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DESCRIPTION AND DISTRIBUTION OF LARVAE OF FOUR SPECIES OF TUNA IN CENTRAL PACIFIC WATERS

By WALTER M. MATSUMOTO

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ABSTRACT

The larvae of four species of tuna—yellowfin (*Neothunnus macropterus*), skipjack (*Katsuwonus pelamis*), little tunny (*Euthynnus yaito*), and frigate mackerel (*Auxis thazard*)—are described in detail. Diagnostic characters are given to aid in the identification of the species.

The geographical and seasonal distributions of tuna larvae in equatorial waters from 1950 to 1952 are described. Yellowfin and skipjack larvae, which were the most abundant of the four species, were found to occur over a wide area between 23° N. and 15° S. latitude, from 120° W. to 180° longitude, the limits of the area investigated. The distribution was generally uniform over the entire area, but a slightly heavier concentration was noticed between 140° W. and 160° W. longitude from 5° S. to about 10° N. latitude. Although the geographical range has not been completely defined, the close adult-larva relationship points to a continuous transoceanic distribution along the equatorial currents. Both species appeared to be uniformly abundant throughout the year.

Nearly all the larvae were concentrated in the top 50 meters of water, with indications of a vertical, diurnal migration.

CONTENTS

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By WALTER M. MATSUMOTO, *Fishery Research Biologist*

BUREAU OF COMMERCIAL FISHERIES

The distribution of tuna larvae in the central Pacific is only one of several facets of an investigation of the life history, distribution, and abundance of tuna being undertaken by the Pacific Oceanic Fishery Investigations (POFI), of the United States Fish and Wildlife Service. The purpose of the present study is to identify and describe the tuna larvae found in these waters, to gain information on the location and time of spawning, and to obtain another measure of the comparative magnitude of the adult populations of the different species.

While it would have been logical and desirable to study the early life history of the tunas, beginning with the eggs, it was not possible to do so, since there were no discernible differences between the eggs of one species of tuna and those of another. All the ripe or near-ripe eggs examined from known species appeared alike (all had an opaque yolk mass and a distinctly noticeable oil droplet), and the range of egg diameter measurements for any one species overlapped that of the others. Consequently, no detailed work was done on their identification.

This paper presents comparative descriptions, based on material from zooplankton hauls, of the larvae of four species of tuna: yellowfin, *Neothunnus macropterus* (Temminck and Schlegel); skipjack, *Katsuwonus pelamis* (Linnaeus); little tunny, *Euthynnus yaito* Kishinouye; and frigate mackerel, *Auxis thazard* (Lacépède). The collections are sufficiently complete to enable us to trace the several species from early through late larval stages. The report also contains discussions of the horizontal and vertical distribution of these larvae, the diurnal variation and species composition of the larval catches, and estimations of the spawning area and time of spawning as evidenced by the development and distribution of the larvae.

NOTE.—Approved for publication, February 26, 1957. Fishery Bulletin 128.

The zooplankton samples from which the tuna larvae were collected were obtained from two main areas, equatorial waters and Hawaiian waters, during the years 1950 to 1952 on eight cruises of the POFI research vessel *Hugh M. Smith*. General station positions are shown in figures 1 and 2 (data on larvae collections for all

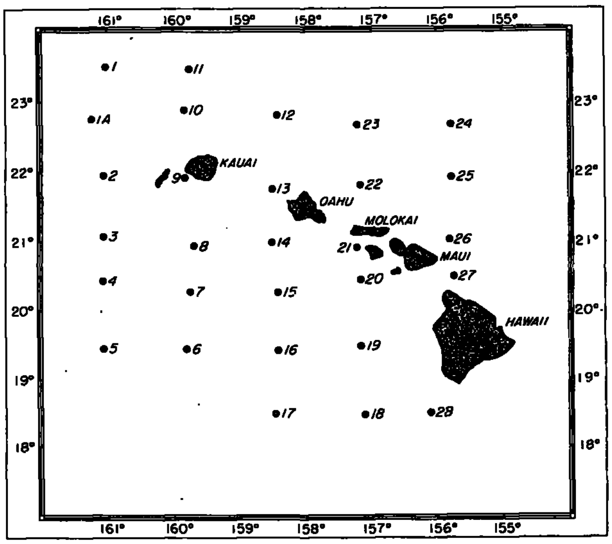

FIGURE 1.—Station locations of the *Hugh M. Smith* during cruise 6 in Hawaiian waters

the cruises are compiled in appendix tables 1 to 8, pp. 67–72). Samples were taken in 1-meter nets (*see* King and Demond, 1953, for detailed description), hauled according to two different methods. The first method was a 1-hour horizontal haul in which three nets were towed simultaneously at three different depths. The second method was a 30-minute oblique haul, a single open net being lowered to a depth of 200 meters and raised to the surface in a continuous operation.

In addition to the material collected by POFI, about 100 specimens of *E. yaito* and over 500 specimens of *A. thazard* taken in waters of the

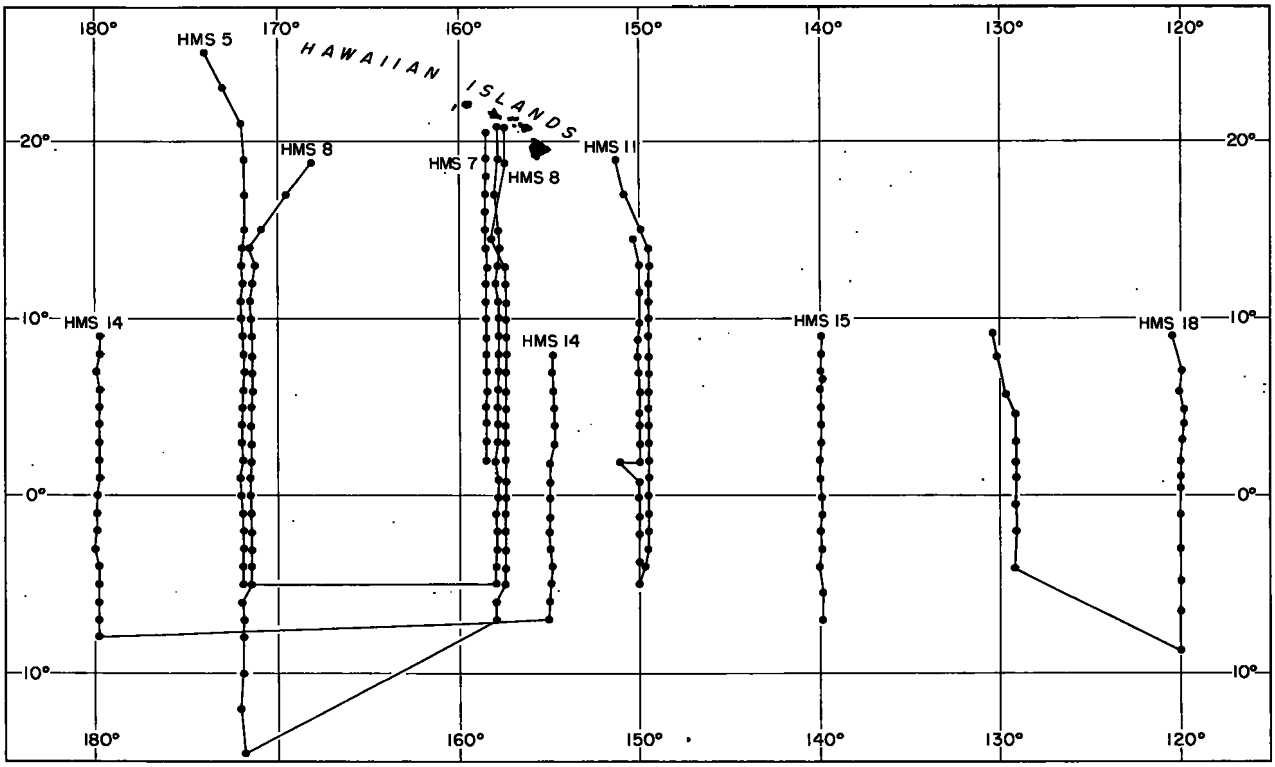

FIGURE 2.—Station locations of the *Hugh M. Smith* in equatorial waters.

East Indies during the 1928–30 *Dana* Expedition were examined.

The author wishes to thank the many POFI staff members who assisted in sorting the fish larvae from plankton samples, Wilvan Van Campen for numerous translations of literature in the Italian and Japanese languages, Tamotsu Nakata for drafting the charts in the text and for his advice on the reproduction of the drawings of tuna larvae, and the various staff members who critically reviewed the manuscript. Special thanks go to Dr. Å. Vedel Tåning, through whose kindness it was possible for us to examine the larval tunas collected during the 1928–30 *Dana* Expedition; to Dr. Milner B. Schaefer, Director of the Inter-American Tropical Tuna Commission, for the loan of juvenile *A. thazard*; to the California Division of Fish and Game for the loan of juvenile *E. lineatus*; to the Gulf Fishery Investigations for the loan of juvenile *E. alletteratus*; and to Dr. E. H. Ahlstrom, South Pacific Fishery Investigations, U. S. Fish and Wildlife Service, for his helpful criticisms and suggestions on the drawings of the larvae.

DESCRIPTION OF SPECIES

While there have been several valuable contributions to the identification of juvenile tunas, very little has been done on the identification of the larvae. The two most complete studies to date are those by Ehrenbaum (1924) and Wade (1951). Ehrenbaum examined larvae collected on the Danish oceanographical expeditions of 1908–10 to the Mediterranean and adjacent seas. The lack of juveniles in his collections did not permit him to make positive species identifications, and although his work has been cited in this paper as a general reference, for the most part his identifications have not been followed. Wade studied the larvae taken from waters around the Philippine Islands and was successful in collecting larval as well as juvenile specimens of *N. macropterus*, *K. pelamis*, and *E. yaito* (Wade 1950). His collections came from an area where adults of five species of Scombridae had previously been recorded [i. e., *Thunnus orientalis*, *T. germo* (=*Germo alalunga*), *Parathunnus mebachi* (=*P. sibi*), *Kishinoella tonggol*, and *N. macropterus*]. While there is good reason to believe that Wade's designation of certain larvae as *N. macropterus* is valid, some doubt exists as to his identification of *E. yaito*.

Prior to Wade's work, Schaefer and Marr (1948a, 1948b) had studied larval and juvenile stages of *N. macropterus*, *K. pelamis*, *E. lineatus*, and *A. thazard* taken off the Pacific coast of Central America. They had no difficulty in identifying the last three species. Regarding the first, their material came from an area where *P. sibi* is relatively scarce and their larger specimens showed anatomical characters that distinguish *N. macropterus*. However, these authors admitted the possibility that the smaller specimens were *P. mebachi* (=*P. sibi*), since identification could not be certain until juveniles of both species were available.

Our *N. macropterus* larvae resembled those examined by Wade and fitted nicely into the series of juveniles collected by Schaefer and Marr. Since ripe or nearly ripe gonads have been taken from adult *P. sibi* in equatorial waters (Yuen 1955), there is a possibility that some of the larvae could also be the young of *P. sibi*. While all indications seem to favor their being *N. macropterus*, final identification must wait until larvae and juveniles of *G. alalunga*, *P. sibi*, and some of the other scombrids have been caught and identified.

A situation somewhat comparable to that obtaining for *Neothunnus-Parathunnus* also exists for the species of *Auxis* discussed here. As pointed out by Wade (1949), the Philippine and East Indian regions have two species of this genus, *A. thazard* and *A. tapeinosoma*, these being rather easily separated as adults but much less so as juveniles. Apparently, only *thazard* occurs in the Hawaiian area,[1] and Hawaiian *Auxis* larvae are accordingly referred to this species. Because the present study also includes East Indian material, the possibility exists that specimens from that area may represent two species even though all material examined appeared identical with the Hawaiian *thazard*. There was no great difficulty in identifying larvae of *K. pelamis* and *E. yaito*.

In this section the detailed description of the smallest recognized specimen is given first. Descriptions of larger specimens follow in size sequence, and only the more prominent characters are noted. Finally, the distinctive characters or combinations of characters by which these species can be separated are discussed. The scheme of describing each specimen in its entirety, instead of following the development of certain anatomical characters throughout the size categories, was chosen because it seemed that this method would be more convenient for the reader. All descriptions and counts of the teeth and chromatophores on the head and body, unless specified otherwise, are based on one lateral half of the body, usually the left.

The smaller specimens were still in the initial stages of development and lacked many of the characters by which the adults are identified. They were separated into species by first segregating those larvae that were similar in appearance and then arranging them in a series according to size. From each series several specimens of various sizes were stained with alizarin according to the method described by Lipman (1935). The larger specimens in these series were more than 10 millimeters fork length and already possessed sufficient adult characters to permit positive identification. The more prominent and persistent characters, other than those used in identifying the larger specimens, were examined and traced down to the smallest individual in each series. The most useful of these characters are listed in tables 4 and 5 (pp. 53, 54). The six measurements used in tables 4 and 5 are defined as follows:

1. Total length: The distance from the tip of the upper jaw to the end of the longest caudal ray when the tail is not forked, and to the end of the middle caudal ray when the tail is forked.
2. Head length: The distance from the tip of the upper jaw to the posttemporal spine when the spine is present, and to the posterior margin of the head at the level of the vertebral column when the posttemporal spine is absent.
3. Mouth length: The distance from the tip of the upper jaw to the middle of the posterior edge of the maxillary, with the mouth closed or agape, varying with the specimen.
4. Snout length: The distance from the tip of the upper jaw to the anterior edge of the orbit.
5. Diameter of orbit: The diameter of the eye socket taken parallel to the body axis.

[1] After this paper was submitted for publication, 21 specimens of long-corseletted *Auxis*, probably *A. tapeinosoma*, were taken about 1 mile offshore from the Island of Lanai in the Hawaiian Islands, November 30, 1957, by the Fish and Wildlife Service research vessel, the *John R. Manning*. This is the first record of the capture of long-corseletted *Auxis* in Hawaiian waters. Inasmuch as the waters around these islands have been subjected to rather intense tuna fishing since the turn of the century and a careful check has been kept of the local fish markets for a form of *Auxis* other than *thazard* for the past 8 or 9 years, we believe that the long-corseletted form occurs very rarely in local waters and that its recent appearance may be due to unusual oceanographic conditions. In our opinion, its discovery does not materially change the larval identification presented here.

6. Dorsal interspace: The distance between the insertion of the first dorsal fin and the origin of the second dorsal.
7. Tooth counts: Counts given for one side only.

In general, tuna larvae are characterized by a compact, triangular visceral mass with a short intestine that is directed ventrally at its posterior end. The entire visceral mass is located well forward in the body, the preanal distance being less than one-half the total body length on specimens up to about 9 mm. A continuous median fin membrane starts at the nape and extends completely around the caudal region to the anal opening. The myomeres, when distinct, number between 38 and 42. The head, mouth, teeth, and eyes are well developed, and prominent preopercular spines are noticeable. Pigmentation is rather sparse, most of it being concentrated over the abdominal sac, over the brain, and in the caudal region, depending on the species.

As an aid in comparing the differences between larvae of various species and at different stages of development, the following summary of the key characters is presented in advance of the detailed descriptions, together with a sketch of a typical tuna larva (fig. 3) in which is incorporated the nomenclature used in this paper.

Neothunnus macropterus

a. Complete lack of chromatophores on the trunk, except over visceral mass, until the larva approaches 14 mm. total length.
b. No chromatophores over the forebrain.
c. Heavy pigmentation on the first dorsal fin in specimens of more than 7 mm.

Katsuwonus pelamis

a. Presence of a distinct chromatophore on the ventral midline of the caudal region.
b. Early appearance of chromatophores over the forebrain in specimens of more than 7 mm. total length.
c. Single chromatophore on middle of mandible in specimens of more than 7 mm.
d. Chromatophores only along outer edge of first dorsal fin.

Euthynnus yaito

a. Up to 4 chromatophores along the posterior base of the anal fin and the first 2 or 3 anal finlets. No chromatophores along the dorsal margin of the caudal region.
b. Series of chromatophores along the mandible, usually extending over the anterior half.
c. Heavily pigmented first dorsal fin.
d. Chromatophore usually present at the symphysis of the pectoral girdle.

Auxis thazard

a. A short series of closely spaced chromatophores on the middorsal, midlateral, and midventral lines of the caudal region.
b. Lower jaw free from pigmentation, except at the tip.
c. First dorsal fin relatively unpigmented, with 3 or less chromatophores at about 12 mm. in total length.
d. Chromatophore usually present at the symphysis of the pectoral girdle.

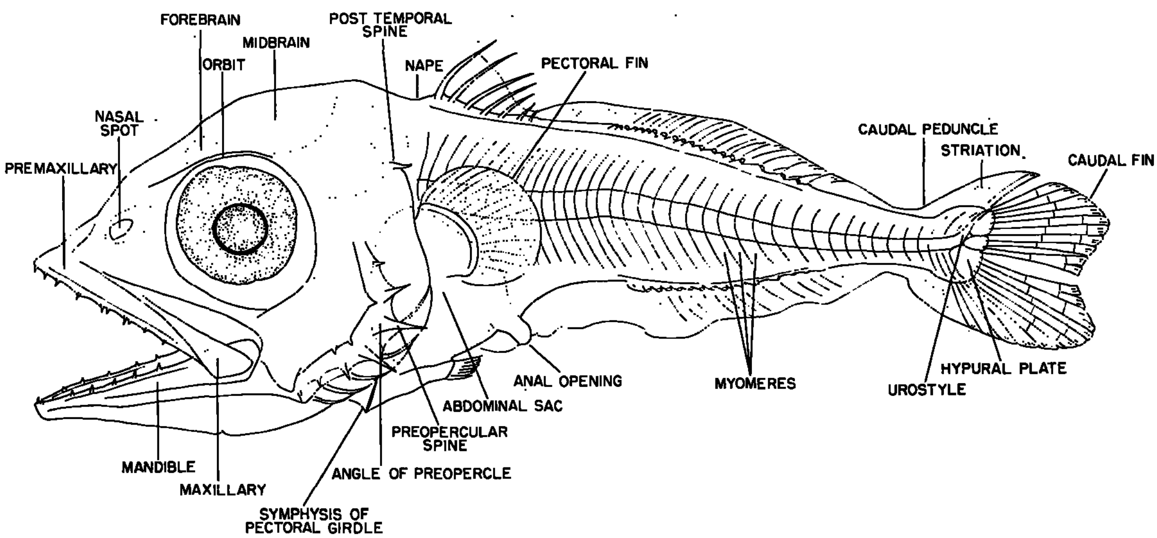

FIGURE 3.—A typical tuna larva with the nomenclature employed for various parts of the body.

