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# LARVAL DEVELOPMENT, GROWTH, AND SPAWNING OF STRIPED MULLET (*MUGIL CEPHALUS*) ALONG THE SOUTH ATLANTIC COAST OF THE UNITED STATES

By WILLIAM W. ANDERSON

FISHERY BULLETIN 144

From Fishery Bulletin of the Fish and Wildlife Service

VOLUME 58

UNITED STATES GOVERNMENT PRINTING OFFICE • WASHINGTON : 1958

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
Price 25 cents

The Library of Congress has cataloged Fishery Bulletin 144 as follows:

**Anderson, William Wyatt,** 1909–

Larval development, growth, and spawning of striped mullet (*Mugil cephalus*) along the South Atlantic coast of the United States. Washington, U. S. Govt. Print. Off., 1958.

501–519 p. illus. 26 cm. (U. S. Fish and Wildlife Service. Fishery bulletin 144)

"From Fishery bulletin of the Fish and Wildlife Service, volume 58."

Includes bibliography.

1. Black mullets. 2. Larvae—Fishes.

SH11.A25 vol. 58, no. 144 597.58 58–62423 ‡

Library of Congress

The series, Fishery Bulletin of the Fish and Wildlife Service, is cataloged as follows:

**U. S.** ***Fish and Wildlife Service.***

**Fishery bulletin. v. 1–**

**Washington, U. S. Govt. Print. Off., 1881–19**

**v. in illus., maps (part fold.) 23–28 cm.**

**Some vols. issued in the congressional series as Senate or House documents.**

**Bulletins composing v. 47– also numbered 1–**

**Title varies: v. 1–49, Bulletin.**

**Vols. 1–49 issued by Bureau of Fisheries (called Fish Commission, v. 1–23)**

**1. Fisheries—U. S. 2. Fish-culture—U. S. I. Title.**

**SH11.A25 639.206173 9–35239 rev 2***

**Library of Congress [r55e½]**

## CONTENTS

## ABSTRACT

The larval and juvenile development of the striped mullet (*Mugil cephalus*) is described and illustrated from about 4 mm. to 116 mm. standard length.

Striped mullet appear to spawn along the south Atlantic coast of the United States from lower Florida to North Carolina over a broad area extending from about the 20-fathom line into the Gulf Stream. The data indicate that spawning occurs from October to February, but is confined largely to the period of November to January, with the peak in December.

Young striped mullet apparently remain at sea until they are from 18 to 28 mm. long (mostly 20 to 25 mm.), at which time they move in to the coast. In Georgia these young appear as early as November on the outer beaches but apparently do not go into the marshy estuarine waters until January.

Growth of young striped mullet in Georgia is estimated. They grow slowly during the colder winter months, but with the warming of the waters in spring growth speeds up. From about March to October the size increase is about 17 mm. a month. Mullet from the earliest spawning (October) reach a length of about 160 mm. standard length by the end of their first year. Growth of mullet as estimated by various workers along the south Atlantic and Gulf coasts of the United States is summarized.

Development of teeth on the tongues of young mullet and loss in the adult are described and illustrated.

# LARVAL DEVELOPMENT, GROWTH, AND SPAWNING OF STRIPED MULLET (*MUGIL CEPHALUS*) ALONG THE SOUTH ATLANTIC COAST OF THE UNITED STATES

By WILLIAM W. ANDERSON, *Fishery Research Biologist*

BUREAU OF COMMERCIAL FISHERIES

The striped mullet (*Mugil cephalus* Linnaeus) is one of the most important food fishes of the Southern United States. It is of greatest importance in Florida, where about 28 to 30 million pounds are taken annually. Fisheries of considerable value exist in several other States—North Carolina, South Carolina, Alabama, and Mississippi. Fishing is done mainly with gill nets, trammel nets, beach seines, and stop nets.

The species has a very wide distribution. Hildebrand and Schroeder (1928, p. 196) give the habitat as, "Warm waters of both hemispheres; on the Atlantic coast of America from Cape Cod to Brazil."

That the early development of this important and common shore fish in the Southern United States has remained a mystery for many years is difficult to believe, but is true. Jacot (1920, p. 222), working with the species in North Carolina, stated, "Thus nothing is known of the spawning grounds of this species and therefore of its eggs or larvae, the earliest stage known being the already well developed young * * *." Jacot's smallest specimens were about 23 mm. total length. Higgins (1928, p. 625), who worked largely in North Carolina, said, "The larval stages of development of the mullet are unknown, but juvenile fish appear in the sounds about Beaufort in early February, when they are from 18 to 25 millimeters in length." Kilby (1949, p. 7), working with striped mullet in Florida, said, "In view of its commercial value and the universally admitted desirability of its conservation and perpetuation as a natural resource of the state, it might be assumed that the life history of the mullet is well known. Such an assumption, however, would be in error, because little has been published on the young, and specimens less than 16 mm. in standard length are apparently unknown." Broadhead (1953, p. 9), working with *M. cephalus* in northwest Florida, stated, "Nothing is known of the egg and larval development and the young fish are first encountered in shallow water, at which time they are about one inch long."

During a biological, chemical, and oceanographic survey of waters off the south Atlantic coast of the United States with the Service's MV. *Theodore N. Gill*, larval specimens of striped mullet, ranging in standard length from about 4 mm. to 30 mm., were obtained in the plankton and dip-net collections—providing a basis for contributing to a better understanding of the life history of one more economically important fish of the region.

This paper describes and illustrates the early larval development of striped mullet; gives occurrence of larval stages in the open ocean; discusses movement of the larvae from open ocean to inshore areas and their development and growth to juvenile size in the inshore areas; and discusses period and location of spawning.

## MATERIAL

General information concerning striped mullet larvae taken in plankton tows and by dip net during cruises of the MV. *Theodore N. Gill* is presented in tables 1 and 2; locations of capture are illustrated in figure 1. (Cruise 1, February 10 to March 10, 1953; cruise 2, April 16 to May 15, 1953; cruise 3, July 15 to August 16, 1953; cruise 4, October 1 to November 14, 1953; cruise 5, January 20 to February 25, 1954; cruise 6, April 14 to April 29, 1954; cruise 7, June 9 to July 13, 1954; cruise 8, August 27 to October 1, 1954; and cruise 9, November 3 to December 12, 1954.)

Occurrence of young striped mullet in the seine collections of two areas in Georgia (open ocean beach and salt marsh) with respect to date, approximate abundance, and size range is presented in tables 3 and 4.

NOTE.—Approved for publication, October 25, 1957. Fishery Bulletin 144.

TABLE 1.—*Larvae of the striped mullet* (Mugil cephalus) *taken in plankton tows on* Theodore N. Gill *cruises 5 and 9, in 1954*

[No larvae were taken on the other 7 cruises]

| Station number | Date | Position | | Number of larvae (standard length) | | | |
|---|---|---|---|---|---|---|---|
| | | North latitude | West longitude | 3–5 mm. | 5.1–7 mm. | 7.1–10 mm. | 10.1–20 mm. |
| Cruise 5: | | | | | | | |
| 2–3 | Jan. 30 | 27°02′ | 79°52′ | 1 | 1 | | |
| 3 | do | 27°00′ | 80°03′ | 2 | | | |
| 3–4 | do | 27°10′ | 80°04′ | 1 | | | |
| 4 | do | 27°20′ | 80°03′ | 14 | 2 | | |
| 10 | Feb. 1 | 28°19′ | 80°12′ | | 2 | | |
| 14 | Feb. 2 | 29°00′ | 80°10′ | | 3 | | |
| 50–49 | Feb. 15 | 32°00′ | 78°16′ | 1 | | | |
| 63 | Feb. 21 | 33°15′ | 76°22′ | | | | 1 |
| 71 | Feb. 22 | 34°03′ | 76°15′ | | | 1 | |
| Cruise 9: | | | | | | | |
| 51 | Dec. 4 | 32°20′ | 77°35′ | 1 | | | |
| 52 | do | 32°35′ | 77°47′ | 2 | | | |
| 59 | Dec. 5 | 33°22′ | 77°37′ | 1 | | | |
| 60 | do | 33°08′ | 77°20′ | 1 | | | |
| 70 | Dec. 8 | 34°18′ | 76°31′ | 1 | | | |
| 71 | do | 34°03′ | 76°15′ | | 1 | | |

TABLE 2.—*Larvae of the striped mullet* (Mugil cephalus) *taken in dip nets on* Theodore N. Gill *cruises 1 and 5, 1953–54*

[No larvae were taken on the other 7 cruises]

| Station number | Date | Position | | Number of larvae (standard length) | | | |
|---|---|---|---|---|---|---|---|
| | | North latitude | West longitude | 10.1–15 mm. | 15.1–20 mm. | 20.1–25 mm. | 25.1–31 mm. |
| Cruise 1: | *1953* | | | | | | |
| Cape Canaveral | Feb. 19 | 28°26′ | 80°32′ | | | 1 | |
| 35 | Feb. 26 | 31°20′ | 80°52′ | | | 1 | |
| 73 | Mar. 6 | 34°09′ | 75°22′ | | | 5 | 3 |
| Cruise 5: | *1954* | | | | | | |
| Standard Station | Jan. 24 | 26°20′ | 76°44′ | | | 1 | 1 |
| Office of Naval Research | Jan. 27 | 25°30′ | 76°30′ | | | | 1 |
| Do | Jan. 28 | 25°30′ | 76°30′ | 1 | | | |
| 4 | Jan. 30 | 27°20′ | 80°03′ | | | 1 | |
| 5 | do | 27°40′ | 80°03′ | | | 1 | |
| 6 | Jan. 31 | 27°40′ | 79°41′ | | | 2 | |
| 15 | Feb. 2 | 28°59′ | 79°48′ | | | 7 | 2 |
| 20 | Feb. 4 | 29°39′ | 80°45′ | | | 4 | |
| 37 | Feb. 10 | 31°38′ | 80°17′ | | 1 | 21 | |
| 38 | do | 31°36′ | 79°51′ | | 1 | 57 | |
| 49 | Feb. 15 | 32°11′ | 78°26′ | 1 | | | |
| 75 | Feb. 22 | 34°39′ | 75°53′ | | | 6 | |
| 76 | do | 34°53′ | 76°09′ | | 3 | | 2 |

TABLE 3.—*Occurrence of young striped mullet* (Mugil cephalus) *in seine collections on St. Simons Beach, Ga., by date, approximate abundance, and size range*

