UNITED STATES DEPARTMENT OF THE INTERIOR, Fred A. Seaton, *Secretary*
FISH AND WILDLIFE SERVICE

OBSERVATIONS ON THE DEVELOPMENT OF THE ATLANTIC SAILFISH *ISTIOPHORUS AMERICANUS* (CUVIER) WITH NOTES ON AN UNIDENTIFIED SPECIES OF ISTIOPHORID

By JACK W. GEHRINGER

Drawings by author

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ABSTRACT

One hundred and sixty-nine istiophorids ranging from 3.4 to 625 mm. in standard length, from the western North Atlantic and the Gulf of Mexico, were examined. Separation to species was not accomplished for specimens below 10 mm. long. Above 10 mm., the Atlantic sailfish, *Istiophorus americanus* (Cuvier), was readily separated from an unidentified species on length of snout.

A developmental series, 3.6 to 374 mm., representing a combination of istiophorids below 10 mm. and the sailfish above 10 mm., is figured, described, and discussed. Several of the unidentified specimens are also figured. Growth and development of various body parts are discussed, with emphasis on the sailfish. Three stages of larval development are suggested: "early larval," below 7 mm.; "midlarval," the 7 to 20 mm. range; and "late larval," the 20 to 100 mm. range.

Analyses of stomachs of 32 specimens revealed: copepods comprised the food of specimens smaller than 6 mm., but were not present in those exceeding 13 mm.; and fish larvae comprised the bulk of food in specimens exceeding 6 mm.

Spawning seasons and areas suggested are as follows: western North Atlantic, April to September, from south of Cuba north to the Carolinas, beyond the 100-fathom line, and closely associated with the Gulf Stream; eastern Gulf of Mexico, April through August; western Gulf, June into August. Surface salinity, oxygen, and temperature values for locations of capture of some istiophorid larvae are given.

It is suggested that the unidentified specimens are more likely to develop into the adult form of the spearfish, *Tetrapturus*, than into the sailfish, *Istiophorus*, or the marlins, *Makaira*.

CONTENTS

OBSERVATIONS ON THE DEVELOPMENT OF THE ATLANTIC SAILFISH *ISTIOPHORUS AMERICANUS* (CUVIER), WITH NOTES ON AN UNIDENTIFIED SPECIES OF ISTIOPHORID

BY JACK W. GEHRINGER, *Fishery Research Biologist*

The South Atlantic Fishery Investigations, conducted by the U. S. Fish and Wildlife Service in cooperation with the U. S. Navy Hydrographic Office, the Office of Naval Research, the Georgia State Game and Fish Commission, and the Florida State Board of Conservation (through the Marine Laboratory, University of Miami), has engaged since July 1952 in a biological, chemical, and physical oceanographic study of the waters between Cape Hatteras and the Florida Straits from the coast to considerably beyond the axis of the Gulf Stream.

Field operations are conducted with the research vessel *Theodore N. Gill*. Biological specimens are collected with standard half-meter silk nets, high-speed metal nets (Arnold and Gehringer, 1952), a continuous plankton sampler, 18-inch diameter dip nets equipped with 10-foot bamboo handles and lined with ⅛-inch nylon mesh, and trolling and hand lines.

During hydrographic observations, at which time the vessel is drifting, dip-net operations are carried out, aided at night by flood and spotlights. Dip-netting sometimes produces relatively rare fish larvae and juveniles. Such was the case on July 29, 1953, between 1700 and 1900 hours during the occupation of regular station 30 (approximately 90 miles east of Brunswick, Ga.) on *Theodore N. Gill* cruise 3, when several small istiophorids were captured. Dip-netting and surface tows on that station and on subsequent stations produced a total of 26 specimens ranging in standard length from 3.4 to 38.8 mm.

Since little has been published on the early life history of the sailfish and other istiophorids, information that could be obtained from the specimens is of considerable value. There was a dearth of material in the 3.8–9.4 mm. range in our collections, however. The United States National Museum kindly loaned their small istiophorid specimens, most of which were in the 3.8–9.4 mm. range, including some from the Gulf of Mexico. I decided to include in the study all available material both from the waters off the South Atlantic Coast of the United States and from the Gulf of Mexico. Additional specimens were loaned by the Gulf Fishery Investigations (Arnold 1955) and various other organizations. Subsequent *Theodore N. Gill* cruises produced several more specimens; one was removed from the stomach of a small swordfish, *Xiphias gladius* (Arata 1954), and one was taken from the stomach of another small istiophorid. Three mounted specimens of Atlantic sailfish, *Istiophorus americanus* (Cuvier), 374 to 625 mm. in standard length, were photographed and measured. In total, 168 specimens were examined.

During my examination of the material I found two groups of fishes to be involved. Those below approximately 10 mm. in standard length did not separate into two groups on any character or group of characters examined, or location or time of capture. The specimens exceeding approximately 10 mm. in standard length separated on some morphometric measurements into two distinct groups which converged at approximately 10 mm. The converging of the two groups at 10 mm. precludes the positive identification, by species, of specimens below 10 mm., so far as my observations are concerned. Beyond 10 mm. one group traces through development to the Atlantic sailfish, *Istiophorus americanus* (Cuvier). The other group, with a maximum size of 45.0 mm. standard length, has not been identified. Lack of specimens exceeding 45 mm. makes positive identification impossible. For these specimens I present selected measurements, counts, and figures, and discuss them with reference to Atlantic sailfish specimens of similar sizes. The unidentified species is represented by 15 specimens exceeding 10 mm. Several specimens below 10 mm., which were taken at the same time as these, possibly belong to the same group.

Though the taxonomy of the istiophorids is in

question, it is generally accepted that there is but one species of Atlantic sailfish: *Istiophorus americanus* (Cuvier). In accordance with Bailey's review (1951) of the authorship of Cuvier and Valenciennes (1831), the single authority is used here as opposed to the common use of both names.

Other members of the staff and members of the crew of the *Theodore N. Gill* assisted in the collection of specimens and various other aspects of the study. Special thanks are extended to Isaac Ginsburg for loan of specimens and for critical reading of the manuscript; to Leonard P. Schultz of the U. S. National Museum for information and loan of specimens; to Royal D. Suttkus of Tulane University, Loren Woods, of the Chicago Natural History Museum, Giles W. Mead, Robert M. Yount of Myrtle Beach, S. C., and Tony Seaman of Morehead City, N. C., for loan of specimens; to Stewart Springer for data; to Albert W. Collier, Jr., and Edgar L. Arnold, Jr., for loan of specimens and critical reading of the manuscript; and to Frank T. Knapp of the Georgia Game and Fish Commission and George F. Arata, Jr., of the Florida Board of Conservation, for critical reading of the manuscript.

METHODS AND DATA

METHODS OF MEASUREMENT

Measurements from the specimens were made with a binocular, stereoscopic microscope and a micrometer eyepiece, except for the three mounted specimens, whose measurements were made with vernier calipers. Measurements of specimens less

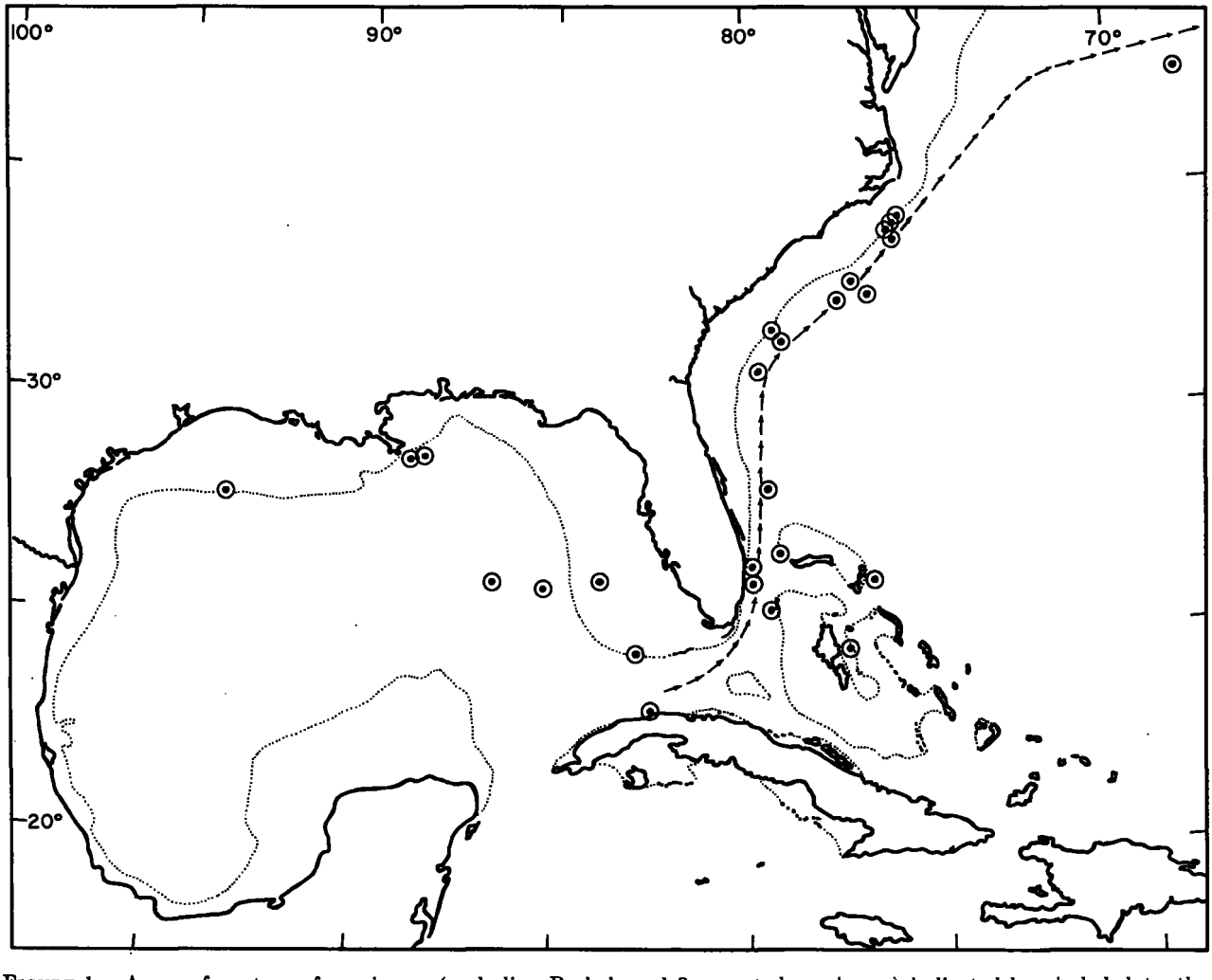

FIGURE 1.—Areas of capture of specimens (excluding Beebe's and 3 mounted specimens) indicated by circled dots, the 100-fathom curve by dotted lines, and the approximate axis of the Gulf Stream by arrows.

than 100 mm. in standard length were recorded to the nearest 0.1 mm., and those of specimens more than 100 mm. in standard length to the nearest millimeter. Measurements of Beebe's (1941), Voss's (1953), and Baughman's (1941a) specimens were taken from their papers.

DEFINITIONS OF TERMS

Standard length.—Tip of snout to tip of urostyle or most posterior extension of hypural segment.

Total length.—Tip of snout to tip of caudal fin, or finfold.

Head length.—Tip of snout to posterior extension of fleshy margin of opercle.

Width of head.—Measurement of widest portion of brain case, at point where dorso-lateral keel of pterotic spine joins orbital crest.

Depth of head.—Vertical measurement of head at posterior angle of jaw.

Snout length.—Tip of snout to anterior margin of eye.

Lower jaw length.—Tip of mandible to posterior angle of the jaw.

Snout extension.—Tip of snout to mandible tip (with mouth closed).

Eye diameter.—Horizontal measurement of eye.

Pterotic spine length.—Tip of spine to point of attachment of dorso-medial keel of spine to head.

Main preopercular spine length.—Tip of main preopercular spine to vertical at posterior edge of preopercle.

Pectoral fin length.—Tip of pectoral fin to insertion.

Pelvic fin length.—Tip of pelvic fin to insertion.

Dorsal fin-ray lengths.—Tips to insertions.

Teeth.—Number of teeth on one side each of the upper and lower jaws.

Pterotic spine serrations.—Numbers of serrations on keels of left and right pterotic spines.

Ratio of secondary preopercular spines.—Number of spines, in ratio, on left side of head.

Number of dorsal, anal, and pectoral fin rays.—Counts are total numbers with no distinction made between spines and soft rays.

MEASUREMENTS AND MERISTIC COUNTS

Table 1 gives selected measurements and meristic counts from the 19 specimens described or figured; table 2 gives selected measurements from 13 Florida specimens described by Voss (1953); table 3 gives selected measurements from two specimens described by Beebe (1941), and 3 mounted specimens from the Gulf of Mexico, described by Baughman (1941a). Voss's, Beebe's, and Baughman's data are plotted with mine on the respective graphs.

TABLE 1.—*Selected measurements and meristic counts from 19 specimens described and figured*

Item	Measurements and counts for specimen No.—																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Measurements in mm:																			
Standard length	3.6	4.7	5.6	6.4	8.1	9.5	11.3	14.6	18.2	20.9	27.4	38.8	56.2	64.1	101	374	[1]11.3	[1]21.0	[1]45.0
Total length	3.8	4.9	6.0	7.1	9.6	11.0	12.5	16.7	20.6	23.8	30.7	42.9	61.0	68.9	.....	419	13.1	24.6	50.5
Head length	2.0	2.2	2.7	3.5	3.9	4.7	5.6	7.0	9.5	10.7	12.9	19.9	29.3	32.6	54	168	5.2	9.0	15.2
Head width	1.1	1.3	1.4	1.7	2.0	2.2	2.3	2.6	2.7	2.9	3.1	3.4	3.6	3.9	8	.....	2.3	3.4	4.8
Head depth	1.4	1.2	1.5	1.8	2.3	2.5	2.5	3.1	3.4	3.8	3.7	4.5	5.1	5.7	7	35	2.6	4.2	7.2
Snout length	0.5	0.7	1.0	1.3	1.2	1.5	2.4	3.2	5.0	5.7	7.4	12.9	21.6	23.9	42	127	1.7	3.0	5.2
Lower jaw length	1.0	1.2	1.7	2.4	2.3	2.7	3.3	4.7	5.3	5.9	6.9	8.4	10.8	11.1	16	55	3.1	5.1	8.5
Snout extension	0.0	0.1	0.1	0.1	0.2	0.2	0.4	0.7	2.1	2.0	3.3	7.6	14.6	16.6	31	79	0.1	0.3	0.8
Eye diameter	0.7	0.7	0.8	1.1	1.3	1.5	1.3	1.7	1.8	2.1	2.3	2.7	3.1	3.0	4	8	1.6	2.6	3.6
Pterotic spine length	0.4	0.7	1.0	0.8	0.6	0.6	1.0	1.0	0.8	1.1	0.9	1.0	0.6	1.0	1	none	1.0	0.9	0.6
Main preopercular spine length	1.2	1.3	1.8	2.1	2.4	1.5	2.0	1.8	2.3	3.0	2.4	2.7	2.7	2.1	.....	*none*	2.3	1.6	1.8
Pectoral fin length	.....	0.8	0.8	1.2	1.3	1.5	1.2	1.8	2.0	2.2	2.7	3.8	5.4	5.1	7	21	1.5	3.0	6.0
Pelvic fin length	none	0.1	0.1	0.2	0.6	1.4	1.2	2.4	3.6	4.5	5.8	8.7	13.5	14.5	[2]19	.....	1.8	6.1	13.5
Dorsal fin-ray lengths:																			
5th	none	none	none	.....	.....	1.1	0.9	1.9	3.2	2.9	5.4	5.9	8.4	7.7	.....	.....	1.2	6.3	12.0
10th	none	none	none	.....	.....	.....	1.3	2.4	3.6	4.5	7.1	10.6	15.6	17.3	.....	.....	.....	6.3	15.6
13th	none	none	none	.....	.....	.....	1.6	2.3	3.9	4.8	7.2	11.5	18.2	18.6	26	.....	.....	6.2	16.4
15th	none	none	none	.....	.....	.....	.....	2.1	3.7	4.7	6.3	11.1	17.4	18.6	.....	.....	1.2	6.0	16.2
17th	none	none	none	.....	.....	.....	.....	.....	.....	4.5	.....	6.6	16.8	18.0	.....	.....	.....	5.7	16.1
20th	none	none	none	.....	.....	.....	.....	.....	.....	3.6	.....	9.3	15.6	16.2	.....	.....	.....	4.8	15.0
Counts:																			
Number *of teeth one side* of jaw:																			
Upper	.....	10	13	14	26	25	27	43	45	51	42	55	86	60	.....	.....	34	36	102
Lower	.....	.....	.....	18	.....	.....	26	48	46	43	52	50	60	85	.....	.....	34	43	80
Pterotic spine serrations:																			
Dorso-lateral keel (left & right)	.....	22-28	30-34	28	...	30	.....	28...	37-36	37-38	45-44	48-43	22-27	.....	.. 43	.....	none	34-34	33-40	35-42
Dorso-medial keel (left & right)	... 14	17-14	... 18	10	...	12	.....	.....	16-21	16-15	18-19	15-14	14-15	.....	.....	.....	none	16-16	11-16	10 ..
Ventral keel (left & right)	.....	.....	.....	.....	.....	.....	14...	16-16	18-18	18-17	17-16	12-17	.....	.. 11	.....	none	15-18	12-15	12-13
Ratio of secondary preopercular spines (upper: lower)	1:0	1:0	1:1	2:1	2:1	2:1	2:1	1:1	2:2	2:2	.....	1:0	.....	.....	.....	none	2:1	.....	.....
Number of dorsal fin rays	fold	fold	fold	.....	42	[2]40	50	50	52	49	51	51	53	55	51	.....	[2]42	44	49
Number of anal fin rays	fold	fold	fold	fold	10	22	22	23	22	23	25	24	24	24	[2]20	.....	16	23	24
Number of pectoral fin rays	fold	fold	fold	16	15	16	18	18	18	17	18	20	18	20	18	.....	14	20	18

[1] Indicates unidentified species.