YELLOWFIN (*NEOTHUNNUS MACROPTERUS*)

The description of this species is based on a study of 264 specimens, whose total lengths range from less than 3.0 mm. to 14.2 mm. (table 1). While the specimens less than 3.9 mm. in length could not be identified positively, they so closely resemble the smallest larva identified as *N. macropterus* that they are included in the total.

The smallest specimen identified as *N. macropterus* measures 3.9 mm. (fig. 4) and has about 40 myomeres. The body is evenly tapered caudally, and the abdominal sac is roundly triangular with the anal region directed sharply downward. The anal opening is well ahead of the midlength of the body. The snout on this specimen is slightly distorted, and no comparison of the head parts involving snout measurements has been attempted, although it is evident that the snout is only slightly longer than half the diameter of the orbit. No teeth are observable on this specimen, but other specimens of about the same length show up to 3 feeble teeth on each ramus of both jaws. Three spines project posteriorly along the edge of the preopercle, the middle one being the longest, and 2 minute spines are present on the surface of the preopercle just anterior to the preopercular spines.

The unpaired fins are not developed, but are represented by a continuous membrane extending from the nape completely around the caudal end of the body to the anal opening. Membranous pectoral fins are present, but ventral fins are lacking.

Head pigmentation is rather sparse, with only about 4 very small, scattered chromatophores over the membrane covering the brain and 2 internal

TABLE 1.—*Number and size range of larval* Neothunnus macropterus *collected by the* Hugh M. Smith *in Hawaiian and equatorial waters*

[See figs. 1 and 2 for location of stations]

Cruise and station	Number of larvae	Size range (mm.)
HAWAIIAN WATERS:		
Cruise 6:		
No. 1	2	5.3-6.0
No. 1A	5	4.4-6.5
No. 2	13	3.0-6.0
No. 5	2	3.5-4.5
No. 6	2	3.8-4.2
No. 7	5	5.4-8.0
No. 8	1	4.6
No. 10	12	3.3-6.1
No. 11	5	4.0-6.8
No. 13	6	4.0-5.6
No. 14	13	3.6-6.0
No. 15	7	4.0-10.2
No. 16	4	3.5-5.6
No. 18	16	3.2-7.5
No. 19	2	5.2-6.5
No. 21	8	3.6-6.5
No. 24	2	4.6-7.45
No. 25	15	3.5-5.6
No. 26	6	3.0-3.9
No. 27	6	2.5(?)-6.5
Total	132	2.5(?)-10.2

TABLE 1.—*Number and size range of larval* Neothunnus macropterus *collected by the* Hugh M. Smith *in Hawaiian and equatorial waters*—Continued

Cruise and station	Number of larvae	Size range (mm.)
EQUATORIAL WATERS:		
Cruise 5:		
No. 8	1	3.3
No. 12	1	4.9
No. 13	2	<3.0, 4.2
No. 14	1	7.0
No. 15	1	<3.0
No. 17	1	<3.0
No. 21	2	4.4, 5.2
No. 25	1	3.8
No. 26	9	3.2-4.6
No. 39	1	6.0
No. 41	1	4.9
No. 42	2	4.9, 5.5
No. 43	1	5.5
No. 45	1	3.5
No. 48	2	3.7, 4.9
No. 51	3	3.1-5.2
Cruise 8:		
No. 9	2	6.2, 7.9
No. 16	1	5.3
No. 21	1	3.0
No. 22	1	<3.0
No. 24	5	<3.0-5.6
No. 77	6	3.5-4.0
No. 78	4	<3.0-4.2
No. 79	2	4.0, 5.0
No. 82	1	14.2
No. 85	1	4.9
No. 93	1	6.2
No. 94	1	4.7
No. 97	1	5.2
No. 101	1	3.7
Cruise 11:		
No. 4	2	<3.0, 4.8
No. 6	2	5.3
No. 8	4	3.1-8.0
No. 9	4	3.2-5.6
No. 10	2	3.5, 3.7
No. 11	7	<3.0-6.6
No. 12	2	5.2, 6.6
No. 22	3	3.3-7.1
No. 23	1	3.0
No. 33	1	6.0
No. 35	1	4.0
No. 36	1	5.9
No. 37	2	4.5, 4.6
No. 40	3	<3.0-3.8
No. 42	1	3.8
No. 46	4	3.0-3.6
Cruise 14:		
No. 12	1	5.0
No. 14	1	5.0
No. 19	3	4.0-4.1
No. 20	1	7.1
No. 21	2	3.7, 4.1
No. 22	1	3.7
No. 30	4	3.8-6.4
No. 31	2	5.7, 7.8
No. 32	3	4.6-7.7
Cruise 15:		
No. 5	4	<3.0-6.0
No. 6	2	5.0, 8.1
No. 7	1	3.0
No. 14	1	4.5
No. 15	1	3.2
No. 16	1	4.1
Cruise 18:		
No. 4	2	3.0, 3.2
No. 5	2	3.1, 3.2
No. 6	1	3.2
No. 8	1	4.6
Total	132	<3.0-14.2

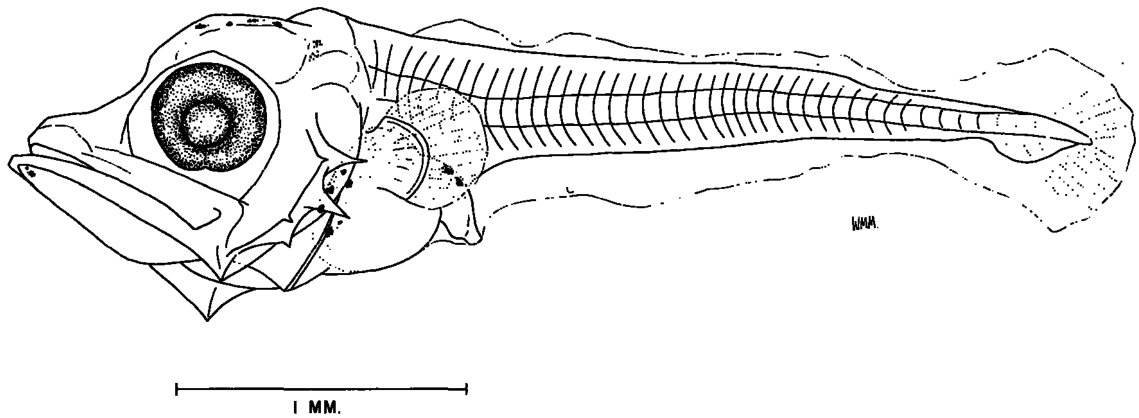

FIGURE 4.—*Neothunnus macropterus*, 3.9 mm. total length.

chromatophores along the posterior margin of the brain. Several large chromatophores are present over the anterior and posterior regions of the abdominal sac, but the rest of the body is free of pigmentation.

A specimen of 4.75 mm. has the same general appearance of the preceding stage, with 39 or 40 myomeres, but the body has deepened slightly. The teeth have increased to 5 on the upper jaw, but the 3 remain on the lower jaw. There is a slightly depressed, ovate, nasal spot on the snout which represents the future nostrils. The preopercular spines have increased to 4: 2 long spines at the angle and 2 small spines on the horizontal edge. There is no change in pigmentation, and the pelvic fins are just emerging as minute fleshy outgrowths from the ventral outline of the body beneath the abdominal sac.

Certain changes are evident in a 5.5-mm. specimen (fig. 5). The head appears slightly larger, 36.8 percent of the total length, and the snout, which is two-thirds the diameter of the orbit, is bluntly pointed. The mouth represents only 60.1 percent of the head length and all the teeth, 8 on the upper jaw and about 4 on the lower jaw, are small and feeble. Six preopercular spines are visible: 1 small spine on the vertical edge; 3 longer spines at the angle, the middle one being the longest; and 2 short spines on the horizontal edge.

The unpaired fins are still represented by a continuous membrane, which has degenerated in the region of the future first dorsal fin and appears slightly heavier there. The membrane also shows signs of degeneration in the region of the caudal peduncle, and about 10 incomplete rays are noticeable in the caudal fin. The pelvic fins are quite evident although they are still rudimentary.

The tips of both jaws bear several small chromatophores, and there are about 14 large chromatophores over the midbrain, although these

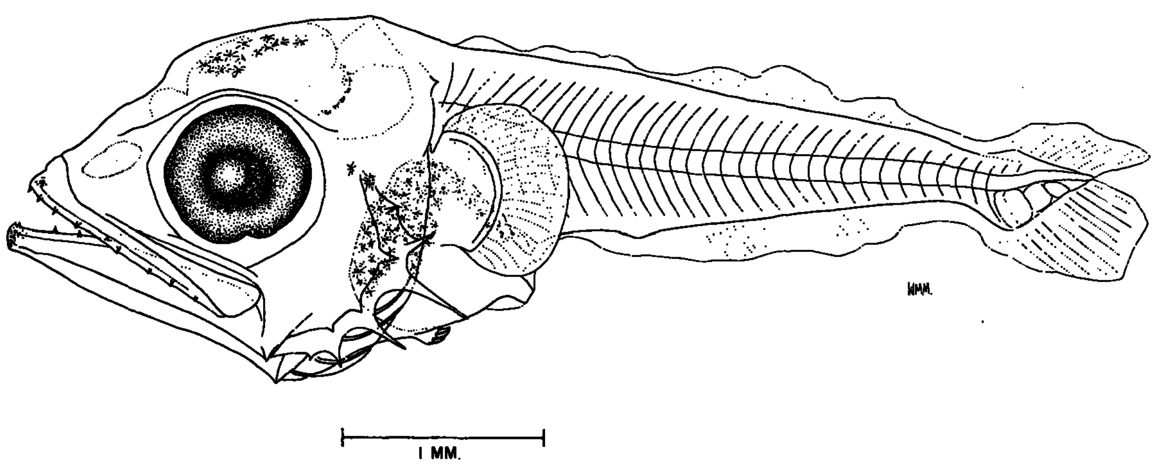

FIGURE 5.—*Neothunnus macropterus*, 5.5 mm. total length.

extend only over half of the brain area. A band of dark pigmentation lies along the posterior margin of the brain, and the 2 dermal chromatophores on the side of the head near the dorsal end of the preopercle make up the remainder of the pigmentation on the head. The dorsal half of the abdominal sac bears numerous large chromatophores, while the rest of the body is unpigmented.

Except for the appearance of 4 short spines in the first dorsal fin, about 12 rays in the caudal fin, and the formation of a very small spine near the posttemporal region, the specimen at 6.4 mm. (fig. 6) remains relatively the same in appearance as the previous one. There is a single, faint chromatophore on the third interradial membrane of the first dorsal fin, and the fin membrane here has degenerated to the height of the spines. The membrane is still high over the rest of the body.

At 7.15 mm. (fig. 7), the anal opening is closer to the midpoint of the body length. The snout is slightly longer, but is still not quite as long as the diameter of the orbit, and the nasal spot is beginning to constrict in the middle. The mouth is not very large and represents 62.1 percent of the head length. There are 10 or 11 small teeth on the maxillary and 6 or 7 similar teeth on the mandible.

The most noticeable development here is in the first dorsal fin, which bears 7 strong spines, the first 5 of them very long. About 19 rays are present in the caudal fin, which is just beginning to fork. The pelvic fins are only slightly larger than in the previous specimen.

There is an increase in the pigmentation over the brain, at the tips of both jaws, and over the abdominal sac. The band of pigment along the

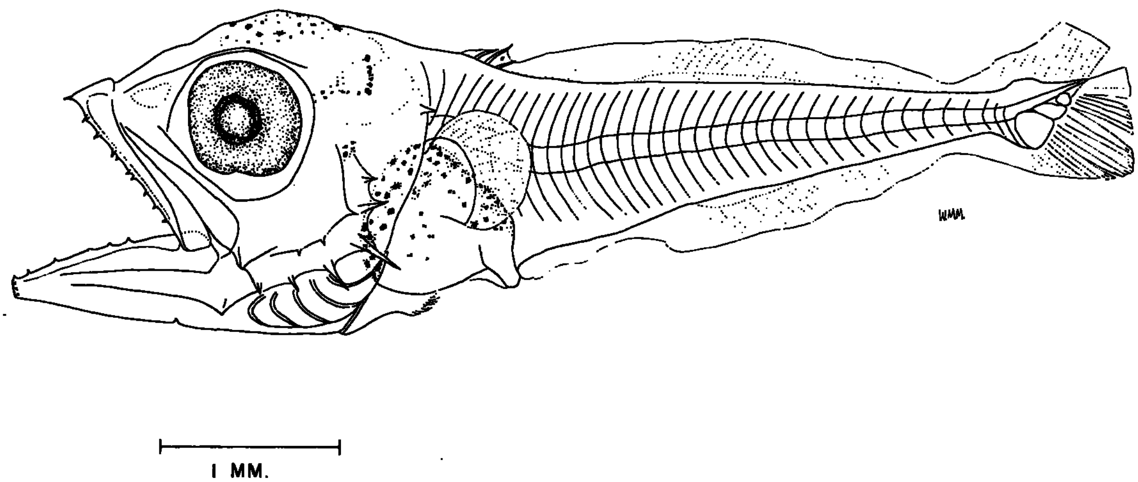

FIGURE 6.—*Neothunnus macropterus*, 6.4 mm. total length.

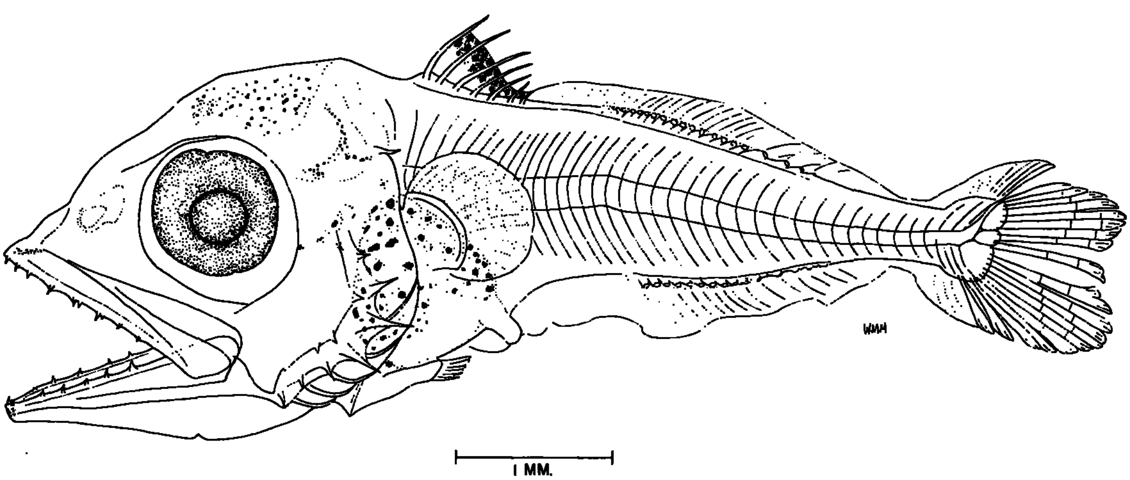

FIGURE 7.—*Neothunnus macropterus*, 7.15 mm. total length.

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posteroventral margin of the brain and the chromatophores near the dorsal end of the preopercle have increased in number and are most noticeable. Two chromatophores are present near the posterior edge of the orbit, and the darkly pigmented distal half of the interradial membrane of the first dorsal fin is rather prominent.

Some interesting development is noted in a stained specimen of 7.45 mm. While many of the dermal bony structures have ossified, the anterior vertebrae are just in the process of ossification. The first six vertebrae appear as "rings" and each of them has a very large, complete neural arch. On succeeding vertebrae the areas of ossification diminish in size until only the bases of the neural and haemal arches and their corresponding spines are evident at about the 14th vertebra. Posteriorly, only the urostyle is completely ossified and the hypural plate is just beginning to ossify.

A 7.95-mm. specimen is shown in figure 8. The general shape of the body remains the same as in the preceding specimen. The more obvious developments are the almost complete separation of the nasal openings, the deeper fork of the caudal fin, and the darker and larger area of pigmentation on the first dorsal fin, which is now almost completely pigmented, except for a narrow strip near its base. About 9 to 10 teeth are present on each jaw and 3 teeth are noticeable on the palatine bone.

While both the dorsal and anal fin rays are represented only by striations, there are 13+13 caudal rays. The pelvic fins, although complete with 1 spine and 5 rays, are very short. The rays of the pectoral fins are not distinct and appear only as striations.

In a 9.2-mm. specimen there is no apparent change in the head size, which is 37.9 percent of the total length of the body (fig. 9). The anal opening is at the midpoint of the body length, and the snout appears longer, its length being about the same as or slightly greater than the diameter of the orbit. The nares are separate, and both upper and lower jaws bear 12 teeth, while the palatine bone has about 4 very small teeth. Seven preopercular spines are discernible: 2 spines on the vertical edge, 2 spines at the angle, and 3 spines on the horizontal edge.

The first dorsal fin has 10 spines and a slightly convex outline. The rays of the second dorsal fin are not clearly defined and no accurate count could be made. There appear to be about 6 or 7 dorsal "finlets" and the anal fin has about 14 rays and 7 finlets, though the finlets are not completely formed and none of them is definitely separated from the others. The caudal fin has 14+15 rays, and the depth of the fork is about one-third the length of the longest caudal fin ray. The pelvic fins have the full adult complement of spines and rays, the longest of which are nearly as long as the longest spine of the first dorsal fin.

A stained specimen of 10.2 mm. shows 13 completely ossified vertebrae, and 13 more which are only partly ossified. The first haemapophysis appears on the 8th vertebra, and closed haemal arches are present only on the 11th, 12th, and 13th vertebrae. On the 12-mm., stained speci-

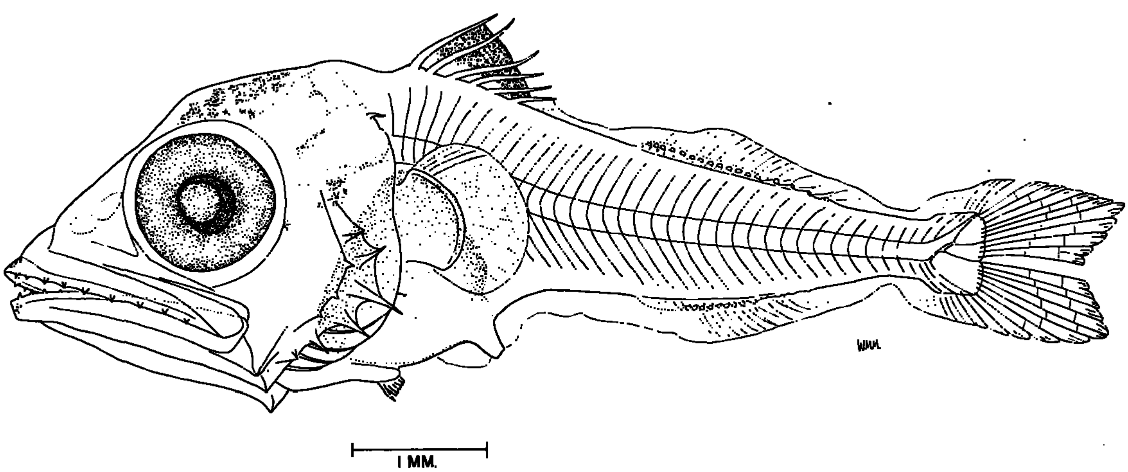

FIGURE 8.— *Neothunnus macropterus*, 7.95 mm. total length.

