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DEVELOPMENT AND DISTRIBUTION OF LARVAL AND JUVENILE FISHES OF THE FAMILY MULLIDAE OF THE WESTERN NORTH ATLANTIC

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Created in 1849, the Department of the Interior—America's Department of Natural Resources—is concerned with the management, conservation, and development of the Nation's water, fish, wildlife, mineral, forest, and park and recreational resources. It also has major responsibilities for Indian and territorial affairs.

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CONTENTS

ABSTRACT

The young of the four species of goatfish (Mullidae) of the western North Atlantic are discussed morphologically, meristically, and ecologically, and developmental changes are described and illustrated.

Pseudupeneus maculatus (smallest, 18.5 mm.) is shown to have an early offshore pelagic stage which differs in appearance from the adult inshore bottom-dwelling stage. The data indicate that, within limits, the change in habitat initiates the metamorphosis, rather than metamorphosis occurring at a specific size. More limited data for *Mullus auratus* (smallest, 8.2 mm.) and *Upeneus parvus* (smallest, 20.8 mm.) suggest a similar life cycle. Nothing is known of *Mulloidichthys martinicus* below 82.5 mm.

The range of *U. parvus* is extended northward to North Carolina and southward to Vitoria, Brazil. *M. martinicus* (possibly market-procured) from as far south as Salvador, Brazil, were examined.

Mullus auratus, previously described as having no teeth in the upper jaw, are shown to have teeth as juveniles, which become obsolete with maturity.

Two keys are given, the first for specimens 10.0 through 82.5 mm., the second for larger specimens.

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By MELBA C. CALDWELL, Fishery Research Biologist

BUREAU OF COMMERCIAL FISHERIES

From February 10, 1953, to December 12, 1954, the U.S. Fish and Wildlife Service made nine exploratory cruises with the motor vessel *Theodore N. Gill* into the waters off the south Atlantic coast of the United States. These cruises were the initial phase of a study of biological, chemical, and physical oceanographic conditions between Cape Hatteras and the Florida Straits. Several small specimens of goatfishes, family Mullidae, were collected. As existing keys to the group proved inadequate for the identification of the young, developmental studies were undertaken for the two species abundant in the area: *Mullus auratus* Jordan and Gilbert and *Pseudupeneus maculatus* (Bloch). Two additional species, *Upeneus parvus* Poey and *Mulloidichthys martinicus* (Cuvier), were included in the study since it was anticipated that they occurred in the waters encompassed by the survey.

Material from other than *Gill* collections has been examined. The cruises of the U.S. Fish and Wildlife Service vessels *Silver Bay* and *Oregon* have contributed many Mullidae to the collections of the Bureau of Commercial Fisheries Biological Laboratory, Brunswick, Ga. (BLBG).

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METHODS

Ernest A. Lachner is presently engaged in a revision of the family Mullidae, and I have given only as much attention to the adults as is necessary to trace development. Briggs (1958) has been followed in nomenclature.

Lachner (1951) has been followed in regard to counts of fin rays, gill rakers, and scales. All gill raker rudiments were counted as gill rakers. Photomicrographic methods of Caldwell and Carlin[1] were used for photographing specimens below 19 mm. Staining methods of Hollister (1934) and Evans (1948) were followed. Pectoral rays were counted on the right side unless the right pectoral was injured, curled, or bent forward. Measurements were made with either a micrometer eyepiece or dial calipers, and were taken at the positions indicated in figure 1.

Measurements of selected body parts less than 100 mm. are recorded to the nearest 0.1 mm., and above this size, to the nearest 0.5 mm. Measure-

[1] Caldwell, David K., and Charles R. Carlin. A photomicrographic adapter for steromicroscopes useful in photographing fish larvae. Copeia, No. 2, 1962, p. 445–446.

TABLE 1.—*Comparison of selected characters of the four species of Mullidae of the western North Atlantic*

[Applicable only to specimens of *Pseudupeneus maculatus*, *Mullus auratus*, and *Upeneus parvus* over 50 mm., and to *Mulloidichthys martinicus* over 82.5 mm. Specimen size at which development of each character occurs is discussed in the text]

Character	Species			
	P. maculatus	*M. auratus*	*U. parvus*	*M. martinicus*
Spinous dorsal fin	8 (first spine minute)	8 (first spine minute)	7	8 (first spine usually embedded in tissue and not visible).
Soft dorsal fin	I, 8	I, 8	I, 8	I, 8.
Anal fin	I, I, 6	I, I, 6	I, I, 6	I, I, 6.
Pectoral fin	13–16	16–17	14–16	15–17.
Pelvic fin	I, 5	I, 5	I, 5	I, 5.
Caudal fin	I, 7+6, I	I, 7+6, I	I, 7+6, I	I, 7+6, I.
Gill rakers:				
Total	26–32	18–21	24–27	26–33.
Lower limb	19–24	12–15	17–19	19–23.
Ceratobranchial bone	12–15	9–11	11–12	12–16 (usually 14–16).
Teeth:				
Upper jaw	Single row of canines below 100 mm.; additional large canines anterolateral to them in larger specimens.	Absent or not visible	Irregular rows of small canines.	Single row of small canines becoming irregularly biserial anteriorly.
Lower jaw	Irregular row of small canines	Single row of small canines becoming irregularly biserial anteriorly.	Irregular rows of small canines.	Single row of small canines becoming irregularly biserial anteriorly.
Vomer	Absent	Peglike teeth on fused palatovomerine bone.	Peglike	Absent.
Palatine	Absent		Peglike teeth at 54 mm. and larger.	Absent.
Lateral line scales	27–31	29–35	36–38	34–39.
Opercular spine	Present	Absent	Absent	Present.
Upper wing of cleithrum	Serrated	Smooth	Smooth	Smooth.
Branchiostegals	3	3	3	3.
Color pattern of metamorphosed specimens after preservation.	Usually retain three black blotches on side.	Pale yellow	Three or four black bars on ventral lobe of caudal fin.	Pale yellow.

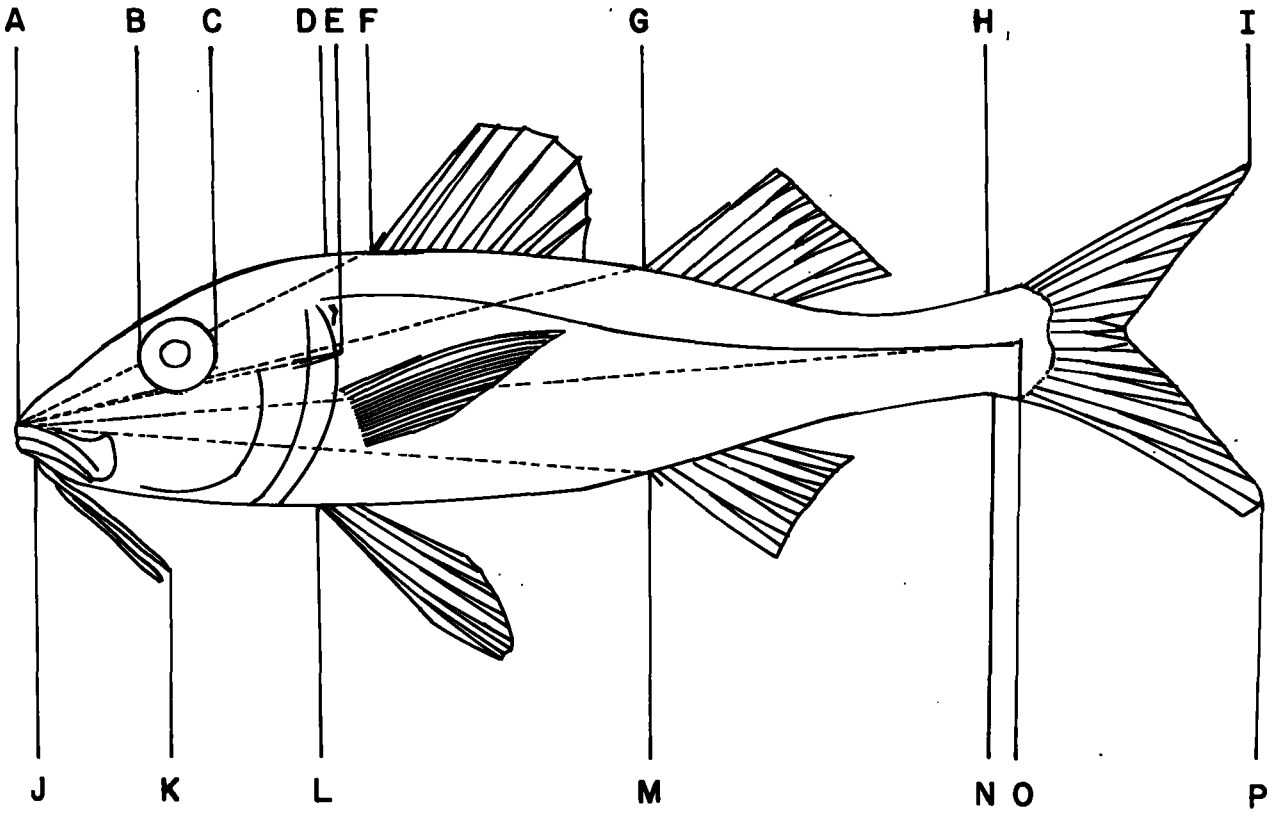

Figure 1.—*Pseudupeneus maculatus*, 48-mm. (UF uncatalogued; Dickinson collection, Bahamas.) Letters indicate points of measurements.

ments of standard length to show size range of specimens captured are indicated to the nearest 0.5 mm. All body lengths are expressed in standard length.

Percentages are indicated to the nearest 0.1 percent.

The upper lip was not included in the measurements involving the tip of snout.

A–B.—*Snout length.* Tip of snout to anterior edge of bony eye socket.

B–C.—*Eye diameter.* Horizontal width of bony eye socket.

C–E.—*Postorbital head length.* Posterior edge of bony eye socket to posterior edge of operculum, inclusive of spine if present.

A–E.—*Head length.* Tip of snout to posterior edge of operculum, inclusive of spine if present.

A–F.—*Snout to first dorsal.* Tip of snout to base of first spine of spinous dorsal.

A–G.—*Snout to second dorsal.* Tip of snout to base of first ray of soft dorsal.

A–M.—*Snout to anal.* Tip of snout to base of first spine of anal fin.

D–L.—*Depth.* Measured at deepest point, slightly anterior to first dorsal fin to origin of pelvics.

H–I.—*Dorsal lobe of caudal.* Origin of first secondary ray of dorsal lobe to tip of longest ray of dorsal lobe.

N–P.—*Ventral lobe of caudal.* Origin of first secondary ray of ventral lobe to tip of longest ray of ventral lobe.

J–K.—*Barbel length.* Anterior edge of base of barbel to tip of longest barbel.

A–O.—*Standard length.* Tip of snout to distal end of hypural bone (base of midcaudal rays).

Interorbital space. Narrowest distance between the bony eye sockets, measured on the dorsal surface.

Gill raker length. Length of first lower-limb gill raker beyond the gill raker at the angle of the arch.

Measurements were made and plotted on distance from first to second dorsal fins and caudal concavity, but the graphs are not included because of the high degree of variability and number of factors that influence these dimensions.

ABBREVIATIONS AND TERMINOLOGY

I have followed Berry (1959) in terminology of the developmental stages.

Larval.—Defined by Berry as, "the stage of development commencing with hatching and ending with the completion of formation of the adult complement of fin rays."

Only the larvae of *Mullus auratus* are considered here. In *M. auratus* the secondary rays of the caudal fin are the last rays to ossify (shown on stained material). This ossification occurs at 10 or 11 mm.

Juvenile.—Berry (1959) defined this stage as, "commencing with the end of the larval stage and terminating with the attainment of sexual maturity." All of my specimens of *P. maculatus* (smallest, 18.5 mm.), *U. parvus* (smallest, 20.8 mm.), and *Mulloidichthys martinicus* (smallest, 82.5 mm.) have reached the juvenile stage.

Adult.—Defined by Berry (1959) as, "commencing with the attainment of sexual maturity." I did not determine at what size this occurs on any of the species under consideration.

I have made no attempt to identify the chromatophores either histologically (Gordon, 1959) or chemically. I suspect, however, that in the goatfishes some of the chromatophores, particularly those in the fins, remain migratory in much larger specimens than has been shown in some other fishes (Parker, 1948).

In discussions of development of the rays, the terms "branching" and "segmentation" refer only to primary branching and segmentation in a ray. "Branching is complete" or "segmentation is complete" refer only to the fact that all rays that are to become branched or segmented have done so at least once.

Some of the specimens examined were collected in locations that are not widely known. For these I have supplied approximate latitudes and longitudes.

A few of the small specimens had no data regarding method of capture and were taken at stations listed in the vessel station lists as "longline," "hook and line," or "drift" stations. Since it is customary for participants of a cruise to use a dip net at stations and since it is improbable that a specimen under 40 mm. should have been caught by these other means, I have designated them as (D?) specimens. The abbreviations used in referring to the different collections are given on page 455. The *Gill* cruises made three different types of stations that I will refer to: Regular (Reg.), Special (Spc.), and Standard (Std.) (Anderson, Gehringer, and Cohen, 1956).

The methods of capture are indicated as follows: trawl (T), dip net (D), stomach contents (SC), market procured (M), and rotenone (R).

KEY TO MULLIDAE OF THE WESTERN NORTH ATLANTIC

Material 10.0–82.5 mm.[2]

A. Minute spine at origin of spinous dorsal (total of 8 spines) (fig. 28).
  B. Lower-limb gill rakers 11–16; over 17 mm., palato-vomerine tooth patch (fig. 31); no opercular spine (fig. 33)_____ *Mullus auratus.*
  BB. Lower-limb gill rakers 17–24; no palato-vomerine tooth patch; over 22 mm., opercular spine (fig. 23) _____*Pseudupeneus maculatus.*

AA. No minute spine at origin of spinous dorsal (total of 7 spines) (fig. 37).
Lower-limb gill rakers, 16–19; ceratobranchial bone gill rakers, 10–12; no opercular spine (fig. 38)_____ *Upeneus parvus.*

As no *Mulloidichthys martinicus* below 82.5 mm. have been examined or described, they are omitted from this key. Between 20 and 80 mm., they could be expected to be devoid of a visible minute spine at the origin of the spinous dorsal (fig. 40) and to have a lower-limb gill raker count of 19–23 and ceratobranchial bone gill raker count of 13–16 (allowing for formation of one additional raker between 20 and 80 mm.). As the opercular spine of *P. maculatus* is developed at 22 mm., the same trend might be expected in *M. martinicus*, a closely related species.

[2] Based upon 30 specimens of *M. auratus*, 48 *P. maculatus*, and 40 *U. parvus*.

Material over 82 mm.[3]

A. Opercular spine (figs. 23 and 43).
  B. Scales 27–31, usually three large black blotches along lateral line (fig. 3), posterior wing of cleithrum serrated (fig. 23)_____ *Pseudupeneus maculatus.*
  BB. Scales 34–39, no black blotches along lateral line, posterior wing of cleithrum not serrated (fig. 43)_____ *Mulloidichthys martinicus.*
AA. No opercular spine.
  C. Minute first dorsal spine (fig. 28), fused palato-vomerine tooth patch (fig. 31), lower-limb gill rakers 12–15_____ *Mullus auratus.*
  CC. No minute first dorsal spine (fig. 37), separate vomer and palatine tooth patches, lower-limb gill rakers 17–19_____ *Upeneus parvus.*

COMPARISON OF SPECIES

Fishes of the family Mullidae, referred to as goatfishes or surmullets, are characterized by the presence of two barbels beneath the chin. Barbel development is discussed in the section on barbels under *M. auratus*. Larvae of juveniles which have not developed barbels, or in which the barbels have not detached from the branchiostegal membrane, can be distinguished by the presence of six to eight spines in the first dorsal fin (Jordan and Evermann, 1896) and a reduced number of branchiostegal rays (four before the barbels form, three after barbel formation). Juvenile Mullidae are most often confused with young Mugilidae, to which they bear a close superficial resemblance. Mugilidae, however, have only four spines in the first dorsal fin (Jordan and Evermann, 1896).

Table 1 (p. 403) lists the major characters of the four species of Mullidae of the western North Atlantic. The table applies only to specimens above a size of 50 mm. For specimens below 50 mm., changes which occur in the various characters are discussed for the species in their individual sections.

Fin ray counts of the spinous dorsal, soft dorsal, anal, pelvic, and caudal fins were constant throughout the size ranges examined, and ranges of pectoral ray counts are constant above 22 mm. When lateral line scales are present, counts show no variability with size of specimen. There is no change in the number of branchiostegal rays (three) after the barbels form (below 20 mm.).

Below 50 mm., the numbers of pectoral fin rays vary somewhat with size of fish.

The adult tooth patterns are not established below 50 mm., and in *P. maculatus*, not before 100 mm.

The opercular spine of *P. maculatus* (and presumbaly *M. martinicus*) is apparent at 21.9 mm. The serrated upper wing of the cleithrum in *P. maculatus*, however, is not obvious below 50 mm.

Adult color patterns become established after metamorphosis, which occurs between 40 and 70 mm.

Morphometric relationships are shown graphically in figures 9 through 21 (p. 415–427).

ECOLOGY OF THE MULLIDAE

Thorson (1957) estimated that 85 to 90 percent of all species in tropical level-bottom communities have a long pelagic life, and two-thirds (on the average) of the level-bottom animals of the boreal seas have pelagic larvae. Hubbs (1941) has pointed out that fishes inhabiting rocks, sand, or weed may have a pelagic stage which is quite different from the adult. The difference is so marked in some species that the two stages have been described and named as different species by competent ichthyologists (Hubbs, 1958; Breder, 1949). In a recent paper Caldwell (1962) has given a detailed analysis of this transformation in *Pseudopriacanthus altus* (Gill).

Four of the six genera of this family are represented in the western North Atlantic. The young of *P. maculatus*, *M. auratus*, and *U. parvus*, representing three of the four genera in the western North Atlantic, have a pelagic stage differing in body shape and coloration from a subsequent inshore stage. A pelagic stage is also indicated within the genus *Parupeneus*. Gosline and Brock (1960) commented that the young of *Parupeneus porphyreus* (Jenkins), a Pacific mullid, appear in shallow water at approximately 40 mm.

As no *M. martinicus* smaller than 82.5 mm. have been taken, the possibility exists that this species does not have a pelagic stage. In addition, I have examined approximately 50 collections of premetamorphosed mullids from the Pacific coast of

[3] Based upon 16 specimens of *P. maculatus*, 27 *M. martinicus*, 20 *M. auratus*, and 11 *U. parvus*.

the Americas and again failed to find any specimen smaller than 72 mm. of the genus *Mulloidichthys*, although at least one species of this genus is not uncommon there. However, there are several other factors that could account for a failure to collect smaller specimens; e.g., failure to collect in the proper locality, failure of this species to come to a night light, and the possibility that this is a diurnal rather than a nocturnal species.

Major physical changes occurring in these fishes following the attainment of a benthic habitat are replacement of the silvery or dark brown pelagic coloration by the adult coloration and the acquisition of a more robust body shape.

The scales of the small pelagic speciments shed easily, whereas those of even the smallest metamorphosed specimens are much more firmly fixed.

PSEUDUPENEUS MACULATUS (BLOCH)

Sources of material and pertinent station data are listed (table 2), and the locations of capture are shown (fig. 2).

DISTRIBUTION

Briggs (1958) gave the range of *Pseudupeneus maculatus* as "New Jersey and Bermuda to Rio de Janeiro and the southern and northeastern Gulf of Mexico."

One specimen (table 2) was procured slightly south of Rio de Janeiro (Santos, Brazil). This was probably a market specimen, and the exact location of its initial capture is uncertain.

On two occasions, juveniles were captured in the Gulf of Mexico in other than the southern or northeastern sectors (fig. 2). These were pelagic specimens, and the locations of capture indicate

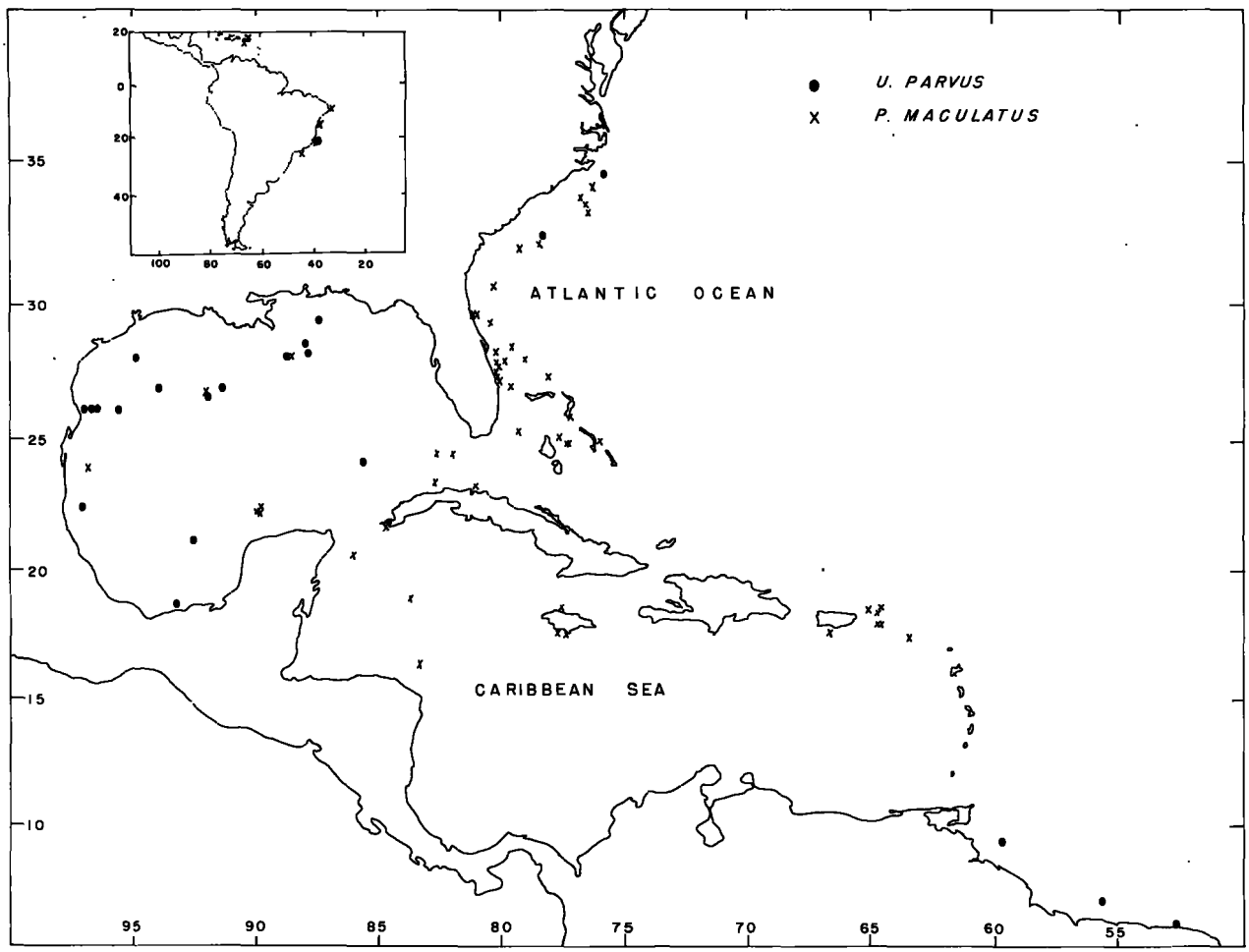

Figure 2.—Locations of capture of *Pseudupeneus maculatus* and *Upeneus parvus*.

TABLE 2.—*Collection and station data for 274 specimens of* Pseudupeneus maculatus *examined*

[Dip net (D), trawl (T), stomach contents (SC), collected with rotenone (R), and market procured (M)]

Station	Latitude	Longitude	Date of capture	Depth of water in which captured	Method of capture	Number of specimens and size range	Collection and catalogue number (if any)
				Fathoms		*mm.*	
WESTERN NORTH ATLANTIC:							
Gill Cr. 2, Reg. 71	34°04′ N.	76°15′ W.	May 9, 1953	16	D	(1) 48.5	BLBG
Silver Bay 1218	33°45′ N.	76°50′ W.	Sept. 3, 1950	23–24	T	(10) 107.0–206.5	BLBG
Gill Cr. 4, Reg. 65	33°42′ N.	76°56′ W.	Nov. 9, 1953	22	D	(1) 18.5	BLBG
Gill Cr. 2, Reg. 63	33°15′ N.	76°23′ W.	May 8, 1953	412	D	(4) 33.0–46.0	BLBG
Gill Cr. 2, Reg. 49	32°12′ N.	78°25′ W.	May 6, 1953	185	D	(1) 43.5	BLBG
Gill Cr. 2, Reg. 42	31°57′ N.	79°18′ W.	May 6, 1953	75	D	(2) 42.0 and 44.0	BLBG
Silver Bay 1549	30°40′ N.	80°15′ W.	Jan. 17, 1960	22–25	T	(1) 160.0	BLBG
Silver Bay 1534	30°39′ N.	80°17′ W.	Jan. 15, 1960	22–23	T	(11) 147.5–198.0	BLBG
Gill Cr. 2, Reg. 20–21	29°40′ N.	80°57′ W.	Apr. 26, 1953	9–15	D	(1) 37.0	BLBG
Silver Bay 1553	29°39′ N.	81°06′ W.	Jan. 19, 1960	9–10	T	(1) 145.5	BLBG
Combat 343	29°19′ N.	80°18′ W.	June 1, 1957	[1] 30	D	(23) 35.0–41.0	BLBG
Gill Cr. 6, Reg. 10	28°20′ N.	80°10′ W.	Apr. 27, 1954	21	D	(2) 45.0 and 47.0	BLBG
Gill Cr. 2, Reg. 8	28°19′ N.	79°26′ W.	Apr. 24, 1953	435	D	(1) 49.0	BLBG
Gill Cr. 5, Spc. Sta. 9	28°00′ N.	79°00′ W.	Feb. 1, 1954	455	D	(16) 48.0–54.0	BLBG
Gill Cr. 2, Reg. 5–6	27°42′ N.	79°46′ W.	Apr. 23, 1953	27–310	SC	(2) 38.5 and 41.0 [2]	BLBG
Gill Cr. 5, Reg. 5	27°40′ N.	80°04′ W.	Jan. 30, 1954	20	D	(1) 42.0	BLBG
Gill Cr. 6, Reg. 5	27°40′ N.	80°04′ W.	Apr. 26, 1954	20	D	(1) 46.0	BLBG
Gull Cr. 1	27°20′ N.	78°00′ W.	Feb. 12, 1953		SC	(2) 40.0 and 44.0 [3]	BLBG
Gill Cr. 6, Reg. 4	27°20′ N.	80°04′ W.	Apr. 26, 1954	13	D	(3) 44.0–45.0	BLBG
Gill Cr. 2, Reg. 3	27°01′ N.	80°04′ W.	Apr. 23, 1953	6	D	(1) 39.0	BLBG
Gill Cr. 4, Reg. 1	27°00′ N.	79°18′ W.	Oct. 12, 1953	356	D	(1) 39.0	BLBG
Gill Cr. 3, Reg. 3	27°00′ N.	80°04′ W.	July 25, 1953	9	D	(1) 40.0	BLBG
Gill Cr. 1, Abaco Light, Anchorage	[4] 25°51′ N.	77°10′ W.	Feb. 15, 1953	[1] 11	D	(10) 54.5–61.0	BLBG
Cat Cay, Grand Bahama Bank	[4] 25°35′ N.	79°15′ W.	July 23, 1955		D	(2) 42.0 and 43.0	BLGT
Cat Cay, Grand Bahama Bank	[4] 25°35′ N.	79°15′ W.	July 14, 1955		D	(6) 38.0–45.0	BLGT
Gill Cr. 5, Near Eleuthera Island, Bahamas.	[4] 25°32′ N.	76°13′ W.	Jan. 27–28, 1954	[1] 1000 to 2000	D	(1) 58.0	BLBG
Gill Cr. 5, Near Eleuthera Island, Bahamas.	[4] 25°32′ N.	76°13′ W.	Jan. 27, 1954	[1] 1000 to 2000	D	(1) 59.5	BLBG
Treasure Island (Salt Cay), Bahamas.	25°06′ N.	77°17′ W.	Aug. 14, 1955	0–2	R	(2) 41.0 and 140.5	ANSP 84851
New Providence Island, Bahamas	25°06′ N.	77°20′ W.	Mar. 23, 1955	17	D	(8) 50.0–56.0	ANSP 84838
Silver Cay, Bahamas	25°06′ N.	77°22′ W.	Apr. 5, 1955	1	R	(25) 49.0–73.5	ANSP 84840
12 mi. west of Nassau, Bahamas	[4] 25°05′ N.	77°24′ W.	July 9, 1958	1	R	(3) 48.0–57.5	UF
Nassau Market, Bahamas			Aug. 17–20, 1955		M	(1) 225.0	UF 3533
Key West, Florida						(1) 69.5	CAS IUM 8509
Key West, Florida						(6) 40.0–62.5	CAS IUM 2400
Key West, Florida						(6) 45.5–81.0	SU 2399
GULF OF MEXICO:							
Garden Key, Florida	[4] 24°38′ N.	82°54′ W.				(2) 48.5 and 50.0	SU 3200
Oregon 1313	28°05′ N.	88°46′ W.	June 9, 1955	980	D	(1) 21.5	CNHM 64714
Oregon 1035	26°40′ N.	92°00′ W.	May 8, 1954	890	D	(1) 43.5	USNM 64712
Oregon 1074	24°00′ N.	96°50′ W.	May 25, 1954	575	D	(1) 47.0	BLBG
Silver Bay 403	22°12′ N.	89°57′ W.	May 11, 1958	27	D	(5) 41.5–45.0	BLBG
Silver Bay 410	21°13′ N.	89°50′ W.	May 12, 1958	27	D	(1) 42.5	BLBG
Oregon 2174	22°23′ N.	89°44′ W.	May 11–12, 1958	15	D	(11) 42.0–51.0	USFWS Icth. Lab.
STRAITS OF FLORIDA:							
Oregon 780	23°30′ N.	82°26′ W.	May 9–10, 1953	900	D	(1) 47.5	TU 5985
CARIBBEAN SEA:							
Oregon 786	21°45′ N.	84°40′ W.	May 15, 1953		D	(4) 44.0–55.0	TU 5991
Oregon 1297	20°50′ N.	86°10′ W.	Apr. 28, 1955	800	D	(11) 41.5–49.0	BLGT
Misterioso Bank off Yucatan, Mexico.			Jan. 4, 1940			(1) 40.0	CNHM 39673
Misterioso Bank off Yucatan, Mexico.			Jan. 4, 1940			(1) 40.5	CNHM 39674
Misterioso Bank off Yucatan, Mexico.			Jan. 4, 1940			(1) 29.0	CNHM 39675
Oregon 1863	16°22′ N.	83°31′ W.	Aug. 20, 1957	165–170	D	(1) 49.0	BLBG
Havana, Cuba						(4) 45.0–159.0	SU 1826
Cuba						(1) 59.0	CAS IUM 11285
Cuba						(1) 144.0	CAS IUM 2642
Eaton Hall Cove, Jamaica	[4] 18°27′ N.	77°20′ W.	Jun. 14, 1958	1	R	(1) 53.5	DKC#C6–1458–1J
Rocky Point Market, Jamaica					M	(1) 171.0	DKC
Kingston Market, Jamaica			Apr. 24, 1959		M	(2) 147.0 and 182.0	DKC
Kingston Market, Jamaica					M	(1) 151.0	DKC
Puerto Rico						(2) 59.0–64.0	CAS IUM 9477
St. Croix, Lesser Antilles						(1) 157.0	CAS IUM 12374
Oregon 2617	18°51′ N.	64°38′ W.	Sept. 27, 1959	41	T	(6) 77.5–103.5	BLBG
Oregon 2625	18°45′ N.	64°47′ W.	Sept. 28, 1959	38	T	(1) 85.0	BLBG
Oregon 2608	18°35′ N.	65°03′ W.	Sept. 26, 1959	42	T	(10) 83.5–155.5	BLBG
Oregon 2619	18°15′ N.	64°49′ W.	Sept. 27, 1959	26	T	(3) 89.0–106.5	BLBG
Oregon 2618	18°15′ N.	64°45′ W.	Sept. 27, 1959	29	T	(17) 67.0–127.0	BLBG
Oregon 2631	17°28′ N.	63°32′ W.	Sept. 30, 1959	19	T	(7) 71.0–110.0	BLBG
British West Indies						(4) 132.5–199.5	SU 4877
WESTERN SOUTH ATLANTIC:							
Recife, Brazil	08°03′ S.	34°51′ W.				(1) 161.5	SU 52240
Bahia, (Salvadore) Brazil	13°00′ S.	38°31′ W.				(3) 79.0–120.5	SU 1735
Bahia, (Salvadore) Brazil	13°00′ S.	38°31′ W.				(1) 113.0	CAS IUM 8534
Vitoria, Brazil	20°18′ S.	40°20′ W.				(5) 58.0–103.0	SU 52247
Santos, Brazil	23°50′ S.	46°40′ W.				(1) 132.0	SU 52248

[1] Estimated from hydrographic chart.
[2] Stomach contents of *Coryphaena hippurus* Linnaeus.
[3] Stomach contents of *Thunnus argentivittatus* (Cuv. and Val.).
[4] Approximate latitude and longitude.

that they were carried there by a branch of the Gulf Stream (Leipper, 1954).