[Size—standard length]

| Date | Number | Approximate size range (mm.) | Date | Number | Approximate size range (mm.) |
|---|---|---|---|---|---|
| Jan. 4, 1956 | 34 | 22 to 26. | June 11, 1956 | 2 | 46 and 62. |
| Jan. 15, 1954 | Many | 20 to 25. | June 22, 1955 | 1 | 108. |
| Jan. 16, 1956 | 14 | 20 to 26. | July 21, 1953 | 1 | 107. |
| | 4 | 96 to 195. | July 24, 1956 | 7 | 79 to 116. |
| Jan. 28, 1954 | Many | 19 to 24. | Aug. 5, 1955 | 2 | 104 and 127. |
| Jan. 30, 1956 | Many | 18 to 27. | Aug. 8, 1956 | 1 | 131. |
| | 3 | 111 to 154. | Aug. 24, 1956 | 2 | 79 and 91. |
| Feb. 12, 1954 | Many | 20 to 28. | Sept. 9, 1956 | 2 | 75 and 85. |
| Feb. 15, 1956 | Many | 18 to 28. | Sept. 27, 1956 | 1 | 165. |
| | 1 | 150. | Oct. 5, 1955 | 5 | 151 to 157. |
| Feb. 29, 1956 | Many | 18 to 29. | Nov. 3, 1955 | 1 | 160. |
| Mar. 11, 1954 | 10 | 21 to 22. | Nov. 16, 1955 | 1 | 150. |
| Mar. 11, 1955 | 17 | 20 to 25. | Nov. 19, 1954 | 4 | 18 to 19. |
| Mar. 25, 1955 | 1 | 20. | Nov. 20, 1956 | 4 | 118 to 143. |
| Mar. 29, 1954 | 9 | 19 to 24. | Dec. 2, 1955 | Many | 114 to 171. |
| Mar. 29, 1956 | 43 | 19 to 35. | Dec. 8, 1953 | 5 | 20 to 21. |
| Apr. 13, 1956 | Many | 19 to 40. | Dec. 18, 1956 | 17 | 100 to 218. |
| May 14, 1956 | 1 | 164. | Dec. 19, 1955 | 33 | 19 to 22. |
| May 28, 1956 | 1 | 53. | | 2 | 102 and 111. |

Mrs. Fanny Lee Phillips kindly loaned me a collection of small striped mullet she obtained at Miami, Fla.: Crandon Park, January 21, 1957, 7 specimens about 8 to 12 mm. standard length; Crandon Beach, January 22, 1957, 5 specimens about 8 to 11 mm.; Crandon Park Beach, January 27, 1957, 5 specimens about 12 to 15 mm.; and Crandon Park Beach, January 28, 1957, 4 specimens about 14 to 18 mm.

## METHODS

The manner of conducting plankton tows, dip netting, and all other procedures used aboard the MV. *Theodore N. Gill* are discussed in Anderson, Gehringer, and Cohen (1956).

Seine collections in Georgia on the open ocean beach on St. Simons Island and in the marshy

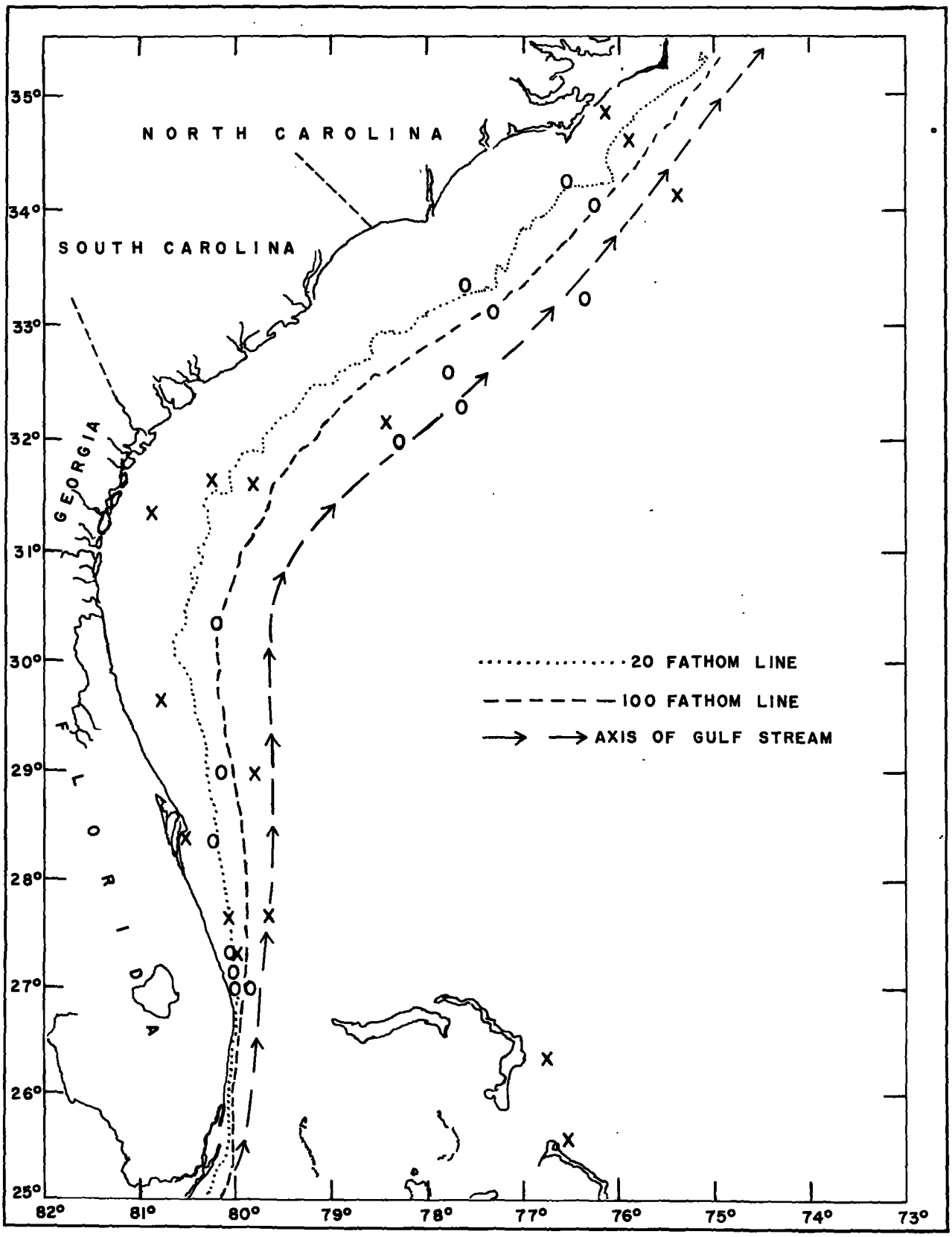


FIGURE 1.—Locations of capture of striped mullet larvae in plankton tows (circles), and by dip nets (X). (See tables 1 and 2 for occurrence data.)

TABLE 4.—*Occurrence of young striped mullet* (Mugil cephalus) *in seine collections in Sapelo Marsh, Ga., by date, approximate abundance, and size range*

[Size—standard length]

| Date | Number | Approximate size range (mm.) | Date | Number | Approximate size range (mm.) |
|---|---|---|---|---|---|
| Jan. 4, 1956 | 16 | 22 to 28. | Apr. 27, 1956 | Many | 21 to 43. |
| Jan. 15, 1954 | Many | 19 to 29. | | 1 | 154. |
| Jan. 16, 1956 | 1 | 22. | May 4, 1954 | 1 | 56. |
| Jan. 28, 1954 | Many | 20 to 28. | May 6, 1953 | Many | 37 to 62. |
| Jan. 30, 1956 | Many | 19 to 23. | May 18, 1954 | 7 | 58 to 72. |
| Feb. 12, 1954 | Many | 19 to 29. | May 20, 1953 | 3 | 50 to 64. |
| Feb 15, 1956 | Many | 22 to 28. | May 24, 1955 | 15 | 39 to 62. |
| | 2 | 128 and 141. | May 28, 1956 | 47 | 30 to 53. |
| Feb. 29, 1956 | 12 | 20 to 25. | June 9, 1955 | 1 | 48. |
| Mar. 11, 1954 | Many | 24 to 37. | June 11, 1956 | 29 | 39 to 54. |
| Mar. 11, 1955 | Many | 24 to 34. | June 18, 1953 | 1 | 63. |
| Mar. 15, 1956 | Many | 22 to 32. | June 26, 1956 | 10 | 35 to 54. |
| | 3 | 92 to 118. | July 8, 1955 | 1 | 60. |
| Mar. 24, 1953 | Many | 24 to 40. | July 10, 1956 | 7 | 43 to 65. |
| Mar. 25, 1955 | Many | 24 to 34. | July 24, 1956 | 13 | 47 to 61. |
| Mar. 29, 1954 | Many | 22 to 40. | Aug. 8, 1956 | 2 | 59 and 69. |
| Mar. 29, 1956 | Many | 19 to 34. | Sept. 19, 1955 | 2 | 60 and 80. |
| Apr. 8, 1955 | Many | 20 to 40. | Oct. 14, 1955 | 1 | 97. |
| Apr. 13, 1956 | Many | 22 to 38. | Oct. 23, 1956 | 2 | 80 and 91. |
| Apr. 16, 1954 | Many | 20 to 52. | Nov. 3, 1955 | 2 | 114 and 143. |
| | 3 | 118 to 130. | Nov. 16, 1955 | 1 | 125. |
| Apr. 22, 1953 | Many | 26 to 56. | Dec. 2, 1955 | 1 | 145. |
| Apr. 25, 1955 | Many | 30 to 50. | | | |

estuarine area behind Sapelo Island were maintained on a biweekly basis from 1953 to 1956.

Measurements of larvae up to about 30 mm. standard length were made with a stereoscopic microscope and a micrometer eyepiece; larger specimens were measured with calipers.

Descriptions are based on preserved material unless stated otherwise.

In discussions of body proportions, only standard lengths (in small specimens from the tip of the snout to tip of the urostyle) were used; in other discussions, the larvae up to a total length of about 7 mm. are referred to in total lengths (in small specimens from tip of snout to tip of finfold or caudal fin), and above 7 mm. in standard length.

The curves portraying rates of growth of body parts and changes in certain body proportions were constructed from original measurements.

The method of presenting larval development is the same as that used for silver mullet, *Mugil curema* Cuvier and Valenciennes (Anderson 1957a). This generally follows Ahlstrom and Ball (1954) in discussing sequences of fin formation, body proportions, and pigmentation.

## OCCURRENCE OF LARVAL AND JUVENILE FORMS

All available data indicate that most young striped mullet remain at sea (over a broad area from North Carolina to southern Florida) until they are from about 18 to 28 mm. long (but largely 20 to 25 mm.), at which time they move into the coast. They have apparently all moved inshore by early spring, as none were dip netted after early March (table 2).

In Georgia, these young appear on the outer beaches as early as November (earliest date recorded was November 19, table 3), but apparently do not go into the marshy estuarine waters until January. They are abundant along the beaches and in the marshy areas during January, February, March, and April; are apparently absent from the outer beaches during May and June, but abundant in the marsh areas during these months, indicating the population of young to be largely in the estuarine areas by May (tables 3 and 4).

During the summer and fall months these young of less than a year of age appear to scatter out so that they are never taken in abundance.