[2] Indicates questionable values.

TABLE 2.—*Selected measurements from 13 Florida specimens described by Voss (1953)*

[In millimeters]

Specimen No.—	Standard length	Total length	Head length	Snout length	Eye diameter	Pterotic spine length	Preopercular spine length	Lower jaw length	Pelvic fin length
1	3.9	4.2	1.5	0.5	0.5	0.4	0.7	0.7	
2	4.8	5.4	2.2	0.6	0.7	0.8	0.3	1.2	
3	5.5	6.5	2.7	0.8	0.9	0.9	1.4	1.8	0.2
4	6.3	7.3	3.8	1.2	1.1	0.8	1.9	1.9	
5	8.0	9.6	4.2	1.3	1.3	0.8	1.1	2.3	0.8
6	15.0	16.7	7.5	3.8	1.6	0.8	2.6	5.1	1.6
7	19.5	22.0	9.7	5.0	2.0	0.7	2.5	5.6	4.0
8	20.0	21.5	9.8	5.0		0.8	2.3	6.2	2.2
9	20.5	22.0	10.9	5.7	2.0	1.0	2.3	5.8	3.5
10	29.5	32.5	15.9	10.0	2.4	1.0	2.6	7.5	6.4
11	37.5	41.0	18.6	12.4	2.8	1.1	2.8	8.9	
12	70.0	76.0	39.0	28.7	3.7	0.4	2.2	12.5	15.0
13	208.0	234.0	94.0	76.0				37.0	46.0

TABLE 3.—*Selected measurements from 2 specimens described by Beebe (1941) and 3 mounted specimens described by Baughman (1941a)*

[In millimeters]

Item	Measurements from Beebe		Measurements from Baughman		
	No. 1	No. 2 [1]	No. 1	No. 2	No. 3
Standard length	70	437	544	849.5	851
Head length	37	169	233	314	324
Snout length	29.3	140	175	228.5	232
Eye diameter	3.4	12	16	22	23
Pterotic spine length	1				
Main preopercular spine length	3				
Lower jaw length	12.6	63		116	118
Snout extension	21	94			
Pelvic fin length	13.4		144	204	
Dorsal fin height	20	130			
Number of dorsal rays	56				
Number of pectoral rays	19				

[1] Measurements are conversions of Beebe's percent-of-standard-length values.

DESCRIPTION OF SPECIMENS

The importance of line drawings, in a developmental series of a fish, to portray metamorphic changes is well understood; therefore I have chosen for illustration (to scale) only those sizes at which important changes are apparent. A complete description is given of the smallest specimen, and for other specimens a brief summary of important changes which have occurred from the preceding size is presented.

A series of specimens ranging in standard length from 3.6 to 374 mm. is figured and discussed. Those exceeding 10 mm. in standard length separated into two readily distinguishable groups, one tracing through development to the Atlantic sailfish, *Istiophorus americanus* (Cuvier), and the other remaining unidentified. Those below 10 mm. did not separate into two distinct groups; hence they are treated as one. Drawings of three specimens of the unidentified species are presented (figs. 23, 24, and 25), with discussion limited to variations from sailfish.

Various authors, Gunther (1873–74), Lutken (1880), Goode (1883), Beebe (1941), LaMonte and Marcy (1941), and Voss (1953), have published figures and descriptions of small sailfish singly or in series. Those described by Voss from waters off southern Florida constitute the most complete series. I am unable to explain the differences between my findings and those of the authors cited.

For comparison with the series of illustrations of sailfish material studied, I include as figure 21 a photograph of a 437-mm. sailfish, from off Texas, described by Beebe (1941), and as figure 22 a line drawing of an adult sailfish to portray general outlines.

LARVA, 3.6 MILLIMETERS

(Fig. 2)

Although the specimen is damaged, it is the smallest complete larva in the material studied, and is smaller than any specimen previously described.

Head.—The jaws are equal, and the snout is not produced. The orbital crest originates anterior to the nostril, curves over the eye (with a large spine over the eye), and continues posteriorly as a serrated ridge continuous with the dorsolateral keel of the pterotic spine. The pterotic spine has 3 serrated keels (dorsolateral, dorsomedial, and ventral in position), is directed posteriorly and parallel to sagittal plane of the body, and prominent serrations on the dorsolateral keel diminish to minute notches on the ridge connecting with the orbital crest. The main preopercular spine has 3 serrated keels (dorsomedial, lateral, and ventromedial in position), arises from the posterior ventral edge of preopercle, is directed posteriorly at approximately a 45-degree angle to sagittal

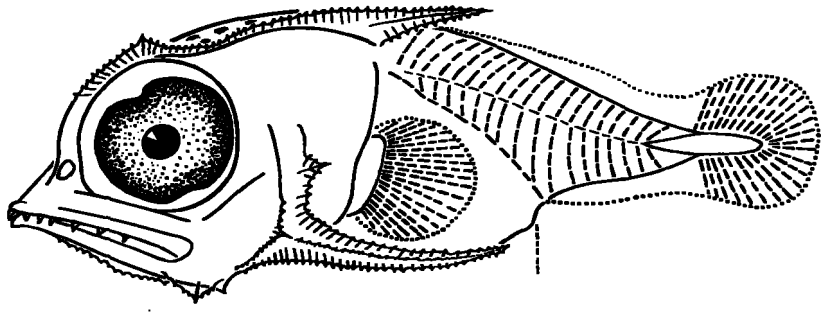

FIGURE 2.—Larva, 3.6 millimeters long (U. S. Nat. Mus. No. 111814).

plane of the body (when opercle is closed), and the ventromedial keel terminates anteriorly at the posterior angle of the lower jaw. The upper secondary preopercular spine is serrated and arises from posterior edge of the preopercle on a serrated keel continuous with the dorsomedial keel of the main preopercular spine. (See figure 3 for arrangement of head spines in the dorsal view of a 3.8-mm. specimen.) The keel on the face of the opercle is serrated and possesses a dominant, acute, and medially situated protuberance. Keels on lower jaw are serrated, and two in number; one arising from the lateral surface of the posterior portion of the jaw and possessing a dominant protuberance, and the other comprising the lower edge of the lower jaw. Teeth are few in number, large, with the anterior ones tusklike. The eye is large, with a diameter one-third the length of the head. The nostril is a single opening in the swollen anterior-basal portion of the orbital crest.

Body.—The body is short and deep, the visceral sac distended with food, and myomeres and the rodlike urostyle are prominent.

Fins.—The dorsal, caudal, and anal are a continuous fold with indistinct supporting structures developing in the caudal portion. The pectoral is round, with indistinct supporting structures. No pelvic fins are present.

Pigmentation.—Pigment has faded from long preservation, and that remaining is limited to a

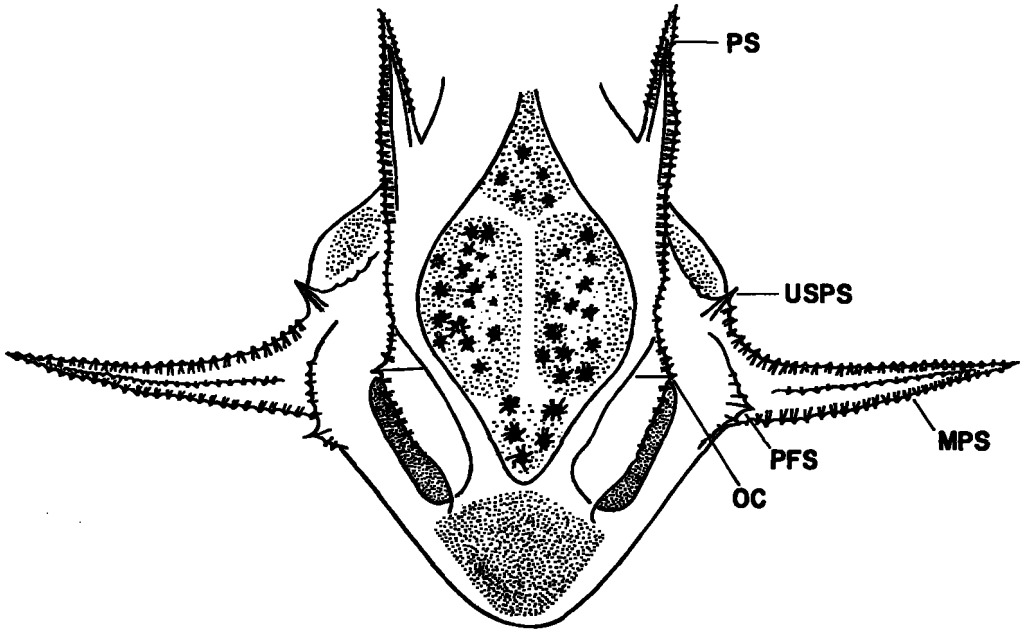

FIGURE 3.—Larva, 3.8 mm. (*Theodore N. Gill* collections), dorsal view of head showing spination and pigmentation. *PS*, pterotic spine; *USPS*, upper secondary preopercular spine; *PFS*, spine on face of preopercle; *MPS*, main preopercular spine (directed at 90° from sagittal plane of body as opercles are open, angle is 45° when opercles are closed); *OC*, orbital crest (showing heavy spine over eye).

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few melanophores (faded to brown color) on the dorsal surface of the brain case. The eyes are black with white pupils (preservation caused a reversal of color from that of the live condition of white eyes and black pupils).

LARVA, 4.7 MILLIMETERS

(Fig. 4)

The visceral sac was nearly empty and not so distended as in other specimens of similar size. The snout is slightly produced and extends beyond the tip of the mandible. The nostril opening has elongated. Pelvic fins are now present, as buds, and indistinct supporting structures have appeared in the dorsal and anal portions of the finfold (which is now notched anterior to the caudal portion), and some rays are discernible in the ventral portion of the caudal.

LARVA, 5.6 MILLIMETERS

(Fig. 5)

The snout and mandible have elongated slightly. Fanglike teeth are present on the tip of the snout. The nostril is partially divided by developing flaps. A lower secondary preopercular spine has appeared on the ventromedial keel of the main preopercular spine. Separation of the finfold into dorsal, caudal, and anal portions is distinct but not complete. Additional caudal rays have appeared, the urostyle has turned upward, and supporting structures in dorsal, anal, and pectoral fins are further developed, but not yet discernible as rays.

LARVA, 6.4 MILLIMETERS

(Fig. 6)

The snout is more elongated and extends farther beyond the tip of the mandible. Several palatine teeth have appeared, and although snout fangs are missing (appear broken off) they are present on other specimens of similar size. Each nostril is now divided (by a flap of skin) into two openings. Two upper secondary preopercular spines are now present. (At this size the height of spinous condition of the head is reached, although the pterotic spines are blunt and appear deformed on this specimen.) Rays are discernible in dorsal and anal fins, the pectoral fin has 16 rays, additional rays are present in the caudal fin, separation of dorsal, anal, and caudal fins is complete, and the pelvic fins have elongated. The pattern of pigmentation is more distinct (probably owing to better color preservation).

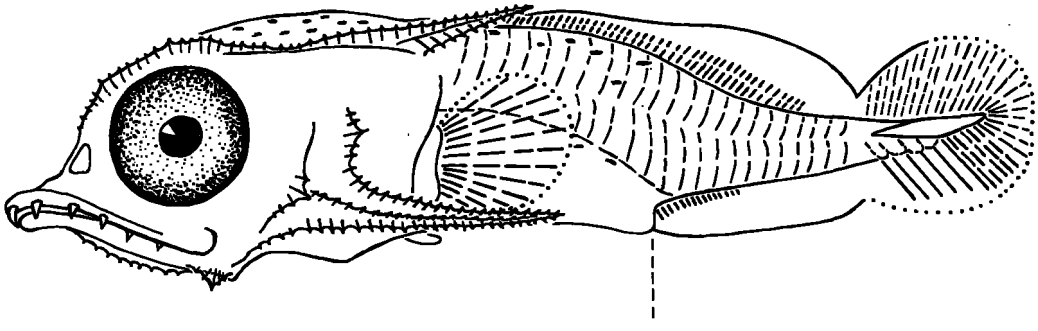

FIGURE 4.—Larva, 4.7 millimeters long (USNM 163332).

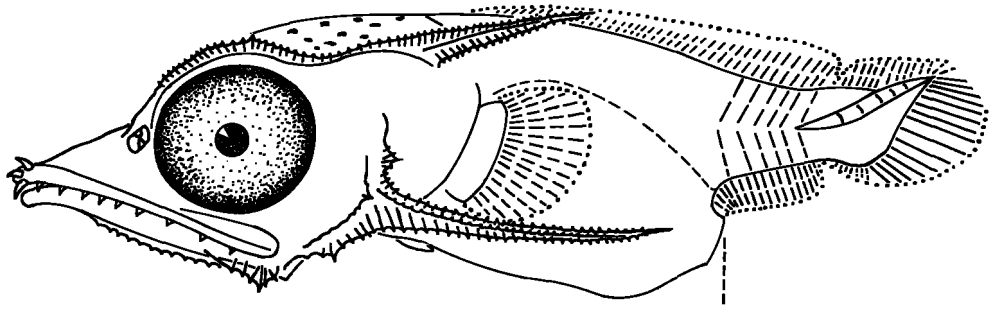

FIGURE 5.—Larva, 5.6 millimeters long (USNM 163333).

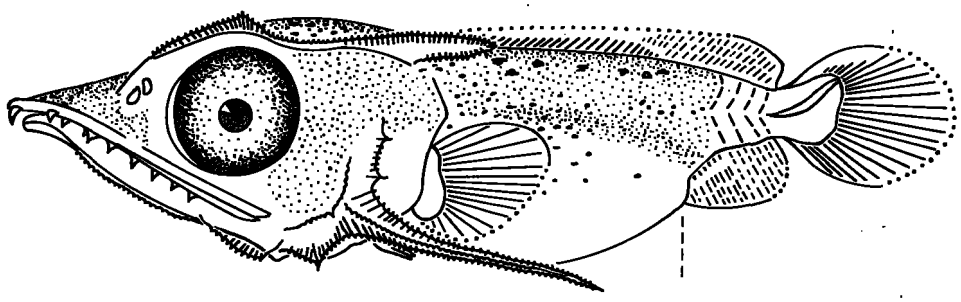

FIGURE 6.—Larva, 6.4 millimeters long (USNM 111814).

LARVA, 8.1 MILLIMETERS

(Fig. 7)

The snout extends farther beyond the tip of the mandible. Many teeth of varied sizes are present in both jaws, and fanglike teeth occur on the tip of the mandible. There are 42 rays in the dorsal fin, 10 in the anal, 15 in the pectoral, and 2 in the pelvic (posterior rays in dorsal fin are less clearly defined than anterior ones), and the caudal fin is notched. The pattern of pigmentation extends over a greater area.

LARVA, 9.5 MILLIMETERS

(Fig. 8)

The anterior opening of each nostril has a collar (formed by a flap of skin). A second lower secondary preopercular spine is present on the left main preopercular spine, but a similar spine was not found on the right main spine, or on either spine of other specimens of similar size. The dorsal fin has increased in height, and when depressed fits into a groove formed from a raised dermal flap on each side of fin (groove ends at

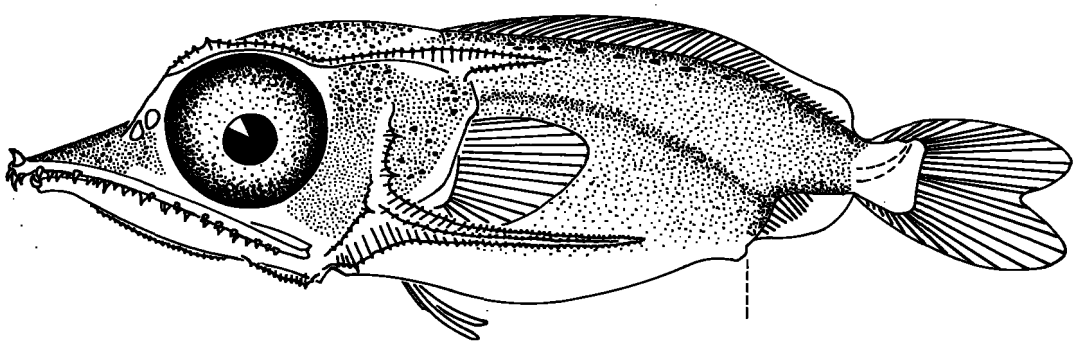

FIGURE 7.—Larva, 8.1 millimeters long (USNM 111814).

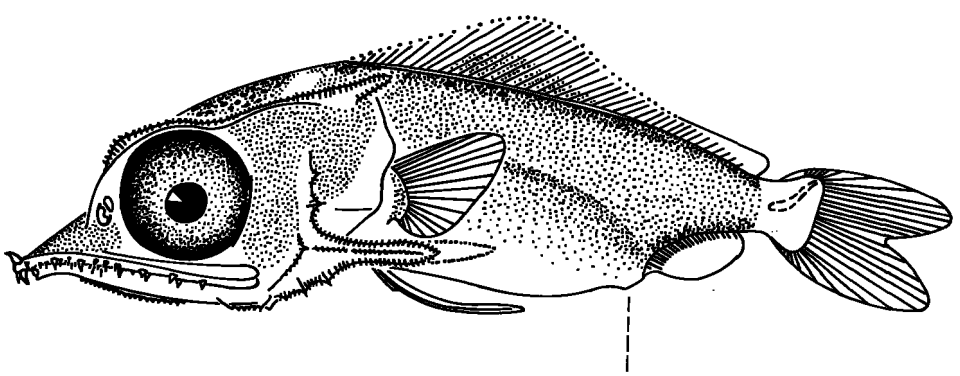

FIGURE 8.—Larva, 9.5 millimeters long (USNM 111814).

approximately the 25th ray); the anal fin has 22 rays; the pectoral fin is quite angular; and the pelvic fins have elongated. Pigment is present on lower middle portion of the dorsal fin.