ECOLOGY

Parr (1930) called attention to two color stages of *P. maculatus* taken in the Bahamas and Turks Island: a blue pelagic form that he took by surface light at night and a more highly colored benthonic stage obtained in a small bottom trawl and never observed at the surface. He observed, ". . . it would seem that the change from the pelagic existence of the young to the benthonic life of the adults does not occur until the fish has reached a length without caudal fin of about 70 mm. . . ."

Figure 3 shows two specimens of *P. maculatus*, 41.0 mm. and 59.5 mm., which exhibit distinctly different body shapes and pigmentation. The smaller one was taken with the aid of rotenone in 1 fathom of water, and the larger individual was dip netted over deep water. Although the specimens are superficially unlike, they both show the characters of *P. maculatus* (table 1). The smaller metamorphosed specimen is developing the three dark blotches which, among the western North Atlantic Mullidae, are peculiar to *P. maculatus*.

Figure 4 shows a series of pelagic specimens dip netted by night light.

I examined another series of 25 young *P. maculatus* from the Bahamas that were apparently undergoing metamorphosis when taken. All characters were those of *P. maculatus*, and some were developing indications of the three dark blotches peculiar to this species (fig. 5, uppermost). This series (fig. 5) was light tan in color as opposed to the dark dip-netted specimens, and for the most part, more robust in body contour (fig. 5, uppermost). Some of the smaller forms, however, had the long slender shape of the pelagic form (fig. 5, lowermost).

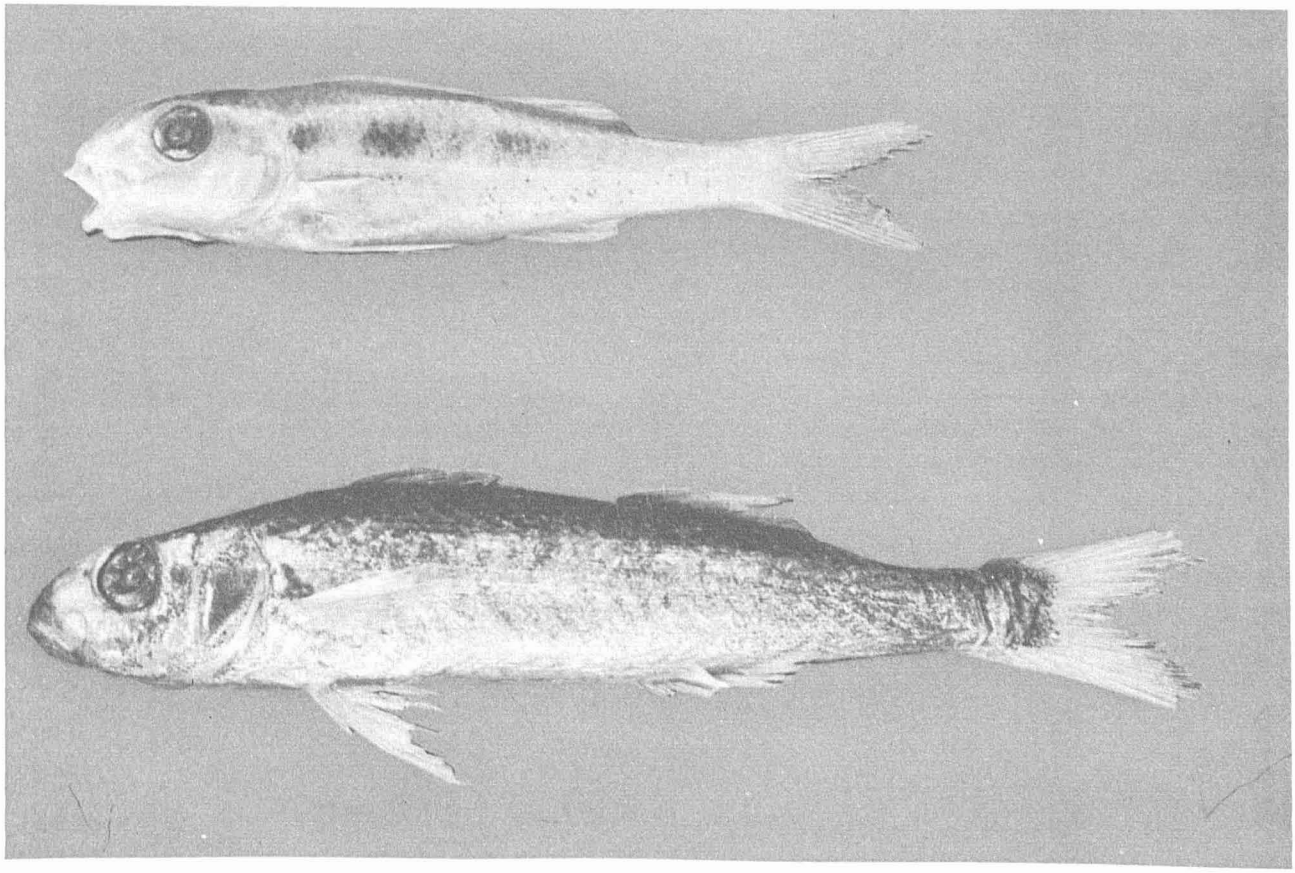

Figure 3.—*Upper.* Bottom-living 41.0-mm. *Pseudupeneus maculatus.* Collected with rotenone in less than 2 fathoms (ANSP 84851; Böhlke collection, Bahamas). *Lower.* Pelagic 59.5-mm. *Pseudupeneus maculatus.* Dip netted over 1,000–2,000 fathoms, by *Gill* personnel. (BLBG)

All of the specimens shown in figures 3, 4, 5, 6, and 7 are juveniles of *P. maculatus*. Figure 6 shows metamorphosed (upper) and pelagic (lower) specimens of similar size for comparison.

The small specimens up to 61.0 mm. were taken by dip net or with aid of rotenone. With one exception, the dip-netted specimens had long, slender, dark bodies typical of pelagic fish. The one exception, a 43.0-mm. specimen, had begun to acquire the three black pigmentation blotches peculiar to *P. maculatus*. The fact that this stage was dip netted over depths as great as 1,000 to 2,000 fathoms (table 2) is evidence of their pelagic mode of life.

The smallest specimen taken by bottom trawl was 67.0 mm. (table 2), and this and all trawled specimens had attained the coloration and most of the body shape of the adult. That these were routinely trawled from the bottom in depths not exceeding 42 fathoms is indication of their shallow-water, bottom-living mode of life. They have also been observed and photographed in this habitat (Longley and Hildebrand, 1941).

When the sizes of specimens, depths of capture, and methods of capture are plotted (table 3, p. 411) the different habitats of the adults and juveniles become apparent. The shallow-water specimens ranged from 41.0 mm. upward, and all of

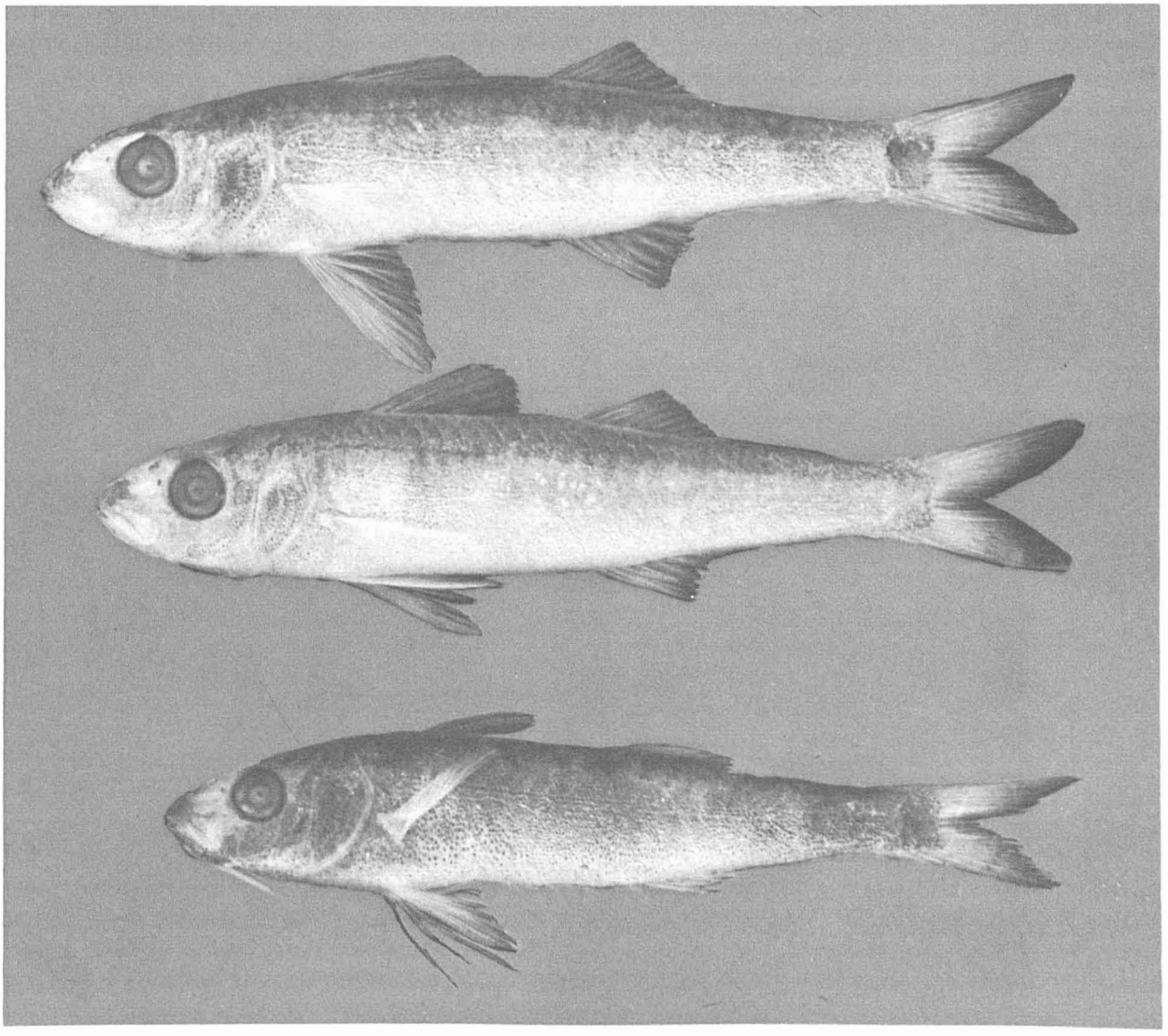

Figure 4.—Pelagic *Pseudupeneus maculatus*. From top to bottom, 53.5 mm., 50.2 mm., and 46.5 mm. Dip netted by *Gill* personnel. (BLBG)

TABLE 3.—*Relation of size of specimen, method of capture, (dip net, D; trawl, T; collected with rotenone, R), and water depths in which captured for* Pseudupeneus maculatus

[Each letter represents the capture of one or more specimens within a particular size range]

DEPTH IN FATHOMS	SIZE RANGE IN MILLIMETERS				
	0–24.5	25.0–49.5	50.0–74.5	75.0–99.5	Over 100
Over 100	D	DDDD DD	DDDD DDD		
75–99					
50–74			D		
25–49		DDD		TTTT	TTT
3–24	D	DDDD DDDD D	DD		TTTT
0–2		RRR	RRR		R

TABLE 4.—*Relation of numbers of pectoral fin rays to standard length of 56 specimens of* Pseudupeneus maculatus

[The upper number is the number of specimens, and the number in parentheses below is the approximate percentage for the respective size range]

Standard length (mm.)	Number of pectoral rays					Number of specimens
	13	14	15	16	17	
0–19.9			1 (100)			1
20.0–29.9			2 (100)			2
30.0–39.9		1 (16.7)	1 (16.7)	3 (50.0)	1 (16.7)	6
40.0–49.9		1 (12.5)	3 (37.5)	4 (50.0)		8
50.0–74.9	1 (4.5)		5 (22.7)	16 (72.7)		22
75.0–99.9			5 (83.3)	1 (16.7)		6
100.0–124.5			1 (33.3)	2 (66.6)		3
125.0–149.5			2 (66.6)	1 (33.3)		3
150.0–200.0			4 (80.0)	1 (20.0)		5

TABLE 5.—*Relation of total numbers of gill rakers to standard length of 60 specimens of* Pseudupeneus maculatus

[The upper number is the number of specimens, and the number in parentheses below is the approximate percentage for the respective size range]

Standard length (mm.)	Number of gill rakers									Number of specimens
	24	25	26	27	28	29	30	31	32	
0–29.9			1 (100)							1
30.0–39.9	1 (16.7)		1 (16.7)	2 (33.3)	2 (33.3)					6
40.0–49.9				3 (37.5)	2 (25.0)	2 (25.0)	1 (12.5)			8
50.0–74.9			1 (3.6)		5 (17.9)	9 (32.1)	6 (21.4)	4 (14.3)	3 (10.7)	28
75.0–99.9				1 (16.7)	4 (66.7)	1 (16.7)				6
100.0–124.5				2 (66.7)				1 (33.3)		3
125.0–149.5			2 (66.7)		1 (33.3)					3
150.0–200.0			1 (20.0)	3 (60.0)	1 (20.0)					5

these had light pigmentation. The body shape of most of them had begun transforming, but some had not (fig. 5, lowermost).

The largest pelagic specimen, 61.0 mm., was taken over shallow water (less than 11 fathoms), but very close to deep water and on a day when the seas were extremely rough. The wind was from the southwest and the 100-fathom line less than a mile southwest of Abaco Light, with the 1,000-fathom line being only about 4 miles distant. The next largest, 58.0 and 59.5 mm., were taken over water depths between 1,000 and 2,000 fathoms. These were juveniles which probably had not found shallow water in which to settle. There was no evidence of color transformation. The transforming 43.0-mm. specimen mentioned above, dip netted over 27 fathoms, was light colored and had begun to acquire the three characteristic lateral blotches of the species. Since it was dip netted over shallow water there is the possibility that it had settled to the bottom and returned to the surface. It showed no evidence of injury.

Thus it seems that *P. maculatus* has two juvenile stages—the first pelagic and the second a shallow-water, bottom-living stage. The pelagic stage is retained until the fish either finds shallow water,

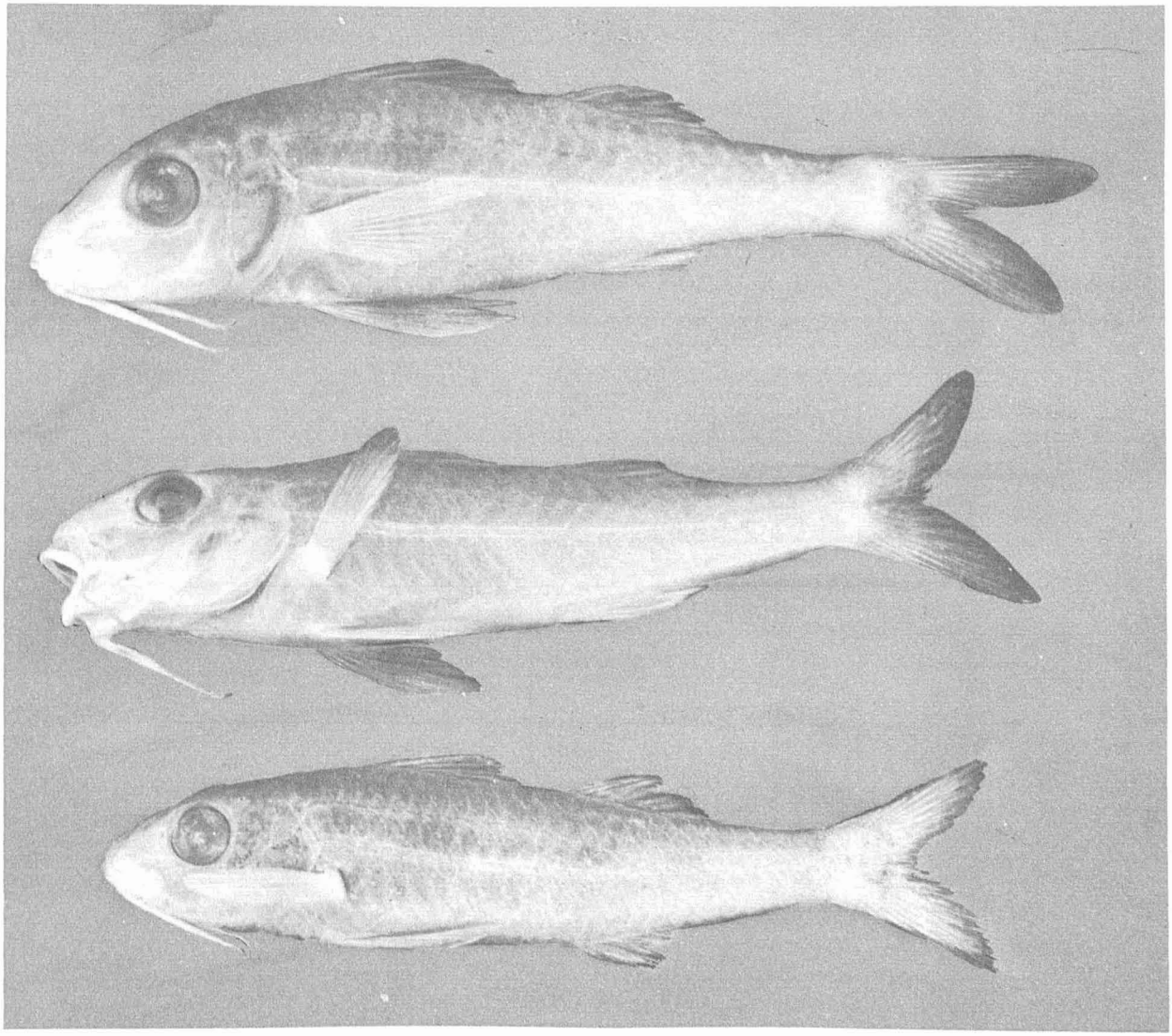

Figure 5.—Collected with rotenone, bottom-living, transforming *Pseudupeneus maculatus*. From top to bottom, 56.5 mm., 51.5 mm., and 49.5 mm. (ANSP 84840; Böhlke collection, Bahamas.)

or, at some size over approximately 61 mm. (the largest dip netted), it may be lost.

The first indication of metamorphosis is loss of the overall dark pigmentation and formation of three black blotches along the lateral line. This is followed by an elevation of both the back and head (also see *P. maculatus*, Sexual Dimorphism). The abrupt increase in body depth is indicated on the graph (fig. 12).

In the inset in figure 12, the dip-netted specimens (long and slender, and silvery or dark brown) are indicated separately from the transforming and transformed specimens caught either by bottom trawl or with the aid of rotenone. The transforming 43.0-mm., dip-netted specimen mentioned above is omitted. Between 40 and 60 mm., the specimens that were still pelagic showed a downward inflection of the depth slope, whereas an upward inflection is demonstrated for the metamorphosing forms.

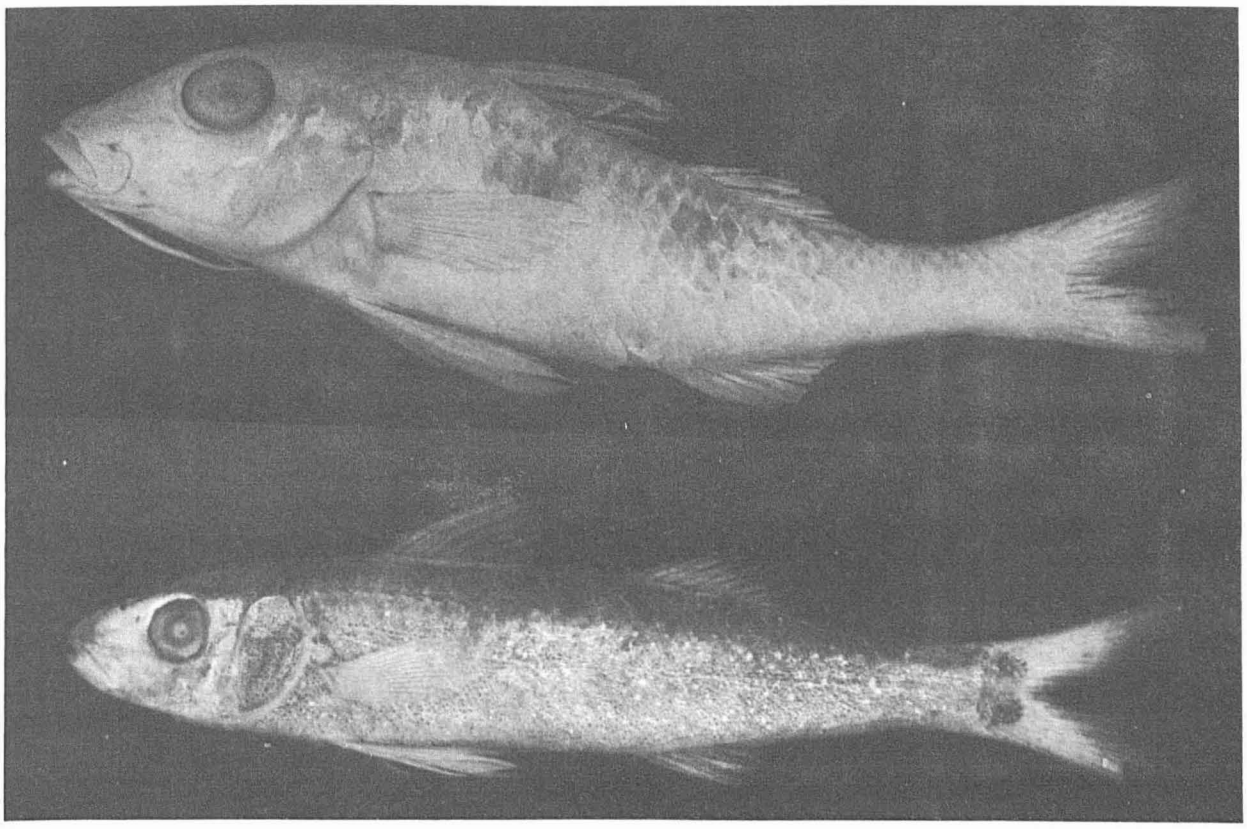

Figure 6.—*Upper.* 59.0-mm. metamorphosed *Pseudupeneus maculatus* (CAS IUM 9477). *Lower.* 58.9 mm. pelagic *Pseudupeneus maculatus.* Dip netted by *Gill* personnel. (BLBG)

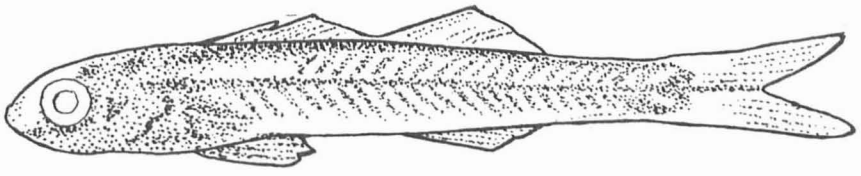

Figure 7.—*Pseudupeneus maculatus*, 18.5 mm. Dip netted by *Gill* personnel. (BLBG)

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GROWTH AND DEVELOPMENT

The smallest *P. maculatus* examined was 18.5 mm. (fig. 7). The presence of a minute first dorsal spine, absence of a palato-vomerine tooth patch, and characteristic pigmentation served to identify this species at this size. The secondary caudal rays, 9 on the dorsal lobe and 10 on the ventral lobe, have ossified and, by my definition, this specimen was a juvenile.

There are no major changes occurring until the juvenile (fig. 4) goes to the bottom and transforms (fig. 5). In the material that I examined, this usually occurred between 40 and 60 mm. At 94.7 mm. (fig. 8) the juvenile has assumed the general appearance of the adult.

Body proportions

Thirteen of the body dimensions measured on 66 specimens selected for size were chosen to depict development of various body proportions. Twenty-one of the 66 were of a series of 25 transforming specimens, ranging from 49.5 to 73.5 mm., taken with the aid of rotenone in less than 1 fathom of water (table 2). Body depth was determined for several additional 40- to 60-mm. pelagic specimens to reveal more clearly the sudden increase in this dimension in this size range. These original measurements are plotted against standard length in figures 9 through 21. The data suggest the inflection in slope for body dimensions to coincide with, or appear shortly after, the size range in which the species changes habitats.

For three of the dimensions, head length (fig. 9), postorbital head length (fig. 10), and snout to anal fin (fig. 11), the rate of increase is constant from the smallest through the largest specimens.

For body depth a straight line can be fitted to the data (fig. 12). In the 50- to 60-mm. size range, however, the pelagic forms are all below the line, and the bottom-dwelling forms are above the line (inset), suggesting sudden increase in this dimension initially upon assumption of a bottom habitat and a cessation of depth growth for pelagic forms in this range. The resumption of the initial rate of increase beyond this transformation period suggests this to be a temporary phenomenon.

Beyond 70- to 80-mm. the rate of increase of eye diameter is constant and slightly lower than the initial rate (fig. 13).

The data for the measurement, snout to spinous dorsal fin (fig. 14), suggest one rate of increase to about 50 mm. and a second slightly higher and constant rate beyond about 60 mm.; but rather than a simple inflection at 50 to 60 mm., there is an upward shift, indicating a sudden increase in this dimension in this range.

The rate of increase for snout to soft dorsal fin (fig. 15) beyond an inflection at about 50 to 60 mm. is constant and slightly higher than the initial rate.

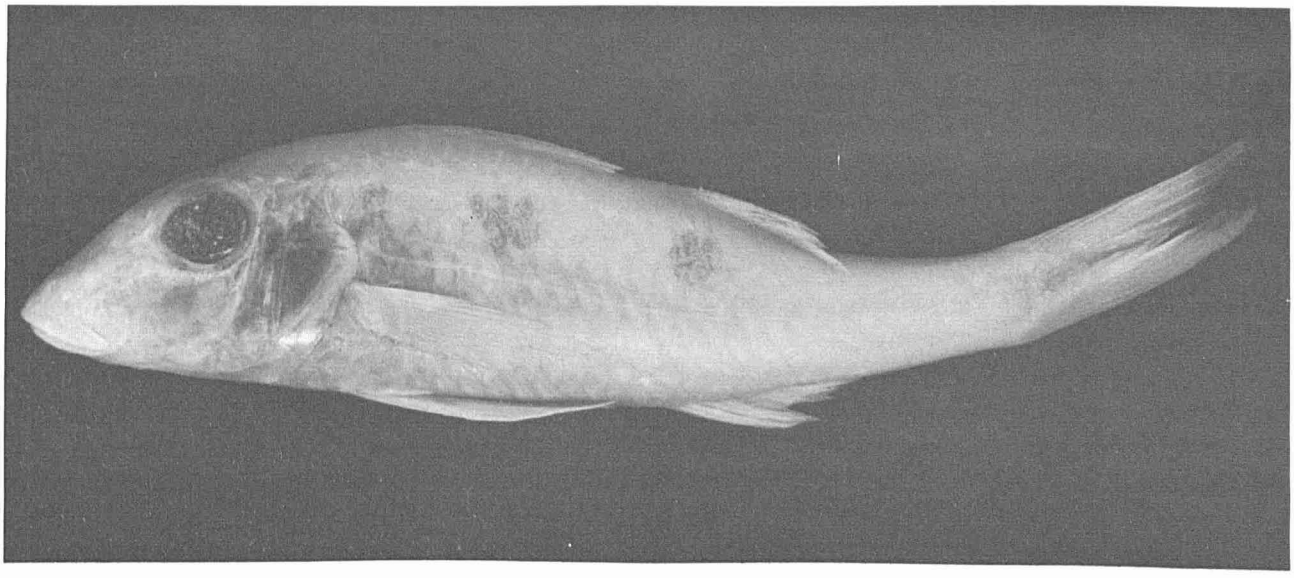

Figure 8.—*Pseudupeneus maculatus*, 94.7 mm. Trawled by *Oregon* personnel. (BLBG)

For length of ventral lobe of caudal fin (fig. 16) the rates of increase to about 60 mm. and beyond 100 mm. are constant and similar. There is an upward shift in the line depicting the ultimate rate in the 70- to 100-mm. size range. For length of dorsal lobe and caudal fin (fig. 17) there is an inflection at 80 to 100 mm. with the initial rate of increase slightly higher than the ultimate rate.