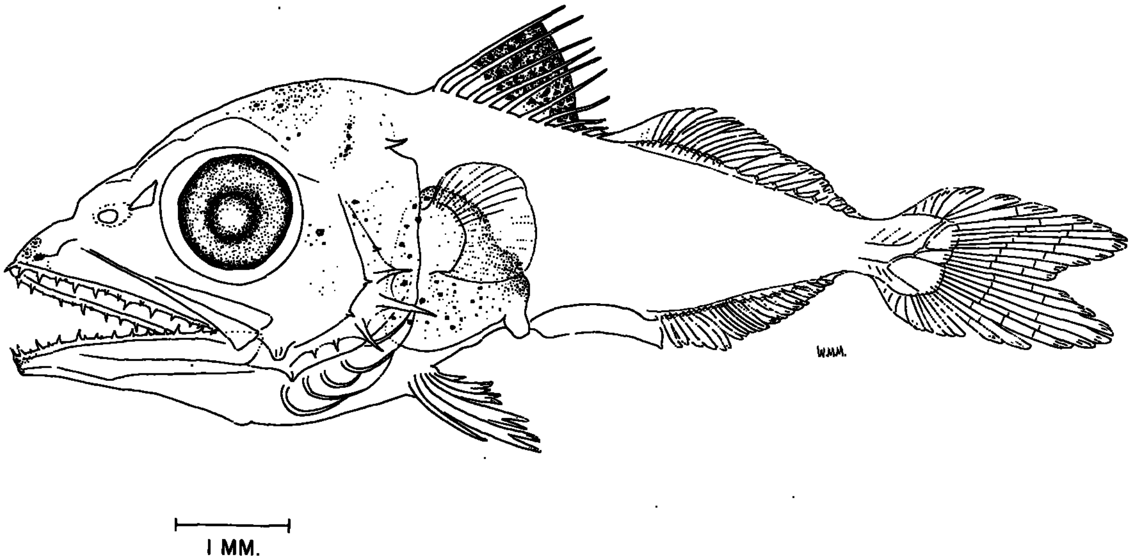

FIGURE 9.—*Neothunnus macropterus*, 9.2 mm. total length.

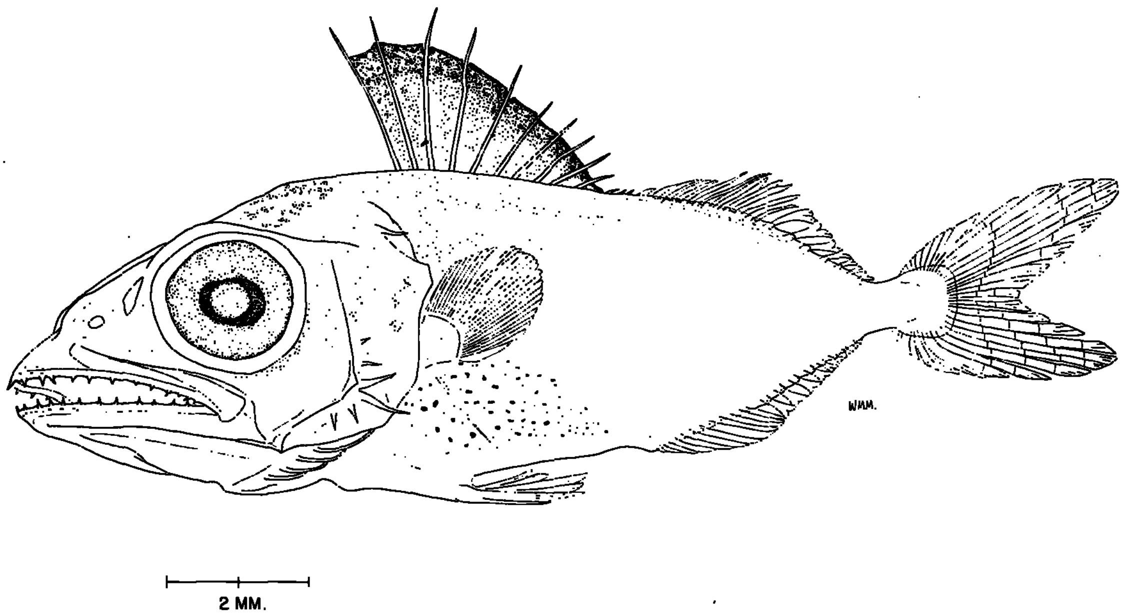

FIGURE 10.—*Neothunnus macropterus*, 14.25 mm. total length.

men all of the vertebrae are ossified, and they number 18 precaudals and 20 caudals, including the urostyle. The first few vertebrae are beginning to assume the hourglass shape of the adult centrum. The haemal arches are narrow, none of them being as wide as the diameter of the centrum at this stage of development.

At 14.25 mm. (fig. 10) the body is much deeper, especially near the insertions of the second dorsal and anal fins. The triangular abdominal sac is large and elongate, and the anal opening is just anterior to the insertion of the anal fin.

The head, which is 39.7 percent of the total body length, appears very large, and the length of the snout is equal to the diameter of the orbit. The nares are well separated, the round, anterior naris being about one-third the size of the nearly elliptical, posterior one. About 13 or 14 teeth are noticeable on both the upper and lower jaws in the unstained specimen. Six preopercular spines are visible, but only the 2 longest ones at the angle still project free from the preopercular bone.

The first dorsal fin is composed of 14 spines and the fin outline appears slightly convex. Both the second dorsal and anal fins consist of 15 rays and 8 finlets. There are about 18+19 rays in the caudal fin, but those near the anterior edges are not clear enough to be counted accurately. The pelvic fin is very large and is almost as long as the pectoral fin, which now bears about 30 rays.

Pigmentation is beginning to resemble that of juveniles. The large chromatophores over the brain still extend over a relatively small area, but numerous, very minute chromatophores appear over the posterior part of the head and extend posteriorly in a band to a point beneath the insertion of the second dorsal fin. There is a patch of similar pigmentation immediately behind the opercle and dorsal to the pectoral-fin insertion. Small chromatophores also line the posteroventral margin of the orbit, while 5 to 6 large chromatophores are present on the surface of the opercle posterior to the eye. Pigmentation over the abdominal sac remains unchanged, while the first dorsal fin is now completely pigmented. A faint line of chromatophores is present along the bases of the first and second dorsal fins, extending posteriorly to about the second dorsal finlet. The rest of the body has no pigmentation.

SKIPJACK (*KATSUWONUS PELAMIS*)

A total of 476 specimens of *K. pelamis* measuring from 2.3 mm. to 20.1 mm. was sorted from plankton collections and examined (table 2). Also studied were 34 specimens from 20.0 mm. to 43.0 mm. collected with dip net at night-light stations in Kingman Reef lagoon in May 1951.

The smallest specimen that could be identified positively as *K. pelamis* measures 3.7 mm. in length (fig. 11); this specimen appears somewhat distorted in preservative. The body is elongate with both the dorsal and ventral outlines tapering evenly to the caudal end. The abdominal sac is roundly triangular in shape with the anal opening slightly anterior to the midpoint of the total length of the body.

Although the snouts on other specimens of comparable size are rather pointed, this is not evident here, probably because of distortion. The upper

TABLE 2.—*Number and size range of larval* Katsuwonus pelamis *collected by the* Hugh M. Smith *in Hawaiian and equatorial waters*

[See figs. 1 and 2 for locations of stations]

Cruise and station	Number of larvae	Size range (mm.)
HAWAIIAN WATERS:		
Cruise 6:		
No. 1	1	6.0
No. 1A	11	4.4–7.0
No. 2	4	4.0–6.0
No. 4	10	3.5–4.5
No. 5	14	3.6–5.5
No. 7	4	4.5–6.5
No. 8	9	3.5–8.5
No. 10	29	2.5 (?)–7.55
No. 11	9	4.1–7.65
No. 13	12	4.0–5.6
No. 15	13	3.2–6.5
No. 16	6	?–8.0
No. 18	27	3.6–8.8
No. 19	3	9.85–12.5
No. 20	2	3.6, 5.0
No. 22	2	4.0, 6.6
No. 24	3	6.2–8.8
No. 25	1	3.7
No. 27	4	3.5–3.7
Total	164	2.5–12.5
EQUATORIAL WATERS:		
Cruise 5:		
No. 2	1	4.5
No. 4	3	3.4–3.6
No. 11	3	4.6–5.0
No. 14	4	3.5–6.1
No. 16	2	9.1, 10.1
No. 19	1	3.8
No. 21	1	4.0
No. 22	8	3.5–8.8
No. 23	24	3.2–6.9
No. 25	17	2.7–4.9
No. 26	2	6.8, 10.0
No. 32	1	4.6
No. 35	1	7.0
No. 36	6	2.9–4.5
No. 37	6	3.3–8.0
No. 38	1	4.6
No. 42	1	6.5
No. 43	2	Distorted.
No. 45	4	3.1–4.0
No. 46	1	4.5
No. 51	2	3.6, 4.6
Cruise 8:		
No. 11	3	4.6–5.6
No. 20	1	7.2
No. 25	2	2.8, 3.0
No. 77	9	3.0–5.4
No. 78	2	4.0, 4.6
No. 79	5	4.1–6.1
No. 80	2	2.5, 5.0
No. 81	2	4.0, 4.2
No. 84	4	5.1–20.1
No. 85	1	3.6
No. 87	1	3.0
No. 88	1	3.0
No. 89	1	3.7
No. 90	8	5.0–6.5
No. 91	3	2.7–6.5
No. 93	1	8.1
No. 94	1	4.0
No. 95	2	5.0, 8.0
Cruise 11:		
No. 1	1	3.6
No. 6	1	5.0
No. 9	1	9.4
No. 10	1	3.1
No. 11	6	2.9–12.6
No. 12	1	6.7
No. 22	2	3.9, 8.0
No. 23	1	5.0
No. 24	2	5.5, 14.9
No. 26	2	6.5
No. 27	3	3.5–5.1
No. 29	21	3.8–6.5
No. 31	7	3.0–8.0
No. 33	1	4.1
No. 36	1	10.9
No. 37	3	3.4–6.3
No. 38	1	6.6
No. 41	1	3.9
No. 42	1	6.1
No. 43	1	4.2

TABLE 2.—*Number and size range of larval* Katsuwonus pelamis *collected by the* Hugh M. Smith *in Hawaiian and equatorial waters*—(Continued)

[See figs. 1 and 2 for location of stations]

Cruise and station	Number of larvae	Size range (mm.)
EQUATORIAL WATERS—Continued		
Cruise 14:		
No. 2	9	3.5–6.0
No. 4	1	3.1
No. 7	1	3.3
No. 8	1	3.0
No. 9	14	3.4–10.3
No. 10	2	5.0, 7.0
No. 12	4	5.0–9.4
No. 14	3	2.3–6.0
No. 17	2	4.2, 9.0
No. 18	3	3.5–5.6
No. 20	7	4.0–6.2
No. 21	8	4.0–4.6
No. 22	2	3.5, 4.5
No. 24	1	3.7
No. 25	2	3.0
No. 29	4	3.2–5.0
No. 30	4	3.5–6.5
No. 32	1	4.0
Cruise 15:		
No. 6	7	3.2–6.5
No. 7	10	3.2–7.5
No. 8	10	3.1–5.0
No. 9	8	2.7–5.9
No. 10	1	19.0
No. 14	3	3.2–4.2
No. 15	1	3.6
No. 17	1	4.5
Cruise 18:		
No. 5	1	4.5
No. 6	1	10.1
No. 21	1	5.0+(distorted).
No. 24	1	5.4
Total	312	2.3–20.1

and lower jaws contain 4 and 6 teeth, respectively, and there are 3 spines along the edge of the preopercle, the middle one being the longest. The pectoral fins are present, but are represented only by a thin membrane, while the pelvic fins are completely absent. The median fins are represented by a continuous membrane which begins at the nape and continues around the caudal end to the anal opening. No fin rays are developed, but a few faint striations can be seen in the caudal region.

Most of the pigmentation is subcutaneous. About 10 small chromatophores are scattered over a fairly large portion of the membrane covering the midbrain. The dorsal edge of the abdominal sac is pigmented with very small chromatophores, while a very large one is evident on the anterior edge. A single chromatophore is present along the midventral line at about the 34th myomere. In all specimens examined the presence of this chromatophore is extremely consistent, although sometimes 2 or 3 replace the usual 1. The only dermal pigmentation on this specimen occurs at the tip of the lower jaw, where 2 to 3 small chromatophores are noticeable.

A specimen of 5.35 mm. (fig. 12) shows some advances in development. The head, representing 38.7 percent of the total length, is very large in relation to the rest of the body, and the sharply pointed snout is slightly longer than the diameter of the orbit. The length of the mouth is equivalent to 71.6 percent of the head length, and is much larger than that of *N. macropterus* of a comparable size. The teeth, 13 on the upper and 11 on the lower jaw, are well developed, and 6 spines are present along the edge of the preopercle. The pigmentation is now more extensive and covers more than half the area of the midbrain. The pelvic fins are seen only as small buds. No vertebrae are formed as yet and myomeres are only faintly visible. They number either 41 or 42.

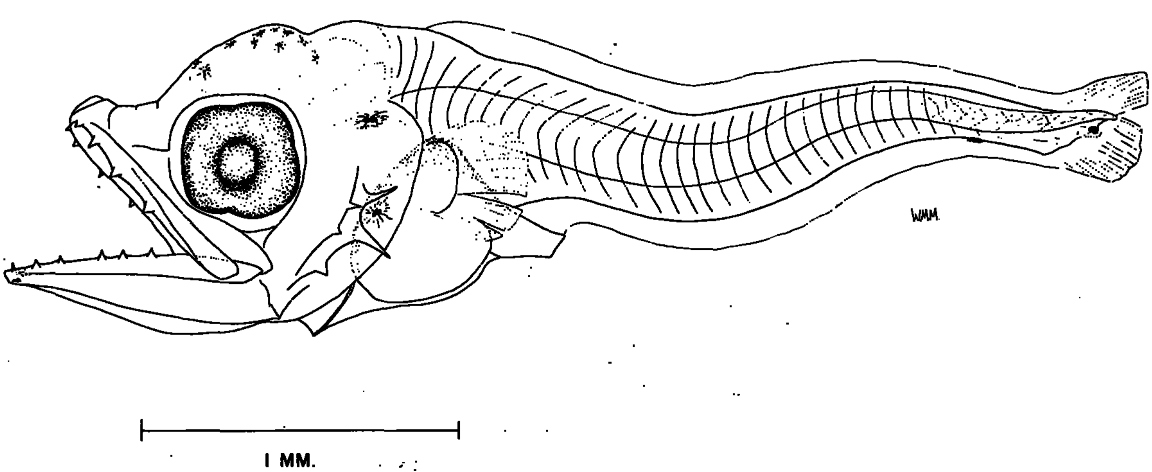

FIGURE 11.—*Katsuwonus pelamis*, 3.7 mm. total length.

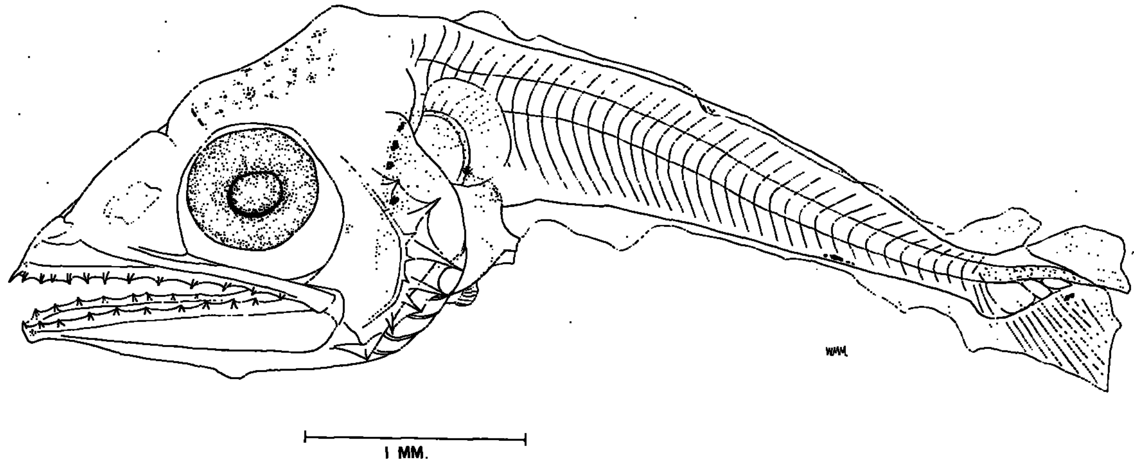

FIGURE 12.—*Katsuwonus pelamis*, 5.35 mm. total length.

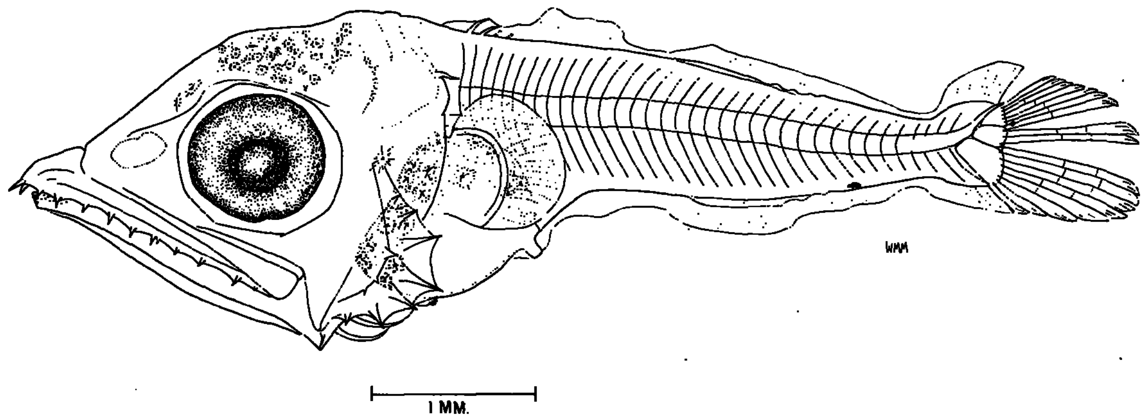

FIGURE 13.—*Katsuwonus pelamis*, 6.7 mm. total length.