SAILFISH LARVA, 11.3 MILLIMETERS

(Fig. 9)

The snout has elongated, but there has been a corresponding elongation of the mandible, and the snout extension remains unchanged. The diameter of the eye is approximately one-quarter the head length (one-third on the previous specimens). The keel on the face of the preopercle is damaged so that no serrations are evident. The dorsal fin has 50 rays, the anal fin 22 rays, and the pectoral fin 18 rays (the full complement of rays has been reached in these 3 fins). The pelvic fins are slightly shorter on this specimen. A groove for the pelvic fins has appeared as an indentation of the belly.

SAILFISH LARVA, 14.6 MILLIMETERS

(Fig. 10)

There is marked elongation of the snout and extension beyond tip of mandible. The teeth are more numerous, with those on the lower jaw more closely set than those on the upper. There is a marked increase in height of dorsal fin, and the the anal fin has 23 rays. A 3-toothed (or 3-pronged) scale, arising from the pectoral girdle, is situated on each side of the body just below the tip of the pterotic spine. There is a general increase in density of pigment.

SAILFISH LARVA, 18.2 MILLIMETERS

(Fig. 11)

The snout is markedly produced (approximately one-half the head length) and extends two-fifths its length beyond the tip of the mandible. Teeth are more numerous. The eye diameter is approximately one-fifth the head length. There is a marked heightening in anterior portion of the dorsal fin and a change in shape, and pelvic fins have lengthened and a third ray has appeared (constituting the full complement). A second 3-toothed scale is found on each side of the body at the pectoral girdle. The caudal peduncle is proportionately more slender. Pigmentation extends over the entire anterior portion of the dorsal fin.

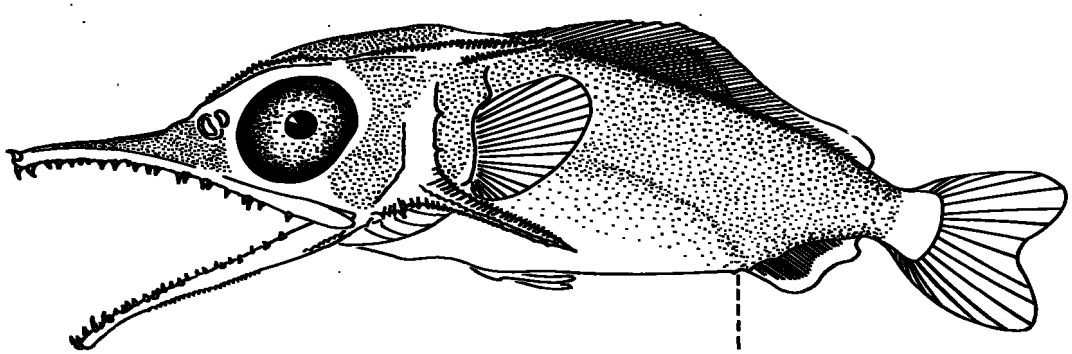

FIGURE 9.—Sailfish larva, 11.3 millimeters long (USNM 163333).

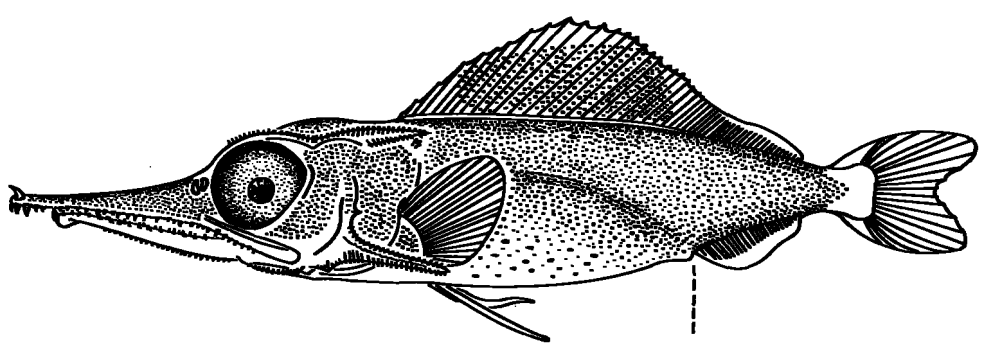

FIGURE 10.—Sailfish larva, 14.6 millimeters long. From *Theodore N. Gill* collections.

SAILFISH LARVA, 20.9 MILLIMETERS

(Fig. 12)

All rays in the dorsal and anal fins extend (for the first time) to fin margins, and the dorsal fin groove extends the entire length of the dorsal fin (previously approximately two-thirds the length of the fin).

SAILFISH LARVA, 27.4 MILLIMETERS

(Fig. 13)

The snout is three-fifths the head length. Fangs have disappeared from the snout tip. The eye diameter is approximately one-sixth the head length (previously one-fifth). A small pore is discernible on each side of the snout just anterior to the nostril. The dorsal fin has increased in height, and the anal fin is indented in central portion.

SAILFISH LARVA, 38.8 MILLIMETERS

(Fig. 14)

The snout extends for one-half its length beyond the tip of the mandible. Teeth are fewer in number in the part of the upper jaw extending beyond tip of mandible. Two pores are present on each side of the snout, one anterior to and one below each nostril. The dorsal fin is higher and more uneven in outline, and an anal fin groove has appeared (formed by a dermal flap on each side of fin). The lateral line is discernible for the first time. The pigmentation has developed into distinct patterns on the body and the dorsal fin.

SAILFISH LARVA, 56.2 MILLIMETERS

(Fig. 15)

The snout is markedly produced (three-quarters the head length) and extends for approximately

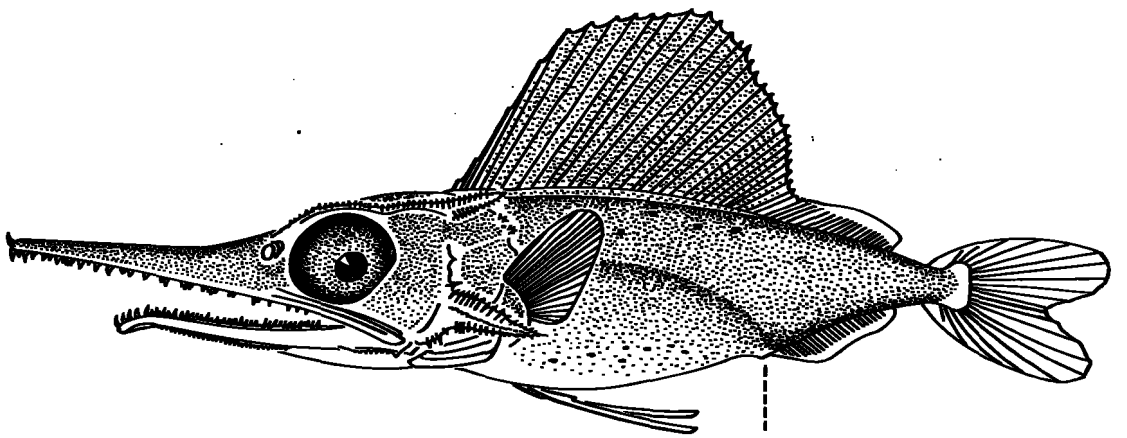

FIGURE 11.—Sailfish larva, 18.2 millimeters long. From *Theodore N. Gill* collections.

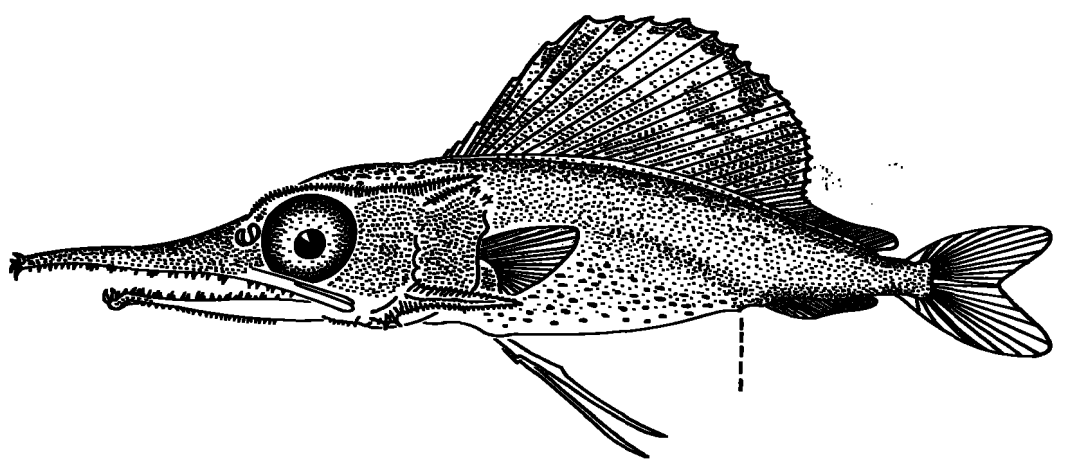

FIGURE 12.—Sailfish larva, 20.9 millimeters long. From *Theodore N. Gill* collections.

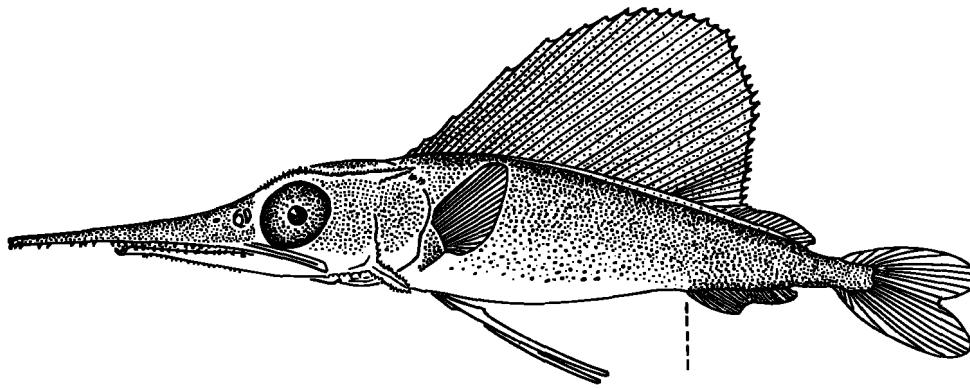

FIGURE 13.—Sailfish larva, 27.4 millimeters long. From *Theodore N. Gill* collections.

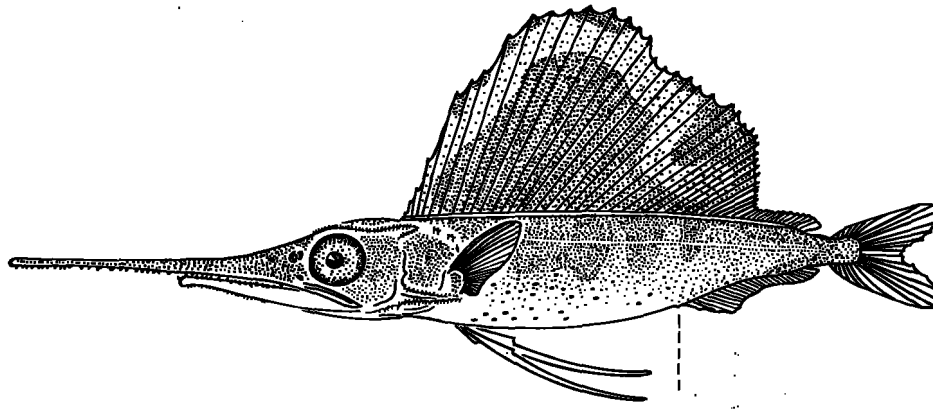

FIGURE 14.—Sailfish larva, 38.8 millimeters long. From *Theodore N. Gill* collections.

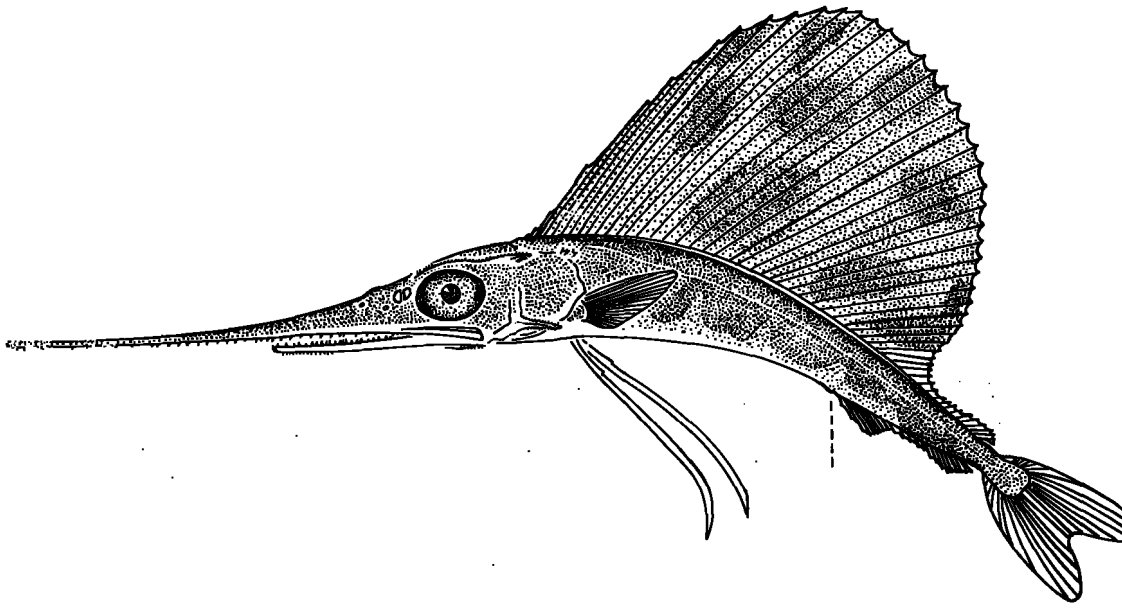

FIGURE 15.—Sailfish larva, 56.2 millimeters long (USNM 163413).

two-thirds of its length beyond the tip of the mandible. The margin of the preopercle is serrated, but no secondary preopercular spines are discernible. The eye diameter is one-tenth the head length. The body is slimmer. The dorsal fin is higher, the pectoral fin longer and more angular, the anal fin has a pronounced notch in its middle portion, and the pelvic fin has increased in length. Dermal spines are present over opercle, preopercle, and body except for the area covered by the pectoral fin (when depressed), but only the tips of the spines protrude through the skin (spines are discernible on a 43-mm. specimen). Dermal spines are fully described in discussion of 64.1-mm. specimen. Pattern of pigmentation on the body is more pronounced.

SAILFISH LARVA, 64.1 MILLIMETERS

(Figs. 16 and 17)

Teeth on the snout beyond mandible tip are weak and few in number, and palatine teeth are present in two patches on each side on upper jaw (one below the nostril and one near the mandible tip). The arrangement of teeth in the lower jaw and posterior portion of upper jaw is portrayed in figure 16. Several pores are present on the snout near the nostrils (fig. 16). The minute dermal spines present on the opercle, preopercle, and uniformly over the body arise from ill-defined plates. The spines are narrow-based, acutely tipped cones which protrude through the skin (fig. 17). The interspinous distance varies from one to two times the spine height.

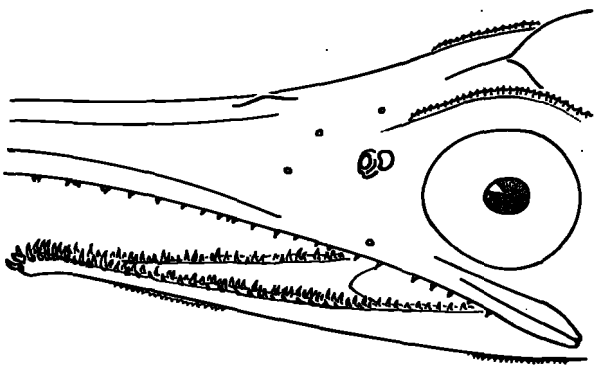

FIGURE 16.—Sailfish larva, 64.1 millimeters long (*Alaska* collections); view of head and teeth, orbital crest, small pores on snout, and serrations on lower jaw.

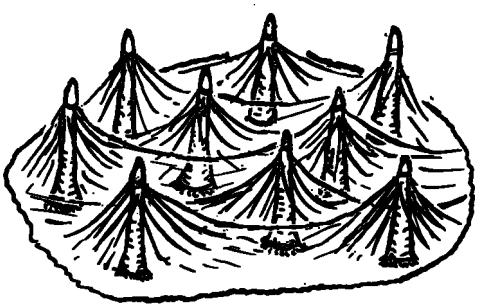

FIGURE 17.—Sailfish larva, 64.1 millimeters long (*Alaska* collections); oblique view of dermal spines, with tips of spines protruding through the skin.

SAILFISH LARVA, 101 MILLIMETERS

(Figs. 18 and 19)

Although the specimen is in poor condition and incomplete, many important characters remain. The snout is four-fifths the head length and extends for three-quarters its length beyond the tip of the mandible. Teeth are few in number in the portion of the upper jaw extending beyond the mandible tip. The serrated keels have disappeared from the lower jaw. (Although not shown in figure 18, serrations on the orbital crest

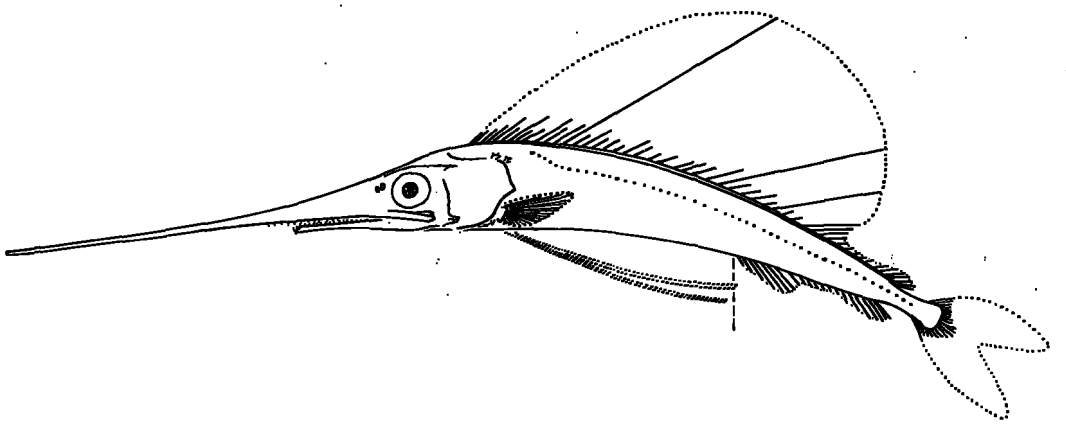

FIGURE 18.—Sailfish larva, 101 millimeters long (USNM 107200).

and pterotic and main preopercular spines remain distinct.) The dermal spines are long, slender, with a gradual taper, and arise from the centers of irregularly shaped (though generally rounded) plates which appear slightly superior to connective tissues. The plates (or bases) have 3 or 4 concentric raised ridges connected at random by numerous raised radials. The concentric ridges make a continuous spiral on some plates, but on others are entirely separate ridges (fig. 19).

