were obviously dying.

Most of the tests were run in Lake Texoma water—water pumped from the Buncombe arm—that had been placed in the culture tubes 2+ hours before inoculation (adequate time for temperature equilibration). This water may have contained supplies of microorganisms but little population growth would be likely in 5 cc water held in darkness.

The salt tolerance experiments used Rock salt added to Lake Texoma water (ca 800 ppm total solids). Sea water was assumed to be 33 ppt. Egg incubation salinity tests used the same culture tubes and techniques as the temperature stress experiments; evaporation was nil in the covered culture tubes. The salt toleration tests on adult *Menidia* used fish that had been maintained at least 48 hours in styrafoam containers. The fish were placed in various sea water concentrations and mortality rates recorded. Only those tests with minimal (25% or less) mortality of controls were used to calculate experimental results. Most experiments (and all discussed below) were done at 20 ± 2°C.

DEVELOPMENTAL TEMPERATURE TOLERANCE

Eggs placed at incubation temperatures shortly after exposure to sperm had successful development between 13.2 and 34.2 C (Figure 1). Survivals were more or less equivalent between 17 and 33.5 C with a narrow upper sublethal temperature zone and a gradual increase in mortality associated with decreasing temperatures below 17 C. These data were paralleled by relative ability of the eggs to gastrulate. Only one egg was able to gastrulate at 34.9 C and none at 35.6 and 36.4 C. In contrast six, four, five, and three gastrulated at 12.6, 12.0, 11.4, and 10.8 C, respectively. The differences occurred despite the greater frequency of inoculations at high temperatures (at high temperatures the eggs died in one day but at low temperatures might live a week without gastrulating).

Large numbers of eggs were incubated at optimal temperatures and then transferred to lethal temperatures at various developmental stages. If transferred before gastrulation the results paralleled those of eggs placed at incubation temperatures shortly after fertilization. If gastrulation had occurred, most eggs de-

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Forage Value of Mississippi Silversides in Lake Texoma

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Introduction

The first specimen of Mississippi silversides, *Menidia audens* Hay, from Lake Texoma was collected by Bonn in 1953; by the summer of 1954 the species was quite common, and by 1959 it was one of the most abundant species in the lake (Riggs and Bonn, 1959). Its abundance in Lake Texoma prompted the present study.

This study is an evaluation of the forage value of *Menidia* in Lake Texoma, based on food habits studies of white bass, *Roccus chrysops* (Rafinesque), (B. B. Moser, unfinished M. S. thesis, University of Oklahoma); white crappie, *Pomoxis annularis Rafinesque,* (Whiteside, 1962); gars, *Lepisosteus* sp., (Echelle and E. B. May, unfinished M. S. theses, University of Oklahoma); and young largemouth bass, *Micropterus salmoides* (Lacepede), done as part of this study.

Methods and Materials

Largemouth bass for food analyses were obtained by seining and electrofishing operations during 1965 and 1966 in the Buncombe Creek arm of Lake Texoma. Electrofishing was done with a boom shocker described by Ming (1964). Collections were made at various times of day and night during all months of the year except December.

A total of 536 young largemouth bass, ranging from 17 to 363 mm total length, were examined, most (73%) of which were collected during May and June. Each kind of food item in the stomachs was enumerated and recorded. Data on food items other than fish were not analysed.

Collections for relative abundance data for the Buncombe Creek arm of the lake were obtained by making one seine haul with a 20-ft, ⅛-inch, ace-mesh seine at each of six stations, once by day and once by night. Collections were made from February through August, 1966. In analysing the data of Table II, each seine haul was treated as one unit of effort.

Results and Discussion

In Lake Texoma, Mississippi silversides began spawning in late March and continued through the month of July (Mense, unfinished M. S. thesis, University of Oklahoma). Whiteside (1962) stated that white crappie spawned in May and June in the lake. Riggs (1955) reported that white bass spawn from April through June, depending on the locality. Largemouth bass in Lake Texoma appear to begin spawning in late April. Based on these spawning dates, *Menidia* apparently is available as food when the young of these game fishes are in their initial fish-eating stages.