The beginnings of the hypural plates are present, and the urostyle has developed and is turned upward.

The greatest change in a 6.7-mm. specimen (fig. 13) is in the first dorsal fin, where 4 spines have developed, the first 2 being very distinct. The only fin showing further development is the caudal, which now contains 18 rays. The urostyle is turned upward and the hypural plates are in a more terminal position. These bones are not yet ossified and do not take a stain.

The number of chromatophores over the midbrain has increased to about 33, and 2 closely set chromatophores are present over the forebrain, well ahead of the main, pigmented area. One or 2 large, dermal chromatophores appear on the side of the head near the dorsal end of the preopercle, while the pigmentation on the abdominal sac shows only a slight increase. No change is shown by the single chromatophore on the midventral line of the caudal region, or in the 41 myomeres.

At 7.1 mm. (fig. 14), the body is very much deeper and the head, composing 43.2 percent of the total length of the body, is still large. The snout length is almost equal to the diameter of the orbit. Eight short spines are present in the first dorsal fin, and the fin rays and finlets of the second dorsal and anal fins are beginning to develop. These appear only as striations in the membrane and cannot be counted accurately. The membrane between the first and second dorsal fins is beginning to degenerate, and there are about 12+11 rays in the caudal fin, the posterior edge of which has just begun to fork.

Pigmentation over the brain is similar to that on the previous specimen, but it extends over almost the entire midbrain area. Two additional chromatophores appear: a small one on the lower jaw, at about one-fourth of the jaw length posterior to the tip, and another on the first dorsal fin at the outer edge of the second interradial membrane.

Several noticeable changes have taken place by the time the species has reached a length of 8.75 mm. (fig. 15). The anal opening is now slightly posterior to the midpoint of the total length of the body. The head is still large, 41.3 percent of the total length, and the snout, which is nearly equal to the diameter of the orbit, is sharply pointed. The growth across the nasal opening is complete, thus forming 2 openings. The mouth is large and represents 66.0 percent of the head length. There are 16 to 18 teeth on both jaws and about 5 on the palatine bone.

Eight or 9 spines are present in the first dorsal fin and, while their number does not differ appreciably from that in the 7.1-mm. specimen, they are nearly twice as long. There are about 10 rays and 6 or 7 finlets in both the second dorsal and anal fins. The pelvic fins are well developed, with 1 spine and 5 rays, while the pectoral fins are only striated.

Changes in pigmentation consist of the appearance of a few more chromatophores over various parts of the body. Several dark chromatophores are scattered on the tip of the snout, and the chromatophore on the lower jaw has moved back

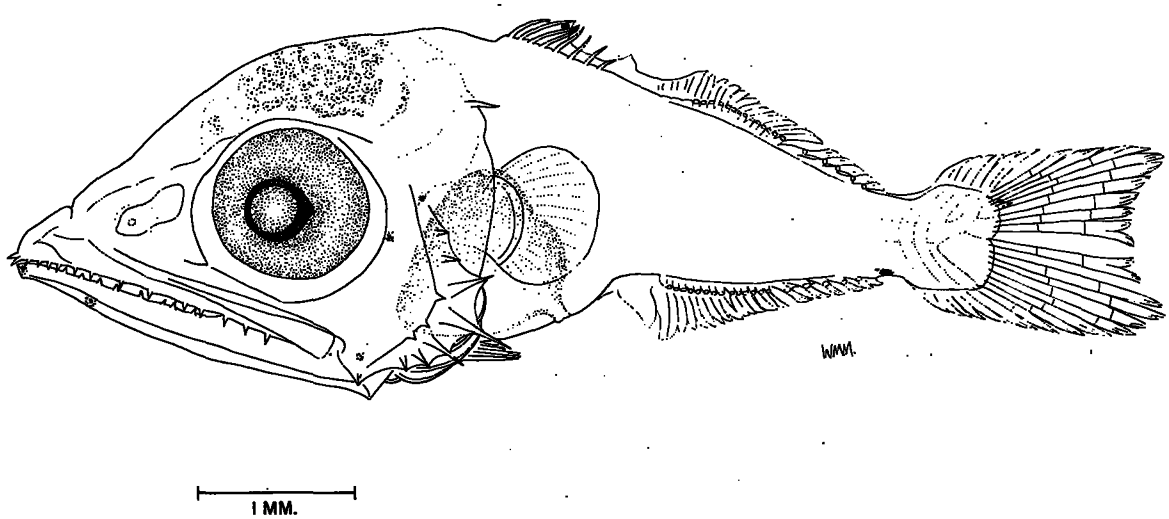

FIGURE 14.—*Katsuwonus pelamis*, 7.1 mm. total length.

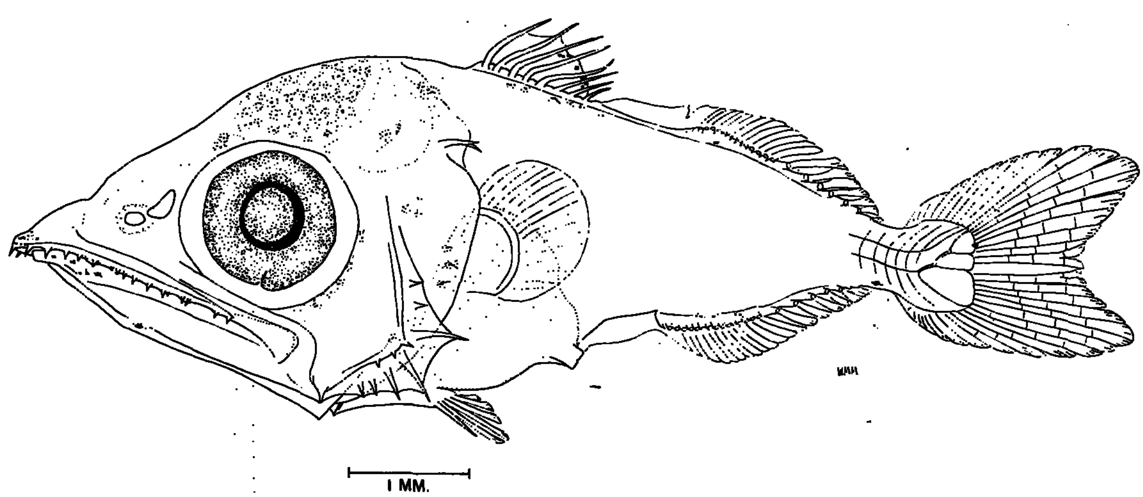

FIGURE 15.—*Katsuwonus pelamis*, 8.75 mm. total length.

to about one-half the length of the mandible. The posteroventral edge of the orbit is lined with about 10 small chromatophores, and about 6 fairly large, faint chromatophores are present on the preopercular surface posterior to the eye. Three or 4 small chromatophores also are noticeable in the posttemporal region, while 6 to 8 chromatophores appear along the base of the first dorsal fin and 1 near the second dorsal fin insertion. The outer edges of the 3d through the 6th interradial membranes of the first dorsal fin are pigmented with about 6 large chromatophores. Three chromatophores are also present along the base of the anal fin.

Rapid vertebral development has occurred between the 8.0-mm. and the 8.8-mm. specimens, both of which were stained. Only the urostyle is ossified on the smaller specimen, while the larger one shows complete ossification of the urostyle and the first 11 vertebrae. The first haemapophysis occurs on the 9th vertebra and the first closed haemal arch on the 11th.

Very definite changes are seen in a 10.9-mm. specimen (fig. 16). The abdominal sac is still roughly triangular, but the anal opening has moved back toward the anal-fin insertion. The nostrils are farther apart and, while the posterior one is still elliptical in shape, the anterior one is now smaller and more circular.

There are 9 preopercular spines: 4 small spines on the horizontal edge, 3 short spines on the vertical edge, and 2 very long spines at the angle. All of these, with the exception of the 2 long ones at the angle, are completely overgrown by the preopercular bone.

Fin development shows the greatest changes. There are 13 definite spines in the first dorsal, about 15 rays plus 8 finlets in the second dorsal, and about 14 rays plus 7 finlets in the anal fin. However, differentiation between the last fin ray and the first finlet is not clearly defined. The caudal fin rays number 16+16, and the pelvic fins show the full complement of 1 spine and 5 rays.

There is an increase in the number of chromatophores over the brain, at the tips of both jaws, and along the posteroventral margin of the orbit. The area posterior to the brain between the posttemporal spine and the dorsal edge of the body bears numerous small chromatophores, which extend backward along the dorsal margin of the body and gradually disappear near the base of the first dorsal finlet. Four small chromatophores are present along the base of the anal fin, and the single, dark chromatophore still persists on the ventral midline of the caudal peduncle. Six large chromatophores appear on the midlateral line of the body between verticals through the second dorsal insertion and the first dorsal finlet.

The vertebral count on a stained specimen of 9.85 mm. is 20 precaudal plus 21 caudal vertebrae, including the urostyle. All of the vertebrae are completely ossified, but none of the centra shows the typical hourglass shape of the adult. The first haemapophysis is on the 9th vertebra, and the first closed haemal arch is on the 11th. There are no inferior foramina along the vertebral column at this stage of development.

At 14.5 mm. (fig. 17), the body does not appear to be quite as deep as in the smaller specimens and the head is smaller in relation to the body (37.2

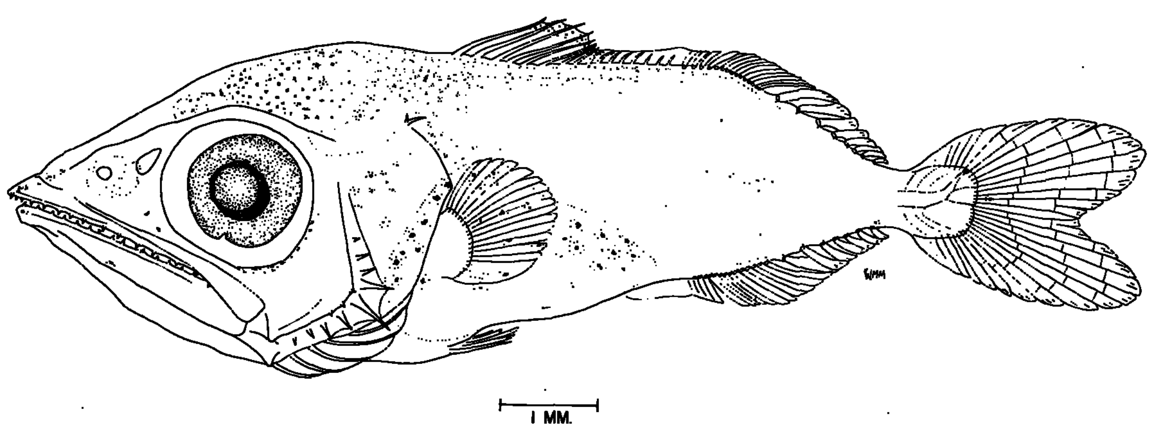

FIGURE 16.—*Katsuwonus pelamis*, 10.9 mm. total length.

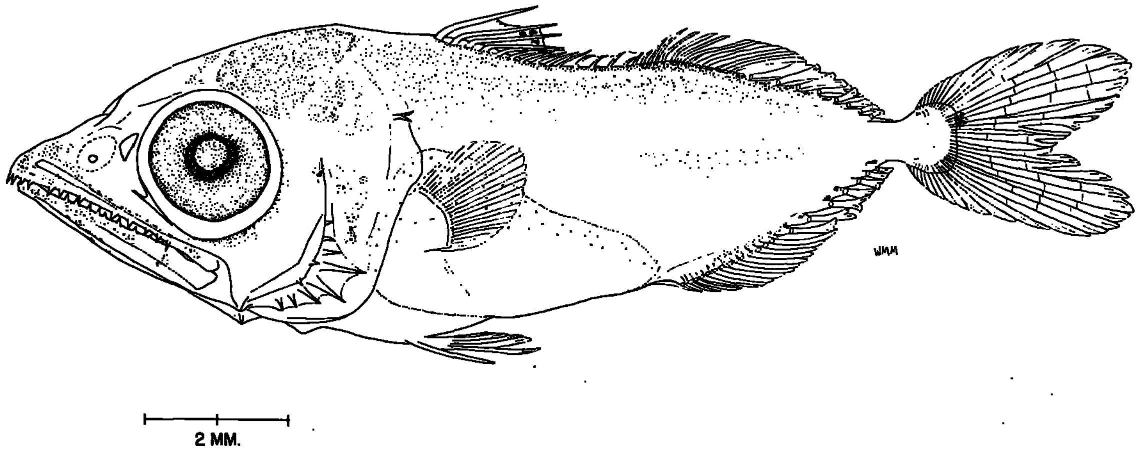

FIGURE 17.—*Katsuwonus pelamis*, 14.5 mm. total length.

percent of total length) than in the previous specimens. The abdominal sac is elongate, and the anal opening is very close to the insertion of the anal fin.

The nostrils are further differentiated, with the round, anterior nostril about one-fifth the size of the triangular, posterior one. The mouth is relatively smaller, 57.9 percent of the head length, and bears about 15 teeth on the upper jaw and about 17 teeth on the lower jaw. Six teeth are also evident on the palatine bone.

The dorsal fin has 16 spines, 15 rays, and 8 finlets, and the first dorsal has assumed the characteristic concave outline of the adult fin. The pelvic fins are very well developed and appear to be a little more posterior than on previous specimens. The pectoral fins have 20 rays, while the well-forked caudal has 22+22 rays.

There are 20 precaudal and 21 caudal vertebrae. The first haemapophysis appears on the 8th or 9th vertebra, while the first completely closed haemal arch is on the 12th. Neither the inferior foramina nor the large haemal arches, which form what Kishinouye (1923) calls the "trellis" and Godsil and Byers (1944) call a "complex basket work," are developed.

Pigmentation is more extensive in all areas described on previous specimens. The chromatophores over the snout have increased in number and line the entire length of the upper jaw. Similarly, two-thirds of the length of the lower jaw is also lined with chromatophores. The midbrain is completely covered with dark, very-closely set chromatophores, and the small patches over the forebrain and on the side of the head immediately posterior to the brain are more intense. The 7 or 8 chromatophores on the surface of the opercle, posterior to the eye, are very large and noticeable. The pigmentation along the posteroventral margin of the orbit is also more intense and extends along nearly half the circumference. Dorsally, the band of chromatophores on the caudal trunk is much wider. It tapers posteriorly and finally terminates near the base of the 5th dorsal finlet. Six or seven darkly pigmented spots are present on the outer edge of the interradial membranes of the first dorsal fin between the 2d and 6th spines. The base of the anal fin is lined with tiny chromatophores, and 3 fairly large chromatophores are present at the bases of the first 3 anal finlets. A band of small chromatophores is also present on the midlateral line beginning at a vertical through the second dorsal insertion and extending to a vertical through the base of the 4th dorsal finlet. The single, large chromatophore at the midventral line of the caudal peduncle still persists, as do the large chromatophores over the dorsal half of the abdominal sac.

A 20.0-mm. specimen, which is not illustrated, was taken at a night-light station in Kingman Reef lagoon, and this individual already shows the characteristic appearance of the juvenile form. The body is narrow and long, with the greatest depth located at a vertical through the pelvic-fin insertion and equal to about one-fourth the total length. The head length is about one-third the total length; and the snout still retains

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the rather sharply pointed profile. Except for the increase in pigmentation over the body, this specimen resembles the 14.5-mm. one very closely. A stained specimen of a similar size shows the dorsal fins with 16 spines, 15 rays, and 8 finlets, and the anal fin with 15 rays and 7 finlets. The pectoral fins consist of 20 or 21 rays and the caudal fin has 22+22 rays. The vertebrae number 20 precaudals and 21 caudals, with the first haemapophysis on the 9th and the first closed haemal arch on the 11th vertebra. The inferior foramina are just beginning to form on the 13th through the 22d vertebrae, but they are not yet completely closed.

This description agrees very closely with Schaefer and Marr's (1948b) 21-mm. specimen and also with Kishinouye's (1926) 26-mm. specimen. Examination of other stained specimens (22 mm., 27 mm., 33 mm., and 49 mm.) shows that many of the adult complement of meristic characters have appeared by the time the species has reached 27 mm. in length. The inferior foramina are completely closed on the 14th through the 33d and 34th vertebrae in the 27- and 49-mm. specimens, respectively. The foramina are slightly increased in size on the latter specimen, but the trellis is still not evident.

LITTLE TUNNY (*EUTHYNNUS YAITO*)

No specimen of *E. yaito* was recognized in our collections. The following description is based on more than 100 larvae, believed to be *Euthynnus*, which were taken in East Indian waters during the *Dana* Expedition of 1928–30. The largest specimen (12.25 mm.) has 39 vertebrae and seems identical in external appearance to the two *E. lineatus* (21 and 26 mm.) taken by the California Department of Fish and Game from the waters off Costa Rica and also to the juveniles of 20 *E. alletteratus* (25 to 55 mm.) taken by the U. S. Fish and Wildlife Service, Gulf Fisheries Investigations, from the Gulf of Mexico. That the larva is definitely not *E. lineatus* can be seen from the vertebral count, for *E. lineatus* normally has only 37 vertebrae. Positive identification, either as *E. yaito* or *E. alletteratus*, would be relatively easy if the gill rakers were fully developed. Since they are not, the larva was designated as *E. yaito* because this species occurs in the central and western Pacific Ocean, while *E. alletteratus* is found in the Atlantic Ocean and the Mediterranean Sea.

The smallest specimen identified as *E. yaito* measures 4.6 mm. in total length (fig. 18). The head length is moderate (33.9 percent of the total length) and there are 40 myomeres. The abdominal sac is nearly triangular in shape, as in the two previous species.

The mouth, representing 71.9 percent of the head length, is fairly large and contains 12 and 9 teeth on the upper and lower jaws, respectively. The snout is comparable to that of *K. pelamis* of similar size, and the distance from its tip to the anterior edge of the orbit is almost equal to the diameter of the orbit. There are 3 long spines along the posterior edges of the preopercle, the one at the angle being the longest.