Interorbital space (fig. 18) appears to experience similar and constant rates of increase below about 40 mm. and above about 60 mm., with a considerable lower rate of increase in the 40- to 60-mm. size range. An inflection occurs in data for length of barbel (fig. 19) between 45 and 55 mm., with the rate of increase constant and lower beyond the inflection than initially.

For snout length (fig. 20) the rate of increase beyond an inflection at 40 to 50 mm. is constant and higher than the initial rate.

For length of the first lower-limb gill raker (fig. 21) there is apparently no increase between the smallest size in which raker lengths was determined (about 21.6 mm.) and about 55 mm. Beyond 55 mm. this part increases in length at a constant rate through the largest size examined.

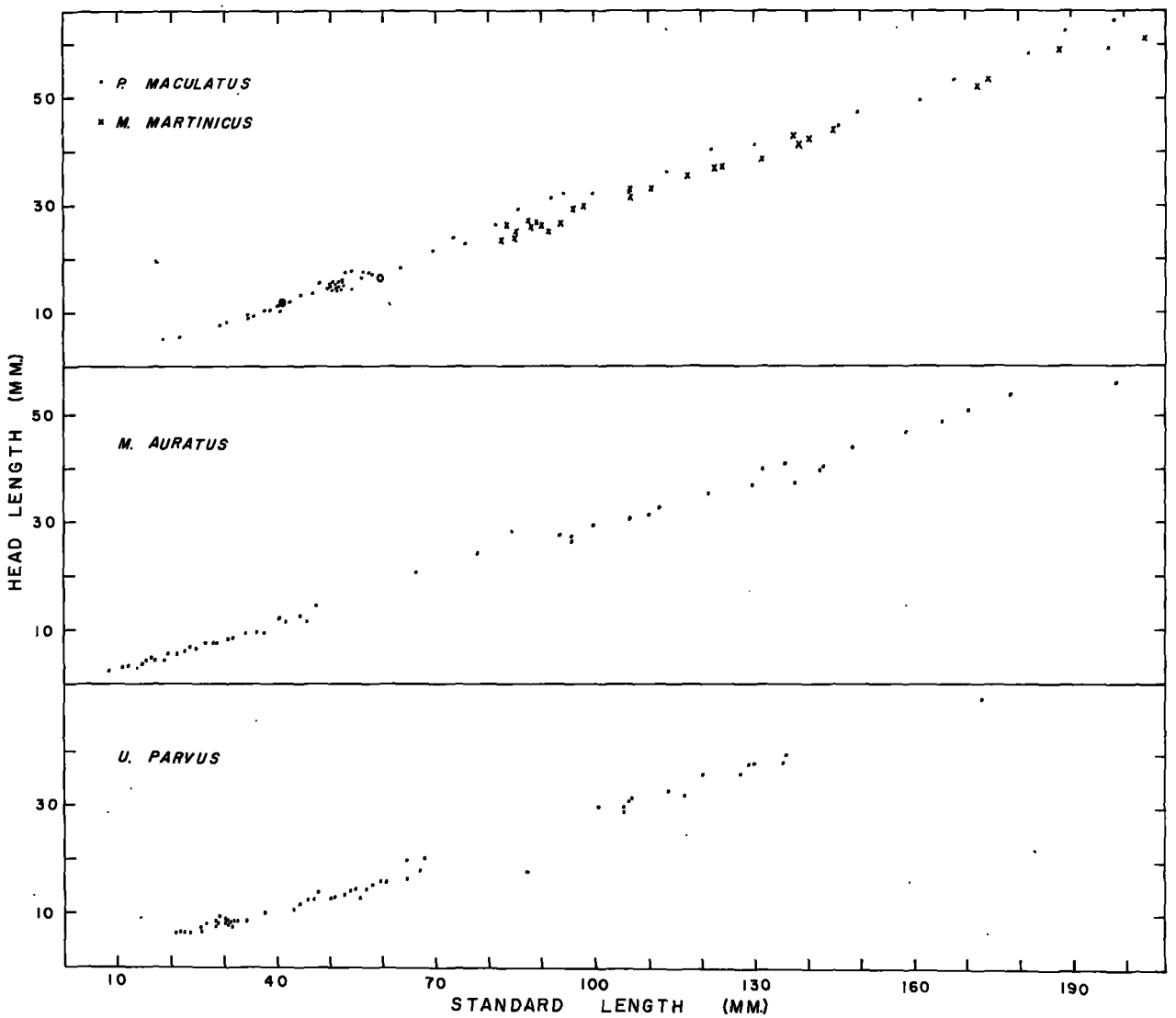

Figure 9.—Relation of head length to standard length of Mullidae of the western North Atlantic. For *Pseudupeneus maculatus*, large black circle indicates smallest metamorphosed specimen (41.0 mm.) and large open circle indicates large pelagic form (59.5 mm.).

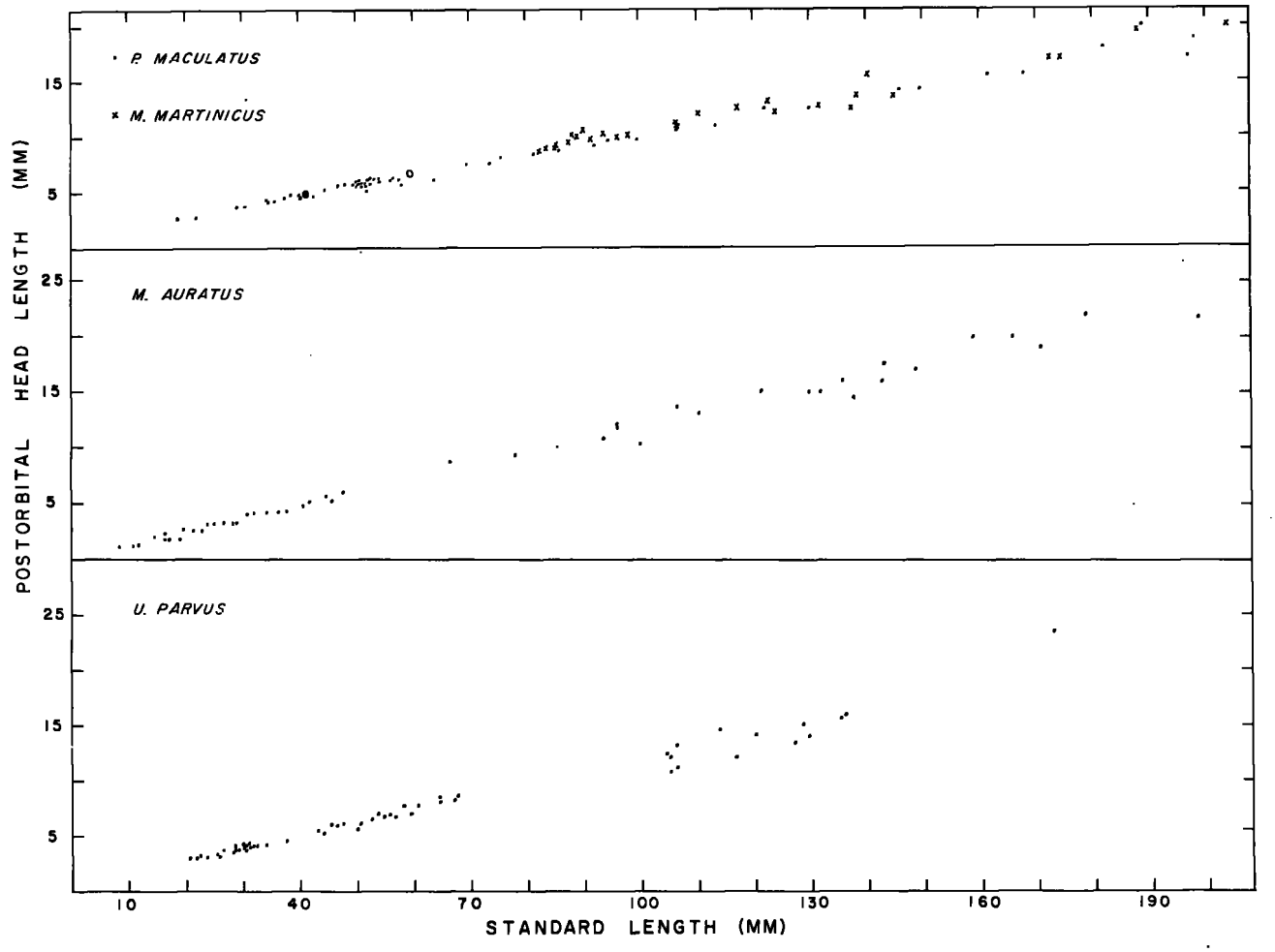

Figure 10.—Relation of postorbital head length to standard length of Mullidae of the western North Atlantic. For *Pseudupeneus maculatus*, large black circle indicates smallest metamorphosed specimen (41.0 mm.) and large open circle indicates large pelagic form (59.5 mm.).

The measurements of the smallest metamorphosed specimen (41.0 mm.) captured with aid of rotenone in a water depth not exceeding 2 fathoms (fig. 3, upper), and of one of the largest pelagic specimens (59.5 mm.) dip netted over a water depth of 1,000 to 2,000 fathoms (fig. 3, lower), suggest the differences between dimensions of metamorphosing or metamorphosed specimens and those of pelagic specimens. All of the specimens below 40 mm. were dip netted and pelagic, and all of the specimens above 50 mm. were taken with aid of rotenone or were trawled, and were bottom-living, with the 59.5-mm. exception.

Pigmentation

The pelagic juveniles were preserved in formalin, and the transitional and metamorphosed forms were preserved in isopropyl alcohol after being fixed in formalin. An 18.5-mm. specimen (fig. 7) was dark tan overall. In lateral view it had a row of large chromatophores along the entire lateral midline. They were set so closely together that they gave the impression of a solid line. This impression was heightened by the closely set, needle-thin fingers of dark brown pigmentation spreading from the matrices of these chromatophores. Above the lateral midline the fingers spread obliquely upward and posteriorly; below the lateral midline the fingers pointed obliquely forward and ventrally. Immediately below the dorsal fins there was a second row of pigment spots paralleling the row along the lateral midline. Above and below the lateral midline,

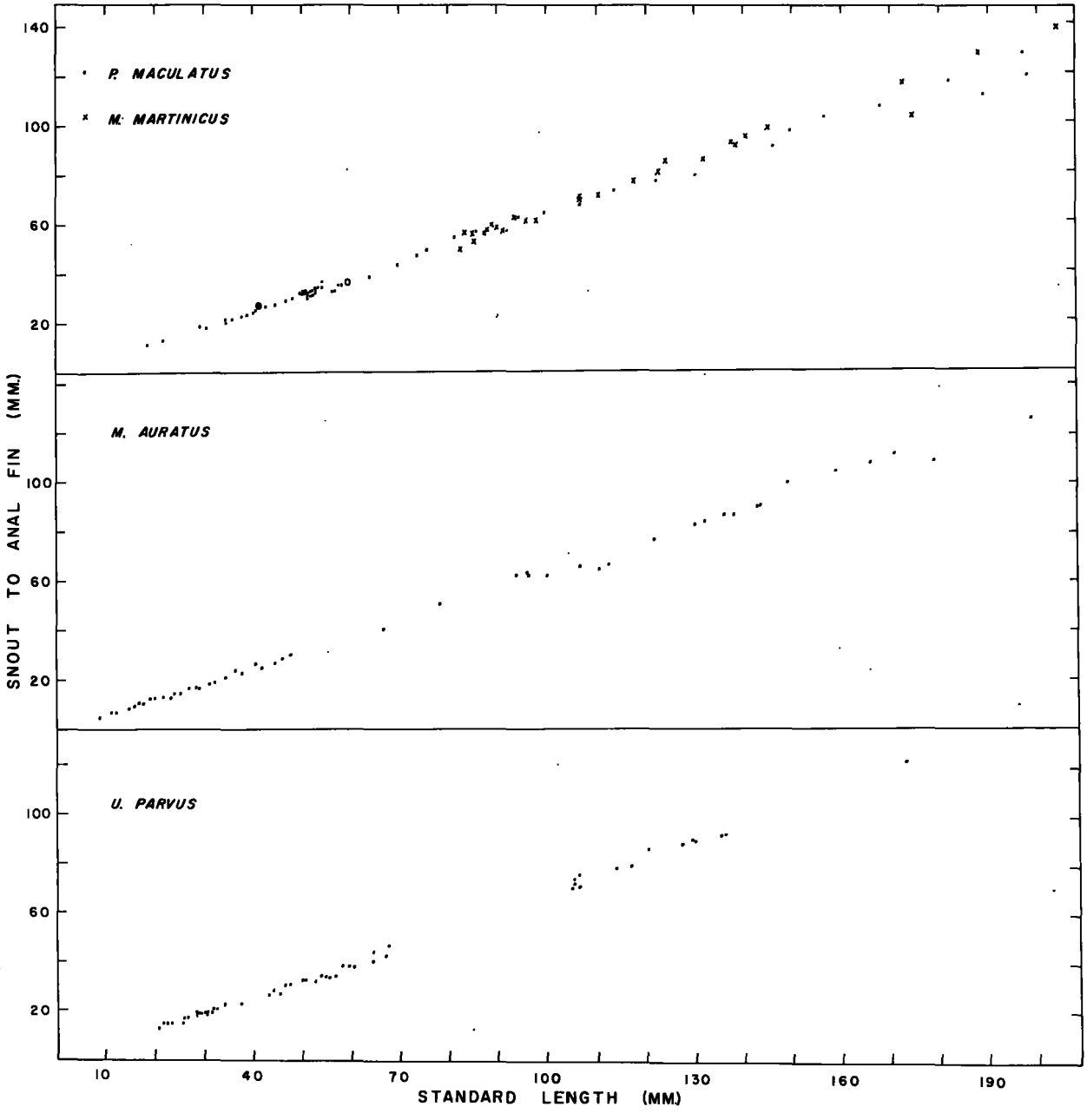

Figure 11.—Relation of distance from snout to anal fin to standard length of Mullidae of the western North Atlantic. For *Pseudupeneus maculatus*, large black circle indicates smallest metamorphosed specimen (41.0 mm.) and large open circle indicates large pelagic form (59.5 mm.).

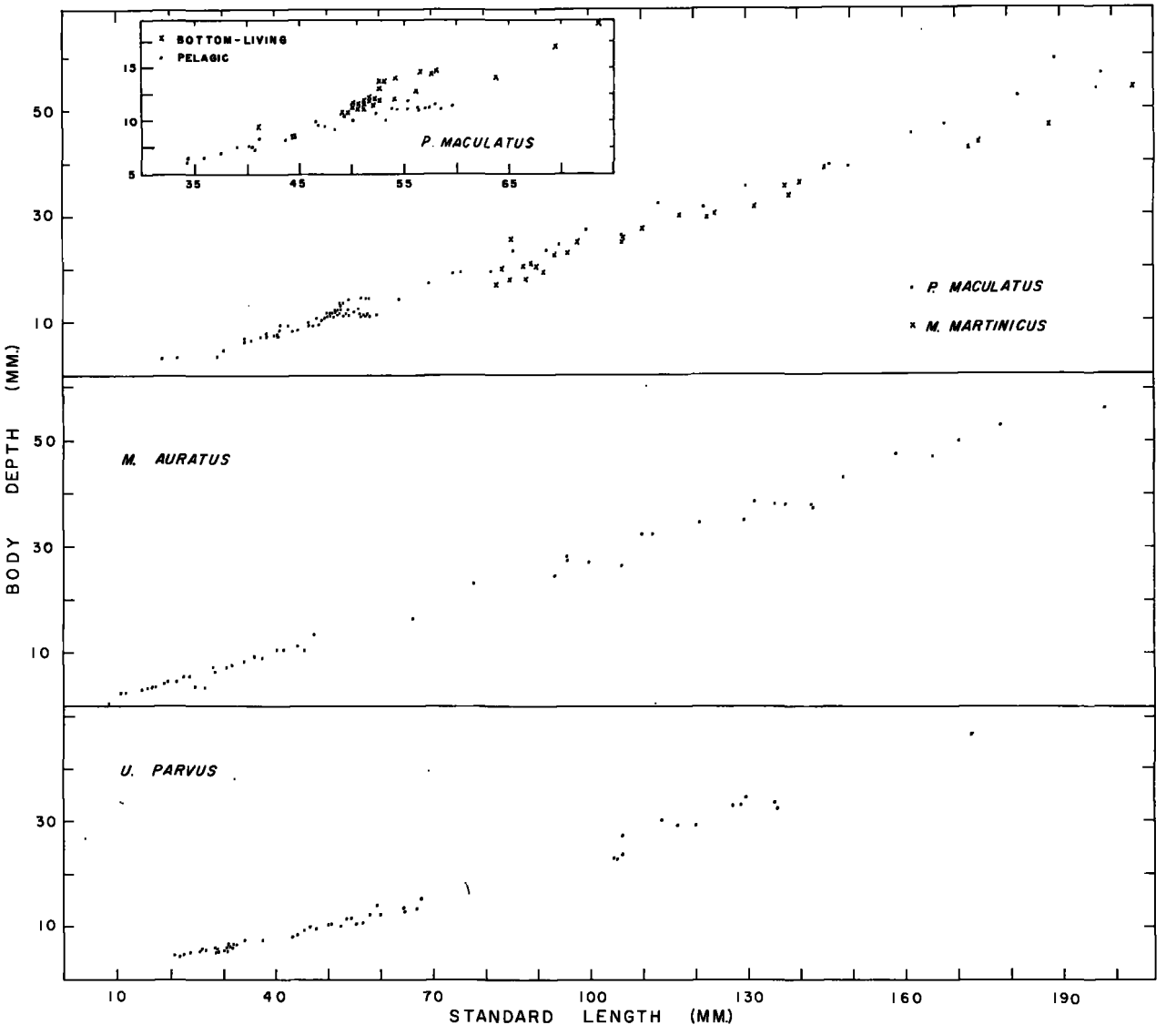

Figure 12.—Relation of body depth to standard length of Mullidae of the western North Atlantic. *Inset.* Depths of pelagic forms as opposed to depths of bottom-living forms of *Pseudupeneus maculatus*.

streaked pigment spots formed bars. These bars were directed anteriorly toward the midline at an oblique angle from the upper and lower lobes of the caudal fin, almost joining at the lateral midline to form several arrow points. Below and immediately above the lateral midline, the areas between the bars were relatively clear of pigment. Immediately below the most dorsal row of pigment spots there was additional pigmentation. In dorsal view, the body showed a single row of large, dark pigment spots along each side of the dorsal fins, which formed a long, slim "V" as the body tapered toward the caudal fin. The areas over the tip of the snout and frontal and supraoccipital bones were heavily pigmented. In ventral view, a double row of chromatophores, similar to the one on the dorsal surface, formed a "V". The fins were clear except for an occasional pigment spot on the caudal.

In a 29.0-mm. specimen the oblique bars above the lateral midline had given place to a homogeneous mottling of pigmentation. The bars below the lateral midline were still retained, the caudal and both dorsal fins had a few pigment spots, and the pelvics and anal were clear. In a 36.5-mm. specimen the oblique bars below the lat-

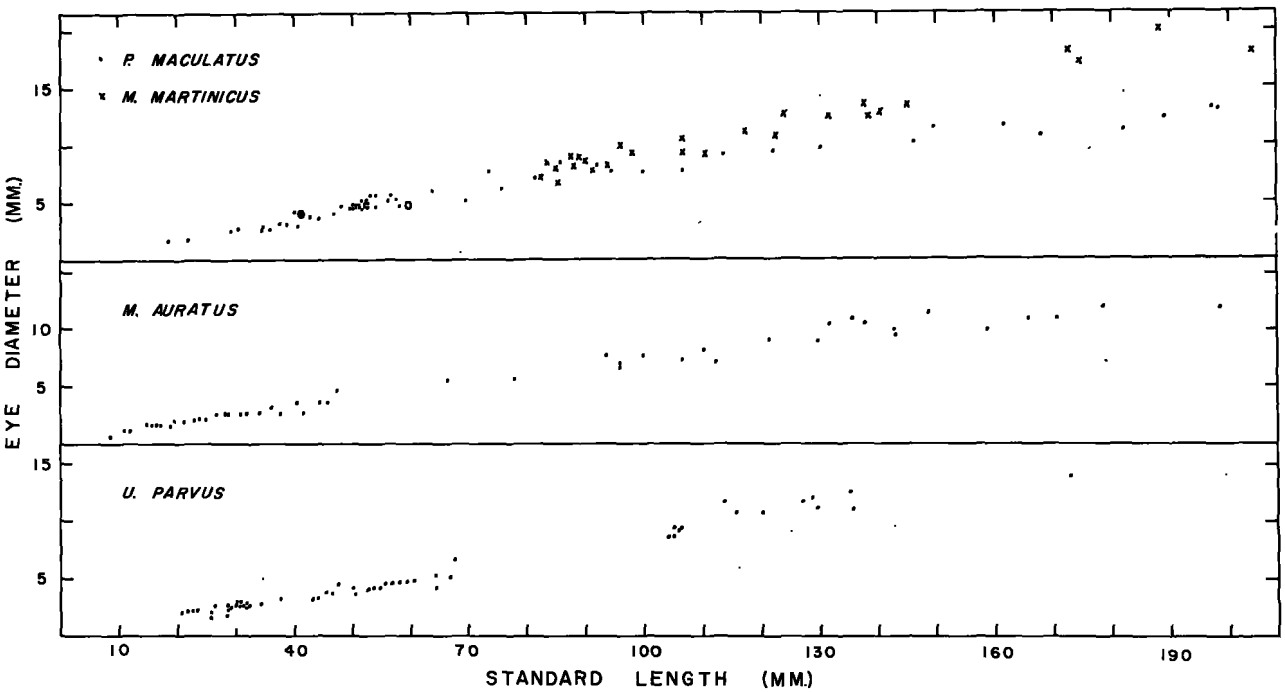

Figure 13.—Relation of eye diameter to standard length of Mullidae of the western North Atlantic. For *Pseudupeneus maculatus*, large black circle indicates smallest metamorphosed specimen (41.0 mm.) and large open circle indicates large pelagic form (59.5 mm.).

eral midline were somewhat obliterated as pigmentation was more diffuse. In the lowermost pelagic specimen in figure 4, there was a clear wavy line which commenced just posterior to the tip of the opercular spine, below the lateral midline, proceeded posteriorly and parallel to the midline to a point above the tips of the pelvic rays, then turned dorsally and back anteriorly to meet the lateral midline. An enlarged mirror-image of this line was above the lateral midline, and together the two formed a heart-shaped design in which the base of the heart points anteriorly. This was typical of *P. maculatus* of this size. In the two larger specimens (fig. 4) this wavy line was elongated posteriorly. The chromatophores between the snout and the supraoccipital bones had coalesced in the 46.5-mm. (lowermost) specimen, and the two dorsal and the caudal fins had pigment spots. Chromatophores were present on the two most dorsal rays of the pectoral fins of the 50.2-mm. specimen.

A point to emphasize is that the degree of color metamorphosis in pelagic juveniles (40 to 75 mm.) does not depend upon size. A 73.5-mm. specimen in this series had about the same coloration as a 49.0-mm. specimen and lacked the black blotches that had already formed in a 41.0-mm. specimen from a different collection.

In the series of metamorphosing forms (fig. 5), the ground color was light tan. The mottling of pigment spots seen on the entire body of the pelagic specimens (fig. 4) was progressively less intense below the lateral midline of the metamorphosing forms, receding first from the ventral edge of the body. The pigmentation of the upper half of the body of the 56.5-mm. specimen (fig. 5, uppermost) was as heavy as that of the pelagic forms. The pigmentation of the fins was no different from that of the fins of the pelagic forms. No lateral black blotches have formed in any of these specimens. Pigment blotches seen in the photograph of the 56.5-mm. specimen (fig. 5) showed up better in the photograph than to the naked eye—this occurred in several instances. In this series of specimens the dark pigmentation of the lateral midline of pelagic specimens was replaced by lighter color. Slightly below the lateral midline was a second light horizontal line, apparently an extension of the lower half of the heart

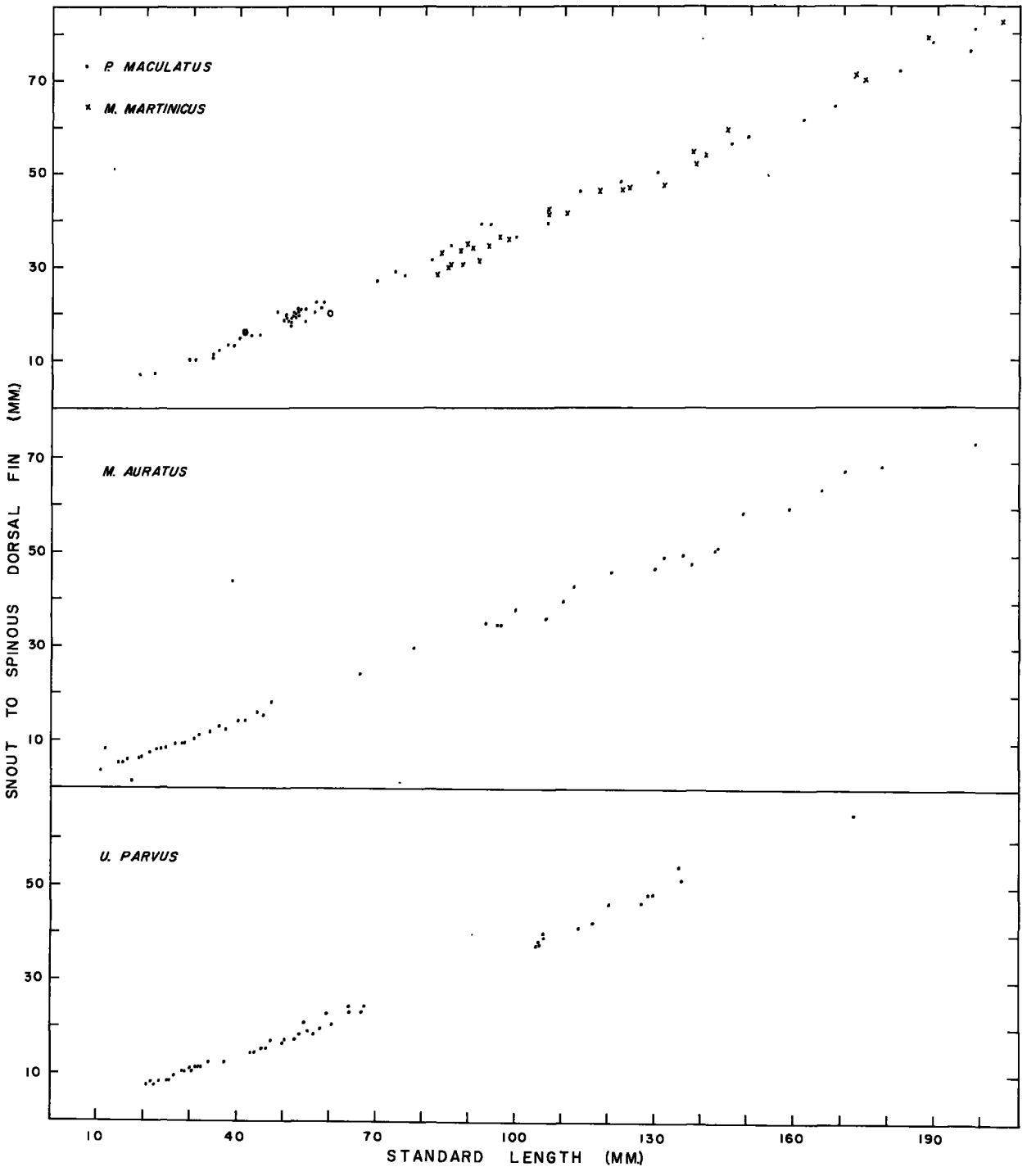

Figure 14.—Relation of distance from snout to spinous dorsal fin to standard length of Mullidae of the western North Atlantic. For *Pseudupeneus maculatus*, large black circle indicates smallest metamorphosed specimen (41.0 mm.) and large open circle indicates large pelagic form (59.5 mm.).