## DEVELOPMENT FROM LARVAL TO JUVENILE STAGES

The smallest larva available was 4.0 mm. total length (3.9 mm. standard length). A developmental series from this larval size to a juvenile size of about 116 mm. is figured and described.

### DEVELOPMENT OF FINS

#### Caudal

When fully developed, the caudal fin has 14 principal rays of which 12 are branched. There are usually about 15 secondary rays of which 7 are dorsal and 8 ventral.

At 4.0 mm. total length (fig. 2) the caudal shows evidence of development by a deep constriction of the finfold and a thickening ventral to the urostyle with initial development of about 7 rays. By 5.4 mm. (fig. 3) the fin has rounded, increased in size, and there is a distinct caudal peduncle, although the finfold is still evident; the urostyle has flexed upward and the 14 principal rays, plus

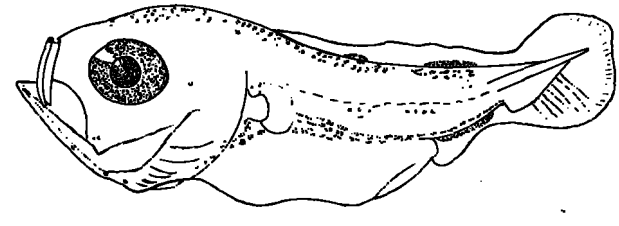

FIGURE 2.—Larva, 4.0 mm. total length.

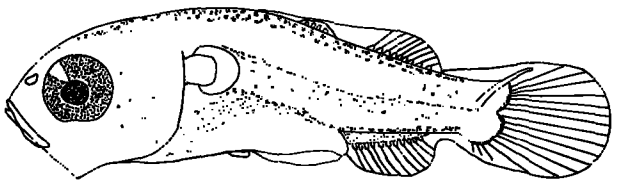

FIGURE 3.—Larva, 5.4 mm. total length.

about 3 ventral secondary rays, are visible. At about 6.7 mm. (fig. 4) some finfold remains, the fin has further increased in size, the caudal peduncle has changed form, the urostyle has reached its maximum flexion, and two dorsal secondary rays have developed. By 6.2 mm. standard length (7.9 mm. total length) the fin has lost the finfold and has about 4 each of dorsal and ventral secondary rays (fig. 5). A full complement of rays, 14 principal and 15 secondary, is present on the 9.7-mm. standard length specimen (fig. 6). By 12.1 mm. (fig. 7) forking of the fin has begun and the middle six of the principal rays are branched. Twelve rays are branched by 19.8 mm. (fig. 8) and the fin has reached final shape by 116 mm. (figs. 9 to 11). Only main forking of the 12 branched principal rays is shown in figures 10 and 11.

The caudal skeleton of a 25-mm. specimen is illustrated in figure 12. It is almost identical to the caudal structure given for *M. curema* by Hollister (1937, pp. 271–274).

**Dorsals**

A normal complement of rays consists of 4 spines in the first dorsal, and 1 spine and 8 soft-rays in the second dorsal.

Development of the dorsal fins is evident at 4.0 mm. total length by a thickening at the position of the bases (fig. 2), although the ray bases cannot be distinguished; the dorsal finfold is prominent and continuous with the caudal finfold. By 5.4 mm. (fig. 3) the 4 ray bases of the first dorsal are evident, the ray bases and 9 rays of the second dorsal (full complement) are well developed, and the finfold has become reduced and changed in shape. At 6.7 mm. (fig. 4) the 4 spines of the first dorsal are well developed and the rays of the second dorsal have increased in length; the finfold is still visible. The finfold has disappeared by 6.2 mm. standard length (7.9 mm. total length), and both spines and rays have increased in length (fig. 5). Branching has occurred in the last ray of the second dorsal by 9.7 mm. (fig. 6), in the last 2 rays at 12.1 mm. (fig. 7), in the last 7 rays at 19.8 mm., and barely in the first soft-ray at 26.9 mm. Development of

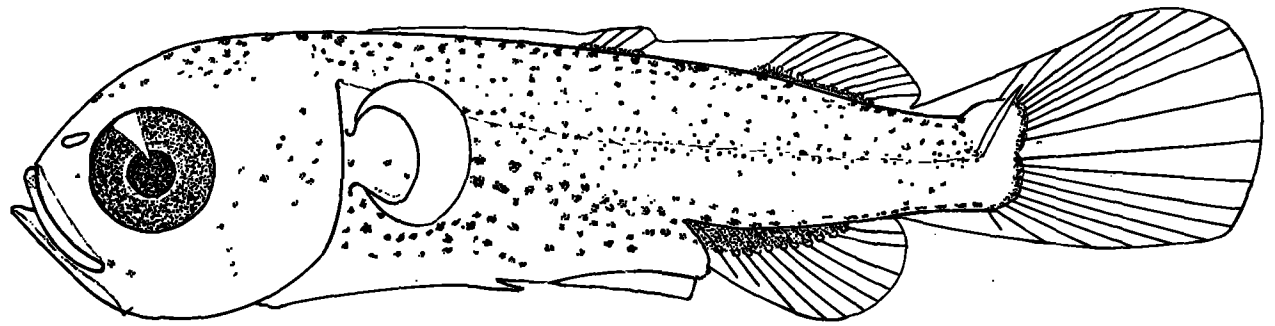

FIGURE 4.—Larva, 6.7 mm. total length.

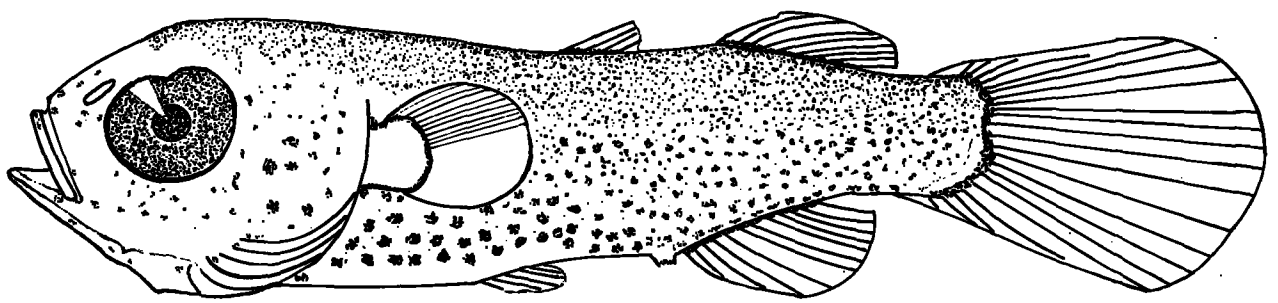

FIGURE 5.—Larva, 6.2 mm. standard length (7.9 mm. total length).

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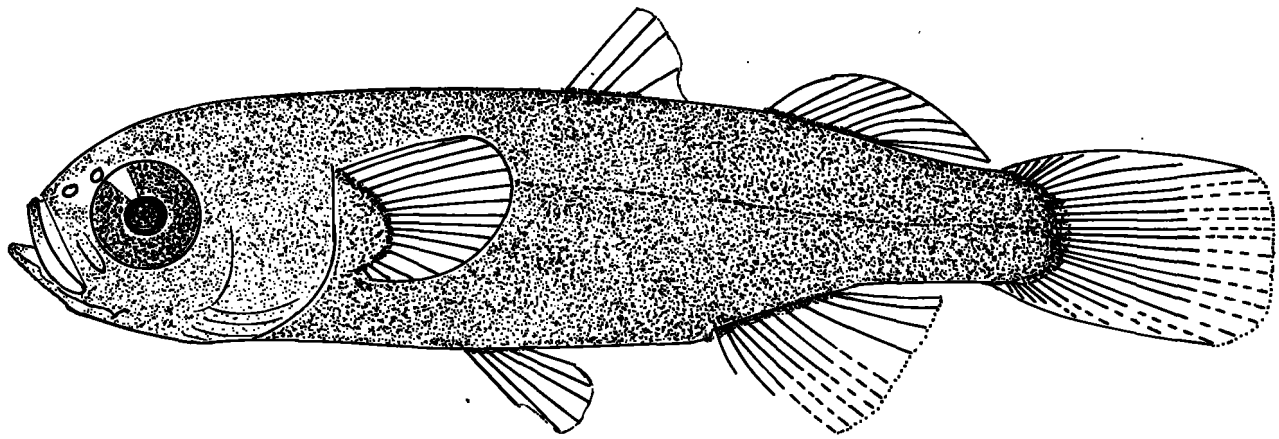

FIGURE 6.—Larva, 9.7 mm. standard length.

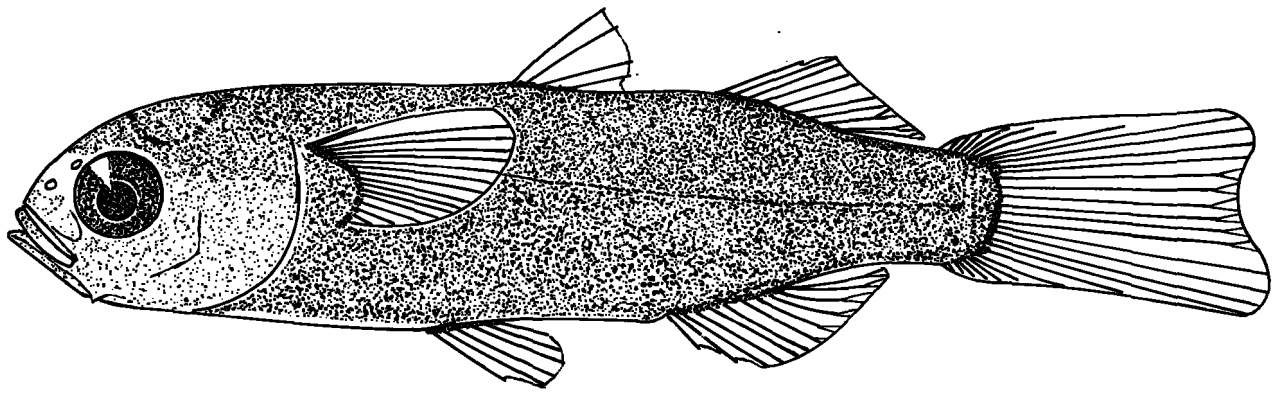

FIGURE 7.—Larva, 12.1 mm. standard length.