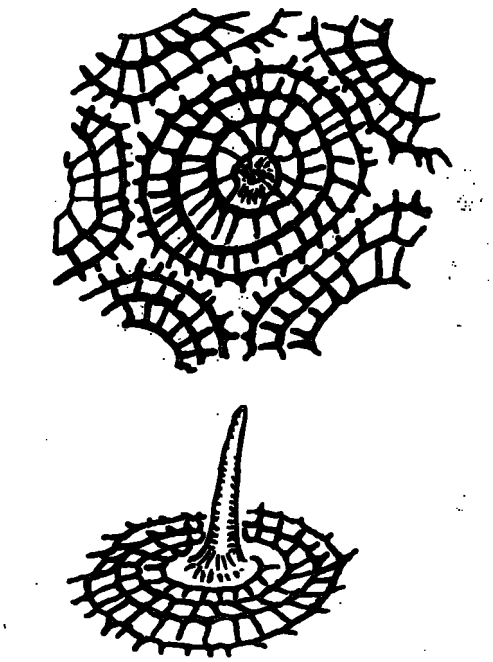

FIGURE 19.—Sailfish larva, 101 millimeters long (USNM 107200): Above, dorsal view of dermal scale; below, oblique view. Diameter of scale approximately 0.6 millimeter.

SAILFISH JUVENILE, 374 MILLIMETERS

(Fig. 20)

Observations are from a mounted specimen, and only those that appear accurate are presented (the first dorsal fin and the pelvic fins are artificial). There is no evidence of spines or serrated keels on the head. The only evidence of teeth are minute spines present mainly on the ventral surface of the snout in the portion extending beyond the tip of the mandible. The caudal fin lobes are long and falcate, and the anal fin is separated.

GROWTH AND DEVELOPMENT

CHANGES IN RATES OF GROWTH OF VARIOUS BODY PARTS

Several of the numerous measurements and meristic counts taken from the 168 specimens examined were selected to portray changes in rates of growth of various body parts. Original measurements were used in establishing the curves appearing in figures 26 to 35. As the graphs are largely self-explanatory, only the salient points are summarized. The curves are drawn to include all specimens less than 10 mm. in standard length, but only the Atlantic sailfish beyond 10 mm. It was considered that insufficient data were available to fit curves for the unidentified species. The following comments apply only to the Atlantic sailfish.

The rate of increase in head length approximates that of the standard length, with indications of a slightly higher rate in specimens smaller than 10 mm. (fig. 26).

The rate of increase in head width approximates that of the standard length in specimens smaller than 10 mm. and falls well below it in specimens between 10 and 100 mm. (The high value for the 101-mm. specimen has been disregarded in drawing the curve, fig. 27.)

The rate of increase in head depth approximates that of the standard length in specimens smaller than 10 mm., decreases and falls below it in specimens between 10 and 40 mm., and increases to approximate it in specimens exceeding 40 mm. (fig. 28).

The rate of increase in snout length exceeds, considerably, that of the standard length in specimens smaller than 10 mm., decreases somewhat (but still exceeds the standard length rate) in specimens between 10 and 100 mm., and falls slightly below it in specimens exceeding 100 mm. (fig. 29).

The rate of increase in lower jaw length exceeds that of the standard length in specimens smaller than 10 mm., decreases and falls below it in specimens between 10 and 100 mm., and increases to approximate it in specimens exceeding 100 mm. (fig. 30).

FIGURE 20.—Young sailfish, 374 millimeters long. (Mounted specimen.) Captured in surf at Myrtle Beach, S. C., by hand, Aug. 3, 1952, by Robert M. and John Yount.

The rate of increase in snout extension is constant and much higher than that of the standard length in specimens smaller than 50 mm., decreases gradually in specimens larger than 50 mm., so that it falls below that of the standard length in specimens exceeding 100 mm. (fig. 31).

The rate of increase in eye diameter exceeds that of the standard length in specimens smaller than 10 mm., decreases to considerably less than it in specimens between 10 and 100 mm., and increases (but remains slightly below it) in specimens exceeding 100 mm. (fig. 32).

The rate of increase in pterotic spine length is initially much higher than that of the standard length, but decreases sharply, and spine growth has ceased in specimens approximately 7 mm long (fig. 33).

The rate of increase in the main preopercular spine length is initially much higher than that of the standard length, but decreases sharply, and spine growth has ceased in specimens approximately 10 mm. long (fig. 33).

The rate of increase in pelvic fin length exceeds, considerably, that of the standard length in specimens smaller than 10 mm., but decreased gradually in specimens between 10 and 20 mm., after which it approximates the standard length rate (fig. 34).

The rate of increase in length of the longest dorsal ray (13th or 15th) exceeds that of the

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standard length in specimens between 10 and 20 mm., but decreases in specimens between 20 and 40 mm., after which it approximates the standard length rate (fig. 35).

DIVERGENCE IN MEASUREMENTS OF BODY PARTS FOR UNIDENTIFIED SPECIES

The length of the snout shows the greatest divergence, which is evident at a smaller size than are other divergent characters. Since the snout length is reflected in the standard length, several graphs were constructed using "standard length minus snout length" as a base for comparison. The "weight" of snout length was thus removed from the base, and comparison of fish with similar body lengths was possible. The divergence in snout length (fig. 36), length of lower jaw (fig. 37), and snout extension (fig. 38), is more clearly defined than in plots against standard length (figs. 29, 30, and 31). When the eye diameter is plotted against snout length, the result is substantially the same: divergence first evident at a standard length of approximately 10 mm. (fig. 39).

Measurements of head depth, head width, and eye diameter, when plotted against "standard length minus snout length," revealed no marked divergence, at least below 20 mm. Values for the unidentified species plot either just above or among the higher values for the sailfish (also noticed in the plots of these values against standard length, figs. 28, 27, and 32).

FIGURE 21.—Sailfish, juvenile 437 millimeters long, "20 inches total length, 437 mm. standard length; taken 3 miles off Aransas Pass, Texas, Aug. 31, 1941, by Aubrey Nelson." (Photograph courtesy of William Beebe.)

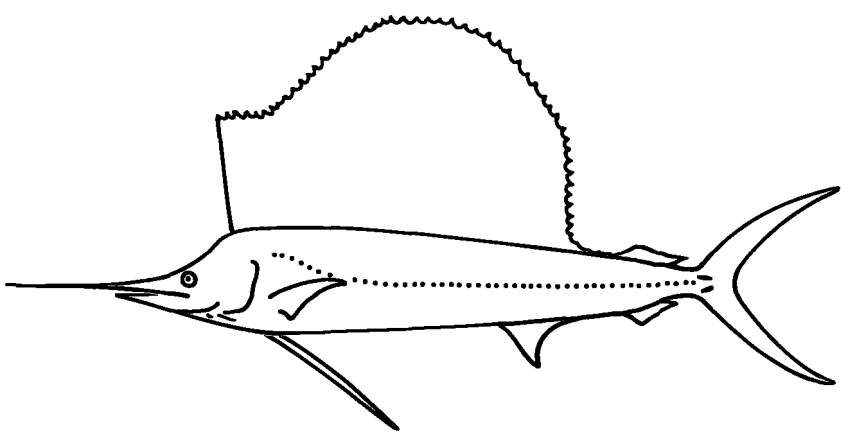

FIGURE 22.—General shape and proportions of adult sailfish.

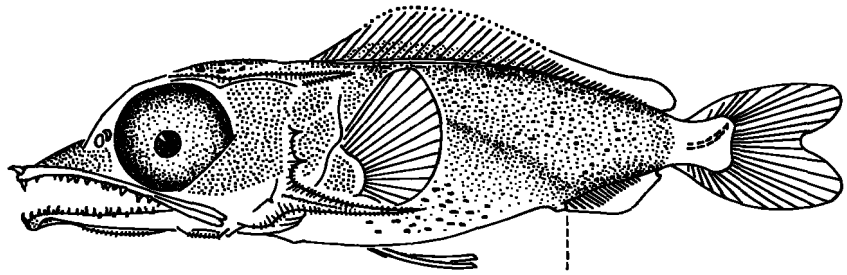

FIGURE 23.—Unidentified species of larva, 11.3 millimeters long. *Theodore N. Gill* collections.

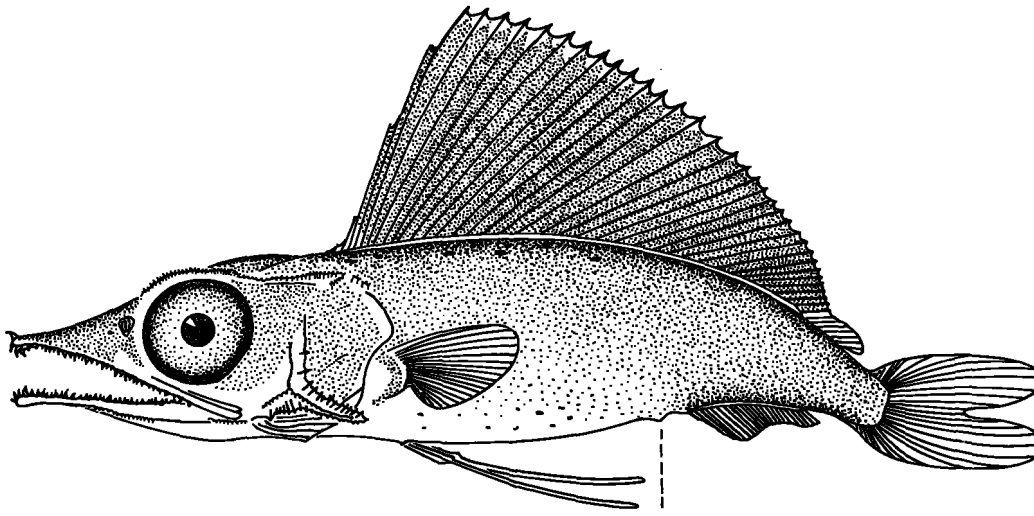

FIGURE 24.—Unidentified species of larva, 21.0 millimeters long, *Theodore N. Gill* collections.

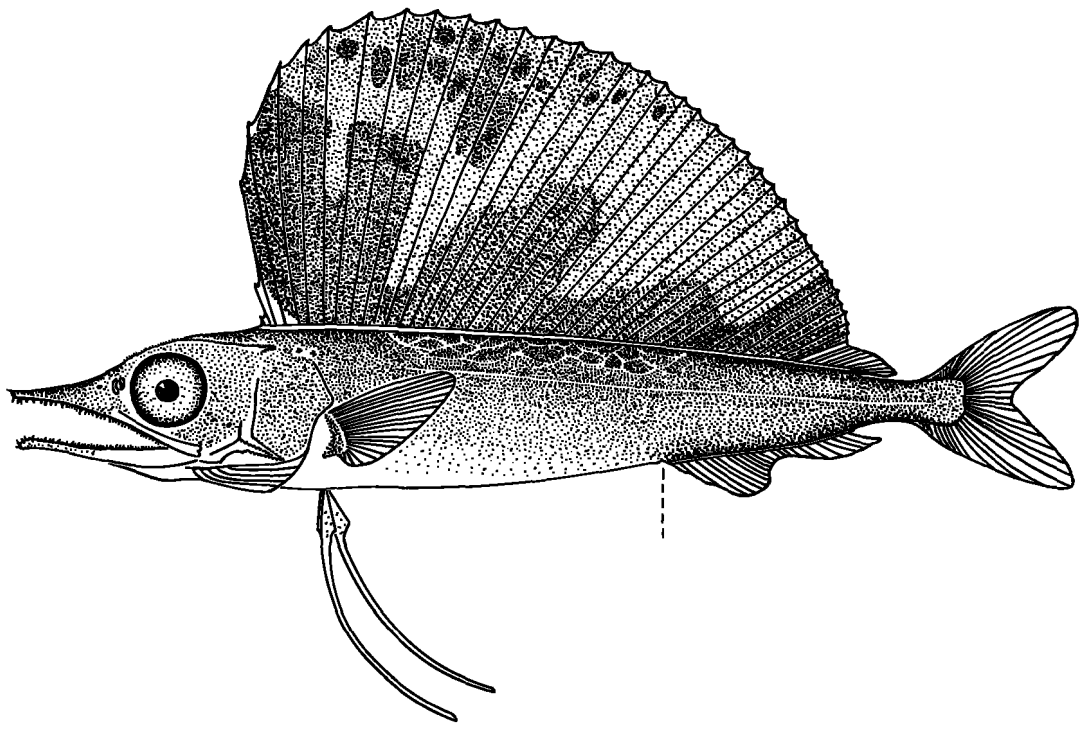

FIGURE 25.—Unidentified species of larva, 45.0 millimeters long, *Theodore N. Gill* collections.

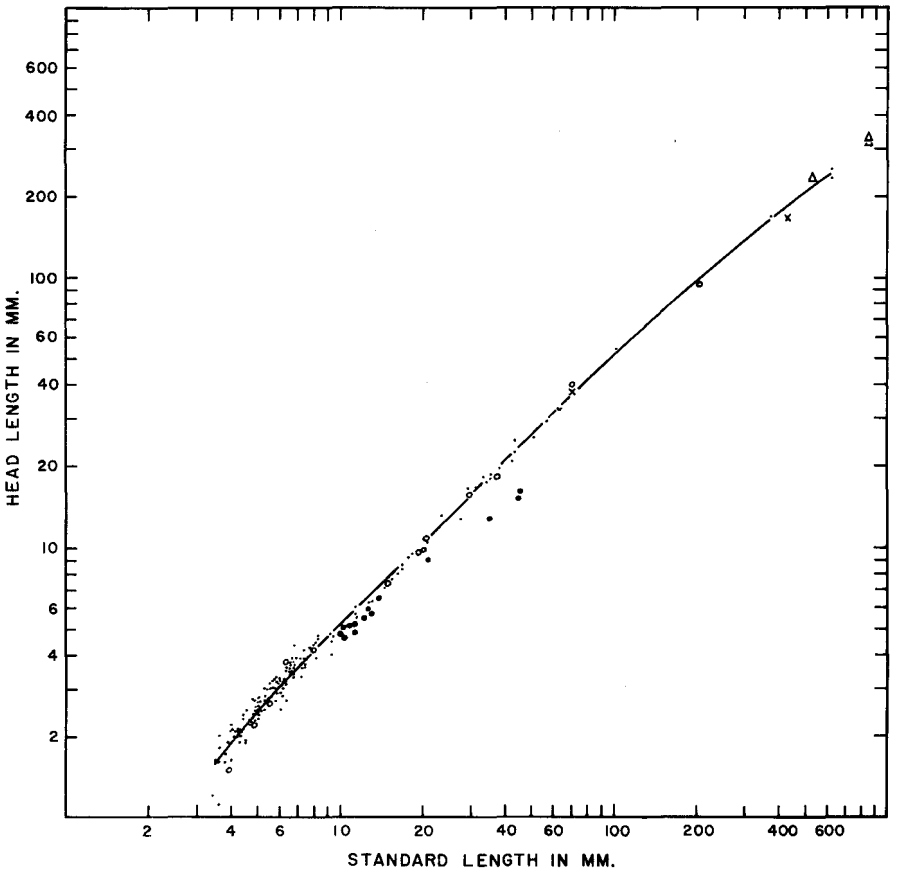

FIGURE 26.—Relation of head length to standard length. Dots represent study specimens; *x*'s, Beebe's specimens; circles, Voss's specimens; triangles, Baughman's specimens; and large black dots, the unindentified species.

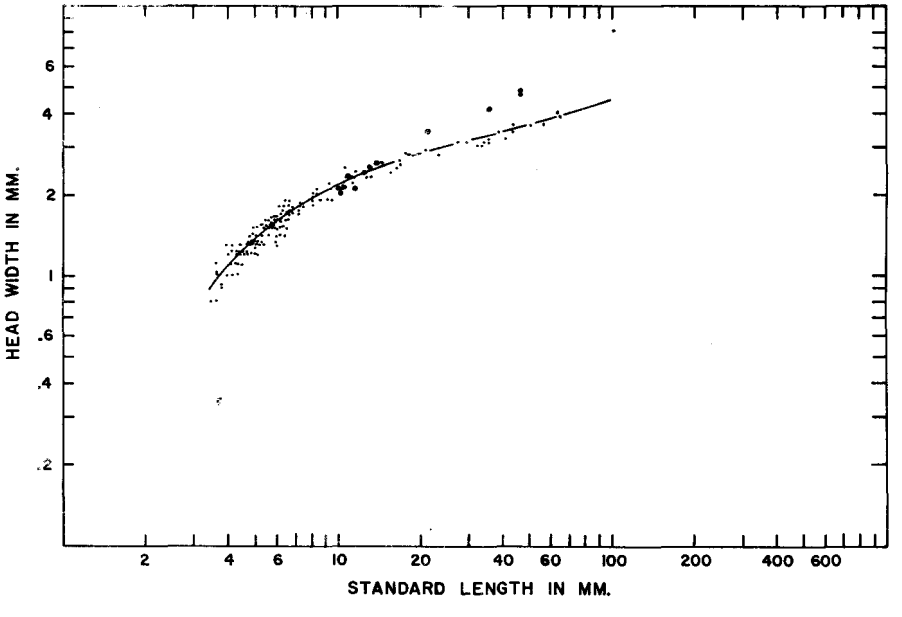

FIGURE 27.—Relation of head width to standard length. Large black dots represent the unidentified species.

