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THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

THE DISTRIBUTION AND IDENTIFICATION OF LARVAL FISHES IN THE BUNCOMBE CREEK ARM OF LAKE TEXOMA WITH OBSERVATIONS ON SPAWNING HABITS AND RELATIVE ABUNDANCE

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

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degree of

DOCTOR OF PHILOSOPHY

BY

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Norman, Oklahoma

1969

THE DISTRIBUTION AND IDENTIFICATION

OF LARVAL FISHES IN THE BUNCOMBE CREEK ARM OF LAKE TEXOMA

WITH OBSERVATIONS ON SPAWNING HABITS AND RELATIVE ABUNDANCE

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THE DISTRIBUTION AND IDENTIFICATION OF LARVAL FISHES IN THE BUNCOMBE CREEK ARM OF LAKE TEXOMA WITH OBSERVATIONS ON SPAWNING HABITS AND RELATIVE ABUNDANCE

CHAPTER I

INTRODUCTION

Studies involving the larval stages of fishes have largely been concerned with anatomical features. Distributional and ecological studies have been neglected, although the value of such work cannot be questioned. Reasons for this neglect include the lack of an effective method for sampling populations of larval fishes and also the difficulty in identifying larval fishes. Recently, reservoir researchers have been using various types of small-mesh trawls for sampling populations of abundant species, especially Dorosoma spp. Faber (1963) studied the pelagial larvae in two Wisconsin lakes and was able to identify eight species from collections made with large plankton nets. No comprehensive work on the total larval fish fauna of any freshwater body is known. The largest single work to date on the early stages of fishes is that of Mansueti and Hardy (1967), which also includes a historical review of early life history studies of fishes found in the Chesapeake Bay region. Many authors, including Fish (1932), Balinsky (1948), and Mansueti and Hardy (1967) have indicated the importance and

need for studying early life history and development of fishes. Nikolskii (1954) stated that lack of knowledge of the distribution of fishes was among the foremost problems of modern ichthyology.

My purpose in this work was to study the diel distribution of larval fishes in the Buncombe Creek arm of Lake Texoma. The problem necessarily included the recognition and description of morphological characters by which the larval forms collected could be identified. The spawning habits of the various species were also studied because of the important relationship to the production of larval populations and because it aided the identification efforts.

Riggs and Bonn (1959) listed about 34 fishes common to the main body of Lake Texoma with about 25 of these common in the Buncombe Creek arm; I collected the larvae and/or young-of-year of at least 28 species in this arm (Table 1).

Lake Texoma is a 93,000-acre reservoir formed by the impoundment of the Red and Washita rivers by the Denison Dam. Buncombe Creek arm (Fig. 2) is approximately four miles long and lies on the north (Oklahoma) side of the Red River arm of the lake. It has a maximum depth of about fifty feet at power pool level (617 feet above sea level) and is subjected to wave action caused by prevailing winds which tend to keep its water well mixed (Grinstead, 1965). Further information on Lake Texoma is contained in publications of the United States Army Corps of Engineers (1948; 1961).

CHAPTER II

METHODS AND MATERIALS

Collection of fishes in this study began April 22, 1965, and continued throughout the remainder of 1965 and through 1966. Shoreline seining and open-water trawling were the two types of sampling employed. Collections were made on a weekly basis from early spring to mid-summer when larvae were most abundant.

The most important information came from 1966 trawl collections which were more complete than those from 1965 and covered the entire spawning period for all species. The emphasis was placed on lacustrine populations and the tributary waters of Buncombe Creek arm were not sampled.

Common and scientific names used in this paper follow the list adopted by the American Fisheries Society (1960). Terminology for the early stages follows that proposed by Hubbs (1944) with inclusion of the term "prejuvenile" as used by Mansueti and Hardy (1967).

Identification of Larvae

One or more of the following procedures were followed in identifying larval fishes collected: 1.) Fertilized eggs of several known species were hatched in laboratory aquaria and larval development was closely followed. 2.) Developmental series were built back from ident-

fiable stages through early larval stages. 3.) Gonadal condition of adult fishes taken in Buncombe Creek arm was followed to determine when larvae of particular species should be present. 4.) Larvae were compared with larval fish illustrations by other authors (Fish 1932; Larimore 1957).

Series of drawings of the larval stages of 14 species were prepared primarily from preserved specimens collected in Buncombe Creek arm of Lake Texoma. Drawings were based on the images of projected photo negatives of pictures taken of the larvae with a 35-mm camera attached to an extension bellows. Detailed completion of the drawings was made while observing individual specimens through a binocular microscope.

Trawl Operation

The trawl used for larval fish sampling was a modified 1/32-inch mesh meter net. The net was attached to a 2 X 3-foot wooden frame which was a copy of larger ones developed and used for midwater trawling by the Oklahoma Fishery Research Laboratory at the University of Oklahoma (Gasaway and Lambou, 1968). To the mouth of the trawl were attached two bridles of light-weight chain (Fig. 1). The upper bridle was much shorter than the lower and was fastened to a 3/16-inch polyethylene line which passed through a 2-inch steel ring at the focal point of the lower bridle. By changing the length of the upper line the mouth of the trawl was tilted upward or downward. This was used to deflect the trawl and change its elevation during the trawling operation. The fixed line attached to the lower bridle of the trawl

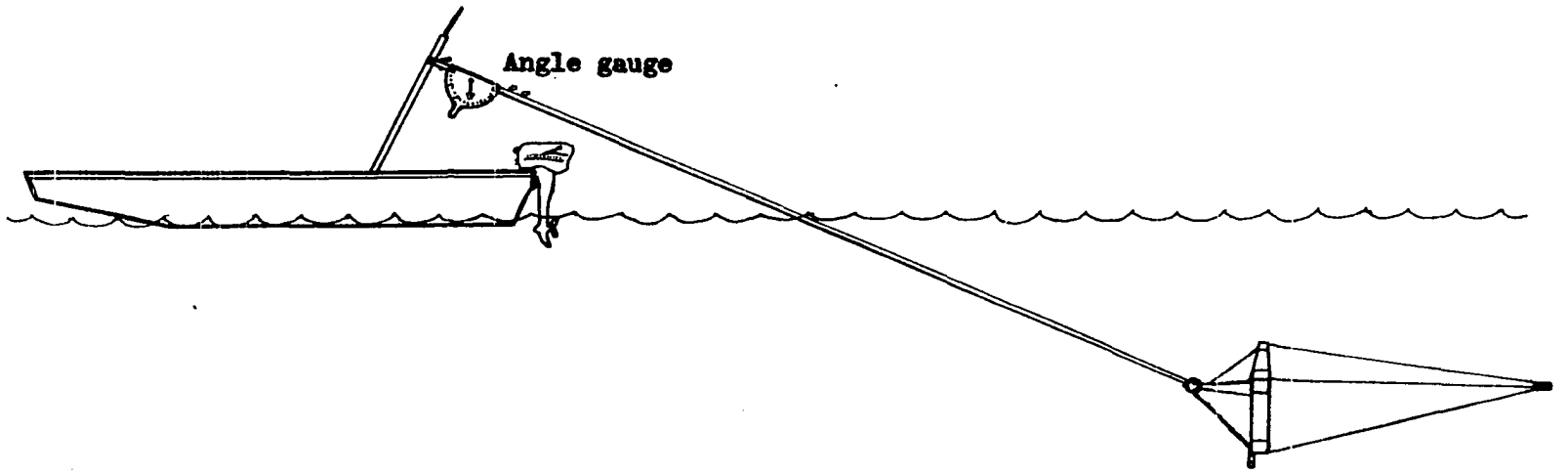


Figure 1. Midwater trawl operation.

(also 3/16-inch polyethylene) was 100 feet long. The depth of the trawl at any angle of the tow line was then simply 100 times the sine of the angle of deflection of the towline from horizontal. During midwater and bottom trawling a 3½-foot section of 2-inch steel pipe was suspended horizontally two inches below the lower board of the trawl frame. This made the trawl stable while below the surface and helped to keep it close to the bottom while bottom-trawling. The pipe also allowed much bottom debris to pass under instead of into the mouth of the trawl. The trawl was pulled behind a 16-foot Polar-Kraft flat-bottom aluminum boat powered by a 16 H.P. Evinrude outboard motor.

I selected six locations in the Buncombe Creek arm for trawling (Fig. 2). The bottom profiles were recorded on a Bendix Depth Recorder and bottom types were determined by taking samples with an Ekman dredge (Fig. 3). Lake level fluctuation during the period of collection was compensated for by moving trawl stations further inshore or further out except at S2 and 5 which were already in maximum depth water for their area of the Buncombe Creek arm.

Taylor (1953) showed that the variability in trawl catches of fishes could be attributed to the heterogeneous distribution of fish species which tended to follow a negative binomial distribution. He illustrated the greater efficiency of a smaller sampling unit in sampling heterogeneous populations. The smaller sampling unit could be obtained by reducing the size of the trawl and/or by reducing the trawling time. Roessler (1965) found that the more common fish species in his trawl collections followed a negative binomial distribution and less common species approached a Poisson distribution. He found that

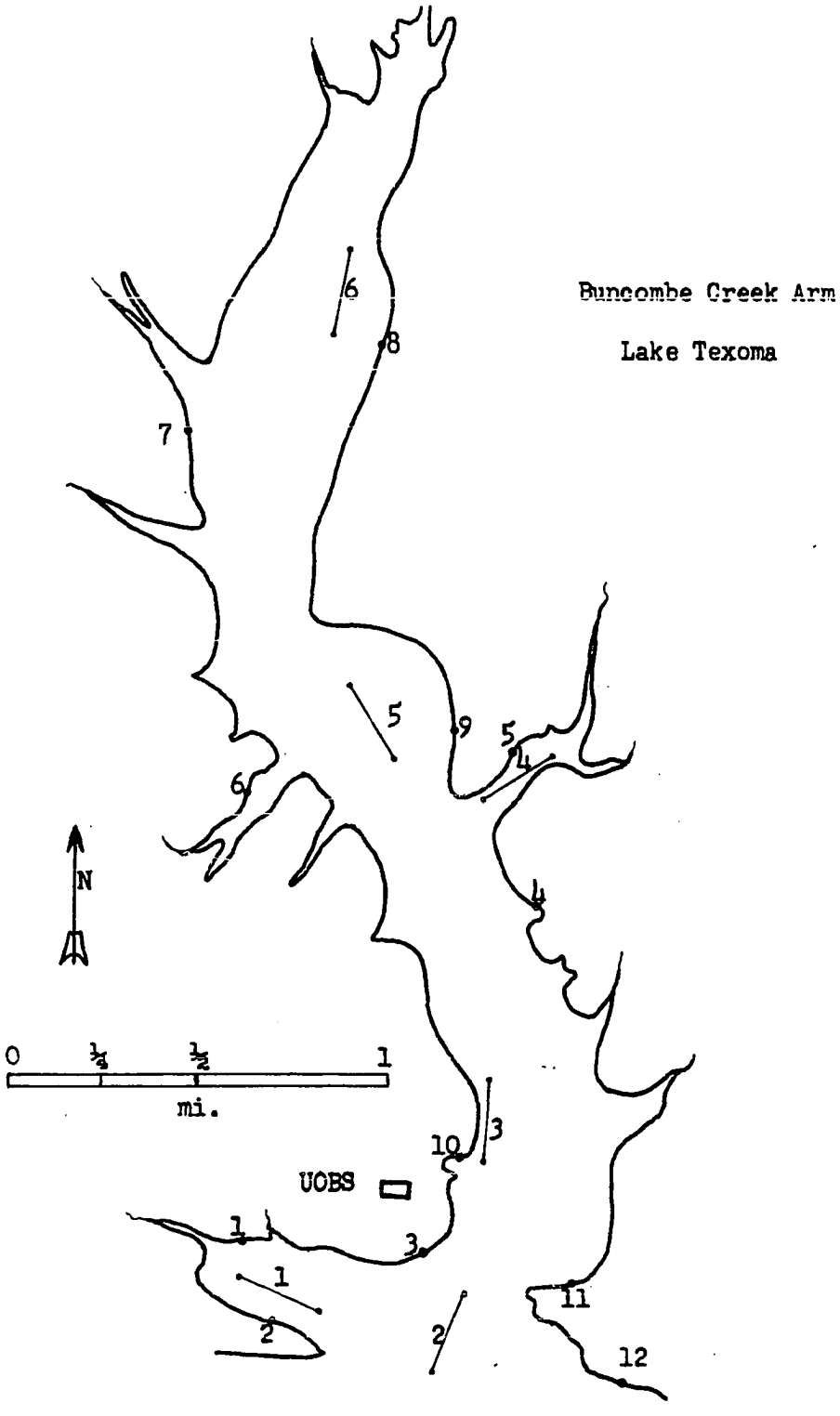


Figure 2. Locations of trawling and seining stations in Buncombe Creek arm of Lake Texoma.

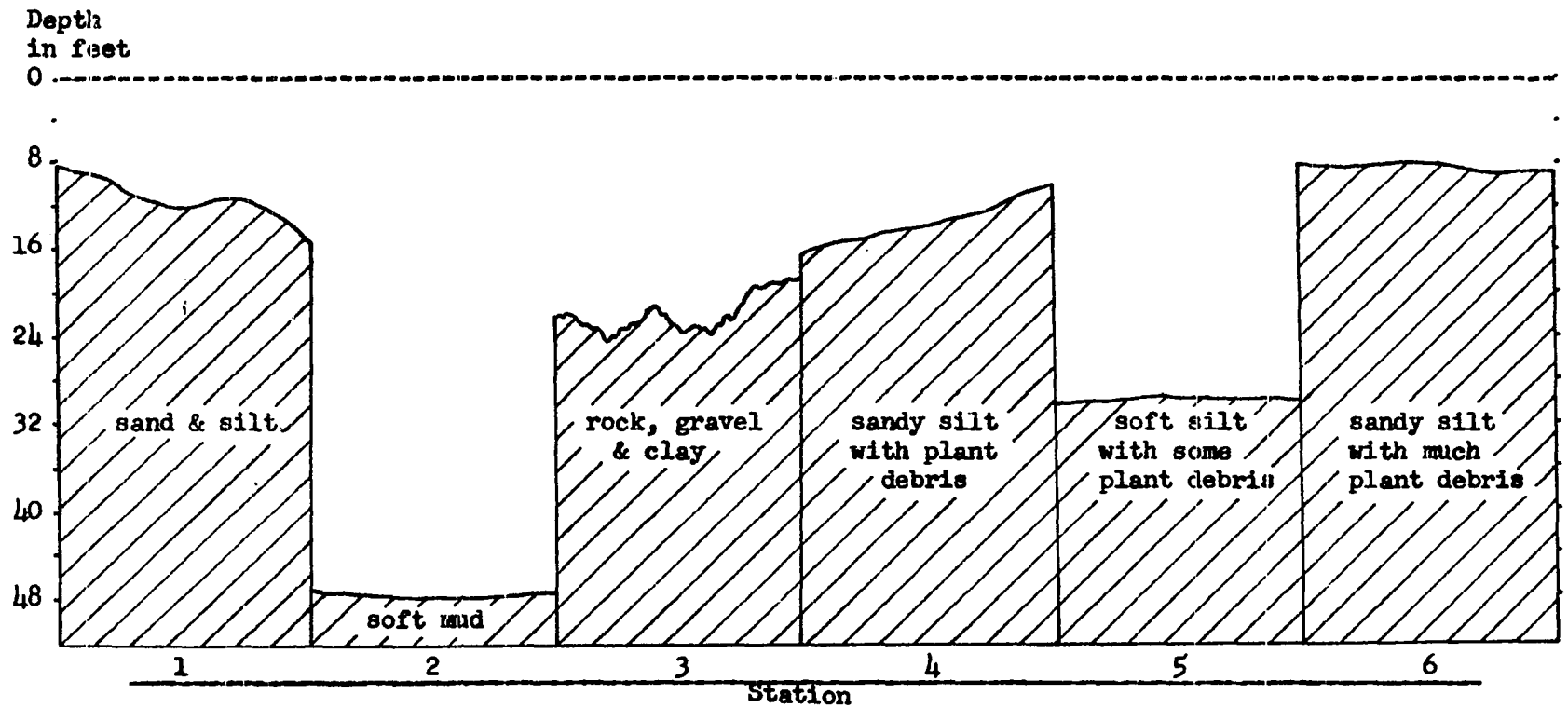


Figure 3. Depth profile of trawling stations in feet with lake elevation at 617 feet above sea level. Three-minute trawl hauls at each station covered a distance of about 150 yards.

paired two-minute trawl drags were more consistent than one four-minute drag for the number of individuals caught.

Trawls of three minutes duration, covering a distance of approximately 150 yards, were utilized in making all collections during this study. Midwater tows began with the trawl on the bottom but the trawl was instantly pulled upward at a sharp angle and I believe that bottom fish contamination of midwater samples was negligible. At the completion of a three-minute haul the trawl was retrieved by hand, vertically from the bottom after midwater and bottom trawls. The weight of the pipe suspended from the bottom of the trawl frame kept the mouth of the trawl from turning upward and catching fish during its ascent. The section of pipe was removed for surface hauls, allowing the trawl to float with no chance of contamination from other depths. Surface and bottom trawl drags were made at each of the six locations but midwater trawls were made only at S2, 3, and 5 where water depth was greatest.

Borges (1950), Cady (1945), Dendy (1948), Houser and Dunn (1967), and others have shown that the presence of a thermocline can lead to depth stratification of fish populations. The work of Grinstead (1965) and my own observations indicate that thermal stratification and the resulting oxygen depletion in deeper water seldom occur in the Buncombe Creek arm of Lake Texoma. In the absence of a thermocline the use of multi-level midwater tows was regarded as unnecessary and midwater trawls were made at one-half the average depth of water at a particular station.

Surface water temperature and time of day were recorded at each

station during sampling. Collections were preserved in 5% formalin and transported to the laboratory for analysis.

Seining

Shoreline seining was carried out on a weekly basis through the spring and early summer of 1965 at twelve locations which represented a variety of habitats and were well distributed around the Buncombe Creek arm (Fig. 2). Seines utilized included a 3 X 3-foot plastic screen of 1/16-inch mesh, a 4 X 6-foot seine of 1/8-inch mesh, and a 12-foot bag seine with a bag of 1/8-inch mesh. The use of these seines was obviously most successful for capturing prejuvenile and juvenile stages of most species, being rather inefficient for the small larvae of many species.

Treatment of Collections

Trawl collections were washed, cleaned, and sorted to species. The length-range and total number of each species were recorded for each collection. All measurements were of total-length to the nearest half-millimeter. All the larvae in the 1966 collections were measured, except in collections containing more than 200 of a species in which case a subsample of 100 or more was taken for length-frequency measurement. These measurements were used in making the size-classes used in distribution analysis.

Seine collections were treated in the same manner as trawl collections except that adults and older juveniles were also counted and measured as a separate group. Total numbers of fishes collected by seining and trawling in 1965 and 1966 are shown in Table 1.

Table 1. Total numbers of fishes collected by seining and trawling in 1965 and 1966 in Buncombe Creek arm of Lake Texoma.

Species	1966 trawl	1965 trawl	1965 seine	1965 seine (adults)*
Dorosoma petenense				24
Dorosoma spp.	191,286	26,614	5,858	
Menidia audens	37,216	15,789	32,584	1,197
Lepomis macrochirus	9,072	3,965	234	16
Pimephales vigilax	1,106	1,557	41	288
Pomoxis annularis	786	19	2	--
Percina caprodes	569	1	9	--
Cyprinus carpio	361	8	116	--
Lepomis megalotis	347	948	29	--
Roccus chrysops	316	5	87	--
Aplodinotus grunniens (575 eggs)	227	51	--	--
Ictalurus punctatus	38	31	1	--
Hybopsis storeriana	25	28	--	1
Notropis venustus	21	5	43	234
Micropterus spp.	21	--	395	--
Hybopsis aestivalis	16	3	--	--
Notropis lutrensis	14	2	12	487
Chaenobryttus gulosus	13	--	--	--
Campostoma anomalum	7	--	1	2
Gambusia affinis	2	1	16	6
Lepisosteus spp.	2	--	13	--
Notropis spp.	2	1	13	--
Etheostoma spectabile	1	1	1	--
Lepomis microlophus	--	--	1	--
Fundulus notatus	--	1	2	--
Pylodictis olivaris	--	2	--	--
Notemigonus crysoleucas	--	--	--	3
Notropis potteri	--	--	3	8
Notropis percobromus	--	1	4	33
Hybognathus placita	--	--	--	2

*All fish that were not young-of-year were classified as adults and the few adults which appeared in trawl collections were not enumerated.

CHAPTER III

SPAWNING HABITS AND RELATIVE ABUNDANCE

Figure 4 illustrates spawning time for the more abundant species in Buncombe Creek arm determined by direct spawning observations, relative size of larvae in collections, and gonadal condition of adults.

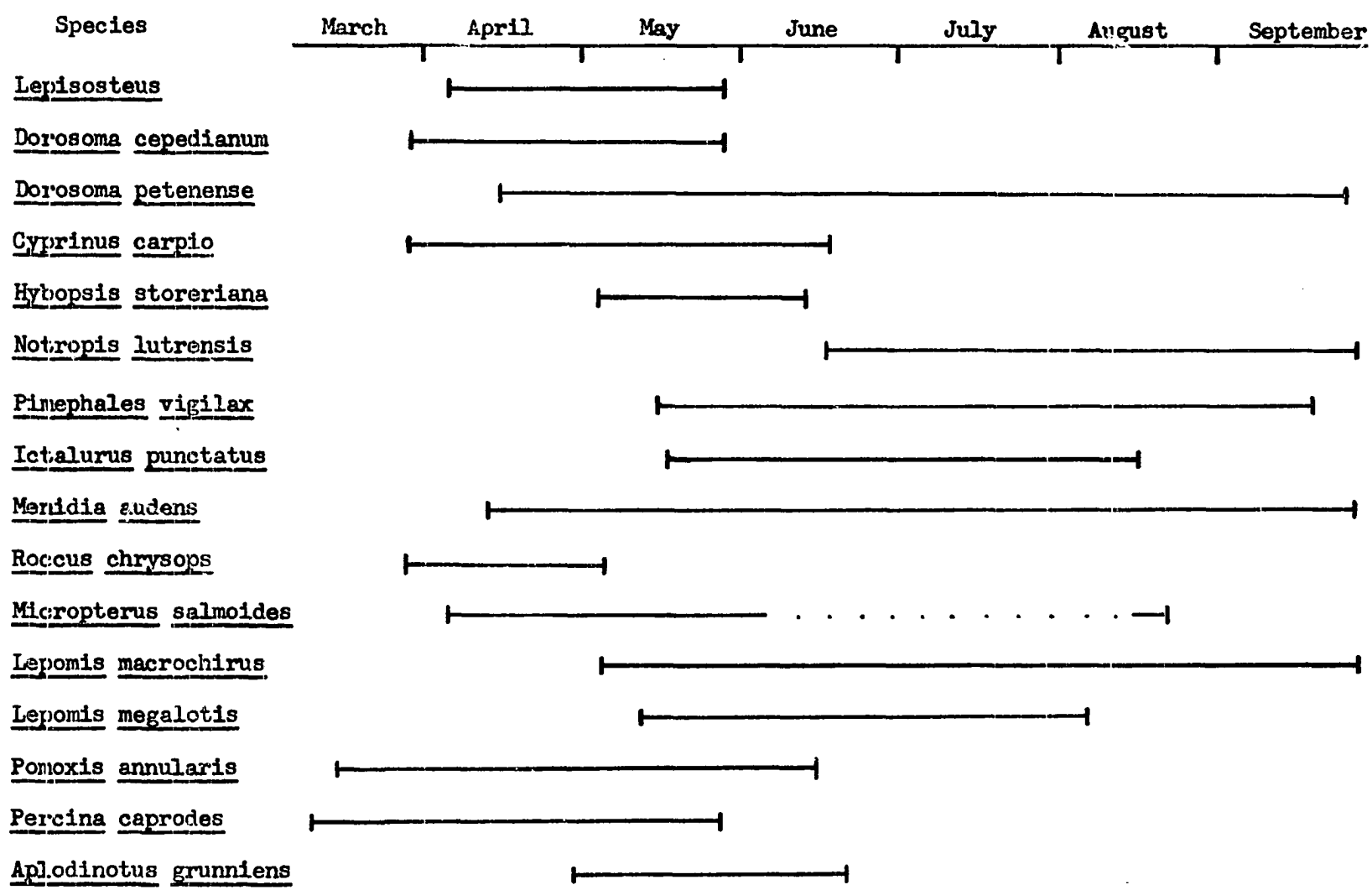
Lepisosteus

Four species of gars are found in Lake Texoma. The longnose gar, Lepisosteus osseus, appears to be the most abundant gar in the lake and in Buncombe Creek arm. The spotted gar, L. oculatus, and the shortnose gar, L. platostomus, are common, but the alligator gar, L. spatula is rarely seen or caught in the lake. May and Echelle (1968) captured three young-of-year alligator gar in 1965, the only young of this species reported from Lake Texoma. Spotted gar appear to spawn earliest of the genus. I observed spawning and collected eggs of this species on April 9, 1966, when the water temperature was 61 F. Apparently nearly all spawning by gars in Lake Texoma occurs in April and May.

Dorosoma

Lake Texoma has two common clupeids, the gizzard shad, Dorosoma cepedianum, and the threadfin shad, D. petenense. The gizzard shad

Figure 4. Spawning time of 16 species of Lake Texoma fishes.



is indigenous to the Red and Washita rivers and has been common in Lake Texoma since impoundment in 1944; the threadfin shad was not reported in the lake until 1957 (Riggs and Moore, 1958).

I have observed spawning activity of both species of shad in Lake Texoma. The only observations of gizzard shad spawning were on March 27, 1968, in upper Buncombe Creek Arm in the inundated creek bed. The water temperature in the creek was 61 F (55 F in the main body of the lake). Warner (1941) found that gizzard shad began spawning when water temperature was about 60 F in Buckeye Lake, Ohio, and Bodola (1966) found that spawning activity was most intense after water temperature had risen to 67 F or more. In Buncombe Creek spawning was seen in several places along the shore between 11:00 A.M. and 1:00 P.M. under light cloud cover. From close range the fish were often seen more than half out of water. Eggs were found adhering to submerged vegetation in the area. Miller (1960) stated that gizzard shad often ascend streams to spawn.

Spawning of D. petenense was observed on several occasions, usually between early morning and noon. They seem to prefer placing their eggs on submerged vegetation, usually just below the water surface. In 1965 when filamentous algae were abundant throughout the spring they were used extensively as a substrate for eggs by spawning fish. Many eggs were also found on clean rock in shallow water, as well as on sticks and grass and other submerged vegetation. Spawning activity was even observed in a mass of foam and sticks swept into the boat harbor by wave action. Earliest observation of threadfin shad spawning was on April 18, in 1965, in about two feet of water over an algal mat.

Condition of gill-netted adults indicated that gizzard shad were usually through spawning by mid-May, but adults netted in 1966 indicated that the slower warming of the water in this year may have prolonged spawning to about the end of May. Warner (1941) found that gizzard shad spawning covered a two-week period in Buckeye Lake. Bodola (1966) reported spawning from early June into July in Lake Erie. In Lake Texoma gizzard shad spawning covered a period of about six weeks with variability due to the rate of warming of the water.

Data from gill-netted adults and size comparison of young-of-year indicate that threadfin shad begin spawning about two weeks later than gizzard shad. Presence of larvae in collections indicated a continual spawning by threadfin shad through late September although larvae production was greatly reduced after early June. Gizzard shad may spawn at age-I (Bodola, 1966) and threadfin shad possibly spawn at age-0 (Shelton, 1964).

Specimens of Dorosoma spp. were most abundant in trawl collections (Table 1), making up over 74% of the total number of young fishes taken. The shads were second to Menidia audens in abundance near the shoreline as indicated by the seine collections.

Cyprinus carpio

The carp, Cyprinus carpio, is common throughout Lake Texoma and was very abundant in shallow weedy areas of Buncombe Creek arm during the spawning periods in 1965 and 1966. Widespread carp spawning activity was observed in the shallow water at the head of Buncombe Creek arm as early as March 27 in 1968, when water temperature was 57 F.

There was obviously a very high mortality in the early stages of carp development for tremendous spawning activity and large numbers of eggs that could be found on submerged vegetation pointed to the production of very large larval populations which apparently never materialized. Appearance of larvae in collections indicated that spawning extended well into June.

Hybopsis storeriana

The silver chub, Hybopsis storeriana, is apparently fairly common in the Buncombe Creek arm of Lake Texoma. They are relatively intolerant of turbidity (Harlan and Speaker, 1956) and appear to spend most of the time in deeper water away from shore. Adult males taken from an experimental gill net on May 7, 1966, were flowing milt and the eggs in one female were nearly ripe. Spawning of the silver chub apparently begins in early May and extends into June.

Notropis lutrensis

Riggs and Bonn (1959) called the red shiner, Notropis lutrensis, the most abundant minnow in Lake Texoma. It was the most abundant adult minnow in my collections in Buncombe Creek arm but larval fish collections indicated it was much lower in abundance than Pimephales vigilax which is apparently more difficult to seine as adults. Red shiner was one of the few common species in the Buncombe Creek arm for which Dowell (1956) captured no young-of-year.