Most of the median fins show very little development, there being about 4 or 5 rays in the caudal and only strong striations representing rays in the

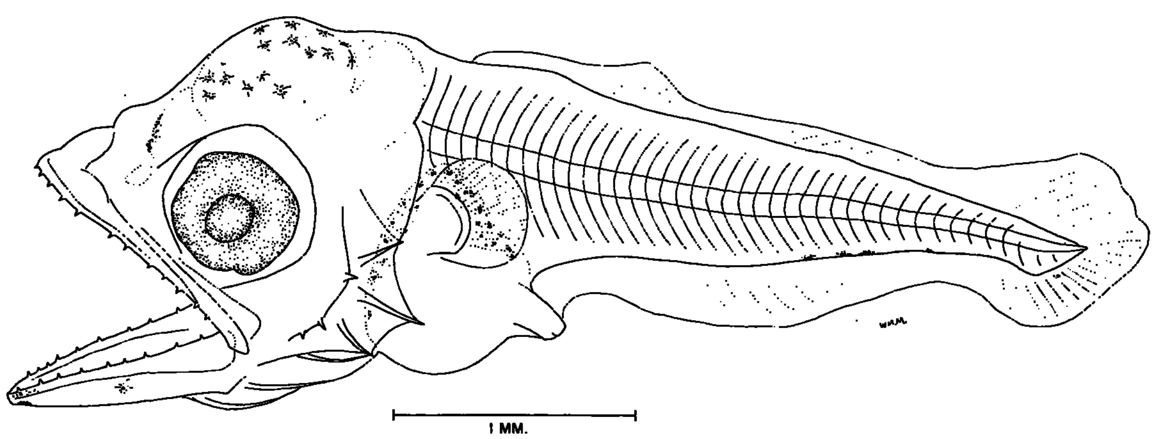

FIGURE 18.—*Euthynnus yaito*, 4.6 mm. total length.

region of the future anal and dorsal fins. The pectoral fins also show only striations, and the pelvic fins are absent.

The pigmentation on the head consists of 3 small chromatophores over the forebrain and about 15 chromatophores over the midbrain. There is a single small chromatophore at the middle of the mandible and another at the symphysis of the pectoral girdle, which is not shown in the drawing. There is no pigmentation along the dorsal edge of the trunk, but 5 chromatophores are present along the ventral margin of the trunk near the caudal region.

A 5.5-mm. specimen (fig. 19) shows marked changes. The proportions of the head, snout, and mouth closely resemble those of *K. pelamis* (see table 4, p. 53). The mouth now contains 13 and 15 teeth in the upper and lower jaws, respectively, and the preopercular spines have increased to 6.

There are 5 short spines in the first dorsal fin and about 9 rays in the caudal. The rest of the median fins and the pectorals still show only strong striations. The pelvic fins are just emerging as small buds.

Pigmentation is more extensive over the midbrain and over the abdominal sac. There is also an increase in the number of chromatophores at the tip of the snout and lower jaw, and the single chromatophore at the middle of the mandible and that at the pectoral symphysis are still evident. In addition, 2 small chromatophores are present on the ventral midline just anterior to the anus, and a single conspicuous chromatophore is present in the first dorsal fin. The dorsal midline of the trunk is still free from pigmentation, while the ventral midline shows 3 well-separated chromatophores in the region of the future anal finlets.

Some noticeable changes are present on the 7.6-mm. specimen (fig. 20), the most prominent

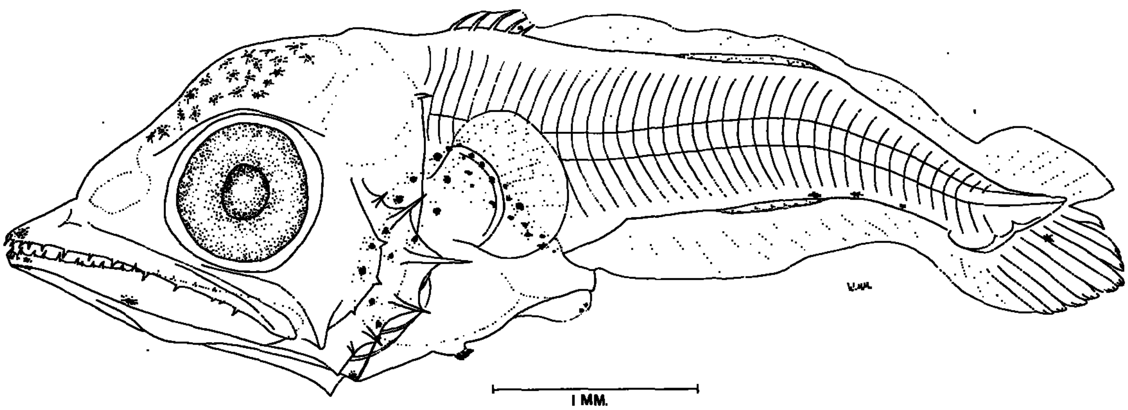

FIGURE 19.—*Euthynnus yaito*, 5.5 mm. total length.

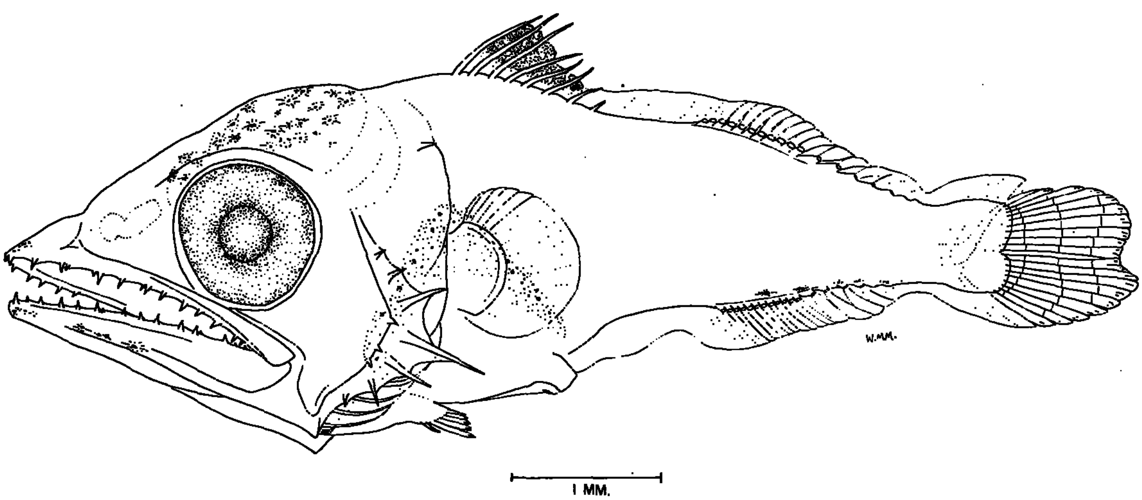

FIGURE 20.—*Euthynnus yaito*, 7.6 mm. total length.

of these being in the pigmentation. The first dorsal fin is almost completely pigmented and the anterior half of the mandible bears a series of 4 or 5 chromatophores.

The head is still large (39.8 percent of the total length) and the length of the snout is much greater than the diameter of the orbit. There are about 16 teeth on both the upper and lower jaws, and 7 spines are noticeable on the posterior edge of the preopercle.

The first dorsal fin has 8 spines, the length of the longest spine being slightly less than half the distance between the dorsal-fin insertions. The second dorsal and anal fin rays are beginning to form and, while the rays themselves are not clearly evident, there appear to be about 11 radials in the second dorsal and 12 in the anal. The radials of the first 7 dorsal finlets and first 6 anal finlets are also evident. The caudal fin shows 9+9 rays, and the pelvic fins, although very small, are complete with 1 spine and 5 rays. Only about 5 rays are noticeable in the pectoral fins. The myomeres remain the same (40 or 41) as in the previous specimen.

A 9.6-mm. specimen (fig. 21) already shows a close resemblance to the juveniles of *E. lineatus* (21 mm.) and *E. alletteratus* (25 mm.), insofar as pigmentation is concerned. The first dorsal fin is heavily pigmented, and the pigmentation at the tip of the snout is more extensive. The number of chromatophores along the lower jaw has increased and chromatophores now extend over two-thirds of the length of the mandible. The chromatophore at the symphysis of the pectoral girdle still persists, and the pigmentation over the rest of the body remains unchanged.

The relative sizes of the head, snout, and mouth are somewhat smaller than those of *K. pelamis* and *N. macropterus*, and only 6 spines are evident along the preopercular edges.

There are 13 spines in the first dorsal fin, the length of the longest spine being greater than half the distance between the dorsal-fin insertions. The second dorsal and anal fins each contains 13 rays. The finlets are poorly developed, but 8 and 7 finlet radials are clearly evident in the dorsal and anal, respectively. The rest of the fins also show an increase in the number of rays.

The largest specimen (not figured) in the series measures 12.25 mm. (tables 4 and 5). Its head is large (40 percent of the total length) and the length of the snout is greater than the diameter of the orbit. The mouth is also large, much more so than in *K. pelamis* and *N. macropterus*, and contains 25 and 28 teeth in the upper and lower jaws, respectively. Staining with alizarin revealed 39 (20+19) vertebrae.

The unpaired fins now have their full complement of spines and rays, with 15 spines in the first dorsal and 14 rays in the second dorsal, and 8 dorsal finlets. The anal fin contains 14 rays and 7 finlets. The longest spine in the first dorsal fin measures about half the distance between the first and second dorsal-fin insertions.

The entire first dorsal fin from the first to the tenth spine is completely pigmented. Small chromatophores are present along the base of the first dorsal fin and over the nape. A series of 4 widely

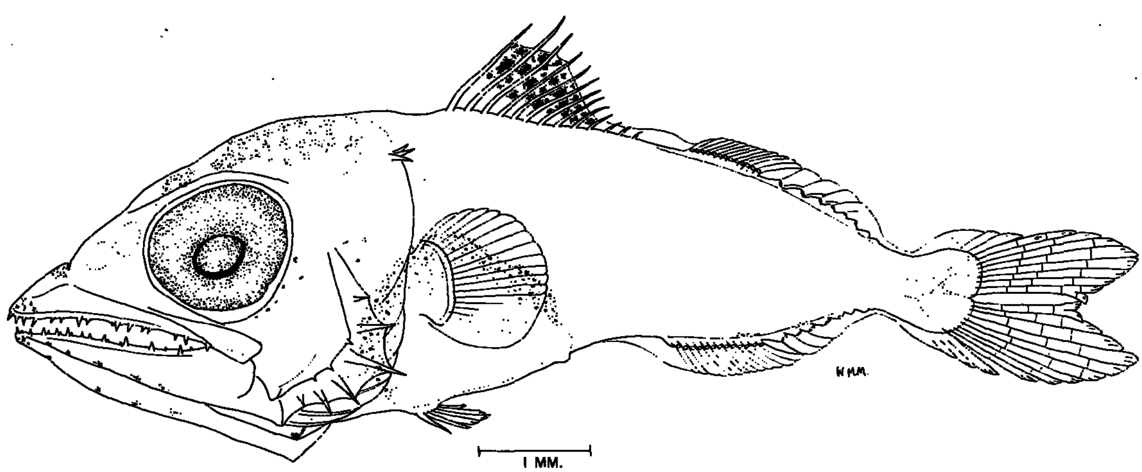

FIGURE 21.—*Euthynnus yaito*, 9.6 mm. total length.

spaced chromatophores is seen along the posterior base of the second dorsal fin and the bases of the first 3 finlets. Similar pigmentation is also present at the bases of the last 3 anal rays and the first 3 finlets. The lower jaw contains 8 well-spaced chromatophores distributed over its entire length, while the rest of the pigmented areas remain as in the 9.6-mm. specimen.

This last specimen has the same pigmentation as the 21-mm. and 26-mm. specimens of *E. lineatus* taken from the waters off Costa Rica by the California Department of Fish and Game. The only major difference is in the number of vertebrae, 37 (20+17), for the 21-mm. Costa Rican specimen as compared with 39 (20+19) for the 12.25-mm. specimen just described.

FRIGATE MACKEREL (*AUXIS THAZARD*)

Of the 38 specimens of *A. thazard* taken by the *Hugh M. Smith* (table 3), only a few specimens were in suitable condition to permit accurate reproduction. Consequently, specimens from the *Dana* collection from the East and West Indies and the Gulf of Panama were used to complete the series.

The 3.7-mm. specimen (fig. 22) described here as probably *A. thazard* is typical of the other specimens in the group ranging from 2.5 to 4.0 mm. in table 3. It has a short head with a very elongate body containing 39 myomeres and tapering very gradually toward the caudal end. The abdominal sac is triangular in shape with the anus located well forward of the middle of the total body length. The greatest depth of the body is at the symphysis of the pectoral girdle, where it is about one-fourth of the total body length.

TABLE 3.—*Number and size range of larval* Auxis thazard *collected by the* Hugh M. Smith *in Hawaiian and equatorial waters*

[See figs. 1 and 2 for location of stations]

Cruise and station	Number of larvae	Size range (mm.)
HAWAIIAN WATERS:		
Cruise 6:		
No. 1A	1	3.6
No. 7	1	6.2
No. 8	4	2.5–8.2
No. 10	10	2.7–3.7
No. 11	2	7.02, 8.1
No. 13	12	3.0–5.2
Total	30	2.5–8.2
EQUATORIAL WATERS:		
Cruise 5:		
No. 21	2	2.6
No. 51	2	4.2, 5.5
Cruise 14:		
No. 26	1	3.6
No. 29	1	3.1
Cruise 15: No. 3	1	7.2
Cruise 18: No. 31	1	4.0
Total	8	2.6–7.2

Since the snout is distorted, no comparisons of the head parts can be made. However, the snout appears very short and blunt and the mouth contains only 5 teeth, 3 on the upper jaw and 2 on the lower. Only 3 preopercular spines are noticeable, the middle one at the angle being the longest. Two small spines are also present on the preopercular surface.

The median fins are represented by a continuous fin membrane which starts at the nape and goes completely around the caudal end to a point slightly anterior to the anal opening. The pectoral fins are also membranous.

The pigmentation is most striking along the ventral midline of the caudal trunk, where 9 small, dark chromatophores are present. While the figured specimen shows a dark chromatophore on the dorsal midline of the caudal peduncle and 2

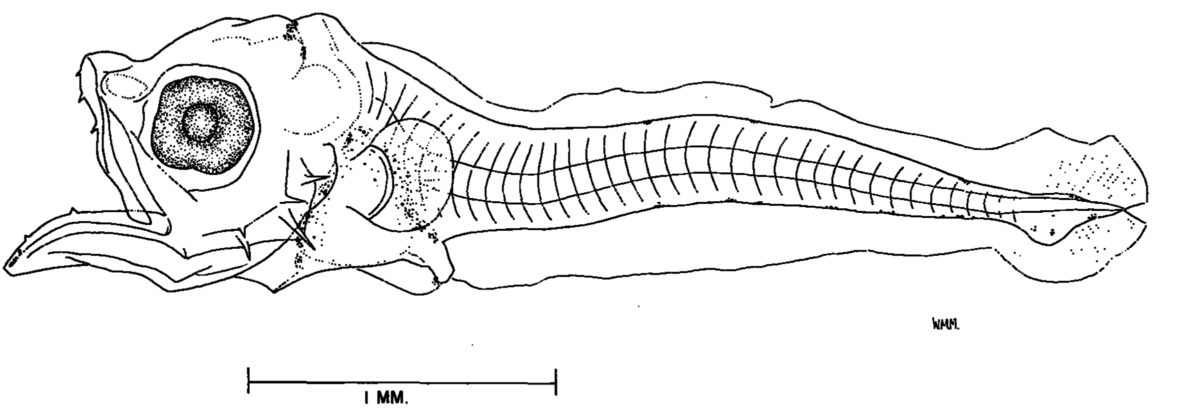

FIGURE 22.—*Auxis thazard* (?), 3.7 mm. total length.

more well-spaced and very light chromatophores near the middle of the body on the dorsal edge, other specimens show only the one on the caudal peduncle. On some specimens even this single chromatophore is absent. Several dark chromatophores are present along the posterior margin of the midbrain, and the very small chromatophores at the tip of the lower jaw are barely noticeable. The abdominal sac is pigmented regularly as in the other species, with most of the pigmentation concentrated along the anterior and dorsal surfaces. A single conspicuous chromatophore is present just anterior to the anal opening, and in this specimen the symphysis of the pectoral girdle does not show any pigmentation.

The smallest specimen identified confidently as *A. thazard* measures 4.5 mm. (fig. 23). The head is moderate (34.2 percent of the total body length) and the body contains 40 myomeres. The snout is short, slightly over three-fourths of the diameter of the orbit, and the mouth is moderately large and measures almost two-thirds of the head length. There are 5 small teeth on the upper jaw and 4 on the lower. The posterior edge of the preopercle bears 3 spines, the longest one located at the angle.

The pigmentation on the head consists of 6 large chromatophores over a small area of the midbrain and a faint tinge of pigment at the tip of the lower jaw. A single chromatophore is present at the symphysis of the pectoral girdle and another just anterior to the anus. The triangular abdominal sac is pigmented regularly, similarly to the three preceding species. A series of 2 to 3 chromatophores is present along the middorsal, midlateral, and midventral lines of the caudal region. In addition, 7 well-spaced chromatophores are present on the posterior half of the trunk along the midventral line.

The unpaired fins are represented by a continuous membrane and except for the caudal fin, where 10 rays are evident, none of the others shows any fin rays. The pectoral fins are also membranous and the pelvic fins are absent.

Only a few changes are noticeable on a 5.5-mm. specimen (fig. 24). The head is small and the moderate mouth, representing 60.3 percent of the head length, contains 12 teeth on each jaw. The snout is somewhat pointed and the distance from its tip to the anterior edge of the orbit is about four-fifths the diameter of the orbit. There are 6 spines along the edge of the preopercle and a small spine is visible in the posttemporal region.

The fins, except for the pelvics, which appear as small buds, show relatively little change from the specimen described above.

The pigmentation on the head consists of about 13 chromatophores which are closely grouped over the midbrain, the rest of the head being unpigmented. The abdominal sac remains the same as in the previous specimen. A series of 2 to 4 chromatophores is present along the middorsal, midlateral, and midventral lines of the caudal region. In addition, 2 widely spaced chromatophores are present along the ventral midline anterior to the caudal peduncle.