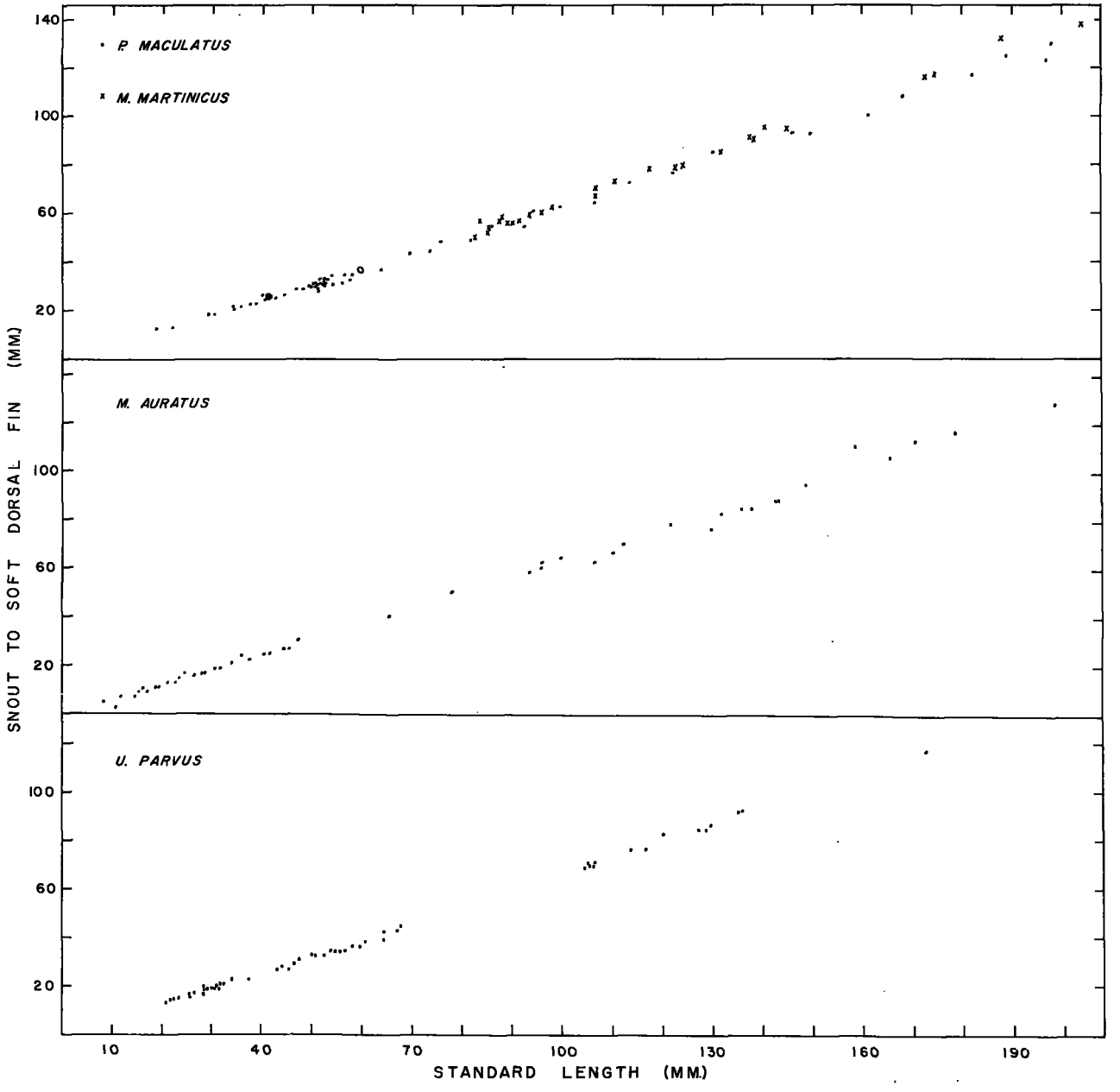

Figure 15.—Relation of distance from snout to soft dorsal fin to standard length of Mullidae of the western North Atlantic. For *Pseudupeneus maculatus*, large black circle indicates smallest metamorphosed specimen (41.0 mm.) and large open circle indicates large pelagic form (59.5 mm.).

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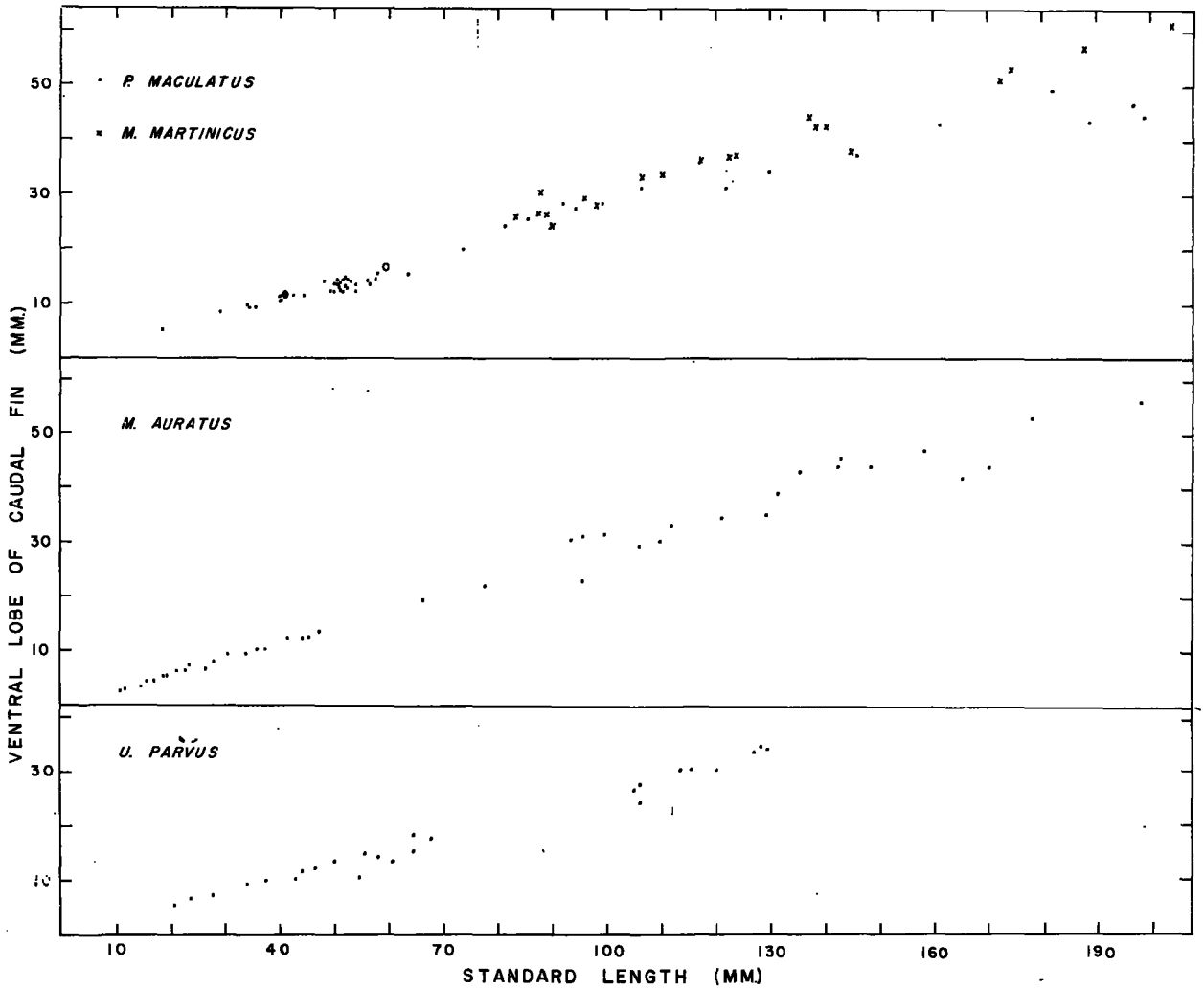

Figure 16.—Relation of length of ventral lobe of caudal fin to standard length of Mullidae of the western North Atlantic. For *Pseudupeneus maculatus*, large black circle indicates smallest metamorphosed specimen (41.0 mm.) and large open circle indicates large pelagic form (59.5 mm.).

design described for pelagic juveniles. The upper half of the heart design had almost disappeared.

The black blotches that appear during metamorphosis were examined on a 94.7-mm. specimen (fig. 8). They were composed primarily of pigmentation of the scales, as there was little pigmentation of the skin. Pigmentation of the winglike process of the cleithrum occurred as the anterior blotch enlarged. At 94.7 mm. the fins had lost their pigment except for a single black patch on the second dorsal. The two light lines along the lateral midline were still obvious.

The following color description is taken from a 175-mm. adult that had been preserved in formalin for 33 days:

Body and head red. Abdomen red. Three black blotches, the first just below the lateral line at the upper edge of the operculum, the second just below the lateral line and slightly posterior to the middle of the first dorsal, and the third along the lateral line below the middle of the second dorsal. First dorsal red, second dorsal reddish-yellow, caudal red. Pectorals orange-red, pelvics red tipped with yellow. Dark streak along lateral midline—caused by coloration within the mesodermal tissue, and not by pigmentation of the scales, as are the three black patches.

Most of the pigment of the 175-mm. specimen was lost during preservation, but the three black

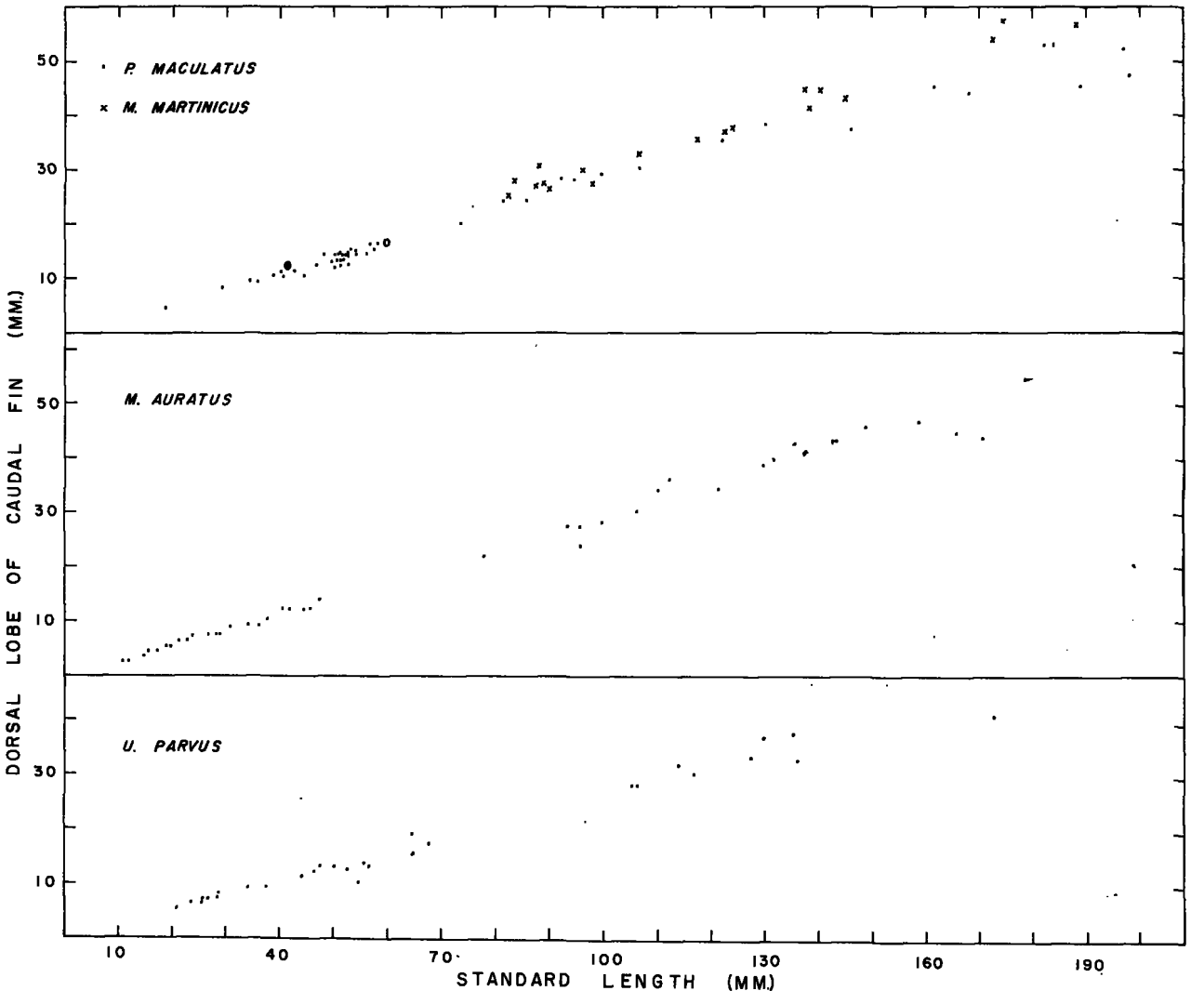

Figure 17.—Relation of length of dorsal lobe of caudal fin to standard length of Mullidae of the western North Atlantic. For *Pseudupeneus maculatus*, large black circle indicates smallest metamorphosed specimen (41.0 mm.) and large open circle indicates large pelagic form (59.5 mm.).

blotches were retained (one 189-mm. specimen had four black blotches). The dark lateral midline streak was obvious on some of the preserved material.

Fins

Spinous dorsal.—All specimens had eight dorsal spines, the most anterior of which was minute (fig. 22).

Soft dorsal.—The adults had nine segmented rays, the last eight of which were branched. In the 18.5-mm. specimen, segmentation had occurred in all but the first ray. Segmentation occurred in the first ray at approximately 40 mm. In the 18.5-mm. specimen only the last ray of the soft dorsal was branched. Seven rays were branched in a 29.0-mm. specimen, and all specimens 37.4 mm. and larger had eight branched rays.

Pectoral.—Pectoral rays were counted on 56 specimens ranging from 18.5 to 197.0 mm., and the counts plotted against size ranges (table 4, p. 411). The single specimen having 13 rays on the right side, the side normally counted, had 15 on the left. All three specimens under 30.0 mm. had 15 rays. In specimens above 30 mm. there was no apparent increase in number of individuals with 16 pectoral rays over the number having 15 rays. The fin has the adult complement of rays at 40 mm.

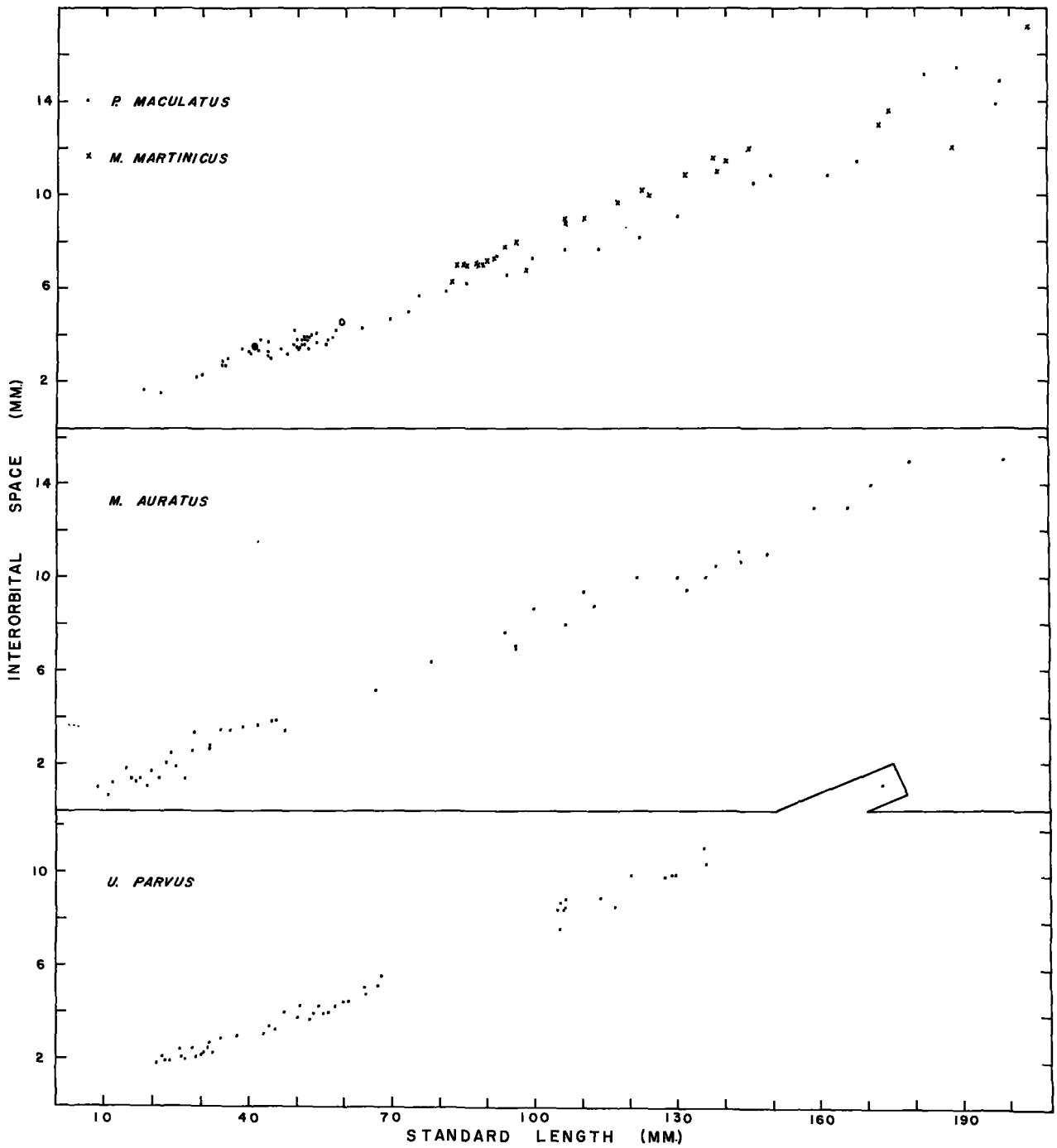

Figure 18.—Relation of interorbital space to standard length of Mullidae of the western North Atlantic. For *Pseudupeneus maculatus*, large black circle indicates smallest metamorphosed specimen (41.0 mm.) and large open circle indicates large pelagic form (59.5 mm.).

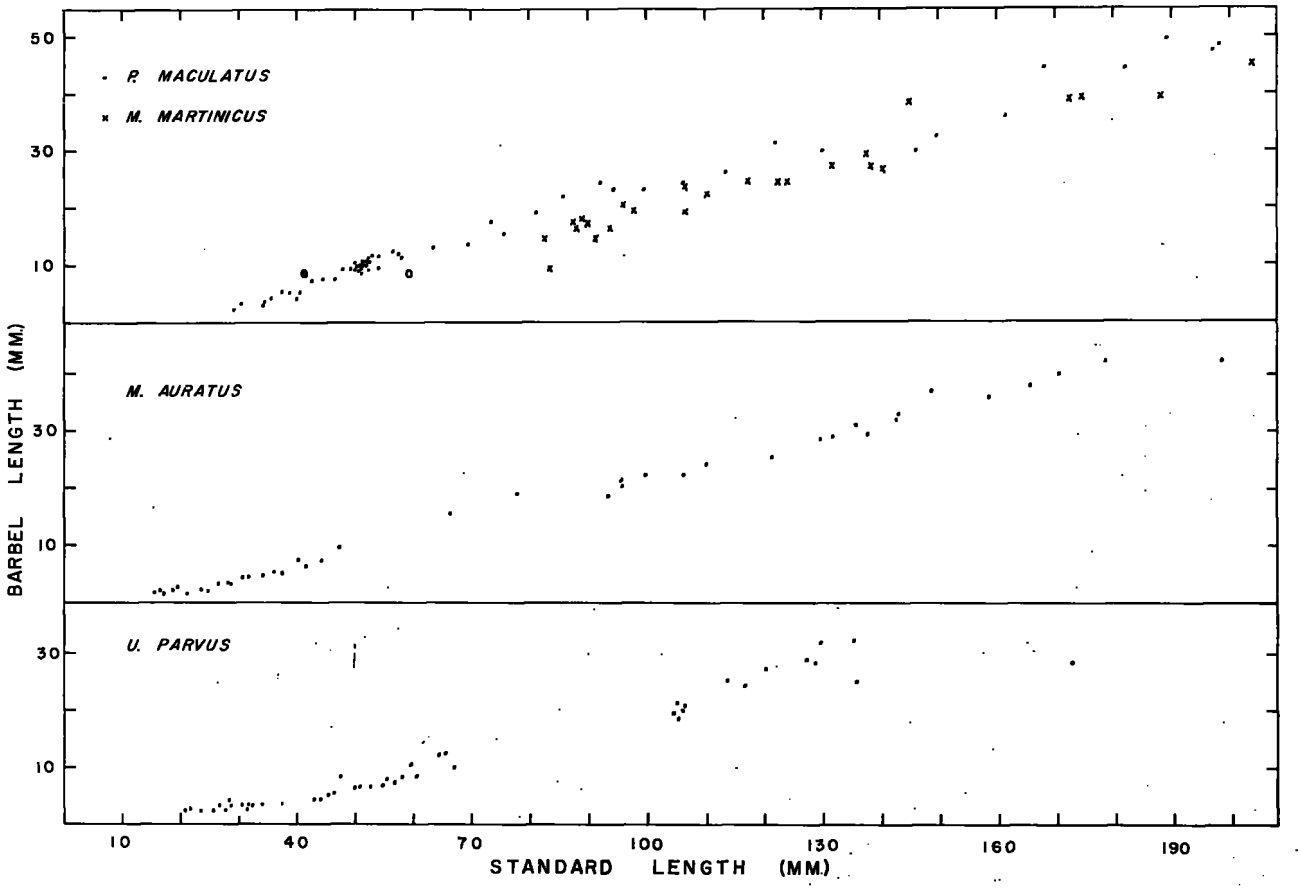

Figure 19.—Relation of barbel length to standard length of Mullidae of the western North Atlantic. For *Pseudupeneus maculatus*, large black circle indicates smallest metamorphosed specimen (41.0 mm.) and large open circle indicates large pelagic form (59.5 mm.).

There were no segmented rays on 21.6-mm. or smaller specimens. In a 29.0-mm. specimen the 5th through the 11th rays were segmented. A 34.1-mm. juvenile had segmentation in the 2d through the 11th rays. A 50.2-mm. specimen with 16 rays had the 2d through the 15th rays segmented. The first ray and the last ray were not segmented on any specimens below 103.4 mm., the size at which segmentation was complete.

Branching began between 21.6 and 29.0 mm., and at 29.0 mm. the fifth ray was branched. A 34.2-mm. specimen had five branched rays, the fourth through the eighth. At 38.8 mm., the number of branched rays had increased to 10, the 3d through the 12th. At 50.2 mm., all but the first two and the last ray were branched. The last ray was not branched on any specimen below 103.5 mm., the size at which branching was complete. The first two rays never branch.

Pelvic.—In the pelvic fin of the 18.5-mm. specimen none of the six rays were branched. A 21.6-mm. specimen had two branched rays, and those 29.0 mm. and larger had five branched rays.

Anal.—The anal fin of the adult has one short spine and seven segmented rays, the last six branched. The seven rays were segmented in an 18.5-mm. specimen, but only the last two were branched. At 29.0-mm. the last six rays were branched.

Caudal.—The principal ray count on all specimens was 15 (i, 7+6, i). Secondary ray counts were made on 12 specimens ranging from 18.5 through 57.5 mm. In specimens larger than this the secondary rays are so overgrown by tissue and scales that counts were unreliable. The secondary ray counts ranged from 8 to 10 in the dorsal lobe and 8 to 11 in the ventral lobe. The smallest specimen had 9 dorsal and 10 ventral secondary

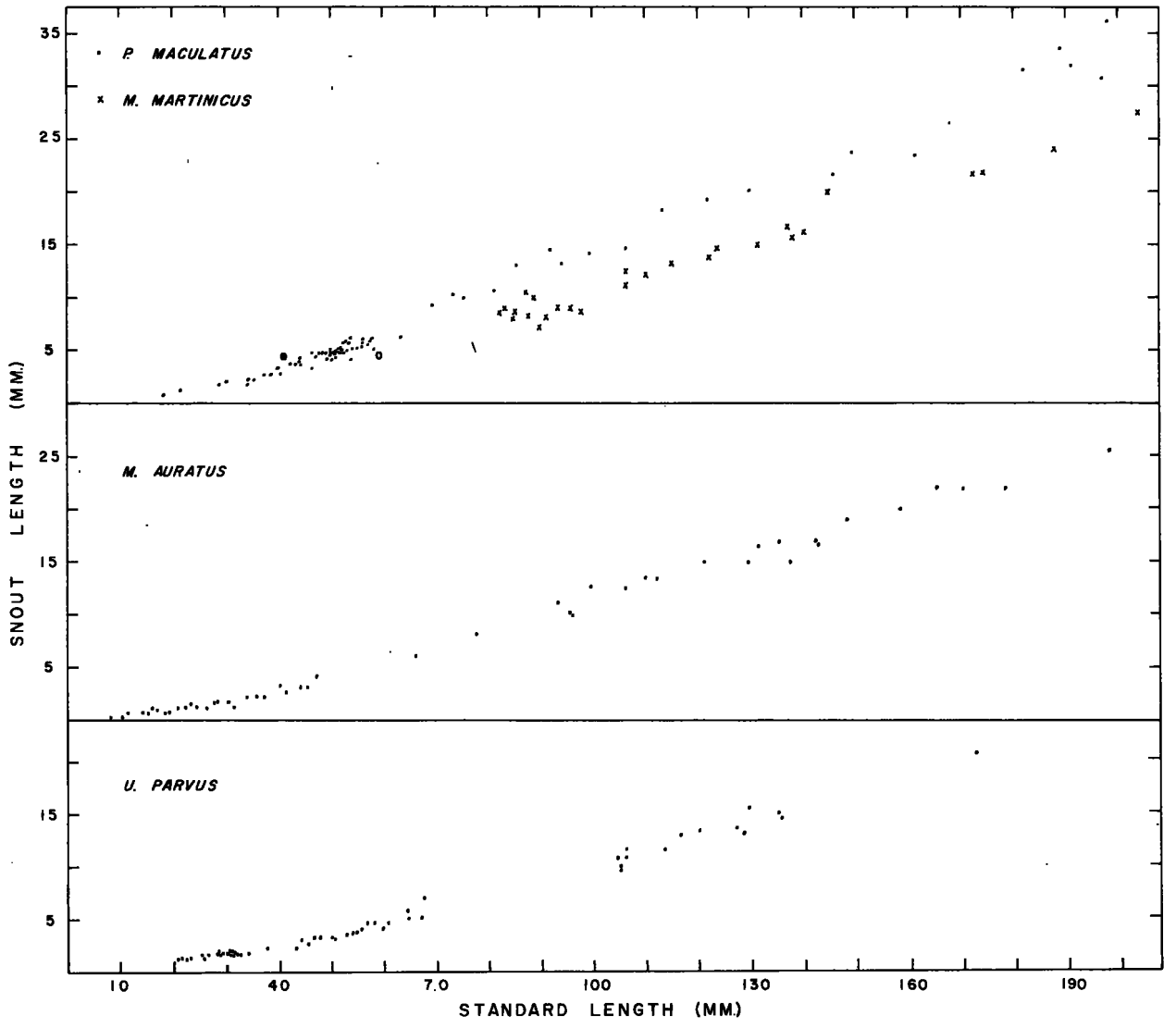

Figure 20.—Relation of snout length to standard length of Mullidae of the western North Atlantic. For *Pseudupeneus maculatus*, large black circle indicates smallest metamorphosed specimen (41.0 mm.) and large open circle indicates large pelagic form (59.5 mm.).

rays, and was considered a juvenile. On both dorsal and ventral caudal lobes, the secondary ray adjacent to the principal rays was segmented. A 57.5-mm. specimen had the first two rays adjacent to the principal rays segmented. The cleared and stained caudal fin of a 178-mm. specimen showed no additional segmentation of either lobe beyond those first two secondary rays adjacent to the principal rays.

Gill rakers

Total.—Total number of gill rakers was counted on 60 specimens. The number of upper-limb gill rakers on two smaller specimens (18.5 and 21.6 mm.) was indeterminate, and the specimens were not available for staining. From 29.0 to 198.0 mm. the total number of gill rakers ranged from 26 to 32, with the exception of one specimen (34.2 mm.) which had 24.

When plotted against total body length ranges (table 5, p. 411), the total number of gill rakers averaged highest in the size range from 50.0 to 74.9 mm. There was a decrease after this size as the gill rakers farthermost from the angle of the arch become overgrown with tissue.

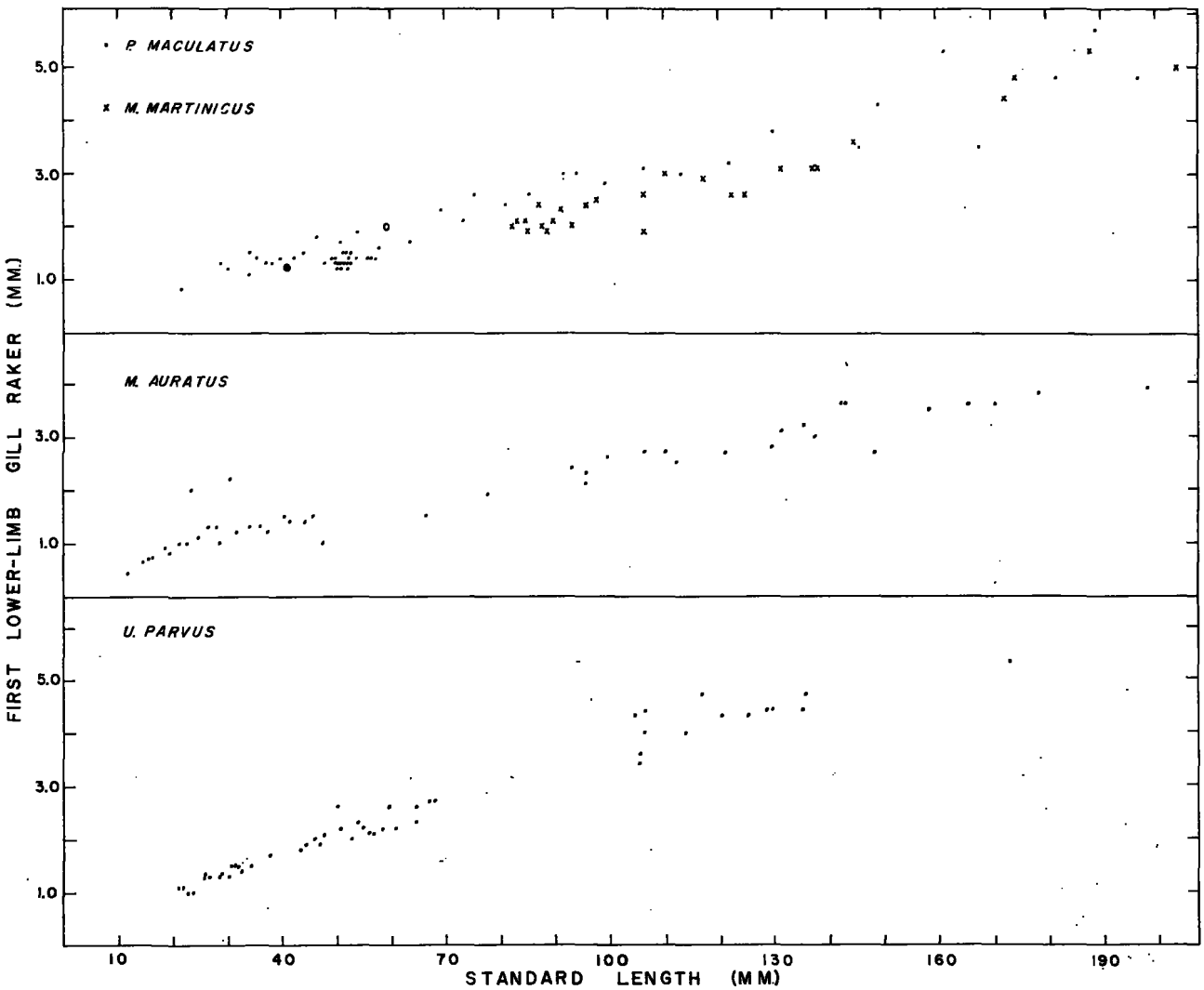

Figure 21.—Relation of length of first lower-limb gill raker to standard length of Mullidae of the western North Atlantic. For *Pseudupeneus maculatus*, large black circle indicates smallest metamorphosed specimen (41.0 mm.) and large open circle indicates large pelagic form (59.5 mm.).