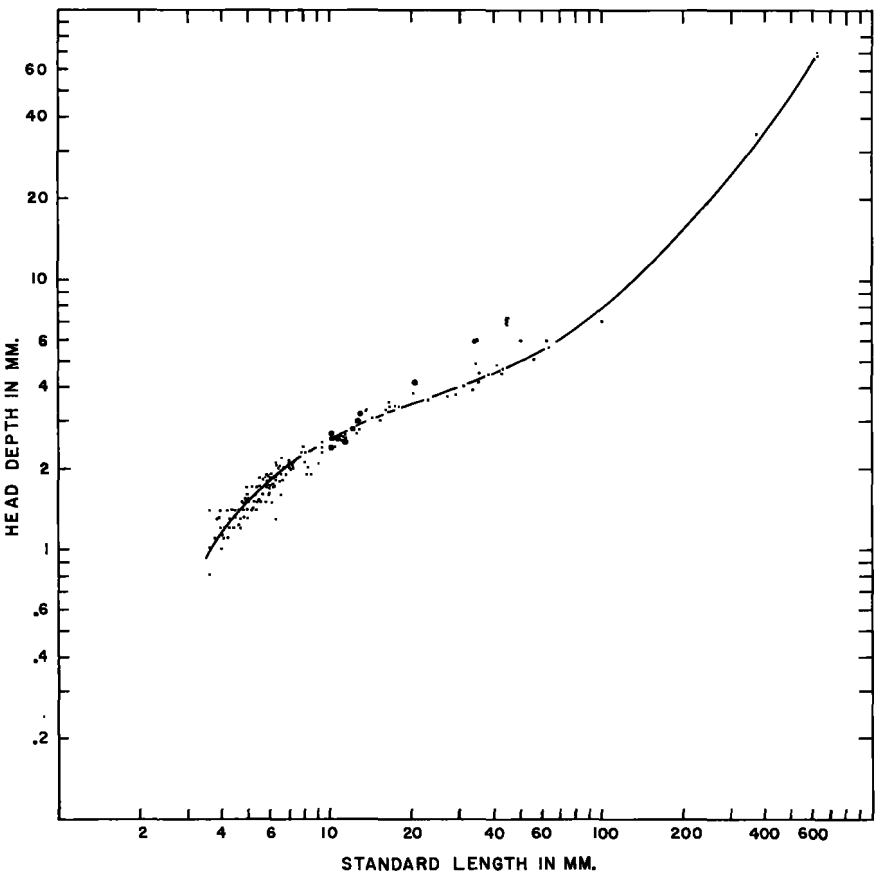

FIGURE 28.—Relation of head depth to standard length. Large black dots represent the unidentified species.

DEVELOPMENT OF FIN RAYS

Tables 4, 5, and 6 show the numbers of rays in the dorsal, anal, and pectoral fins of specimens of different sizes. Counts listed include both the Atlantic sailfish and the unidentified species. The following discussion of the numbers of rays in the fins applies only to the Atlantic sailfish for specimens exceeding 10 mm. Specimens below 10 mm. include both the Atlantic sailfish and the unidentified species.

The number of rays in the dorsal fin of specimens which exceeded 10 mm. in length ranged from 47 to 57 (table 4). In those exceeding 26 mm. in length the full complement of rays is present, and the number ranged from 49 to 57, with 75 percent having 49 to 53. The smallest specimen with a complement of 49 rays or more is 11.3 mm. in length, and the largest with fewer than this number is 16.2 mm.

TABLE 4.—*Distribution of specimens by length and by number of rays in the dorsal fin*

Length	Number of specimens with ray count of—															
	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
10.0–13.9 mm	[1]1	[1]3	[1]2	[1]2	[1]1	1	0	0	3	0	0	0	0	0	0	0
14.0–17.9 mm	0	0	0	0	0	1	0	1	1	1	2	0	0	0	0	0
18.0–21.9 mm	0	0	[1]1	0	0	0	0	1	0	0	1	0	0	0	0	0
22.0–25.9 mm	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
26.0–101 mm	0	0	0	0	0	0	0	1([1]2)	3	5	[1]1	3	1	1	[2]1	1
Total	[1]1	[1]3	[1]3	[1]2	[1]1	3	0	3([1]2)	7	6	3([1]1)	3	1	1	1	1

[1] Unidentified specimens.

[2] Specimen from Beebe (1941).

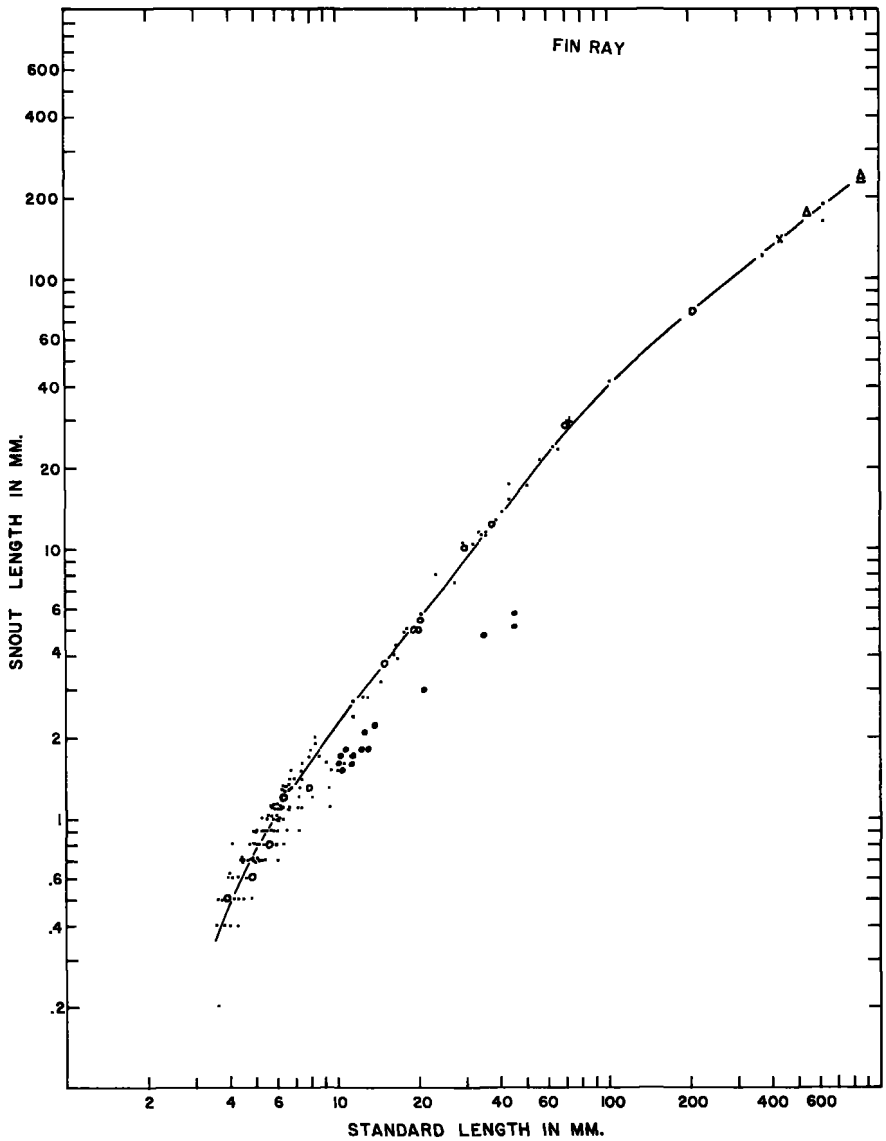

FIGURE 29.—Relation of snout length to standard length. Dots represent study specimens; x's, Beebe's specimens; circles, Voss's specimens; triangles, Baughman's specimens; and large black dots, the unidentified species.

The number of rays in the anal fin of specimens between 6.0 and 9.9 mm. ranged from 20 to 22 (table 5). In sailfish specimens between 10 and 25.9 mm. the number ranged from 20 to 23. In specimens between 26 and 101 mm. the number ranged from 24 to 28 (excluding the 101-mm. specimen with a damaged anal fin which has 20 recognizable rays), with 92 percent having 24 to 26. I consider that the break at the 26-mm. size results from an inadequate sample. The smallest specimen with a complement of 22 or more rays is 9.5 mm., and the largest with fewer than this number (excluding the 101-mm. specimen mentioned above) is 23.3 mm.

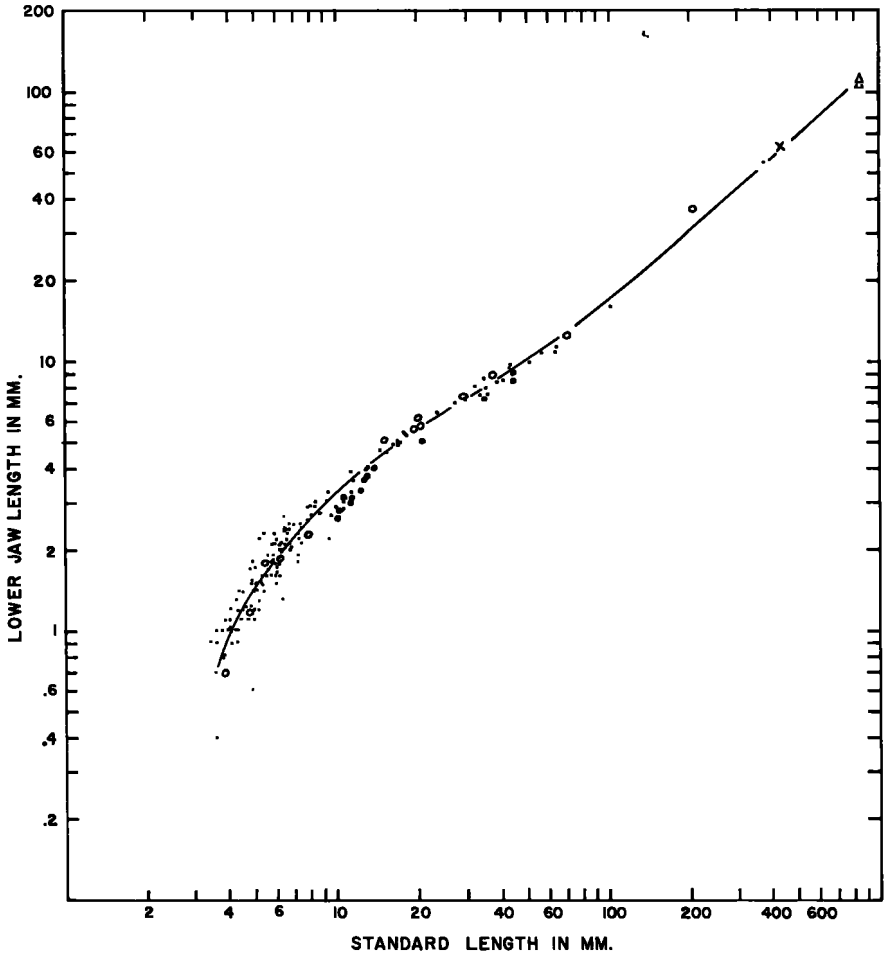

FIGURE 30.—Relation of lower jaw length to standard length. Dots represent study specimens; *x*, Beebe's specimen; circles, Voss's specimens; triangles, Baughman's specimens; and large black dots, the unidentified species.

TABLE 5.—*Distribution of specimens by length and by number of rays in the anal fin*

Length	Number of specimens with ray count of—												
	16	17	18	19	20	21	22	23	24	25	26	27	28
6.0–9.9 mm	0	0	0	0	2	0	1	0	0	0	0	0	0
10.0–13.9 mm	[1] 4	0	[1] 2	[1] 1	1([1] 2)	2	1	1([1] 1)	0	0	0	0	0
14.0–17.9 mm	0	0	0	0	0	1	1	3	0	0	0	0	0
18.0–21.9 mm	0	0	0	0	1	0	1	[1] 1	0	0	0	0	0
22.0–25.9 mm	0	0	0	0	0	1	0	0	0	0	0	0	0
26.0–101 mm	0	0	0	0	1	0	[1] 1	0	9([1] 1)	2([1] 1)	1	0	1
Total	[1] 4	0	[1] 2	[1] 1	5([1] 2)	4	4([1] 1)	4([1] 2)	9([1] 1)	2([1] 1)	1	0	1

[1] Unidentified specimens.

The number of rays in the pectoral fin of specimens between 6.0 and 9.9 mm. ranged from 16 to 18 (table 6). Sailfish exceeding 10 mm. in length had complements ranging from 16 rays to 20. In specimens exceeding 26 mm., the number ranged from 18 to 20, with 82 percent having 18 rays. The smallest specimen with a complement of 18 rays or more is 7.9 mm. in length, and the largest with fewer than this number is 23.3 mm.

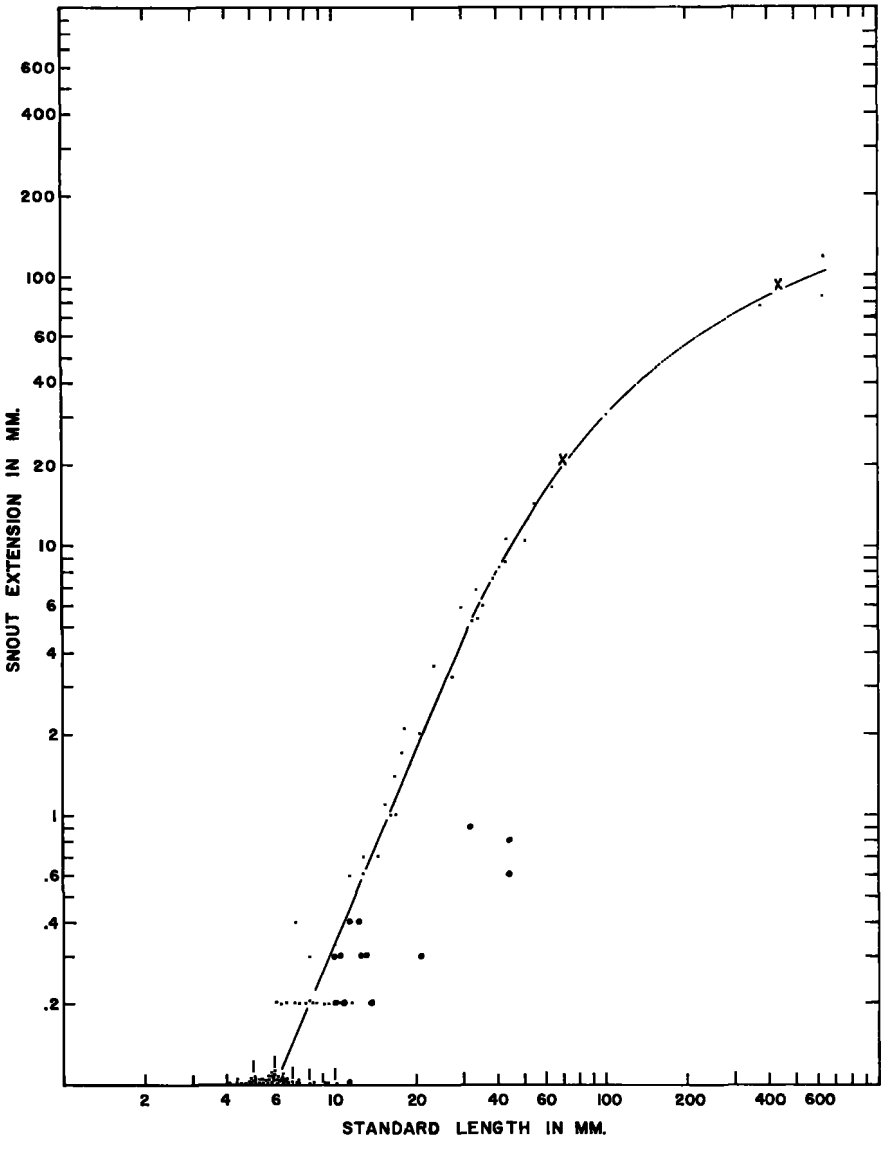

FIGURE 31.—Relation of snout extension to standard length. Dots represent study specimens; *x*'s, Beebe's specimens; and large black dots, the unidentified species.

TABLE 6.—*Distribution of specimens by length and by number of rays in the pectoral fin*

Length	Number of specimens with ray count of—								
	14	15	16	17	18	19	20	21	22
6.0–9.9 mm	0	0	8	0	2	0	0	0	0
10.0–13.9 mm	[1]1	0	3([1]2)	[1]1	2([1]4)	[1]1	1([1]1)	0	0
14.0–17.9 mm	0	0	2	1	2	1	0	0	0
18.0–21.9 mm	0	0	0	1	1	0	[1]1	0	0
22.0–25.9 mm	0	0	1	0	0	0	0	0	0
26.0–101 mm	0	0	0	0	14([1]1)	[2]1	2([1]1)	0	[1]1
Total	[1]1	0	14([1]2)	2([1]1)	21([1]5)	2([1]1)	3([1]3)	0	[1]1

[1] Unidentified specimens.
[2] Specimen from Beebe (1941).

SECONDARY PREOPERCULAR SPINES

The numbers of upper and lower secondary preopercular spines, in ratios (for specimens with recognizable spines) are shown in table 7. A pattern (herein called ratio, upper:lower) prevails in the number of upper and lower spines for size groups, although considerable overlap of ratios is found. Of primary interest is the size at which the 2:1 ratio (apparently the height of normal spine development) occurs. Although several specimens smaller than 5.5 mm. have a 2:1 ratio, this ratio does not become dominant until a speci-

men size of approximately 6.5 mm. Specimens exceeding 10 mm. have considerable variation, and on specimens exceeding 40 mm. the spines are difficult to discern.

Until such time as identification of specimens less than 10 mm. to species is accomplished, the pattern must be presented as representing one group.