Spawning activity of N. lutrensis was observed in late July, August, and early September in both 1965 and 1966. The fish were seen in small aggregations along the rocky shoreline southeast of

the Biological Station. On August 19, when water was 89 F, spawning was observed in shallow water where eggs were deposited in a vertical crack in a rock in water 2-4 inches deep. The rock was retrieved and found to have several hundred eggs in various stages of development adhering to the walls of the crack. The eggs were placed in laboratory aquaria and nearly all had hatched within 94 hours at 84 F. On May 26, 1967, gravid adults were taken from a tributary stream and eggs were stripped and artificially fertilized. These eggs hatched in 120 hours at 74 F. During late July and August the lake level was often dropping at a rate of about one inch per day and would therefore leave most red shiner eggs layed at less than four inches depth exposed before hatching. This could lead to severe fluctuations in the population density of this species in Lake Texoma.

It appears that N. lutrensis spawns over a long period in the lake and its tributaries, beginning at least as early as mid-May in tributary streams which warm up more quickly than the lake. It is possible that no spawning occurs in the lake proper until mid-June when water temperature reaches about 80 F. Maximum spawning activity can be observed along shorelines of Buncombe Creek arm in August.

Notropis venustus

The blacktail shiner, Notropis venustus, is similar to N. lutrensis in many aspects of behavior, morphology, and distribution. It appears to be slightly less abundant and occupies much territory in common with the red shiner. Male N. venustus have been observed in spawning activity that closely resembles that of the red shiner and the spawning period of the two species is apparently very similar. Hybridization be-

tween the two species occurs commonly.

Pimephales vigilax

Riggs and Bonn (1959) referred to the bullhead minnow, Pimephales vigilax, as the second most abundant minnow in Lake Texoma and indicated it was increasing in abundance. It now appears to be the most common minnow in the Buncombe Creek arm and is possibly the most abundant in the lake. In 1966 trawling 1106 P. vigilax larvae and young-of-year were captured; these with the 1557 taken in 1965 made this the fifth most abundant species in my collections.

The bullhead minnow spawning period, as determined by collection of larvae in Buncombe Creek arm, probably covered a period from mid-May to early September. Relative size of specimens in the 1965 collections indicated spawning covered a similar period in 1965 but began about two weeks earlier when water temperature was about 70 F. Numbers of larvae began to decline in late August, probably as a result of reduction in the adult spawning population. Spawning activity was not observed for P. vigilax but it is believed to be similar to that of P. promelas described by Dobie, et al (1948).

Ictalurus punctatus

The channel catfish, Ictalurus punctatus, is abundant in Lake Texoma and probably makes up well over 50% of the catfishes present (Jenkins, 1956). Of the five catfishes listed for Texoma by Riggs and Bonn (1959), young-of-year of only the channel catfish (70 specimens) and the flathead catfish, Pylodictis olivaris (two specimens), appeared in my collections.

Channel catfish prolarvae spend several days in the nest absorbing most of their heavy yolk before forming schools which may exist for days to weeks (Harlan and Speaker, 1956). Mansueti and Hardy (1967) summarized the limited dexcriptions available on the early development of I. punctatus. Figure 19-B represents a 16.2-mm prejuvenile from Lake Texoma.

Channel catfish apparently begin spawning in the Buncombe Creek arm in late May and continue spawning well into August. Juveniles collected indicate most active spawning to occur in late May and early June. Canfield (1947) indicated that spawning began in hatchery ponds when water temperature reached 75 F.

Menidia audens

The Mississippi silverside, Menidia audens, is very abundant in Lake Texoma and large aggregations are quite commonly seen near the shore from May through September. Riggs and Dowell (1956) reported that Menidia was first taken in Lake Texoma in 1953 and had become very abundant in 1954. Since then it has almost completely replaced the brook silverside, Labidesthes sicculus, which was formerly quite abundant.

In my collections Menidia larvae and young-of-year were second in abundance only to Dorosoma and I believe they were second only to D. petenense in the Buncombe Creek arm. Near the shore the abundance of no other species approached that of Menidia. Saunders (1959) referred to Menidia as a "plankton feeder of the littoral zone". Abundance of the young in the littoral zone is further supported by their

predominance in the fish diet of young gars (Echelle, 1967), and of largemouth bass (Echelle and Mense, 1968). My collections and those of Mense (1967) indicate that Menidia live less than two years, with age-group-I fish absent from collections by late July.

Spawning apparently begins in mid-April and continues well into September. In 1966, Menidia larvae reached peak abundance in early June trawl collections then declined to the smallest collection total on August 21. It appears that spawning was continual throughout the summer but somewhat reduced during the peak water temperatures of August. I believe that spawning in late summer was not by age-group-0 fish but rather by the remnant of the adult population although no adults were taken in August and September seine collections.

Roccus chrysops

The white bass, Roccus chrysops, is the most important sport fish in Lake Texoma. Dowell (1956) found that the white bass was the third most abundant species in gill-net catches in the Buncombe Creek arm, making up 14% of the 7,218 fish caught. Since Dowell's study the white bass may have become more numerous due to the presence since 1957 of the important forage fish Dorosoma petenense. Reproduction of the white bass was studied by Riggs (1955) who indicated that in lakes without suitable tributaries for the spawning migration the fish would spawn over firm-bottom shoal areas. Bonn (1953) indicated that in the absence of a rise in lake level in early spring the white bass spawned on wind-swept points in Lake Texoma. It appears from the number of larvae captured that relatively little spawning occurred in the Bun-

combe Creek arm which has no major inflow from its tributaries. Only 316 larvae and young-of-year were collected in 1966, making white bass the tenth most abundant species in these collections.

I found what appeared to be a spawning aggregation in the inundated creek-bed at the head of Buncombe Creek arm on March 27, 1968, and eggs of the species were collected in this area on the same date by W. L. Shelton. Water was 61 F in the creek and 55 F in the lake on this date. No larvae as small as 6 mm were captured after May 13 and it appears that early May was the latest spawn in 1966 in this part of Lake Texoma. The spawning of white bass in the Buncombe Creek arm apparently covers a period from about the first of April to early May.

Micropterus

The largemouth bass, Micropterus salmoides, and the spotted bass, M. punctulatus, are abundant in Lake Texoma. In my collections 5.3% of the Micropterus were identified as spotted bass.

Micropterus spawning appears to begin in early April in Lake Texoma, reaching a peak in late April and early May. Breder (1936) indicated that the minimum nesting temperature for Micropterus was 15.5 C. A 15-mm M. salmoides was collected on September 3, 1966, showing some late summer spawning to occur. Comparative sizes of specimens of the two species in collections indicated little difference in their spawning periods.

Lepomis macrochirus

The bluegill, Lepomis macrochirus, is apparently the most abundant centrarchid in Lake Texoma. It was the fourth most abundant

species in my collections, with 9,072 taken in the trawl in 1966. Carbine (1939) found that this prolific spawner produced an average of 17,914 fry per nest.

Bluegill appear to begin spawning in Buncombe Creek arm in early May. After July 10, collections contained progressively fewer larvae but a 4-mm specimen was captured on September 4, indicating that in in 1966 spawning occurred until about the first of September. A rise in lake level in early September of 1966 may have resulted in earlier than usual termination of spawning. In 1965 a 6-mm specimen was caught on September 24, indicating that spawning continued into late September.

Lepomis megalotis

The longear sunfish, Lepomis megalotis, was quite common in the Buncombe Creek arm during this study and nests could be found easily in June and July in calm water areas with rocky or sandy bottom.

Breder (1936) indicated that most Lepomis begin spawning when water temperature reaches 20 C. I first collected longear sunfish larvae on May 27 in 1966 when maximum length of specimens taken was 7 mm. Specimens 6 mm long were taken August 21, 1966. These larvae indicated that longear spawning extended from mid-May until mid-August. Specimens trawled in 1965 indicated a very similar period of spawning. Longear sunfish may be colonial nesters in favorable areas, building nests less than a foot apart in water less than a foot deep (Witt and Marzolf, 1954). In 1966, 347 longear sunfish young were collected in the trawl; in 1965, 948 were trawled.

Pomoxis annularis

The white crappie, Pomoxis annularis, is fairly abundant in the lake and many are caught by anglers in March, April, and May each year. Hansen (1944, 1965) found colonies of crappie nests in water four inches to five feet deep and indicated nests were usually associated with plant growth to which the eggs adhered. Bottom vegetation is uncommon in Lake Texoma due to fluctuation of water level but much terrestrial vegetation is inundated when water level rises in spring. In 1966, 786 Pomoxis larvae and young-of-year were collected by trawling in the Buncombe Creek arm, making this the sixth most abundant species in my collections. These first appeared in collections made March 27, indicating that spawning may have occurred as early as mid-March. A 6-mm specimen captured on June 19 indicated that spawning continued to mid-June. Whiteside (1964) found the peak spawning of white crappie to occur in late April and early May in Lake Texoma.

Percina caprodes

The logperch, Percina caprodes, is the only darter abundant in Lake Texoma, and is fairly common in silty areas along the shore and in the tributaries (Riggs and Bonn, 1959). It is probably the first fish to spawn in the Buncombe Creek arm. Specimens 7.5 mm long were collected on March 27 in 1966, indicating that spawning occurred as early as mid-March. Spawning into late May was indicated by the collection of 6-mm logperch on May 27. It was the seventh most abundant species that I collected; 569 P. caprodes larvae and young-of-year were trawled in 1966.

Aplodinotus grunniens

The freshwater drum, Aplodinotus grunniens, is fairly common in the Buncombe Creek arm of Lake Texoma. Adult freshwater drum have been shown to prefer moderately deep water close to the bottom (Borges, 1950; Cady, 1945).

Freshwater drum eggs were first collected in 1966 on April 29 when the water temperature was 63 F, and last collected on June 19 when the water temperature was 80 F. Daiber (1953) found that most drum spawning occurred in July in western Lake Erie. Peak spawning in 1966 in the Buncombe Creek arm appeared to occur in late May. Spawning appears to have occurred commonly in late afternoon or early nighttime, since 75.5% of the eggs (575) were taken in night trawling. Welsh and Breder (1923) indicated that all known sciaenids produce small pelagic eggs. Schneider and Hasler (1960) found there was a daily rhythm of sound production by male drum during the spawning period which reached peak intensity by 2:00 P.M. and was maintained at a high level until 7:00 P.M. They indicated there were no drumming sounds after sundown and the first were heard at about 10:00 A.M. daily. They also indicated that spawning was related to the daily rise in water temperature and that no drumming or spawning occurred on cloudy days.

CHAPTER IV

IDENTIFICATION OF LARVAL FISHES

Lepisosteus

The gars lay large opaque eggs that produce large, heavily pigmented larvae. These were the largest larvae that appeared in my collections, being 8-10 mm long at hatching and possessing a large opaque yolk. There is little possibility of confusing gar larvae with the larvae of other species occurring in Lake Texoma. Due to the small number of young gars collected, no attempt was made to distinguish between the larvae of the species present. Various larval stages of L. osseus have been illustrated and described by Agassiz (1878), Mark (1890), Balfour and Parker (1881), and others, and these were used in compiling a developmental series by Mansueti and Hardy (1967).

Dorosoma

The very young of threadfin and gizzard shad are very similar in appearance, and most biologists attempt to use fin-ray counts for positive identification. Moore (1957) indicated that D. petenense has 14-15 dorsal rays and usually 20-25 anal rays; D. cepedianum has 12 dorsal and usually 29-34 anal rays. In Lake Texoma the median fin-rays of larval threadfin shad were not well formed until the fish reached 18-20 mm total length. Rays of gizzard shad were not well formed at lengths

of less than 21-23 mm. At total-lengths less than 18-20 mm these two species were so similar that I was unable to distinguish between them. Positive identification is further complicated by the fact that the two species are known to hybridize (Minckley and Krumholz, 1960). C. D. Riggs and W. L. Shelton (personal communication) have collected hybrids of the two species in Lake Texoma.

Warner (1941) described and illustrated the major changes in external morphology of the egg and larva of the gizzard shad through juvenile developmental stages. Bodola (1966) found that gizzard shad were 3.5 mm long at hatching and 5.2 mm four days later. Figure 5 shows a series of larval threadfin shad drawn from specimens taken from late spring and summer collections in Lake Texoma. Figure 19-C is a 24.2-mm gizzard shad which is in approximately the same stage of development as the 20.3 mm threadfin shad (Fig. 5-H).

Cyprinidae

Carp larvae (Fig. 6) are generally similar in form to other cyprinid larvae. They are too large in prolarva stages to be confused with Notropis lutrensis or N. venustus larvae, but are similar in size to Pimephales vigilax prolarvae (Fig. 10). The yolk sac is larger and more opaque than in P. vigilax and early carp larvae are also shorter and more stocky. Beyond the prolarva stage carp larvae are too strongly pigmented to be confused with other related forms. The yolk is persistent and feeding begins long before it is completely absorbed.

Silver chub larvae (Fig. 7) are very similar in appearance to the larvae of P. vigilax, but can be distinguished in the postlarva stages

by a generally more slender form, especially in the region of the caudal peduncle. The silver chub also has a longer, less blunt snout and the fins are larger.

Notropis lutrensis larvae (Fig. 8) are very similar in appearance to N. venustus larvae (Fig. 9) both in size and morphological features. They are known to interbreed and I have observed many interspecific aggregations during periods of spawning activity. I was unable to determine significant difference in the two species until anal fin-rays formed at about 9 mm total-length. N. lutrensis has nine anal rays and N. venustus has eight. The larvae of these species were much smaller than Cyprinus and Pimephales at similar stages of development. Saksena (1962) described the post-hatching stages of the red shiner and made camera lucida sketches of the larvae raised from a hormone-induced spawning in laboratory aquaria. Balinsky (1948) found that internal pigmentation visible in live specimens was useful in identification of larval cyprinid fishes, but the specific areas of pigmentation he used were not evident enough in the preserved Notropis specimens from my collections to be of value.

Menidia audens

Menidia larvae (Fig. 11) are characterized by an extremely short gut and a well-developed swimbladder in very early developmental stages. Also present at hatching are very large dark pigment spots on the head and belly. The genital openings and anus migrate backward during development between the pelvic fins to a position in front of the anal fin. Menidia are very distinctive as larvae and not likely to be confused

with the larvae of other species (except the now very rare brook silverside).

Roccus chrysops

White bass larvae (Fig. 12) were most similar in general appearance to Percina caprodes larvae. Prolarval stages are much smaller in Roccus than in Percina. After yolk absorption white bass larvae are characterized by a thick muscular gut and large easily distinguished myomeres. Pigmentation is almost absent in all larval stages. The mouth is very large in all stages of development subsequent to jaw formation.

Centrarchidae

Largemouth bass larvae (Fig. 13) are generally similar to Lepomis larvae but are more stocky and slightly larger than similar stages of L. megalotis which they resemble most. Young largemouth bass also have more pigmentation on top of the head in early stages and are less laterally compressed than other centrarchids. Specimens of Micropterus longer than 15 mm could be identified as largemouth or spotted bass by body conformation and pigmentation patterns.

Bluegill larvae (Fig. 14) are generally similar in appearance to longear sunfish larvae (Fig. 15) but somewhat slimmer at all stages. They are also similar in early stages to Pomoxis larvae but have a smaller mouth, a longer gut, and are larger at comparable stages of development. Drawings of similar juvenile stages of L. macrochirus and L. megalotis (Figs. 14-H and 15-H) show that these can be easily distinguished by pigmentation in the form of the vertical bars which

are much wider than the space between them in longear sunfish, narrower or about equal in bluegill. Prior to this pigmentation these two Lepomis can usually be separated on the basis of body conformation and anal fin-ray counts. Longear sunfish larvae are also characterized by precocious development of fin-rays. Caudal rays are present in the prolarva and at about 8 mm the spiny dorsal rays are present. Bluegill are 11-12 mm long before spiny rays are visible in the dorsal fin.

Pomoxis annularis larvae (Fig. 16) are most similar in general aspect to those of Lepomis but are somewhat smaller at hatching (Fig. 14-A, Fig. 15-A, & Fig. 16-A). After yolk absorption, Pomoxis becomes larger anteriorly but maintains a longer more slender trunk posterior to the swimbladder. The upward deflection of the notochord in formation of the hypural plate occurs at about 10 mm, total-length. In L. megalotis it is deflected upward at 6 mm and in L. macrochirus at 7-8 mm (Figs. 15-A & 14-D). All young crappie captured in this study were classified as white crappie although the black crappie is known to be in the lake. Whiteside (1964) captured only one black crappie in 1962-63 along with 1,828 white crappie in the Buncombe Creek area. All the young-of-year of this genus in my collections were white crappie.

Percina caprodes

Percina larvae (Fig. 17) are relatively elongate, slim larvae with large mouths. They might be confused with some older shad larvae except that the gut in logperch has a greater diameter and is shorter, extending only slightly posterior to the middle of the body. Figures 17-C and D show larvae with their guts full of small cladoc-

erans which appeared to be their favorite food item. Later stages of logperch larvae are generally similar to white bass larvae but have a longer gut, delayed swimbladder development, and are much longer in comparable stages of development.

Aplodinotus grunniens

Aplodinotus larvae (Fig. 18) hatch at a very early stage of development. The eyes are not pigmented and only rudimentary at hatching. Breder (1962) indicated that rapid hatching at a low stage of development is characteristic of pelagic eggs. The large oil droplet which makes the egg buoyant is posteriorly placed in the prolarva and causes it to float belly-side up with the head angled downward. Postlarvae have a very large mouth, large head, and a very slender trunk and caudal region. The eggs and larvae are very transparent, even when reared in aquaria. Freshwater drum larvae are fairly distinctive and did not closely resemble any other species in the collections. The eggs of this species were described by Davis (1959). Hiodon alosoides which is present in Lake Texoma is also known to produce semi-buoyant eggs but these are much larger than those of the drum and the larvae are quite different in appearance (Battle and Sprules, 1960).

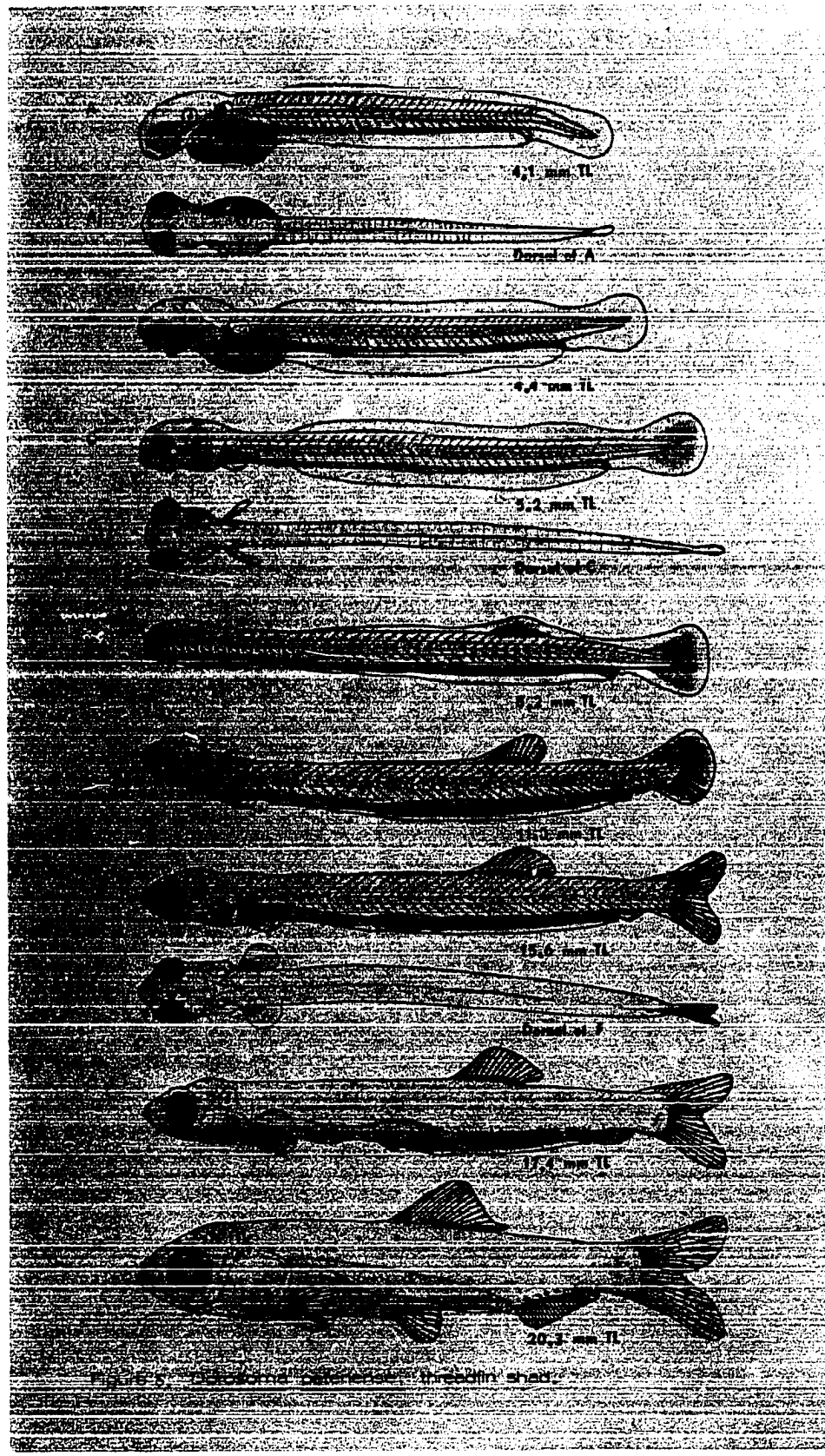


Fig. 6.5. "Dorosoma" petenense, threadfin shad.

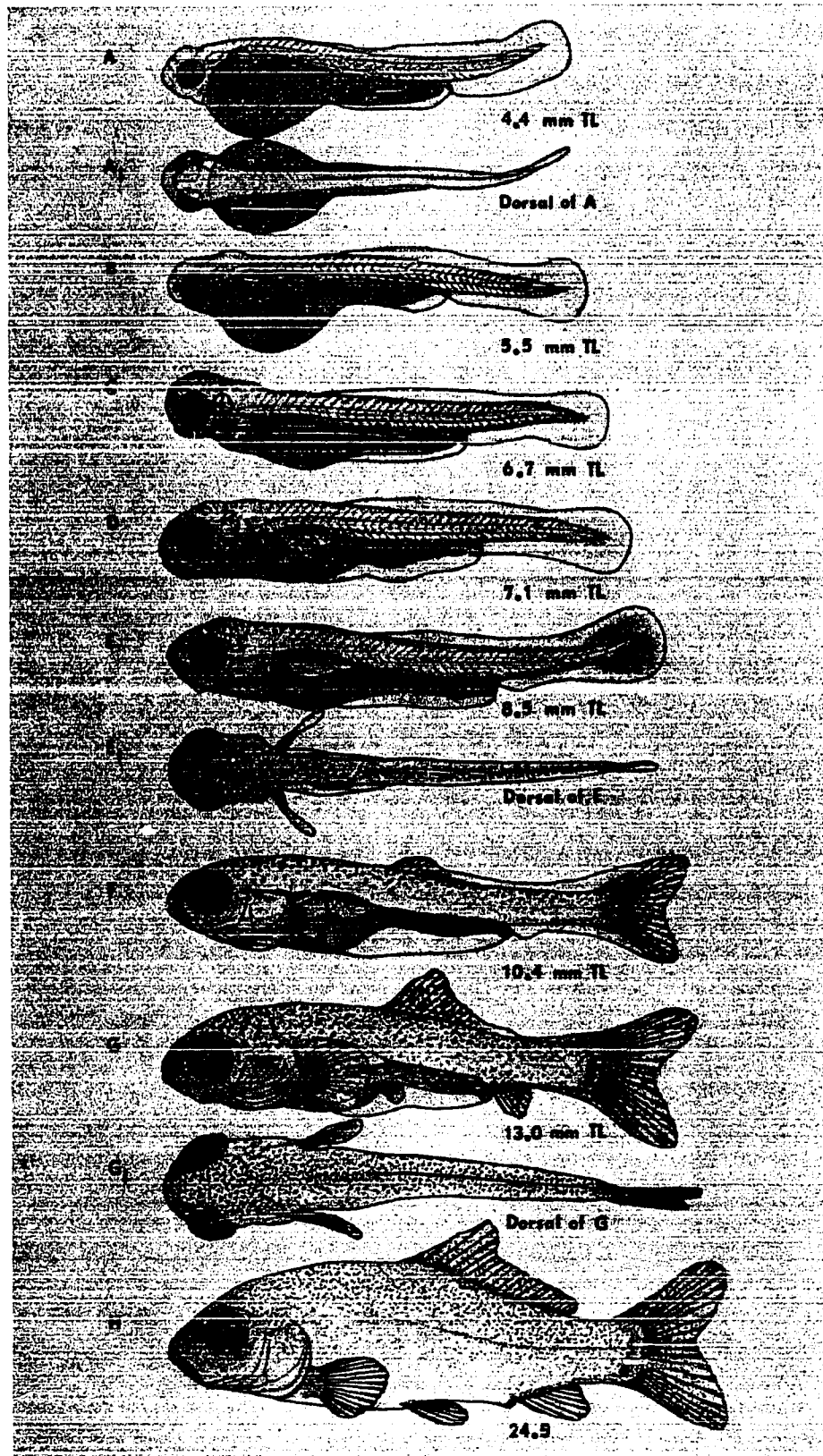


Figure 6. Cyprinus carpio. carp.