Lower limb.—The lower-limb gill rakers were counted on these 60 specimens as well as the two smaller specimens mentioned above. The number of lower-limb gill rakers ranged from 19 to 24, with the exception of 1 specimen (21.6 mm.) which had 17 (table 6, p. 428).

The average number increased with size up through a 50.0- to 74.9-mm. size range, then decreased as the rudiments became overgrown with tissue.

Ceratobranchial bone.—The number of gill rakers on the ceratobranchial bone was counted on 32 specimens. Of these, 2 (18.5 and 34.2 mm.) had 11, 1 had 15 (85.8 mm.), and the remainder had from 12 to 14.

Teeth

Upper jaw.—Among the Mullidae of the western North Atlantic, curved canines in the upper jaw anterior and lateral to the main row of canines are peculiar to *P. maculatus*. Teeth were not evident in an 18.5-mm. specimen, but were present in one of 21.6 mm. The left premaxillary bone of a 46-mm. specimen had a regular series of 14 erupted canine teeth, plus 6 unerupted teeth in the 6th, 8th, 10th, 14th, 17th, and 19th positions from

TABLE 6.—*Relation of numbers of lower-limb gill rakers (exclusive of one at angle of arch) to standard length of 62 specimens of* Pseudupeneus maculatus

[The upper number is the number of specimens, and the number in parentheses below is the approximate percentage for the respective size range]

Standard lenth (mm.)	Number of lower-limb gill rakers								Number of specimens
	17	18	19	20	21	22	23	24	
0–19.9				1 (100)					1
20.0–29.9	1 (50.0)			1 (50.0)					2
30.0–39.9			2 (33.3)	2 (33.3)	2 (33.3)				6
40.0–49.9				3 (37.5)	3 (37.5)	2 (25.0)			8
50.0–74.9			1 (3.6)	2 (7.1)	5 (17.9)	12 (42.9)	5 (17.9)	3 (10.7)	28
75.0–99.9			1 (16.7)	3 (50.0)	2 (33.3)				6
100.0–124.5			1 (33.3)	1 (33.3)		1 (33.3)			3
125.0–149.5			2 (66 7)		1 (33.3)				3
150.0–200.0			2 (40.0)	2 (40.0)	1 (20.0)				5

TABLE 7.—*Collection and station data for 587 specimens of* Mullus auratus *examined*

[Dip net (D), trawl (T), and stomach contents (SC)]

Station	Latitude	Longitude	Date of capture	Depth of water in which captured	Method of capture	Number of specimens and size range	Collection and catalogue number (if any)
WESTERN NORTH ATLANTIC:				*Fathoms*		*mm.*	
Gill Cr. 2, Reg. 76	34°53′ N.	76°10′ W.	May 11, 1953	8	D	(4) 25.5–39.0	BLBG
Silver Bay 1267	34°35′ N.	75°55′ W.	Sept. 11, 1959	24	T	(47) 100.0–126.0	BLBG
Silver Bay 1269	34°32′ N.	75°57′ W.	Sept. 12, 1959	25	T	(26) 94.0–128.5	BLBG
Silver Bay 1268	34°32′ N.	75°53′ W.	Sept. 11, 1959	30–31	T	(2) 114.5 and 117.0	BLBG
Silver Bay 1299	34°21′ N.	76°34′ W.	Sept. 23, 1959	14	T	(7) 108.0–121.0	BLBG
Gill Cr. 1, Reg. 73	34°09′ N.	75°22′ W.	Mar. 6, 1953	[1] 1500	D	(1) 16.0	BLBG
Silver Bay 1214	34°02′ N.	77°35′ W.	Sept. 3, 1959	11	T	(2) 181.5 and 202.5	BLBG
Silver Bay 1215	33°56′ N.	77°20′ W.	Sept. 3, 1959	15	T	(1) 197.5	BLBG
Silver Bay 1508	33°49′ N.	77°27′ W.	Dec. 9, 1959	18	T	(1) 150.5	BLBG
Silver Bay 1209	33°41′ N.	77°40′ W.	Sept. 2, 1959	11–12	T	(2) 117.5 and 134.5	BLBG
Silver Bay 1692	33°21′ N.	77°17′ W.	Feb. 28, 1960	25–26	T	(1) 149.0	BLBG
Silver Bay 1204	33°21′ N.	77°24′ W.	Sept. 1, 1959	15–16	T	(4) 109.0–128.0	BLBG
Silver Bay 1349	33°18′ N.	78°44′ W.	Oct. 19, 1959	9	T	(1) 131.0	BLBG
Silver Bay 1673	33°14′ N.	77°41′ W.	Feb. 27, 1960	18–19	T	(1) 163.0	BLBG
Silver Bay 1354	33°06′ N.	78°46′ W.	Oct. 19, 1959	11	T	(1) 117.0	BLBG
Silver Bay 1361	33°00′ N.	78°40′ W.	Oct. 20, 1959	15–16	T	(5) 118.0–126.5	BLBG
Silver Bay 1733	33°00′ N.	78°26′ W.	Mar. 7, 1960	17	T	(1) 159.0	BLBG
Silver Bay 1358	32°58′ N.	78°13′ W.	Oct. 20, 1959	23–24	T	(1) 134.5	BLBG
Silver Bay 1364	32°54′ N.	79°12′ W.	Oct. 21, 1959	11	T	(5) 117.5–128.5	BLBG
Silver Bay 1734	32°51′ N.	78°39′ W.	Mar. 7, 1960	17	T	(1) 166.5	BLBG
DeVeaux's Bank, vicinity of Charleston, S.C.					SC	(1) 96.0 [2]	ChM 31.150.6
S.E. of Edisto River Sea Buoy, vicinity of Charleston, S.C.			Feb. 24, 1958	18		(1) 143.0	ChM 58.2.11
Silver Bay 1359	32°45′ N.	78°23′ W.	Oct. 20, 1959	50	T	(1) 134.0	BLBG
Silver Bay 1742	32°41′ N.	78°27′ W.	Mar. 8, 1960	45–68	T	(8) 129.0–165.0	BLBG
Combat 299	32°22′ N.	78°14′ W.	Apr. 21, 1957	250	D?	(9) 15.0–29.0	BLBG
Combat 428	32°17′ N.	79°10′ W.	June 25, 1957	24–28	T	(1) 66.5	UMIM 1972
Gill Cr. 2, Reg. 49	32°12′ N.	78°25′ W.	May 7, 1953	185	D	(14) 24.0–37.5	BLBG
Gill Cr. 2, Reg. 43	32°12′ N.	79°33′ W.	May 6, 1953	17	D	(3) 21.5–29.0	BLBG
Silver Bay 1754	32°06′ N.	79°11′ W.	Mar. 9, 1960	49–50	T	(2) 170.0 and 174.5	BLBG
Gill Cr. 2, Reg. 42	31°57′ N.	79°18′ W.	May 6, 1953	75	D	(16) 19.0–33.0	BLBG
Gill Cr. 2, Reg. 36	31°42′ N.	80°38′ W.	May 5, 1953	12	D	(1) 17.5	BLBG
Gill Cr. 2, Reg. 31	31°00′ N.	79°59′ W.	April 28, 1953	28	D	(2) 15.0 and 18.0	BLBG
Silver Bay 1621	30°48′ N.	80°29′ W.	Jan. 28, 1960	20	T	(1) 155.0	BLBG
Gill Cr. 2, Reg. 25	30°20′ N.	80°35′ W.	Apr. 27, 1953	18	D	(4) 17.5–25.0	BLBG
Silver Bay 2084	29°53′ N.	80°34′ W.	May 5, 1960	21	T	(2) 145.0 and 159.0	BLBG
Gill Cr. 2, Reg. 20–21	29°40′ N.	80°57′ W.	Apr. 26, 1953	9	D	(13) 34.5–39.0	BLBG
Gill Cr. 2, Reg. 19	29°39′ N.	80°23′ W.	Apr. 26, 1953	23	D	(2) 37.5 and 38.0	BLBG
Silver Bay 460	29°38′ N.	80°14′ W.	June 13, 1958	75	T	(1) 138.0	BLBG
Combat 488	29°30′ N.	80°13′ W.	Aug. 19, 1957	50	T	(3) 132.0–147.0	BLBG
Combat 350	29°27′ N.	80°20′ W.	June 3, 1957	28	T	(1) 131.0	BLBG
Combat 339	29°19′ N.	80°18′ W.	June 1, 1957	25	T	(3) 136.0–168.0	BLBG
Combat 335	29°03′ N.	80°13′ W.	June 1, 1957	28	T	(1) 171.0	BLBG

See footnotes at end of table.

TABLE 7.—*Collection and station data for 587 specimens of* Mullus auratus *examined*—Continued

[Dip net (D), trawl (T), and stomach contents (SC)]

Station	Latitude	Longitude	Date of capture	Depth of water in which captured	Method of capture	Number of specimens and size range	Collection and catalogue number (if any)
WESTERN NORTH ATLANTIC—Con.				*Fathoms*		*mm.*	
Combat 334	29°15′ N.	80°13′ W.	June 1, 1957	30	T	(1) 125.0	BLBG
Gill Cr. 2, Reg. 13	29°00′ N.	80°33′ W.	Apr. 25, 1953	9	D	(15) 23.5–39.5	BLBG
Gill Cr. 6, Reg. 10	28°20′ N.	80°10′ W.	Apr. 27, 1954	21	D	(1) 28.0	BLBG
Gill Cr. 5, Reg. 6	27°40′ N.	79°41′ W.	Jan. 31, 1954	260	D	(3) 18.0–22.0	BLBG
Gill Cr. 6, Reg. 4	27°20′ N.	80°01′ W.	Apr. 26, 1954	13	D	(25) 28.0–41.0	BLBG
Gill Cr. 2, Reg. 3	27°01′ N.	80°04′ W.	Apr. 23, 1953	6	D	(145) 8.0–42.0	BLBG
GULF OF MEXICO:							
Pompano 5, 14 mi. west of Charlotte Harbor, Fla.			Apr. 21, 1949	10		(1) 40.0	BLBG
Ellen, Sea Horse Reef, Fla			June 19, 1949		T	(1) 47.5	UMIM 3105
Oregon 2159	28°03′ N.	83°50′ W.	Apr. 9, 1958	21	D	(6) 22.0–39.5	BLBG
Oregon 602	29°32′ N.	86°21′ W.	July 12, 1952	80	T	(2) 134.0 and 163.0	TU 6067
Oregon 1095	27°10′ N.	96°17′ W.	June 5, 1954	175	T	(1) 149.0	TU 12890
Oregon 1081	26°10′ N.	96°59′ W.	June 2, 1954	15	T	(1) 78.5	UF
Oregon 2470	20°12′ N.	91°59′ W.	Apr. 14, 1959	10	D	(1) 43.0	USFWS Icth. Lab.
Silver Bay 403	22°12′ N.	89°57′ W.	May 11, 1958	27	D	(170) 12.0–46.0	BLBG
Silver Bay 410	22°13′ N.	89°50′ W.	May 12, 1958	27	D	(1) 40.0	BLBG
Oregon 2174	22°23′ N.	89°44′ W.	May 11–12, 1958	15	D	(9) 40.0–45.0	USFWS Icth. Lab.
Silver Bay 411	22°11′ N.	88°53′ W.	May 14, 1958	23	T	(2) 156.0 and 173.0	BLBG

[1] Estimated from hydrographic chart. [2] Regurgitated by young royal tern.

TABLE 8.—*Relation of size of specimen, method of capture (dip net, D; trawl, T), and water depths in which captured for* Mullus auratus

[Each letter represents a capture of one or more specimens within a particular size range]

DEPTH IN FATHOMS	SIZE RANGE IN MILLIMETERS				
	0–24.5	25.0–49.5	50.0–74.5	75.0–99.5	Over 100
Over 100	DDD	DDDD			T
75–99	D	D			TT
50–74					T
25–49	DD	DDD	T	T	TTTT TTTT
0–24	DDDD DD	DDDD DDDD DDDD D			TTTT TTTT TTTT TTTT TTTT

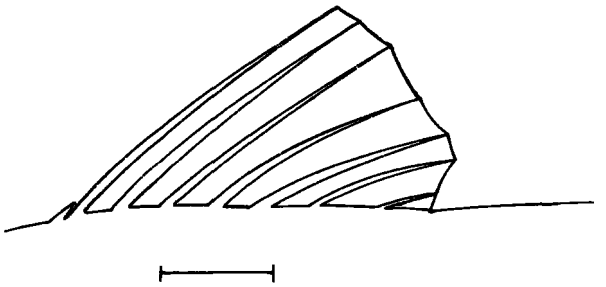

Figure 22.—Spinous dorsal fin of 46.0-mm. *Pseudupeneus maculatus*. Line equals 2 mm.

the anterior end of the premaxilla. None of the unerupted teeth was out of position in the series, and those that had erupted curved somewhat toward the back of the mouth. The right premaxillary had 19 erupted teeth and 2 unerupted teeth toward the back of the jaw, an adult complement of teeth in the main row.

The left premaxillary bone of a 94.8-mm. specimen had a regular series of 14 inwardly curved canine teeth plus sockets containing undeveloped teeth in the fourth and ninth positions. The right premaxillary was similar but had in addition a larger canine, in the fourth position in the regular row, directed toward the right side of the month and curved upward. This single, larger, backwardly curving canine anterior to the regular series was not apparent in any specimen under 79.2 mm. Of the specimens examined for this character, it was present in 25 percent of those 80 to 100 mm., 50 percent of those 100 to 130 mm., and 90 percent of those over 130 mm. This tooth either forms in addition to the regular series, or is one that enlarges, becomes hooked, and migrates to a position anterior to the others in the regular row of teeth.

A 108.0-mm. specimen did not have the large canine seen on the 94.8-mm. specimen. The left premaxillary bone had a row containing 19 evenly spaced, fully developed teeth and two unerupted teeth in the 16th and 19th tooth sockets. The right premaxillary had a developing tooth and socket at the base of the second tooth in addition to the regular series of erupted and erupting teeth.

The upper jaw of a 119.5-mm. specimen had a row of canines which were for the most part curved down and toward the back of the mouth.

The two front teeth curved toward each other and the back of the mouth. Anterolateral to these on each of the premaxillaries was a large canine which curved anteriorly and outward. Set slightly above the regular series of teeth, the one in the right premaxillary was between the fourth and fifth teeth, and the one on the left was between the third and fourth teeth. Medial to the two oversized teeth, and set above and between the bases of the second and third teeth in the regular row, were large sockets each containing a developing tooth much larger than those in the regular series. These pointed toward the floor of the mouth. A second oversized canine was found above, anterior to, and in addition to the regular series. This second oversized canine had not erupted on any specimen examined smaller than 115 mm. and was seen on 50 percent of the specimens over this size.

A 146-mm. specimen had, anterior to the regular row, a third large canine on each premaxillary bone. These were medial to the other two and curved toward each other and upward. Noticed on 20 percent of the larger specimens, this third canine sometimes appeared on only one of the premaxilliaries.

I examined only two specimens over 200 mm., one 206 mm., the other 225 mm., and each had the additional curved canines. Three was the maximum number found on either half of the premaxillary.

Lower jaw.—Teeth were not evident in an 18.5-mm. *P. maculatus*, but were visible in all specimens 21.6 mm. and larger. A 49-mm. specimen had 12 and 13 canine teeth in a single row on the left and right dentaries respectively.

Vomerine and palatine.—No teeth were seen on the vomerine or palatine bones of any specimen of *P. maculatus*.

Scales

Lateral line scales were counted on 41 specimens ranging from 41.0 to 197.0 mm. The counts ranged from 27 to 31 with the two extremes being encountered only once (2.4 percent). The other counts were 28 (46.3 percent), 29 (29.3 percent), and 30 (19.5 percent). Specimens up through a size of 38.8 mm. had either no scales (18.5 mm.) or only a few along the dorsal and ventral surfaces concentrated in the regions of the dorsal and anal fins, and one large scale in the axilla of the pectoral (21.6 through 38.8 mm.). Whereas it is possible that scales do not develop except in these regions before a size of approximately 40 mm., the fact

that a 41.0-mm. metamorphosed specimen had an adult complement of 30 firmly fixed lateral line scales makes this unlikely.

A 30.1-mm. specimen had no ctenii on the scales, but a 42.4-mm. specimen had 18 ctenii on one of the scales. These ctenii appear to be set into marginal sockets. The ctenii had increased to 52 in a 50.2-mm. specimen and 141 in a 189.0 mm. specimen. The ctenii of the scales of the 189.0-mm. specimen had changed in appearance so that they resembled sharply pointed cells protruding from the margin of the scale, the outermost of a series of other cell-like structures, rectangular in shape.

Barbels

In an 18.5-mm. specimen both barbels were free from the branchiostegal membrane except at the tip of the right barbel. In a 21.6-mm. specimen, neither barbel was free, but had separated at the base. Both barbels were free at 29.0 mm. and larger sizes.

Operculum

The adult has a strong opercular spine at about the anterior end of the lateral midline. There was no evidence of this spine on an 18.5-mm. specimen. It was noted on a specimen of 21.6 mm., but the tip did not extend to the margin of the operculum. On a 29.0-mm. specimen it was clearly seen, as it was on all larger specimens examined. A second small spine, anterior to the large spine, was noted on an occasional large specimen.

Cleithrum

The cleithrum had an enlarged winglike process just posterior to the upper angle of the opercular flap. It had a remarkable resemblance to a scale as it acquired the pigmentation occurring as a dark blotch in this region. At a size of approximately 40 mm., the same size at which the scales become ctenoid, this small prominent bone had serrations, further increasing its similarity to a ctenoid scale. At sizes above 50 mm. this serrated cleithral wing was the quickest and easiest method of identifying *P. maculatus*, as this character is peculiar to this species of the Mullidae of the western North Atlantic.

The upper wing of the cleithrum of a 46.0-mm. juvenile and its position relative to the operculum and opercular spine are illustrated (fig. 23).

Figure 23.—Operculum and cleithrum of 46.0-mm. *Pseudupeneus maculatus*. Line equals 2 mm.

SPAWNING

Forty-mm. specimens taken as early as January 1 and as late as July 25 (table 2) suggest a protracted spawning period.

SEXUAL DIMORPHISM

Eight large, mature *P. maculatus*, four 190.0- to 206.0-mm. males and four 165.0- to 181.0-mm. females, were examined for sexual dimorphism. The males tended to have higher arched backs and more angular facial profiles, whereas the females tended to be more fusiform and have a sloping facial profile. The angulation of the profile and arched back of the male was more pronounced with increase in size.

The 197.0-mm. specimen plotted on the graphs of body proportions (figs. 9 through 21) is a female, and the 198.0-mm. specimen is a male. These two specimens, the most extreme of the ones examined, illustrate sexual dimorphism for this species.

MULLUS AURATUS JORDAN AND GILBERT

Pertinent station data and sources of material are given in table 7, p. 429.

DISTRIBUTION

Briggs (1958) listed the range of *Mullus auratus* as Bermuda and Nova Scotia to the West Indies and throughout the Gulf of Mexico. All of my specimens (table 7) fall within this range, and their locations of capture are shown in figure 24.

ECOLOGY

A pelagic larval existence is suggested for *M. auratus* by the capture of the young up to 46 mm. by dip net only. Specimens 47.2 mm. and larger were taken by bottom trawl (table 8, p. 429).

The larval and premetamorphosed juveniles were, for the most part, preserved in formalin and ranged in color from dark to medium brown. The metamorphosed juveniles and adults were tan, yellowish, or red, depending on the length of time that they had been preserved, and had many varicolored stripes on their fins (stripes disappear with preservation).

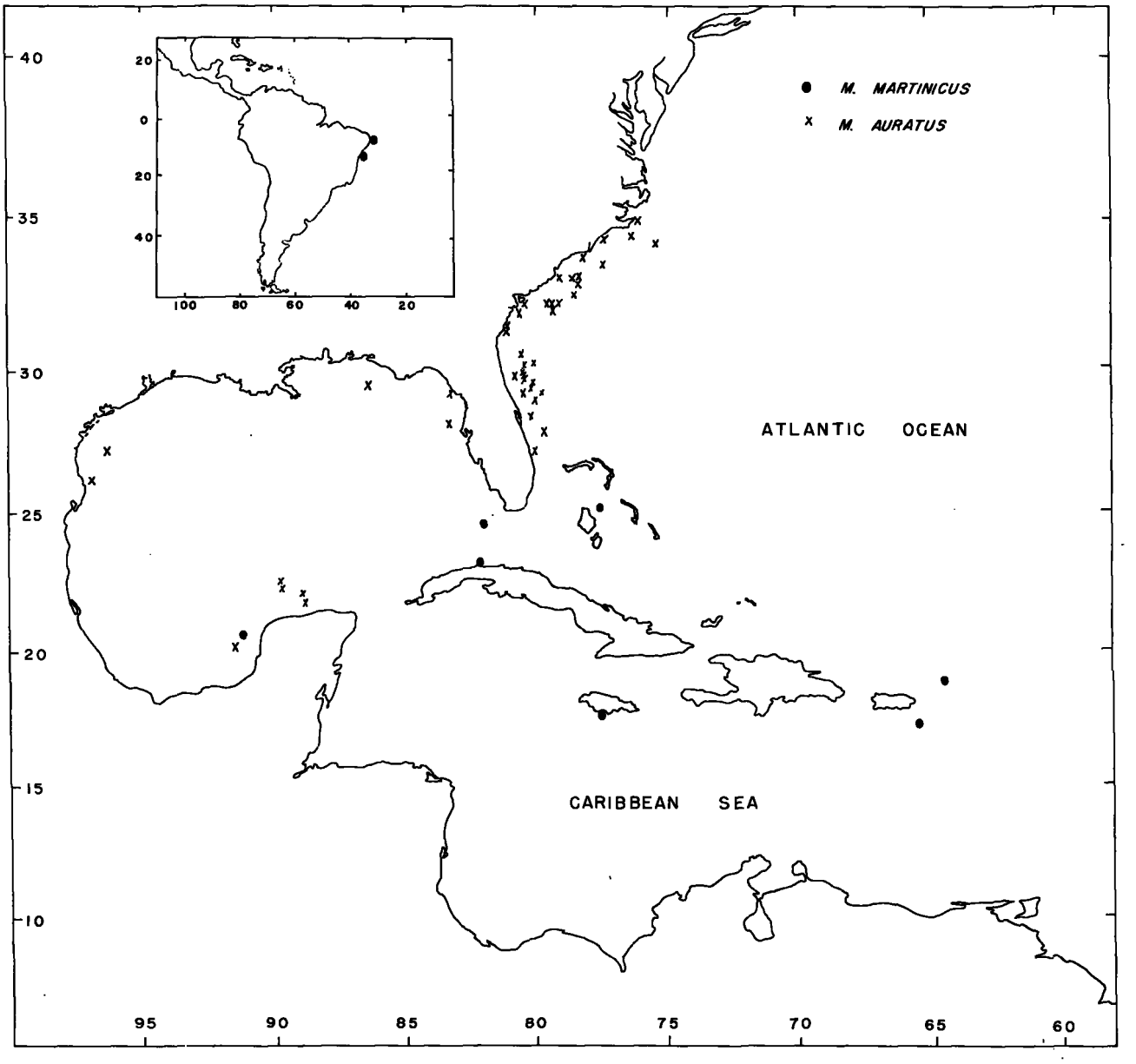

Figure 24.—Locations of capture of *Mullus auratus* and *Mulloidichthys martinicus*.

As young *M. auratus* were taken in numbers by dip net through 46 mm., but all specimens 47.2 mm. and larger were taken only by bottom trawl (table 8), it appears that the species can terminate its pelagic existence and descend to the bottom when it reaches a size of approximately 45 mm. It was at this size that the species changed markedly in appearance, as shown in the photograph (fig. 25), in which the upper fish is a 47.2-mm. specimen taken at Seahorse Reef (Cedar Keys), Fla., by trawl; the lower fish is a pelagic 45.8-mm. specimen dip netted off Yucatan. This metamorphosing 47.2-mm. *M. auratus* was the only specimen in the size range from 46 to 66 mm. available for examination, and it was the only specimen with which a direct comparison could be made with a pelagic form of similar size. However, on the basis of this one specimen, *M. auratus* does undergo a metamorphosis, but the change of appearance is not so marked as in *P. maculatus*. The graphs of body dimensions for *M. auratus* (figs. 9 through 21) do not indicate marked or abrupt changes in dimensions at 45 mm. except in snout length and head length, but these might become evident if more specimens of the size 50-70 mm. were examined (see Body Proportions, *M. auratus*).

No juveniles were taken in the deeper waters of the Gulf of Mexico in spite of the thorough work by the U.S. Fish and Wildlife Service vessels in this area in recent years. This could indicate either that juveniles prefer shallower waters or that the adults do not spawn in or close to deep water. Some small specimens were taken off the Atlantic coast in deep water, but a comparison of the water depths at locations of capture of the three species on which I have comparative data (tables 2, 7; and 12, p. 435) shows that those depths for *P. maculatus* and *U. parvus* tend to be greater than those for *M. auratus*. A pelagic existence of shorter duration could explain the chunkier shape as opposed to the long, slender shape of pelagic juveniles of *P. maculatus*.