Menidia are about 5 mm long at hatching and by September maximum total lengths approximate 85 mm. Adults reach maximum lengths of about 130 mm and have a maximum life span of about 16 months. Ovaries of 37 *Menidia* examined by Mense (loc. cit.) in 1965 and 1966 contained both immature and mature eggs, indicating more than one spawn by individuals. The number of mature eggs per fish ranged from 384 to 2094. Small adult size, coupled with the early and prolonged spawning period and relatively high reproduction rate, make large numbers of fish available to adults as well as young-of-year piscivorous fishes throughout the year.

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Moser (loc. cit.) found *Menidia* to be the predominant food item in white bass 38 to 148 mm, total length. Although less important in larger specimens, silversides were a significant item in white bass of all sizes, and occurred in bass taken in all seasons of the year, with maximum numbers occurring in May and June.

Whiteside (1962) classified *Menidia* as a "miscellaneous food item" in stomachs of 719 white crappie from Lake Texoma. In Buncombe Creek the white crappie occurs primarily at depths exceeding 4 ft (Grinstead, 1965) while *Menidia* rarely reaches depths greater than 5 ft (Mense, loc. cit.). The infrequent occurrence of *Menidia* in crappie stomachs may be explained by the difference in habitat preference of the two species.

Menidia was the most important fish in the stomachs of the largemouth bass we examined, representing 78% of the 290 fish identified to family and occurring in 72% of the stomachs containing identifiable fish (Table I). *Menidia* occurred in largemouth bass as small as 24 mm, and, although insignificant compared with other food items, it represented 90% of the 146 fish identified from bass of less than 50 mm total length.

TABLE I. SEASONAL OCCURRENCE OF FISHES FOUND IN STOMACHS OF 536 LARGEMOUTH BASS TAKEN FROM LAKE TEXOMA IN 1965 AND 1966.

	Menidia	Dorosoma	Centrarchids	Cyprinids
Winter (11) 4*				
frequency	1	3	1	0
number	1	8	1	0
Spring (189) 29				
frequency	24	4	1	1
number	116	4	1	1
Summer (306) 66				
frequency	45	13	9	3
number	107	31	13	6
Fall (30) 1				
frequency	1	0	0	0
number	1	0	0	0
Total (536) 100				
frequency	71	20	11	4
% frequency	71	20	11	4
number	225	43	15	7
% of identified fishes	78	15	5	3

* Numbers in this column refer to the number of stomachs containing identifiable fish; numbers in parentheses refer to the total number of stomachs examined.

Menidia ranging from sac fry to adults were usually found singly in the stomachs of largemouth bass. Instances in which bass were found filled with *Menidia* (e.g., a 30-mm specimen contained 49 sac fry) may have resulted from the schooling behavior of young silversides. Throughout the summers of 1965 and 1966, schools of several hundred young silversides were common near shore. Such schools move through littoral areas in swarms and are relatively easy prey for predaceous fishes resting among the vegetation.

Based on relative abundance data (Table II) *Menidia* may be the most important buffer species in littoral areas of the lake. *Menidia* represented 71% of total number of fish taken and was the predominant species sampled in every month. Because of its abundance, it probably lessens the degree of inter- and intraspecific predation among game fish. Furthermore, studies indicate that the abundance of *Menidia* probably reduces predation on game fish by nongame species such as gars. May (loc. cit.) found that *Menidia* represented 54% of the fish found in adult longnose gar, *Lepisosteus osseus* (Linnaeus). *Menidia* represented 82% of 466 fish found in 386 young gars examined by Echelle (loc. cit.), while only 3% were game species. This is significant since most of these gars were taken from littoral habitats where young largemouth bass were quite common.

Based on this study, *Menidia* appears to be most important as food for those fish that feed in surface waters or in littoral areas of the lake. *Menidia* was important for the white bass, a species that feeds in littoral areas and at the surface in open waters. It was also important for gar and young largemouth bass, but was relatively unimportant for the white crappie, a species of deeper water.