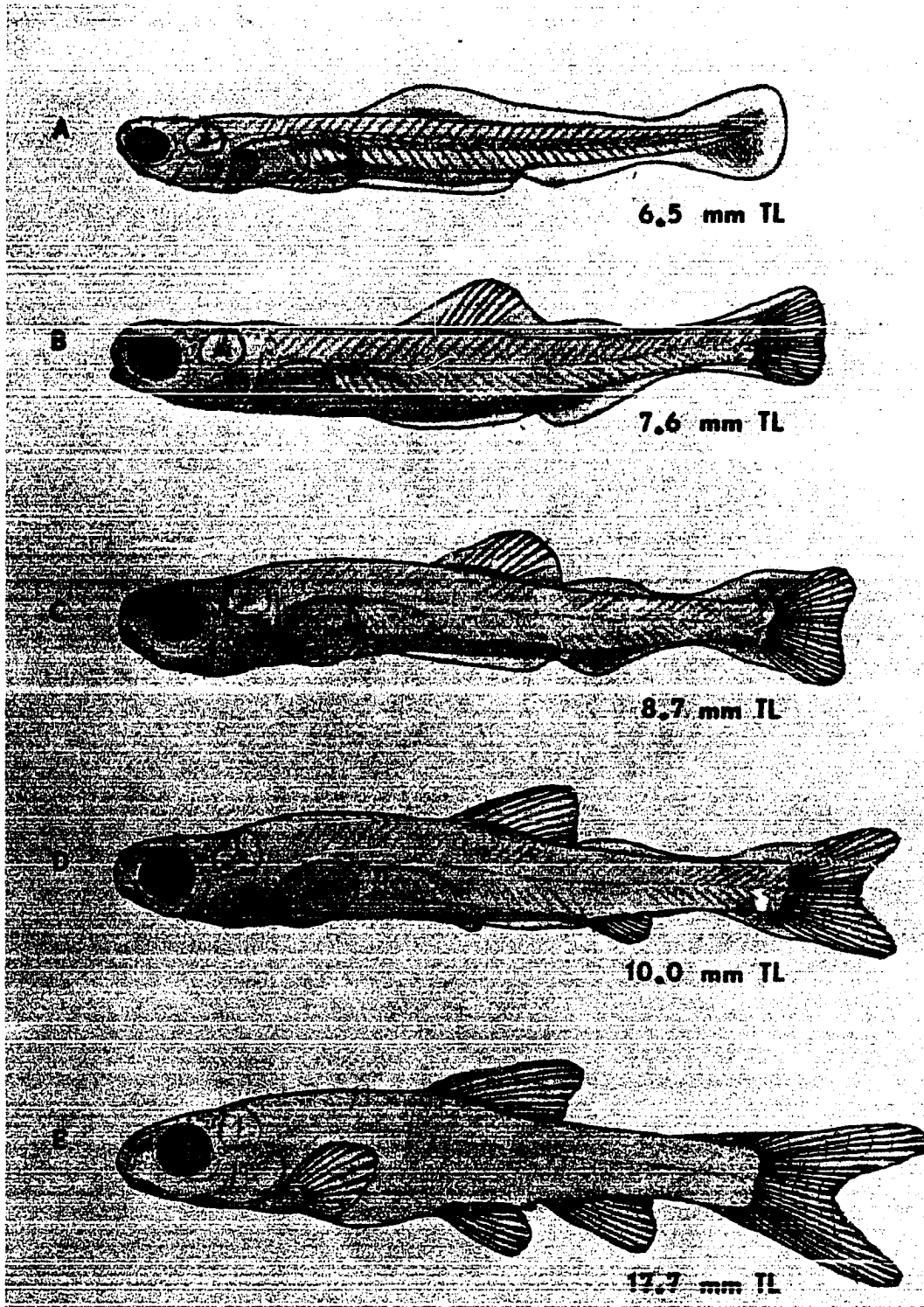
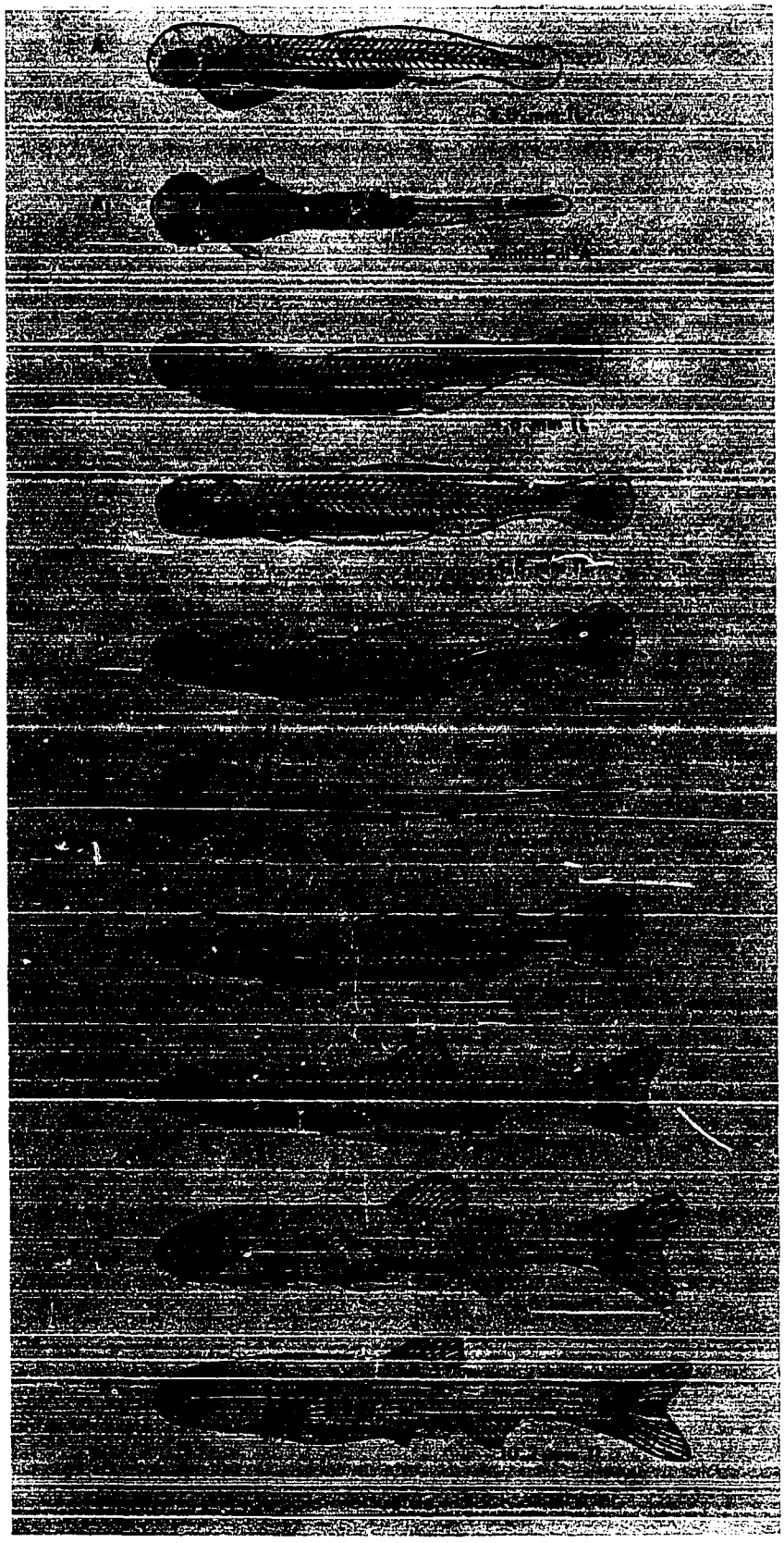
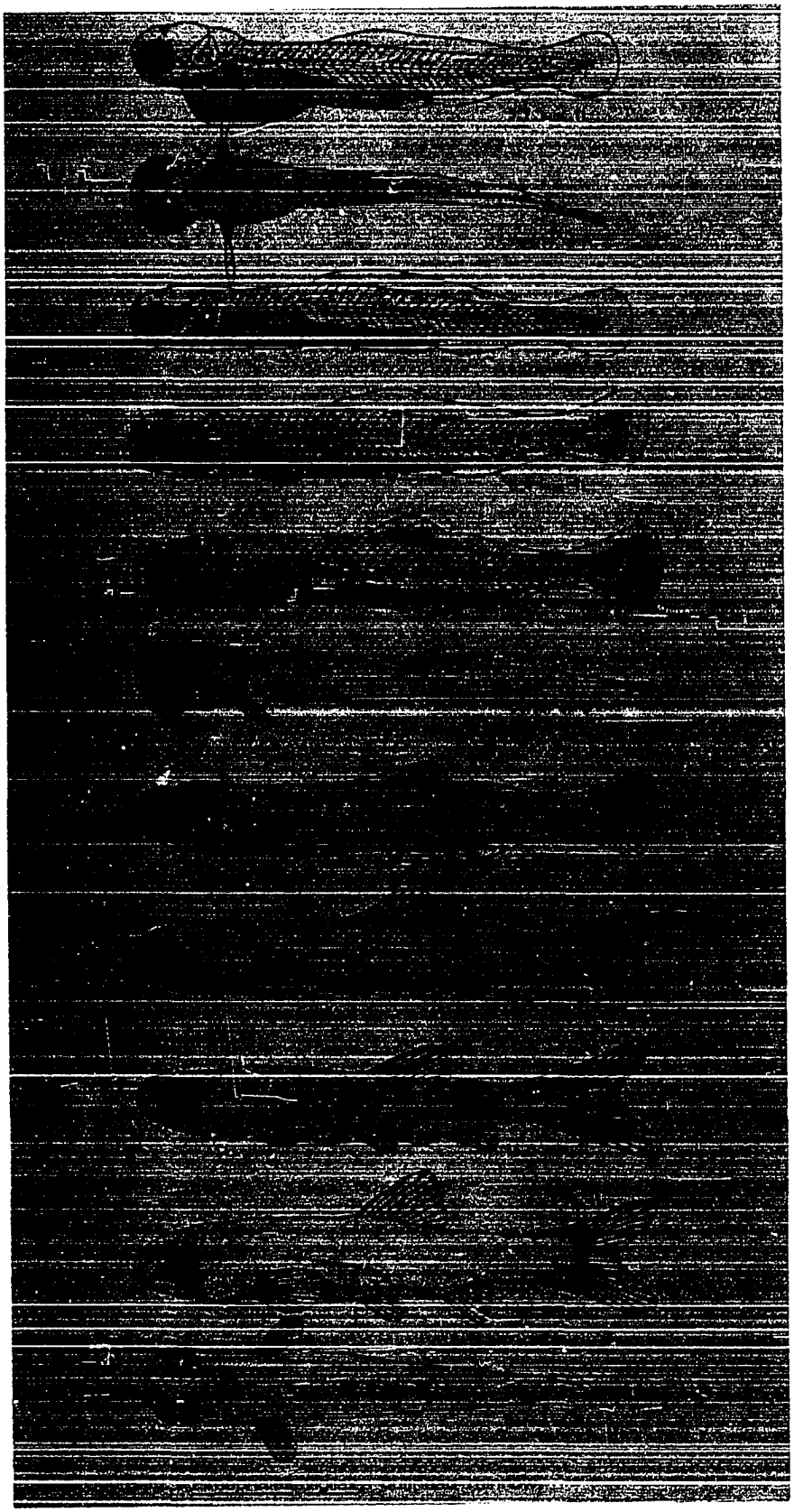


Figure 7. Hybopsis storeriana, silver chub.





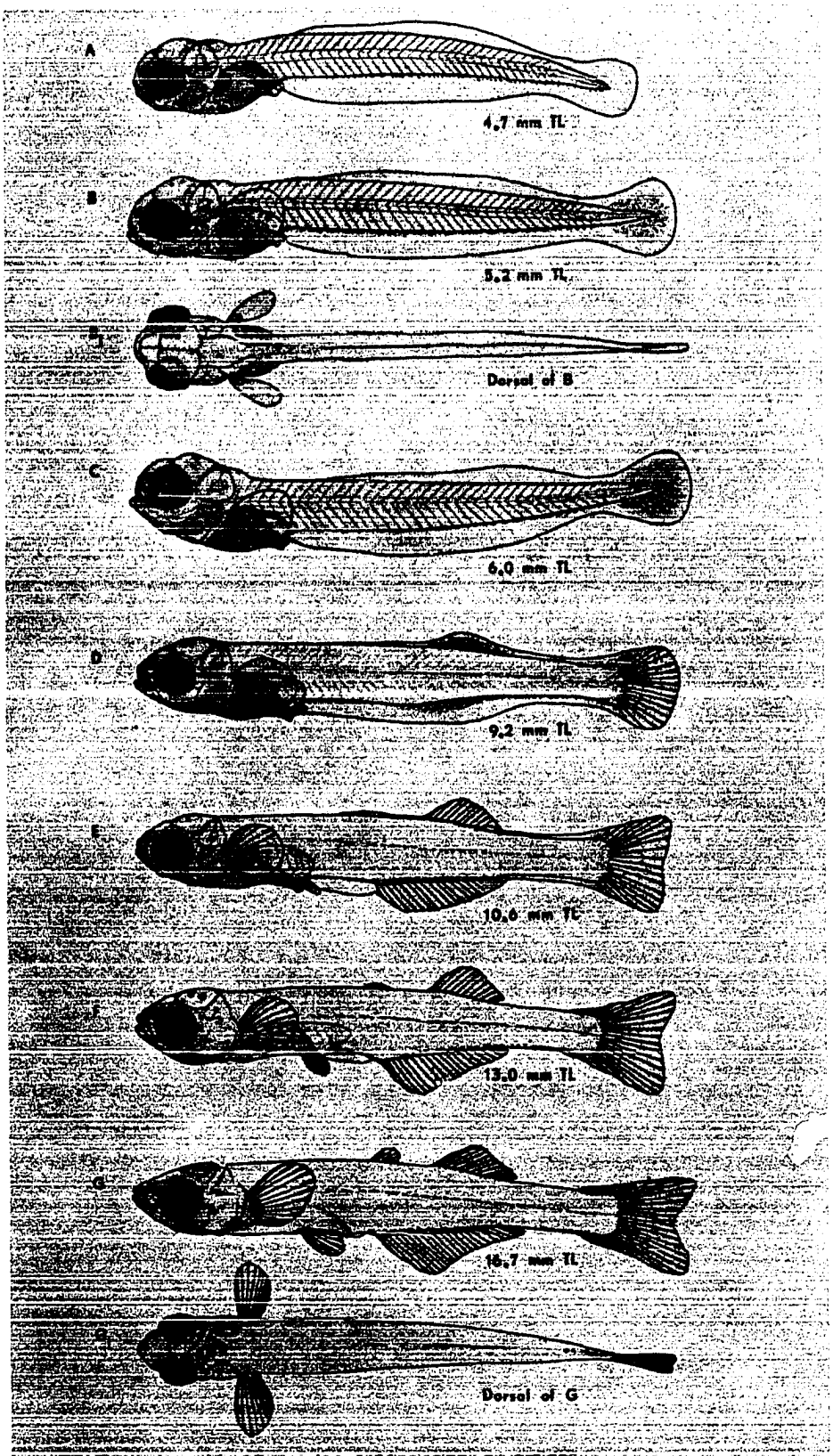


Figure 11. Menidia audens, Mississippi silversides.

2,4 mm TL

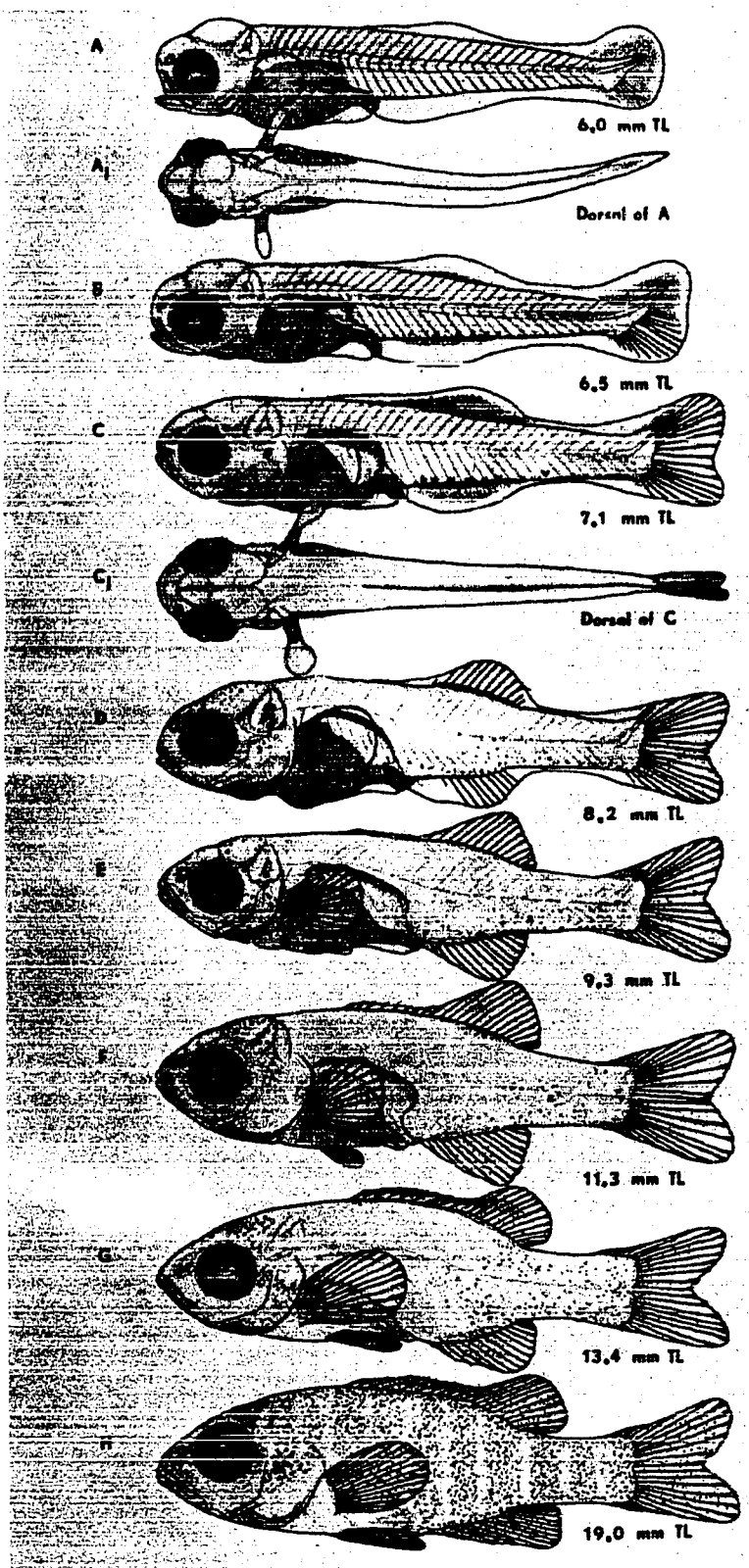
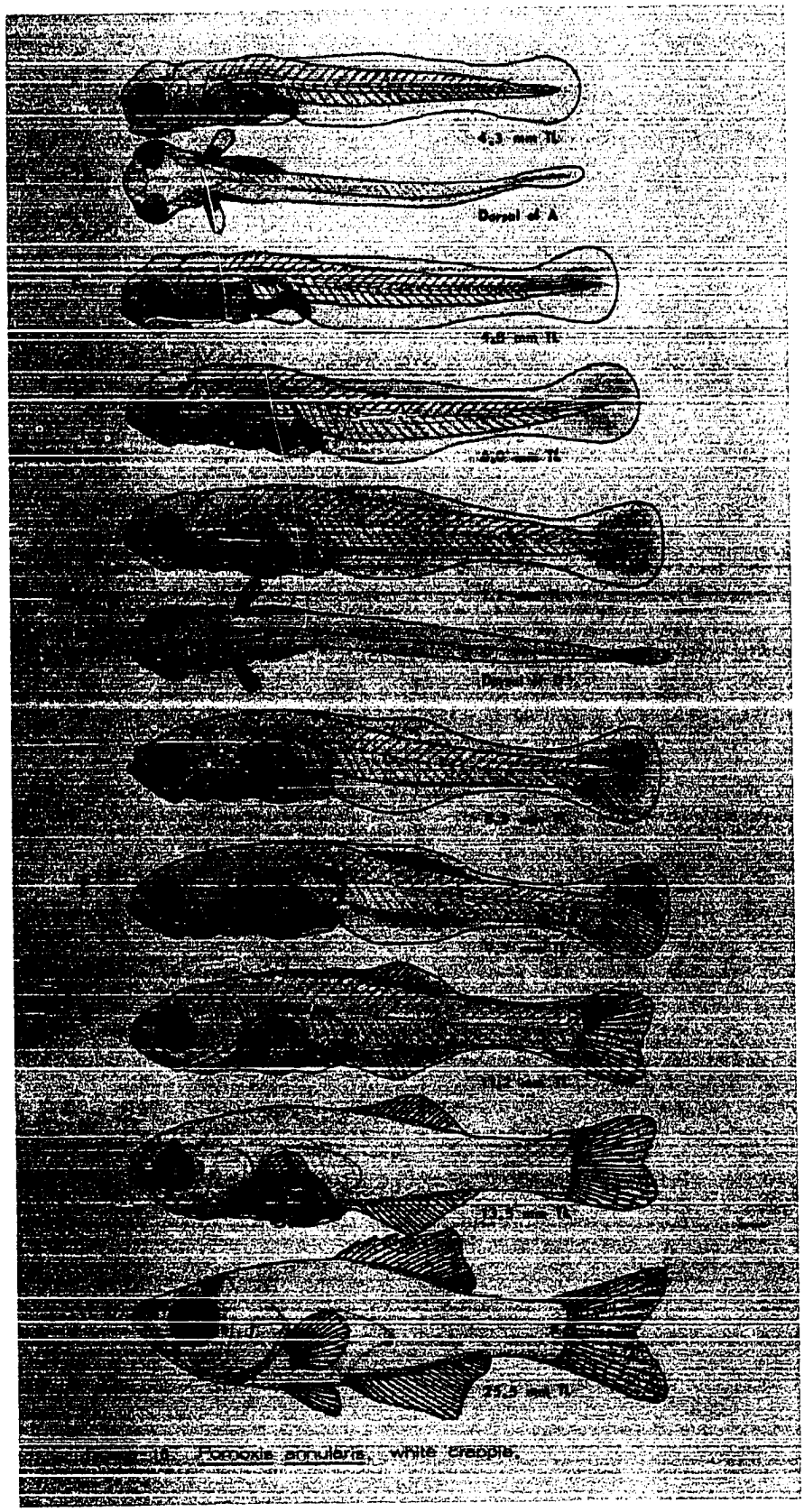


Figure 15. Lepomis megalotis, longear sunfish.



[illegible] 16. Pomoxis annularis, white crappie.

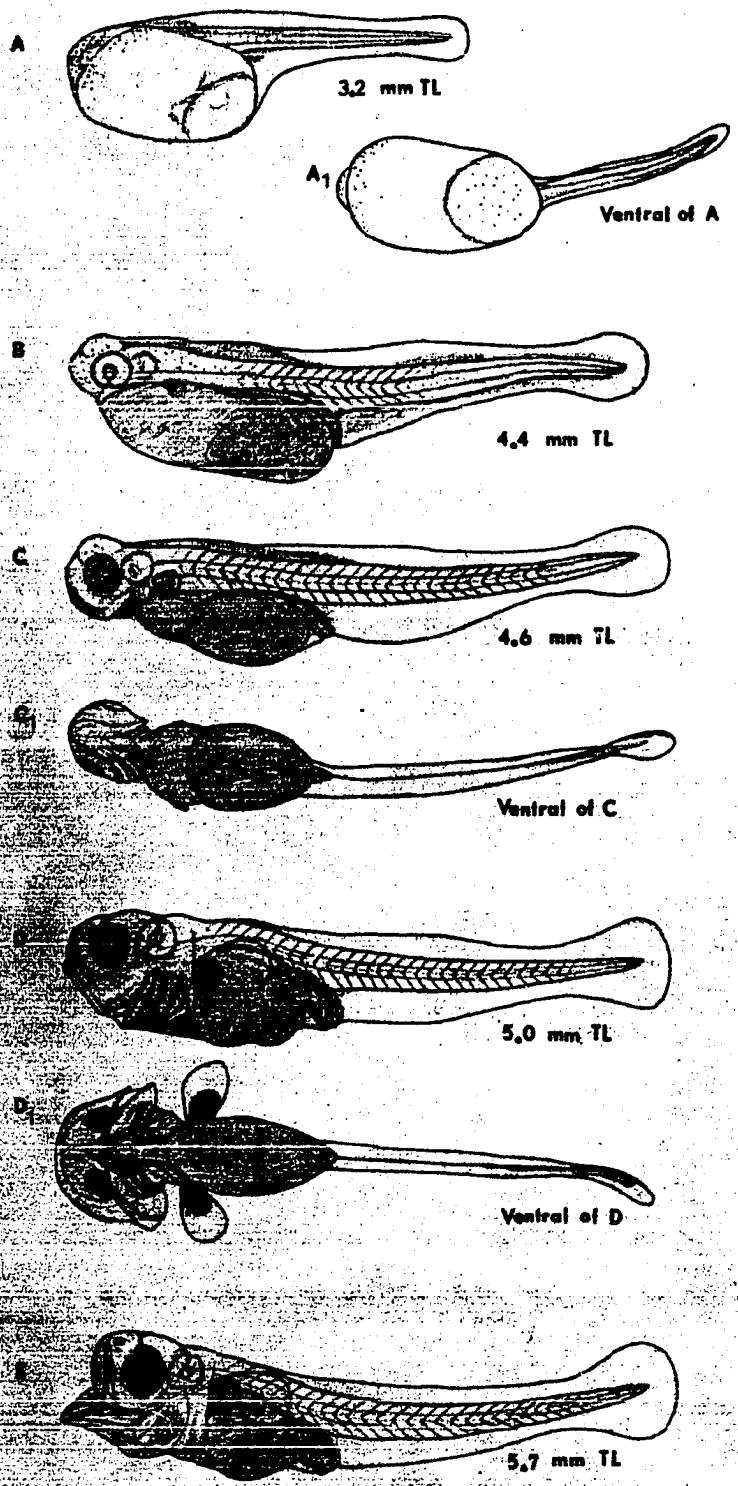
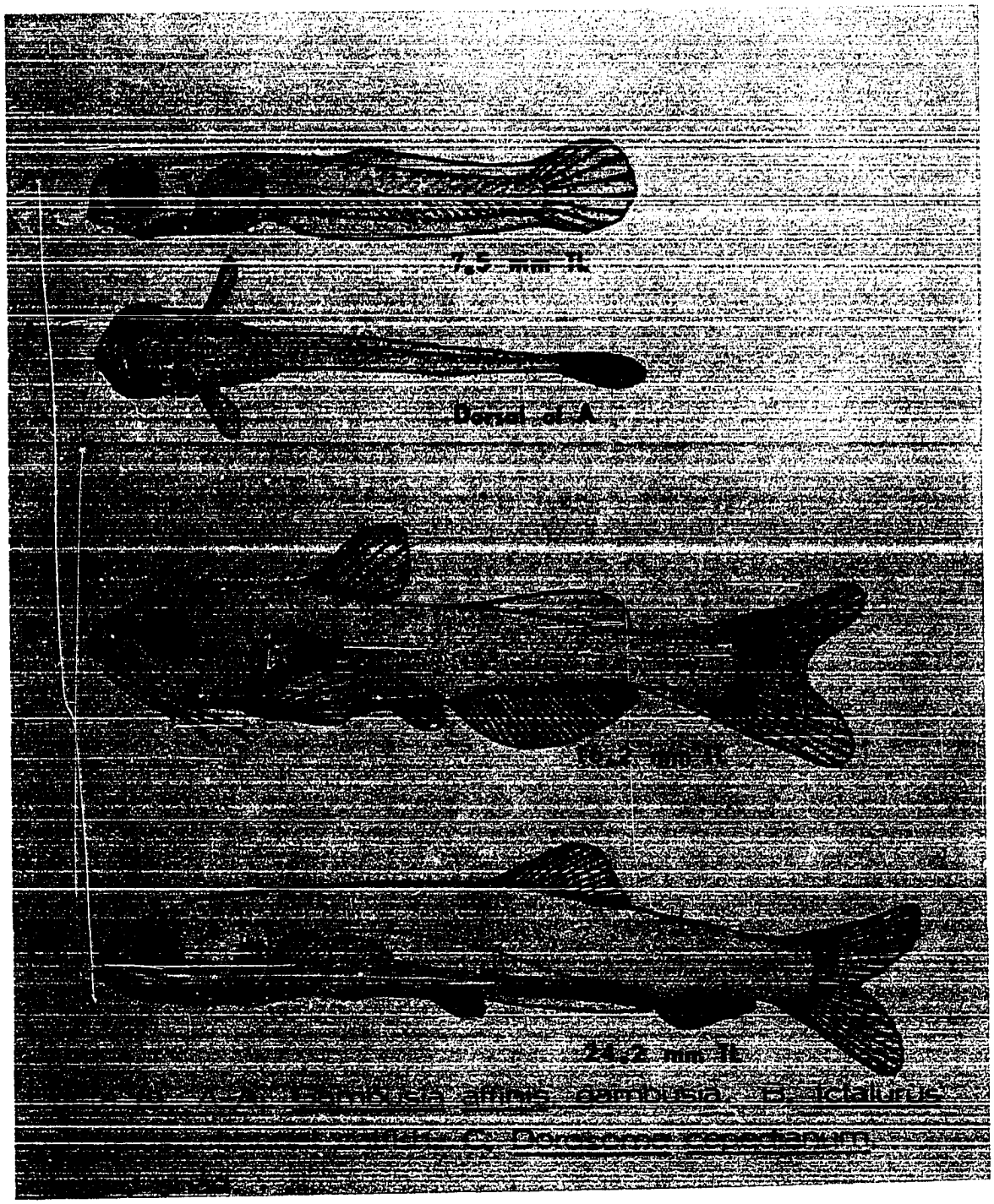


Figure 18. Aplodinotus grunniens, freshwater drum.

6,8 mm TL
8,7 mm TL
20,5 mm TL



[illegible] A-A. Gambusia affinis gambusia. B. Ictalurus [illegible] C. Dorosoma cepedianum.

CHAPTER V

DISTRIBUTION

A large number of factors are known to influence the distribution of fishes. Most of these factors have been determined in investigations concerned with adult fishes but larval and juvenile fishes undoubtedly respond to most of the same stimuli. Since thermal stratification was not an important distributional factor in Buncombe Creek arm the most important environmental factor in larval fish distribution may have been light. Breder (1962) pointed out that opaque eggs and larvae are usually found in places protected from radiation and that transparency is associated with the pelagic environment. He also indicated that night vertical migrations of larvae may be an adaptation for limiting exposure to radiation. Aquatic vegetation may also be important as a factor in the distribution of young fishes. Werner (1967) indicated there was regular migration between a heavily vegetated littoral zone and the open limnetic zone by bluegill fry during their development. The widely fluctuating water level in Lake Texoma prevents formation of large beds of rooted vegetation in the littoral zone, minimizing this type of habitat. Species interaction is probably very important in the distribution of young fishes but is difficult to evaluate. Nikolskii (1963) indicated large shoals of fish are

often composed of more than one species. My collections in Lake Texoma indicate that the larvae and early juveniles of threadfin and gizzard shads often form heterogeneous schools.

Since vision is so important to schooling (Keenleyside, 1955), turbidity and darkness probably affect the formation and size of schools and also the behavior of the school. Some of the Lake Texoma species (channel catfish, largemouth bass) are strong schoolers during early development but become less gregarious as adults. Local conditions of wave action and turbidity are other factors known to affect fish distribution. Seine collections made in highly turbid areas of Lake Texoma indicate the young of several species (shads, white crappie, freshwater drum) are much more abundant near the shore in these areas than in the relatively clear water of the Buncombe Creek arm.

Lepisosteus

My observations of young gar in Lake Texoma indicate that they prefer shallow calm water near emergent vegetation, often within inches of the shoreline, and move further from the shoreline as they increase in size. I have seen aggregations of five to ten larvae (about 20 mm long) around one small emergent plant near shore. Individuals longer than 25 mm were almost always solitary. Breathing habits of the young gars allow them to maintain a buoyancy which makes it possible for them to float at the surface without swimming activity. Echelle (1967) found that nearly all the food of young gars was surface organisms; the fishes taken were nearly all Menidia, with a significant percentage of Gambusia.

Only 15 gars appeared in my collections, 13 in 1965 seining and two in 1966 night surface trawl collections. Range in total-length of gars collected was 10 to 26 mm.

Dorosoma

The young shad were divided into four size-groups for comparison. Group-1 fish were larvae from hatching to 5.5 mm and included weak swimming larvae whose movements were probably largely vertical migrations in response to light and the heavy yolk. Group-2 fish (6-10 mm) were active, feeding larvae but still relatively weak swimmers with no fin-rays developed. Group (10.5-20 mm) included larvae which were obviously much better swimmers and most had fin-rays well developed in caudal and dorsal fins. Group-4 fish (20.5 mm and longer) were mainly prejuvenile and juvenile Dorosoma most of which had a full complement of fin-rays in all fins.

Larvae of groups 2 and 3 made up 96% of the young shad collected in 1966. The relatively low number of group-1 specimens (2.4%) was related to shad spawning being concentrated near shore and in shallow water and to the fact that group 1 had a size spread of only 1½ mm (smallest shad collected were about 4 mm long). The lowest number of fish were from group 4 (1.6%); this was due primarily to their greater ability to avoid the trawl (95.5% were taken in night collections).

Horizontal Distribution

Group-1 larvae were not abundant at any trawl station but larger collections of this size-group were made at S4 and 5 which were evidently near preferred spawning areas (Fig. 20). Distribution of larvae

of groups 2 and 3 appeared to be similar at midwater and bottom but group 2 was much less abundant at S5 in surface hauls. Group 3 may have avoided the proximity of the shoreline more strongly than the smaller group-2 fish. The reduced number of larvae near the bottom at S3 may have been due in part to poor sampling as a result of the rugged bottom profile at this location. Group-4 fish were taken more readily at midwater but were not particularly abundant in the collections at any of the six locations.