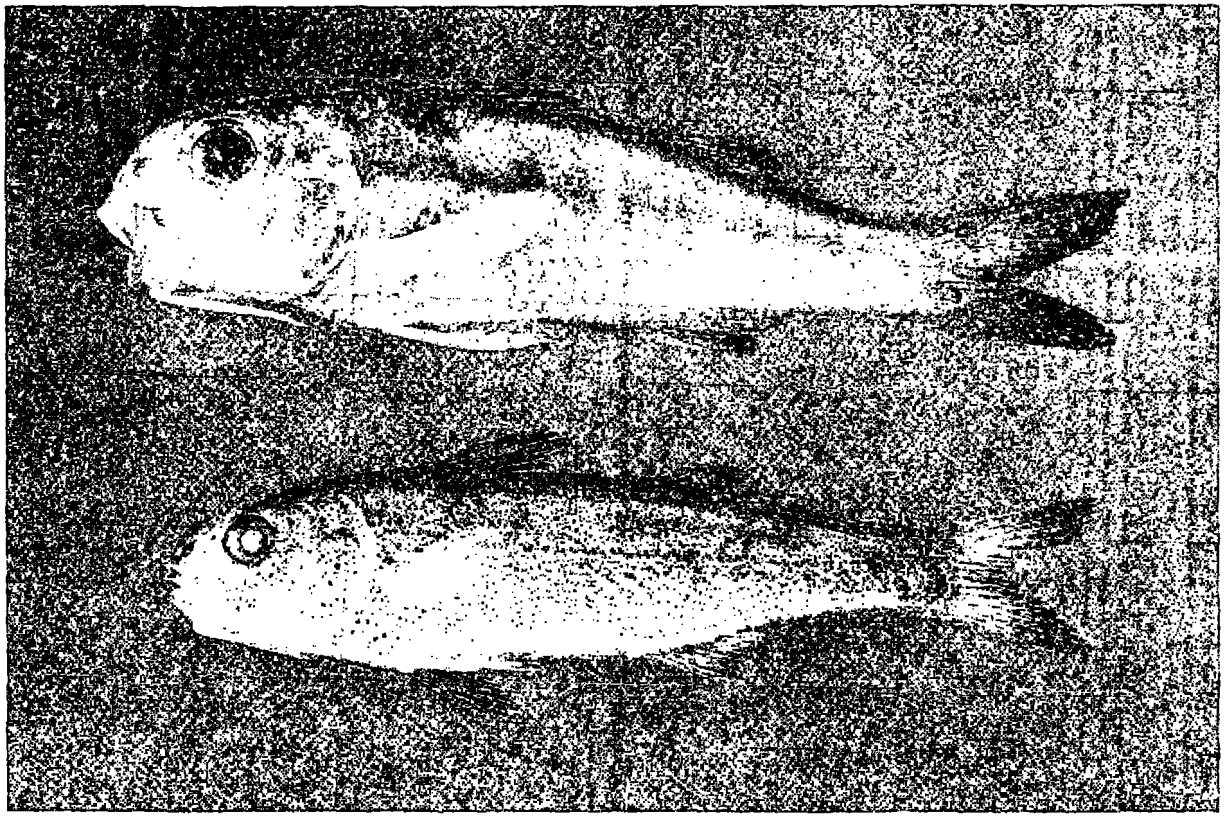

Figure 25.—Juvenile *Mullus auratus*. *Upper*. 47.2-mm. metamorphosed. trawled specimen (UMIM 3105). *Lower*. 45.8-mm. dip netted specimen. (BLBG)

TABLE 9.—*Relation of numbers of pectoral rays to standard length of 48 specimens of* Mullus auratus

[The upper number is the number of specimens, and the number in parentheses below is the approximate percentage for the respective size range]

Standard length (mm.)	Number of pectoral rays							Number of specimens
	11	12	13	14	15	16	17	
0–9.9	1 (50)	1 (50)						2
10.0–19.9		1 (12.5)	1 (12.5)		3 (37.5)	3 (37.5)		8
20.0–29.9					3 (42.9)	4 (57.1)		7
30.0–39.9					3 (60.0)	2 (40.0)		5
40.0–49.9					1 (25.0)	2 (50.0)	1 (25.0)	4
50.0–74.5						1 (100)		1
75.0–99.5						4 (100)		4
100.0–124.5						4 (80.0)	1 (20.0)	5
125.0–149.5					2 (28.6)	5 (71.4)		7
150.0–200.0						4 (80.0)	1 (20.0)	5

TABLE 10.—*Relation of total numbers of gill rakers to standard length of 48 specimens of* Mullus auratus

[The upper number is the number of specimens, and the number in parentheses below is the approximate percentage for the respective size range]

Standard length (mm.)	Total number of gill rakers								Number of specimens
	16	17	18	19	20	21	22	23	
0–9.9		1 (100)							1
10.0–19.9	1 (12.5)		1 (12.5)	3 (37.5)	1 (12.5)	2 (25.0)			8
20.0–29.9					4 (57.1)	2 (28.6)	1 (14.3)		7
30.0–39.9					1 (20.0)	2 (40.0)	2 (40.0)		5
40.0–49.9						3 (60.0)	1 (20.0)	1 (20.0)	5
50.0–74.9					1 (100)				1
75.0–99.9				3 (75.0)	1 (25.0)				4
100.0–124.5			1 (20.0)	3 (60.0)	1 (20.0)				5
125.0–149.5				4 (57.1)	2 (28.6)	1 (14.3)			7
150.0–200.0			2 (40.0)	1 (20.0)	1 (20.0)	1 (20.0)			5

TABLE 11.—*Relation of the numbers of lower-limb gill rakers (exclusive of one at angle of arch) to standard length of 48 specimens of* Mullus auratus

[The upper number is the number of specimens, and the number in parentheses below is the approximate percentage for the respective size range]

Standard length (mm.)	Number of lower-limb gill rakers						Number of specimens
	11	12	13	14	15	16	
0–9.9		1 (100)					1
10.0–19.9	1 (12.5)		3 (37.5)	4 (50.0)			8
20.0–29.9				5 (71.4)	2 (28.6)		7
30.0–39.9				3 (60.0)	2 (40.0)		5
40.0–49.9				1 (20.0)	3 (60.0)	1 (20.0)	5
50.0–74.9				1 (100)			1
75.0–99.9			2 (50.0)	2 (50.0)			4
100.0–124.5			3 (60.0)	2 (40.0)			5
125.0–149.5		1 (14.3)	1 (14.3)	5 (71.4)			7
150.0–200.0			3 (60.0)	1 (20.0)	1 (20.0)		5

TABLE 12.—*Collection and station data for 53 specimens of* Upeneus parvus examined

[Dip net (D), trawl (T), and stomach contents (SC)]

Station	Latitude	Longitude	Date of capture	Depth of water in which captured	Method of capture	Number of specimens and size range	Collection and catalogue number (if any)
WESTERN NORTH ATLANTIC: (Off North America)				*Fathoms*		*mm.*	
Silver Bay 1269	34°32′ N.	75°57′ W.	Sept. 12, 1959	25	T	(1) 106.0	BLBG
Silver Bay 1268	34°32′ N.	75°53′ W.	Sept. 11, 1959	30–31	T	(1) 105.0	BLBG
Combat 299	32°22′ N.	78°14′ W.	Apr. 21, 1957	250	D?	(1) 25.5	BLBG
GULF OF MEXICO:							
Oregon 1438	24°08′ N.	85°25′ W.	Jan. 29, 1956	2064	D	(1) 45.5	BLBG
Oregon 1313	28°05′ N.	88°46′ W.	June 9, 1955	980	D	(9) 22.0–32.0	CNHM 64714
Oregon 1145	28°17′ N.	87°52′ W.	July 26, 1954	1300	D	(1) 31.5	CNHM 64713
Oregon 1124	28°36′ N.	87°58′ W.	July 18, 1954	1200	D	(1) 25.5	TU 13073
Oregon 806	29°28′ N.	87°30′ W.	July 17, 1953	35	D?	(1) 34.0	TU 6869
Oregon 0.4, South of Dauphin Island; Mobile Bay, Ala.			Apr. 21, 1950			(1) 37.5	TU 13125
Oregon 1795	28°04′ N.	94°51′ W.	Mar. 16, 1957	35	T	(1) 64.5	CNHM 64232
Oregon 1100	27°00′ N.	93°55′ W.	June 11, 1954	600	D	(2) 28.5 and 44.0	TU 11739
Oregon 1102	26°58′ N.	91°55′ W.	June 12, 1954	600	D	(1) 28.0	TU 12838
Oregon 1035	26°40′ N.	92°00′ W.	May 8, 1954	890	D	(6) 46.5–60.5	CNHM 64712
Oregon 1089	26°10′ N.	96°25′ W.	June 4, 1954	40	D	(1) 50.0	BLBG
Oregon 1087	26°10′ N.	96°40′ W.	June 3, 1954	29	T	(3) 120.0–135.0	TU 10645
Oregon 1081	26°10′ N.	96°59′ W.	June 2, 1954	15	T	(4) 47.5–64.0	UF
Oregon 1078	26°05′ N.	95°25′ W.	May 27, 1954	1050	D	(1) 55.5	BLBG
Oregon 1038	25°30′ N.	92°00′ W.	May 10, 1954	1760	D	(1) 43.0	TU 10833
Oregon 1038	25°30′ N.	92°00′ W.	May 10, 1954	1760	D	(1) 50.0	BLBG
Oregon 1070	22°30′ N.	96°57′ W.	May 24, 1954	1056	D	(1) 23.5	TU 10885
Oregon 1485	22°20′ N.	97°05′ W.	Apr. 3, 1956	1060	D	(2) 21.0 and 21.5	TU 12789
Oregon 1057	18°45′ N.	93°15′ W.	May 16, 1954	19	T	(4) 113.5–128.5	USNM 158460
Oregon 1477	21°22′ N.	92°25′ W.	Mar. 29, 1956	114	D	(1) 26.5	UMIM
WESTERN NORTH ATLANTIC: (Off South America)							
Oregon 2221	09°22′ N.	59°43′ W.	Aug. 28, 1958	50	[1] SC	(1) 105.0	BLBG
Oregon 2274	06°54′ N.	55°40′ W.	Sept. 3, 1958	26–27	T	(2) 68.0 and 106.0	BLBG
Oregon 2304	06°12′ N.	52°34′ W.	Sept. 11, 1956	38	T	(1) 67.0	CNHM 64715
WESTERN SOUTH ATLANTIC:							
Vitoria, Brazil	20°18′ S.	40°20′ W.				(1) 172.4	SU 52245
Vitoria, Brazil	20°18′ S.	40°20′ W.				(1) 135.5	SU 52246
Entreposta da Pesca, Brazil						(1) 104.0	SU 52244

[1] Stomach contents from *Saurida normani* Longley.

GROWTH AND DEVELOPMENT

Juvenile *M. auratus* were easily distinguished from other young western North Atlantic Mullidae by the combined characters of a minute first dorsal spine and the characteristic tooth patch formed by the fusion of the vomerine and palatine bones (fig. 31). This patch was evident on all specimens over 14 mm. The absence of teeth in the upper jaw, a useful character in identification of the adults, is reevaluated under the section designated "teeth."

Larval *M. auratus*, 9.5–9.8 mm., are illustrated in figure 26. Except for incomplete ossification of the secondary caudal rays, the larvae had reached the juvenile stage.

At a size of 45.8 mm. (fig. 25, lower) the juveniles have acquired the barbels characteristic of the family, and the stripes on the first dorsal fin, characteristic of the adult, have appeared.

The transition from a pelagic to a bottom-living appearance (fig. 25, upper) takes place at approximately 47 mm. The pelagic juvenile coloration is lost, the adult coloration is acquired, and the body becomes more robust.

Figure 27 shows a 78.0-mm. specimen taken by bottom trawl, and at this size it had assumed the adult appearance.

Body Proportions

Thirteen of the body dimensions measured on a total of 49 specimens chosen at random except for size selection are plotted against standard length in figures 9 through 21.

The rate of increase in dimension of body part is constant throughout the size range of specimens examined for postorbital head length, snout to anal fin, body depth, snout to soft dorsal fin, ventral lobe of caudal fin, dorsal lobe of caudal fin, and interorbital space (figs. 10, 11, 12, 15, 16, 17, and 18, respectively). For barbel length, there is little if any change in dimension between 15 and 25 mm., after which there is an increase, and the rate of increase remains constant to the largest size (fig. 19). For head length and snout length an inflection occurs at about 45 mm., and the rate beyond this size is constant and slightly higher than below 45 mm. (figs. 9 and 20). For distance from snout to spinous dorsal fin, an inflection occurs at about 130 mm., with the rate of increase

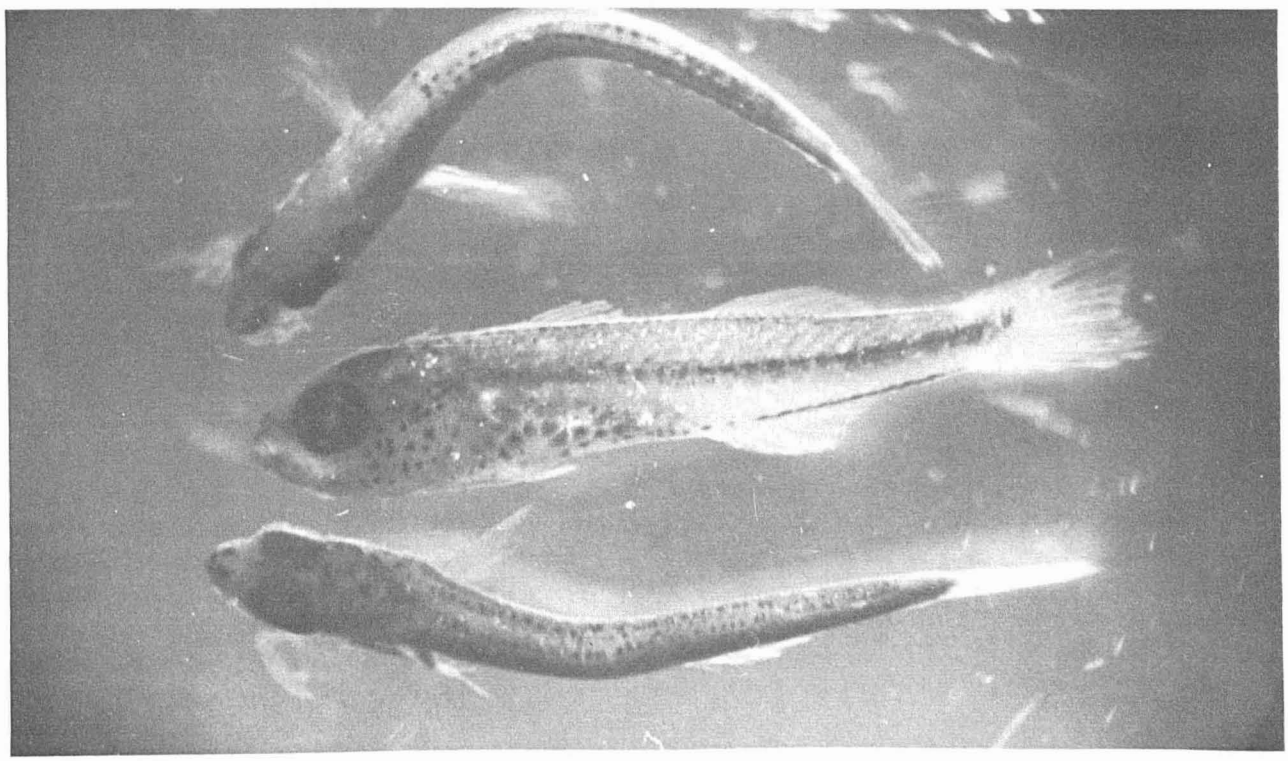

Figure 26.—Larval *Mullus auratus*. *Top:* 9.5 mm., ventral view; *middle:* 9.8 mm., lateral view; *bottom:* 9.6 mm., dorsal view. Dip netted by *Gill* personnel. (BLBG)

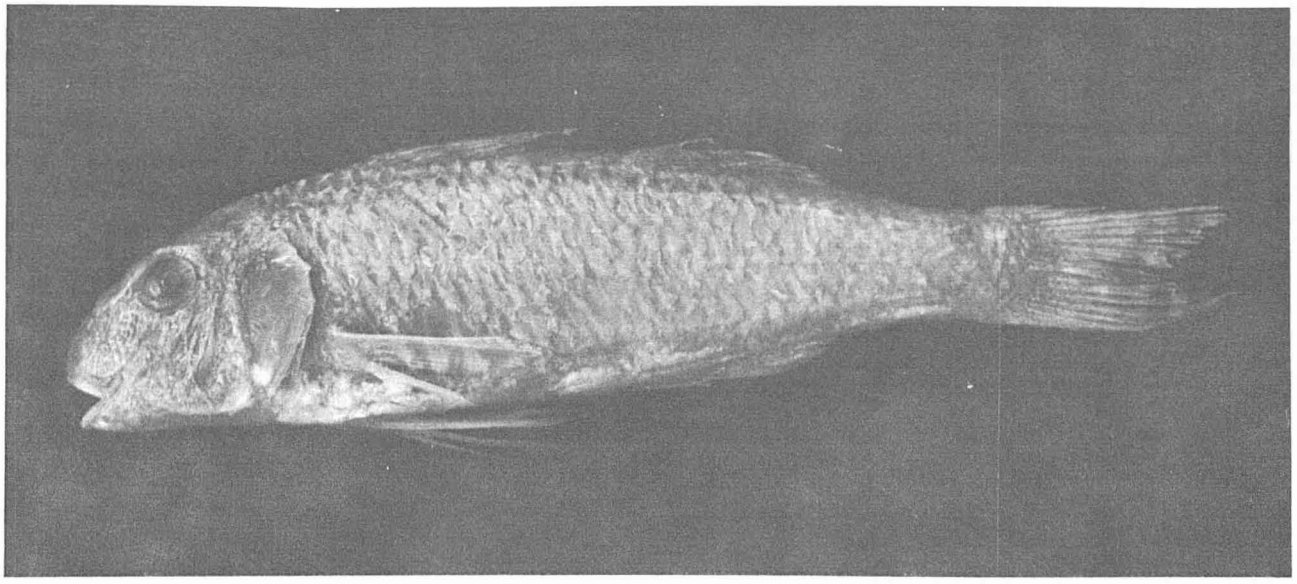

Figure 27.—78.0-mm. *Mullus auratus*. Trawled by *Oregon* personnel. (UF uncatalogued.)

beyond 130 mm. slightly higher than for smaller sizes (fig. 14). For length of first lower-limb gill raker the rate of increase beyond about 30 mm. is less than for sizes below 30 mm. (fig. 21); and for eye diameter the rate of increase beyond about 100 mm. is also slightly less than for smaller sizes (fig. 13).

There were too few 50- to 70-mm. *M. auratus* to demonstrate an abrupt increase in body depth at this size similar to that for *P. maculatus* (fig. 12). If *M. auratus* has this sudden increase in the body depth at the time of color metamorphosis (see Pigmentation., *M. auratus*), the graph could still show the same slope as it does. The increase could be apparent as a step rather than an upward inflection of slope, and this step would probably occur between 40 and 70 mm. as it does in metamorphosing *P. maculatus*. Even if this step does occur, juvenile *M. auratus* are not as slender-bodied as juvenile *P. maculatus*, and the step would probably not be as marked.

Pigmentation

The 9.5- and 33.6-mm. specimens discussed below were from the same dip net sample and were preserved in formalin. The photomicrograph (fig. 26) of larval *M. auratus* shows larvae 9.5 to 9.8 mm. in three views illustrating pigmentation. A lateral view (center larva) shows a series of horizontally elongated pigment patches along the lateral midline beginning at a point below the termination of the first dorsal fin and extending to the hypural bone. Above the lateral midline the surface was almost covered with light tan pigment which was without pattern. A line of darker pigment spots occurred adjacent to the second dorsal fin. Below the lateral midline, in the area between the posterior margin of the operculum and the origin of the anal fin, there were several large dark spots surrounded by buff-colored areas. The area above the anal fin was clear except for some pigment just below the lateral midline, and a row of dark chromatophores along the ventral midline.

In dorsal view (fig. 26, lowest specimen) there was a line of large pigment spots, dark in the center with tan radiations, on each side of the dorsal fins. These began behind the head and proceeded posteriorly as far as the secondary caudal rays. A long slender "V" was formed by the two rows as the body tapered toward the caudal fin. The cluster of pigment spots over the snout was marked when the specimen was viewed from this aspect.

The ventral view (uppermost in fig. 26) showed a similar "V," formed by a row of large pigment spots along each side on the ventral midline. Just posterior to the origin of the anal fin, the radiations from the dark centers of the chromatophores had so spread as to coalesce.

All of the fins were clear except the caudal which had a few scattered pigment spots on the base, giving the impression that they were mi-

grating posteriorly from the integument over the hypural bone.

A 17.5-mm. specimen showed light tan pigmentation diffused throughout the area that was clear in the 9-mm. specimens (that section below the lateral midline and above the anal fin). A few pigment spots were evident on both dorsal fins, and pigment had spread to about midway of the caudal fin.

In a 23.0-mm. specimen, pigmentation in the thoracic region appeared to be spreading from the large chromatophores seen in the smaller specimens. Just below the dorsal fins a second row of pigment spots was present above the row of chromatophores along the lateral midline. Anal, pelvic, and pectoral fins were still unpigmented. The chromatophores of the principal rays of the caudal fin had extended along the edges of the rays for about three-quarters their length.

In a 33.6-mm specimen, the pigmentation of the first dorsal fin had spread across the interspinous membranes to form a stripe about two-thirds of the distance from the base of the fin to the tips of the spines. The pigment spots about midway between this stripe and the base of the fin were grouped to indicate the formation of a second stripe. Other pigmentation remained the same.

In a 45.8-mm. formalin-preserved specimen (fig. 25, lower specimen), the second stripe of the first dorsal fin was complete across the interspinous membranes. In the distal one-third of the second dorsal fin there was a pigmented area on each ray just below a similarly pigmented area on the preceding ray. This gave the impression of a posteroventrally directed, oblique black stripe. A similar stripe, but extending through only the first four rays, was forming near the base of the fin.

The 47.2-mm. metamorphosed juvenile (fig. 25, upper specimen) had a uniform light tan background. The lower half of the body was clear of chromatophores except for tiny scattered pigment spots. The upper half retained some large pigment spots, and the scales had pigment on their margins. A third stripe had made its appearance on the second dorsal fin.

The 78.0-mm. specimen (fig. 27), preserved in isopropyl alcohol, was virtually devoid of scales and was tan throughout. There were no pigment spots in the body except for a few minute ones along the dorsal surface. This specimen was one of the few *M. auratus* I examined that retained pigmentation of the caudal fins. Pigment spots were grouped along the principal rays to form four bars in the upper lobe and five in the lower.

The following notes on the color of an adult *M. auratus* were taken from a specimen which had been in formalin for 13 days:

> Head red. Sides red above the lateral midline, shading to a silvery abdomen. Bright red stripe along midline, below which are two yellow stripes. Pectorals pink with four faint stripes (color not recorded). Pelvics clear with four yellow stripes. Anal yellow. First dorsal clear with two stripes, upper bright orange, lower yellow. Second dorsal clear with four stripes, yellow flecked with black. Dorsal half of caudal with seven or eight faint bars, some bright red, some orange, and some yellow. Ventral half of caudal with faint bars, the number indeterminate (color not recorded).

Specimens that had been in preservative for a considerable length of time were a pale yellow throughout and had lost all distinctive markings.

Fins

Spinous dorsal.—With one exception all of the specimens examined had eight spines in the first dorsal fin, including the small first spine (fig. 28). One specimen had seven spines including the small first spine.

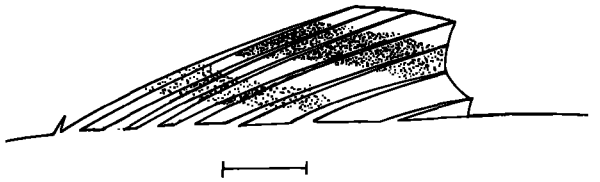

Figure 28.—Spinous dorsal fin of 44.9-mm. *Mullus auratus*. Line equals 2 mm.

Soft dorsal.—The adult complement is one unbranched ray plus eight branched rays.

At 11.9 mm. there was no segmentation, but the last eight rays were segmented on a 14.5-mm. specimen. The first ray did not usually segment before 47 mm.

The last ray was branched at 9 mm. Additional branching did not occur until 18 mm.; it was complete at 40 mm.

Pectoral.—All of the specimens examined showed an adult complement of 15 to 17 fin rays

after 16 mm. The numbers of fin rays are plotted against size in table 9, p. 434.

Segmentation began with the third ray at approximately 25 mm., then proceeded ventrally through the rays until the first ray and the last ray segmented at approximately 47 mm.

A 25-mm. specimen had no branched rays, but at 27 mm. there were four branched rays, the fourth through the seventh. At 47 mm. all except the first two rays were branched—the first two rays never branch.

Pelvic.—Segmentation apparently occurred simultaneously in all five soft rays. There was no segmentation in any of the specimens examined up to 14 mm., but specimens over 14.5 mm. had all pelvic soft rays segmented.

Branching, which had not occurred through 18.7 mm., was complete at 25 mm.

Anal.—All adult specimens examined had one spine, one unbranched ray, and six branched rays. Segmentation began at approximately 14 mm. and was complete by 16 mm.

The smallest specimen, 8.2 mm., had the last ray branched. Additional branching was not evident until 17 mm. and was complete at 21 mm.

Caudal.—There were 15 principal rays on all specimens examined. All principal rays were segmented at 9.3 mm.

The innermost rays were the first to branch, beginning at about 14 mm., and branching was complete on all specimens over 18.7 mm.

Between 14.5 and 42 mm. the number of secondary rays was 9 or 10 in the dorsal lobe and 8 to 10 in the ventral lobe. Nine is the usual number for each lobe. After 42 mm. the anterior rays were overgrown by tissue and scales and could not be counted.

At 9 mm. the five dorsal and four ventral secondary rays were unsegmented. On a stained 10.9-mm. specimen, there were eight unsegmented secondary rays in each lobe. At 14.5 mm. there were 18 secondary rays, and the first ray adjacent to the principal rays in both dorsal and ventral lobes had segmented. The secondary ray second from the principal caudal rays in each lobe was not segmented in fish less than about 45 mm. A cleared and stained 154.0-mm. adult had segmentation in only the first two secondaries adjacent to the principal rays in each lobe.

Gill rakers

Total and lower limb.—Both total number of gill rakers (16–23) and numbers of gill rakers on the lower limb (11–16, exclusive of the one at the angle of the arch) were counted on 48 specimens, ranging in size from 9 to 199 mm. Below 9 mm. counts were not reliable. Counts are plotted against size in tables 10 and 11, pp. 434, 435. In both instances there was an increase in average number of gill rakers with increase in size up to 50 mm., then the average number decreased with further increase in size of specimens (decrease was in the number of rudiments as they appeared to be overgrown by tissue).

Ceratobranchial bone.—Counted on 10 specimens (28.6 to 138.8 mm.), of which 1 had 9 gill rakers, 1 had 11, and the others had 10.

Teeth

Upper jaw.—Contrary to generic descriptions (based on adult specimens), *M. auratus* less than 50 mm. do have visible teeth in the upper jaw. Consequently, keys to the Mullidae which use the teeth to separate the genera are confusing when applied to specimens smaller than 50 mm., and the possibility exists that *M. auratus* may be involved.

The genus *Mullus* was first described by Linnaeus in the 10th edition of "Systema Naturae" (1758), but there was no mention of the teeth either in this or the 12th edition (1766). In the 13th edition (Linnaeus and Gmelin, 1789) the teeth were first mentioned (translation)—". . . mandibulae and palate armed with small teeth . . . ." Whether "mandibulae" refers to both upper and lower jaws, I can't say. Turton (1806) interpreted the word mandibulae as "jaws." Since Linnaeus, *Mullus* has been described in the literature as being without teeth in the upper jaw. Günther (1859) said of the teeth of the genus *Mullus*, ". . . none in upper jaw," and Jordan and Evermann (1896) used the same words, ". . . none in upper jaw . . . ." However, in the original description of *M. auratus* by Jordan and Gilbert (1882), which named *M. auratus* as a subspecies of *Mullus barbatus*, the authors stated, "Teeth . . . on upper jaw obsolete . . . ." Examination of the juveniles of the species has shown that this last observation by Jordan and Gilbert was accurate.

Small canine teeth were apparent on the upper jaw of *M. auratus* of 12 mm. A 21-mm. specimen had 3 or 4 teeth on each side of the upper jaw, and

a 37.0-mm. specimen (fig. 29) had about 15 teeth on each half of the premaxillary. These varied in size and pointed obliquely downward and toward the back of the mouth. They were freely movable in their sockets, but did not dislodge when teased with a probe. At 45 mm., many small teeth were evident, but the upper lip was beginning to overgrow and mask them. The upper lip continued this growth over the teeth, and in a 47-mm. specimen the lip had to be turned back to reveal the presence of three teeth on the left premaxillary bone and five on the right. No teeth were evident in larger specimens, even when the lip was turned back, but when the right premaxillary bone of a 106.5-mm. specimen was dissected and stained, two teeth were revealed (fig. 30). There were also two tooth sockets medial to the teeth. The premaxillary bone of a 154-mm. specimen was dissected and stained, but neither teeth nor tooth sockets were found.

Lower jaw.—No teeth were visible on the lower jaw of any specimen of *M. auratus* below 21 mm. A 37-mm. specimen had several small canine teeth in a single row toward the back of the mouth.

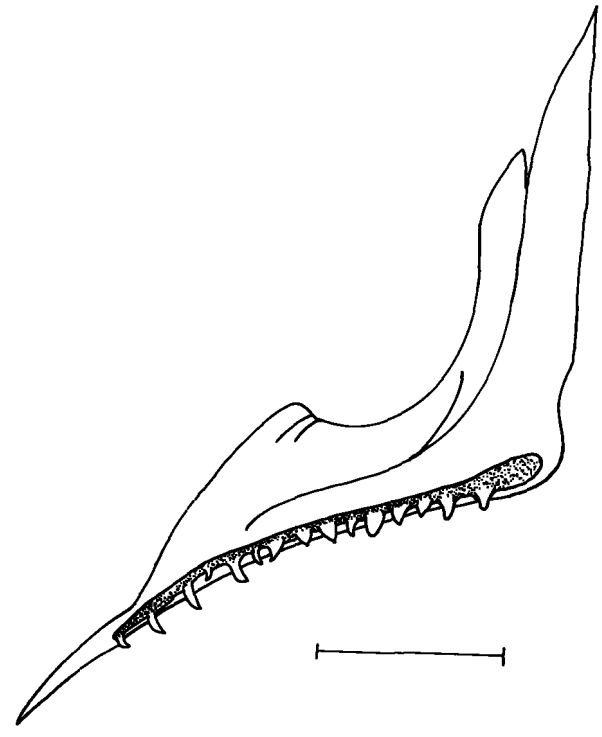

Figure 29.—Cleared and stained left premaxillary of 37.0-mm. *Mullus auratus*. Line equals 0.5 mm.

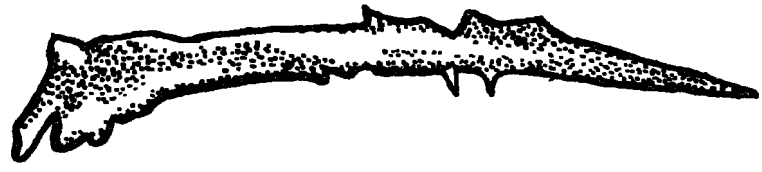

Figure 30.—Drawing of dissected and stained right premaxillary of 106.5-mm. *Mullus auratus*.

These teeth are irregularly biserial anteriorly—the adult arrangement of the small, inconspicuous teeth in the lower jaw.

Vomerine and palatine.—M. auratus has the characteristic tooth patch of the genus *Mullus*, formed by the joining of the vomer and palatine bones (Lachner, 1954). This character alone will serve to distinguish this species from the other western North Atlantic mulloid fishes.

At 10.9 mm. there was a single palato-vomerine bone patch on each side of the median line of the roof of the mouth, but no teeth were evident. A 17-mm. specimen had the bone patches, separated by 0.1 mm. at their closest point (the anterior ends), with three teeth on one patch and two on the other. A 37.0-mm. specimen had about 15 coarse, peglike, slightly pointed teeth present on each patch (fig. 31). These are similar to the tooth patches of the adult except for number of teeth. The stained and dissected palato-vomerine tooth patches of a 154-mm. specimen had about 55 teeth per patch.

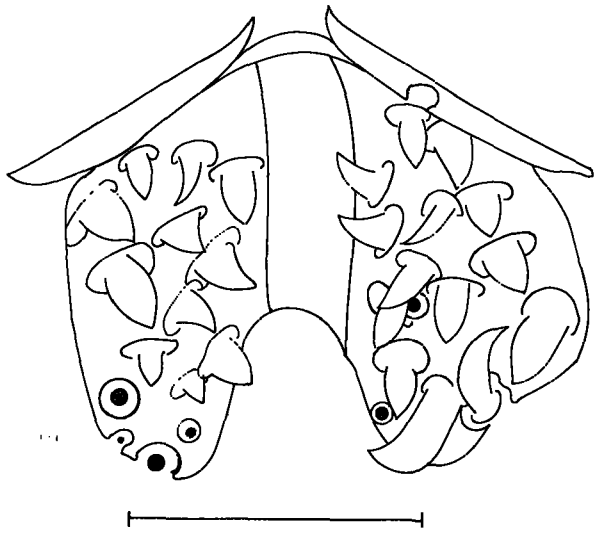

Figure 31.—Cleared and stained palato-vomerine tooth patch of 37.0-mm. *Mullus auratus*. Line equals 0.5 mm.

Scales

Lateral line scales were counted on 28 specimens ranging in size from 44.8 to 199.0 mm. The range in counts held for small sizes through the largest specimens, 29 to 35 (mean of 32), with 32 and 33 most frequently encountered. This is somewhat lower than the count of "about 40" given by Jordan and Evermann (1896) and Beebe and Tee-Van (1933) for *M. auratus*.