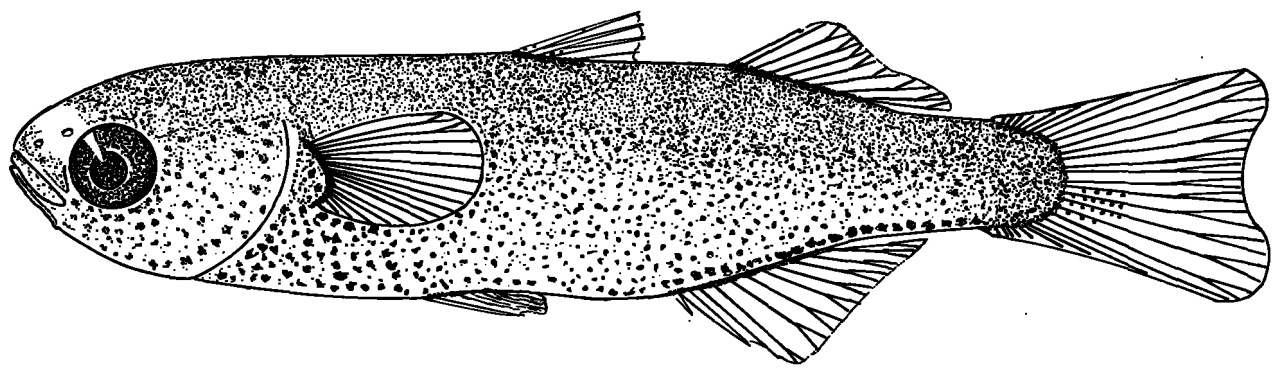

FIGURE 8.—Larva, 19.8 mm. standard length.

the dorsal fins to final shape is illustrated in figs. 8 to 11.

**Anal**

Juvenile and adult striped mullet have 3 spines and 8 branched soft-rays in the anal fin. Larval striped mullet have 2 spines and 9 soft-rays, the third spine forming from the first soft-ray when the young are between about 35 and 45 mm. standard length. I class the specimens as juveniles when this third anal ray has fused into a spine.

The developing anal base is visible at 4.0 mm. total length (fig. 2), although no ray bases have formed. By 5.4 mm. (fig. 3) the full complement of anal rays (11) has developed. Branching has occurred in the last ray at 6.2 mm. standard length (7.9 mm. total length), in the last 5 rays at 12.1

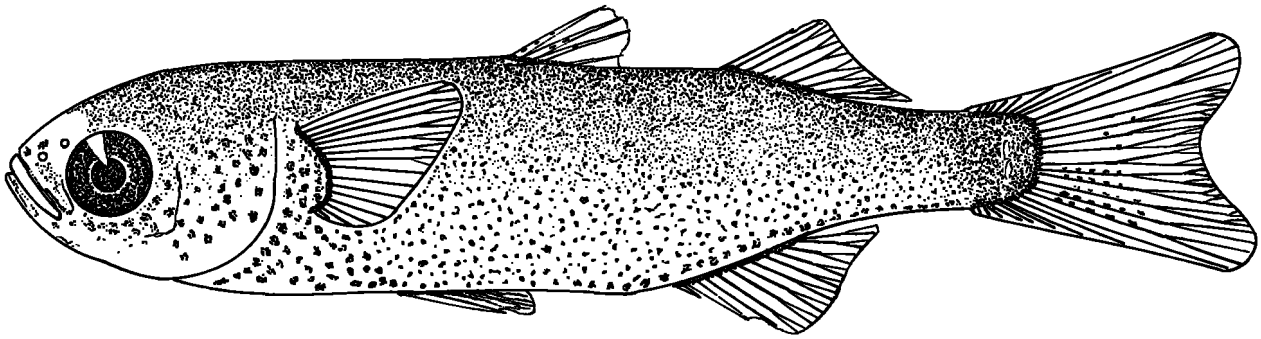

FIGURE 9.—Larva, 26.9 mm. standard length.

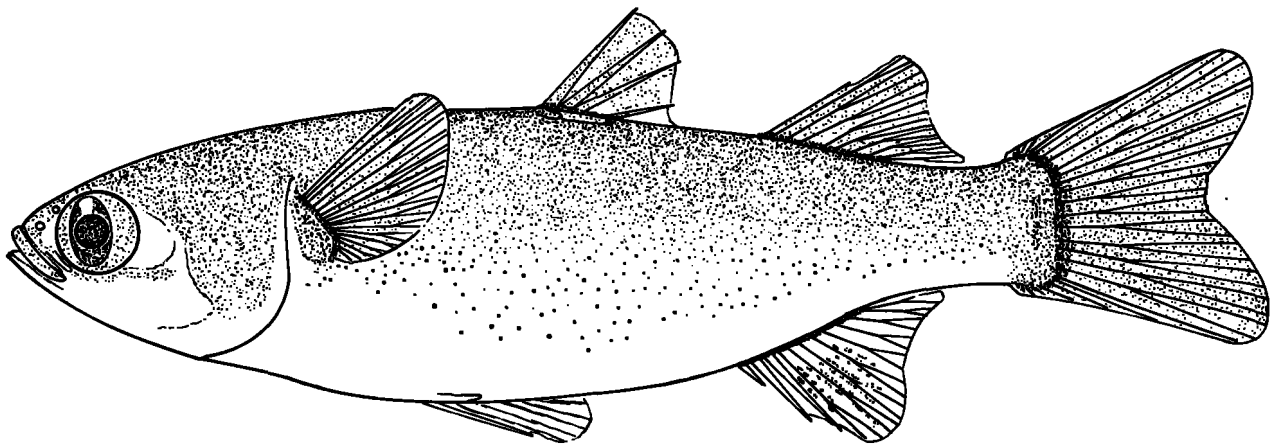

FIGURE 10.—Juvenile, 55 mm. standard length.

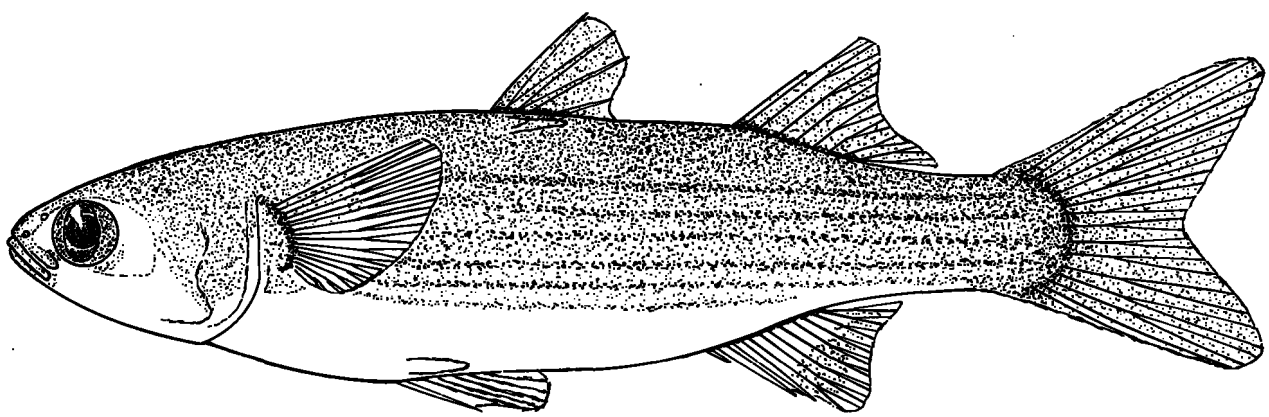

FIGURE 11.—Juvenile, 116 mm. standard length.

mm., and in the last 8 rays by 19.8 mm. (figs. 5 to 8). The finfold is lost between 6.7 and 7.9 mm. total length (figs. 4 to 5). Final fin shape is reached in juveniles between 55 mm. and 116 mm. (figs. 10 and 11).

**Pectorals**

The pectoral fin is evident at 4.0 mm. total length as a fleshy, rayless structure. No rays are discernible at 6.7 mm. total length but at 6.2 mm. standard length (7.9 mm. total length) 9 or 10 rays have developed in the upper part of the fin (figs. 4 and 5). The full complement of rays (16 or 17—rarely 15 or 18) is present in the 9.7-mm. specimen (fig. 6). Branching of the rays and development of this fin to final shape are demonstrated in figures 8 to 11.

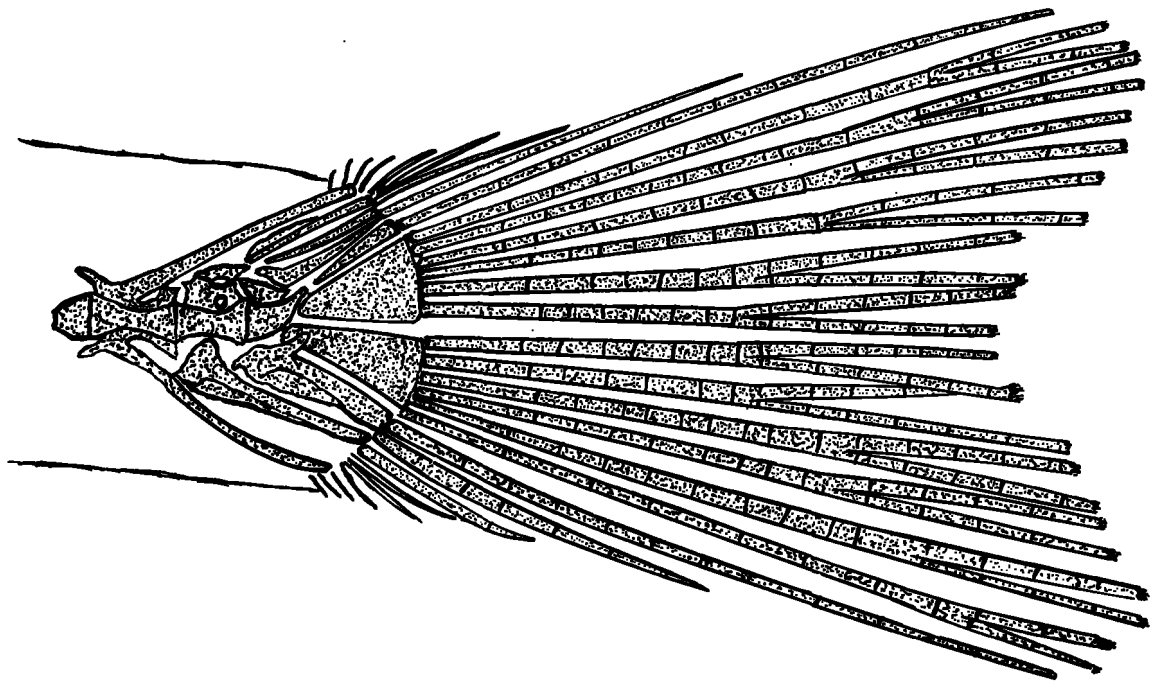

FIGURE 12.—Caudal skeleton of a 25-mm. specimen. (Camera Lucida drawing from cleared and stained material.)

**Ventrals**

Ventral-fin buds are not present at 4.0 mm. total length but have formed by 5.4 mm. (figs. 2 and 3). Rays are present at 6.2 mm. standard length (7.9 mm. total length) and the full complement of 6 rays is present at 9.7 mm. (figs. 5 and 6).

## PIGMENTATION

At about 4.0 mm. total length (fig. 2) pigment spots occur dorsally from the head through the position of the second dorsal fin, on the ventral aspect of the body from the anus to the developing caudal peduncle and along the dorsal surface of the body cavity from the pectoral fin to the anus, scattered along the midline of the body, and scattered sparsely on the sides of the head.