Table II. Catch Per Unit Effort of Seining in Lake Texoma, 1966.

	Winter	Spring	Summer	% of Total
Menidia	7.4	34.3	713.8	71.1
Dorosoma	0.2	5.3	265.4	25.9
Lepomis	0.2	1.1	17.4	1.8
Pimephales	4.9	0.5	5.4	0.6
Notropis	0.3	1.0	2.0	0.3
Micropterus	0.0	0.4	1.0	0.1
Gambusia	0.0	0.0	1.4	0.1
All other	0.0	0.2	0.9	0.1
Units of effort	12	55	71	

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Estimating Fecundity in Mississippi Silversides, Menidia audens (Pisces: Atherinidae)

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INTRODUCTION

Jordan and Evermann (1896) give the two type locations for Mississippi silversides, *Menidia audens* Hay, as the Mississippi River near Vicksburg, Mississippi, and near Memphis, Tennessee. These were the only places from which the species was known in 1896; however, the Mississippi silversides apparently is found throughout the lower Mississippi River drainage, in Reelfoot Lake, Tennessee (Rice, 1942), and as far north as the southwestern tip of Kentucky (Clay, 1962).

Except for range descriptions, information on this species is scarce. Apparently nothing has been published on the fecundity of Mississippi silversides, although Saunders (1959) studied the embryology of the fish. The purpose of this study was to estimate fecundity of the Mississippi silversides and to evaluate different methods for rapid estimation of the fecundity of this species.

METHODS AND MATERIALS

Thirty-two specimens of Mississippi silversides containing mature eggs were collected from Lake Texoma during spring and summer, 1966. The specimens ranged from 68 to 118 mm in total length. While several sizes of eggs were evident in each ovary examined, mature eggs were readily distinguishable from all others by their larger size, transparency, and yellowish coloration (Saunders, 1959).

Ovaries were removed from each fish and placed separately in petri dishes containing a small amount of water. The amount of water used was important: if too much was used, turbulence confused the count, while if no water was used, the adhesive eggs tended to stick together and became difficult to count.

After placing an ovary in the petri dish, a sagittal incision was made through the ovary wall, and the eggs scraped out with a scalpel. A binocular microscope was used to separate and count mature eggs. A dropper was helpful in removing groups of eggs after they had been counted.

RESULTS AND DISCUSSION

The mean number of mature eggs contained in 31 fish was 984, with a standard deviation of 358.6 and a range from 384 to 1699. One female 86 mm in total length contained only 225 eggs. Since it is probable that it was partially spent at time of capture, this fish was excluded from analyses. One unusually large female caught in 1965 contained 2094 mature eggs, but was not included in analyses because of inadequate information.

Four measurements were compared with numbers of mature eggs to determine the best technique for estimating fecundity: 1) total length, 2) ovary weight, 3) total weight, and 4) body weight. Body weight was considered as the weight of the fish after ovary removal. Ovary weight was determined indirectly by subtracting body weight from total weight.

Graphs with fitted regression lines for these four relationships are contained in Figure 1, with statistics for the four relationships shown in Table I. All four comparisons were found to be statistically reliable, but