TABLE 7.—*Distribution of specimens by length and by ratios of secondary preopercular spines*

Standard length	Number of specimens with spine ratio (upper:lower) of—			
	1:0	1:1	2:1	Other [1]
3.4 mm	1			
3.5 mm				
3.6 mm	3			
3.7 mm				
3.8 mm	2			
3.9 mm	1			
4.0 mm	3			
4.1 mm	2	1		
4.2 mm	1			
4.3 mm	5			
4.4 mm	1	2		
4.5 mm	1	1		
4.6 mm				
4.7 mm	3			
4.8 mm	2		1	
4.9 mm	2	3		
5.0 mm	3		3	
5.1 mm	1			1 (2:0)
5.2 mm			1	
5.3 mm	1	2		
5.4 mm		1	2	
5.5 mm			2	
5.6 mm		1	1	
5.7 mm			2	
5.8 mm		1	4	
5.9 mm		2	2	1 (2:0)
6.0 mm	1		2	1 (2:0)
6.1 mm		1	1	
6.2 mm		2	1	
6.3 mm			2	
6.4 mm		2	2	
6.5 mm			1	
6.6 mm			2	
6.7 mm		1	3	1 (2:2)
6.8 mm			1	
6.9 mm			1	
7.0 mm				
7.2 mm			3	
7.3 mm			1	1 (2:0)
7.4 mm		1	2	
7.9 mm			1	
8.0 mm			1	
8.1 mm			3	
8.3 mm				1 (2:2) 1 (3:1)
8.6 mm			1	
9.2 mm			1	
9.4 mm			1	1 (2:3)
9.5 mm			1	
10.1 mm			[2] 2	
10.3 mm			[2] 2	
10.6 mm			1	
10.8 mm				[2] 1 (2:2)
11.3 mm			[2] 2	1 (2:2)
11.4 mm			[2] 1	
11.5 mm			1	
12.3 mm				[2] 1 (2:3)
12.8 mm			1	[2] 1 (2:2)
13.0 mm			[2] 2	
13.9 mm				[2] 1 (3:2)
14.6 mm		1		
16.2 mm			1	
16.9 mm			1	1 (2:2)
17.8 mm			1	
18.2 mm				1 (2:2)
20.9 mm				1 (2:2)
23.3 mm				1 (3:1)
29.5 mm				1 (3:3)
32.4 mm			1	
43.4 mm			1	
43.7 mm				1 (2:2)

[1] Ratio shown in parentheses. [2] Unidentified specimens.

PTEROTIC SPINE SERRATIONS

The number of serrations on the dorsomedial and ventral keels of the pterotic spine ranges from 10 to 20, with but few exceptions, throughout the size range of specimens examined. The number of serrations on the dorsolateral keel increases from a range of 18–25 on 4-mm. specimens. to 24–42 on 10-mm. specimens, to 28–44 on 25-mm, specimens, and holds relatively stable between 44 and 49 on larger specimens.[1]

We should expect less variation in number of serrations on keels of specimens exceeding 10 mm. in length, since growth of pterotic spines ceases when specimens are approximately 7 mm. in length (fig. 33).

TEETH

The number of teeth in relation to specimen size is shown in figure 40. For the sizes shown, there is an increase in number of teeth with an increase in specimen size; and the range is narrower in the smaller specimens than in the larger ones (many teeth of all sizes in larger specimens, but only a few well-developed ones in the smaller ones). Teeth were present in all specimens examined, but the 101-mm. specimen was badly damaged, and an accurate count could not be made. The remaining teeth of this specimen were not so large, relatively, as those of smaller specimens. Counts of 102 and 110 for one-half the upper jaw of the 45.0-mm. specimens of the unidentified species exceed those for Atlantic sailfish specimens to 64 mm.

DEVELOPMENT OF PIGMENTATION

Observations on the development of pigment include all specimens below 10 mm. in length, and only the Atlantic sailfish specimens above 10 mm. Notes on variations from this pattern of development in the unidentified species follow the observations on the Atlantic sailfish.

There are a few large melanophores on the dorsal surface of the brain case of the 3.4-mm. specimen. There is a gradual increase in the pigmentation (consisting of small chromatophores) extending to the dorsal surfaces of the snout and the body on specimens approximately 4 mm. long, down the sides of the head and body posteriorly to the anus at approximately 5 mm., and to the

[1] Specimens of unidentified species 45.0 mm. long had counts of 37 and 50. Otherwise, all counts for the species fell within those for Atlantic sailfish.

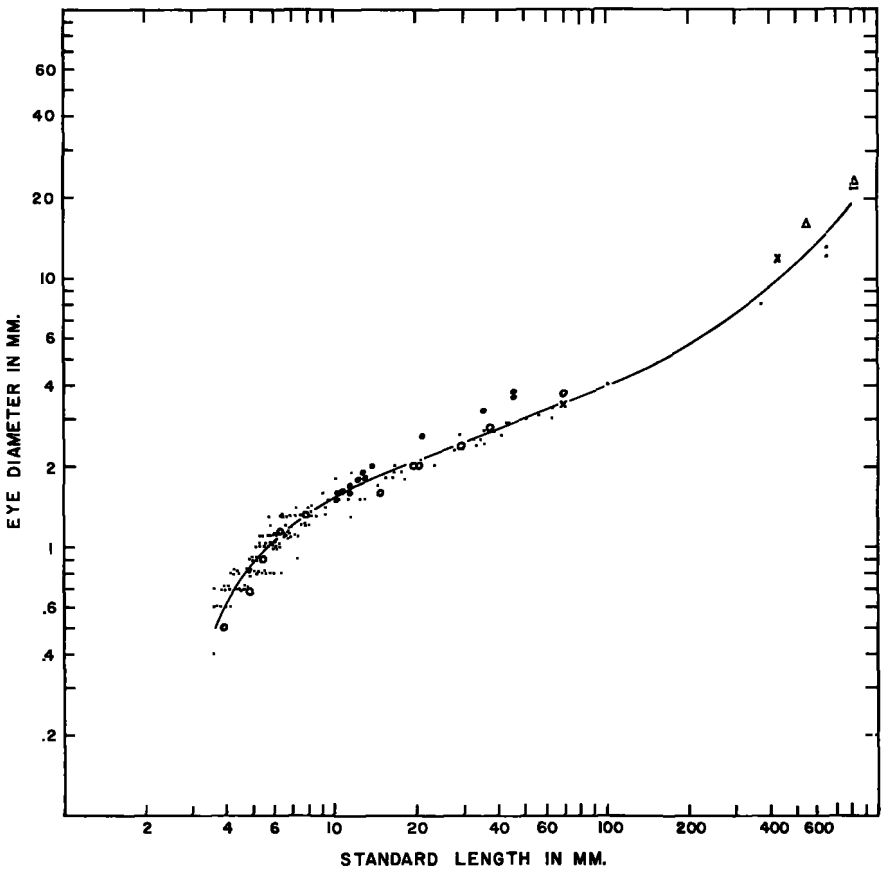

FIGURE 32.—Relation of eye diameter to standard length. Dots represent study specimens; x's, Beebe's specimens; circles, Voss's specimens; triangles, Baughman's specimens; and large black dots, the unidentified species.

caudal fin, with increasing density, at approximately 10 mm. The preopercle and opercle are less densely pigmented than the dorsal part of the snout or body at any particular size. At the 6-mm. size, scattered melanophores appear in the pattern of chromatophores over the dorsal surface of the body. In specimens smaller than 10 mm., the dorsal surface of the brain case is pigmented by scattered melanophores.

In specimens exceeding 10 mm., the pigmentation changes little except for a gradual increase in density. Generally it is as follows: Upper jaw and sides of head, blue-black; mandible, nonpigmented; eye, silver with black pupil; upper body, dark blue to black; and lower sides of body anterior to the anus and caudal, blue. The belly is a silvery white, fins are usually translucent (except for the dorsal), and spines are nonpigmented. Pigmentation on the dorsal fin develops from a scattering of chromatophores on the lower central portion at approximately 10 mm. to generally dense areas (with scattered less dense areas) at approximately 20 mm. Tips of dorsal fin rays are nonpigmented, and pigment on the dorsal fin extends posteriorly to approximately the 35th ray. Bars (or blotches) of chromatophores appear on the body at approximately 35 mm. and persist through the size range of specimens examined.

Color notes on fresh specimens (15–20 mm. in standard length) are as follows: Dorsal surface of head and body, steel-blue; sides of head and upper opercles, blue-black; eye, silver-white with a blue tinge and black pupil; ventral sides of body from anus posterior, blue; anal and pectoral fins, hyaline; caudal fin, translucent white; dorsal fin anterior portion generally blue-black with yellow and white streaks on rays, and posterior portion, hyaline; and ventral fins are tinged with yellow.

The principal variations from this pattern of development in the unidentified species are as follows: (1) In general, the pigment on the dorsal

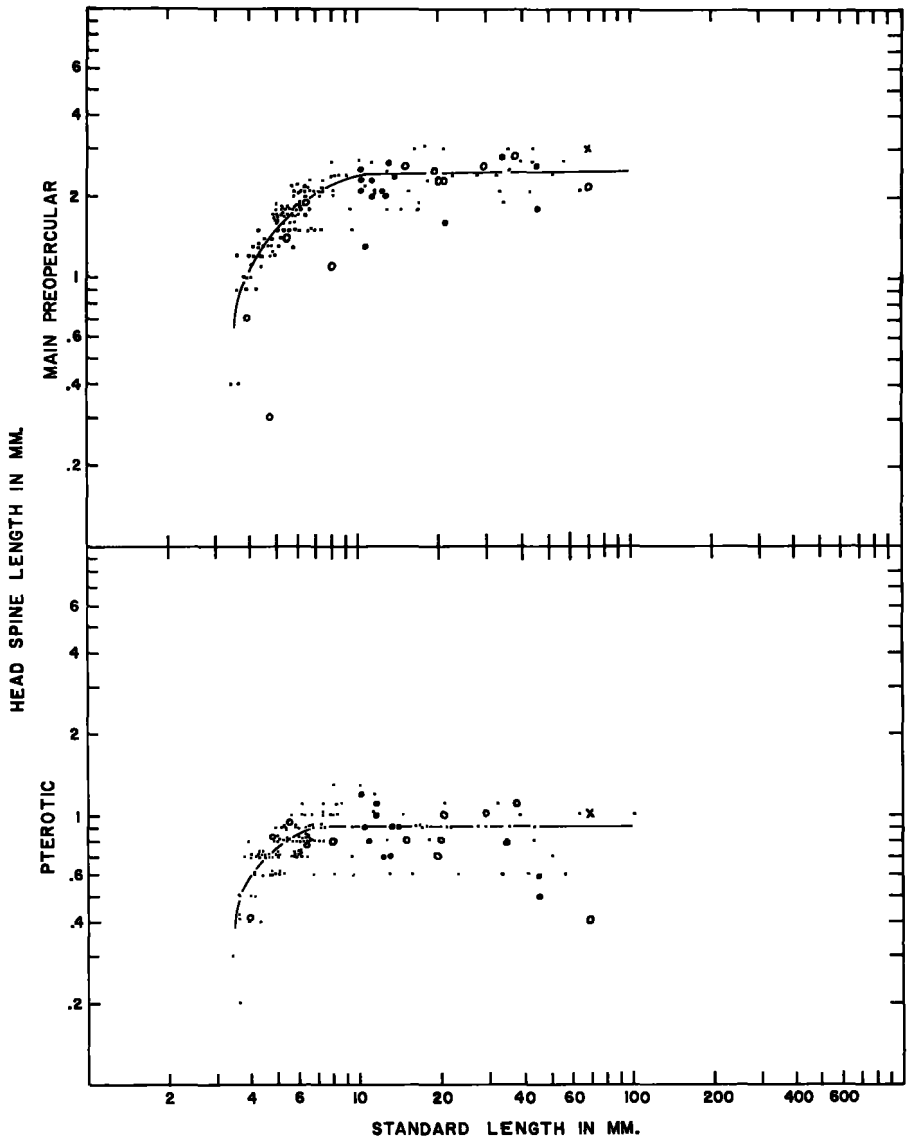

FIGURE 33.—Relation of head-spine lengths to standard length. Dots represent study specimens; x, Beebe's specimen; circles, Voss's specimens; and large black dots, the unidentified species.

fin is present farther posteriorly than on the sailfish, and (2) there are no dark bars or blotches on the sides of the body, as are present on sailfish exceeding approximately 35 mm. in standard length. Color notes on live 35–45 mm. specimens of the unidentified species do not vary noticeably from those given above for the Atlantic sailfish.

SUMMARY OF GENERAL GROWTH AND DEVELOPMENT OF THE ATLANTIC SAILFISH [2]

1. From 3.4 to 7 mm., head spination develops rapidly, and the pterotic spine growth ceases at approximately 7 mm.

2. From 7 to 10 mm., head spination reaches its maximum and no further development occurs, the snout begins to elongate, and rays begin to appear in the fins.

3. From 10 to 20 mm., the snout elongates farther and the snout extension increases, and the dorsal, anal, pelvic, and pectoral fins develop their full complement of rays.

4. From 20 to 50 mm., the snout elongates and snout extension increases, the dorsal, anal, pec-

[2] Points 1 and 2 are summaries of development of all specimens below 10 mm., since no separation to species was made below this size.

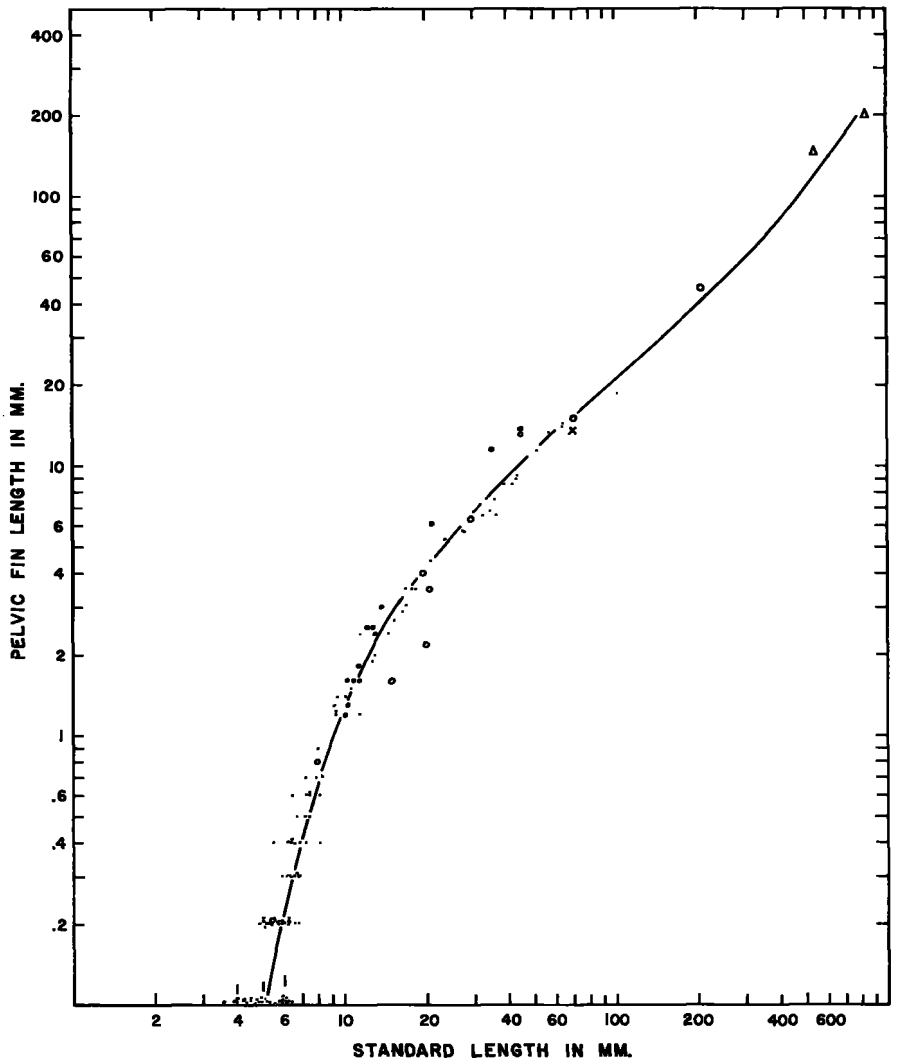

FIGURE 34.—Relation of pelvic fin length to standard length. Dots represent study specimens; x, Beebe's specimen; circles, Voss's specimens; triangles, Baughman's specimens; and large black dots, the unidentified species.

toral, and pelvic fins develop in size and shape, and dermal spines appear.

5. From 50 to 100 mm., the snout elongates farther, but the snout extension stabilizes, the dorsal and anal fins further develop in size, shape, and progress toward their eventual division, and dermal spines develop further.

On the basis of the foregoing observations on growth and development, I have divided the specimens less than 100 mm. in length into three categories.

The size range below 7 mm. has been designated "early larval," that period during which the head spines are developing (by 7 mm. all except the pterotic spine have ceased growing), and finfolds have little differentiation of rays.

The size range from 7 to 20 mm. has been designated "midlarval," that period during which all spine development ceases (at approximately 10 mm.), fins receive their full complement of rays and undergo changes in size and shape, and the snout begins to elongate.