Shad larvae were generally more abundant in the upper end of the Buncombe Creek arm and the largest collections and most consistent presence of shad was at S6.

The sporadic appearance of large catches in the seine in the daytime indicates the close schooling of the young shad. No such large groups appeared in night collections (8 shad was the largest night sample). Keenleyside (1955) found that vision was the only sense involved in Scardinius joining a school although blinded fish remained in an area where odor of the species was. Sense of smell may thus be utilized in keeping schools of some species from scattering widely at night but the young shad appeared to be well dispersed at night. Of 5,858 young shad collected by seining only 43 were caught at night, although night collections amounted to almost 20% of the seining effort. The apparent reduction in the number of shad near the shoreline at night may also be related to the apparent nightly migration of the predaceous Roccus chrysops into the shallow water zones. Seine collections of small juvenile shad (20-40 mm) taken June 14 indicated that the two species may have been schooling together. Fishes col-

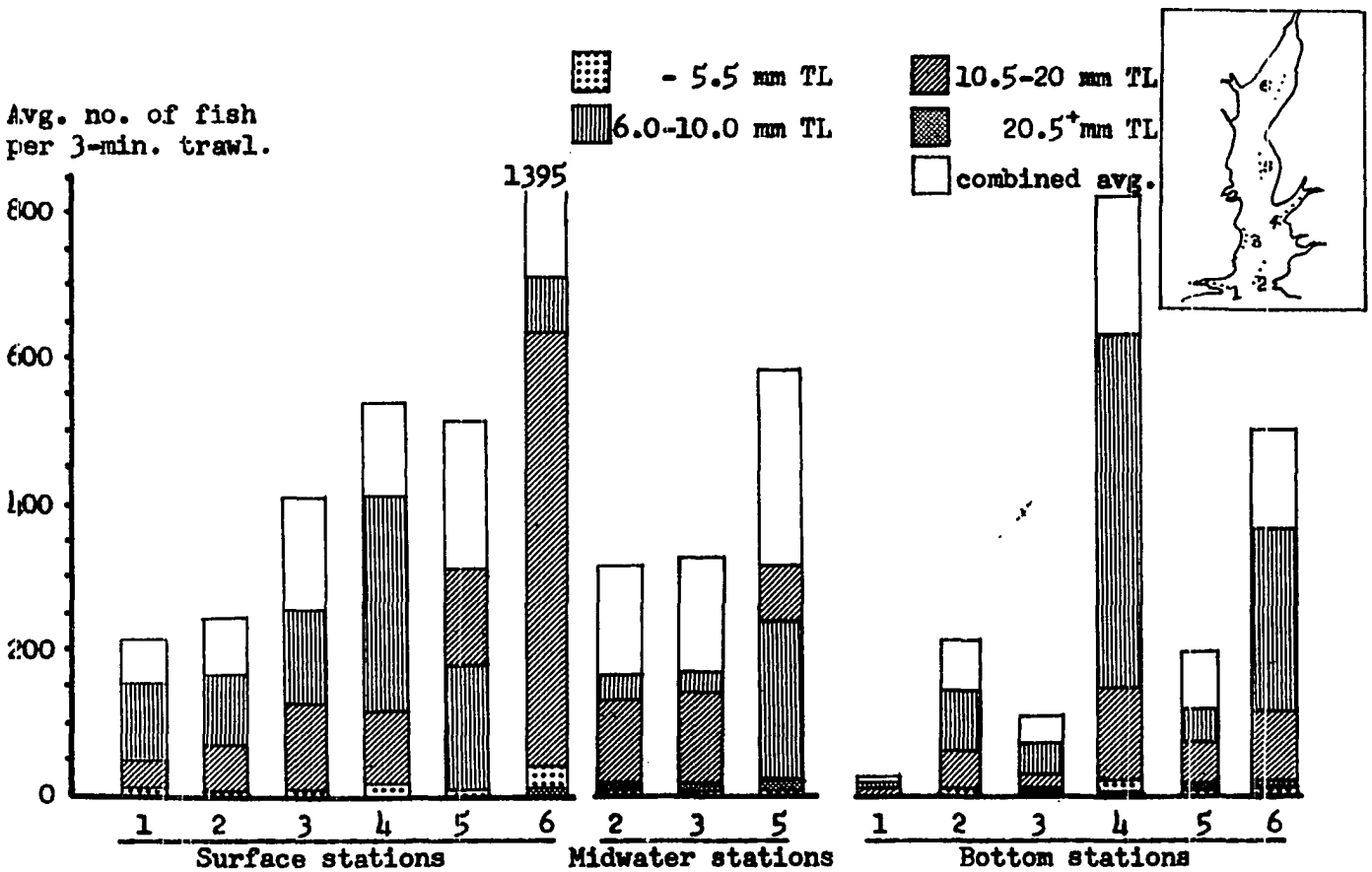


Figure 20. Horizontal distribution of four size-groups of Dorosoma taken at six trawling sites. Data from 451 collections made from April 8, through October 7, 1966, during both day and night.

lected at S8 on this date included 38 gizzard and 131 threadfin shad, while the collection at 10 contained 20 gizzard and 294 threadfin shad. The number and presence of shad in seine collections was quite variable but at S7 and 8 at the upper end of Buncombe Creek arm, there were shad in 59 and 53% of the collections, respectively. S7 also yielded the largest total number of shad. Shad were more abundant in collections made over shallow gentle-sloping bottoms and were rare to absent in collections made where the bottom slope was steep and rocky. It appears that the young shad usually maintain sufficient distance from the shoreline to prevent capture by seining along steep shorelines. Bodola (1966) indicated that young gizzard shad move into deeper water offshore as they become larger.

Vertical Distribution

Figure 21 illustrates the vertical distribution of the four size-groups of Dorosoma larvae and young-of-year as shown by the 1966 trawling effort. Shad were much more abundant at the surface (100,605) than at midwater (33,676) or bottom (56,995), with an average of 546.76 fish per three-minute surface trawl. When the totals are divided into night versus day it can be seen that the shad were more abundant near the surface in daytime (495.61 per trawl) and more abundant at midwater (646.38 per trawl) at night. The overall averages and day averages show a reduction in population density with depth. At night the fish were more evenly distributed vertically.

Group-1 Dorosoma were more abundant at the surface in both day and night collections than at midwater or bottom. Warner (1941)

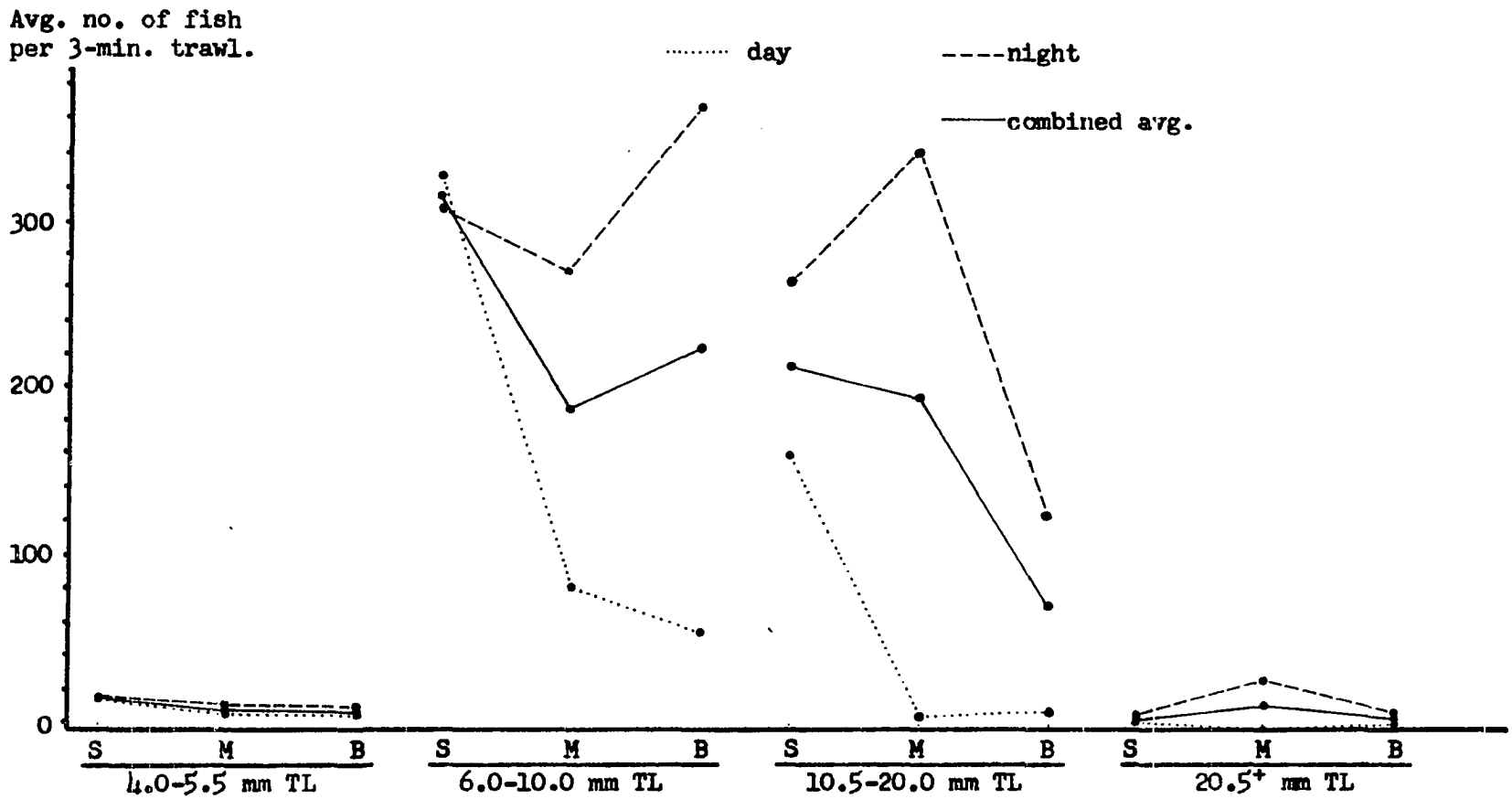


Figure 21. Vertical distribution of four size-groups of Dorosoma. Data from 451 collections made from April 8 to October 7, 1966, and including 184 surface, 83 midwater, and 184 bottom trawls.

found that the larvae went through two days of vertical activity after hatching in aquaria and Bodola (1966) observed this for three to four days before more typical swimming occurred. Very young shad have also been observed to concentrate on the lighted side of aquaria. Group-2 larvae also exhibited a strong surface preference in the daytime but were more evenly dispersed at night and slightly more abundant near the bottom. Group-3 larvae were much more abundant at the surface in daytime, while at night they were most abundant at midwater and the lowest number was in bottom collections. Group-4 shad were essentially absent from daytime collections and were most abundant in midwater collections at night. Group 4 was the only size-group which failed to show overall surface preference and I believe this was due to their ability to escape the trawl; escape being much greater, due to better visibility, in the well-lighted water near the surface. Borges (1950) reported millions of 1 to 2-inch gizzard shad schooling at the surface from July through September in Lake of the Ozarks, Missouri. Houser and Dunn (1967) reported that young-of-year threadfin shad in Bull Shoals Reservoir, Arkansas, were sharply stratified at night between the thermocline and surface but my collections show that stratification of the larvae and early juveniles did not occur in the absence of a thermocline.

In general, shad larvae were more concentrated near the surface in daytime and least abundant near the bottom. At night the distribution was more random with groups 3 and 4 more abundant at midwater and group 2 more abundant near the bottom. Group 1 appeared to maintain a similar distribution in both day and night but had midwater and bottom catches

making up a higher percentage of the catch at night.

Cyprinus carpio

Carp larvae become strong swimmers with good vision at an early age and are not easily captured at larger sizes. Only 19 (5.3%) of 361 larval and young-of-year carp taken in 1966 trawling were captured in daytime collections and all but five of the total were less than 9 mm in total-length. Specimens in 1965 seine collections were of a similar size, most being 6 to 9 mm long. The absence of larvae from hatching (about 4.5 mm) to 5.5 mm from my collections is related to the three to four-day inactive period reported by Smallwood and Smallwood (1931) for heavy-yolked prolarvae after hatching.

Since almost all carp captured were in the early larval stages (5.5-8.5 mm) no division into size-groups was made. In the 1966 trawl collections young carp were most abundant in the cove trawls (S1 and 5) and shallow water at S6 in both surface and bottom trawls (Figs. 22 & 23). The larvae taken in the trawl were caught almost entirely in surface collections made at night (Fig. 23). Nikolskii (1963) stated that carp larvae use cement organs to attach to objects in well-oxygenated water near the surface. Carp were infrequent in daytime collections when most were taken near the bottom. Apparently few carp larvae move out of the shallow areas and they were much more infrequent in collections at deep-water trawl stations (S2, 3, and 5). Swee and McCrimmon (1966) reported observing thousands of fry in shallow depressions in areas where carp had spawned and noted that there was no schooling tendency.

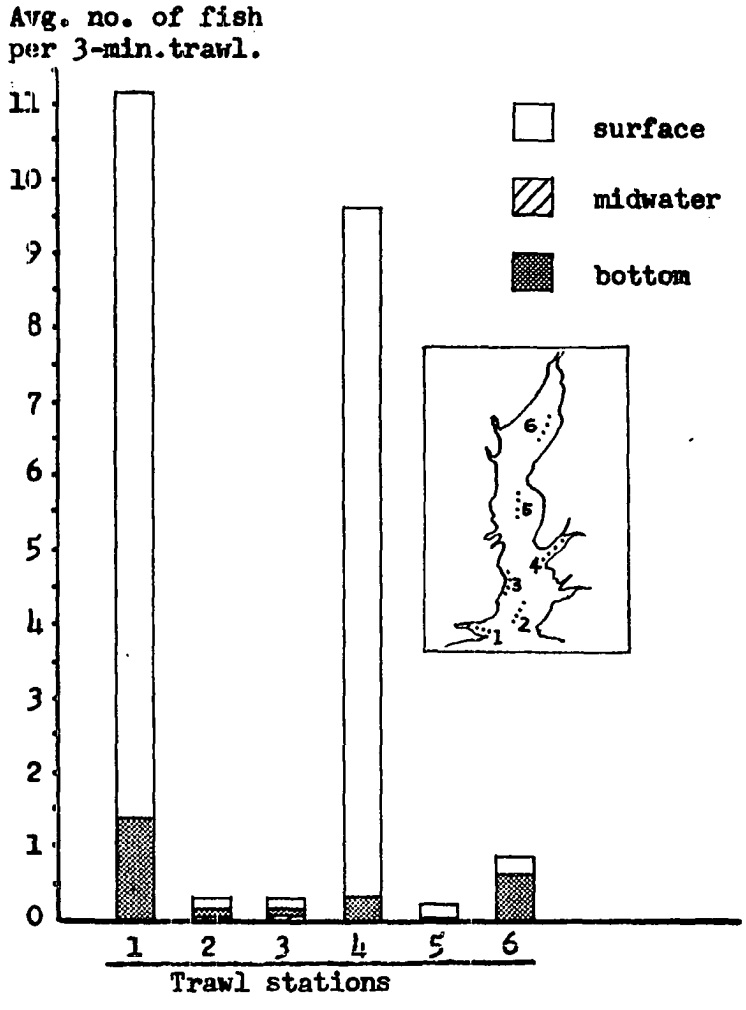


Figure 22. Horizontal distribution of carp larvae at six trawl stations. Data from 210 trawls made from April 30 through June 12, 1966.

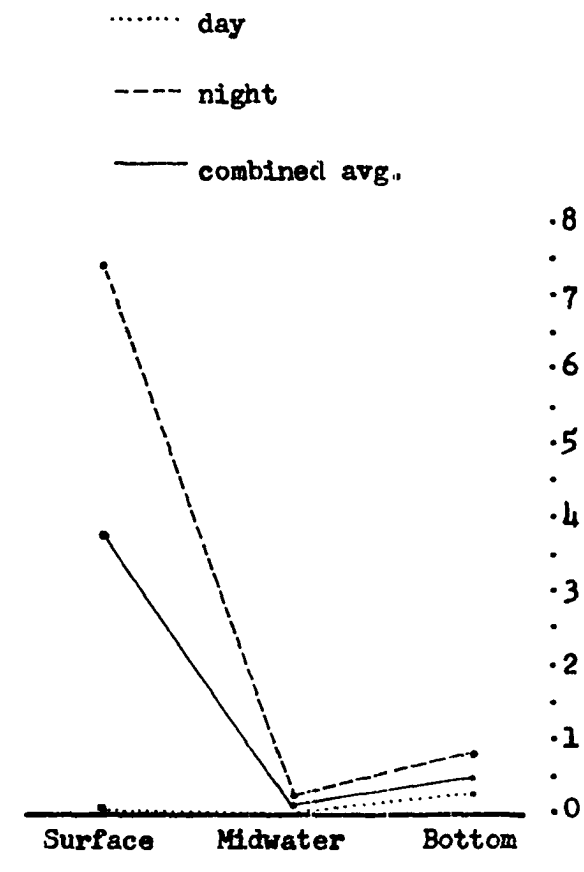


Figure 23. Vertical distribution of larval carp. Data from trawls made from April 30 to June 12, 1966.

Seine collections of young carp in 1965 included 116 individuals. There was apparently fair abundance near shore since all were captured in daytime seining. These were nearly all taken at calm-water stations; a total of only five larvae was taken at S2, 3, 4, 7, and 12 where wave action was more severe.

Hybopsis storeriana

Most of the silver chub collected were taken in the trawl at S1, 3, and 5 (49 of 53). Only one of these was taken in the daytime and 46 were in bottom samples. Only one adult and no young were captured in 1965 seining.

Notropis lutrensis and N. venustus

The sampling gear appeared to be especially inefficient for sampling the larvae of Notropis spp. This is indicated by comparing the number of adults caught to the number of larvae and juveniles, especially in the seine. The trawl data however, indicate a very narrow range of distribution in which these species are limited to the shallow water near the shoreline. An important factor involved in their capture is the strong swimming ability which develops at a very small size. Traps like those designed by Breder (1960) may be much more efficient for sampling populations of red and blacktail shiners.

In 1966 trawl collections 14 young red shiner (9-22 mm) were taken. All were collected at night; 11 in surface hauls, 2 in bottom hauls, and 1 at midwater. In these collections 21 N. venustus were captured. These also were taken only at night; 15 in surface trawls and 6 in bottom samples. All Notropis trawled in both years came from

S1, 3, and 4, which are the three stations closest to a shoreline. It appears that there is some loss of orientation to the shoreline in the dark but most specimens taken in the trawl samples remained near the surface in areas not far from shore.

Pimephales vigilax

Bullhead minnow distribution was analyzed only on the basis of night trawl collections made in 1966 since only three of 1106 young were captured in daytime. In 1965, 83 of 1557 were caught during day hauls but day catches for both years were made only in bottom samples. The young Pimephales were divided into three size-groups for analysis of distribution as shown by the 1966 collections. Group-1 larvae (about 5 to 6.5 mm) made up 14.1% of the total catch and were primarily the yolk-bearing prolarvae. Group-2 larvae (7-10 mm) included 31.7% of the total and were active feeding larvae with fin-rays developing in the dorsal and daudal fins. Group 3 (10.5 mm and longer) made up 54.2% of the catch and was composed of late larval and juvenile bullhead minnows.

Horizontal Distribution

Young bullhead minnows were most abundant in collections made at the shallow water stations (Fig. 24). Numbers collected at the deep-water stations far from shore (S2 and 5) were very small and midwater collections contained a significant number of young Pimephales only at S3 near the shoreline. The distribution patterns indicate that the group-1 larvae were more widespread near the surface and the larger fish were more restricted to the cove areas (S1 and 4). The differ-

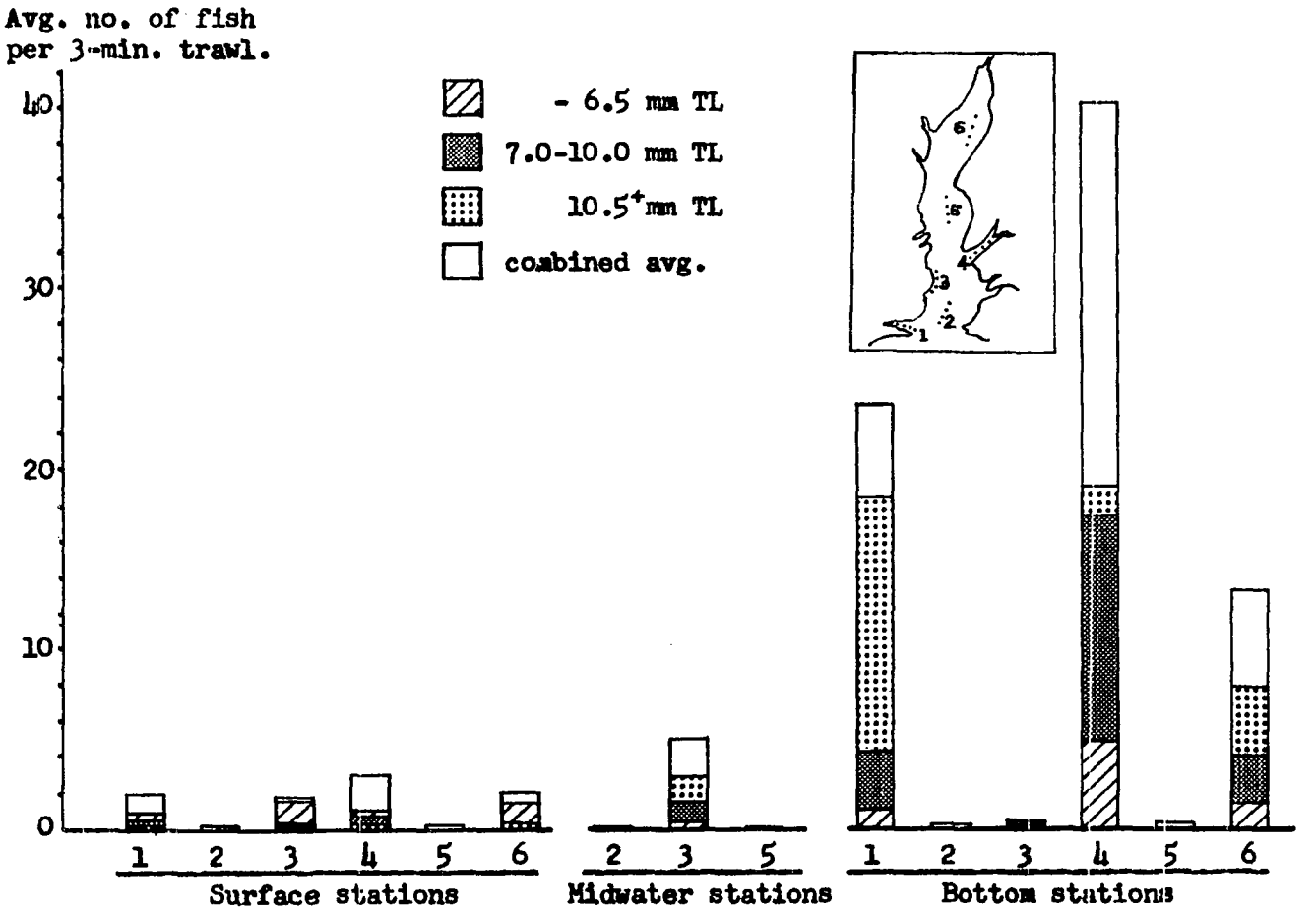


Figure 24. Horizontal distribution of three size-groups of Pimephales vigilax taken at six trawling sites. Data from 175 night trawls made from May 21 through October 7, 1966.

ences in surface and bottom distribution between size-groups at S1, 3, 4, and 6 were tested with 2 by 4 contingency tables applied to the total numbers collected. The surface distribution of group 1 was found to be significantly different from that of groups 2 ($p < .01$) and 3 ($p < .02$) which were similar. Near the bottom, distribution of groups 1 and 2 was not significantly different ($.70 > p > .50$) but both were significantly different from group 3 ($p < .0001$). Spawning sites were probably widespread along the shoreline and smaller larvae dispersed from these areas into deeper water at night. As the young fish matured they moved into the protected cove areas.

Vertical Distribution

All size-groups of Pimephales were most abundant in bottom trawls (Fig. 25). However, by the use of 2 by 3 contingency tables the distributions of the three size-groups, compared in pairs, at surface, midwater, and bottom, were found to be significantly different from each other ($p < .02$). Group-1 larvae were fairly numerous in surface collections, probably due to vertical migration in the lowered intensity of light at night. The vertical distributions of groups 2 and 3 were more similar, being concentrated near the bottom. It appears that after an initial strong upward movement by the prolarvae at night the P. vigilax larvae maintain a position near the bottom in relatively shallow water where light intensity is optimum. They apparently all stay near the bottom in shallow water in the daytime, with some upward movement and dispersal at night.

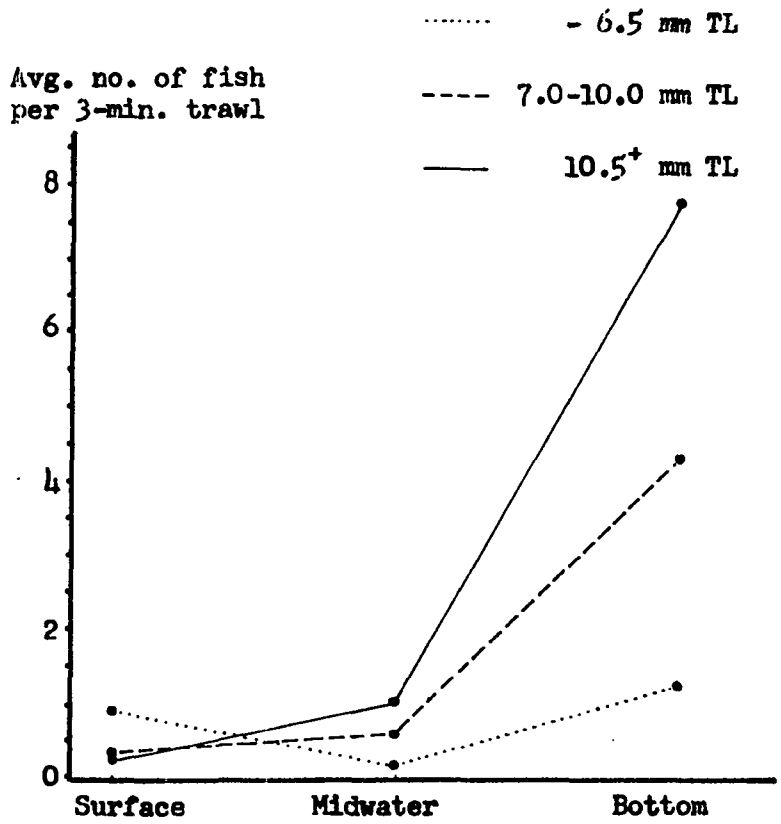


Figure 25. Vertical (night) distribution of three size-groups of Pimephales vigilax. Data from 175 night collections made from May 21 through October 7, 1966, and including 70 surface, 35 midwater, and 70 bottom trawls.

Ictalurus punctatus

Night collecting took 69 of the 70 young channel catfish whose size-range was 13.5 to 26 mm. Of the 69 fish taken by trawling, 27 (14-16.5 mm) were in surface collections where the sample sizes were 1, 5, 6, and 15. Bottom collections contained 37 specimens; the sample size was most often a single specimen. Channel catfish longer than 16 mm were taken almost exclusively in bottom samples. It appears that schooling tendency and migration to the surface are greatly reduced in fishes over 16 mm long. Collections made in coves (S1 & 4) included 46 of the young channel catfish.

Menidia audens

Menidia larvae and young-of-year were divided into three size-groups for analysis of distribution. Size-group 1 was composed of larvae 4 to 10 mm long and included fish from hatching through median fin-ray development. Group 2 included larvae from 10.5 to 15 mm long which were developing rays in the lateral fins. Group 3 (15.5 mm and longer) was composed primarily of juveniles.