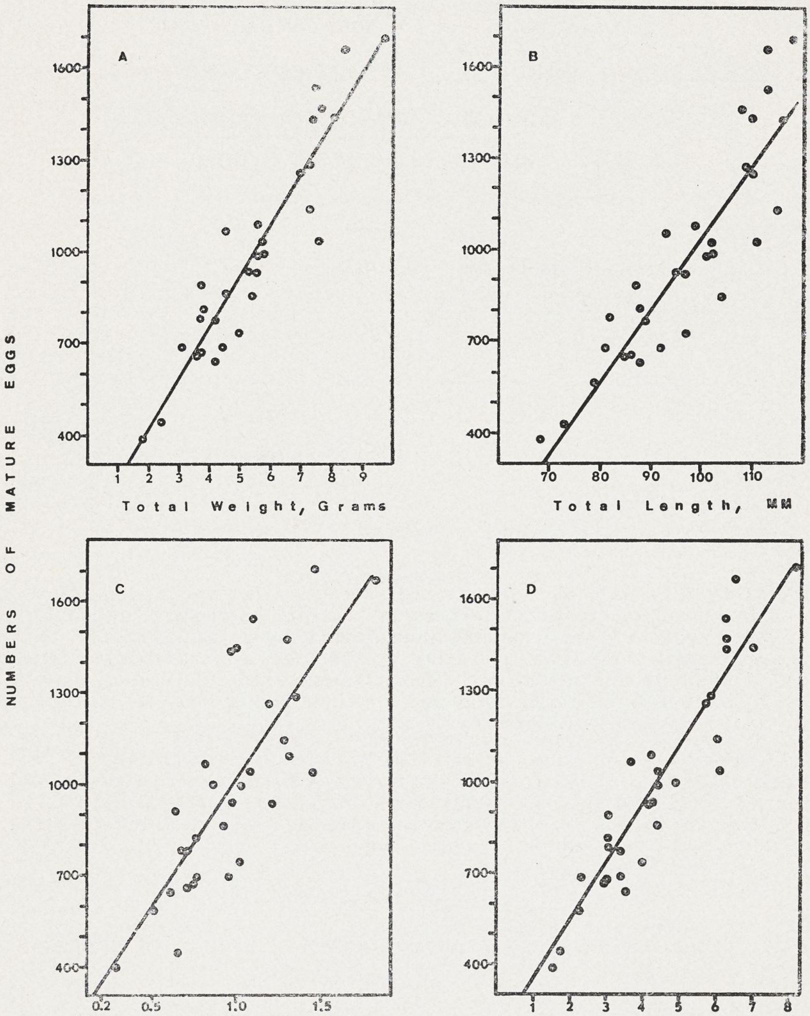

Figure 1. Correlation graphs and fitted regressions for total weight, total length, ovary weight, and body weight, A. B. C, and D respectively, with mature numbers of eggs for the Mississippi silversides.

TABLE I. STATISTICS FOR COMPARISONS OF TOTAL LENGTH, TOTAL WEIGHT, BODY WEIGHT, AND OVARY WEIGHT WITH MATURE EGG NUMBERS IN *Menidia audens*.

	Length	Total weight	Body weight	Ovary weight
Correlation coefficient, *R*	0.8724	0.9129	0.9122	0.7748
95% confidence interval, *R*	0.748 to 0.937	0.826 to 0.958	0.825 to 0.957	0.578 to 0.886
Test for correlation:				
T value	9.80**	12.86**	11.97**	6.57**
Regression:				
B	23.29	192.84	846.75	165.90
A	—1278.18	126.99	153.10	83.90
95% confidence interval, *B*	18.34 to 28.24	156.41 to 175.39	181.27 to 204.40	764.76 to 928.73

to different degrees. The 95% confidence intervals for the correlation coefficient, *R*, probably give the best comparable estimate of reliability. The total weight and body weight relationships have the narrowest confidence intervals, while the confidence interval for the total length relationship was only slightly larger. The confidence interval for the correlation of mature egg numbers and ovary weight was the widest.

It is apparent that the correlation between body length and numbers of mature eggs is the most practical method from which to estimate the fecundity of a population of Mississippi silversides, although correlations between both total weight and body weight with numbers of mature eggs are probably more reliable. The reason for the poorer correlation between mature egg numbers and ovary weight could be due to variability in numbers of immature eggs contained in each individual pair of ovaries.