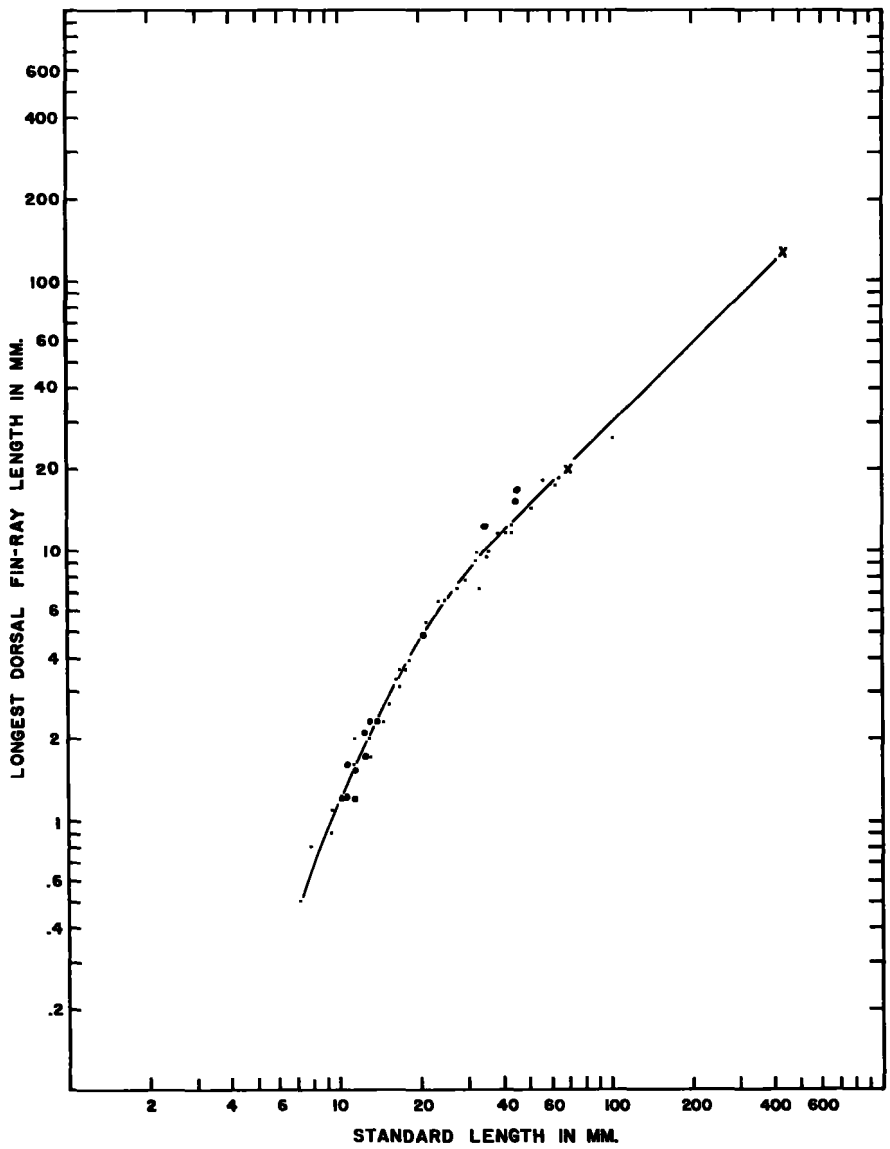

FIGURE 35.—Relation of length of longest dorsal fin-ray to standard length. Dots represent study specimens; x's, Beebe's specimens; and large black dots, the unidentified species.

The size range between 20 and 100 mm. has been designated "late larval," that period during which head spines begin to disappear (although pterotic and main preopercular spines persist at 101 mm.), fins undergo other changes in size and shape (toward eventual division in dorsal and anal fins), dermal spines develop, and jaw teeth begin to disappear. While juvenile characters are developing within this range, it is my opinion that the important larval characters which persist preclude the use of the term "juvenile" for specimens below 100 mm.

SUMMARY COMPARISON OF ATLANTIC SAILFISH WITH UNIDENTIFIED SPECIES

A summary of the principal differences between specimens of the Atlantic sailfish and the unidentified species at comparable sizes is outlined in table 8.

TABLE 8.—*Comparison of certain characters from selected specimens of the Atlantic sailfish and the unidentified species*

Character	Atlantic sailfish	Unidentified species
Size	11.3 mm.	11.3 mm.
Snout length	4/5 length of head.	1/3 length of head.
Number of fin rays:		
Dorsal	50.	42.
Anal	22.	16.
Pectoral	18.	14.
Size	20.9 mm.	21.0 mm.
Snout length	1/2 length of head.	1/3 length of head.
Snout extension	1/3 length of snout.	1/10 length of snout.
Mandibular keels	Noticeably serrate.	Minutely serrate.
Number of fin rays:		
Dorsal	49.	44.
Anal	23.	23.
Pectoral	17.	20.
Longest dorsal fin ray	Number 13 to 15.	Number 5.
Dorsal fin, anterior lobe	Terminates at about the 25th ray.	Terminates at about the 37th ray.
Dorsal fin, pigment	Extends posteriorly to 25th ray.	Extends posteriorly to 37th ray.
Pelvic fin rays	Third is twice length of first.	First and third equal in length.
Size	38.8–56.2 mm.	45.0 mm.
Snout length	3/5 to 3/4 length of head.	1/3 length of head.
Snout extension	1/2 to 2/3 length of snout.	1/7 length of snout.
Mandibular keels	Present (minutely serrate).	Absent.
Number of fin rays:		
Dorsal	51–53.	49.
Anal	24.	24.
Pectoral	18–20.	18.
Longest dorsal fin ray	Number 13 to 15.	Number 13.
Dorsal fin, anterior lobe	Terminates at about the 40th ray.	Terminates at about the 40th ray.
Dorsal fin, pigment	Extends posteriorly to 33–37th ray.	Extends posteriorly to the 40th ray.
Pelvic fin rays	Third is twice length of first.	Third and first equal in length.
Body pigment	Distinct barred or blotched pattern.	No bars or blotches.
Dermal spines	Discernible at 43 mm. as spines which protrude slightly through skin, uniformly distributed over body.	Distinct spines arising from individual base plates, uniformly distributed except for irregularly sized patches on body above lateral line (skin has worm track appearance). (Dermal spines resemble those in Beebe, 1941, text figure 2 for *Istiophorus greyi* Jordan & Hill—84 mm.)

FOOD HABITS

Prior to Beebe's report (1941) that copepods are the primary food of small sailfish, and Voss's observations (1953) on the food of postlarval and juvenile sailfish, little is found on the subject in the literature. The stomachs of 32 istiophorid specimens from the *Theodore N. Gill* collections were examined, and stomach contents are listed in table 9. With reference to this table it should be noted that copepods constituted the food of specimens less than 6 mm. long. At this size fish larvae also were eaten, and no specimen exceeding 13 mm. had copepods in its stomach. Voss (1953) also found evidence of change in the diet of young sailfish from copepods to fish larvae at a size of approximately 6 mm.

Of particular interest are the small istiophorids removed from the stomachs of three of the specimens (one 10.2 mm. long from a 21.0-mm. specimen, one 6.6 mm. long from a 13.0-mm. specimen, and part of one with a head 2.4 mm. long from a 16.2-mm. specimen). One specimen 6.0 mm. long removed from the stomach of a 21.9-mm. swordfish (*Xiphias gladius*), Arata (1954), had copepods in its stomach. An unidentified species of fish occurred frequently in the stomachs of several specimens taken 90 miles east of Brunswick, Ga., July 29, 1953, and flying fish predominated in the stomachs of others taken 150 miles east of Charleston, S. C., August 10, 1953. During the collection of the latter, small flying fish were also dipnetted. Small istiophorids were "relatively abundant" in the water when the above collections were made. Some fish larvae were larger than half the length of the fish that had eaten them. These data add support to the theory advanced by previous

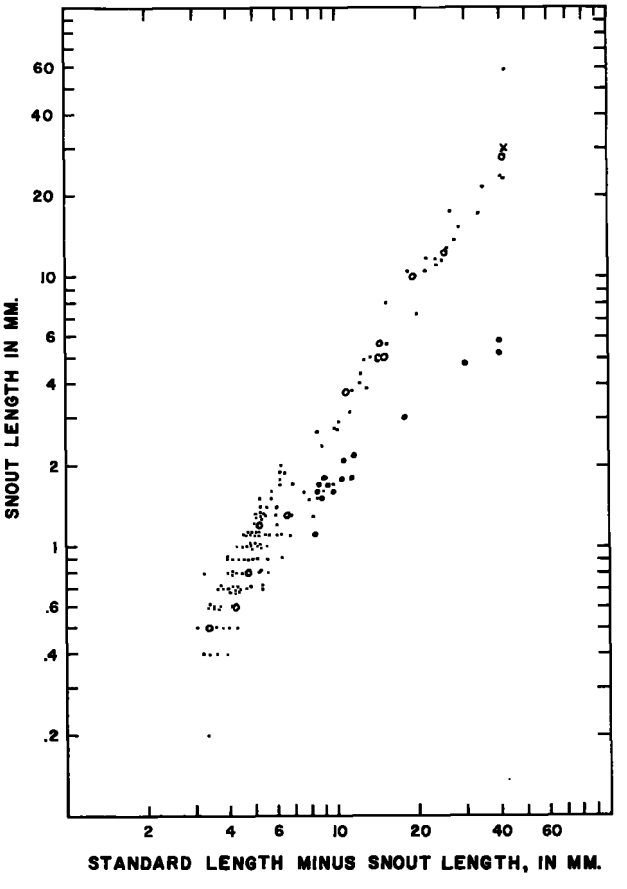

FIGURE 36.—Relation of snout length to standard length minus snout length. Large black dots represent the unidentified species.

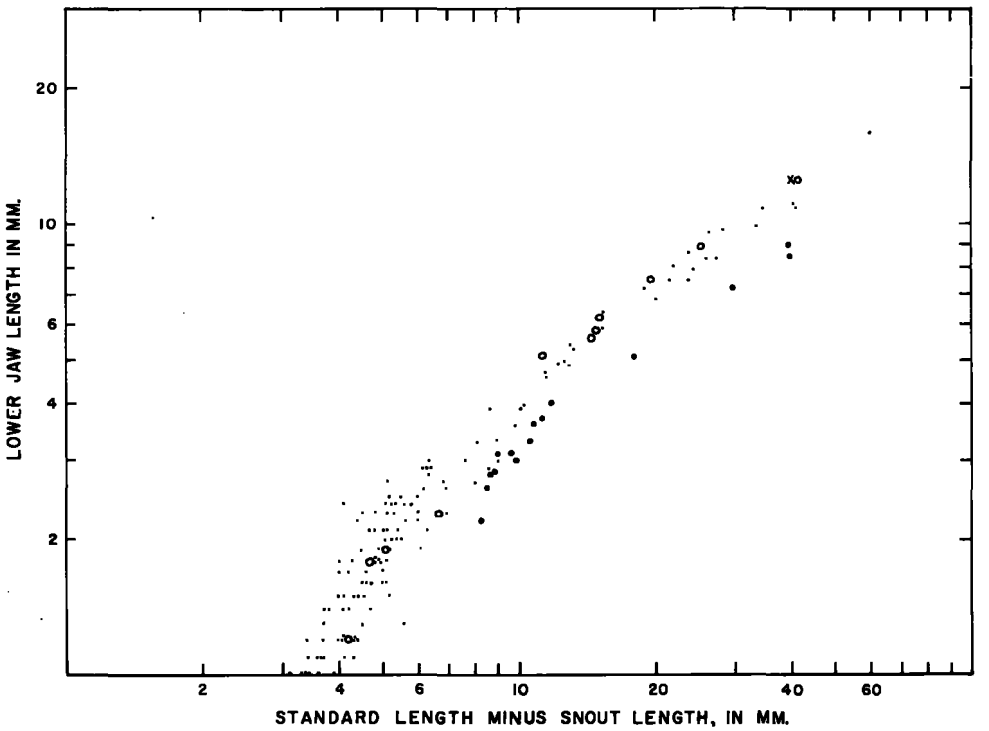

FIGURE 37.—Relation of lower jaw length to standard length minus snout length. Large black dots represent the unidentified species.

TABLE 9.—*Stomach contents of specimens from* Theodore N. Gill *collections*

Size of fish	Contents
3.9 mm	5 copepods.
5.4 mm	Parts of 9 copepods.
6.0 mm	3 copepods; parts of 7 copepods.
6.0 mm	7 copepods; parts of 1 fish larva.
9.4 mm	2 copepods; parts of 3 fish larvae (heads 1.4 mm.).
10.1 mm.[1]	1 fish larva,[2] 4.2 mm.
10.1 mm	1 copepod; part of 1 fish larva.
10.3 mm.[1]	1 fish larva,[2] 4. 8 mm.
10.3 mm.[1]	1 fish larva, 6.0 mm.; part of 1 fish larva.[2]
10.8 mm.[1]	4 fish larvae,[2] approximately 5.4 mm.
11.3 mm.[1]	Part of one fish larva (head, 3.0 mm.).
11.4 mm.[1]	1 fish larva,[2] 6.6 mm.; piece of another fish larva.
12.3 mm.[1]	1 copepod; part of 1 unidentified crustacean; 1 fish larva,[2] 5.1 mm.; part of 1 fish larva.
12.8 mm.[1]	1 fish larva,[2] 7.2 mm.
12.8 mm	4 flying fish larvae, 4.8 to 6.0 mm.; head of 1 fish larva.
13.0 mm.[1]	2 copepods; 1 istiophorid larva, 6.0 mm.
13.0 mm	1 flying fish larva, 4.8 mm.; parts of 2 other fish, one approximately 6.0 mm.
13.9 mm.[1]	1 flying fish larva, 5.1 mm.; 1 fish larva,[2] 7.2 mm.
14.6 mm	Part of one fish larva (head, 2.1 mm.).
15.3 mm	3 flying fish larvae, 3.6 mm.; parts of 2 flying fish larvae.
16.2 mm	1 istiophorid larva (head 2.4 mm.).
16.9 mm	Part of 1 fish larva (head, 1.8 mm.).
16.9 mm	1 fish larva, 8.4 mm.
17.8 mm	3 fish larvae, 3.0 mm., 3.6 mm., and 7.2 mm.
18.2 mm	1 thin fish larva, 11.4 mm.; part of fish larva.
20.9 mm	Parts of fish larva.
21.0 mm.[1]	1 istiophorid larva, 10.2 mm.
27.4 mm	Parts of fish larva.
34.5 mm.[1]	Parts of fish larvae.
38.8 mm	8 flying fish larvae, 4.8 to 8.7 mm.; 2 fish larvae, 6.3 mm. and 6.6 mm.; parts of 3 fish larvae.
45.0 mm.[1]	Parts of fish larvae.
45.0 mm.[1]	Parts of fish larvae.

[1] Unidentified species.
[2] All fish listed under footnote 2 appear to be identical, and unless otherwise noted, measurements given are of standard lengths.

workers, that the food of an organism is determined largely by what is available, rather than by selection.

SPAWNING

Locations of capture for Voss's specimens (Voss 1953) and those examined by me are shown in figure 1. Unless otherwise noted all observations on specimens more than 10 mm. in length are of the Atlantic sailfish, and all specimens less than 10 mm. are treated as a group.

ATLANTIC

1. With the exception of one specimen from the Tongue of the Ocean and two off Elbow Cay (both locations in the Bahama Islands), all larvae taken were closely associated with the approximate axis of the Gulf Stream, at or beyond the 100-fathom line.

2. Specimens less than 6 mm. long were taken during May from Miami, Fla., to Cape Lookout, N. C.; but were not taken after July 2 off Miami, July 29 off Georgia, and September 2 off North Carolina.

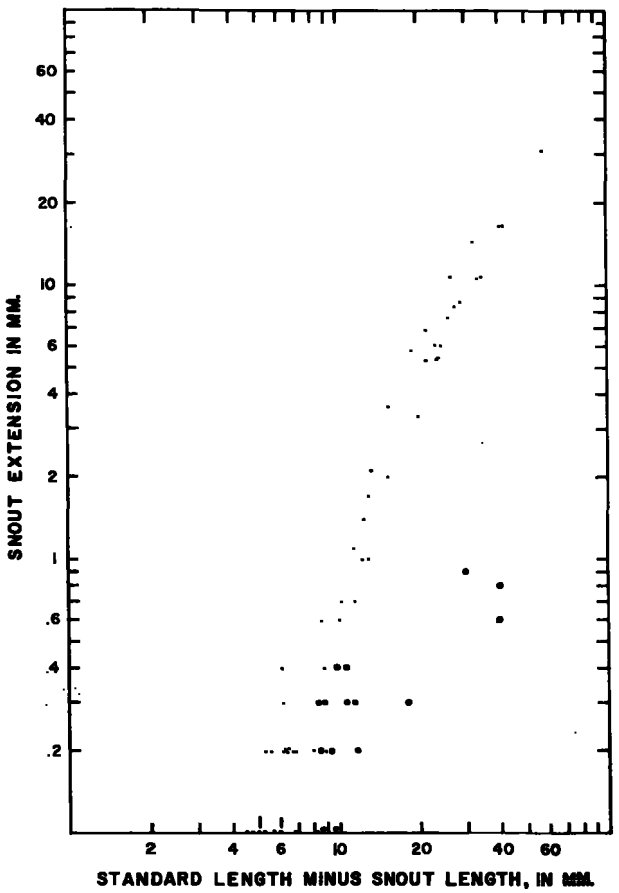

FIGURE 38.—Relation of snout extension to standard length minus snout length. Large black dots represent the unidentified species.

3. Specimens between 6 and 10 mm. long were taken during July and August off Georgia, and during August and September off the Carolinas. Specimens between 10 and 20 mm. long were taken during June off Elbow Cay, Bahamas, July off Miami, August off Georgia, August and September off the Carolinas, and August off Virginia.

4. A 37.5-mm. specimen was taken in July off southern Florida, one 38.8 mm. long in August off South Carolina, one 29.5 mm. long in September off North Carolina, one 101 mm. long in October off South Carolina, and one 20.9 mm. long in October in the Tongue of the Ocean, Bahamas.

5. Three specimens of the unidentified istiophorid (34.5, 45.0, and 45.0 mm.) were taken off Settlement Point, Grand Bahama Island, during late August.

6. A 208-mm. specimen was taken during March off South Florida, and one 374 mm. long in August off South Carolina.

The association of larval specimens with the Gulf Stream indicates that their early development takes place in the warm Stream waters. The larger southern specimens could conceivably have been spawned below Cuba, and the smaller North Carolina specimens off North Carolina. Thus, spawning appears to extend from April to September from south of Cuba north to Carolina waters, and beyond the 100-fathom line. LaMonte and Marcy (1941) suggest May to August for the Atlantic, and Voss (1953) suggests April through August for Florida. There is a northward shift in size occurrences as the season progresses, indicating a corresponding northward shift in general spawning season.

Gulf of Mexico

1. Specimens were taken in the northern and eastern Gulf, all of which were east of the Mississippi River except for one group (fig. 1).