Horizontal Distribution

The peak abundance of Menidia at S1 (Fig. 26) may have been a result of greater spawning in this area due to the presence of large beds of submerged and emergent dead Polygonum, Typha, and grasses. Hildebrand (1922) found that Menidia menidia and M. beryllina spawn in vegetated areas where the eggs attach to the vegetation by a bundle of attachment strands. Group-1 larvae were most common in surface collections at all locations but were essentially absent from midwater

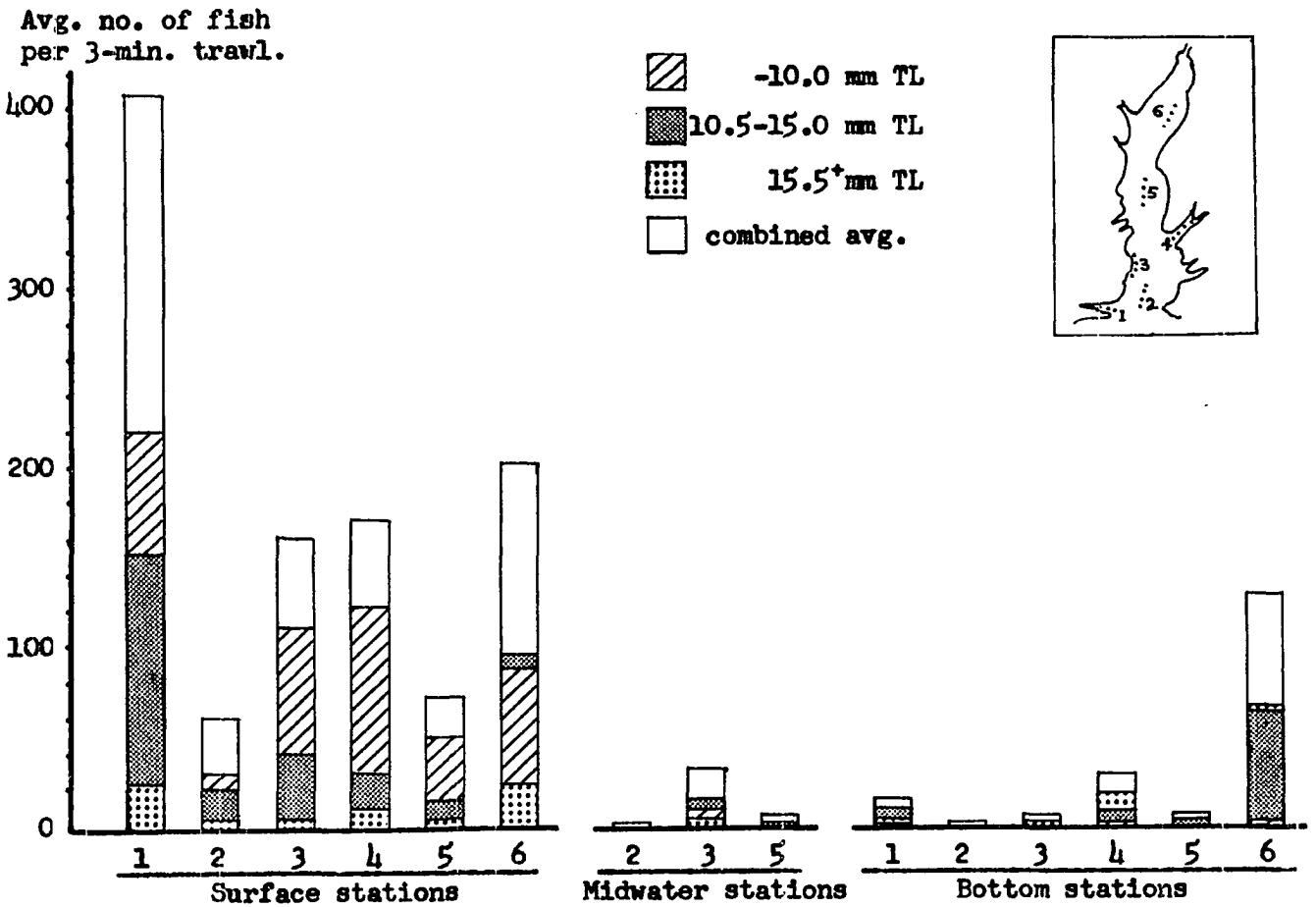


Figure 26. Horizontal distribution of three size-groups of Menidia audens taken at six trawling sites. Data from 427 trawls made from April 18 through October 7, 1966, during both day and night.

and bottom collections. Groups 2 and 3 exhibited similar patterns of abundance except that a significant number were caught on bottom, especially at S6 where water was shallowest.

The large number of Menidia collected in the relatively small effort of seining compared to trawling in 1965 (Table 1) indicates a preference for shallow water. Seining data also indicated little difference in day and night concentration near shore with the slight reduction of abundance in night collections possibly due to the dispersal of large aggregations. Mense (1967) also found no significant difference in the concentration of Menidia near the shore in day and night. Most were taken in the relatively shallow water near the open lake and they appeared to avoid the more turbid areas and small coves.

Vertical Distribution

Menidia were only abundant in trawls made at the surface (Fig. 27). Although an average of only 3.24 group-2 larvae appeared in surface samples in the daytime and only .21 group 3 fish, these groups were present only at the rate of .18 and .01 per haul, respectively, in daytime bottom hauls. All groups were present in similar numbers in night midwater trawls but group 1 was much less abundant than the other two groups in night bottom collections. The relatively large swimbladder of the group-1 larvae probably helped to keep these larvae near the surface. At night groups 1 and 2 maintained a strong surface preference. Group 3 was slightly more abundant in bottom collections at night due to a few large collections at S4 and 6. It is apparent that fish of all size-groups remain in close proximity to the surface

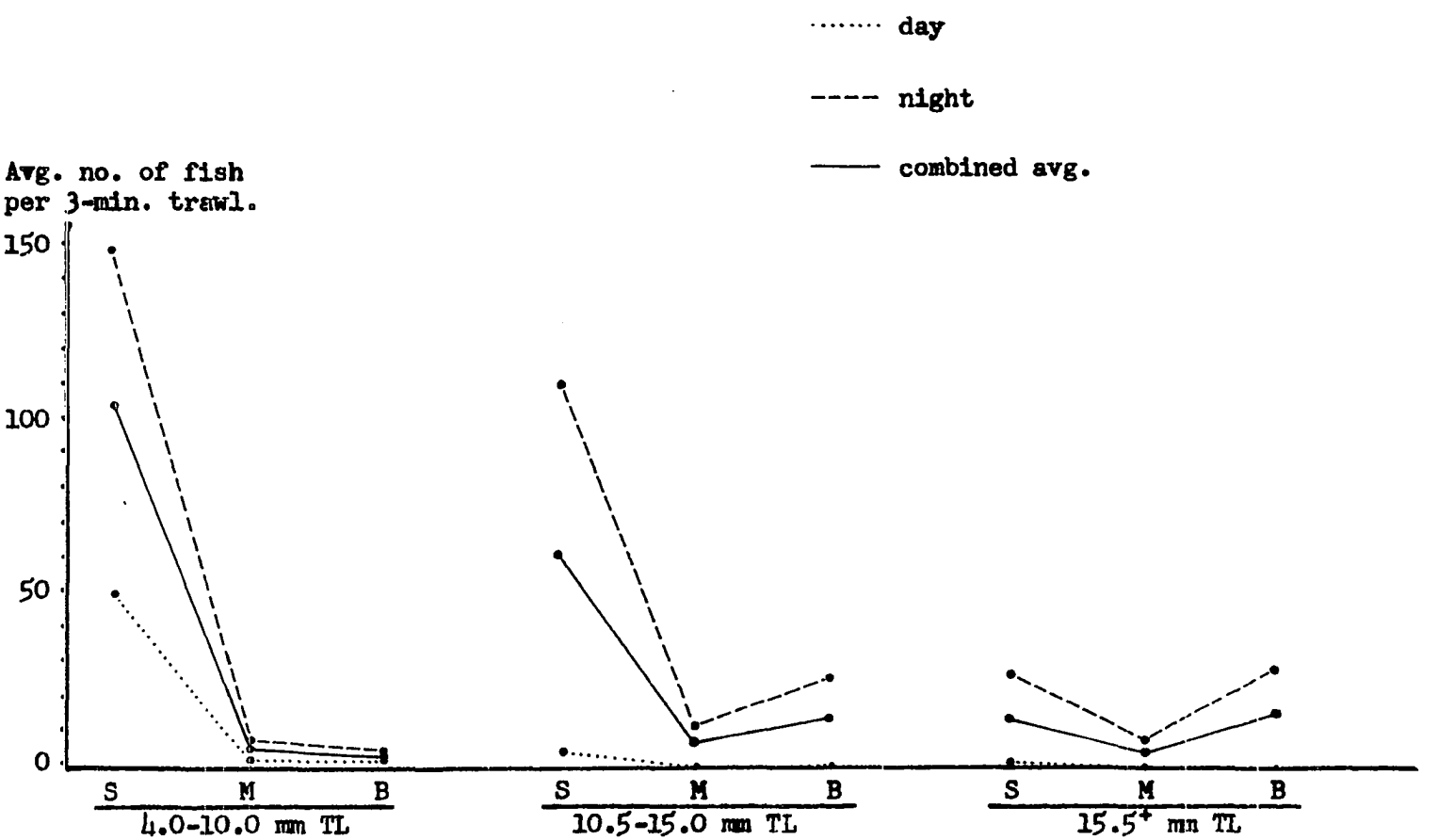


Figure 27. Vertical distribution of three size-groups of Menidia audens. Data from 427 collections made from April 18 to October 7, 1966, and including 172 surface, 83 midwater, and 172 bottom trawls.

in daytime but many spread to deeper water at night, especially the larger individuals which may go to the bottom in shallow water. Although the daytime distribution of the three size-groups appeared similar, a 3 by 3 contingency table using the total number collected at surface, midwater, and bottom, showed that there was significant difference between size-groups ($p < .0001$). The difference was primarily a reflection of the small number of group-1 larvae in bottom samples. The daytime distribution of groups 2 and 3 was not significantly different ($p > .50$) as shown by comparison in a 2 by 3 contingency table. At night the distribution of groups 2 and 3 was significantly different ($p < .0001$) with a higher percentage of the larger Menidia being near the bottom. The day and night vertical distributions of all size groups at night were significantly different from their daytime distributions ($p < .0003$).

The strong surface concentration of all sizes of Menidia is apparently affected greatly by light distribution, possibly reflected light from the bottom as well as direct sunlight. Large schools of Menidia larvae and juveniles have been observed swimming near the shoreline and around boats and buoys floating in the lake in the daytime and they concentrate around lights at night.

Roccus chrysops

White bass taken in 1966 trawling were divided into two size-groups for analysis of distribution. Group-1 larvae ranged from 4 to 10 mm and made up 56.7% of the total catch; all were past the prolarva stage and larger specimens had well-developed rays in the caudal fin.

Group 2 included larval, prejuvenile, and juvenile stages; the largest was 35 mm long.

Horizontal Distribution (Figure 28)

The distribution of the two size-groups based on tha total number collected at each location was found to be significantly different ($p < .0001$) using 2 by 6 contingency tables for surface and bottom collections. Midwater distribution was found to be not significantly different ($p = .12$). In shallower water the group-2 white bass were more closely associated with the bottom, in deeper water they were more abundant near the surface. Some white bass spawning apparently occurred in the small tributaries above S4 where the smaller larvae were most abundant. The larger larvae were relatively more numerous in open water.

The smallest white bass seined in 1965 was a 21-mm specimen taken on May 15; largest was a 131-mm juvenile taken on September 1. Smaller specimens probably would have been taken if night seining had begun earlier. Night collections amounted to only 19.8% of the seining effort but contained 80.5% of the young-of-year white bass. All but one of the young white bass taken in daytime were collected near sunset. There was no apparent preference for a particular type of shoreline area.

Vertical Distribution (Figure 29)

White bass larvae were fairly susceptible to trawl collection in both day and night with 31.6% of the total taken in day trawls. In daytime samples groups 1 and 2 were almost absent from surface collec-

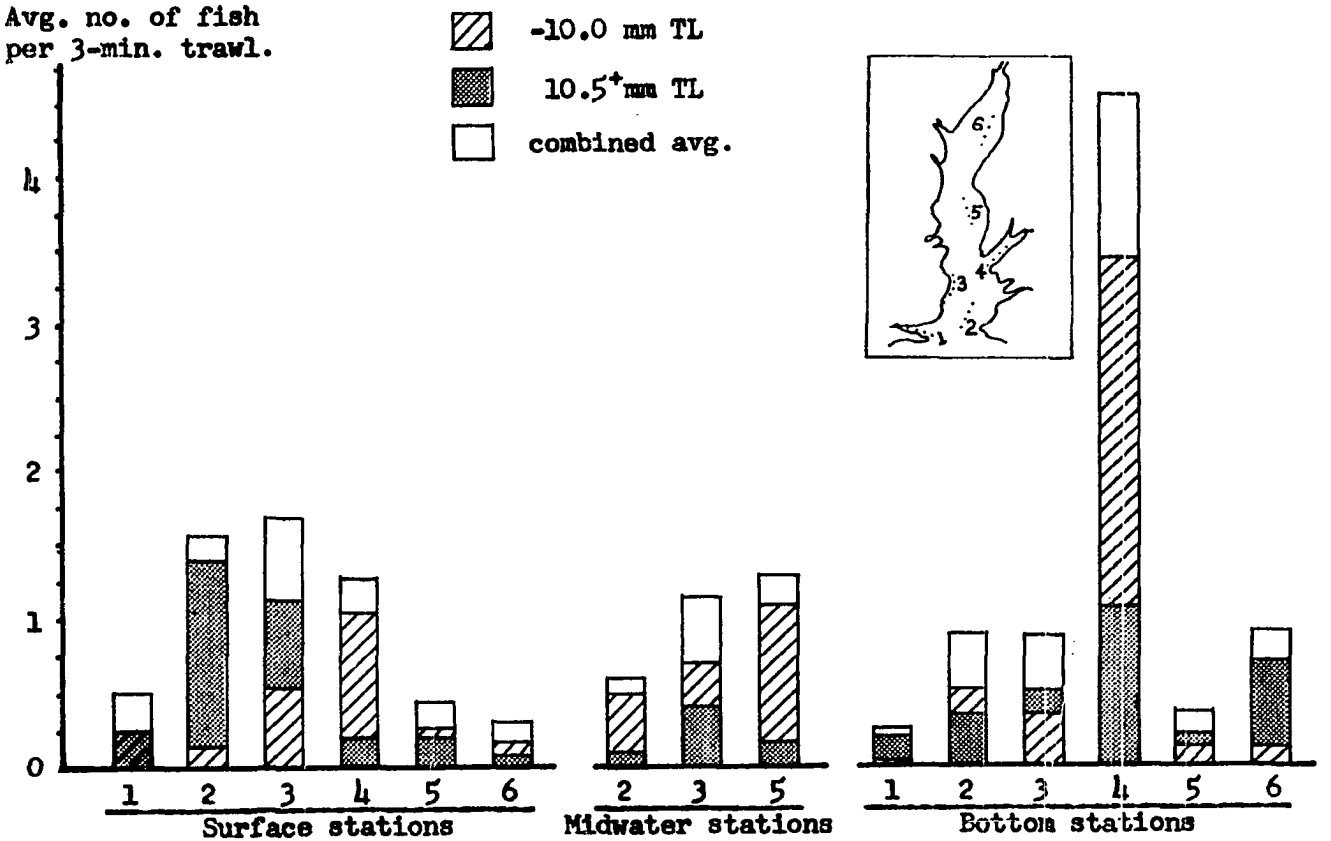


Figure 28. Horizontal distribution of two size-groups of Roccus chrysops taken at six trawling sites. Data from 282 trawls made from April 18 through June 19, 1966, in both day and night.

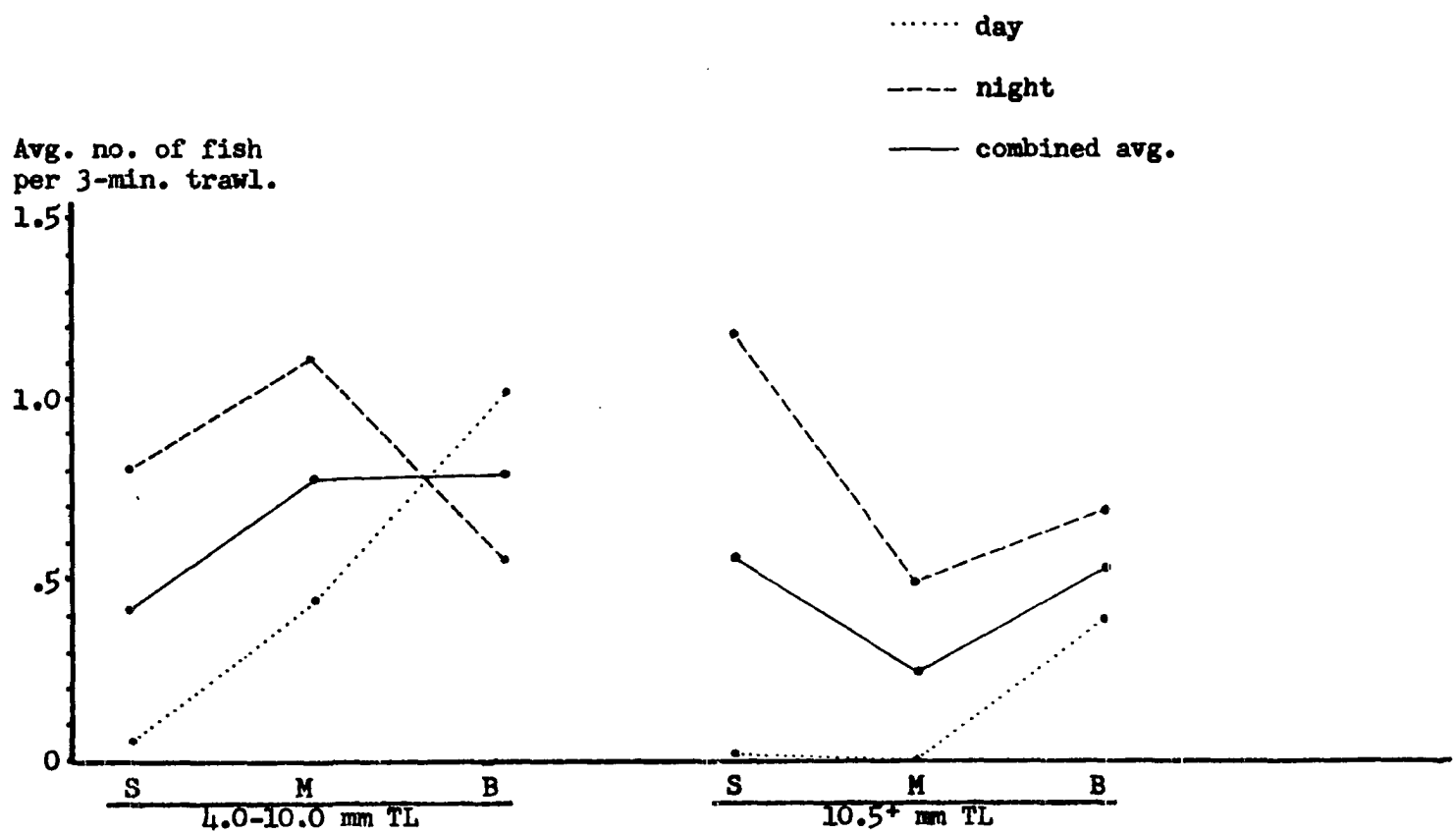


Figure 29. Vertical distribution of two size-groups of Roccus chrysops. Data from 282 collections made from April 18 to June 19, 1966, and including 114 surface, 54 midwater, and 114 bottom trawls.

tions (only .05 and .02 per haul, respectively). A 2 by 3 contingency table applied to the totals collected at surface, midwater, and bottom, indicated there was no significant difference ($p = .11$) in the daytime distribution of the two size-groups. At night group-1 larvae were most numerous at midwater (1.11 per haul). Group-2 larvae were essentially all taken near the bottom (96%) in daytime but were most numerous at the surface in night collections, showing a stronger upward migration than group 1. The use of a 2 by 3 contingency table confirmed that there was significant difference ($p < .005$) in distribution of the two size-groups at night.

It appears that R. chrysops larvae over 4 mm in length and juveniles stay away from the shore and surface in the daytime. With the lower light intensities of late afternoon and night they move into surface and shoreline water, apparently remaining there throughout the night. Bonn (1953) also found it was more difficult to collect young white bass by seining in daytime than at night.

Micropterus

The small number of larval Micropterus in my collections was in part a reflection of their long period of development in and around the nest (Fish, 1932) and the tendency of guarding males to keep the young in close groups. Only seven specimens 7 mm long and less were taken in trawl collections. The 21 Micropterus trawled in 1966 were collected in shallow water, with the majority (18) at night. The larger specimens were all in bottom samples while most of the smaller fish were in surface collections. There was apparently little dispersal

of larvae into open water.

No larval stages were present among the 395 prejuvenile and juvenile Micropterus seined in 1965; these ranged in length from 15 to 124 mm and identification as largemouth or spotted bass was possible. Both species were most abundant in the small cove at S6 where the water was always calm and usually clear. Dowell (1956) indicated that largemouth bass appeared to be attracted to certain coves in the Buncombe Creek arm and Ridenhour (1960) found that young M. salmoides concentrated in heavy vegetation when it was available. Seine collections were smallest at the wave-swept shores where turbidity was often high and no vegetation was present.

Lepomis macrodhirus

Bluegill from the 1966 trawl collections were divided into three size-groups for analysis of distribution. Group-1 larvae were those from hatching to 5.5 mm. Group 2 included larvae 6 to 12 mm, and group 3 was composed of fish 12.5 mm and longer. Groups 1, 2, and 3 made up 25.7, 62.9, and 11.4% of the catch, respectively. Daytime collections (120) contained 18.1% of the young bluegill; night collections (175) included 81.9%.

Horizontal Distribution

Small bluegill larvae (group 1) were more abundant in trawls at S3 and 4 (Fig. 30), indicating heavy spawning near these areas which had nearby rocky shorelines. Fair numbers of group-1 larvae in surface collections in open water show bluegill larvae to be active and widespread in the lake at an early age. Group-2 larvae were infrequent

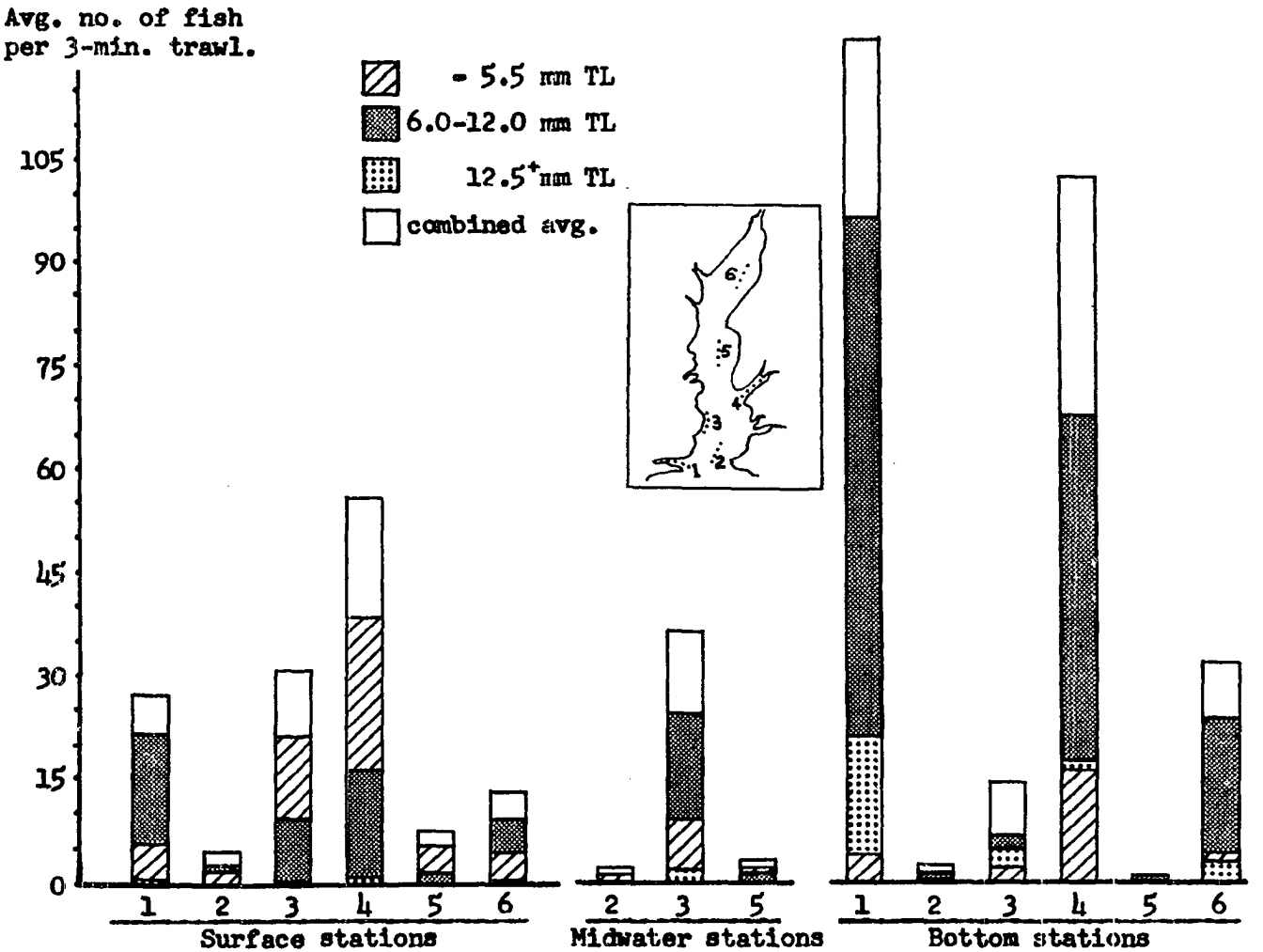


Figure 30. Horizontal distribution of three size-groups of Lepomis macrochirus taken at six trawling sites. Data from 295 trawls made from May 21 through October 7, 1966, in both day and night.

in samples from the deepwater stations and were more concentrated in the coves. Group-3 bluegill were essentially absent from open water areas and rarely caught in surface collections. Bottom distribution of these larger fish was similar to that of the group-2 bluegill with an even higher percentage of their number taken in the coves. There was obviously a strong shift in the distribution with increasing size from the widespread group 1 to the cove concentrated group 3. Werner (1967) found that bluegill migrated back to the littoral zone from the limnetic zone when they were 7-8 weeks old (21-25 mm long).

In 1965, 234 larval and young-of-year bluegill were taken by seining. These ranged in length from 5 to 48 mm and first appeared in June 14 collections. They were most common in calm silt-bottom areas. Bluegill appeared to be in loose aggregation near the shore with only 17 of the 234 taken as singles in the 207 seine collections.

Vertical Distribution (Figure 31)

In the daytime group-1 larvae were concentrated near the surface. At night they showed a more even distribution but were still more abundant at the surface than at midwater or bottom levels. Group-2 larvae were primarily on bottom in the daytime but more were near the surface than at midwater. Many were present, however, im midwater collections at S3 which was located near the shore. At night group 2 was again caught most readily in bottom trawls (over 49 per haul) but was also present in fair abundance at midwater and surface levels. Group-3 fish appeared to stay close to the bottom in both day and night. Young bluegill of all sizes that moved far from shore remained near the

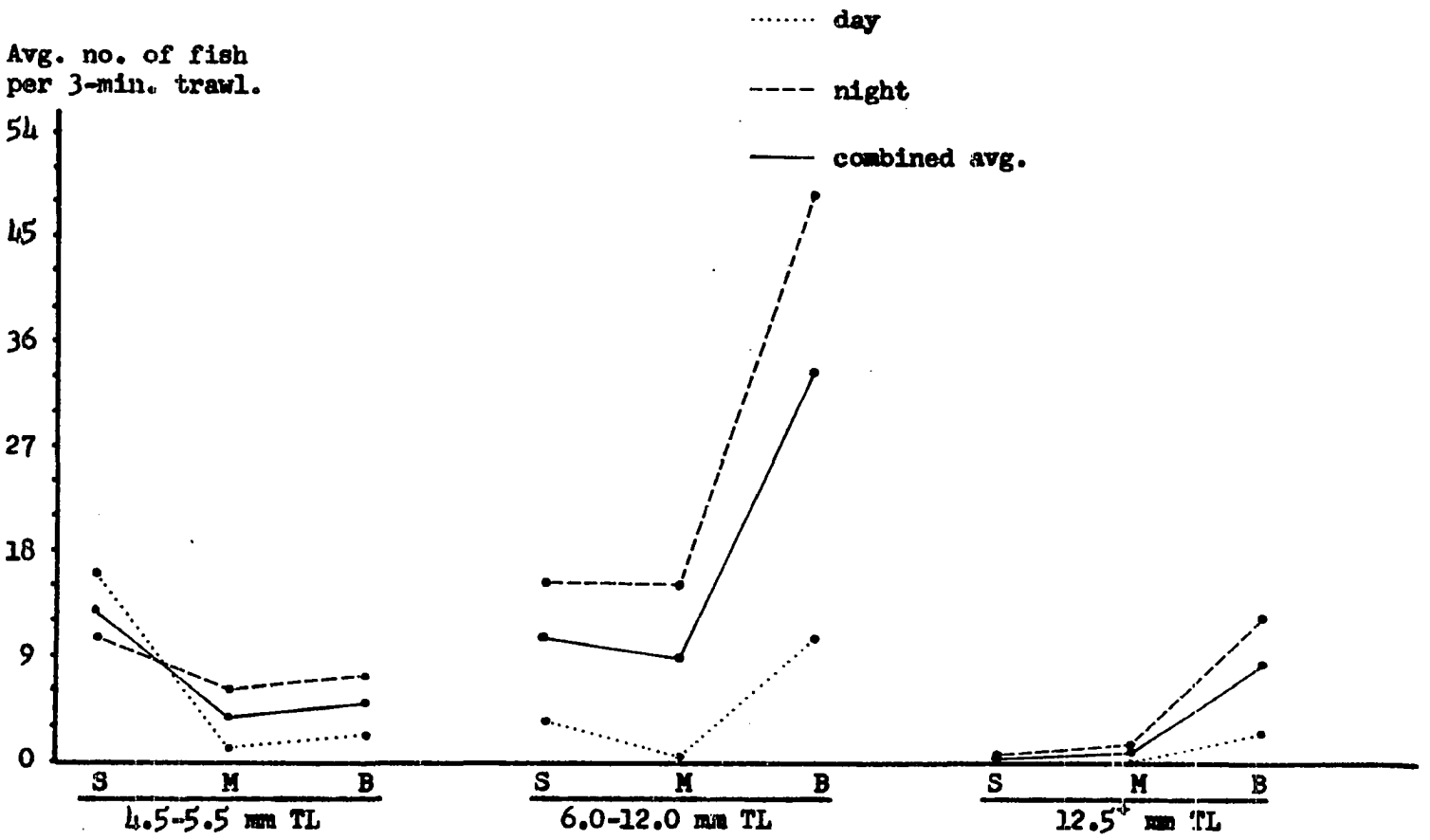


Figure 31. Vertical distribution of three size-groups of Lepomis macrochirus. Data from 295 collections made from May 21 through October 7, 1966, and including 118 surface, 59 midwater, and 118 bottom trawls.

surface but in shallow water they were much more abundant near the bottom, especially the fish over 6 mm in length.