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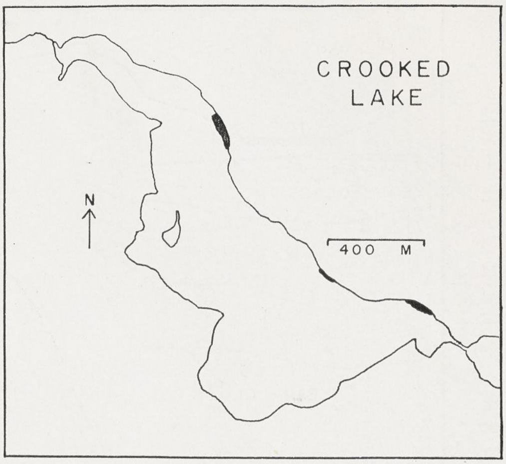

FIGURE 1.—Localities seined (darkened areas) for brook silversides in Crooked Lake, Indiana.

Life History of the Brook Silverside, *Labidesthes sicculus*, in Crooked Lake, Indiana[1]

The brook silverside, *Labidesthes sicculus* (Cope), is a common forage fish in the lakes and streams of eastern North America. This annual fish is the only widespread atherinid in the freshwaters of the United States and Canada. It ranges from Minnesota, through southern Ontario and southern Quebec, to New York and south to Texas and to Florida. Silversides occur throughout Indiana (Gerking, 1945) and are abundant in the northern lake district. They occur in schools at the water surface and frequently make short jumps out of the water. Much information on the life history and feeding habits of silversides has been gained through the studies of Hubbs (1921), Cahn (1927), Ewers and Boesel (1935), Boesel (1937), Fogle (1959), and Keast and Webb (1966). This paper presents additional observations on the life history of silversides.

STUDY AREA AND METHODS

Silversides were studied in Crooked Lake (Figure 1), located in the headwaters of the Tippecanoe River drainage, part of the Wabash system of Indiana. This marl lake lies on the border of Noble and Whitley counties in northern Indiana at 41°16′ N latitude and 85°29′ W longitude, 35 km northwest of Fort Wayne. It has a length of 2005 m, a maximum depth of 33 m, a mean depth of 14 m, an area of 76 ha, and an elevation of 276 m above sea level. During the summers of 1966 and 1967 the surface pH ranged between 8.4 and 8.7 at mid-day. Summer Secchi disk readings ranged from about 5.0 m in July and early August to as low as 3.0 m in late August. Surface temperature is given in Figure 2. The only inlet is a 75 m channel connecting Crooked Lake with Little Crooked Lake, which also contains silversides. The outlet was dry during much of the 1966 summer. Although Kirsch (1895) did not report silversides in Crooked Lake he did note them from the following nearby lakes: Shriner, Cedar, Round, Big, and Loon.

Silversides were seined at least once a month, except in February, in a bag seine 11 m long, 3.2 mm oval mesh, between 9 January 1966 and 23 August 1967. On 5 November 1965, a sample was collected with a 6.4 mm sq mesh seine. Seining was usually conducted at dusk, between 1800 and 2100 hrs. Newly hatched silversides were collected with a fine mesh dip net. Scales were removed from the side beneath the first dorsal fin.

[1] Contribution No. 807, Department of Zoology, Indiana University.