The extreme deciduousness of the scales during the pelagic stage is demonstrated by the following figures. One hundred and eight *M. auratus*, ranging in size from 9.3 to 36.4 mm., were examined in an attempt to determine the manner in which scale formation occurs. Fifty-one of these specimens, ranging from 9.3 to 34.4 mm., were totally devoid of scales. The 57 specimens with one or more scales ranged from 21.8 to 36.4 mm., and none had more than four scales in the lateral line. Scales present in the specimens below 30 mm. were usually around the dorsal fins and restricted to above the lateral line.

In a second series of 33 slightly larger specimens ranging from 19.6 to 45.8 mm., 12 specimens (19.6 to 37.4 mm.) had no scales. Two individuals, 44.8 and 45.3 mm., had 30 lateral line scales—these were the smallest specimens on which scale counts were possible.

A scale from a 25.5-mm. specimen lacked ctenii, but one from a 45-mm. specimen had about 10 ctenii. There were 65 ctenii on a scale from a 117-mm. specimen, and 186 on a scale from a 199-mm. adult.

Barbels

According to Lo Bianco (1907), Jobert (1872) was the first to advance the theory that the barbels of the family Mullidae are nothing more than displaced branchiostegal rays. Zincone (1876) had given the theory some consideration, but was forced to the conclusion that he could neither deny nor confirm the hypothesis, as the question could only be resolved embryologically, and he had been unable to obtain fertile eggs in aquaria. Lo Bianco (1907) quoted Raffaele (1888) as saying that, whereas he (Raffaele) was able to obtain the fertile eggs of *Mullus surmulletus*, which hatched in 3 to 4 days, the larvae died in 7 or 8 days after hatching, and there was no trace of tactile barbels at this stage of development. Lo Bianco said that he too had seen eggs laid in captivity by *Mullus*, and also effected artificial fertilization of both local species (*Mullus surmulletus* and *Mullus barbatus*), but the larvae died as soon as the yolk-sac was absorbed.

In the summer of 1906, Lo Bianco obtained a series of *Mullus* from the Gulf of Naples, 6 to 15 mm. in length, plus a few specimens 22, 26, and 30 mm. in length. From these he gave a detailed description of the development of the barbels, and in the summation of his work he stated (1907), "From this observation of mine is demonstrated the origin of the barbels of *Mullus from the first branchiostegal* . . . ."[4]

Also, Montalenti (1937) made this statement in regard to the Mullidae (translation), "In the pelagic individual about 35 mm. long the first branchiostegal ray detaches from the membrane and constitutes the barbels characteristic of this fish."

The series of *M. auratus* I examined demonstrated the barbels developed from the bone that appeared in the 8.2-mm. specimen to be the first branchiostegal ray. The barbel development is similar to that described by Lo Bianco for a Mediterranean *Mullus*, but occurs at a smaller size.

Figure 32 shows the position of the branchiostegals of an 8.2-mm. *M. auratus* which agreed in size and shape with those in Lo Bianco's illustration of an 8-mm. Mediterranean *Mullus* (1907, fig. 2). Lo Bianco's measurements were probably

[4] My translation of Lo Bianco's statement.

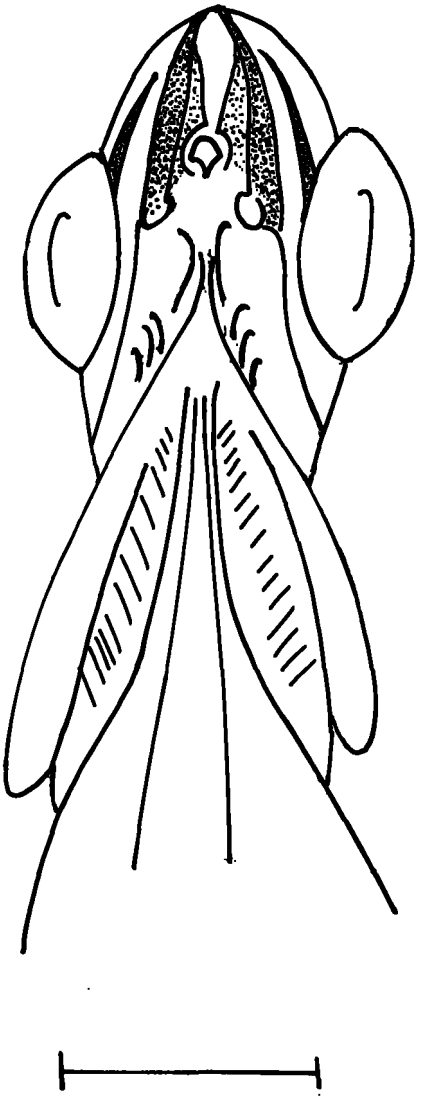

Figure 32.—Ventro-dorsal view of head of cleared and stained 8.2-mm. *Mullus auratus* showing position of branchiostegal rays. Line equals 1 mm.

expressed in total lengths. In the 8.2-mm. *M. auratus*, the position of the first ray was more anterior relative to the eyes and point of fusion of the branchiostegal membrane than in Lo Bianco's specimen; in these respects it conformed most closely with his illustration of a 22-mm. *Mullus* (Lo Bianco, 1907).

Two 19-mm. stained specimens of *M. auratus* showed the first branchiostegal rays displaced as far forward as the anterior edge of the eye. They still retained the same general shape as the other branchiostegal rays and were separated from each other by a distance of 0.3 mm. at their closest point. Barbel length was 2.3 mm. on one specimen and 2.6 mm. on the other. Three of the four barbels on the two specimens had detached from the branchiostegal membrane. Lo Bianco noted that this separation from the membrane occurred between 26 and 30 mm. in his series of *Mullus*. In *M. auratus*, one of the barbels was detached in a fish as small as 9 mm.; the barbel at this size measured less than 2 mm. One 14.5-mm. specimen had both barbels free. On the other hand, a 24.5-mm. specimen had one barbel still attached to the membrane. This is the largest specimen in which any barbel remained attached, and all of the specimens between 14.5 mm and 24.5 mm. had at least one barbel free.

At 28 mm. the bases of the barbels had shifted forward past the posterior edge of the mouth, and the anterior ends of the bases had joined together.

Operculum

The opercular bone (fig. 33) did not possess a spine on any specimen examined, and the posterior edge is rounded and smooth.

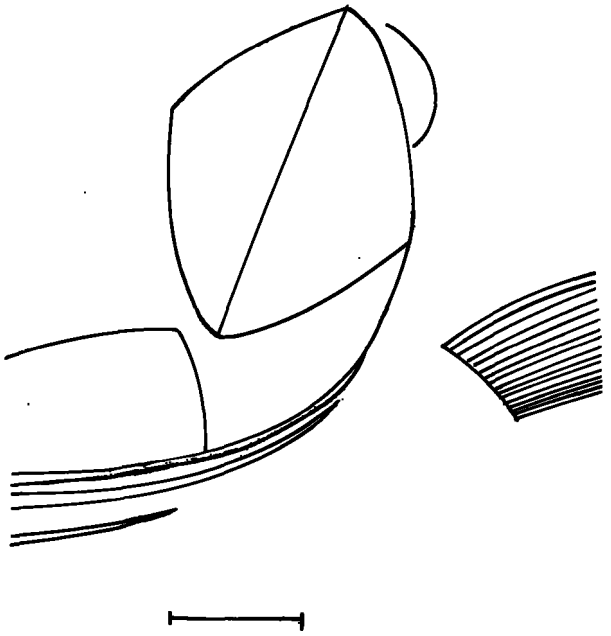

Figure 33.—Operculum and cleithrum of 44.9-mm. *Mullus auratus*. Line equals 2 mm.

Cleithrum

This small inconspicuous bone (fig. 33), almost covered by the opercular flap, had no serrations as it does in *P. maculatus*.

SPAWNING

The young *M. auratus* taken on the *Gill* cruises were all collected between January and May (table 7). The smallest specimen (8 mm.) was collected in April.

UPENEUS PARVUS POEY

DISTRIBUTION

Briggs (1958) gave the range of *Upeneus parvus* as eastern Florida to the Lesser Antilles and throughout the Gulf of Mexico. Lachner (1954) reported, "Known from . . . Cuba, Tobago (Norman, 1922), Puerto Rico, and Tortugas."

Several recent captures extend the range of *U. parvus* considerably northward. Two specimens were taken off Cape Lookout, N.C., by the U.S. Fish and Wildlife Service vessel *Silver Bay*, at successive stations, 1268 and 1269 (table 12), in depths of 25 to 30 fathoms. Also, included in the BLBG collection, there is a 26-mm. mullid, taken off the coast of South Carolina with 9 small *M. auratus*. It lacks the minute 1st dorsal spine and the palato-vomerine tooth patch typical of *M. auratus*. Its pigmentation and gill raker count of 5–1–17 (12 on the ceratobranchial bone) are typical of *U. parvus* at this size, and I have designated it as this species.

In addition, three specimens of this species were taken off the northeast coast of South America by the U.S. Fish and Wildlife Service vessel *Oregon* at stations 2221, 2274, and 2304 (table 12, p. 435), and I have examined three specimens from Brazil previously identified as *Pseudomulloides carmineus* Miranda-Ribeiro (Miranda-Ribeiro, 1915). Two were labeled "Vitoria, Brazil," and the third as simply "*Entraposta da Pesca*" (fish market?). The only differences I could find between these specimens and *U. parvus* were that they had one fewer lower-limb gill raker (17), and possibly a shorter barbel length and smaller eye. These differences, even if real, are not of specific or even subspecific importance. Ernest A. Lachner of the USNM, currently revising the Mullidae, identified them as *U. parvus*, which extends the southern range for this species to Vitoria, Brazil. The three specimens are included as *U. parvus* in table 12 and in these discussions. The labels from these Brazil specimens do not state that they were market-procured, but this could be the case. They could have been brought into the markets from some distance away, and the exact locality records may be questioned.

Figure 2 gives the locations of capture of the specimens examined; table 12 gives pertinent station data and present location of material.

ECOLOGY

Briggs reported (1958) that *U. parvus* is a shore fish, as are all of the four species of western North Atlantic Mullidae. This is supported by the data on specimens examined (table 12). All adult specimens over 100 mm. were taken by bottom trawls in water depths ranging from 19 to 50 fathoms (tables 13 and 14, p. 444). Longley and Hildebrand (1941) reported that this species was repeatedly taken in water depths of 40 to 60 fathoms. That they are bottom-dwellers is shown by their being taken consistently in bottom trawls.

The juveniles have an offshore pelagic stage that differs from the adult in appearance. The specimens examined on which complete station data are available ranged from 20.8 to 135.0 mm., and are individually listed in order of size in table 13. All specimens smaller than 47.5 mm. were taken by dip net. The locations of capture (table 12) show small specimens taken in the middle of the Gulf of Mexico (*Oregon* Stations 1035 and 1102). This is roughly 100 to 150 miles from the nearest shallow water, the Campeche Bank, and approximately 250 miles from the nearest major land mass (fig. 2). In this vicinity a branch of the Gulf Stream flows northwesterly from the Yucatan Channel toward Galveston, Texas (Leipper, 1954), so probably these fish were spawned in the shallow waters south of the Campeche Bank and carried across the 1,000-fathom line. All of the specimens over 60.7 mm. were taken by bottom trawl (table 13), indicating that, whereas metamorphosis can be delayed up to a point, juveniles over approximately 60 mm. either find their normal adult habitat and descend to the bottom, their normal adult habitat, or perish.

The dip-netted specimens, regardless of standard lengths, are long and slender, a shape typical of pelagic fish. They are dark brown, and in spite of preservation, some of them have retained the silvery abdomen common to a pelagic stage (Hubbs, 1941). None has lost the juvenile pigmentation. Except for one, which is discussed later, the shallow-water specimens from 47.5 to

TABLE 13.—*Collection and station data for 53 specimens of* Upeneus parvus, *by individual specimen by size*

[Dip net (D), trawl (T), and stomach contents (SC)]

Size	Station	Method of capture	Depth of water in which captured	Day and month of capture	Latitude	Longitude
mm.			*fathoms*			
20.8	*Oregon* 1485	D	1060	Apr. 3	22°20′ N.	97°05′ W.
21.6	*Oregon* 1485	D	1060	Apr. 3	22°20′ N.	97°05′ W.
22.2	*Oregon* 1313	D	980	June 9	28°05′ N.	88°46′ W.
23.3	*Oregon* 1070	D	1056	May 24	22°30′ N.	96°57′ W.
25.5	*Oregon* 1124	D	1200	July 18	28°36′ N.	87°58′ W.
25.7	*Combat* 299	D?	250	Apr. 21	32°22′ N.	78°14′ W.
26.7	*Oregon* 1477	D	114	Mar. 29	21°22′ N.	92°25′ W.
28.1	*Oregon* 1102	D	600	June 12	26°58′ N.	91°55′ W.
28.3	*Oregon* 1100	D	600	June 11	27°00′ N.	93°55′ W.
28.5	*Oregon* 1313	D	980	June 9	28°05′ N.	88°46′ W.
29.0	*Oregon* 1313	D	980	June 9	28°05′ N.	88°46′ W.
30.0	*Oregon* 1313	D	980	June 9	28°05′ N.	88°46′ W.
30.5	*Oregon* 1313	D	980	June 9	28°05′ N.	88°46′ W.
30.5	*Oregon* 1313	D	980	June 9	28°05′ N.	88°46′ W.
30.8	*Oregon* 1313	D	980	June 9	28°05′ N.	88°46′ W.
31.0	*Oregon* 1313	D	980	June 9	28°05′ N.	88°46′ W.
31.4	*Oregon* 1145	D	1300	July 26	28°17′ N.	87°52′ W.
32.1	*Oregon* 1313	D	980	June 9	28°05′ N.	88°46′ W.
34.0	*Oregon* 806	D?	35	July 17	29°28′ N.	87°30′ W.
37.5	*Oregon* 0.4	-------	-------	Apr. 21	South of Dauphin Island, Mobile Bay, Ala.	
43.0	*Oregon* 1038	D	1760	May 10	25°30′ N.	92°00′ W.
44.0	*Oregon* 1100	D	600	June 11	27°00′ N.	93°55′ W.
45.4	*Oregon* 1438	D?	2064	Jan. 29	24°08′ N.	85°25′ W.
46.5	*Oregon* 1035	D	890	May 8	26°40′ N.	92°00′ W.
47.5	*Oregon* 1081	T	15	June 2	26°10′ N.	96°59′ W.
50.0	*Oregon* 1089	D	40	June 4	26°10′ N.	96°25′ W.
50.5	*Oregon* 1038	D	1760	May 10	25°30′ N.	92°00′ W.
52.5	*Oregon* 1035	D	890	May 8	26°40′ N.	92°00′ W.
53.8	*Oregon* 1035	D	890	May 8	26°40′ N.	92°00′ W.
54.6	*Oregon* 1081	T	15	June 2	26°10′ N.	96°59′ W.
55.5	*Oregon* 1078	D	1050	May 27	26°05′ N.	95°25′ W.
56.6	*Oregon* 1035	D	890	May 8	26°40′ N.	92°00′ W.
58.0	*Oregon* 1035	D	890	May 8	26°40′ N.	92°00′ W.
59.5	*Oregon* 1081	T	15	June 2	26°10′ N.	96°59′ W.
60.7	*Oregon* 1035	D	890	May 8	26°40′ N.	92°00′ W.
64.2	*Oregon* 1081	T	15	June 2	26°10′ N.	96°59′ W.
64.5	*Oregon* 1795	T	35	Mar. 16	28°04′ N.	94°51′ W.
67.0	*Oregon* 2304	T	38	Sept. 11	06°12′ N.	52°34′ W.
67.9	*Oregon* 2274	T	27/26	Sept. 3	06°54′ N.	55°40′ W.
105.0	*Silver Ray* 1268	T	31/30	Sept. 11	34°32′ N.	75°53′ W.
[1] 105.0	*Oregon* 2221	SC	50	Aug. 28	09°22′ N.	59°43′ W.
106.0	*Oregon* 2274	T	27/26	Sept. 3	06°54′ N.	55°40′ W.
106.0	*Silver Ray* 1269	T	25	Sept. 12	34°32′ N.	75°57′ W.
113.5	*Oregon* 1057	T	19	May 16	18°45′ N.	93°15′ W.
116.5	*Oregon* 1057	T	19	May 16	18°45′ N.	93°15′ W.
120.0	*Oregon* 1087	T	29	June 3	26°10′ N.	96°40′ W.
127.0	*Oregon* 1057	T	19	May 16	18°45′ N.	93°15′ W.
128.5	*Oregon* 1057	T	19	May 16	18°45′ N.	93°15′ W.
129.5	*Oregon* 1087	T	29	June 3	26°10′ N.	96°40′ W.
135.0	*Oregon* 1087	T	29	June 3	26°10′ N.	96°40′ W.

[1] Stomach contents from *Saurida normani*.

TABLE 14.—*Relation of size of specimen, method of capture (dip net, D; trawl, T), and water depths in which captured for* Upeneus parvus

[Each letter represents a capture of one or more specimens within a particular size range]

DEPTH IN FATHOMS	SIZE RANGE IN MILLIMETERS				
	0–24.5	25.0–49.5	50.0–74.5	75.0–99.5	Over 100
Over 100	DDD	DDDD DDDD DD	DDD		
75–100					
50–74					
25–49		D	DTTT		TTTT
0–24		T	T		T

TABLE 15.—*Relation of the numbers of pectoral fin rays to standard length of 47 specimens of* Upeneus parvus

[The upper number is the number of specimens, and the number in parenthesis below is the approximate percentage for the respective size range]

Standard length (mm.)	Number of pectoral fin rays				Number of specimens
	13	14	15	16	
20.8–21.6	1 (50.0)	1 (50.0)			2
22.2–29.9		3 (33.3)	6 (66.7)		9
30.0–39.9		2 (25.0)	4 (50.0)	2 (25.0)	8
40.0–49.9		1 (20.0)	3 (60.0)	1 (20.0)	5
50.0–59.9		1 (11.1)	7 (77.8)	1 (11.1)	9
60.0–68.0		1 (20.0)	3 (60.0)	1 (20.0)	5
105.0–119.5			2 (40.0)	3 (60.0)	5
120.0–135.0			3 (75.0)	1 (25.0)	4

60.7 mm. taken by bottom trawl exhibit a completely different appearance from the dip-netted specimens of the same size taken usually over deep water. The metamorphosed specimens from shallow water are more robust. The changes that occur in dimensions of body parts between 40 and 60 mm. are reflected in the graphs of body proportions (figs. 9 through 21). A metamorphosed juvenile and a pelagic juvenile of similar size are shown in figure 34. The specimen uppermost in the photograph is 54.6 mm., taken at 15 fathoms by bottom trawl, and has the adult appearance. The lower specimen in the photograph is 52.5 mm., taken at the surface over deep water (890 fathoms) by dip net, and shows no evidence of metamorphosis.

A 67.9-mm. specimen taken by bottom trawl at a depth of 27 or 26 fathoms has the slender pelagic shape, but its coloration is intermediate between pelagic and bottom types. The juvenile pigmentation is still present on the snout and upper half of the body, but stripes are evident on the dorsal fins, and bars are present on the caudal fin (probably a metamorphosing form which has just reached its adult habitat).

GROWTH AND DEVELOPMENT

Young *U. parvus* below approximately 50 mm. had neither the vomerine nor the palatine teeth typical of the genus *Upeneus*.

Unlike *M. auratus* and *P. maculatus*, *U. parvus* had no visible minute first dorsal spine.

Gill raker counts (fig. 35) should serve to distinguish *U. parvus* from *M. martinicus* at sizes before the scales and teeth develop. No *M. martinicus* below 82.5 mm. have been examined, however, and the separation on gill raker counts is based on the assumption that the number of lower-limb gill rakers in *M. martinicus* prior to 82.5 mm. is not markedly smaller.

The smallest specimen examined, 20.8 mm., (fig. 36) was a juvenile. There were no major changes in the pelagic juvenile (fig. 34, lower) up to the time of transition, which occurred between 40 and 60 mm., after which the juvenile had the appearance of a young adult (fig. 34, upper).

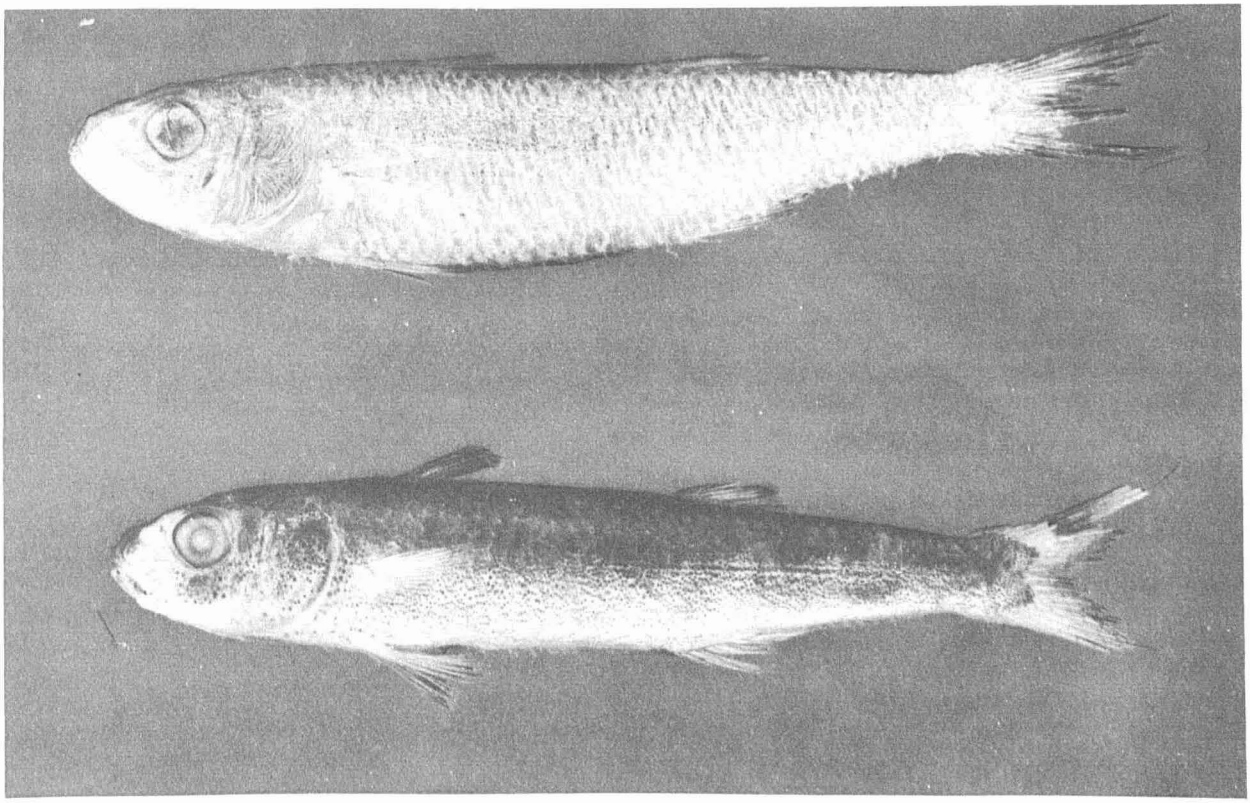

Figure 34.—*Upper.* Bottom-living 54.6-mm. *Upeneus parvus* trawled by *Oregon* personnel. (UF) *Lower.* Pelagic 52.5-mm. *Upeneus parvus* dip netted by *Oregon* personnel. (CNHM 64712)

Body Proportions

Nine of the 13 body dimensions (measured on 53 specimens) plotted against standard length show an inflection in rate of increase with the initial rate lower than that beyond the point of inflection. For head length, body depth, eye diameter, snout to spinous dorsal fin, and snout to soft dorsal fin, the inflection occurs at about 60 to 70 mm. (figs. 9, 12, 13, 14, and 15, respectively); for snout to anal fin the inflection, at about 50 to 60 mm. (fig. 11); and for interorbital space, barbel length, and snout length, at about 40 to 50 mm. (figs. 18, 19, and 20, respectively). For length of first lower-limb gill raker an inflection occurs at about 40 to 50 mm., but the rate beyond about 50 mm. is lower than initially (fig. 21). Constant rates of increase throughout the size range of specimens examined are suggested for postorbital head length, and lengths of ventral and dorsal lobes of caudal fin (figs. 10, 16, and 17, respectively).

The inflections occur at or slightly after the time the juveniles move inshore to assume a bottom-dwelling existence.

Pigmentation

A 20.8-mm. specimen (fig. 36), preserved in isopropyl alcohol, had a medium tan background color. There was a lateral midline row of large dark pigment spots which extended from the upper posterior edge of the operculum to the

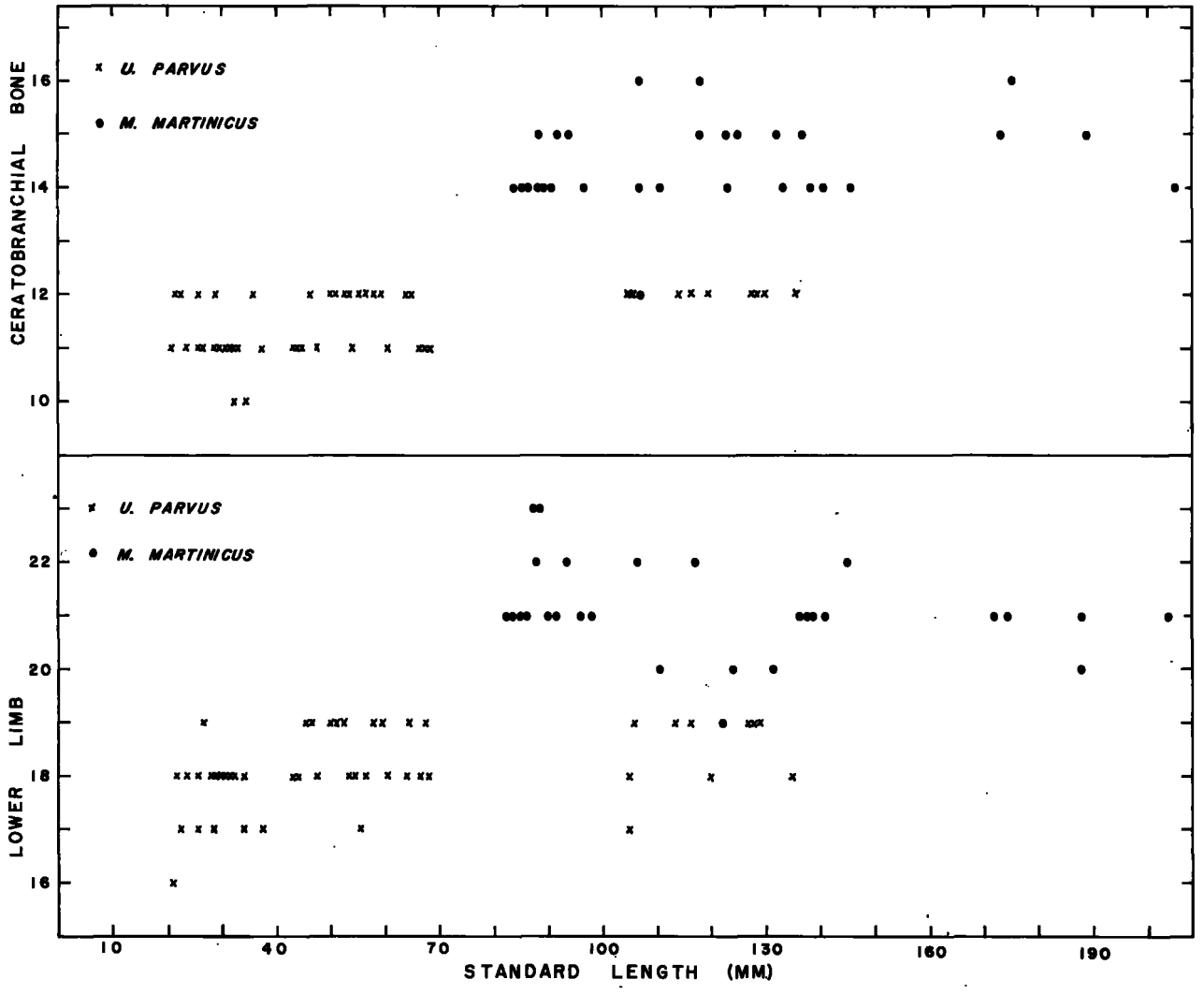

Figure 35.—Lower-limb and ceratobranchial-bone gill rakers of *Upeneus parvus* and *Mulloidichthys martinicus*.

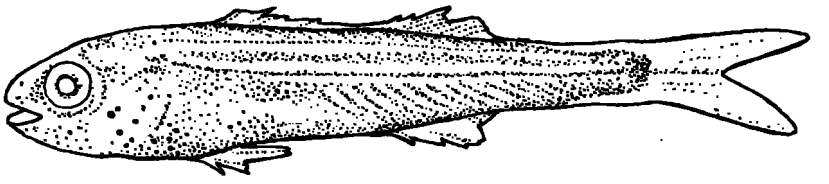

Figure 36.—*Upeneus parvus*, 20.8-mm. Dip netted by *Oregon* personnel. (TU 12789)
(Drawings 7, 30, and 36 by Mary Butler.)

hypural bone. Narrow strips immediately dorsal and ventral to the row were not pigmented, making the row of pigment spots particularly striking. About halfway between the lateral midline and the dorsal surface was a second row of lighter pigment spots also with unpigmented strips just dorsal and ventral which emphasized this row. Between the two rows the pigmentation consisted of scattered chromatophores. Above this second line of chromatophores, and beginning about midway between the two dorsal fins and extending to the insertion of the second dorsal, the pigment spots were arranged in short light bars which extended obliquely downward and posteriorly. Below the lateral midline, the pigment spots on the anterior half of the body were patternless, but, beginning about halfway between the operculum and the hypural base, they formed several oblique bars extending downward and posteriorly. The head was covered with a mingling of large and small chromatophores.

In dorsal view, a congregation of chromatophores was evident in the region of the snout. The dorsal surface of the body had a row of large pigment spots on each side of the dorsal fins, beginning just behind the head and extending to the secondary caudal rays. The two rows formed a long slender "V," as the body of the fish narrowed posteriorly.

A similar "V" was formed ventrally by a row of chromatophores on each side of the anal fin, beginning at the origin of the anal fin and extending to the secondary caudal rays. There were a few pigment spots on the rays of the first dorsal, the second dorsal, and the caudal fins. The pectoral, pelvic, and anal fins were clear.