In the sea-stage larvae, from about 5 to 27 mm., development of pigment on the body and head is a process of spreading and intensifying as illustrated in figures 3 to 9. One of the striking characteristics is the large, less-numerous melanophores on the ventral aspect of the body as compared with the smaller, more numerous ones of the dorsal aspect. In some specimens, as in figures 6 and 7, the more typical pigmentation described gives way to pigmentation so dense as to make the specimens almost black.

In juveniles of about 55 mm. (fig. 10) the larger melanophores have disappeared and the fish have a peppered appearance with numerous small pigment spots on the dorsal aspect which thin rapidly toward the belly—pigment is absent on the lower sides of the head and body. Between this size and about 116 mm. the typical "striped" pigmentation develops (fig. 11).

At 12.1 mm. (fig. 7) there is no pigmentation in any of the fins, but at 19.8 and 26.9 mm. there are a few pigment spots in the first dorsal fin and a patch on the caudal fin (figs. 8 and 9). By 55 mm.—and remaining essentially the same at 116 mm.—pigment has developed in the second dorsal, anal, and pectoral fins, and has intensified as illustrated in figures 10 and 11.

Young striped mullet go through what has been termed a "silvery" stage. Kilby's (1949, p. 15) description is better than most accounts in the literature:

> Living individuals are of a brilliant silver ventrally and laterally and show no pattern on the sides. Dorsolaterally the silver becomes progressively duller until the color reaches a dusky tan on the dorsal surfaces of the head and body. All surfaces are irridescent and show flashes of pale, whitish blue as the light strikes the fish from different angles.

His smallest specimens were 16 mm. standard length. He also states that the silvery coloration fades rapidly when the specimens are preserved in formalin and becomes dull and dusky within a few days. Jacot (1920, p. 205) found this "silvery" stage in specimens 23 mm. (his smallest) to about 32 mm. total length, but found it difficult to distinguish those from 30 to 35 mm. as silvery or dusky, because the two colors merged at this size.

## BODY PROPORTIONS

The relations of distances from snout to insertions of the first dorsal fin, second dorsal fin, and anal fin, to standard length show less variation than the other characters studied. There is an initial rapid rate of increase up to about 6 mm., a slowing down between about 6 mm. and 25 to 30 mm., a slight upward shift in the regression lines at about 25 to 30 mm., and then rather uniform development to about 200 mm. These relationships are illustrated in figures 13 and 14.

The relations of head length, eye diameter, and body depth at pectoral to standard length are illustrated in figures 14 and 15. The same general pattern of development occurred as in relations of distances from snout to insertions of fins to standard length—an initial rapid rate of increase to about 6 mm., a slowing down between 6 mm. and 25 to 30 mm., an upward shift in the regression lines at about 25 to 30 mm. (30 to 40 mm. for eye diameter), followed by a rather uniform rate of development to about 200 mm.—but the variations were greater. I found a similar pattern of development in the silver mullet, *M. curema* (Anderson 1957a).

## MISCELLANEOUS STRUCTURES

### Scales

These structures begin to develop when the larvae are between 8 and 10 mm. standard length, and are well developed and evident over the body and head in specimens 12 to 14 mm. Jacot (1920) gave a detailed account of scale characters and development in young from about 23 mm. total length (about 19 mm. standard length) up to adults.

### Preorbital

The preorbital bone becomes evident in specimens between 8 and 10 mm. standard length, but there are no serrations at this stage—serrations become evident in specimens between 15 and 19 mm. I found a range of from 7 to 13 serrations on the preorbital bones of larvae between about 19 and 30 mm. Anderson (1957b) illustrates the preorbital, maxillary, and premaxillary bones of a 30-mm. specimen of *M. cephalus* in comparison with those of *M. curema* and *Agonostomus monticola* (Bancroft). Jacot (1920, p. 205) said of *M. cephalus*—

> The *preorbital* in the juvenile stage has some 10 or 12 points, teeth or serrations, of fair size. As the fish grows these points become more and more numerous, less slender and less distinct. In older fish they become blunt and stocky until in a large individual (502 mm.) there were 53 teeth on the margin, crowded so as to place about 4 to a millimeter.

### Teeth

The best description of adult teeth characters for the genus *Mugil* is given by Schultz (1946, p. 389)—

> the teeth in the lower lip are setiform or ciliform, partly embedded or conspicuous; teeth in upper lip similar. The outer row of teeth in both lips is usually more prominent, with simple tips, and if inner rows occur these are either bifid or trifid, at least on adults (apparently the teeth in certain species of this genus become bifid or even trifid in large adults); * * *

He also stated—

> In this genus I find that in small specimens of certain species the teeth have simple tips, but later the inner teeth have bifid tips and in the largest adults some possess trifid tips. The teeth of the outer row usually have simple tips, but in some large specimens these are bifid too.

I found no evidence of developing teeth in a series of striped mullet larvae ranging between 12 and 15 mm. In a 17.5-mm. specimen, I found a single row of 8 to 10 small, simple-tipped teeth barely protruding from each half of the upper lip—none in the lower lip. In cleared and stained specimens of about 19.5 mm., I found from 15 to 20 simple-tipped teeth in a single row in each half of the upper lip—none in the lower lip. A cleared and stained 25-mm. specimen had about 23 to 24 simple-tipped teeth in a single row in each half of the upper lip (these teeth were beginning to curve inward at the tips), and a single row of about 15 simple-tipped teeth in each half of the lower lip.

Cleared and stained mouthparts of a 52-mm. specimen revealed the upper lip had a double row of teeth—the outer row having much larger teeth, which curved inward at the tips much in resemblance of a leaf rake. There were about 42 to 44 simple-tipped teeth to each side of the lip in the

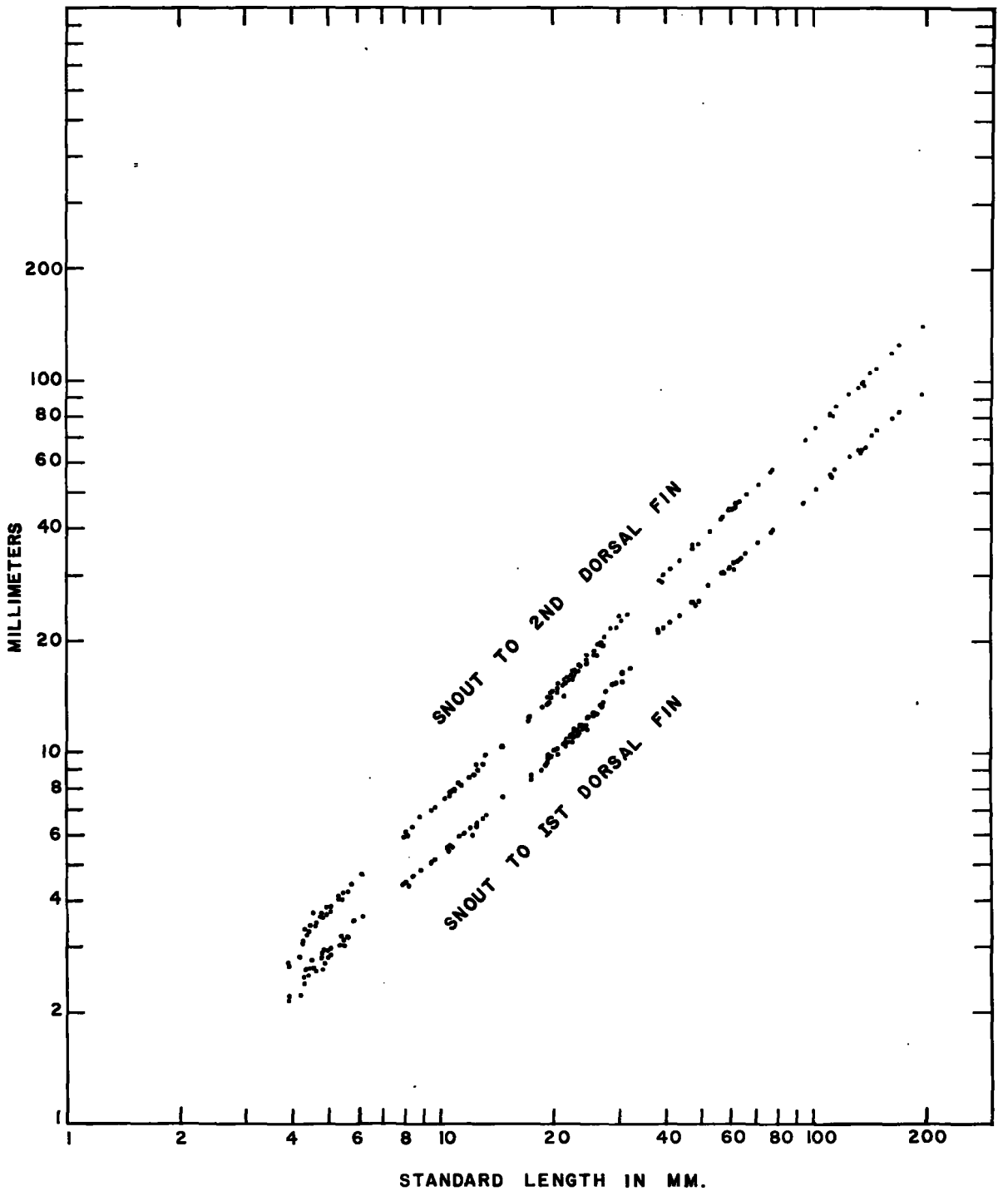


FIGURE 13.—Relation of the distances from snout to insertions of first and second dorsal fins to standard length. (Specimens smaller than 7 mm. were from plankton tows in open ocean; some specimens about 8 to 18/⑱ mm. were taken near Miami, Fla. (see Material, p. 502), and some were dip netted in open ocean; specimens 15 to 28 mm. were dip netted in open ocean; and those 29 to about 200 mm. were seined from marsh and beach areas in Georgia.)