Further changes are apparent on a 7.05-mm. specimen (fig. 25). The head is slightly larger and the anus is at the middle of the total length of the body. The snout is pointed and is almost equal in length to the diameter of the orbit. The mouth is large and represents 61.4 percent

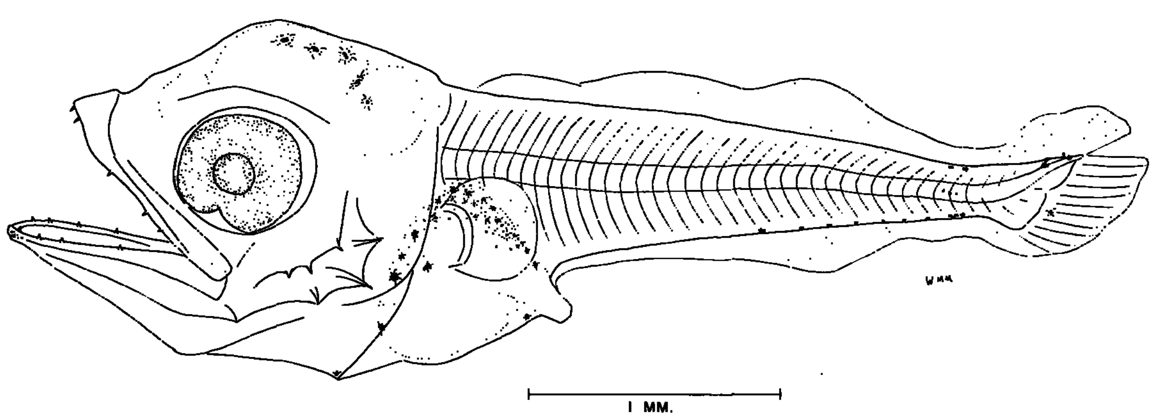

FIGURE 23.—*Auxis thazard*, 4.5 mm. total length.

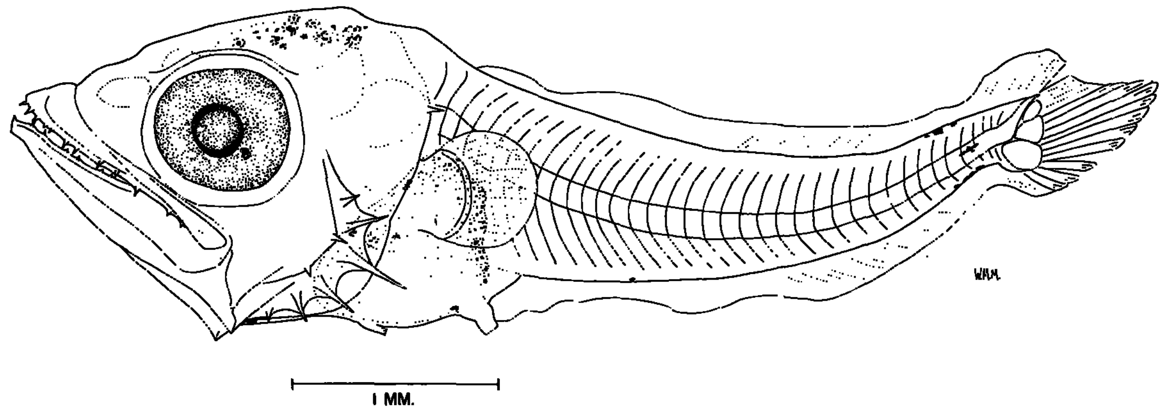

FIGURE 24.—*Auxis thazard,* 5.5 mm. total length.

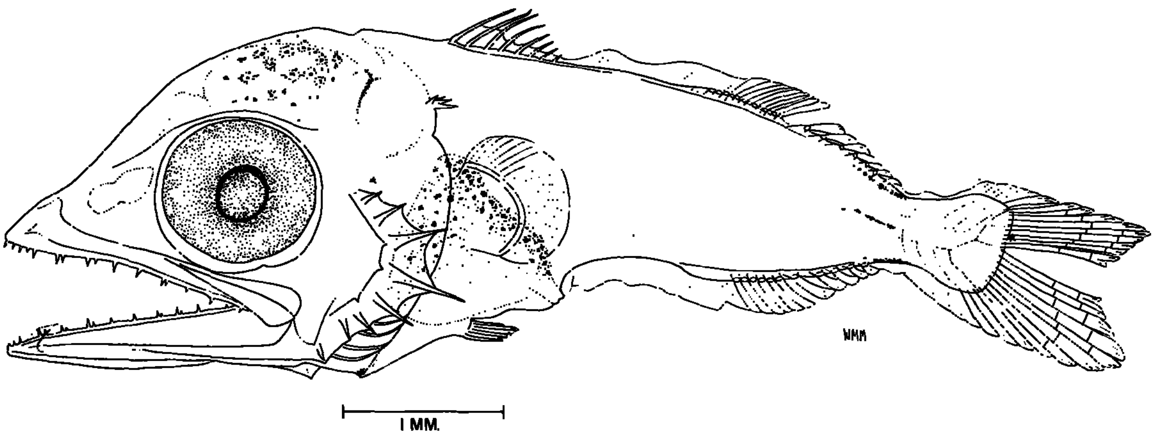

FIGURE 25.—*Auxis thazard,* 7.05 mm. total length.

of the head length. Sixteen to seventeen prominent teeth are present on each ramus of the upper and lower jaws, and 1 tooth is evident on the palatine bone. There are 7 preopercular spines: 2 spines on both the vertical and horizontal edges and 3 long spines at the angle, the middle one being the longest. The single posttemporal spine now has 4 prongs.

The first dorsal fin has 8 spines, the second through the fourth spines being longer than the first. The length of the longest spine is less than one-third the distance between the insertions of the first and second dorsal fins. About 10 rays are present in the second dorsal fin, followed by 6 or 7 dorsal finlets. The anal fin contains about 6 rays and 4 to 5 finlets, while the caudal fin with 10+11 rays is just beginning to fork. The pectoral fins have 7 rays, and the well-developed pelvic fins have 1 spine and 3 to 4 rays.

The pigmentation over the head and the abdominal sac is more extensive than on the previous specimen, and the chromatophores on the caudal region now number 6, 5, and 4 along the mid-dorsal, midlateral, and midventral lines, respectively. The chromatophore at the symphysis of the pectoral girdle is still present, but the single chromatophore anterior to the anal opening is absent. In addition to these, only 1 very faint chromatophore is present on the side of the head near the dorsal origin of the preopercle.

After staining, the 7.05-mm. specimen shows 11 completely ossified vertebrae. From the 12th through the 15th vertebrae only the bases of the neural and haemal arches are ossified. The urostyle is completely ossified, while the 2 preceding vertebrae are only partially so. There are 40 myomeres on this specimen.

Except for a slight increase in pigmentation, an 8.20-mm. specimen (not figured) shows development similar to that of the 7.05-mm. specimen just described. The most noticeable differences are the absence of the chromatophore at the symphysis of the pectoral girdle and the presence of a few small chromatophores on the first dorsal fin.

A 9.7-mm. specimen (fig. 26) has the same general appearance as the preceding specimen. The head (34.7 percent of the total length) appears small, while the anus is now located in the posterior half of the body.

There are 9 spines in the first dorsal fin, the length of the longest one being less than one-fourth the distance between the insertions of the first and second dorsal fins. There are 12 rays in the second dorsal followed by 8 dorsal finlets. The anal consists of 10 rays and 7 finlets. Each pectoral fin contains 15 rays, while the pelvics are complete with 1 spine and 5 rays. The caudal fin consists of 12 dorsal and 13 ventral rays.

Only slight changes are noted in the pigmentation, with 3 chromatophores present over the forebrain, 1 over the tip of the snout, and a few scattered chromatophores over the preopercle. The series of chromatophores along the middorsal line has increased to 16 and extends almost to the insertion of the second dorsal fin. Similarly, the chromatophores along the midventral line also have extended forward to the middle of the anal fin. The midlateral series contains 7 chromatophores.

The 11.2-mm. specimen (fig. 27) differs in several ways from the 9.7-mm. specimen. The head and snout appear much smaller than those of the three previous species. The mouth, however, is moderate (representing 58.6 percent of the head length) and contains 21 and 18 teeth on the upper and lower jaws, respectively. The anus has moved back still further, and the abdominal sac has become more elongate. The nasal depression has completely divided into two separate nostrils, the anterior one being associated with the nasal rosette.

The dorsal and anal fins and finlets have the full complement of spines and rays, and the

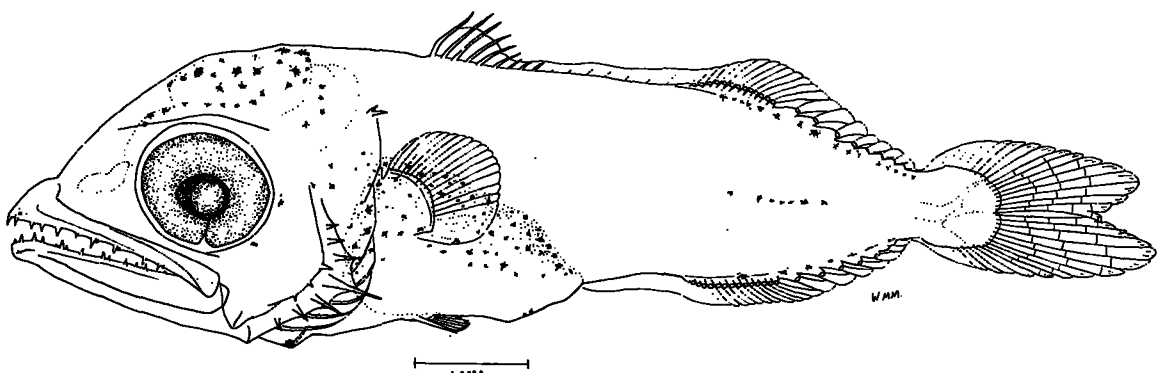

FIGURE 26.—*Auxis thazard*, 9.7 mm. total length

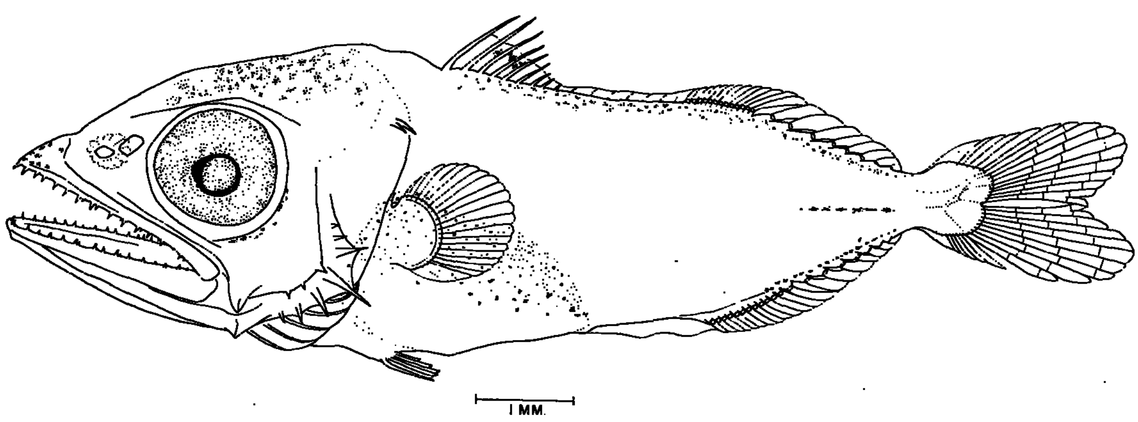

FIGURE 27.—*Auxis thazard*, 11.2 mm. total length.

length of the longest spine of the first dorsal fin is slightly less than one-third the distance between the first and second dorsal-fin insertions. The pectoral fins have 19 or 20 rays, while the caudal fin consists of 14+14 rays.

There are quite a few changes in the pigmentation at this size. The first dorsal fin contains 3 large chromatophores, and the pigmentation over the dorsal edge of the body now extends to the origin of the first dorsal fin. Other areas showing increased pigmentation are the snout, midbrain, and posteroventral margin of the orbit.

The 11.2-mm. specimen has 7 rather weak spines representing the future subcutaneous spines of the dorsal interspace (Schaefer and Marr, 1948a). The specimens of juvenile *A. thazard* measuring between 11 and 50 mm. from Costa Rica, Colombia, and the Galapagos Islands also have weak spines in the dorsal interspace. In many instances these spines project freely and are easily seen. On the basis of all characters considered, the larvae described here are identical with the juveniles of *A. thazard* from the coastal waters of Central America.

COMPARISON OF SPECIES

It is extremely difficult, if not impossible, to differentiate the larvae of various species of tuna by using the methods employed in identifying the adults. Measurements and meristic counts are not applicable because the larvae are undergoing rapid growth and differentiation. Development is apparently so rapid that even specimens of comparable sizes show marked differences in many characters.

During this study it was found that certain chromatophores and patterns of pigmentation persisted throughout the size ranges examined, and these markings seemed much more reliable than the other characters. Consequently, identification and description of the various species were based primarily on pigmentation, and the other characters were used only supplementally (tables 4 and 5).

TABLE 4.—*Comparison of body proportions among larvae of four species of tuna, by total length*

[Asterisk (*) indicates measurements not accurate; snout distorted in preservation]

Size group	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Euthynnus yaito*	*Auxis thazard*
Head length/ total length:	*Percent*	*Percent*	*Percent*	*Percent*
3 mm	*31.2	*28.3		*25.3
4 mm			33.9	34.2
5 mm	36.8	38.7	37.7	35.8
6 mm	32.4	38.5	41.7	33.0
7 mm	35.2	43.2	39.8	39.4
8 mm	36.4	41.3	38.8	
9 mm	37.9		33.5	34.7
10 mm		38.4		36.2
11 mm				36.3
12 mm			40.0	
14 mm	39.7	37.2		
Mouth length/head length:				
3 mm	*57.8	*69.7		*59.4
4 mm			71.9	65.4
5 mm	60.1	71.6	72.0	60.3
6 mm	57.0	68.2	66.0	63.1
7 mm	62.1	68.6	67.1	61.4
8 mm	60.5	66.0	61.3	
9 mm	61.9		59.1	56.9
10 mm		67.9		55.7
11 mm				58.6
12 mm			65.3	
14 mm	56.9	57.9		
Snout length/orbit diameter:				
3 mm	*65.0	*75.0		*66.7
4 mm			99.9	85.0
5 mm	68.9	103.6	103.6	81.5
6 mm	70.5	98.2	105.8	88.2
7 mm	86.2	94.1	117.4	90.7
8 mm	82.7	93.9	91.3	
9 mm	104.3		91.6	86.4
10 mm		103.4		78.6
11 mm				88.4
12 mm			112.9	
14 mm	100.6	87.5		
Total length of specimen:	*Mm.*	*Mm.*	*Mm.*	*Mm.*
3 mm	*3.90	*3.70		*3.70
4 mm			4.60	4.50
5 mm	5.50	5.35	5.50	5.50
6 mm	6.40	6.70	6.00	6.25
7 mm	7.15	7.10	7.60	7.05
8 mm	7.95	8.75	8.00	
9 mm	9.20		9.60	9.70
10 mm		10.90		10.90
11 mm				11.20
12 mm			12.25	
14 mm	14.25	14.50		

Among the four species described, *E. yaito* and *A. thazard* can be separated from *N. macropterus* and *K. pelamis* quite readily by the pigmentation of the body. Larvae of both species bear a single chromatophore at the symphysis of the pectoral girdle and another on the midline of the body just anterior to the anal opening. The occurrence of these chromatophores is somewhat variable, and in some instances either one of the two may be absent. Nevertheless, the presence of either one is quite conclusive evidence that the specimen is either *E. yaito* or *A. thazard*, since no other species examined has these chromatophores. Mead (1951), in his descriptions of *A. thazard* and *E. lineatus* from the Pacific coast of Central America, found that the chromatophore at the symphysis of the pectoral girdle was present in the majority of his specimens. Wade (1951) did not mention this chromatophore, but our examination of the larvae collected by him from Philippine waters showed it to be regularly present on specimens which he designated as *E. yaito* and *Auxis* sp.(?), and absent from *K. pelamis* and *N. macropterus*. Besides this character, *E. yaito* and *A. thazard*

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bear a series of chromatophores (3 or more) along the ventral midline of the caudal trunk.

Three, or possibly four, distinctive patterns of pigmentation permit the separation of *E. yaito* from *A. thazard.* The first dorsal fin is generally more heavily pigmented in *E. yaito.* The first sign of this pigmentation is seen on a 5.5-mm. specimen with the appearance of 1 faint chromatophore. When the species is about 7 mm. in length the distal half of the first dorsal fin appears black. The pigmented area increases with growth of the larva and the entire fin is almost completely pigmented at about 12 mm. In *A. thazard* this pigmentation does not start to appear until the species has attained a length of about 10 mm. An 11.2-mm. specimen has only 2 or 3 faint chromatophores near the distal edge of the fin membrane.