Group-1 larvae exhibited a preference for well-lighted water and few were taken near the bottom in deep water. Of 267 group-1 bluegill captured in deep water (S2, 3, and 5) in the daytime, only one was in a bottom haul; in shallow water (S1, 4, and 6) 71 of 598 were in bottom hauls. At night in deep water 62 of 602 were in bottom hauls, while in shallow water 447 of 866 were taken near the bottom. The larger larvae and juveniles become strongly bottom oriented and showed a preference for well-lighted shallow water areas, especially in the coves.

Lepomis megalotis

The longear sunfish from 1966 trawl collections were divided into three size-groups for analysis of distribution. Group 1 included larvae up to 6 mm, total-length. Group-2 larvae were 6.5 to 10 mm long and most had fin-rays in all median fins. Group-3 fish were 10.5 mm and longer and most were in the juvenile stage of development with fin-rays in all fins.

Horizontal Distribution (Figure 32)

Data on the distribution of the three size-groups of L. megalotis indicate they were almost absent in areas far from shore (S2 and 5). Stations having nearby rocky shorelines were sites of greatest abundance. Similar peaks of abundance were shown by all size-groups, however, the smaller group-1 larvae were more widespread; this was the only size-group taken in bottom trawls in deep, open water.

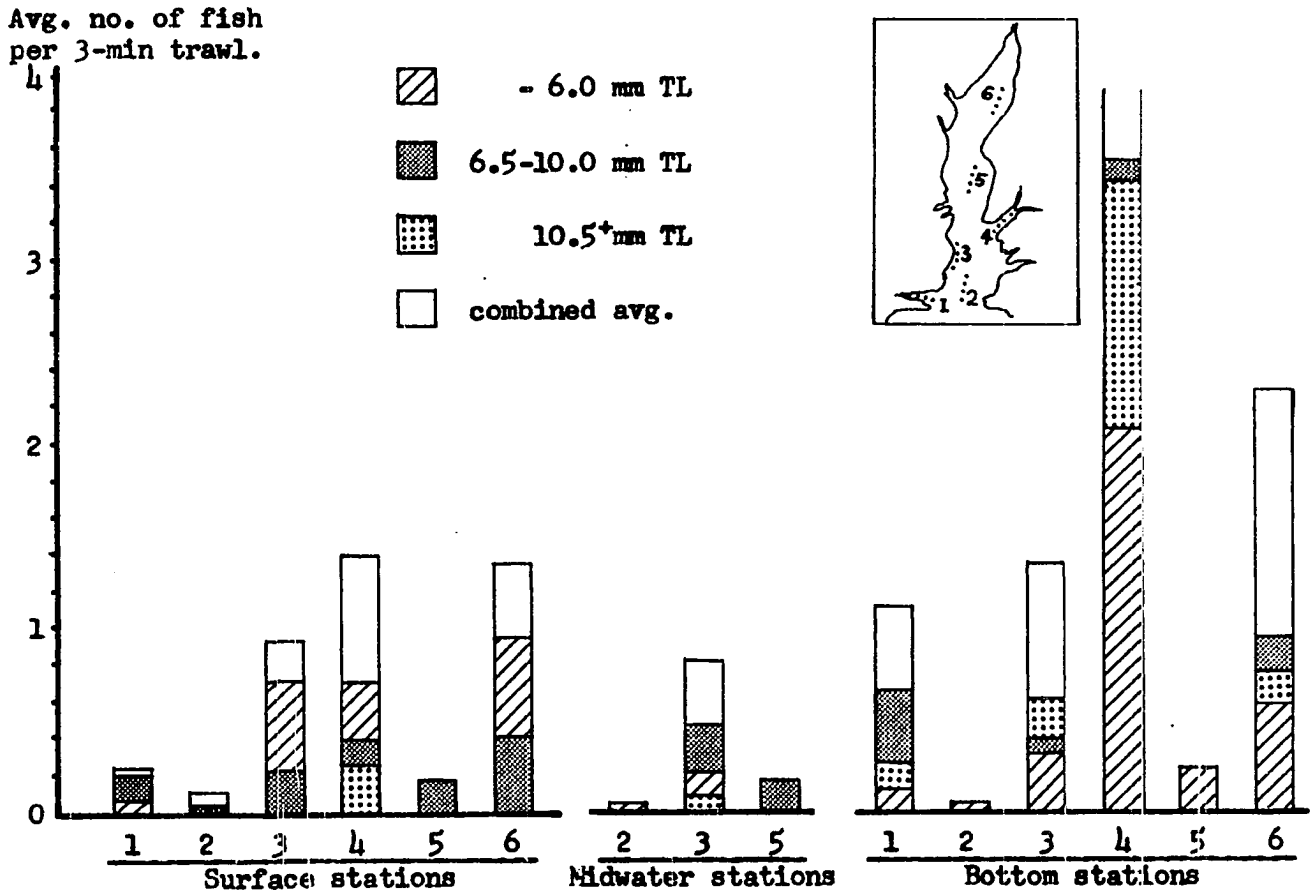


Figure 32. Horizontal distribution of three size-groups of Lepomis megalotis taken at six trawling sites. Data from 265 trawls made from May 27 through October 7, 1966, during both day and night.

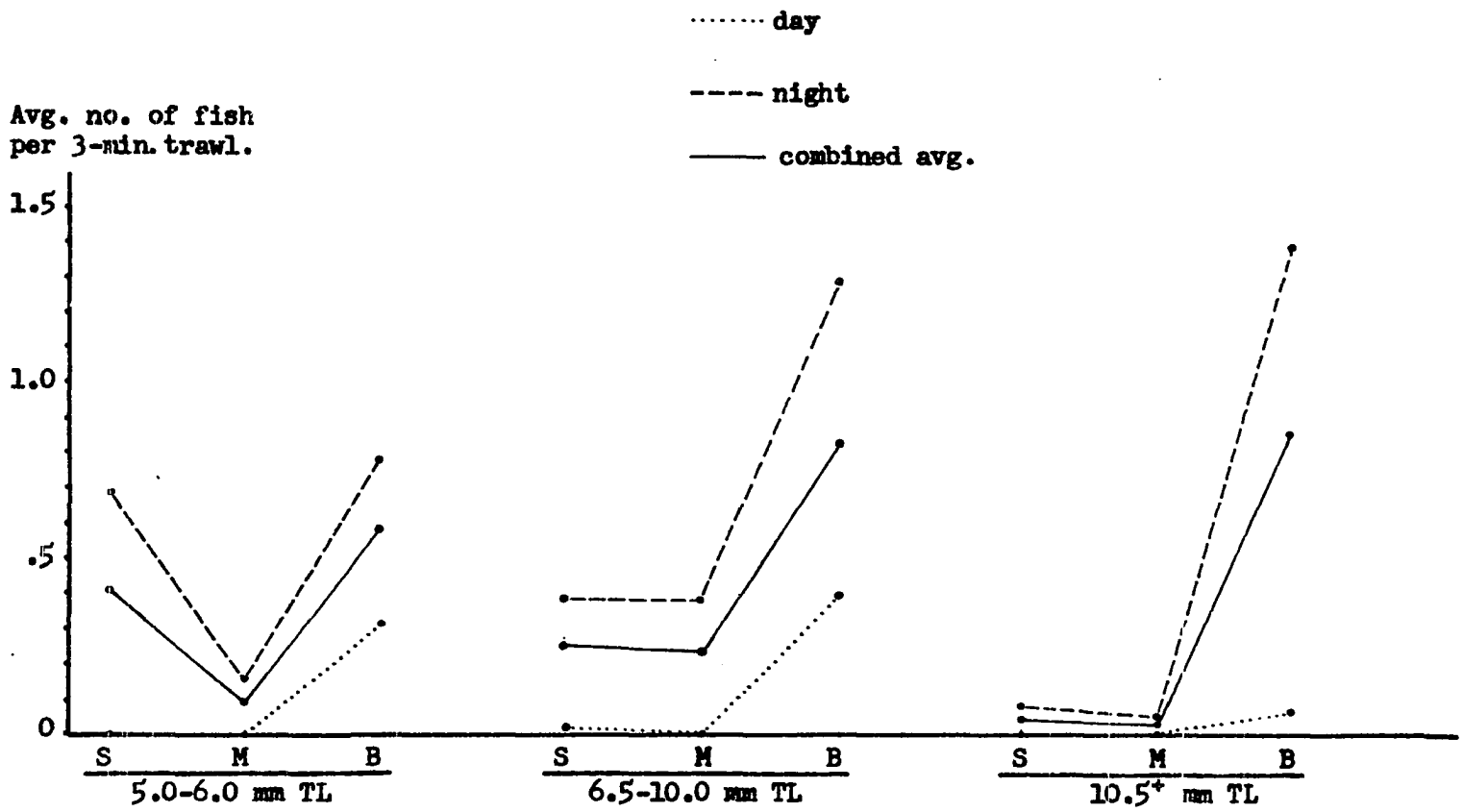


Figure 33. Vertical distribution of three size-groups of Lepomis megalotis. Data from 265 collections made from May 27 through October 7, 1966, and including 106 surface, 53 midwater, and 106 bottom trawls.

Longear sunfish seined in 1965 ranged in length from 10 to 73 mm. They rarely were taken near wave-swept shorelines but otherwise were widely distributed.

Vertical Distribution (Figure 33)

All except one of the young longear sunfish captured in the daytime were taken in bottom collections. At night, group 1 (mostly late prolarvae) was only slightly more abundant in bottom collections (.78 per haul) than in surface collections (.69 per haul). Group-2 larvae were by far most abundant in the night bottom collections. Group-3 fish, mostly juveniles, showed an even stronger affinity for the bottom than the other size-groups. Midwater collections were small for all size-groups and most fish were taken at S3 near the shoreline. Based on the totals collected at surface, midwater, and bottom and using a 3 by 3 contingency table the distributions of the three size-groups were found to be significantly different ($p < .0001$). Young longear sunfish are apparently restricted to shallow water areas near bottom in daytime but some of the smaller larvae swim upward and disperse at night.

Pomoxis annularis

For distribution analysis Pomoxis larvae and juveniles were divided into three size-groups. Group 1 included larvae from hatching to 4.5 mm. Group-2 larvae were 5 to 10 mm long and group 3 was composed of fish 10.5 mm and longer. Group 1 contained 189 larvae (24%), group 2, 533 (67.9%), and group 3, 64 larvae and juveniles (8.1%).

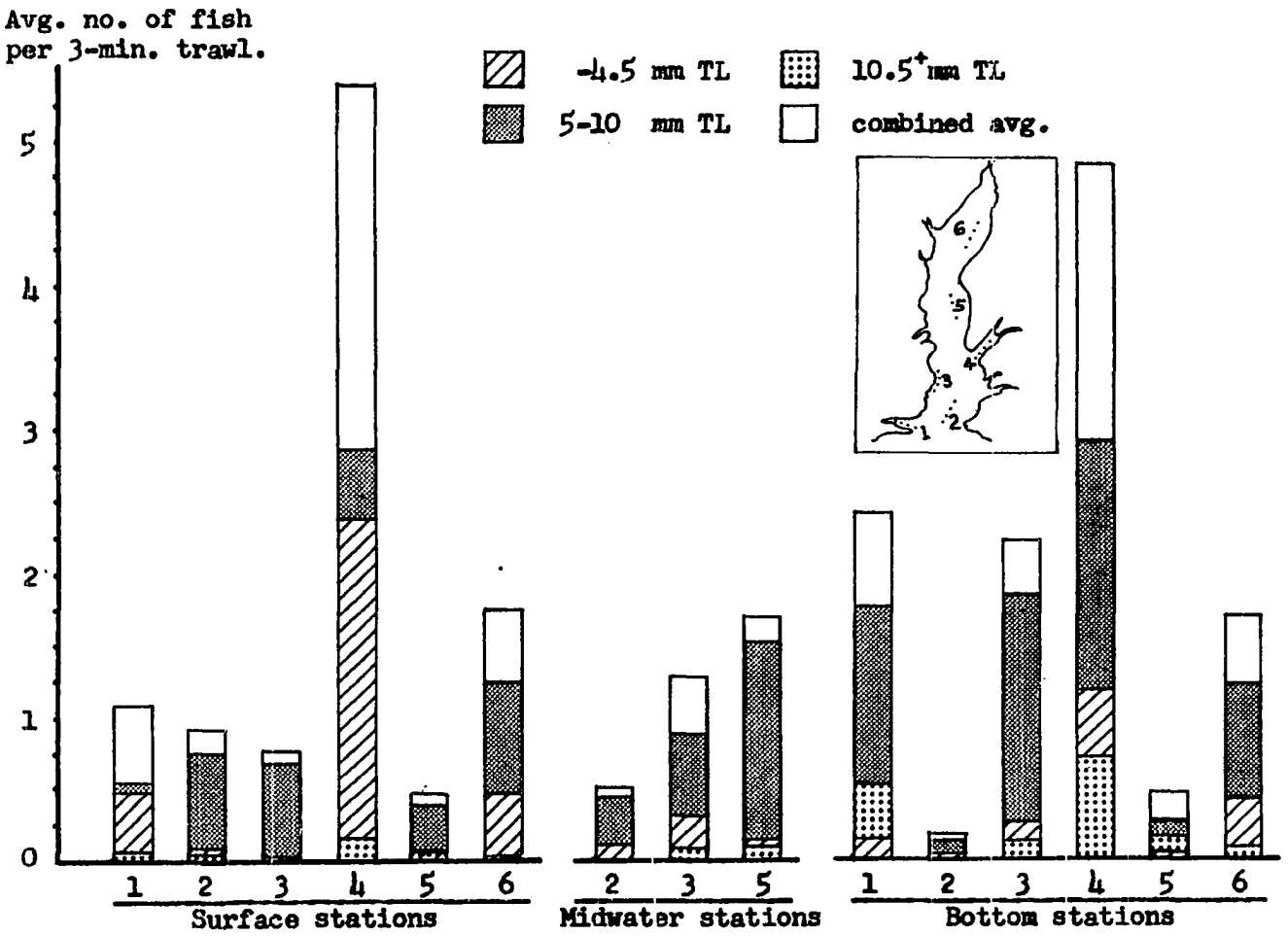


Figure 34. Horizontal distribution of three size-groups of Pomoxis annularis taken at six trawling sites. Data from 456 collections made from March 27 through August 21, 1966, during both day and night.

Horizontal Distribution (Figure 34)

The differences in the numbers of fish of the three size-groups collected in surface trawls at the six stations were tested using a 3 by 6 contingency table. This indicated there was significant difference in distribution between the size-groups ($p < .0003$). A similar test applied to bottom collection totals also indicated significant difference ($p < .0003$) in the distributions near the bottom. Group-1 larvae were more abundant at the shallow water stations (S1, 4, and 6) which were apparently closer to spawning areas. Group-2 larvae were more widespread in the lake, being fairly abundant in surface and mid-water collections. Group-3 fish appeared to prefer the cove areas. Very few larvae were collected near the bottom in deep water far from shore and it appears that those which migrated into open water stayed at higher levels. Larvae were more abundant in April in the upper part of Buncombe Creek arm, then later (May 27 through June 19) became more abundant in the trawls at S1, 2, and 3. This may have been due to early spawning occurring in the shallower water of the upper end of the arm where water warmed more rapidly.

Vertical Distribution (Figure 35)

The differences in the numbers of fish in each size-group taken at the three collection levels were tested using 3 by 3 contingency tables. These indicated significant difference in the vertical distribution of size-groups in both day ($p < .001$) and night ($p < .0001$). The use of 2 by 3 contingency tables applied to totals collected at each level indicated significant difference in day versus night dis-

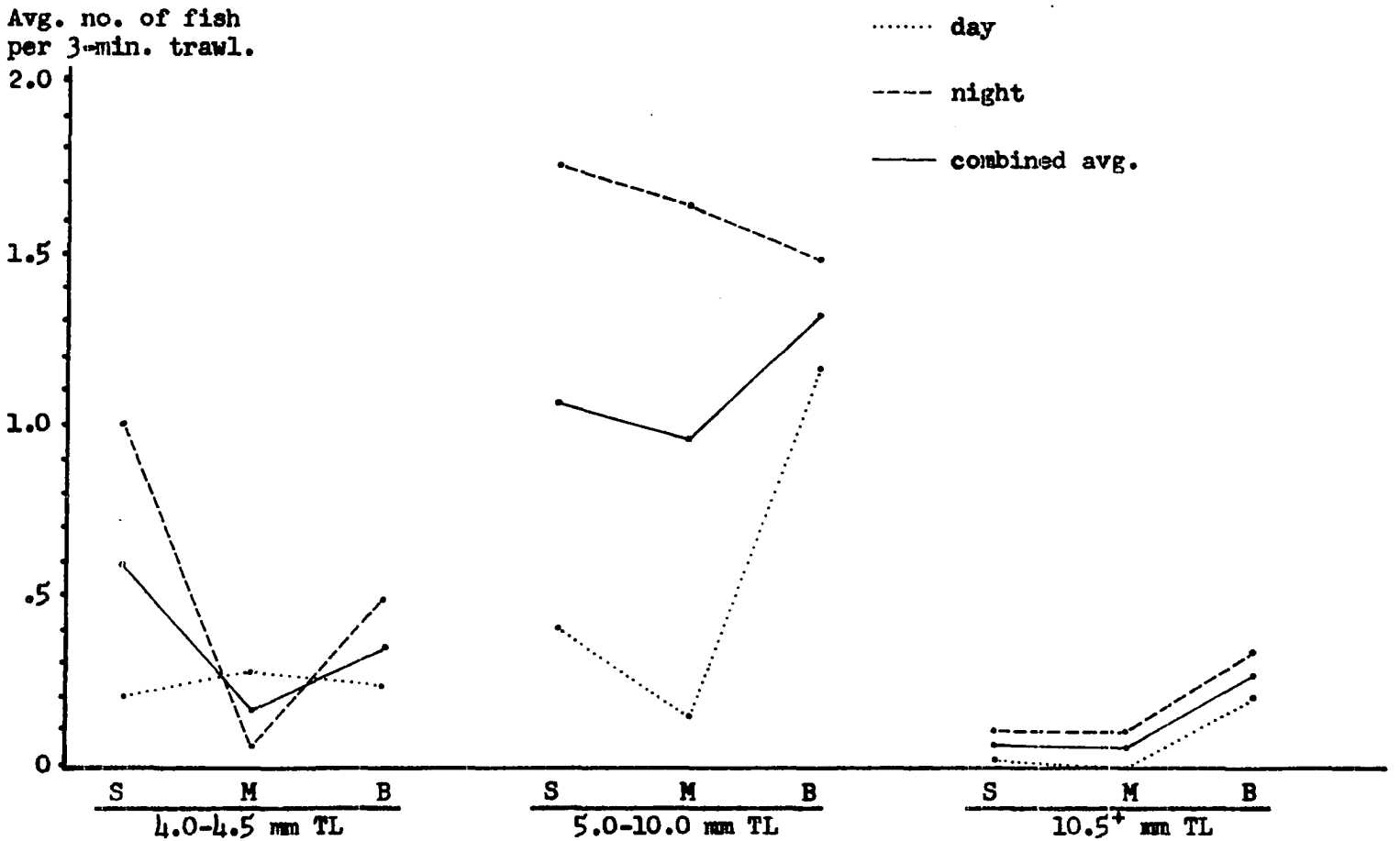


Figure 35. Vertical distribution of three size-groups of Pomoxis annularis. Data from 456 collections made from March 27 through August 21, 1966, and including 192 surface, 78 mid-water, and 186 bottom trawls.

tribution of size-groups 1 ($p < .0001$) and 2 ($p < .0001$) but not for group 3 ($.08 > p > .05$). The very small group-1 fish appeared to be fairly evenly distributed vertically in daytime when 28.6% of this group was captured. They showed a much higher concentration near the surface at night. Group-2 larvae were more abundant in bottom hauls in daytime and almost absent from midwater trawls. At night this size was caught almost equally well at all three levels. Group-3 Pomoxis were caught primarily in bottom trawls and were slightly more abundant there in night collections.

Pomoxis annularis larvae appear to avoid strong illumination in daytime but move upward at night. Grinstead (1965) found that light penetration was a factor in vertical distribution of white crappie with the adults nearer the surface in more turbid water. I took the largest average number of larvae under 10 mm at the surface at night. As the fish became larger they were more abundant near the bottom but did not show the very strong affinity for the bottom in shallow water which was characteristic of Lepomis of a similar size.

Percina caprodes

Logperch taken in 1966 trawl collections were divided into three size-groups for analysis of distribution. Group 1 was essentially all prolarvae that ranged from hatching (about 4.5 mm) to 6 mm in length. Group 2 was composed of larvae ranging in size from 6.5 to 15 mm. Group-3 fish were 15.5 mm and longer and included large larvae, prejuveniles, and juveniles.

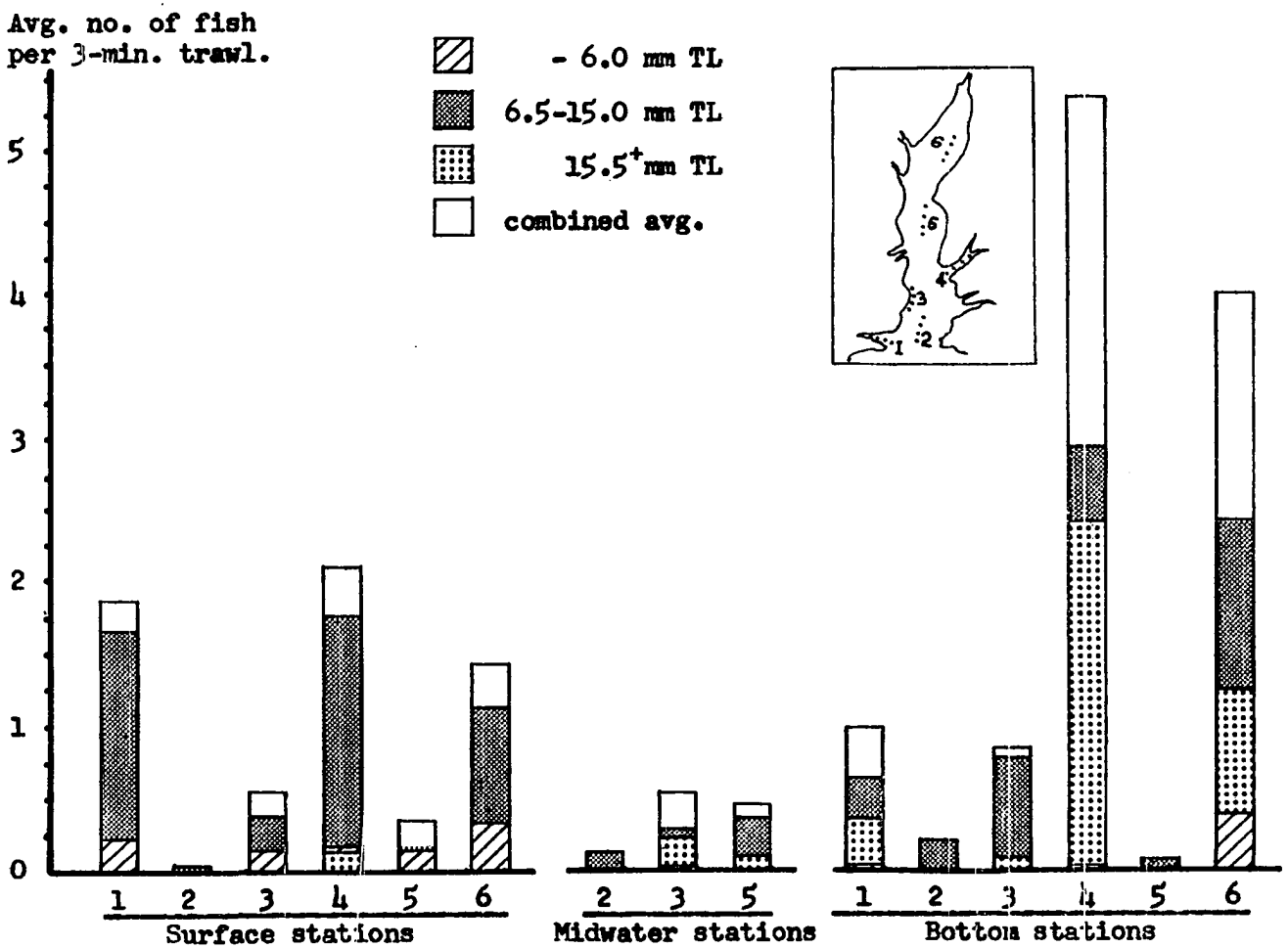


Figure 36. Horizontal distribution of three size-groups of Percina caprodes taken at six trawling sites. Data from 441 trawls made from March 27 through August 7, 1966, during day and night.

Horizontal Distribution

Logperch were almost absent from open water and were most abundant in shallow water areas (Fig. 36). There was a general tendency for greater abundance toward the upper end of the Buncombe Creek arm. A 2 by 6 contingency table using total numbers of group-1 and group-2 larvae collected at the surface in the six locations indicated significant difference in distribution ($p < .03$). Group 1 was apparently more restricted to shallow areas than the larger group-2 fish. Group 3 was rarely taken in surface collections. Group 1 was seldom taken near the bottom but appeared to be fairly widespread in surface water. A 2 by 6 contingency table indicated significant difference ($p < .005$) in numbers of groups 2 and 3 at the bottom in the six localities trawled. The larger fish appeared to be more restricted to the shallow water areas. Group-2 larvae were more abundant in open water than group 1 or group 3, indicating a wider dispersal in the intermediate size, then a strong movement of larger larvae and juveniles to more protected shallow water.

Vertical Distribution (Figure 37)

The daytime collections contained 34.6% of the 569 logperch captured in 1966. In daytime group-1 larvae (8.3% of total) were more abundant near the bottom; at night nearly all were taken in surface collections. A 2 by 3 contingency table comparing the totals collected at the three levels indicated there was significant difference in the day and night distribution of the group-1 fish ($p < .001$). Group-2 larvae (68.2% of total) exhibited similar distributions but

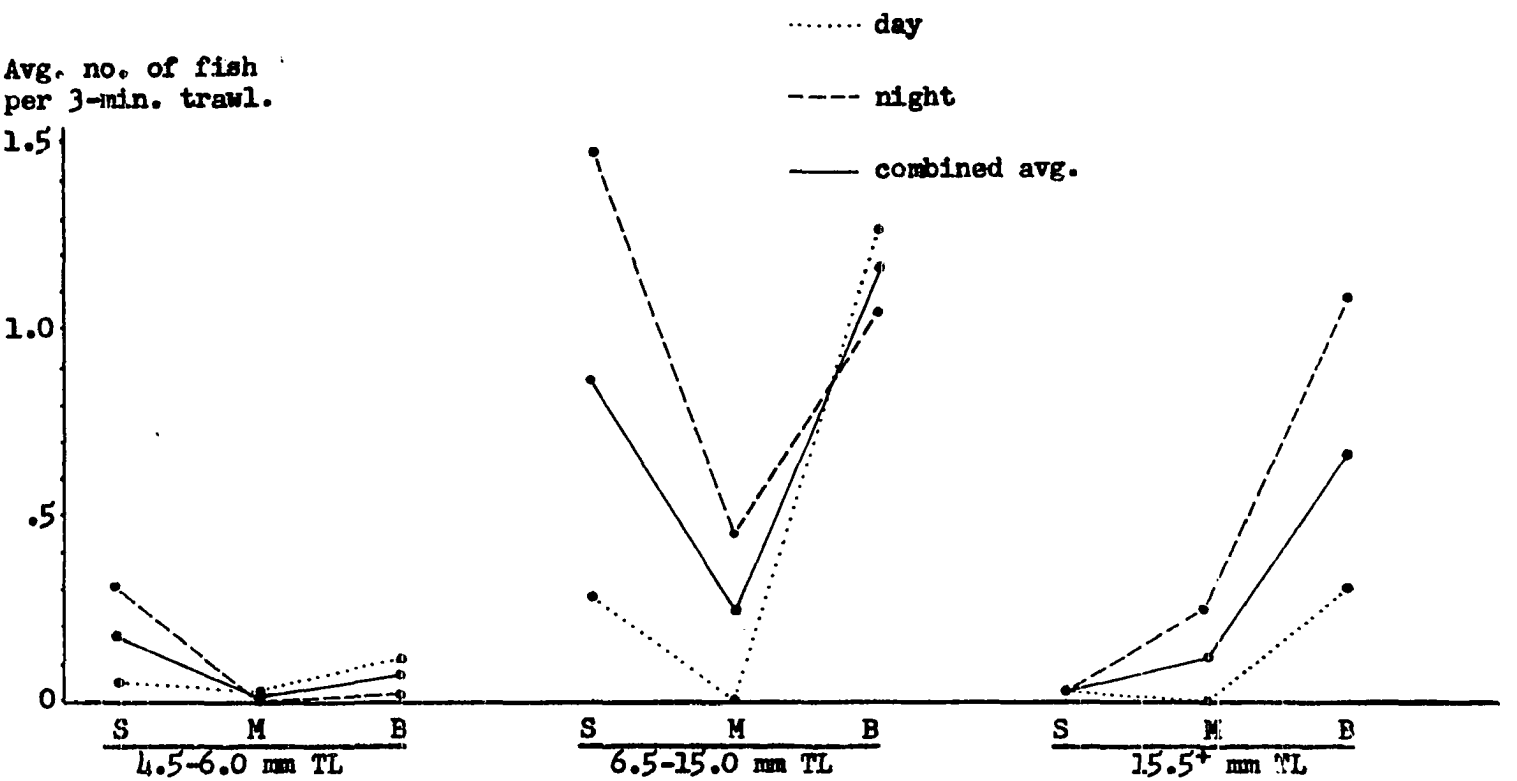


Figure 37. Vertical distribution of three size-groups of Percina caprodes. Data from 441 collections made from March 27 through August 7, 1966, and including 186 surface, 75 mid-water, and 180 bottom trawls.

were absent from midwater collections in daytime and a considerable percentage of the total was taken near the bottom at night. This size-group also showed significant difference in the numbers collected at the three levels in day and night collections. Group 3 (23.5% of total) was low in abundance at the surface both in daytime and at night and was mostly taken near the bottom. There was no significant difference in the day and night distribution of this group ($.15 > p > .10$).