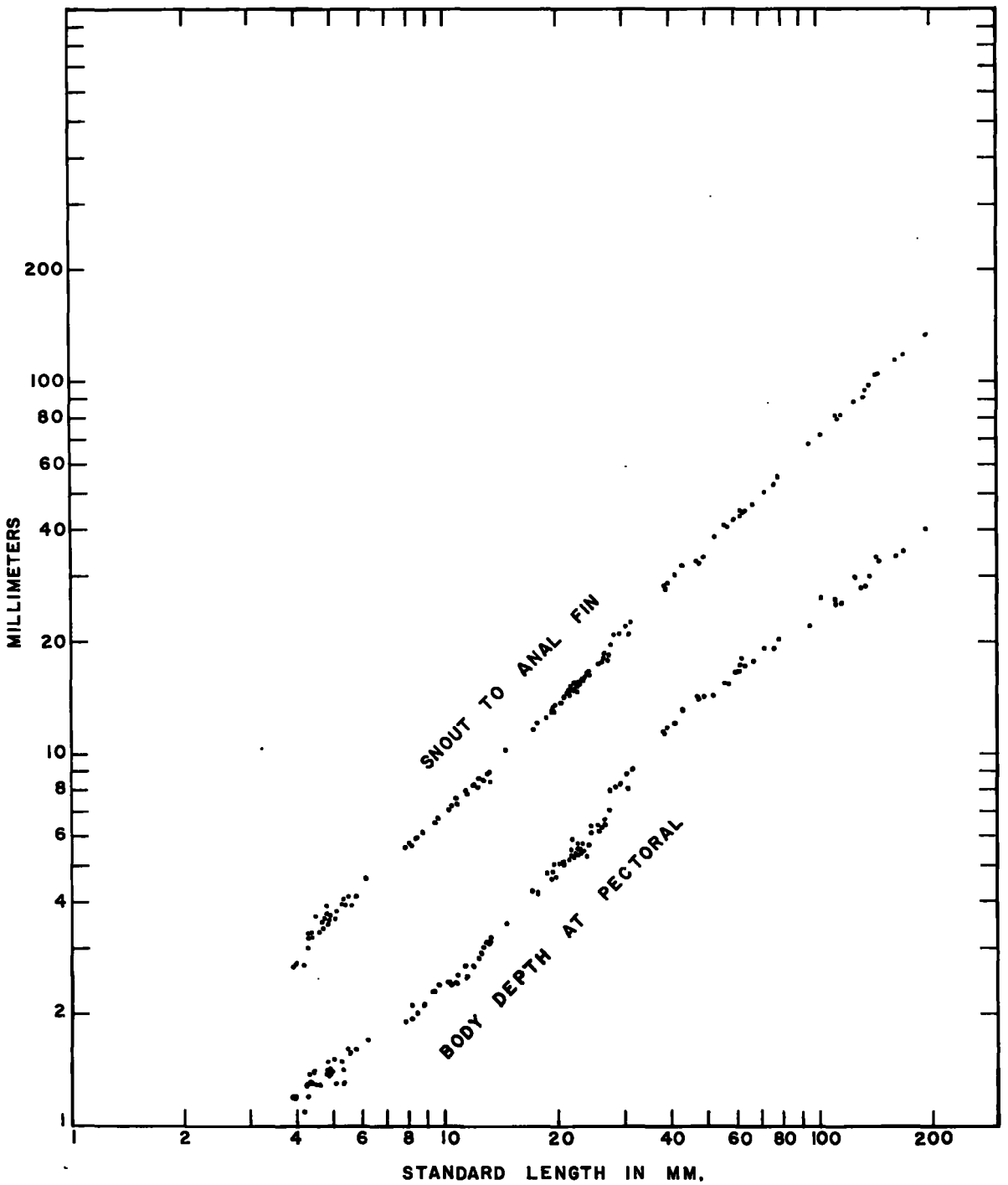


FIGURE 14.—Relation of the distance from snout to insertion of anal fin and of body depth at pectoral to standard length.

outer row, and about 33 to 35 inward pointing, bifid-tipped teeth to each side in the inner row. The lower lip had about 45 to 48 simple-tipped teeth in a single row to each half of the lip.

In the cleared and stained mouthparts of a 105-mm. specimen, there were about 62 to 64 teeth with simple tips to each half of the upper lip in the outer row. The inner set of teeth of the

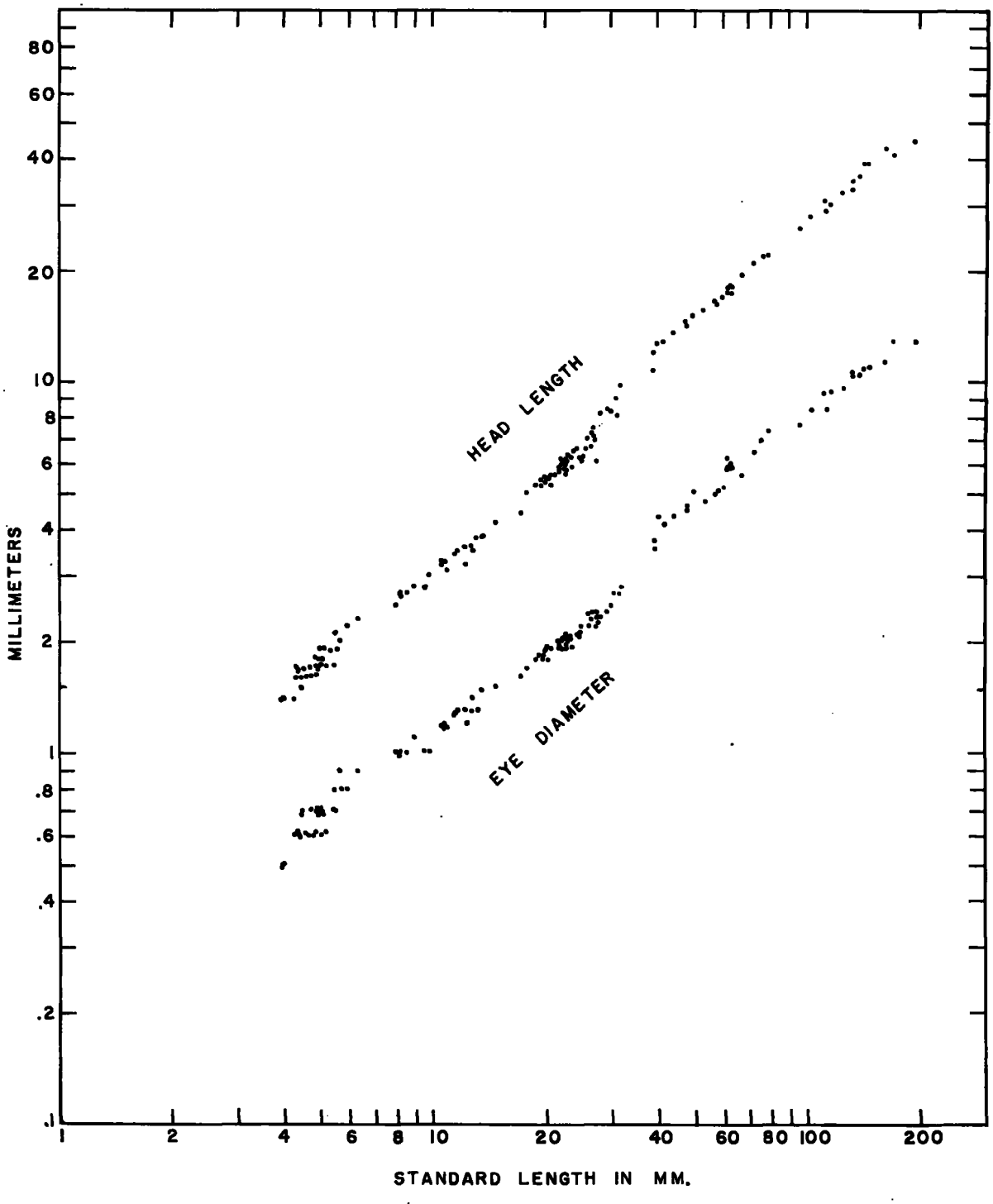


FIGURE 15.—Relation of head length and of eye diameter to standard length.

upper lip was no longer in a single series, but rather was "brushlike" in arrangement with 2 to 4 close-set rows—there were about 130 to 150 teeth to each half of the lip, all with bifid tips and curving inward. There were two rows of teeth in a single series in the lower lip—those of the outer row much the larger. In the outer row, there were 80 to 85 teeth to each half of the lip, all with simple

upcurved tips; and in the inner row from 50 to 55 to each half of the lip, all with bifid tips.

Schultz (1946, p. 389) indicated that in the genus *Mugil*, teeth are probably not present on the vomer, palatines, and tongue. Examinations of cleared and stained material of *M. cephalus* verified the absence of teeth on the vomer and palatines.

The tongue presents a peculiar picture of development of teeth in the larval and juvenile stages and of their loss in the adult stage. In a 19-mm. standard length specimen, about 16 small, simple-tipped teeth were arranged around the edges of the tongue (fig. 16). Development of the teeth and bony structures supporting them in specimens of 29, 59, and 117 mm. standard length is illustrated in figures 17 to 19. The tongue from a 390-mm. adult had no teeth on the outer surface, but when the outer covering of the tongue was removed the bony structures (without teeth) shown in figure 20 were found embedded in the tongue. It would appear that with age the teeth and supporting structures are overgrown, with the teeth and at least part of the bony structures being absorbed.

The cleared and stained tongues from 60-mm. and 122-mm. specimens of *M. curema* had no teeth or bony structures.

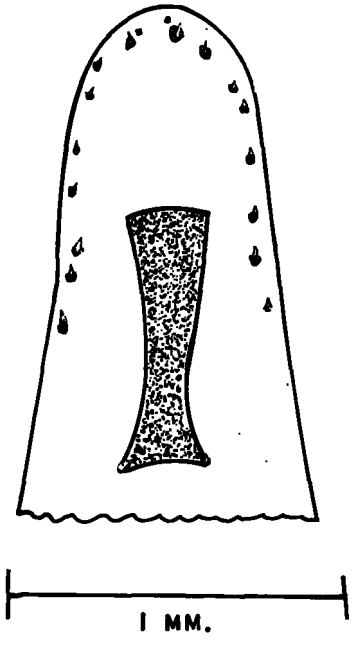


FIGURE 16.—Teeth on the tongue of a 19-mm. specimen. (Camera Lucida drawing from cleared and stained material.)

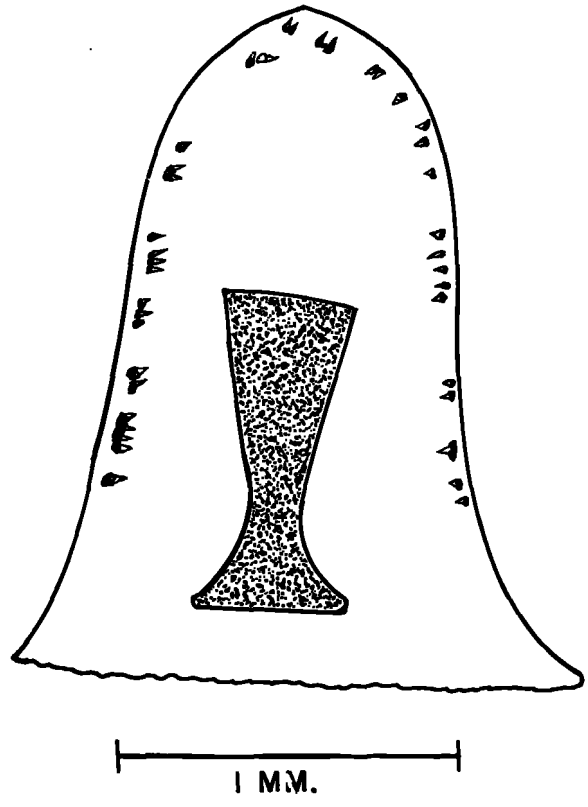


FIGURE 17.—Teeth on the tongue of a 29-mm. specimen. (Camera Lucida drawing from cleared and stained material.)