TABLE 5.—*Summary of the more prominent diagnostic characters of tuna larvae at various sizes, by species*

Character	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Euthynnus yaito*	*Auxis thazard*
	3.9 mm.	**3.7 mm.**	**4.6 mm.**[1]	**4.5 mm.**[1]
Teeth	Not clearly seen	4 upper; 6 lower	12 upper; 9 lower	5 upper; 4 lower.
Preopercular spines	3	3	3	3.
Myomeres	About 40	Incomplete	40	40.
1st dorsal spines				
1st dorsal fin outline				
Pigmentation:				
1st dorsal fin				
Middorsal line	No chromatophores	No chromatophores	No chromatophores	2 chromatophores on caudal peduncle.
Midlateral line	do	do	do	3 chromatophores on caudal peduncle.
Midventral line	do	1 chromatophore on caudal peduncle.	5 chromatophores on posterior half of body.	3 chromatophores on caudal peduncle; 7 to middle of body.
Tip of pectoral girdle	do	No chromatophores	1 chromatophore	1 chromatophore.
Anal opening	do	do	No chromatophores	Do.
Midbrain	4 chromatophores over small area.	10 chromatophores over large area.	15 chromatophores over large area.	6 chromatophores over small area.
Forebrain	No chromatophores	No chromatophores	3 chromatophores	No chromatophores.
Mandible (other than at tip)	do	do	1 chromatophore at middle	Do.
	5.5 mm.	**5.35 mm.**	**5.5 mm.**[1]	**5.5 mm.**
Teeth	8 upper; 4 lower	13 upper; 11 lower	13 upper; 15 lower	12 each jaw.
Preopercular spines	6	6	6	6.
Myomeres	38	41 or 42	40 or 41	About 39.
1st dorsal spines			5; longest spine <1/5 dorsal interspace.[2]	
1st dorsal fin outline				
Pigmentation:				
1st dorsal fin			1 chromatophore	
Middorsal line	No chromatophores	No chromatophores	No chromatophores	3 chromatophores on caudal peduncle.
Midlateral line	do	do	do	2–3 chromatophores on caudal peduncle.
Midventral line	do	1 chromatophore on caudal peduncle.	3 chromatophores at bases anal and finlets.	4 chromatophores on caudal peduncle; 2 near middle of body.
Tip of pectoral girdle	do	No chromatophores	1 chromatophore	1 chromatophore.
Anal opening	do	do	2 chromatophores	Do.
Midbrain	14 chromatophores over small area.	24 chromatophores over large area.	18 chromatophores over wide area.	13 chromatophores over moderate area.
Forebrain	No chromatophores	No chromatophores	3 chromatophores	No chromatophores.
Mandible (other than at tip)	do	do	1 chromatophore at middle	Do.
	7.15 mm.	**7.1 mm.**	**7.6 mm.**[1]	**7.05 mm.**
Teeth	10–11 upper; 6–7 lower	15 each jaw	16 each jaw	16–17 each jaw.
Preopercular spines	6	7	7	7.
Myomeres	40	41	40 or 41	40.
1st dorsal spines	7; longest spine <1/2 dorsal interspace.[2]	8; longest spine <1/3 dorsal interspace.[2]	8; longest spine <1/2 dorsal interspace.[2]	8; longest spine <1/3 dorsal interspace.[2]
1st dorsal fin outline				
Pigmentation:				
1st dorsal fin	6 chromatophores	1 chromatophore	Almost completely pigmented.	No chromatophores.
Middorsal line	No chromatophores	No chromatophores	No chromatophores	6 chromatophores on caudal peduncle.
Midlateral line	do	do	do	5 chromatophores on caudal peduncle.
Midventral line	do	1 chromatophore on caudal peduncle.	2 chromatophores—well separated.	4 chromatophores on caudal peduncle.
Tip of pectoral girdle	do	No chromatophores	1 chromatophore	1 chromatophore.
Anal opening	do	do	do	No chromatophores.
Midbrain	50+ chromatophores over small area.	50 chromatophores over large area.	45 chromatophores over entire area.	25 chromatophores over moderate area.
Forebrain	No chromatophores	2 chromatophores	3 chromatophores	No chromatophores.
Mandible (other than at tip)	do	1 chromatophore 1/4 distance from tip.	4–5 chromatophores over anterior half.	Do.

See footnotes at end of table.

TABLE 5.—*Summary of the more prominent diagnostic characters of tuna larvae at various sizes, by species*—Continued

Character	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Euthynnus yaito*	*Auxis thazard*
	7.95 mm.	**8.75 mm.**	**8.0 mm.**[1]	**7.7 mm.**[1]
Teeth	9–10 each jaw	16–18 each jaw	18 upper; 19 lower	15 upper; 17 lower.
Preopercular spines	7	7	7	7.
Myomeres	40	41–42	40	40–41.
1st dorsal spines	7	8 or 9	10; longest spine=⅔ dorsal interspace.[2]	6; longest spine=¼ dorsal interspace.[2]
1st dorsal fin outline				
Pigmentation:				
1st dorsal fin	Almost entire height to 6th spine.	6 chromatophores on outer fin edge.	Large chromatophores on outer ⅔ of fin.	No chromatophores.
Middorsal line	No chromatophores	6–8 chromatophores at base 1st dorsal; 1 at origin 2d dorsal.	No chromatophores	8 chromatophores on caudal peduncle.
Midlateral line	do	No chromatophores	do	4 chromatophores on caudal peduncle.
Midventral line	do	3 chromatophores at base anal; 1 on caudal peduncle.	2 chromatophores at bases anal and finlet.	6 chromatophores at bases anal and finlet.
Tip of pectoral girdle	do	No chromatophores	1 chromatophore	1 chromatophore.
Anal opening	do	do	No chromatophores	Do.
Midbrain	22 chromatophores over small area.	45+chromatophores over wide area.	About 46 chromatophores over entire area.	About 25 chromatophores over fairly large area.
Forebrain	No chromatophores	2–3 chromatophores	5–6 chromatophores	No chromatophores.
Mandible (other than at tip)	do	1 chromatophore ½ distance from tip.	5 chromatophores over anterior half.	Do.
	9.2 mm.	**10.9 mm.**	**9.6 mm.**[1]	**9.7 mm.**[1]
Teeth	12 each jaw	15 each jaw	17 upper; 19 lower	13 upper; 14 lower.
Preopercular spines	7	9	6	7.
Myomeres/vertebrae	13 ossified vertebrae (on 10.2-mm. specimen).	20+21 vertebrae (on 9.85-mm. specimen).	20+19 vertebrae (on 9.7-mm. stained specimen).	40 myomeres.
1st dorsal spines	10; longest spine=¾ dorsal interspace.[2]	13; longest spine <½ dorsal interspace.[2]	13; longest spine >½ dorsal interspace.[2]	9; longest spine <¼ dorsal interspace.[2]
1st dorsal fin outline	Slightly convex	Concave	Slightly concave	Convex(?).
Pigmentation:				
1st dorsal fin	Almost entire height to 8th spine.	Chromatophores on outer edge to 12th spine.	Distal ⅔ nearly completely black.	No chromatophores.
Middorsal line	No chromatophores	Chromatophores to 1st dorsal finlet.	No chromatophores	5 chromatophores on caudal peduncle; 11 chromatophores at bases 2d dorsal and finlets.
Midlateral line	do	6 chromatophores forward of caudal peduncle.	do	7 chromatophores on caudal peduncle.
Midventral line	do	4 chromatophores at bases anal and finlets; 1 on caudal peduncle.	2 chromatophores at bases anal and finlet.	3 chromatophores on caudal peduncle; 6 chromatophores at bases anal and finlets.
Tip of pectoral girdle	do	No chromatophores	1 chromatophore	1 chromatophore.
Anal opening	do	do	No chromatophores	2 chromatophores.
Midbrain	Chromatophores (number?) over small area.	80 chromatophores over large area.	23 chromatophores over large area.	About 25 chromatophores over large area.
Forebrain	No chromatophores	4 chromatophores	5 chromatophores	3 chromatophores.
Mandible (other than at tip)	do	1 chromatophore	4 chromatophores over anterior two-thirds.	No chromatophores.
	14.25 mm.	**14.5 mm.**	**12.25 mm.**[1]	**11.2 mm.**[1]
Teeth	13–14 each jaw	15 upper; 17 lower	25 upper; 28 lower	21 upper; 18 lower.
Preopercular spines	6	8	8	7.
Vertebrae	18+20 (on 12-mm. specimen)	20+21	20+19	Not observed.
1st dorsal spines	14; longest spine=⅗ dorsal interspace.[2]	16; longest spine=½ dorsal interspace.[2]	15; longest spine about ½ dorsal interspace.[2]	9; longest spine <⅓ dorsal interspace.[2]
1st dorsal fin outline	Convex	Concave	Concave	Convex(?).
Pigmentation:				
1st dorsal fin	Completely black	6 or 7 chromatophores on outer edge of fin.	First 10 spines black	3 chromatophores near distal edge.
Middorsal line	Band of chromatophores to 1st finlet.	Band of chromatophores to 5th finlet.	4 chromatophores at bases 2d dorsal and finlets.	Series of chromatophores from 1st dorsal origin to caudal peduncle.
Midlateral line	No chromatophores	Band of chromatophores from 2d dorsal to 4th finlet.	No chromatophores	7 chromatophores on caudal peduncle.
Midventral line	do	Band of chromatophores at bases anal and finlets; 1 on caudal peduncle.	4 chromatophores at bases anal and finlets.	Series of chromatophores from anal insertion to caudal peduncle.
Tip of pectoral girdle	do	No chromatophores	1 chromatophore	1 chromatophore.
Anal opening	do	do	No chromatophores	No chromatophores.
Midbrain	Numerous chromatophores over small area.	Numerous chromatophores over large area.	Numerous chromatophores over large area.	About 36 chromatophores over medium-sized area.
Forebrain	No chromatophores	12 chromatophores	5 chromatophores	4 chromatophores.
Mandible (other than at tip)	do	Chromatophores on ⅔ of length.	8 chromatophores over entire length.	No chromatophores.

[1] *Dana* Expedition collection.
[2] Distance between insertions of first and second dorsal fins.

The second character that separates these two species is the series of chromatophores along the mandible in *E. yaito*. The first indication of mandibular pigmentation is seen in the 4.6-mm. specimen, where a single chromatophore appears at the middle of the lower jaw. *A. thazard* lacks this pigmentation until it reaches a length of about 15 mm. The only other species which has pigment on the mandible is *K. pelamis*, but in our specimens this species showed only 1 chromatophore at about 7 mm., and this persisted unchanged until a length of 10.9 mm. had been reached. At 14.5 mm. the mandible of *K. pelamis* is well pigmented, but at this size other characters easily separated it from *E. yaito*.

Two other areas of pigmentation in *A. thazard* help to separate it from *E. yaito*. These are the dorsal and lateral edges of the body in the caudal region. The chromatophores on the middorsal line are always present in *A. thazard*, while those on the midlateral line appear indistinct among the specimens below 4.5 mm.

It should be mentioned that in *A. thazard* pigmentation of the caudal region varies considerably, especially on the midlateral line. A number of specimens measuring up to 7 or 8 mm. lacked this pigmentation (fig. 28). Whether they represent another species, *A. tapeinosoma*, is difficult to determine, since a complete series of larvae of this type could not be assembled. All other characters of these specimens lead us to believe that they belong to the genus *Auxis*.

Several excellent characters separate *N. macropterus* from *K. pelamis*. Between 8.0 and 14.25 mm., *N. macropterus* can be distinguished from *K. pelamis* by the almost completely pigmented first dorsal fin. This pigmentation is first noticeable on a 6.4-mm. specimen and is represented by a single, small chromatophore. *K. pelamis* also has some pigmentation on the first dorsal fin, which seems to develop much later than in *N. macropterus*, for only 1 or 2 very faint chromatophores are present in specimens measuring about 7 mm.

Another notable character of *N. macropterus* is the complete lack of pigmentation in the caudal region of the body until the larva approaches 14.0 mm. In the remaining three species described here, some pigmentation is present in the caudal region at all sizes.

The final character which is peculiar to *N. macropterus* is the complete absence of pigmentation over the forebrain on specimens of all sizes. In *K. pelamis* this pigmentation is present in specimens down to 7.1 mm. *N. macropterus* smaller than 7.15 mm. can be separated from *K. pelamis* by the small area of pigmentation over half or less than half the area of the midbrain, whereas in *K. pelamis* this pigmentation extends over almost the entire midbrain area. The only possible confusion in separating individuals of these two species measuring less than 7.15 mm. is in the rare cases where the chromatophore at the caudal peduncle of *K. pelamis* is absent. However, in such cases the relatively shorter snout and smaller mouth of *N. macropterus* (table 4), together with the difference in pigmentation over the midbrain, help to separate these two species.

Among *N. macropterus* larger than 9.2 mm., the outline of the first dorsal fin is definitely convex, and the longest spine of the fin is about three-fifths the distance between the first and second dorsal fin insertions (table 5). The fin outline of *K. pelamis* is concave in a 10.9-mm. specimen, and its longest spine is less than one-half the distance between the insertions of the first and second dorsal fins.

Larger specimens of *K. pelamis* can be most readily identified by staining the vertebrae. A count of 20 precaudal and 21 caudal vertebrae is

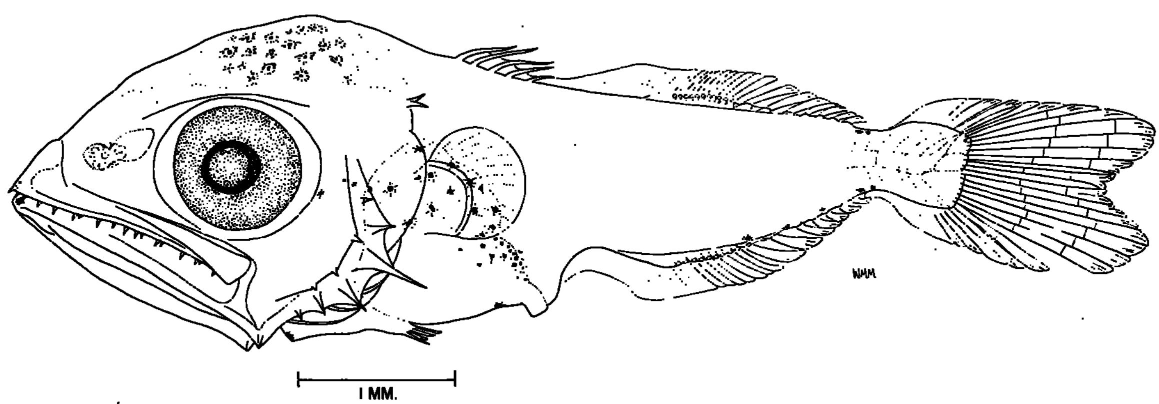

FIGURE 28.—*Auxis* sp. (?), 7.2 mm. total length.

definitive for this species, and this count can be obtained from specimens measuring only 9.85 mm. Where staining is not feasible, this species can be identified by the single distinct chromatophore at the ventral midline of the caudal peduncle throughout the entire size range. This chromatophore is absent only rarely, but at times there may be 2 instead of the usual 1. Moreover, *K. pelamis* between the sizes of 7.1 mm. and 10.9 mm. have a single chromatophore near the tip of the mandible in the smaller specimens and near the middle of the mandible in larger specimens.

K. pelamis smaller than 7.0 mm. can be distinguished from the other species by the single chromatophore at the midventral line of the caudal peduncle, by the larger mouth and longer snout, and by the large area of pigmentation over the midbrain. Forty-one or 42 myomeres can be counted on specimens of *K. pelamis* whereas other species have 41 or fewer.

DISTRIBUTION OF TUNA LARVAE IN THE CENTRAL PACIFIC

In the sections to follow we shall discuss mainly the distribution of the two species of tuna, *Neothunnus macropterus* and *Katsuwonus pelamis*, which comprise the bulk of our catch of tuna larvae, for the purpose of gaining some insight into the distribution and spawning habits of these fish. Included are discussions on horizontal and vertical distribution, species composition of the catches, and spawning areas and seasons as evidenced from the size composition of the catches. In addition to the identified larvae there is a small, unidentified group consisting in the main of small (less than 3 mm.) and damaged larvae. Since there is little reason to suppose this group contains additional species, this and the small group of *Auxis thazard* are not considered in the discussions on distribution and spawning seasons.

A vast area of the Pacific was sampled, extending from 25° N. to 15° S. latitude and from 120° W. to 180° longitude. The hydrography of this area was studied, and experimental fishing with longline gear (described in Niska 1953) also was conducted in the region between 14° N. and 9° S. latitude during the period when the plankton hauls were made.

Hydrographic observations in this region indicate a current system composed of a westerly flowing North Equatorial Current with its southern boundary varying with longitude and with season, but generally at about 10½° N. latitude; a westerly flowing South Equatorial Current with its northern edge at about 5½° N. latitude; and an easterly flowing Equatorial Countercurrent between the North and South Equatorial Currents. The width of the Countercurrent varies from 4° to 7½° and it shifts north and south over a distance of from 2° to 5° during different periods of time and at different longitudes (Cromwell 1954, table 1). These currents could have an important effect on the distribution of free-floating eggs and of newly hatched larvae, which are not yet capable of swimming about extensively.

HORIZONTAL DISTRIBUTION

Range of distribution

Approximate collecting locales for tuna larvae taken during 1950–52 are shown in figure 29. Each dot represents the occurrence of the designated species and has no quantitative connotation. Tuna larvae, both *N. macropterus* and *K. pelamis*, were taken as far north as 25° N. latitude in the vicinity of Midway Island, the most northerly area sampled during this period. Zooplankton collections presently being made in central Pacific waters up to about 45° N. latitude may show a further extension of the northern limit of larval-tuna distribution, for preliminary examination of zooplankton samples collected from this area (at 31° N. latitude along 143° W. longitude) during the winter of 1954 shows a few tuna larvae, too small for positive identification. South of the Equator, larvae have been taken at 14½° S. latitude in the vicinity of Samoa, the southernmost latitude at which a plankton station has been occupied by POFI vessels. In an east-west direction, larvae were taken at all longitudes sampled, from 120° W. to 180°. The area of larval occurrence as shown by the broken lines in figure 29 approaches 4 million square miles.

Latitudinal distribution of *Katsuwonus pelamis* and *Neothunnus macropterus*

The latitudinal distributions of the two species of tuna which comprise almost the entire larval-tuna catch in equatorial waters are plotted in figure 30, together with the corresponding adult catches on longline gear (the latter from Murphy and Shomura 1953a, 1953b). The north-south

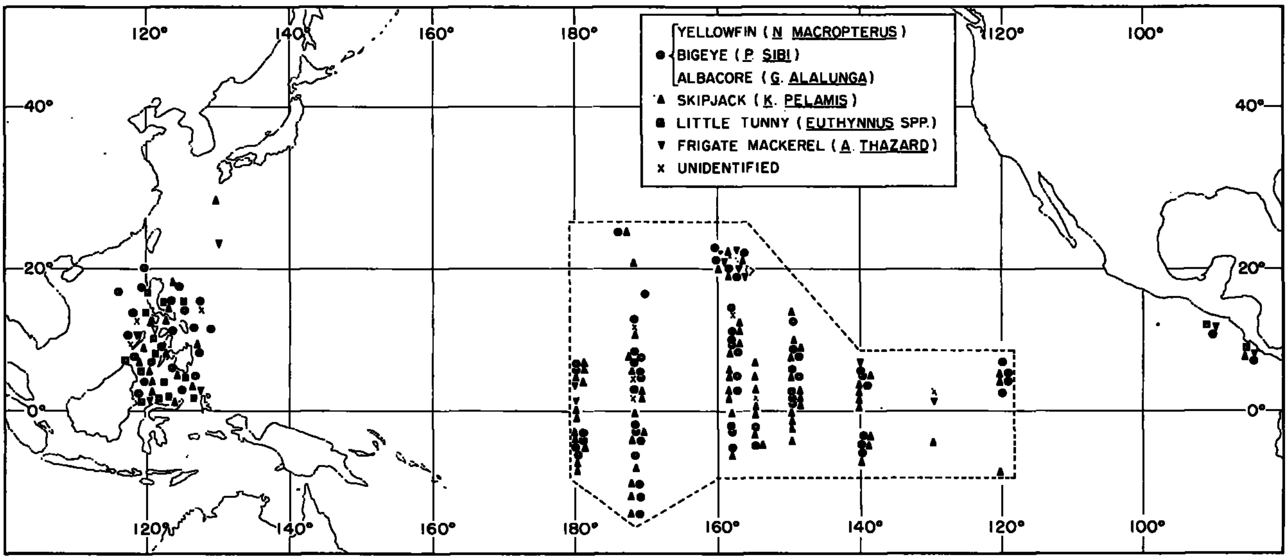

FIGURE 29.—Localities of capture of tuna larvae in the equatorial Pacific. Broken lines enclose area of POFI collections.