2. Specimens less than 6 mm. long were taken from late April to the middle of August.

3. Specimens 6 to 10 mm. long were taken from June into August.

4. A 64.1-mm. specimen was taken in May, and several between 23 and 64 mm. long were taken during August and September.

From information given by Leipper and Drummond (1952), it appears that surface Gulf of Mexico waters are divided; and it may be assumed that two separate spawning areas exist, one west and one east of a line from the Mississippi River to the eastern tip of the Yucatan Peninsula. The distribution of larval specimens in the southeastern Gulf indicates that spawning took place in the area. The small specimens taken in the northwestern Gulf off the Texas and Louisiana coasts indicate that spawning occurred in this area, which was not necessarily associated with spawning in the southeastern Gulf. In view of the surface currents (Leipper and Drummond, 1952)

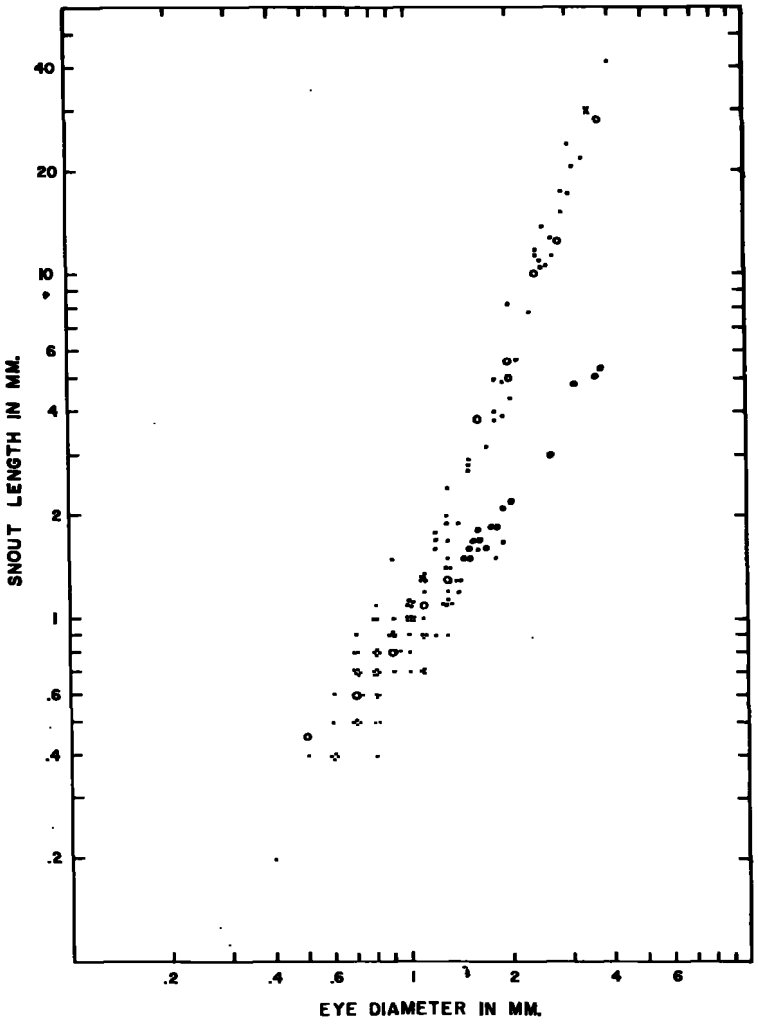

FIGURE 39.—Relation of eye diameter to snout length. Large black dots represent the unidentified species.

the larger specimens taken off the Mississippi Delta seem to be associated with spawning in the southeastern Gulf, these specimens having been carried northward by the prevailing currents. The 64.1-mm. larva taken in the east central Gulf during May could have been spawned in the Gulf, or farther south, late in the previous spawning season. It would appear that spawning in the southeastern Gulf extends from April through August. The spawning period in the western Gulf is less clearly defined since small specimens were taken only during June. However, Baughman (1941) reports that females with roe in all stages of development were taken during early August off the Texas coast.

ECOLOGICAL NOTES

In table 10 are presented available surface salinity, oxygen, and temperature values for the locations at which some larvae were taken. Too little data are available for correlation of specimen occurrence with these factors.

Of interest concerning the capture of specimens in the *Theodore N. Gill* collections are the following points: All were taken at the surface from deep, open-water areas; none were associated with seaweed; most were taken during daylight hours; and those few taken at night did not appear to be especially attracted to light (although several of the larger specimens from the Gulf of Mexico were reported as having been attracted to lights).

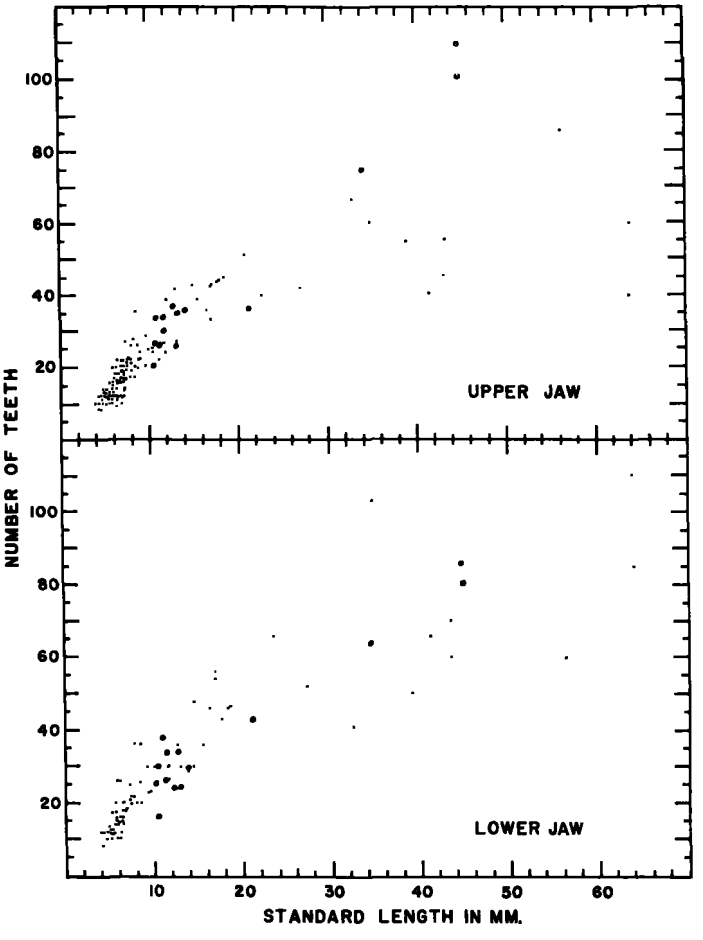

FIGURE 40.—Relation of number of teeth in left side of upper and lower jaws to standard length. Large black dots represent the unidentified species.

TABLE 10.—*Surface temperatures, salinities, and oxygen concentrations for locations of capture of some istiophorid larvae*

[Some data were made available by the U. S. Hydrographic Office, and other data were taken from the Report of the U. S. Commissioner of Fisheries for 1885 and records of the U. S. National Museum]

Number of specimens	Captured		Position		Temperature (°C)	Salinity (‰)	Oxygen (ml/L)
	Date	Hour	Latitude	Longitude			
17	July 29, 1953	1700–1845	30°57′ N	79°37′ W	28.3	35.8	4.6
3	Aug. 5, 1953	1930	31°57′ N	79°16′ W	29.0	36.0	4.7
7	Aug. 10, 1953	1830	32°54′ N	77°04′ W	27.9	35.7	4.7
1	do	2300	32°39′ N	76°46′ W	28.8	36.0	4.5
1	Oct. 7, 1953	2000	24°37′ N	77°18′ W	28.4	36.2	4.5
1	May 5, 1953	2000	31°41′ N	79°00′ W	27.0	36.2	4.8
1	Oct. 21, 1885		32°36′ N	77°29′15″ W	22		
3	Aug. 29, 1885	Night	37°23′ N	68°08′ W	27		
2	Sept. 3, 1914	1045–1210	34°12′52″ N	76°01′58″ W	28.9		
10	Sept. 2, 1914	1500–1600	34°24′ N	75°48′20″ W	29.3		
26	do	1325–1435	34°21′ N	75°51′40″ W	29.7		
58	do	1755–1900	34°17′46″ N	75°53′10″ W	29.2		
1	May 10, 1953	0230	33°52′ N	75°59′ W	25.4	36.3	4.6
1	June 12, 1954	2000	26°25′ N	76°48′ W	27.9	36.8	4.5
1	July 26, 1953	1800	28°18′30″ N	79°26′ W	28.8	35.9	4.7
1	June 13, 1954	1200	26°25′ N	76°48′ W	27.7	36.6	4.6

POSSIBLE IDENTITY OF THE DIVERGENT SPECIMENS

Speculation on the identity of the divergent specimens leads through a maze of confused records and contradictions. There are four generally recognized istiophorids in the Western North Atlantic: the Atlantic sailfish, *Istiophorus americanus* (Cuvier); the white marlin, *Makaira albida* (Poey); the blue marlin, *M. ampla* (Poey); and the spearfish, *Tetrapturus belone* Rafinesque.

As discussed previously, the unidentified specimens very closely resemble young of the Atlantic sailfish, but have been separated from this species mainly on the characters of snout length and snout extension. On this basis, I must place the unidentified specimens in one or the other of the genera *Makaira* or *Tetrapturus*.

Adult specimens of the marlins (*Makaira*) are separated from the spearfish (*Tetrapturus*) on the following major characters:

1. Length of snout and snout extension. The spearfish has a much shorter snout and snout extension than either the marlin or the sailfish.

2. Shape and height of dorsal fin. The whole dorsal is well developed and more uniformly high in the spearfish, placing it between the marlins and sailfish.

3. Length of ventral fins. The spearfish has considerably longer ventrals than the marlin, but shorter than the sailfish.

On the basis of these three characters, the unidentified specimens more nearly resemble the spearfish (*Tetrapturus*) than they do the marlins (*Makaira*). Using the development of the sailfish as a guide, it is logical to me that the unidentified specimens are more likely to develop into the adult form of *Tetrapturus* than of *Makaira*.

Sparta (1953) figures and describes eggs and larvae he believes to be *Tetrapturus belone* Rafinesque. His 5.24-mm. finfold larva does not remotely resemble my istiophorid specimens of a similar size, and is much less developed than my 3.6-mm. istiophorid. However, it rather closely resembles swordfish larvae, *Xiphias gladius* Linnaeus, of a similar size (Sanzo 1922). Sparta gave egg diameters of approximately 1.48 mm. for his possible *T. belone* Rafinesque, while Nakamura (1938) reported that a hooked shortnosed spearfish, *T. angustirostris* Tanaka, released eggs about 1 mm. in diameter as it was being lifted out of the water.

SUMMARY

1. Measurements and meristic counts were taken from 168 specimens of the family Istiophoridae, including the Atlantic sailfish *Istiophorus americanus* (Cuvier), ranging in standard length from 3.4 to 625 mm., from the waters off the South Atlantic Coast of the United States and the Gulf of Mexico, and selected measurements were obtained from the literature on 18 specimens. Twenty specimens representing the sailfish and an unidentified species of istiophorid, ranging in standard length from 3.6 to 374 mm., are described and illustrated at sizes selected to show important changes.

2. Growth and development of various body parts are discussed, summarized, and illustrated with graphs, with particular reference to the sailfish. Three stages of larval development are suggested: "Early larval," below 7 mm., during the period of rapid development of head spines; "mid-larval," the 7 to 20 mm. range, within which growth of head spines ceases, the snout begins to elongate, and fins receive their full complement of rays and undergo changes in size and shape; and "late larval," the 20 to 100 mm. range, within which head spines begin to disappear, fins further develop in size and shape, dermal spines develop, and jaw teeth begin to disappear.

3. Data on an unidentified species of istiophorid are presented with Atlantic sailfish material, from which it is distinguishable above 10 mm. in standard length. Below this size, separation is not made, since no valid character for separation was found. Discussion of the unidentified species appears where pertinent throughout the text. Divergence of certain characters, in particular the shorter snout and snout extension, is discussed with the idea of throwing light on possible identity.

4. Pigment is limited to a few melanophores on the dorsal surface of the brain case on the 3.4-mm. specimen. At 5 mm., pigment is present on sides of head and body posteriorly to the anus; it spreads to the caudal fin, down the sides, and onto the dorsal fin at approximately 10 mm. It becomes denser, extends farther down the sides, and spreads generally over the anterior portion of the dorsal fin at approximately 20 mm. Bars (or blotches of pigment) appear on the body at approximately 35 mm. General color of pigmentation on specimens exceeding 20 mm. (except for barred areas) is blue-black on the dorsal surface, grading

to silver-white below. Pectoral, pelvic, anal, and caudal fins, and the posterior portion of the dorsal fin are hyaline, while the anterior portion of the dorsal fin has a varied pattern of blue-black. The pigment pattern of the unidentified species differed only in extent of pigment farther posteriorly on the dorsal fin, and absence of bars on the body.

5. The stomachs of 32 larvae from waters off the South Atlantic Coast of the United States were examined, and it was found that copepods constituted the food in larvae less than 6.0 mm. long, fish larvae were the major food item of larvae larger than 6.0 mm., no copepods were present in specimens longer than 13 mm., and no fish larvae were present in specimens less than 6.0 mm. long. One unidentified species of fish occurred most frequently, although flying fish larvae were also numerous, and istiophorid larvae were present in the stomachs of 3 specimens. Some larvae were larger than one-half the length of the fish that had eaten them.

6. In the Atlantic Ocean off the coast of the United States, spawning occurs from April to September in the area from south of Cuba north to the Carolinas, beyond the 100-fathom line, closely associated with the Gulf Stream, and with a northward advance as the season progresses. In the Gulf of Mexico two separate spawning areas beyond the 100-fathom line are apparent: the southeastern Gulf from April through August, and the western Gulf less clearly defined, but at least during June and probably into August.

7. Surface salinity, oxygen, and temperature values for locations of capture of some specimens are presented, with no attempt made to correlate with specimen occurrence because of the paucity of data.

8. The possible identity of the divergent specimens is discussed, and the suggestion made that the divergent specimens are more likely to develop into the adult form of *Tetrapturus* than of either *Istiophorus* or *Makaira*.

SPECIMENS STUDIED

The names of owners, their numbers, numbers of specimens, date, and location of capture (fig. 1) for all specimens studied follow:

U. S. National Museum: No. 107200 (1 specimen), Oct. 21, 1885, *Albatross*–2624, 32°36′ N., 77°29′15″ W.; No. 116945 (1 specimen), June 6, 1929, Tortugas, Fla.; No. 92635 (3 specimens), Aug. 29, 1885, *Albatross*–2566, 37°23′ N., 68°08′ W.; No. 111815 (2 specimens), Sept. 3, 1914, *Fishhawk*–D8248, 34°12′52″ N., 76°01′58″ W.; No. 111816 (1 specimen), July 28, 1915, *Fishhawk*, 30 miles south of Lookout Lightship, N. C.; No. 163332 (10 specimens), Sept. 2, 1914, *Fishhawk*–D8245, 34°24′ N., 75°48′20″ W.; No. 163333 (26 specimens), Sept. 2, 1914, *Fishhawk*–D8244, 34°21′ N., 75°51′40″ W.; No. 111814 (58 specimens), Sept. 2, 1914, *Fishhawk*–D8246, 34°17′46″ N., 75°53′10″ W.; No. 163413 (5 specimens), Sept. 2, 1953, *Oregon*–829, 28°52′ N., 88°45′ W.

Tulane University: Group No. 47, Cat. No. 6741 (2 specimens), Aug. 12, 1953, *Oregon*–820, 28°42′ N., 88°48′ W.; Group No. 47, Cat. No. 6817 (2 specimens), Aug. 11, 1953, *Oregon*–819, 28°58′ N., 88°20′ W.

Chicago Natural History Museum No. 45453 (2 specimens), Sept. 2, 1953, *Oregon*–829, 28°52′ N., 88°45′ W.

Giles Mead: (1 specimen) Sept. 2, 1953, *Oregon*–829, 28°52′ N., 88°45′ W.

Gulf Fishery Investigations: (1 specimen) May 30, 1952, *Alaska*–III–2, 26°00′ N., 85°15′ W.; (1 specimen), April 29, 1951, *Alaska*–I–1–23, 23°11′ N., 82°24′ W.; (2 specimens), Aug. 15 ,1951, *Alaska*–III–1–11, 26°09′ N., 83°50′ W.; (6 specimens), June 1, 1953, *Alaska*–11, 3C tow 27, 27°55′ N., 93°38′ W.; (4 specimens), June 8, 1953, *Alaska*–11, tow 19, 26°09′ N., 86°34′ W.

R. M. Yount: (1 mounted specimen), Aug. 3, 1952, from surf, Myrtle Beach, S. C.

Tony Seaman: (2 mounted specimens), taken off Morehead City, N. C.

South Atlantic Fishery Investigations, *Theodore N. Gill* collections: (15 specimens) [2] July 29, 1953, 30°57′ N., 79°37′ W.; (3 specimens) Aug. 5, 1953, 31°57′ N., 79°16′ W.; (7 specimens) Aug. 10, 1953, 32°54′ N., 77°04′ W.; (1 specimen) Aug. 10, 1953, 32°39′ N., 76°46′ W.; (1 specimen) Oct. 7, 1953, 24°37′ N., 77°18′ W.; (1 specimen) May 10, 1953, 33°52′ N., 75°59′ W.; (2 specimens), June 12–13, 1954, 26°25′ N., 76°48′ W.; (1 specimen), July 26, 1953, 28°18.5′ N., 79°26′ W.; (1 specimen) from stomach of 21.9-mm. *X. gladius* taken July 29, 1953, 30°57′ N., 79°37′ W.; (1 specimen) from stomach of 13.0-mm. isti-

[2] This group includes 12 specimens of the unidentified species

ophorid taken July 29, 1953, 30°57′ N., 79°37′ W.; (1 specimen) May 5, 1953, 31°41′ N., 79°00′ W. (3 specimens) [3] Aug. 29, 1954, 26°54′ N., 79°07′ W.

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[3] Specimens of the unidentified species.

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