**Adipose eyelid**

This structure is not evident in specimens under 30 mm., but appears to begin development at sizes between 30 and 40 mm. By about 50 mm. it is well developed and covers much of the eye (fig. 10). A detailed account of this structure is given by Jacot (1920, pp. 205–206).

**Nostrils**

The nostril is single and oval in shape at 5.4 mm. total length, the opening becomes gradually longer and slenderer up to 6.2 mm. standard length, and the nostril is double with well-separated openings at 9.7 mm. (figs. 3 to 6).

**Gill rakers**

Adults have been reported to have as many as 83 gill rakers on the lower limb of the first arch (Fowler 1936, p. 585). The number of gill rakers increases with age or size, as I found the following counts of gill rakers on the lower limb of the first arch in a series of larval and juvenile specimens: 15 in a 19-mm. standard length fish; 22 in a 29-

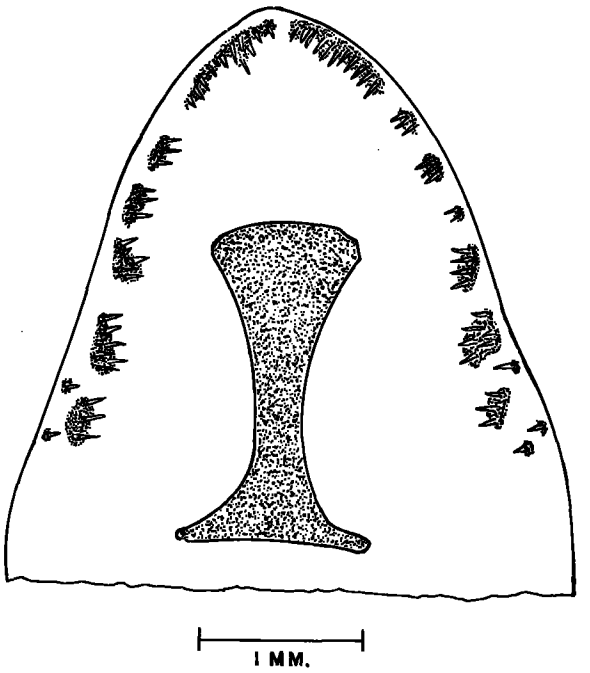


FIGURE 18.—Teeth on the tongue of a 59-mm. specimen. (Camera Lucida drawing from cleared and stained material.)

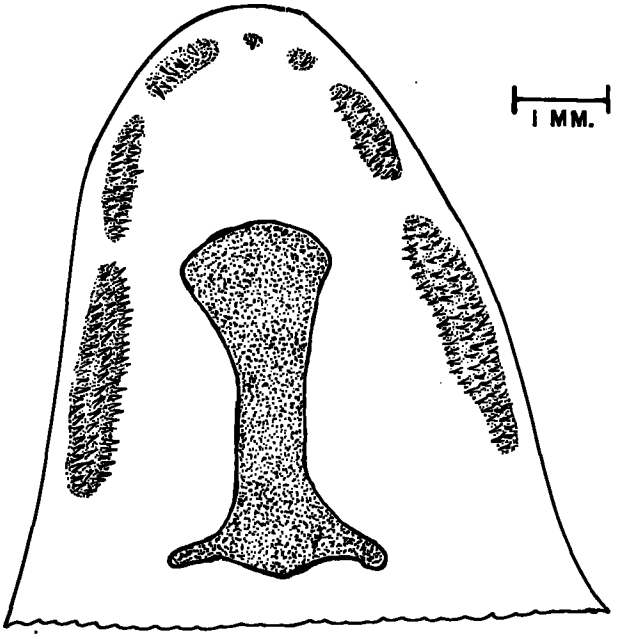


FIGURE 19.—Teeth on the tongue of a 117-mm. specimen. (Camera Lucida drawing from cleared and stained material.)

mm. specimen; 32 in a 59-mm. specimen; and 48 in a 117-mm. specimen.

## GROWTH

Two investigators have estimated the growth of striped mullet along the south Atlantic coast of the United States.

Jacot (1920, p. 220), working largely in North Carolina, said, "The arrival of the jumping mullet in April marks the beginning of its second season on our Atlantic coast; its age ranges from 14 to 17 months and its size from 120 to 200 mm. (5 to 8 inches)." Converted to standard lengths these fish would be 95 to 160 mm. In his summary (p. 227), Jacot said the fish have reached a foot or more (300+ mm. total length or 235 mm. standard length) by the second fall (October and November), and are 2 years old and mature.

Higgins (1928, pp. 528–529), also working in North Carolina, stated—

> Juvenile mullet of 22 millimeters body length appear at Beaufort by the middle of January. They become more abundant during February, March, and April, but there is little growth until the middle of April, when the water temperature reaches about 20° C. In May the rate of growth increases rapidly and continues, at an average of approximately 2 centimeters per month, through October.

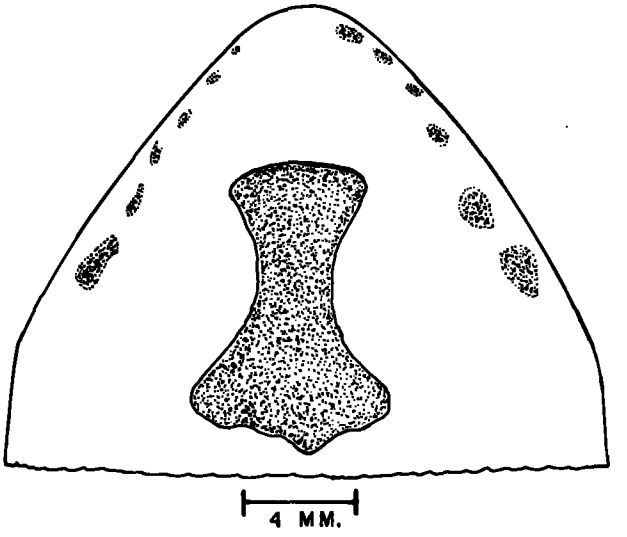


FIGURE 20.—Bony structures in the tongue of a 390-mm. specimen. (Camera Lucida drawing from cleared and stained material.)

He also said,

> The yearling stock that appears at Beaufort in the middle of January as individuals less than 1 inch long and attains a total length of about 7 inches by October seldom is taken.

(Seven inches=177 mm. total length or about 140 mm. standard length.) Higgins also indicated

(p. 626) that in the sounds during the winter and spring months he found a size group of mullet which ranged from 110 to 180 or 190 mm. body length (approximates standard length).

For Georgia, I estimated the growth of striped mullet from the seine material. The first recruits appeared along Georgia beaches in November when about 18 or 19 mm. standard length (fig. 21). By January, the largest of these recruits were about 29 mm., indicating a growth of only 5 mm. a month. No growth was evident during the coldest winter months, but between February and March the growth was about 10 mm.—this coincides with warming of the waters along the Georgia coast (Anderson 1957a). From March to October, increase in size progresses at a rate of about 17 mm. a month. From these data it appears that striped mullet in Georgia from the earliest spawning (October; see Spawning, p. 518) reach a length of about 160 mm. standard length by the end of their first year. Those spawned later in the season, and hence being several months younger, reach a size of 90 to 100 mm. by winter (fig. 21).

During the winter and early spring (November to April), it is evident that at least two year classes of striped mullet are represented in the seine collections (fig. 21). The older group, which ranges in size from about 95 to 160 mm., represents fish late in their first year to early in their second year of life (a similar situation was reported for North Carolina by both Higgins and Jacot). Applying the growth rate of 17 mm. a month, it seems quite probable that the smallest of these would reach a size of about 200 mm. by late fall or at approximately 2 years of age (Jacot estimated 300+ mm. total length or about 235 mm. by the second fall and 2 years old). We captured only a few of these larger mullet.

Kilby (1949, p. 19), from work on the west coast of Florida said,

> Assuming that the larger specimens collected in succeeding months represent the larger specimens of preceding months, it appears that a given specimen of 18 mm. in October may reach approximately 27 mm. by late November, 35 mm. by the latter half of January, 54 mm. by mid-March, and 65 mm. by mid-April.

This growth is comparable to the rate of increase I have found for the species in Georgia, but indicates a more steady rate of growth not interrupted by a period of no growth during midwinter.

Gunter (1945, p. 51), from work in lower Texas, indicates that the young striped mullet appear on Texas beaches as early as November at a size of 24 to 25 mm. total length (about 20 mm. standard length) and that the largest of these reach a size of about 108 mm. total length (about 87 mm. standard length) by June. This rate of growth is identical to that which I find for the species in Georgia. However, Gunter indicates the largest specimens of this group to be 148 mm. total length (about 117 mm. standard length) in November at about 1 year of age. This growth rate from June to November is much lower than the rate I found for Georgia and Higgins found for North Carolina. I believe, as Gunter himself suggested, that some of his mullet in these later months were *M. curema*—this would more nearly fit the size range that might be expected at this time of year for *M. curema* (Anderson 1957a).

In summary, it appears that the growth rates of striped mullet as indicated by these studies in widely separated sections of the south Atlantic and Gulf coasts of the United States are quite comparable, except that in North Carolina a more extended winter season delays growth for a longer period in the spring. Figure 22 is a diagrammatic presentation of the growth rates, for the first year only, as presented by various workers from North Carolina to Texas.

## SPAWNING

Suggestions as to time and place of spawning for the striped mullet along the south Atlantic and Gulf coasts of the United States have been made by several investigators. Before presenting my own findings, a summary of these previous observations is desirable.

Jacot (1920), from work in North Carolina, said that spawning occurs from September to December with peak spawning in October and November. He indicated with reference to place of spawning (p. 222) that "they move slowly down the coast *en masse* both outside and inside the Banks, spawning as necessity demands."