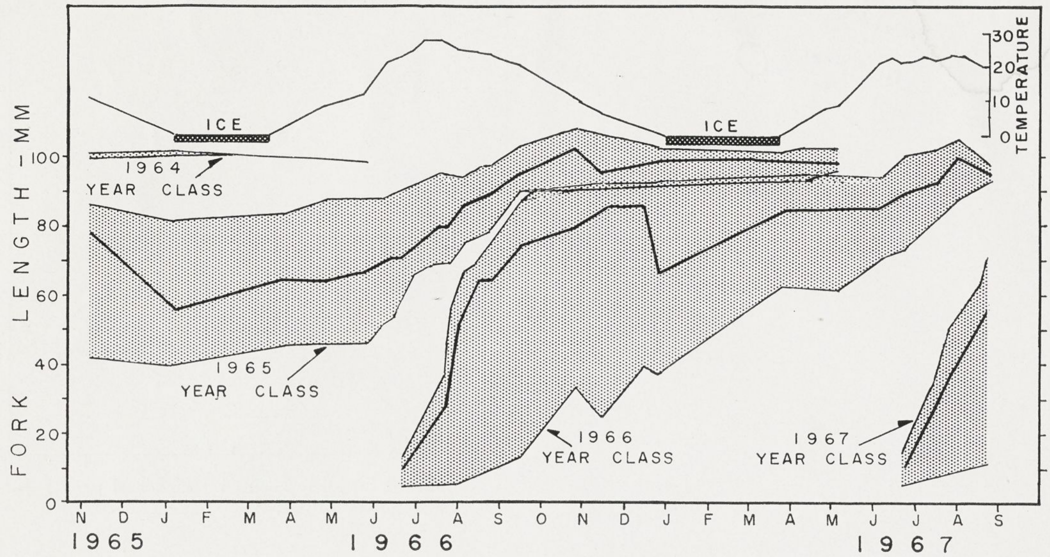

FIGURE 2.—Growth of brook silversides in Crooked Lake. The mode (heavy line) and range (thin line) are indicated for each year class. Total number of fish employed is about 11,500. Surface temperature near shore at dusk in °C is superimposed.

The recommendations of Hubbs and Lagler (1964) were followed in making meristic counts.

RESULTS AND DISCUSSION

In 1966, silversides spawned from at least 17 June to 5 August. Spawned eggs were numerous when their presence was detected on 17 June. They remained numerous until 19 July and were found as late as 5 August. Most eggs were attached to *Scirpus* and were most abundant on the offshore portion of the bed, to water depths of 80 cm. Eggs were seldom found near shore where *Scirpus* was dense. Many eggs were also found attached to *Potamogeton*. Paired silversides were observed around the emergent aquatic vegetation, *Nymphaea*, *Nuphar*, *Peltandra*, and *Pontederia*. These plants, which were not as abundant as *Scirpus*, supported few eggs. Silverside eggs were commonly found attached to floats placed in the limnetic area over water 25 m deep and on the anchor-rope of floats, to depths of 9 m. It is not known whether the eggs were laid at these depths or whether they became passively attached. In April the eggs in silversides were 0.15–0.25 mm diameter. Fully ripe females in June had eggs which were 0.8–1.2 mm and orangish but also had many immature whitish eggs of 0.2–0.6 mm. The distinctive long filament attached to eggs was about 0.008 mm in diameter (measured from enlarged photographs). In the ovary each egg was enveloped by its filament. Virtually all eggs had one filament, as noted by Hubbs (1921) and Cahn (1927). Fogle (1959), however, found two filaments on each egg. Eyed eggs that were taken from Crooked Lake and hatched in the laboratory produced young of 4 mm total length.

Because of the fast growth rate and short life-span of silversides the length-frequency method was used for age and growth determinations. An analysis of scales was also employed but was necesary for age determination in few individuals. First year growth of silversides is rapid (Figure 2). The rate at which maximum size is reached exceeds that of all but one species in the list of Beverton and Holt (1959). Some young of the 1966 year class, when 3 months old (mid-September), had already reached the modal size of the 12 month old spawning group of the same year class.

In both 1965 and 1966 there was a marked decrease in the modal length of the popula-

- lacustrine atherinid: Basilichthys bonariensis (common name: pejerrey) native to lake system of Buenos Aires Province to Santa Fe, La Pampa, Cordoba & San Luis: known for quality & firmness of flesh - introduced into Chile & Japan - at fish Culture Station of Kanagawa - raised to 30 cm & 150 g. - introduced into L. Tsukui.

fm. F.A.O. fish cult. bull. 2(2):10
Jan. 1970

ALSO:

Statement:

" Brook trout, rainbow trout, Scotch lake trout, and steelhead trout are now firmly established in Colorado, noneof them being indigenous. The brook trout affords better fishing than the native black-spotted trout, and more eggs of brook trout can be colledted in Colorado than in any other state, where hatcheries are located, to which the species is native."