It appears that the early larvae have a strong tendency to move toward the surface. This was moderated by light intensity. The larger larvae and juveniles failed to make the migration toward the surface at night, and were more restricted to the proximity of the bottom.

Aplodinotus grunniens

The distribution of 575 eggs collected in the trawl in 1966 (Fig. 38) indicates that most spawning occurred in the most open water and was lowest in the shallow water and coves. Wirth (1958) indicated drum spawning could be observed near or at the surface on calm days in water far from shore in Lake Winnebago, Wisconsin. Most of the eggs in Lake Texoma floated near the surface but a fair percentage occurred at midwater and bottom levels. A 2 by 3 contingency table indicated there was significant difference in the vertical distribution of the eggs in the daytime and at night ($p < .01$). A higher percentage of the eggs was found near the bottom in daytime; the eggs apparently lose buoyancy or are driven downward by waves. Eggs from all three levels of collection were usually in similar stages of development and all floated in the preservative (5% formalin).

The 227 freshwater drum larvae captured in 1966 trawling were divided into three size-groups for analysis of distribution. Group 1 was composed of small weak larvae ranging in length from about 3 mm to 5 mm. Group 2 included active feeding larvae 5.5 mm to 10 mm long and group 3 included all drum 10.5 mm and longer. Group 1 was least abundant in the collections (20.7%); group 3 was most abundant (51.1%). Day collections contained 20.3% of the total (227), mostly taken in bottom samples; however, 51.1% of group 1 was captured in daytime. Only three of the 116 group-3 drum were captured in daytime.

Horizontal Distribution (Figure 38)

Surface trawls took only small numbers of drum at all stations and there were not enough taken in the collections to show significant differences in the three size-groups. A 3 by 6 contingency table was applied to the numbers of fish of the three size-groups collected at the six bottom collecting sites. The results indicated a significant difference ($p < .0001$) in distribution near the bottom. The larger fish (group 3) were most abundant in collections near shore, especially at S3. Possibly larger young drum prefer relatively deep water near a shoreline. In more turbid areas of Lake Texoma juvenile drum are often abundant in shallow water near shore at night, but none were collected by seining in the relatively clear water of the Buncombe Creek arm.

Vertical Distribution (Figure 39)

There appears to have been little difference in the daytime vertical distribution of the three size-groups which were all predominant in bottom collections. Numbers in night collections were significantly

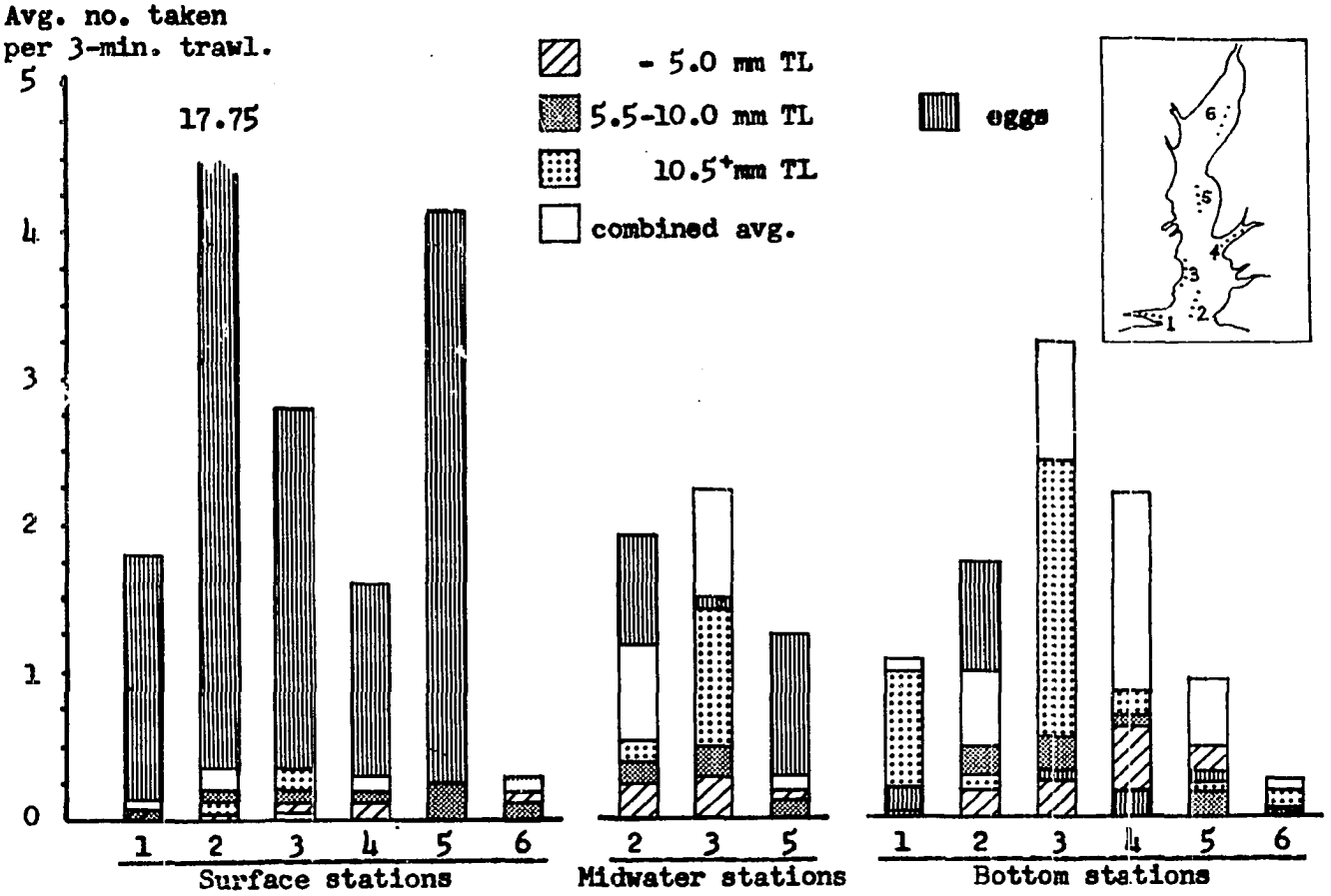


Figure 38. Horizontal distribution of the eggs and three size-groups of the young of Aplodinotus grunniens taken at six trawling stations. Data from 240 trawls made from April 30 through June 19, 1966, for eggs, and May 13 through July 10, 1966, for larvae. Data for day and night collections are combined.

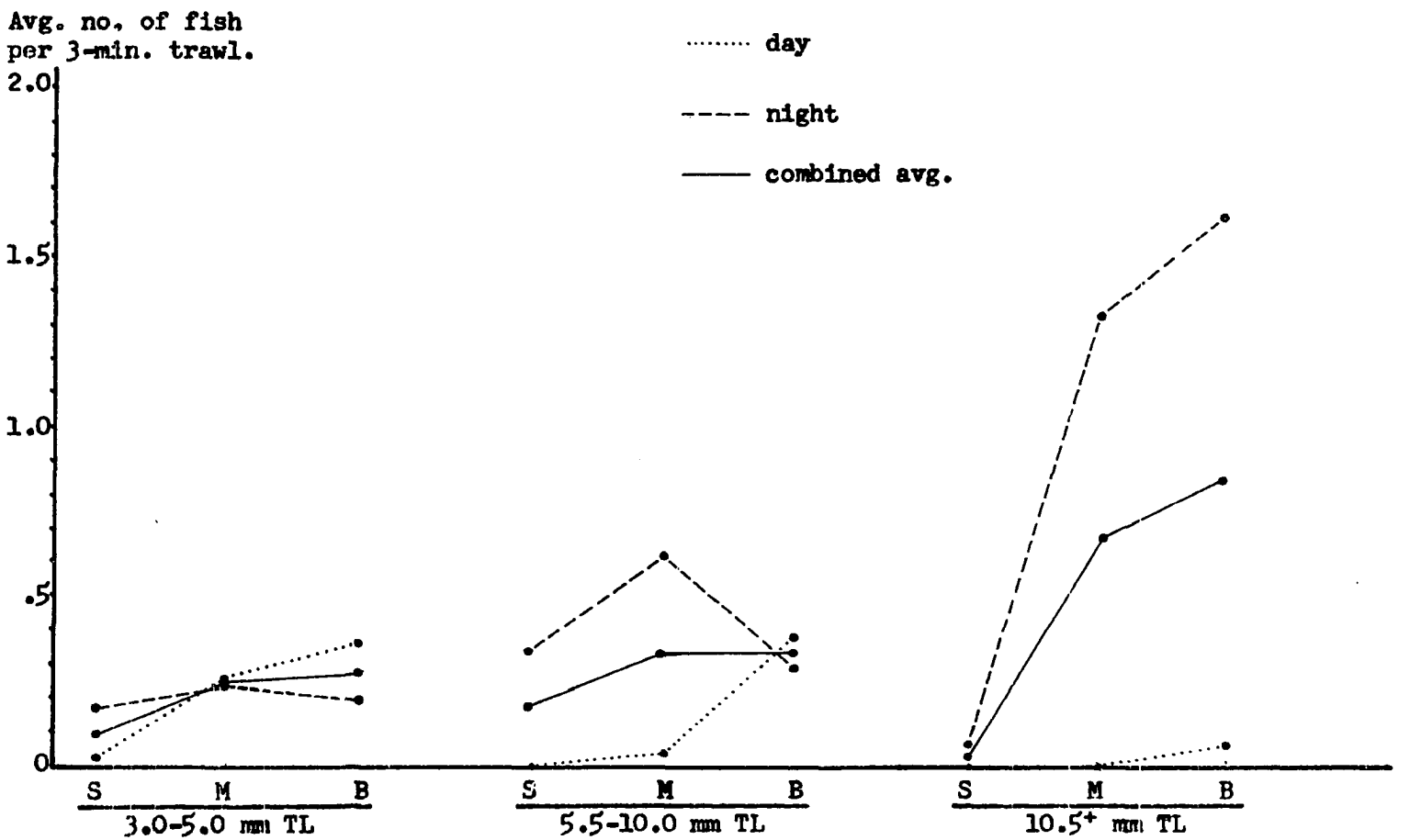


Figure 39. Vertical distribution of three size-groups of Aplodinotus grunniens in 1966. Data from 240 trawls made from May 13 through July 10 and including 96 surface, 48 mid-water, and 96 bottom collections.

different however, as was shown when a 3 by 3 contingency table was applied to the totals for the three size-groups collected at the three collection levels. ($p < .0001$). Group-3 fish were mostly taken near the bottom at night but many were present at midwater. Groups 1 and 2 were both most numerous in midwater samples at night. A 2 by 3 contingency table applied to test the difference in these two size-groups indicated they were not significantly different in night distribution ($.80 > p > .70$).

Freshwater drum larvae and juveniles appear to be strongly influenced by light, staying in darker water most of the time. Even in bottom samples they were more abundant at deepwater trawl stations. There was a decrease in nocturnal upward migration as the fish increased in size.

CHAPTER VI

SUMMARY

1. The diel horizontal and vertical distributions of larval and early juvenile fishes in the Buncombe Creek arm of Lake Texoma were studied from collections made in 1965 and 1966. Larval and young-of-year fish populations were sampled with a modified 1/32-inch-mesh meter net (trawl) and seines of various sizes. Spawning time and relative abundance of larvae were established for several species.

2. Drawings of the developmental stages of 14 species (threadfin shad, carp, silver chub, red shiner, blacktail shiner, bullhead minnow, Mississippi silverside, white bass, largemouth bass, bluegill, longear sunfish, white crappie, logperch, and freshwater drum) were made to illustrate identification features.

3. Larvae and/or young-of-year of at least 28 species of fishes from 11 families were collected during this study. Ten species were abundant enough in collections to be divided into two to four size-groups for analysis of distribution.

4. The gars, Lepisosteus, were not abundant in my collections. The large heavily pigmented larvae of gars were very easy to distinguish from all species in the collections. Spotted gar spawning was observed as early as April 9, and the spawning of all gar was appar-

ently over by late May. Postlarvae and juveniles appear to spend most of the time at the surface in protected areas very near the shoreline. Smaller individuals may congregate around objects in the water. Larger juveniles are less gregarious and stay further from shore.

5. The family Clupeidae is represented in Lake Texoma by two abundant species, Dorosoma cepedianum and D. petenense. The threadfin shad was by far the most abundant species in the collections. The gizzard shad was probably the third most abundant species in the collections, Menidia audens also being more abundant. The larvae of the two shads are very similar and I was unable to distinguish them until a total-length of 18-20 mm was attained. Dorosoma larvae were easy to distinguish from others by their long slender body form. Gizzard shad spawned from late March to late May. Threadfin shad began spawning in mid-April and spawned throughout the summer. Larvae and juveniles of both species of shad apparently school together and the schooling instinct was stronger in the daytime. The shads were more abundant in the upper end of Buncombe Creek arm and exhibited preference for surface waters in daytime. Vertical distribution was more random at night. Dorosoma appear to prefer shallow water but avoid the area close to the shoreline.

6. I collected larvae or young-of-year of nine cyprinids. Of these Pimephales vigilax was by far most abundant. Second most abundant was Cyprinus carpio. All members of this family were similar as larvae in having moderately large yolk sacs at hatching and a moderately long gut. Relative size and pigmentation were important characters in distinguishing species. Carp began spawning in late March

but other cyprinids did not spawn until mid-May. Carp spawning was completed by mid-June; Pimephales, N. lutrensis and N. venustus continued to spawn through September. The early stages of all species appeared to stay near the bottom and close to shore in daytime. At night many spread to deeper water areas but remained near the surface, especially the prolarvae.

7. No larval stages, only prejuvenile or juvenile catfishes were collected including two Pylodictis olivaris (16-18.5 mm) and 70 channel catfish (13.5-26 mm). Most active spawning apparently occurred from late May through early June but channel catfish spawning also occurred in August. Numbers of smaller channel catfish (14-16 mm) in collections indicated that they were schooling near the surface at night. Specimens longer than 16 mm were most often taken individually on the bottom at night.

8. Menidia audens was by far the most abundant species in water near the shoreline. The larvae have distinctive morphology and pigmentation and are easy to distinguish from other species. The spawning period for Menidia extended from early April to mid-September. This species was generally more abundant toward the mouth of Buncombe Creek arm. There was a strong shoreline preference in shallow clear water near the open lake. All sizes of Menidia exhibited a strong preference for surface water in both day and night. At night there was some downward migration by larger larvae and juveniles.

9. Roccus chrysops larvae and young-of-year were tenth most abundant in collections. The larvae are easily recognized by the presence of large myomeres and a thick muscular gut. Larvae appar-

ently stay away from the surface and the shoreline in the daytime but move into these areas at night. Larger larvae were more widespread in open water and the upward night migration was stronger in young white bass over 10 mm long. Spawning in Buncombe Creek arm was from late March to early May.

10. Larvae and young-of-year of seven centrarchids (four genera) were collected. Lepomis macrochirus, was the most abundant, followed in order of abundance by Pomoxis annularis, L. megalotis, Micropterus salmoides, M. punctulatus, Chaenobryttus gulosus, and L. microlophus. Pomoxis was the first to spawn, beginning in March and continuing into June. Micropterus spawned from early April to mid-June with some spawning by M. salmoides in late August. Lepomis macrochirus spawning began in early May and continued to late September. L. megalotis spawned from mid-May to mid-August. The distribution of all members of this family was generally similar in that the younger larvae were more widespread in the lake and more abundant near the surface. The larger young of all species exhibited a preference for shallow water near the bottom. Pomoxis and L. macrochirus were most widespread in the lake. In deeper water the tendency was to be nearer the surface, while in shallow water most were near the bottom. Pomoxis was the only centrarchid with larvae which appeared to avoid close proximity to the shoreline.

11. Percina caprodes was apparently the first species to spawn in the Buncombe Creek arm; the spawning extended from early March to late May. The larvae were generally similar to white bass larvae but were larger and longer at similar stages of development. Smaller

larvae were evenly distributed vertically in the daytime but were much more abundant near the surface at night. Larger individuals were taken almost exclusively near the bottom and apparently they moved closer to shore as they increased in size. Percina were abundant only in shallow water.

12. Aplodinotus grunniens egg distribution indicated that most spawning by this species occurred in the open water of Buncombe Creek arm far from shore. Most of the eggs floated near the surface but many were also taken at midwater and bottom. Eggs were first collected on April 30, and last collected on June 19. The postlarvae are characterized by a very large head and mouth and a short slender trunk. All larvae were more abundant at midwater and bottom levels with the larger larvae more concentrated near the bottom. The larvae and juveniles apparently avoided the well-lighted water near the shoreline.

LITERATURE CITED

Aggassiz, Alexander. 1878. The development of Lepidosteus. Proc. Amer. Acad. Arts and Sci., 14:65-76.

American Fisheries Society. 1960. A list of common and scientific names of fishes from the United States and Canada. Second Edition. Report of the committee on names of fishes, presented at the 89th annual meeting. Amer. Fish. Soc., Special Pub. No. 2: 102 pp.

Balfour, Francis M., and W. N. Parker. 1881. On the structure and development of Lepidosteus. Proc. Roy. Soc. London, 33(217): 112-119.

Balinsky, B. I. 1948. On the development of specific characters in cyprinid fishes. Proc. Zool. Soc. London, 118(2):335-344.

Battle, Helen I., and William M. Sprules. 1960. A description of the semibuoyant eggs and early developmental stages of the goldeye, Hiodon alosoides (Rafinesque). J. Fish. Res. Bd. Canada, 17(2): 245-266.

Bodola, Anthony. 1966. Life history of the gizzard shad, Dorosoma cepedianum (Le Sueur), in Western Lake Erie. U. S. Fish and Wildl. Serv., Fish Bull., 65(2):391:425.

Bonn, Edward W. 1953. The food and growth rate of young white bass (Morone chrysops) in Lake Texoma. Trans. Amer. Fish. Soc., (1952)82:213-221.

Borges, H. Milton. 1950. Fish distribution studies, Niangua arm of the Lake of the Ozarks, Missouri. J. Wild. Mgt., 14(1):16-33.

Breder, C. M. Jr. 1936. The reproductive habits of the North American sunfishes (family Centrarchidae). Zoologica, 21(1):1-48.

Breder, C. M. Jr. 1960. Design for a fry trap. Zoologica, 45:155-159.

Breder, C. M. Jr. 1962. On the significance of transparency in osteichthyid fish eggs and larvae. Copeia, 1962(3):561-567.

Cady, Earl R. 1945. Fish distribution, Norris Reservoir, Tennessee, 1943. I. Depth distribution of fish in Norris Reservoir. J. Tennessee Acad. Sci., 20(1):103-114.

Canfield, H. L. 1947. Artificial propagation of those channel cats. Prog. Fish-Cult., 9(1):27-30.

Carbine, W. F. 1939. Observations on the spawning habits of centrarchid fishes in Deep Lake, Oakland County, Michigan. Trans. N. Amer. Wildl. Conf., 4:275-287.

Daiber, F. C. 1953. Notes on the spawning population of the freshwater drum (Aplodinotus grunniens Rafinesque) in Western Lake Erie. Amer. Midl. Nat., 50:159-171.

Davis, C. C. 1959. A planktonic fish egg from fresh water. Limnol. and Oceanogr., 4(3):352-355.

Dendy, Jack S. 1948. Predicting the depth distribution of fish in three TVA storage type reservoirs. Trans. Amer. Fish. Soc., 75(1945):65-72.

Dobie, John, O. Lloyd Meehean, and B. N. Washburn. 1948. Propagation of minnows and other bait species. U. S. Fish and Wildl. Serv., Circ. 12: 113 pp.

Dowell, Virgil E. 1956. Activity patterns and distribution of fishes in Buncombe Creek arm of Lake Texoma. Doctor's Dissertation, University of Oklahoma, Norman, Oklahoma.

Echelle, Anthony A. 1967. The food habits of young-of-year gars (Lepisosteus) in Lake Texoma, with notes on spawning and development. Master's Thesis, University of Oklahoma, Norman, Oklahoma.

Echelle, Anthony A., and James B. Mense. 1968. Forage value of Mississippi silversides in Lake Texoma. Proc. Oklahoma Acad. Sci., 47(1966):394-396.

Faber, D. J. 1963. Larval fish from the pelagic region of two Wisconsin lakes. Dissertation Abstracts, 24(4):1756.

Fish, Marie Poland. 1932. Contributions to the early life histories of sixty-two species of fishes from Lake Erie and its tributary waters. Bull. U. S. Bur. Fish., 47(10):293-398.

Gasaway, Charles R., and V. W. Lambou. 1968. A simple surface-midwater trawl. Prog. Fish-Cult., 30(3):178-180.

Grinstead, Bobby G. 1965. The vertical distribution of the white crappie, Pomoxis annularis, in the Buncombe Creek arm of Lake

Texoma. Master's Thesis, University of Oklahoma, Norman, Oklahoma.

Hansen, Donald F. 1944. On nesting of the white crappie, Pomoxis annularis. Copeia, 1943(4):259.

Hansen, Donald F. 1965. Further observations on nesting of the white crappie, Pomoxis annularis. Trans. Amer. Fish. Soc., 94(2): 182-184.

Hildebrand, Samuel F. 1922. Notes on habits and development of eggs and larvae of the silversides Menidia menidia and Menidia beryllina. Bull. U. S. Bur. Fish., No. 918, 38:113-120.

Houser, Alfred, and James E. Dunn. 1967. Estimating the size of the threadfin shad population in Bull Shoals Reservoir from mid-water trawl catches. Trans. Amer. Fish. Soc., 96(2):176-184.

Hubbs, Carl L. 1944. Terminology of early stages of fishes. Copeia, 1943(4):260.

Jenkins, Robert M. 1956. Growth of the blue catfish, Ictalurus furcatus, in Lake Texoma. So'west. Nat., 1(4):166-173.

Keenleyside, M. H. A. 1955. Some aspects of the schooling behavior of fish. Behaviour, 8(2-3):183-248.

Larimore, R. W. 1957. Ecological life history of the warmouth (Centrarchidae). Bull. Illinois Nat. Hist. Surv., 27(1):1-83.

Mansueti, Alice J., and Jerry D. Hardy, Jr. 1967. Development of fishes of the Chesapeake Bay region. Part I. Port City Press, Baltimore: 202 pp.

Mark, E. L. 1890. Studies of Lepidosteus. Bull. Harvard Mus. Comp. Zool., 19(2):1-129.

May, E. B., and A. A. Echelle. 1968. Young-of-year alligator gar in Lake Texoma, Oklahoma. Copeia, 1968(3):629.

Mense, James B. 1967. Ecology of the Mississippi silversides, Menidia audens Hay, in Lake Texoma. Master's Thesis, University of Oklahoma, Norman, Oklahoma.

Miller, R. R. 1960. Systematics and biology of the gizzard shad (Dorosoma cepedianum) and related fishes. U. S. Fish and Wildl. Serv. Fish. Bull., 60(173):371-392.

Minckley, W. S., and Louis Krumholz. 1960. Natural hybridization between the clupeid genera Dorosoma and Signalosa with a report on the distribution of S. petenense (Gunther). Zoologica, 44(4):171-182.

Moore, George A. 1957. Fishes. [in Blair, et al, Vertebrates of the United States. McGraw Hill Book Co. Inc. N. Y.] :33-210.

Nikolskii, G. V. 1954. Special Ichthyology. 2nd. ed. Moscow, U. S. S. R. Transl. from Russian, Israel program for Sci. Transl., Jerusalem: 538 pp.

Nikolskii, G. V. 1963. The ecology of fishes. Transl. from Russian, L. Birkett, translator. Acad. Press, New York: 352 pp.

Ridenhour, R. L. 1960. Abundance, growth and food of young game fish in Clear Lake, Iowa, 1949 to 1957. Iowa State J. Sci., 35:1-23.

Riggs, Carl D. 1955. Reproduction of the white bass Morone chrysops. Invest. Indiana Lakes and Streams, 1955(4):87-110.

Riggs, Carl D., and Edward W. Bonn. 1959. An annotated list of the fishes of Lake Texoma, Oklahoma and Texas. Sou'west. Nat., 4(4):157-168.

Riggs, Carl D., and Virgil E. Dowell. 1956. Some recent changes in the fish fauna of Lake Texoma. Proc. Oklahoma Acad. Sci., 35(1954):37-39.

Riggs, Carl D., and George A. Moore. 1958. The occurrence of Signalosa petenense in Lake Texoma. Proc. Oklahoma Acad. Sci., 38(1957): 64-67.

Roessler, Martin. 1965. Analysis of the variability of fish populations taken by otter trawl in Biscayne Bay, Florida. Trans. Amer. Fish. Soc., 94(4):311-319.

Saksena, Vishnu P. 1962. The post-hatching stages of the red shiner, Notropis lutrensis. Copeia, 1962(3):539-544.

Saunders, R. P. 1959. A study of the food of the Mississippi silversides, Menidia audens (Hay), in Lake Texoma. Master's Thesis, University of Oklahoma, Norman, Oklahoma.

Schneider, Hans, and Arthur D. Hasler. 1960. Laute und lauterzeugung beim susswassertrommler Aplodinotus grunniens Rafinesque (Sciaenidae, Pisces). Zeitschrift fur vergleichende Physiologie, 43:499-517.

Shelton, William L. 1964. The threadfin shad, Dorosoma petenense (Gunther): oogenesis, seasonal ovarian changes and observations on life history. Master's Thesis, Oklahoma State University, Stillwater, Oklahoma.

Smallwood, W. M., and Mary L. Smallwood. 1931. The development of the carp, Cyprinus carpio. I. The larval life of the carp,

with special reference to the development of the intestinal tract. J. Morphol. 52(1):217-231.

Swee, U Boon, and Hugh R. McCrimmon. 1966. Reproductive biology of the carp, Cyprinus carpio L., in Lake St. Lawrence, Ontario. Trans. Amer. Fish. Soc., 95(4):372-380.

Taylor, Clyde C. 1953. Nature of the variability in trawl catches. U. S. Fish and Wildl. Serv., Fish. Bull., 54(83):145-166.

United States Army Corps of Engineers. 1948. Denison Dam and Lake Texoma information pamphlet, Red River, Texas and Oklahoma. Revision of March, 1948. (mimeo.): 22 pp.

United States Army Corps of Engineers. 1961. Water resources development by the U. S. Army Corps of Engineers in Oklahoma (mimeo.): 51 pp.

Warner, Edward N. 1941. Studies on the embryology and early life history of the gizzard shad, Dorosoma cepedianum (Le Sueur). Doctor's Dissertation, Ohio State University, Columbus, Ohio.

Welsh, William W., and C. M. Breder, Jr. 1923. Contributions to life histories of Sciaenidae of the eastern United States coast. Bull. U. S. Bur. Fish., 39(945):141-201.

Werner, Robert G. 1967. Intralacustrine movements of bluegill fry in Crane Lake, Indiana. Trans. Amer. Fish. Soc., 96(4):416-420.

Whiteside, Bobby G. 1964. Biology of the white crappie, Pomoxis annularis, in Lake Texoma, Oklahoma. Master's Thesis, Oklahoma State University, Stillwater, Oklahoma.

Wirth, Thomas L. 1958. Lake Winnebago freshwater drum. Wisconsin Conserv. Bull., 23(5):30-32.

Witt, A. Jr., and R. Marzolf. 1954. Spawning and behaviour of the longear sunfish, Lepomis megalotis megalotis. Copeia, 1954 (2):188-190.

APPENDIX

Appendix 1. Summary of collecting effort in the Buncombe Creek arm. Seining, 1965.

Date	Number of collections made		Size* of seines used	Average water temp. F	
	Day	Night		Day	Night
IV/25	10	--	3'x3'	73	
V/2	12	--	3'x3' & 4'x6'	73	
V/9	12	--	" "	73	
V/15	12	--	" "	72	
V/22	12	--	" "	78	
VI/1	12	--	" "	80	
VI/7	12	--	" "	83	
VI/14	12	12	3'x3' & 12' bag	83	82
VI/21	12	5	" "	86	83
VI/28	12	6	" "	82	84
VII/8	12	--	" "	86	
VII/18	--	12	" "		87
VIII/16	12	--	" "	85	
VIII/31	12	6	" "	85	82
IX/24	12	--	" "	75	

* The 3'x3' seine was of 1/16-inch mesh, the 4'x6' seine of 1/8-inch mesh, and the bag seine had a 1/8-inch mesh bag.

Appendix 1 (Continued)

Trawling, 1965.

Date	Number of collections made Day	Night	Lake* level	Avg. surface temp. F Day	Night
V/7	6(surface)	--	610.0	72	
V/15	6 "	--	610.7	73	
V/22	6 "	--	611.6	79	
VI/2	6 "	--	612.7	79	
VI/6	12(no midwater)	--	612.9	81	
VI/9	6(surface)	6(surface)	612.7	81	82
VI/14	15	15	612.8	82	
VI/19	15	15	613.5	84	84
VI/26	15	--	614.1	83	
VII/1	15	15	614.4	88	86
VII/9	15	15	614.5	88	86
VII/16	15	15	613.8	89	87
VII/29	15	15	612.6	86	85
VIII/10	12	15	611.8	87	88
VIII/30	15	8	610.1	85	84
IX/25	15	--	610.0	76	

* Lake level in feet above sea level. Data from U. S. Army Corps of Engineers, Denison Dam.