Higgins (1928, p. 625), also working in North Carolina, said—

> At present no spawning fish have been observed, nor have the eggs been taken in tow nets, but it is believed that proper means will reveal the presence of eggs in the open sea. As the fish with evidently mature eggs are taken on their seaward migration at this time of year, spawning

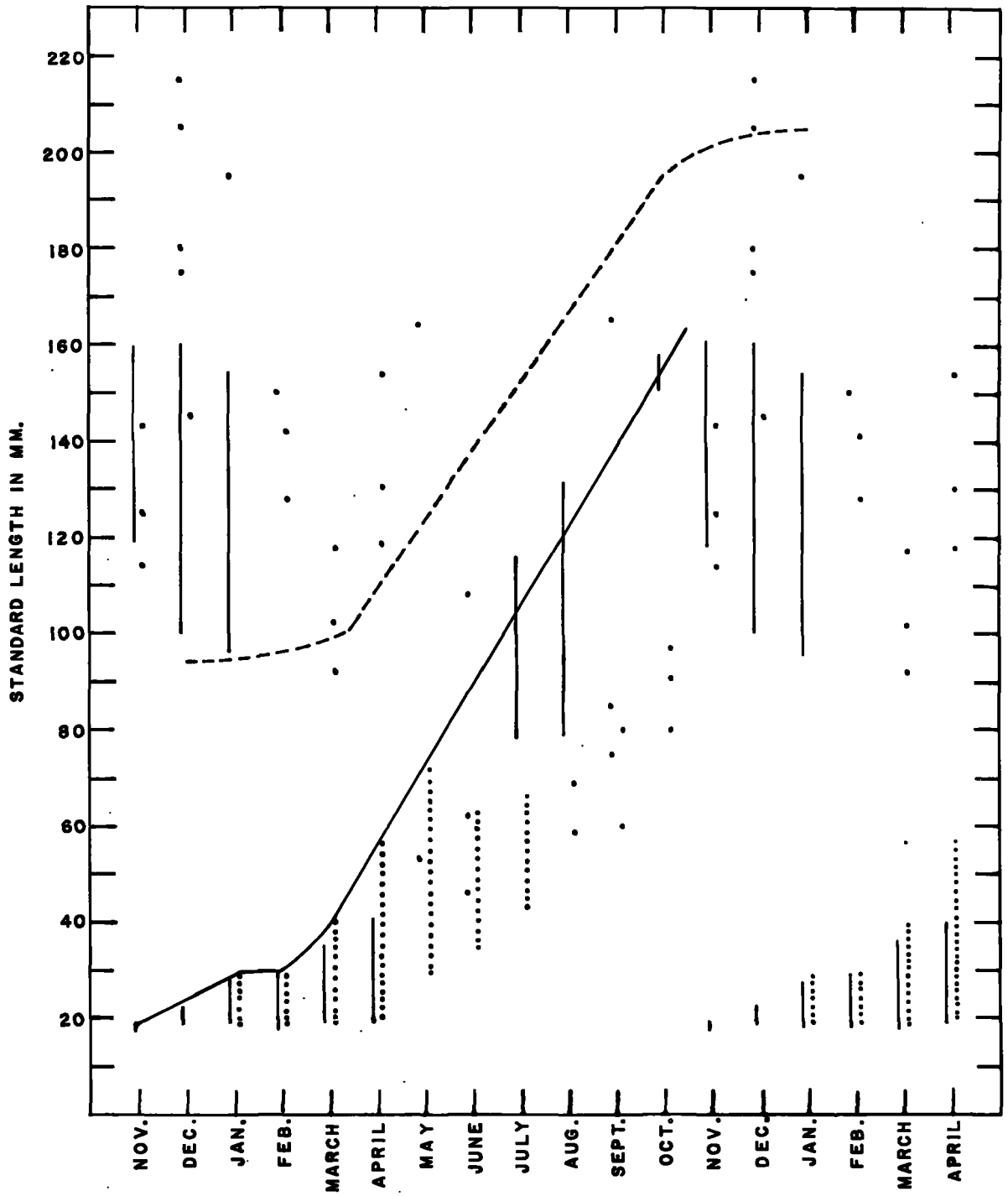


FIGURE 21.—Monthly size ranges of striped mullet, *M. cephalus*, seined from two locations in Georgia: St. Simons Beach (vertical solid line) and Sapelo Marsh (vertical dotted line). Data cover period of March 1953 to December 1956. Size ranges given represent the smallest to largest specimens taken during any given month in this period. Isolated specimens are indicated by large black dots (see tables 3 and 4 for occurrence data). The growth curves are discussed in text.

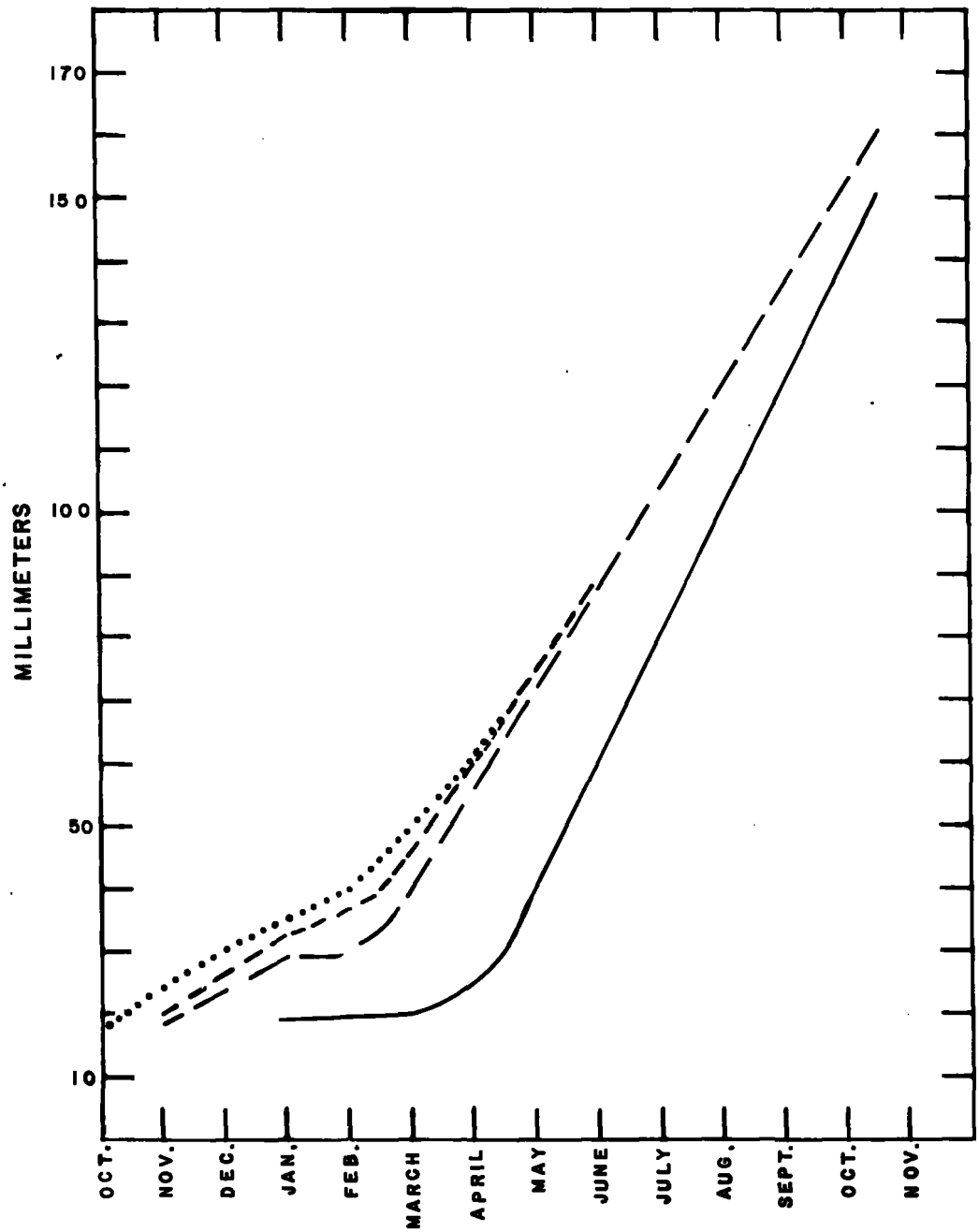


FIGURE 22.—Growth of striped mullet during first year of life as estimated by several workers; Higgins for North Carolina (solid line); Anderson for Georgia (long dashes; present paper); Gunter for Texas (short dashes); and Kilby for west coast of Florida (dotted line).

may be said to occur during November and December; and it is likely that the spawning season is of limited duration, as the eggs are of approximately the same development throughout the ovaries of the fish, and as the young appear the following spring in very uniform size groups.

Taylor et al. (1951, p. 115) indicated that adult striped mullet in North Carolina "school up" in the fall (October and November) and move to the inlets. Of these he said,

> These fish carry spawn, indicating that this is a spawning migration. The fish move out of the inlets in November and December, usually on a northerly wind (according to old-timers) and spawn in the ocean. Spawning is believed to occur in the vicinity of the inlets because

within 2 or 3 weeks, young mullet are found entering the inlets.

Gunter (1945, p. 51) said of striped mullet in Texas—

> In summary, the large mullet go to the Gulf in the fall and congregate near the passes on the outside beaches. Spawning takes place there and extends from late October to early January, with the peak probably falling in late November and early December.

Broadhead (1953, p. 21), from work in northwest Florida, said—

> No observations of the spawning of mullet have been made in northwest Florida. However, indirect evidence indicates that the fish spawn offshore, probably from 5 to 20 miles, in the Gulf of Mexico.

He indicated (p. 6) that this spawning occurs in the late fall and is about completed by early December.

Kilby (1955, p. 213), from work along Florida's west coast, said—

> In summary, the breeding season is long, extending from October through May at Cedar Key and from December through July at Bayport.

In summary, these workers, excepting Kilby, have indicated a late-fall to winter spawning period (October to January limits—peak November to December), and most indicate that spawning occurs at sea, ranging from close to shore to some 20 miles at sea.

My observations on time and place of spawning along the south Atlantic coast of the United States are based on three sets of data: Larvae taken in plankton tows from the MV. *Theodore N. Gill* operations (table 1); larvae from dip-net collections of the *Gill* cruises (table 2); and occurrence of young on the Georgia coast as indicated by seine collections in beach and marsh habitats (tables 3 and 4).

Figure 1 illustrates the locations of capture of larvae from plankton and dip-net operations.

Information from plankton tows alone (table 1) shows a spawning season extending from late November or early December into February. Assuming a period of 3 to 4 weeks for larvae to attain a size of about 20 mm., the dip-net data (table 2) likewise indicate a spawning season of December into February. Under the same assumption, data from Georgia seine collections (tables 3 and 4) show that spawning occurs as early as October, with November 19 the earliest date larvae about 20 mm. were taken; but these small larvae were not taken in abundance until January, indicating a peak spawning beginning in December. From these data, the spawning season of striped mullet along the south Atlantic coast of the United States is indicated as October to February, but it is confined largely to a period of November to January with the peak in December.

My evidence is that striped mullet spawn offshore from lower Florida to North Carolina over a broad area extending from about the 20-fathom line into the Gulf Stream. Figure 1 illustrates that larvae taken in plankton tows were over this area, whereas none were taken near shore except in lower Florida where the Continental Shelf is narrow and the Gulf Stream close to shore. I found silver mullet to spawn in this same offshore habitat (Anderson 1957a).

There is only one authentic record of observations of spawning activities of striped mullet, and this is further evidence of offshore spawning. Arnold and Thompson (1958) report observing a school of mullet spawning in the Gulf of Mexico over the Continental Slope in depths from 500 to 900 fathoms about 40 to 50 miles southeast of the Mississippi River Delta.

In contrast with spawning of the silver mullet, which begins in early spring when water temperatures are rising over the Continental Shelf (Anderson 1957a), the striped mullet spawn during late fall or winter, when water temperatures are falling.

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