The 52.5-mm. pelagic juvenile (fig. 34, lower specimen), preserved in alcohol, had a stripe of pigment spots along the lateral midline. This stripe was almost obscured on the anterior half of the body by heavy pigmentation, but was still prominent along the posterior half of the lateral midline. Above the midline, pigmentation was heavy and gave this section a dark brown color. Below the midline, the pigment spots, over a tan background, gradually became less dense and were very scattered on the ventral surface. Pigmentation on the head was dense, especially in the snout region. The fins had the same pigmentation as on the 20.8-mm. specimen, except for chromatophores over the rays of the dorsal half of the pectorals.

The 54.6-mm. metamorphosed shallow-water form (fig. 34, upper specimen) was preserved in isopropyl alcohol. The ground color was light tan with many pigment spots above the midline. Below the lateral midline, pigment spots were sparse. The pectoral, pelvic, and anal fins were clear. In the first dorsal, second dorsal, and anal fins, chromatophores were clustering to form the bars characteristic of the adult.

When Poey (1851) described *U. parvus*, he gave a color description. As the publication in which the description is found is not always available and, if available, the Spanish is old and difficult to translate, I include a translation of the color description here.

The back of the fish is bright red and it changes imperceptibly to white as it approaches the bottom of

the stomach. It has a yellow stripe running lengthwise down the side and others of the same color, but narrower, running below and parallel. It has yellow ventral and anal fins and the other fins are white with dark and narrow stripes . . . . The head does not bear yellow stripes; the dorsal and caudal fins have black stripes running obliquely from the front to the back; three in the first dorsal, two in the second, and five in each lobe of the tail, which is deeply indented . . . . I have seen some in May of 1852 of three, five, and six inches and none in the preceding years. Among those of three inches there was one which had five black spots under the yellow longitudinal stripes . . . .

The preserved specimens examined were pale yellow except for three or four black bars, invariably retained, on the ventral lobe of the caudal fin.

A mullid from the western North Atlantic that has retained these bars in preservative should be suspected of being *U. parvus*, as *M. auratus*, the other species that has bars on the caudal fin, (see Pigmentation, *Mullus auratus*) loses them very rapidly in preservative. *Mulloidichthys martinicus* is not reported as having a barred caudal (Longley and Hildebrand, 1941; Beebe and Tee-Van, 1928; Nichols, 1929), and I did not observe bars either. Nor were bars noted on the caudal fin of any of the 274 specimens of *P. maculatus* examined.

Fins

Spinous dorsal.—*U. parvus* had seven spines in the first dorsal (fig. 37). A minute first spine was lacking on all specimens.

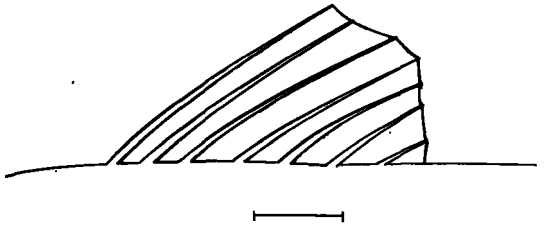

Figure 37.—Spinous dorsal fin of 44.0-mm. *Upeneus parvus*. Line equals 2 mm.

Soft dorsal.—The adults had a second dorsal ray count of one unbranched ray and eight branched rays, all segmented. The smallest specimen (20.8 mm.) had eight segmented rays, four of which were branched. The second ray, the last to branch in this fin, had branched at 43 mm.

The first ray, which was the last to segment, became segmented by about 26 mm.

Pectoral.—The number of pectoral rays in the larger specimens ranged from 14 to 16 (table 15, p. 444). Of the 23 specimens examined over 50 mm., 8.7 percent had 14, 65.2 percent had 15, and 26.1 percent had 16. Of the smaller specimens examined, only one had fewer than 14 rays, a 21.6-mm. specimen with 13 rays. The percentage of specimens with 15 or 16 rays, however, increases with size until a maximum is reached at some point between 68 and 105 mm., a range in which I had no specimens.

Segmentation was not manifest on either the 25.6- or 26.7-mm. specimens, but was on a 28.1-mm. specimen, and all rays were segmented by 60 mm. Segmentation proceeded in advance of branching, and the number of segmented rays exceeded the number of branched rays by two to four at all stages.

The first two rays were not branched on any specimen. Branching was complete on a 64.2-mm. specimen.

Pelvic.—The smallest specimen (20.8 mm.) had the adult complement of fin rays, I, 5, and the soft rays were all branched as well as segmented.

Anal.—The anal fin of the 20.8-mm. specimen has the adult complement of rays, I, i, 6. There were six segmented rays, four of which were branched. In a 21.6-mm. specimen segmentation was evident in all seven rays, and between 30 and 34 mm. branching was complete.

Caudal.—In the specimens examined the caudal fin principal ray count of the genus *Upeneus* was i, 7 + 6, i; this count agrees with that of Lachner (1954). A secondary ray counts on unstained or undissected material over 55 mm. were of dubious accuracy, but on 13 specimens up to this size I counted 16 secondary rays. On all specimens over 34 mm. the first two rays adjacent to the principal rays on both the dorsal and ventral lobes were segmented. Further segmentation of secondary rays was not studied, as no larger specimens were available for staining.

Gill rakers

Total number of gill rakers, number of lower-limb gill rakers, and number of gill rakers on the ceratobranchial bone were counted in specimens ranging in size from 20.8 to 172.5 mm. (tables 16 and 17, p. 449, and fig. 35).

TABLE 16.—*Relation of the total numbers of gill rakers to standard length of 54 specimens of* Upeneus parvus

[The upper number is the number of specimens, and the number in parentheses below is the approximate percentage for the respective size range]

Standard length (mm.)	Total number of gill rakers					Number of specimens
	23	24	25	26	27	
20.0–29.9	2 (18.2)	2 (18.2)	6 (54.5)	1 (9.1)		11
30.0–39.9		3 (33.3)	5 (55.6)	1 (11.1)		9
40.0–49.9			2 (40.0)	2 (40.0)	1 (20.0)	5
50.0–74.9			5 (33.3)	4 (26.7)	6 (40.0)	15
75.0–99.9						--------
100.0–124.5			3 (37.5)	2 (25.0)	3 (37.5)	8
125.0–149.5		1 (20.0)	1 (20.0)	1 (20.0)	2 (40.0)	5
150.0–200.0				1 (100)		1

TABLE 17.—*Relation of the numbers of lower-limb gill rakers (exclusive of one at angle of arch) to standard length of 54 specimens of* Upeneus parvus

[The upper number is the number of specimens, and the number in parentheses below is the approximate percentage for the respective size range]

Standard length (mm.)	Number of lower-limb gill rakers				Number of specimens
	16	17	18	19	
20.0–29.9	1 (9.1)	3 (27.3)	6 (54.5)	1 (9.1)	11
30.0–39.9		2 (22.2)	7 (77.8)		9
40.0–49.9			3 (60.0)	2 (40.0)	5
50.0–74.9		1 (6.7)	7 (46.7)	7 (46.7)	15
75.0–99.9					—
100.0–124.5		2 (25.0)	2 (25.0)	4 (50.0)	8
125.0–149.5		1 (20.0)	1 (20.0)	3 (60.0)	5
150.0–200.0		1 (100)			1

TABLE 18.—*Collection and station data for 35 specimens of* Mulloidichthys martinicus *examined*

[Market procured (M), trawl (T), and collected with rotenone (R)]

Station	Latitude	Longitude	Date of capture	Depth of water in which captured	Method of capture	Number of specimens and size range	Collection and catalogue number (if any)
WESTERN NORTH ATLANTIC:				*Fathoms*		*mm.*	
5 mi. west of Nassau, Bahamas	[1] 25°05′ N.	77°30′ W.	Aug. 11, 1958	0–1	R	(2) 85.0 and 90.0	UF
Nassau Fish Market, Bahamas			Aug. 17–20, 1955		M	(2) 172.5 and 204	UF 3534
Clifton Pier, New Providence Island, Bahamas.	[1] 25°02′ N.	77°35′ W.	Aug. 11, 1958	1–2	R	(5) 83.5–106.5	UF
Key West, Fla						(1) 145.0	SU 508
GULF OF MEXICO:							
Oregon							
Campeche Banks			Dec. 7, 1952			(2) 98.0 and 145.0	CNHM 59818
CARIBBEAN SEA:							
Havana, Cuba						(1) 205.0	CAS IUM 26913
Havana, Cuba						(1) 137.5	SU 1724
Havana, Cuba						(1) 146.5	CAS IUM 2670
Kingston Market, Jamaica			Apr. 24, 1959		M	(5) 122.5–140.5	DKC.
Kingston Market, Jamaica			June 1957		M	(1) 188.0	DKC.
St. Croix, West Indies						(3) 85.5–110.0	CAS IUM 12375.
St. Croix, West Indies						(1) 82.5	SU 21854.
British West Indies						(4) 217.5–246.0	SU 4768.
Oregon 2625	18°45′ N.	64°46′ W.	Sept. 28, 1959	38	T	(1) 174.5	BLBG.
WESTERN SOUTH ATLANTIC:							
Recife, Brazil	08°03′ S.	34°51′ W.				(2) 117.5 and 131.5	SU 52250.
Salvador, Brazil	13°00′ S.	38°31′ W.				(2) 88.0 and 91.5	SU 52242.
Salvador, Brazil	13°00′ S.	38°31′ W.				(1) 94.0	SU 52243.

[1] Approximate latitude and longitude.

Total.—The adult complement of total number of gill rakers (25–27) was reached by 40 mm. (table 16, p. 449).

Lower limb.—The adult complement (17–19) also was attained by 40 mm., but the percentage of specimens with 19 continued to increase through 150.00 mm. (table 17, p. 449).

Ceratobranchial bone and comparison with M. martinicus.—The data indicate that the juveniles of *U. parvus* and *M. martinicus* may be separated on gill raker counts. The gill rakers of *U. parvus* are plotted against those of *M. martinicus* to show both the number of gill rakers on the lower limb and the number of gill rakers on the ceratobranchial bone (fig. 35). The latter character shows less intraspecific variation than the former. The terminus of the ceratobranchial bone was determined by manipulation of the gill arch and observation of the point that the break occurs between the ceratobranchial and basibranchial bones. The gill raker that may seem to occur between the two bones is included in counts for the ceratobranchial bone.

The graphs show a clear separation of the species *U. parvus* and *M. martinicus*. Up to a size of 34 mm., *U. parvus* possessed 10 to 12 gill rakers on the ceratobranchial bone, and 11 or 12 after this size. Above 82 mm., *M. martinicus* had 14 to 15, except for a 107-mm. specimen with 12 gill rakers on the right side (the side normally counted) but 14 on the left. The maximum number of lower-limb gill rakers in *U. parvus* was 19, and the minimum in *M. martinicus* was usually 20 or more (one specimen of *M. martinicus* had 19).

Teeth

Upper jaw.—Teeth were present in the upper jaw of all the specimens examined; the smallest was 20.8 mm.

Lower jaw.—No teeth were evident in the lower jaw of the 20.8- or 21.6-mm. specimens and one 28.0-mm. specimen, but were seen in all others.

Vomerine.—No teeth were apparent on the vomerine bone in a stained specimen of 44.0 mm., but they had formed in the 45.6-mm. specimen. Small teeth were present in all juveniles larger than 44 mm., with the exception of one 52.5-mm. specimen.

Palatine.—The palatine teeth seemed more variable than the vomerine in the time of their formation. They were present in a 45.4-mm. juvenile and in all of the specimens over 53.8 mm., but in the interval between these sizes some of the specimens had them and some did not. In the more mature forms, the number of palatine teeth increased rapidly, and the palatine bones of the adults presented coarse, slightly pointed, peglike teeth which were very much more numerous than the vomerine teeth.

Scales

Counts were possible on only a few specimens as the scales are very deciduous. A 22.0-mm. specimen, however, had 37 fully developed ctenoid scales in the lateral line, which is within the adult complement (36 to 38) (Lachner, 1954).

A 56-mm. specimen had 10 ctenii on the margin of one of the scales, and there were 55 on a scale of a 129.5-mm. specimen.

Barbels

In the smallest specimen, 20.8 mm., the right barbel was completely free of the branchiostegal membrane, but the left had not yet separated. The 21.6-mm. specimen had both barbels still attached. The 22.2-mm. specimen had the left barbel attached completely and the right barbel almost free, but still attached at the distal end. The 23.3-mm. and larger specimens had perfectly formed barbels free of the membrane. Thus, in *U. parvus* we have somewhat earlier development of the barbels than in *M. barbatus* or *M. surmuletus* as described by Lo Bianco (1907).

Operculum

No opercular spine was present on any specimen examined, although there was a projection of the opercular bone (fig. 38) in the same location as the opercular spine of *P. maculatus* and *M. martinicus* (figs. 23 and 43).

Cleithrum

When the scales were removed the cleithrum (fig. 38) was revealed as a prominent bone without the serrations found on the upper wing of the cleithrum of *P. maculatus* (fig. 23).

SPAWNING

The gonads of mature specimens, one male, 120 mm., and two females, 130 and 135 mm., taken by bottom trawl at 29 fathoms, June 3, 1954, in the Gulf of Mexico were found to be between stages IV and V in their development (the eggs or milt fill from one-half to the entire body cavity) using the classification given by Broadhead (1953).

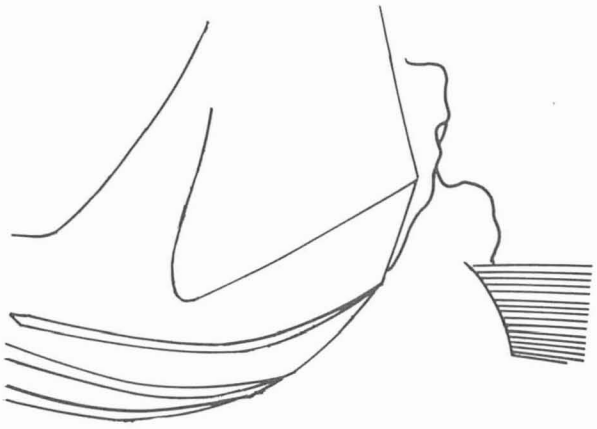

Figure 38.—Operculum and cleithrum of 44.0-mm. *Upeneus parvus*. Line equals 2 mm.

MULLOIDICHTHYS MARTINICUS (CUVIER)

No juveniles below 82.5 mm. were available for examination. Neither the exploratory operations of the *Theodore N. Gill* off the south Atlantic coast of the United States, nor the extensive work done by the *Oregon* in the Gulf of Mexico and in the Caribbean resulted in the capture of any specimen of this species below 82.5 mm. Other likely sources of material were investigated without success.

The likelihood of the appearance of these juveniles in the waters off the south Atlantic coast of the United States necessitates the inclusion of this species in a study of juvenile Mullidae of these waters, and they are discussed within the limits of the material available. Pertinent station data and present location of the material examined are listed in table 18, p. 449.

DISTRIBUTION

Briggs (1958) listed the range of *Mulloidichthys martinicus* as Bermuda and the Florida Keys to the Lesser Antilles, Panama, and the western Gulf of Mexico.

I examined adult specimens of this species from as far south as Salvador, Brazil, but as these could have been market-procured (data not given), the precise locality of their capture may be questioned. Locations of captures of the material examined are shown in figure 24.

ECOLOGY

An enigma is posed by the absence of juveniles of *M. martinicus* in collections where they might be anticipated. Parr (1930) noted this absence of pelagic specimens of *M. martinicus* in his collecting in the Bahamas and Turks Island (surface light at night) where the adults are plentiful, and referred to it as "peculiar." My smallest specimen with data (83.5 mm., table 18) was taken with aid of rotenone in 6 to 8 feet of water. The data on much of the material were scanty, but one large specimen was taken by bottom trawl.

GROWTH AND DEVELOPMENT

The smallest *M. martinicus* examined was 82.5 mm. (fig. 39). At this size, there was no external evidence of a minute first dorsal spine, a strong opercular spine was evident, and the anterior teeth in both upper and lower jaws were irregularly biserial.

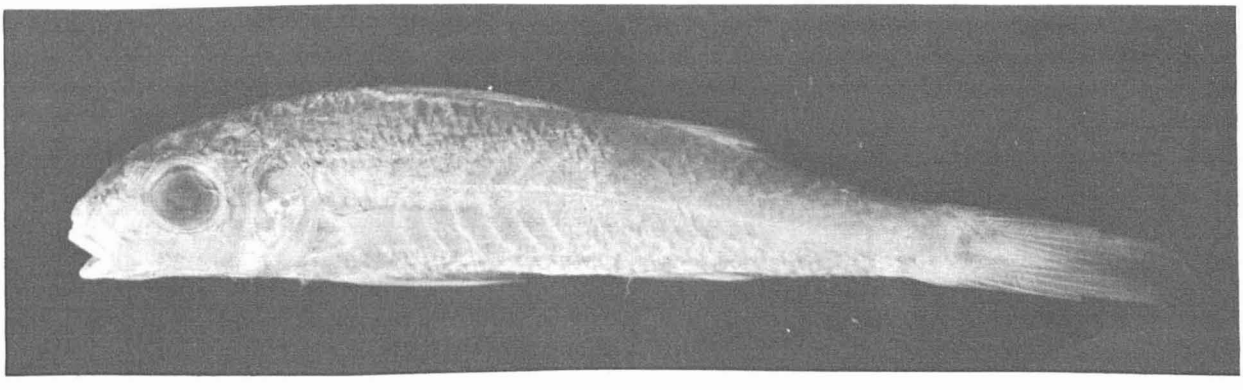

Figure 39.—*Mulloidichthys martinicus*, 82.5 mm. (SU 21854)

Body Proportions

Thirteen body proportions were measured on 27 specimens from 82.5 to 204.0 mm. (figs. 9 through 21).

There is possibly a slight inflection between 150 and 180 mm. for interorbital space (fig. 18), with a suggestion of a lower rate of increase beyond the inflection than initially. The other characters show a constant rate of increase within the size range of available material.

Pigmentation

Specimens up to 122 mm. that were preserved in alcohol were either pale yellow overall or yellow with silvery abdomen and sides up to the lateral midline. Above this size, the colors were dark to light tan or yellow. Some retained red on the head and anteriorly on the lateral midline. Two, 174.5 and 188.0 mm., were tan with dark lateral midlines. Fins were clear on all specimens.

Fins

Spinous dorsal.—The literature is conflicting in regard to the number of spines. Opinion is about equally divided as to whether there are 7 spines (Cuvier and Valenciennes, 1829; Storer, 1846; Meek and Hildebrand, 1923; Beebe and Tee-Van, 1933) or 8 (Jordan and Evermann, 1896; Nichols, 1929; Evermann and Marsh, 1902). An examination of 27 specimens of the species explains the divergence of opinion. Visual examination shows some have a spiny protuberance resembling a very short spine at the origin of the 1st dorsal. If the area is carefully probed, some specimens show this structure embedded and on others probing reveals nothing (fig. 40). When present, the spiny protuberance is usually movable in all directions. A cleared and stained spinous dorsal fin of a 138.5-mm. specimen (fig. 41) shows the structure, completely covered by soft tissue.

I X-rayed similar-sized specimens of the four species of western North Atlantic Mullidae to observe the bony structure anterior to the spinous dorsal, seen on some, but not all, species (fig. 42). X-ray evidence points to an intergrading of this character between species. The species are arranged from top to bottom in the X-ray positive in ascending order of magnitude of the bony structure.

In *U. parvus* (106.0 mm.) the spiny protuberance at the origin of the first dorsal fin was small, round and well covered with soft tissue. The interneurals numbered three and were set well in advance of the spines.

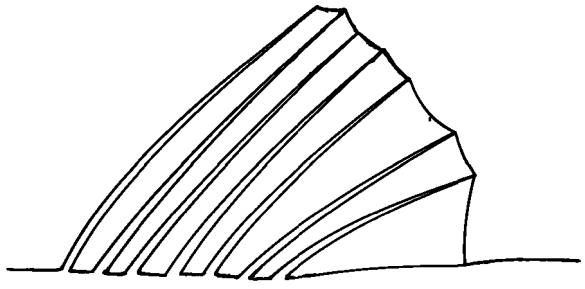

Figure 40.—Spinous dorsal fin of 83.5-mm. *Mulloidichthys martinicus*. Line equals 5 mm.

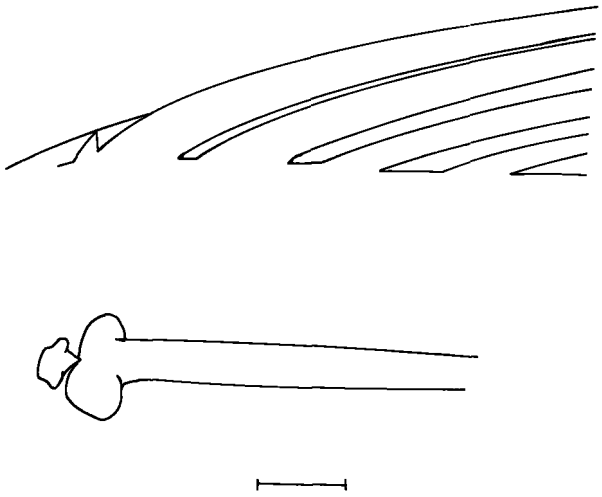

Figure 41.—Cleared and stained spinous dorsal fin of 138.5-mm. *Mulloidichthys martinicus*. *Upper:* lateral view; *lower:* dorso-ventral view. Line equals 2 mm.

In *M. martinicus* (105.5 mm.) the structure was small, pointed obliquely up and back, and was covered with soft tissue. The interneurals numbered three (first not dense), and were set well in advance of the spines.

In *M. auratus* (105.5 mm.) the structure gave the appearance of a rudimentary spine. The interneurals numbered three and were not placed as far forward as in the two previously mentioned species. The spine protruded from the soft tissue.

In *P. maculatus* (106.5 mm.) the structure gave the appearance of a rudimentary spine, slightly larger than that of *M. auratus*. It projected well beyond the soft tissue. What appeared in the

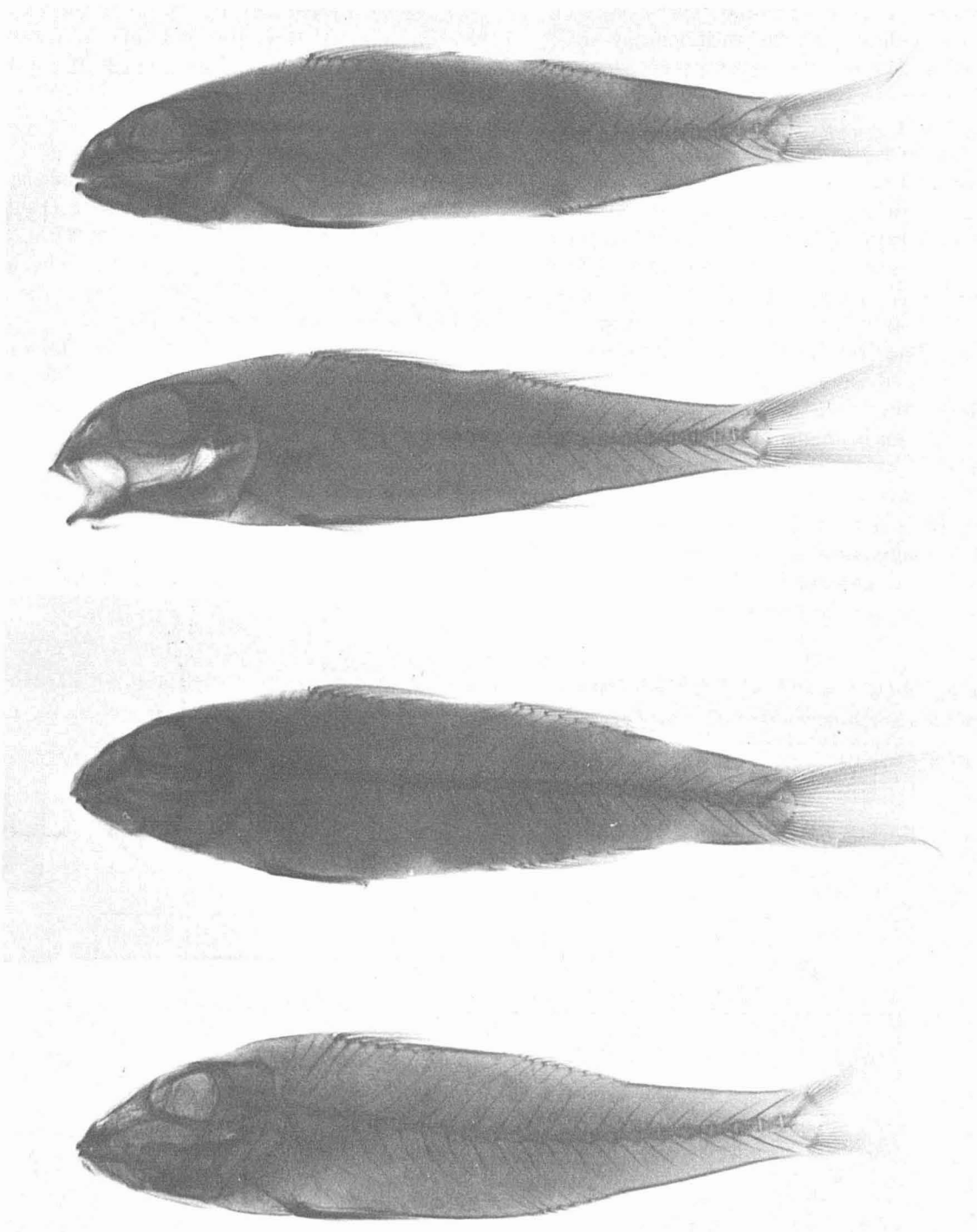

Figure 42.—X-ray positive of Mullidae of the western North Atlantic. In descending order: 106.0-mm. *Upeneus parvus*, 105.5-mm. *Mulloidichthys martinicus*, 105.5-mm. *Mullus auratus*, and 106.5-mm. *Pseudupeneus maculatus*.

X-ray to be the third interneural was located farther posteriorly than in the other species and appeared to articulate with the rudimentary spine. All species appear to have seven pterygiophores, although there may be a question in *P. maculatus* as to whether the bone with which the minute spine articulates is properly termed an interneural or a pterygiophore.

Soft dorsal.—On all material there were nine segmented soft rays, eight of which were branched.

Pectoral.—Counts on 27 specimens ranged from 15 (twice) to 17 (once). In an 83.5-mm. specimen the first and the last two rays were not segmented. The first ray was the last to segment; it was segmented in a 140.3-mm. specimen. In the 83.5-mm. specimen, the first two and the last two rays were not branched, but the last two rays were branched at approximately 138 mm. The first two rays never branched.

Pelvic.—Rays numbered I, 5—all five soft rays branched and segmented by 82.5 mm.

Anal.—Rays numbered I, i, 6 on all material.

Caudal.—Principal rays numbered i, 7+6, i on 10 specimens. The secondary rays were overgrown with tissue in all material. None of the material was stained. It was not possible to count the number of secondary rays, even in the X-ray specimens (fig. 42).

Gill Rakers

Total.—Total numbers of gill rakers of 25 specimens were correlated with size ranges (table 19, p. 449). They ranged from 26 to 33 with 26, 27, and 33 encountered only once each. The larger specimens averaged fewer gill rakers as the rudiments become overgrown with tissue.

Lower limb and ceratobranchial bone.—The lower-limb gill rakers and those of the ceratobranchial bone are discussed and compared with those of *U. parvus* in the section on *U. parvus* (fig. 35).

The material from the more southern latitudes tended to have higher numbers of gill rakers on the ceratobranchial bone; 2 of the 3 specimens with 16 are from Brazil and the other from St. Croix.

TABLE 19.—*Relation of total numbers of gill rakers to standard length of 25 specimens of* Mulloidichthys martinicus

[The upper number is the number of specimens, and the number in parentheses below is the approximate percentage for the respective size range]

Standard length (mm.)	Total number of gill rakers								Number of specimens
	26	27	28	29	30	31	32	33	
82.5-99.5			1 (10.0)	2 (20.0)	3 (30.0)	1 (10.0)	2 (20.0)	1 (10.0)	10
100.0-124.5		1 (16.7)	1 (16.7)	2 (33.3)		1 (16.7)	1 (16.7)		6
125.0-149.5				2 (40.0)	2 (40.0)	1 (20.0)			5
150.0-204.0	1 (25.0)		1 (25.0)	1 (25.0)	1 (25.0)				4

Teeth

Upper and lower jaw.—All specimens had a row of small canines posteriorly in each jaw; these rows were irregularly biserial anteriorly.

Vomerine and palatine.—Absent.

Scales

Counts ranged from 34 to 39 (mean of 36) on 21 specimens, with 35 being the number most frequently encountered. The scale of a 138.0-mm. specimen had 83 ctenii, and one from a 188.0-mm. specimen had 122.

Barbels

Fully developed and normal on all material.

Operculum

All material had a strong spine on the operculum at the anterior terminus of the lateral midline. Slightly dorsal to this is a small crenulated tab (fig. 43).

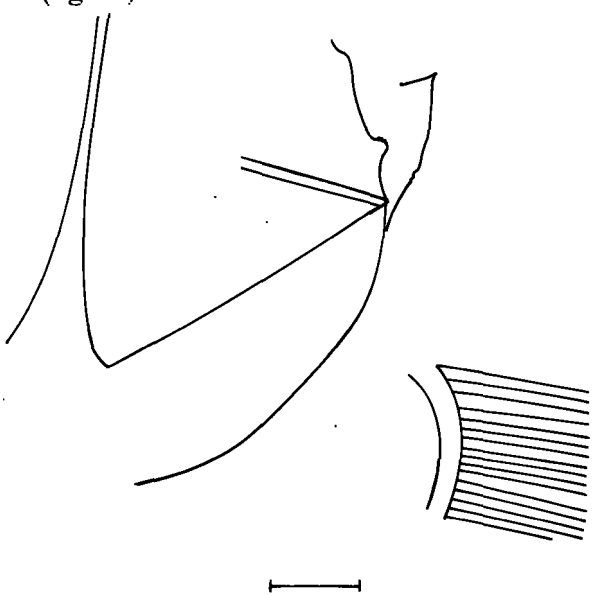

Figure 43.—Operculum and cleithrum of 83.5-mm. *Mulloidichthys martinicus*. Line equals 2 mm.

Cleithrum

No serrations were observed on the posterior wing of the cleithrum of any specimen.

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