Appendix 1 (Continued)

Trawling, 1966.

Date	Numbers of collections made Day	Night	Lake* level	Avg. surface temp. F Day	Night
III/27	12(no midwater)	--	613.1	59	
IV/1	12 "	6(surface)	613.1	59	59
IV/8	12 "	12(no midwater)	612.8	62	62
IV/18	12 "	--	612.0	67	
IV/23	15	15	611.7	64	64
IV/30	15	15	616.8	63	63
V/7	15	15	617.5	74	77
V/13	15	15	616.8	68	66
V/21	15	15	616.4	76	78
V/27	15	15	616.2	84	80
VI/4	15	15	615.6	78	77
VI/11	15	15	614.9	81	81
VI/19	15	15	614.7	81	79
VI/26	15	15	614.2	84	83
VII/10	15	15	612.7	88	87
VII/24	--	15	611.3		85
VIII/7	15	15	610.1	89	88
VIII/21	--	15	609.6		85
IX/4	--	15	611.6		83
X/7		10	612.7		70

* Lake level in feet above sea level. Data from U. S. Army Corps of Engineers, Denison Dam.

Appendix 2. Numbers of fishes collected in 1966 trawling.

Dorosoma

Station	Samples	4-5.5 mm $\bar{Y}$	4-5.5 mm S.E.	6-10 mm $\bar{Y}$	6-10 mm S.E.	10.5-20 mm $\bar{Y}$	10.5-20 mm S.E.	20.5+ mm $\bar{Y}$	20.5+ mm S.E.
1s	31	8.7	3.36	150.3	62.91	47.8	35.69	.5	.39
1b	31	.7	.32	11.3	4.81	6.8	3.27	4.7	2.42
2s	31	5.4	2.05	171.6	68.33	66.7	31.41	.5	.26
2m	28	8.7	5.71	161.1	98.11	131.7	71.57	10.1	5.18
2b	31	8.0	6.89	143.9	100.25	57.0	50.70	2.7	1.24
3s	31	8.4	3.46	272.7	142.78	125.6	61.92	.1	.07
3m	28	5.1	2.76	163.7	87.13	146.5	73.48	12.3	8.41
3b	31	3.0	1.40	69.6	39.57	23.9	14.58	5.4	2.68
4s	31	17.6	9.84	409.0	221.63	116.5	55.30	.9	.53
4b	31	15.3	2.96	659.1	545.24	147.6	106.82	3.2	1.42
5s	30	4.7	1.66	177.7	98.14	321.9	231.57	5.7	.62
5m	27	7.8	3.44	244.1	107.25	315.0	157.87	17.9	8.35
5b	30	3.0	1.55	110.7	69.09	72.4	60.66	11.3	6.13
6s	30	43.5	23.81	709.2	400.64	634.9	374.31	7.1	3.37
6b	30	12.1	5.31	357.0	195.07	114.1	72.77	18.4	8.30
Day									
Surface	84	13.9	6.94	322.7	137.88	158.6	94.44	.3	.34
Midwater	36	5.8	2.07	80.0	45.05	5.6	4.25	.03	.03
Bottom	84	4.1	1.25	55.1	24.91	5.6	3.02	1.2	.73
Night									
Surface	100	15.2	5.31	306.1	94.50	264.4	107.80	4.2	1.00
Midwater	47	8.3	3.93	272.3	92.55	342.4	108.44	23.6	7.54
Bottom	100	9.5	3.81	368.0	149.20	124.2	46.00	12.8	3.25
Combined									
Surface	184	14.6	4.27	313.7	80.97	216.1	72.58	2.4	.56
Midwater	83	7.3	2.39	189.0	55.33	196.3	60.82	13.4	4.23
Bottom	184	7.0	2.14	225.0	81.71	70.1	25.01	7.5	1.79

Pimephales vigilax

		5-6.5 mm $\bar{Y}$	5-6.5 mm S.E.	7-10 mm $\bar{Y}$	7-10 mm S.E.	10.5+ mm $\bar{Y}$	10.5+ mm S.E.
Surface	70	.93	.23	.39	.17	.30	.09
Midwater	35	.14	.15	.60	.52	1.06	.45
Bottom	70	1.23	.43	4.33	1.62	7.73	1.94

Appendix 2 (Continued)

Pimephales vigilax

Station	Samples	5-6.5 mm $\bar{Y}$	5-6.5 mm S.E.	7-10 mm $\bar{Y}$	7-10 mm S.E.	10.5+ mm $\bar{Y}$	10.5+ mm S.E.
1s	12	.92	.45	.75	.62	.50	.27
1b	12	1.00	.75	4.17	2.46	18.42	7.82
2s	12	.08	.09	.0		.0	
2m	12	.0		.0		.0	
2b	12	.0		.0		.25	.26
3s	12	1.42	.75	.25	.15	.17	.12
3m	12	.42	.44	1.67	1.59	3.08	1.59
3b	12	.08	.09	.08	.09	.25	.15
4s	12	1.25	.57	1.08	.82	.83	.46
4b	12	4.92	2.40	17.33	9.23	18.92	7.95
5s	11	.27	.17	.0		.0	
5m	11	.0		.09	.10	.0	
5b	11	.0		.0		.0	
6s	11	1.63	.97	.18	.14	.27	.14
6b	11	1.27	.73	4.00	2.39	7.91	4.04

Cyprinus carpio

Station	Day+Night samples	$\bar{Y}$	S.E.
1s	14	11.14	7.39
1b	14	1.43	.91
2s	14	.36	.22
2m	14	.14	.10
2b	14	.21	.07
3s	14	.36	.20
3m	14	.14	.10
3b	14	.29	.18
4s	14	9.57	9.71
4b	14	.36	.22
5s	14	.21	.17
5m	14	.07	.07
5b	14	0.0	
6s	14	.86	.64
6b	14	.64	.32

	Samples	Day $\bar{Y}$	Day S.E.	Night $\bar{Y}$	Night S.E.	Day+Night $\bar{Y}$	Day+Night S.E.
Surface	42	.02	.02	7.48	3.97	3.75	1.97
Midwater	21	0.0		.24	.11	.12	.05
Bottom	42	.24	.22	.76	.42	.49	.16

Appendix 2 (Continued)

Menidia audens

Station	Samples	4-10 mm $\bar{Y}$	4-10 mm S.E.	10.5-15 mm $\bar{Y}$	10.5-15 mm S.E.	15.5+ mm $\bar{Y}$	15.5+ mm S.E.
1s	29	222.1	99.12	157.1	96.94	25.5	13.85
1b	29	1.9	.86	10.7	5.65	2.3	1.25
2s	29	30.3	11.36	25.2	16.17	6.0	3.35
2m	28	.8	.33	.4	.22	1.4	.93
2b	29	.3	.14	.5	.25	.8	.37
3s	29	112.4	52.84	41.9	18.72	7.2	3.17
3m	28	9.5	6.51	16.7	12.49	5.9	5.05
3b	29	2.0	.96	1.2	.88	1.8	.83
4s	29	123.5	58.79	32.7	15.02	14.7	8.29
4b	29	1.4	.79	7.4	4.56	19.4	9.77
5s	28	48.1	18.68	18.2	8.80	5.5	2.58
5m	27	1.3	.57	2.4	1.39	3.6	1.96
5b	28	1.1	.71	1.8	1.35	1.6	.87
6s	28	85.6	44.75	94.3	52.60	23.7	3.95
6b	28	2.7	2.07	62.0	58.03	63.4	58.13
Day							
Surface	78	49.22	21.68	3.24	1.27	.21	.11
Midwater	36	.39	.18	0.0		0.0	
Bottom	78	.37	.20	.18	.12	.01	.003
Night							
Surface	94	149.62	41.39	110.07	34.59	24.98	5.31
Midwater	47	6.57	3.86	11.89	7.42	6.53	3.24
Bottom	94	2.57	.78	24.99	17.21	26.86	17.66
Combined							
Surface	172	104.09	24.60	61.63	18.86	13.74	2.89
Midwater	83	3.89	2.18	6.73	4.18	3.70	1.83
Bottom	172	1.58	.43	13.74	9.38	14.69	9.62

Appendix 2 (Continued)

Roccus chrysops

Station	Samples	4-10 mm $\bar{Y}$	4-10 mm S.E.	10.5+ mm $\bar{Y}$	10.5+ mm S.E.
1s	19	.26	.27	.26	.14
1b	19	.05	.06	.21	.14
2s	19	.16	.12	1.42	1.07
2m	18	.50	.24	.11	.11
2b	19	.53	.31	.37	.20
3s	19	.53	.35	1.16	1.01
3m	18	.72	.41	.44	.29
3b	19	.37	.21	.53	.34
4s	19	1.05	.78	.21	.17
4b	19	3.47	2.34	1.11	.60
5s	19	.26	.16	.21	.17
5m	18	1.11	.93	.17	.13
5b	19	.16	.12	.21	.14
6s	19	.21	.21	.11	.08
6b	19	.16	.09	.74	.37
Day					
Surface	60	.05	.03	.02	.02
Midwater	27	.44	.24	0.0	
Bottom	60	1.02	.70	.38	.18
Night					
Surface	54	.81	.32	1.17	.52
Midwater	27	1.11	.64	.48	.22
Bottom	54	.54	.25	.67	.20
Combined					
Surface	114	.41	.15	.56	.24
Midwater	54	.78	.34	.24	.11
Bottom	114	.79	.39	.53	.14

Appendix 2 (Continued)

Lepomis macrochirus

Station	Samples	4-5.5 mm $\bar{Y}$	4-5.5 mm S.E.	6-12 mm $\bar{Y}$	6-12 mm S.E.	12.5+ mm $\bar{Y}$	12.5+ mm S.E.
1s	20	5.05	2.47	22.00	10.26	.55	.22
1b	20	4.25	2.47	96.85	45.70	21.85	10.60
2s	20	2.10	.77	2.50	1.00	0.0	
2m	20	.75	.39	.60	.32	.10	.05
2b	20	.60	.40	.90	.48	0.0	
3s	20	21.40	11.71	9.20	3.79	.10	.10
3m	20	9.25	5.33	24.70	3.95	2.10	1.03
3b	20	2.30	1.31	7.00	3.80	4.75	3.06
4s	20	37.90	24.41	16.70	6.51	.85	.46
4b	20	17.05	7.73	67.65	23.65	17.80	5.56
5s	19	5.15	.79	2.00	1.00	.05	.05
5m	19	1.45	.74	1.25	.67	0.0	
5b	19	.45	.35	.55	.26	.10	.11
6s	19	4.35	1.91	9.15	4.60	.10	.08
6b	19	4.60	2.29	24.05	11.69	3.50	1.53
	Day						
Surface	48	16.08	10.60	3.33	1.60	0.0	
Midwater	24	.71	.35	.08	.04	0.0	
Bottom	48	1.58	.71	10.56	5.04	2.23	.85
	Night						
Surface	70	10.67	2.54	15.30	3.63	.47	.15
Midwater	35	6.06	3.03	15.11	7.07	1.26	.41
Bottom	70	7.27	2.46	49.04	14.38	12.19	3.44
	Combined						
Surface	118	12.87	4.52	10.43	2.25	.28	.09
Midwater	59	3.88	1.80	9.00	4.17	.75	.35
Bottom	118	4.96	1.48	33.39	8.76	8.14	2.06

Appendix 2 (Continued)

Lepomis megalotis

Station	Samples	5-6 mm $\bar{Y}$	5-6 mm S.E.	6.5-10 mm $\bar{Y}$	6.5-10 mm S.E.	10.5+ mm $\bar{Y}$	10.5+ mm S.E.
1s	18	.06	.06	.22	.14	0.0	
1b	18	.17	.13	.67	.53	.28	.19
2s	18	.06	.06	.06	.06	0.0	
2m	18	.06	.06	0.0		0.0	
2b	18	.06	.06	0.0		0.0	
3s	18	.72	.63	.22	.14	0.0	
3m	18	.22	.23	.50	.30	.11	.11
3b	18	.33	.24	.39	.26	.61	.63
4s	18	.72	.41	.39	.22	.28	.24
4b	18	2.11	1.48	3.56	1.97	3.44	2.32
5s	17	0.0		.18	.11	0.0	
5m	17	0.0		.18	.12	0.0	
5b	17	.24	.24	0.0		0.0	
6s	17	.94	.80	.41	.33	0.0	
6b	17	.59	.34	.94	.49	.76	.46
Day							
Surface	42	0.0		.02	.02	0.0	
Midwater	21	0.0		0.0		0.0	
Bottom	42	.31	.13	.38	.18	.07	.07
Night							
Surface	64	.69	.29	.39	.12	.08	.06
Midwater	32	.16	.13	.38	.18	.06	.06
Bottom	64	.78	.42	1.30	.57	1.38	.67
Combined							
Surface	106	.42	.18	.25	.07	.05	.04
Midwater	53	.09	.08	.23	.11	.04	.04
Bottom	106	.59	.26	.93	.35	.86	.40

Appendix 2 (Continued)

Pomoxis annularis

Station	Samples	4-4.5 mm $\bar{Y}$	4-4.5 mm S.E.	5-10 mm $\bar{Y}$	5-10 mm S.E.	10.5+ mm $\bar{Y}$	10.5+ mm S.E.
1s	32	.47	.39	.53	.22	.06	.04
1b	31	.13	.08	1.77	1.03	.52	.22
2s	32	.09	.09	.75	.30	.06	.03
2m	26	.08	.05	.42	.21	0.0	
2b	31	.03	.03	.13	.06	0.0	
3s	32	.03	.03	.69	.38	.03	.03
3m	26	.31	.19	.88	.44	.08	.06
3b	31	.26	.16	1.84	.91	.13	.10
4s	32	2.38	1.14	2.88	1.56	.16	.09
4b	31	1.19	.81	2.94	1.86	.71	.32
5s	32	.06	.04	.38	.14	0.0	
5m	26	.12	.09	1.50	.82	.08	.08
5b	31	.03	.03	.26	.14	.16	.09
6s	32	.47	.29	1.25	.73	.03	.03
6b	31	.42	.18	1.23	.56	.06	.05
Day							
Surface	96	.19	.07	.41	.12	.01	.01
Midwater	36	.28	.14	.14	.06	0.0	
Bottom	96	.23	.08	1.16	.40	.20	.11
Night							
Surface	96	.99	.40	1.74	.58	.10	.04
Midwater	42	.05	.05	1.64	.58	.10	.06
Bottom	90	.47	.28	1.58	.69	.33	.11
Combined							
Surface	192	.59	.22	1.07	.30	.06	.02
Midwater	78	.16	.07	.95	.31	.05	.03
Bottom	186	.33	.22	1.32	.39	.26	.07

Appendix 2 (Continued)

Percina caprodes

Station	Samples	4.5-6 mm $\bar{Y}$	4.5-6 mm S.E.	6.5-15 mm $\bar{Y}$	6.5-15 mm S.E.	15.5+ mm $\bar{Y}$	15.5+ mm S.E.
1s	31	.23	.13	1.65	.72	0.0	
1b	30	.03	.03	.63	.32	.33	.13
2s	31	0.0		.03	.03	0.0	
2m	25	0.0		.12	.12	0.0	
2b	30	0.0		.20	.13	0.0	
3s	31	.16	.09	.39	.18	0.0	
3m	25	.03	.04	.24	.15	.28	.20
3b	30	0.0		.77	.41	.07	.03
4s	31	.19	.10	1.77	.90	.13	.09
4b	30	.03	.03	2.93	1.57	2.40	.85
5s	31	.16	.12	.19	.14	0.0	
5m	25	0.0		.36	.22	.08	.02
5b	30	0.0		.07	.05	0.0	
6s	31	.32	.15	1.13	.45	0.0	
6b	30	.37	.18	2.40	1.02	1.23	.46
Day							
Surface	96	.05	.03	.28	.12	.02	.02
Midwater	36	.03	.03	0.0		0.0	
Bottom	96	.11	.06	1.27	.52	.30	.08
Night							
Surface	90	.31	.08	1.48	.42	.02	.02
Midwater	39	0.0		.46	.19	.23	.16
Bottom	84	.02	.02	1.05	.35	1.10	.33
Combined							
Surface	186	.18	.04	.86	.21	.02	.02
Midwater	75	.01	.02	.24	.11	.12	.08
Bottom	180	.07	.03	1.17	.32	.67	.16

Appendix 2 (Continued)

Aplodinotus grunniens

Station	Samples	3-5 mm $\bar{Y}$	3-5 mm S.E.	5-10 mm $\bar{Y}$	5-10 mm S.E.	10.5+ mm $\bar{Y}$	10.5+ mm S.E.	eggs $\bar{Y}$	eggs S.E.
1s	16	.06	.07	.06	.07	0.0		1.81	1.62
1b	16	0.0		.06	.07	1.00	.59	.19	.15
2s	16	.06	.07	.19	.15	.12	.09	17.75	10.03
2m	16	.25	.13	.38	.22	.56	.47	1.94	.80
2b	16	.19	.11	.50	.24	.31	.19	1.75	.84
3s	16	.12	.09	.19	.11	.06	.07	2.75	1.29
3m	16	.31	.17	.50	.29	1.44	.89	1.50	1.01
3b	16	.25	.26	.56	.31	2.44	1.66	.31	.22
4s	16	.12	.13	.19	.19	0.0		1.62	1.23
4b	16	.62	.65	.69	.59	.88	.54	.19	.15
5s	16	0.0		.25	.26	0.0		4.19	2.26
5m	16	.19	.11	.12	.13	0.0		1.25	.66
5b	16	.50	.30	.19	.11	.25	.11	.31	.22
6s	16	.19	.19	.12	.13	0.0		.31	.32
6b	16	.06	.07	0.0		.19	.11	.06	.07
Day									
Surface	48	.02	.02	0.0		0.0		2.23	.78
Midwater	24	.25	.10	.04	.04	0.0		.58	.26
Bottom	48	.35	.23	.38	.21	.06	.06	.42	.25
Night									
Surface	48	.17	.08	.33	.13	.06	.04	7.25	3.36
Midwater	24	.25	.12	.62	.25	1.33	.67	2.54	.93
Bottom	48	.19	.10	.29	.11	1.62	.61	.52	.16
Combined									
Surface	96	.09	.04	.17	.06	.03	.02	4.74	1.73
Midwater	48	.25	.08	.33	.13	.67	.33	1.56	.48
Bottom	96	.27	.12	.33	.12	.84	.30	.47	.15

Appendix 3. Tests of significance.

Pimephales vigilax

Size-group in relation to surface collection site.

Size	1	3	4	6	Total
I	11	17	15	18	61
	13.9	13.9	19.4	13.9	
II	9	3	13	2	27
	6.1	6.1	8.6	6.1	
Total	20	20	28	20	88

Chi-square = 11.48
p <.01

Size-group in relation to surface collection site.

Size	1	3	4	6	Total
I	11	17	15	18	61
	12.6	14.1	18.6	15.6	
III	6	2	10	3	21
	4.4	4.9	6.4	5.4	
Total	17	19	25	21	82

Chi-square = 10.10
p <.02

Size-group in relation to surface collection site.

Size	1	3	4	6	Total
II	9	3	13	2	27
	8.4	2.8	12.9	2.8	
III	6	2	10	3	21
	6.6	2.2	10.1	2.2	
Total	15	5	23	5	48

Chi-square = .63
ns

Size-group in relation to bottom collection site.

Size	1	3	4	6	Total
I	12	1	59	14	86
	13.7	.4	59	12.8	
II	50	1	208	44	303
	48.3	1.6	208	45.2	
Total	62	2	267	58	389

Chi-square = 1.54
ns

Size-group in relation to bottom collection site.

Size	1	3	4	6	Total
I	12	1	59	14	86
	32.1	.6	39.4	13.9	
III	221	3	227	87	538
	200.9	3.4	246.6	87.1	
Total	233	4	286	101	624

Chi-square = 26.23
p <.0001

Size-group in relation to bottom collection site.

Size	1	3	4	6	Total
II	50	1	208	44	303
	97.6	1.4	156.7	47.2	
III	221	3	227	87	538
	173.4	2.6	278.3	83.8	
Total	271	4	435	131	841

Chi-square = 63.04
p <.0001

Size-group in relation to collection level at night.

Size	Surface	Midwater	Bottom	Total
I	65	5	86	156
	28.3	8	119.7	
II	27	21	303	351
	63.7	18	269.3	
Total	92	26	389	507

Chi-square = 84.07
p <.0001

Size-group in relation to collection level at night.

Size	Surface	Midwater	Bottom	Total
I	65	5	86	156
	17.8	8.7	129.6	
III	21	37	541	599
	68.2	33.3	497.4	
Total	86	42	627	755

Chi-square = 178.30
p <.0001

Size-group in relation to collection level at night.

Size	Surface	Midwater	Bottom	Total
II	27	21	303	351
	17.7	21.4	311.8	
III	21	37	541	599
	30.3	36.6	532.2	
Total	48	58	844	950

Chi-square = 8.11
p <.02

Menidia audens

Size-group in relation to collection level in daytime.

Size	Surface	Midwater	Bottom	Total
I	3839	14	29	3882
	3827.9	13	41	
II	250	0	14	264
	263.3	.9	2.8	
III	16	0	1	17
	16.8	.1	.2	
Total	4108	14	44	4166

Chi-square = 47.33
p <.0001

Size-group in relation to collection level in daytime.

Size	Surface	Midwater	Bottom	Total	
II	253	0	14	267	
	252.9	0	14.1		Chi-square = .01
III	16	0	1	17	ns
	16.1	0	.2		
Total	269	0	15	284	

Size-group in relation to collection level at night.

Size	Surface	Midwater	Bottom	Total	
II	10347	559	2349	13255	
	9127.9	622.7	3504.5		Chi-square = 1958.56
III	2348	307	2525	5180	p <.0001
	3567.1	243.3	1369.5		
Total	12695	866	4874	18435	

Collection level of size-group 1 in relation to day and night.

	Surface	Midwater	Bottom	Total	
Day	3839	14	29	3882	
	3757.3	67.8	56.9		Chi-square = 73.1
Night	14064	309	242	14615	p <.0001
	14145.7	255.2	214.1		
Total	17903	323	271	18497	

Collection level of size-group 2 in relation to day and night.

	Surface	Midwater	Bottom	Total	
Day	253	0	14	267	
	209.3	11	46.7		Chi-square = 43.75
Night	10347	559	2349	13255	p <.0001
	10390.7	548	2316.3		
Total	10600	559	2363	13522	

Collection level of size-group 3 in relation to day and night.

	Surface	Midwater	Bottom	Total	
Day	16	0	1	17	
	7.7	1	8.3		Chi-square = 16.42
Night	2348	307	2525	5180	p = .0003
	2356.3	306	2517.7		
Total	2364	307	2526	5197	

Roccus chrysops

Size group in relation to surface collection site.

Size	1	2	3	4	5	6	Total
I	5	3	10	20	5	4	47
	4.2	12.7	13.5	10.2	3.8	2.5	
II	5	27	22	4	4	2	64
	5.8	17.3	18.5	13.8	5.2	3.5	
Total	10	30	32	24	9	6	111

Chi-square = 30.31
p <.0001

Size-group in relation to bottom collection site.

Size	1	2	3	4	5	6	Total
I	1	10	7	66	3	3	90
	3	10.2	10.2	52.2	4.2	10.2	
II	4	7	10	21	4	14	60
	2	6.8	6.8	34.8	2.8	6.8	
Total	5	17	17	87	7	17	150

Chi-square = 28.32
p <.0001

Size-group in relation to collection level in daytime.

Size	Surface	Midwater	Bottom	Total
I	3	12	61	76
	3	9.1	63.8	
II	1	0	23	24
	1	2.9	20.2	
Total	4	12	84	100

Chi-square = 4.32
p = .11 ns

Size-group in relation to collection level at night.

Size	Surface	Midwater	Bottom	Total
I	44	30	29	103
	51	20.5	31.5	
II	63	13	37	113
	56	22.5	34.5	
Total	107	43	66	216

Chi-square = 10.63
p = .005

Lepomis megalotis

Size-group in relation to collection level at night.

Size	Surface	Midwater	Bottom	Total
I	44	5	50	99
	23.3	6	69.7	
II	25	12	83	120
	28.3	7.3	84.5	
III	5	2	88	95
	22.4	5.7	66.8	
Total	74	19	221	314

Chi-square = 50.26
p <.0001

Pomoxis annularis

Size-group in relation to surface collection site.

Size	1	2	3	4	5	6	Total	
I	15	3	1	76	2	15	112	
	11.5	9.8	8.2	58.7	4.7	19		
II	17	24	22	92	12	40	207	Chi-square = 32.68
	21.3	18.2	15	108.5	8.8	35.1		p = .0003
III	2	2	1	5	0	1	11	
	1.2	1	.8	5.8	.5	1.9		
Total	34	29	24	173	14	56	330	

Size-group in relation to bottom collection site.

Size	1	2	3	4	5	6	Total	
I	4	1	8	37	1	13	64	
	13.1	.9	12.1	26.2	2.4	9.3		
II	55	4	57	91	8	38	253	Chi-square = 34.74
	51.9	3.4	47.7	103.7	9.7	36.6		p <.0003
III	16	0	4	22	5	2	49	
	10	.7	9.2	20.1	1.9	7.1		
Total	75	5	69	150	14	53	366	

Size-group in relation to collection level in daytime.

Size	Surface	Midwater	Bottom	Total	
I	18	10	22	50	
	12.9	3.3	33.8		
II	39	5	111	155	Chi-square = 19.57
	39.9	10.4	104.7		p <.001
III	1	0	19	20	
	.2	1.3	13.5		
Total	58	15	152	225	

Size-group in relation to collection level at night.

Size	Surface	Midwater	Bottom	Total	
I	95	2	42	139	
	67.4	18.6	53		
II	167	69	142	378	Chi-square = 53.84
	183.3	50.5	144.2		p <.0001
III	10	4	30	44	
	21.3	5.9	16.8		
Total	272	75	214	561	

Collection level of size-group 1 in relation to day and night.

	Surface	Midwater	Bottom	Total
Day	18	10	22	50
	29.9	3.2	16.9	
Night	95	2	42	139
	83.1	8.8	47.1	
Total	113	12	64	189

Chi-square = 28.5
p <.0001

Collection level of size-group 2 in relation to day and night.

	Surface	Midwater	Bottom	Total
Day	39	5	104	148
	59.1	18.4	70.6	
Night	167	59	142	368
	146.9	45.6	175.4	
Total	206	64	246	516

Chi-square = 45.43
p <.0001

Collection level of size-group in relation to day and night.

	Surface	Midwater	Bottom	Total
Day	1	0	19	20
	3.4	1.2	15.3	
Night	10	4	30	44
	7.6	2.8	33.7	
Total	11	4	49	64

Chi-square = 5.46
.08> p> .05 ns

Percina caprodes

Size-group in relation to surface collection site.

Size	1	2	3	4	5	6	Total
I	7	0	5	6	5	10	33
	4.9	.2	2.9	10.4	1.9	7.7	
II	51	1	12	55	6	35	160
	54.1	.8	14.1	50.6	9.1	37.3	
Total	58	1	17	61	11	45	193

Chi-square = 12.4
p <.03

Size-group in relation to bottom collection site.

Size	1	2	3	4	5	6	Total
II	19	6	23	88	2	72	210
	18.4	3.8	15.9	101.5	1.3	69.2	
III	10	0	2	72	0	37	121
	10.6	2.2	9.1	58.5	.7	39.8	
Total	29	6	25	160	2	109	331

Chi-square = 18.6
p <.005

Collection level of size-group 2 in relation to day and night.

	Surface	Midwater	Bottom	Total
Day	27	0	122	149
	61.4	6.9	80.6	
Night	133	18	88	239
	98.6	11.1	129.4	
Total	160	18	210	388

Chi-square = 76.99
p <.0001

Collection level of size-group 3 in relation to day and night.

	Surface	Midwater	Bottom	Total
Day	2	0	29	31
	.9	2.1	28	
Night	2	9	92	103
	3.1	6.9	93	
Total	4	9	121	134

Chi-square = 4.36
ns

Aplodinotus grunniens

Size-group in relation to bottom collection site.

Size	1	2	3	4	5	6	Total
I	0	3	4	10	8	1	26
	3.2	3	9.7	6.5	2.8	.7	
II	1	8	9	11	3	0	32
	3.9	3.7	12	8.1	3.5	.9	
III	16	5	39	14	4	3	81
	9.9	9.3	30.3	20.4	8.7	2.4	
Total	17	16	52	35	15	4	139

Chi-square = 41.09
p <.0001

Size-group in relation in relation to level of collection at night.

Size	Surface	Midwater	Bottom	Total
I	8	6	9	23
	3.4	6.7	12.8	
II	16	15	14	45
	6.7	13.2	25.1	
III	3	32	78	113
	16.9	33.1	63.1	
Total	27	53	101	181

Chi-square = 40.29
p <.0001

Size-group in relation to level of collection at night.

Size	Surface	Midwater	Bottom	Total
I	8	6	9	23
	8.1	7.1	7.8	
II	16	15	14	45
	15.9	13.9	15.2	
Total	24	21	23	68

Chi-square = .55
ns

Collection level of eggs in relation to day and night.

	Surface	Midwater	Bottom	Total
Day	107	14	20	141
	111.6	18.4	11	
Night	348	61	25	434
	342.4	56.6	34	
Total	455	75	45	575

Chi-square = 20.79
$p < .0003$