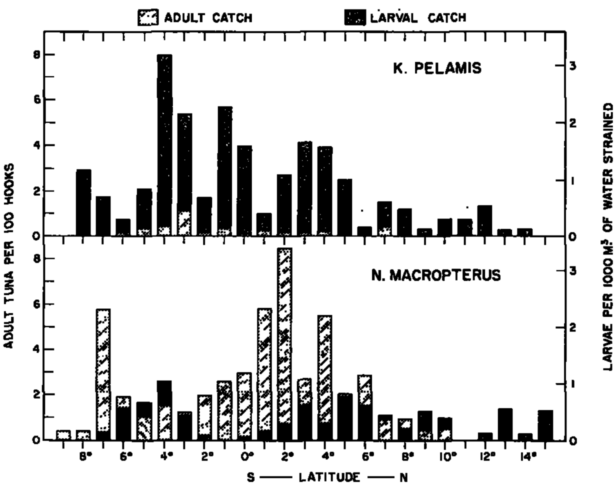

FIGURE 30.—Latitudinal distribution of the adult *Katsuwonus pelamis* and *Neothunnus macropterus*, as indicated by longline catch, and of the larvae.

range was limited by 14° N. and 9° S. latitudes in conformity with the range of fishing stations. The catch figures for both adults and larvae represent the averages of all the longitudes sampled during identical years.

Although our longline catches may not provide a true measure of the abundance of adult *K. pelamis*, they would seem to indicate that the distribution of these fish (fig. 30, upper panel) is somewhat skewed to the south, with the peak at 3° S. latitude. Larval abundance shows a similar trend, but the latitudinal range of the larvae exceeds that of the adults. This is understandable when we realize that fishing effort was reduced at the northern and southern extremities.

The adult *N. macropterus* catches (fig. 30, lower panel) present a different distribution pattern. There are two peaks, one is slightly north of the Equator and another at 7° south of the Equator. As explained by Murphy and Shomura (1953a, 1953b, and 1955) the tunas, especially *N. macropterus*, are perhaps indirectly associated with the phenomenon of upwelling that occurs along the Equator. Large catches of adult *N. macropterus* were made slightly to the north and south of the Equator where the upwelled water had aged sufficiently to allow populations of tuna forage to develop. The larval *N. macropterus* catches show a similar, but more pronounced, bimodal distribution which, although it is slightly displaced to the north, is likely related to the adult catches.

Longitudinal distribution of *Katsuwonus pelamis* and *Neothunnus macropterus*

Consideration of the larval-tuna catches (fig. 31) was limited to stations between 9° N. and 9° S. latitude, the zone in which there was the most concentrated fishing for adults, in order to compare the catches of larval and adult tuna.

It can be seen from the upper panel in figure 31 that the abundance of *K. pelamis* larvae seemed fairly uniform from 180° to 140° W. longitude and the adult abundance was uniform from 170° W.

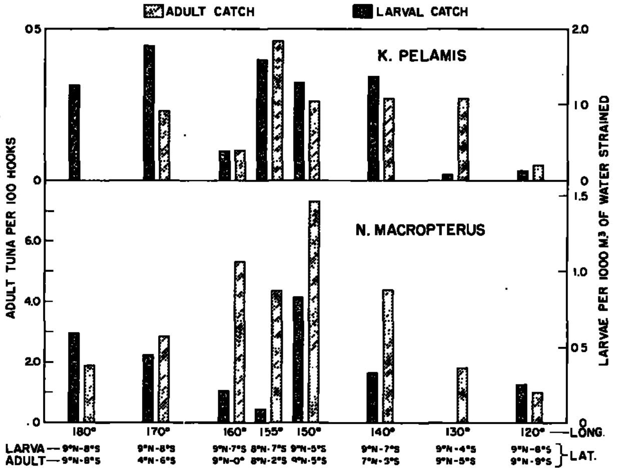

FIGURE 31.—Longitudinal distribution of the adult *Katsuwonus pelamis* and *Neothunnus macropterus*, as indicated by longline catch, and of the larvae for the area 9° N. to 9° S. latitude.

to 130° W. longitude, apart from the low catches of both larvae and adults at 160° W. longitude. The low catches of larvae at 130° W. and 120° W. longitude suggest that there is little spawning of *K. pelamis* in this region.

The adult *N. macropterus* distribution varied slightly from that of *K. pelamis* (fig. 31, lower panel), for they were found from 180° to 120° W. longitude with a peak at 150° W. longitude. The larval *N. macropterus* abundance also peaked at the 150th meridian, but aside from this there was little correspondence in the density of larvae and adults. The apparent absence of larvae at 130° W. longitude suggests that this longitude may be near the eastern limit of favorable *N. macropterus* spawning grounds. The salient feature of both *N. macropterus* and *K. pelamis* distribution is that, with the exception of *N. macropterus* along 130° W. longitude, tuna larvae were taken at all the longitudes where the adults were found.

West of 180° longitude the adults of *N. macropterus*, *K. pelamis*, and other tunas are caught all the way to the Asian coast. On the basis of the adult-larva relationship, it can be expected that tuna larvae will also be found in the region between 180° and the coast of Asia. This is not entirely supposition, for Wade (1950, 1951) has reported the capture of large numbers of these larvae from the waters surrounding the Philippine Islands. In the eastern Pacific, Schaefer and Marr (1948a, 1948b) and Mead (1951) found larval and juvenile tunas off the Pacific coast of Central America. The widely distributed records of larvae (fig. 29) together with the apparent parallels between adult and larval-tuna catch rates suggest that tuna larvae are generally distributed across the Pacific Ocean, although not necessarily with uniform abundance.

Records of larval-tuna captures in the Atlantic Ocean also seem to support the probability of a transoceanic distribution of tuna larvae. The Equatorial Current system roughly follows the same pattern in the Atlantic Ocean as in the Pacific Ocean, and tuna larvae have been taken (Ehrenbaum 1924) in a band of water between 32° N. and 7° S. latitude from the Cape Verde Islands to the coasts of Florida and Brazil (fig. 32).

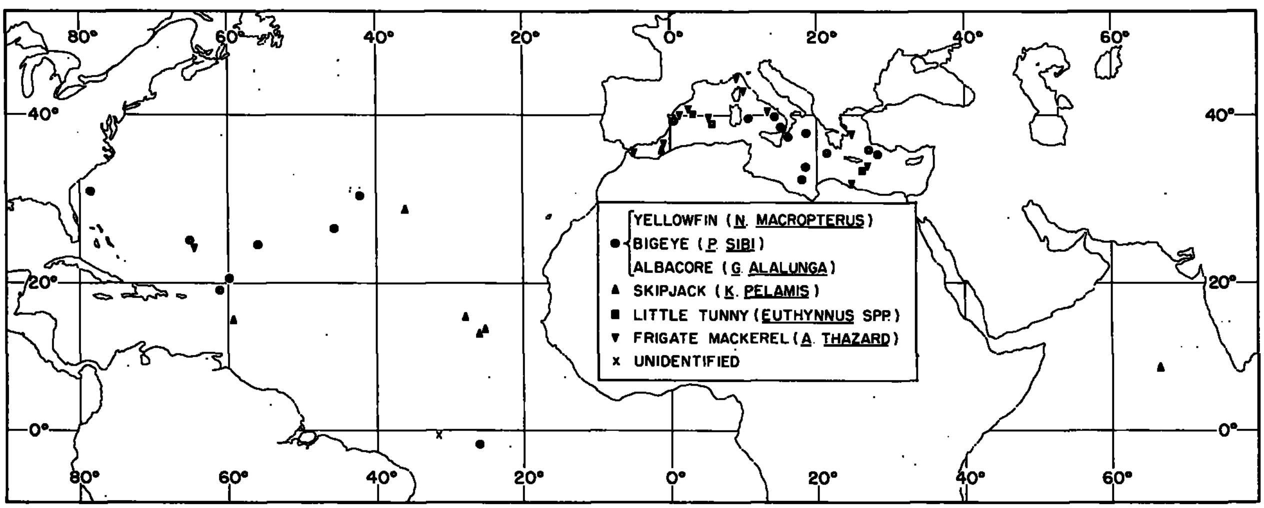

FIGURE 32.—Localities of capture of larval tunas in the Atlantic and Indian Oceans and in the Mediterranean Sea.

It is interesting to note that there are extensive records of larval tunas in the Mediterranean Sea and a record from the Indian Ocean.

VERTICAL DISTRIBUTION OF TUNA LARVAE

The data from cruise 6 of the *Hugh M. Smith* in Hawaiian waters (fig. 1) were used in studying the vertical distribution of tuna larvae. During each haul, 3 nonclosing nets, fishing at different depths, were towed simultaneously in a horizontal plane for 1 hour. At each station one of the following sets of towing depths was used: 0, 50, 150 meters; 0, 100, 150 meters; 0, 100, 200 meters; or 0, 150, 300 meters (appendix table 2, p. 68). The catches made on this cruise (table 6) show very clearly that tuna larvae are concentrated in the surface layers. Further, it is possible that all or most of the deep catches are contaminants, obtained while the nets were being raised and lowered.

TABLE 6.—*Abundance of tuna larvae in Hawaiian waters, per 1,000 cubic meters of water strained, for various depths and times of hauling*

[The figures in parentheses represent number of tows]

Time of tow	Depth in meters					
	Surface	50	100	150	200	300
Day	1.70(16)	0.42(4)	0.21(10)	0.08(8)	0.44(8)	0.36(2)
Night	8.49(9)	0.98(2)	0.55(4)	0.71(6)	1.18(3)	1.15(3)

The amount of contamination can be computed if the average concentration of larvae in the upper strata and the time spent by the net in passing through them are known.[2] It is interesting to note that, assuming the surface tows are representative of the upper 50 meters or the layer between the surface and the next shallowest net, contamination correction accounts for all of the deeper night catches and nearly all of the deeper day catches (fig. 33).

A vertical, diurnal migration of the larvae is suggested in the raw catches and is clearly shown when the surface tows are plotted according to the hour of hauling (fig. 34). (For the present, dodging is not considered; it will be shown later

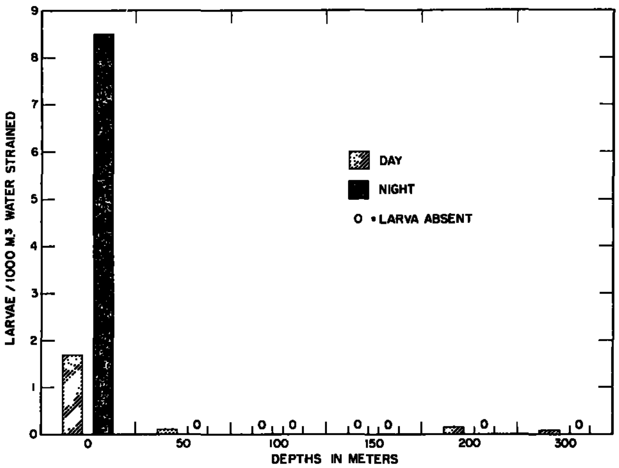

FIGURE 33.—Vertical distribution of tuna larvae from the Hawaiian area corrected for contamination, assuming that the surface hauls are representative of the upper 50 meters.

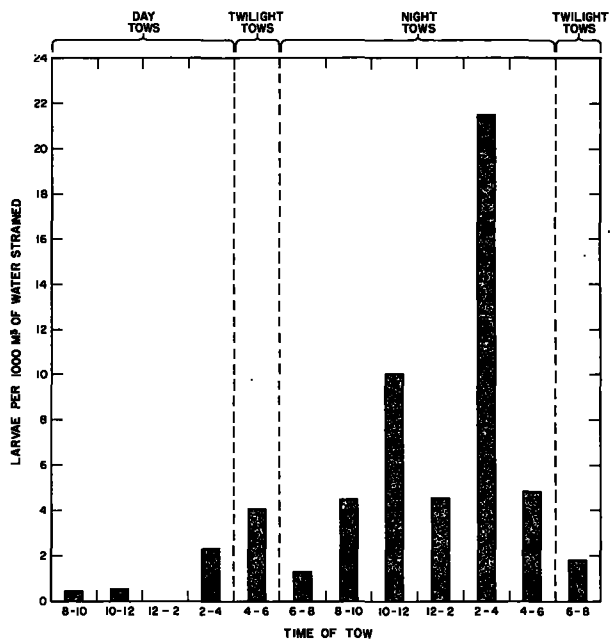

FIGURE 34.—Larval-tuna catch at various times of the day.

to be relatively unimportant.) Relatively poor catches were experienced during the day, when the larvae presumably were beyond the depth of the surface net. The catches increased after twilight as the larvae apparently migrated to the surface, the greatest catches being made between 10 p. m. and 4 a. m. The catches declined as the downward migration occurred with the approach of daylight.

The depth of the diurnal, vertical migration of

[2] The following formula was used to compute contamination:

$$\text{Average number of contaminants} = \frac{\text{Average time a lower net spent in surface layer}}{\text{Average total elapsed time of tows of the surface net}} \times \text{Average surface catch.}$$

The several amounts were then subtracted from the figures in table 6 and the corrected catches plotted in figure 33.

the tuna larvae cannot be specified, but its maximum can be inferred from our material. A large series of 200-meter oblique hauls in the equatorial region (table 7) shows no statistically significant diurnal variation ($t=1.421$, $P=0.14$), thus suggesting that migration may not occur down to 200 meters. That the migration is of even more limited scope is suggested by the corrected vertical distribution (fig. 33). If migration occurs down to 200 meters, then in the horizontal tows the day catches at the greater depths should be larger than the night catches and also they should be larger than the day catches at the surface. The fact that the subsurface catches are consistently less than the surface day catches suggests a migration which is probably limited to a depth of less than 50 meters, and the main concentration of larvae in the daytime occurred between the levels sampled by the surface and the 50-meter horizontal tows.

TABLE 7.—*Comparison of day and night catches of tuna larvae by 200-meter oblique tows in equatorial waters*

Time of tow	Number of tows	Larvae/1,000 m.³ of water strained
Day	49	1.50
Night	34	2.23

During the review of vertical migration and vertical distribution the problem of dodging was temporarily disregarded. It must be examined, however, and its effect considered because it can possibly bias comparisons of hauls between depths and between day and night. The presence or absence of dodging can best be examined in the 200-meter oblique tows, assuming that the net had passed through the entire vertical range of larval distribution, thus minimizing or possibly eliminating the effects of vertical migration in the catches. The night catches, although not significantly different from day catches, are about 1.5 times the latter (table 7), suggesting that dodging may have occurred. Even if the relatively greater catches in the night hauls were due to dodging, it will be noted from table 6 that the ratio of night to day catches at the surface is much greater (4.99: 1), suggesting a vertical migration, despite allowances made for the effects of dodging. Additional evidence in favor of vertical migration is provided by the relatively low night-day ratios at greater depths (table 6) as compared with the high ratio of the surface catches.

There is also little evidence in support of dodging when the frequency of captures of the larger larvae are considered, the implication here being that the larger larvae are more capable of dodging the net than are the smaller larvae. In the equatorial area, four larvae 10 mm. or larger were taken during the day and only one at night. In the Hawaiian area only two larvae over 10 mm. were obtained and these were taken at night.

Considering all the evidence, it appears that dodging may alter the catches but not enough to seriously bias our conclusions that most of the larvae live near the surface during both day and night, and that there is a vertical, diurnal migration through relatively shallow depths.

SPECIES COMPOSITION OF THE LARVAL CATCH

Our discussion of species composition is based entirely on catches from the equatorial area between 120° W. longitude and 180°, and 9° N. and 9° S. latitude so that the composition of the larval catch can be compared with that of adults from the same area. Three of the four species of tuna larvae described previously are represented in the plankton samples, while the larvae of two other species of tuna, *Parathunnus sibi* and *Germo alalunga*, either were not taken or were not recognized.

Of the three species of larvae identified (table 8), *A. thazard* constitutes an insignificant portion of the catch, 1.2 percent of the total number of tuna larvae. The *N. macropterus* and *K. pelamis* larvae comprise 22.5 and 59.2 percent, respectively. This is in contrast to the species composition of the longline catch of adults, 73.0 percent of which were *N. macropterus* and 4.4 percent *K. pelamis*. However, the longline catches probably do not provide a reliable estimate of the true abundance of *K.*

TABLE 8.—*Species composition of larval and adult tunas taken in equatorial waters*

Species	Larvae[1]		Adults[2]	
	Number taken	Percent of total catch	Number taken	Percent of total catch
Neothunnus macropterus	107	22.5	889	73.0
Katsuwonus pelamis	281	59.2	54	4.4
Auxis thazard	6	1.2		
Germo alalunga			68	5.6
Parathunnus sibi			206	16.9
Unidentified	81	17.0		
Total	475		1,217	

[1] Plankton hauls.
[2] Longline catches.

pelamis since the gear is designed and fished with the primary objective of capturing the much-larger, deep-swimming *N. macropterus*. Thus, the low catch figures for *K. pelamis* represent only a few chance catches made by the longline.

The predominance of *K. pelamis* larvae in the plankton catches presents an interesting indication of the probable adult concentration. If we assume that both species have the same fecundity and larval mortality, it would appear that the adult *K. pelamis* population is about two and one-half times that of the *N. macropterus*. However, it is known that the *K. pelamis* ovaries are smaller than the *N. macropterus* ovaries and contain fewer eggs; therefore, this estimate of the relative numerical predominance of *K. pelamis* is minimal. Thus, there is the possibility that a population of *K. pelamis* exists in this region of sufficient size to support a commercial fishery, if the schools can be located. To date, however, only a few schools, consisting mostly of small fish, have been observed and they have occurred mostly in the immediate vicinity of islands and atolls.

AREA AND LOCALITY OF SPAWNING

Most studies of spawning have been based upon observations on the condition of the gonads, and the spawning locality has been assumed to be near the site where females with running or nearly ripe eggs have been captured. This method is applicable to fishes with limited migratory movements or to those that are relatively weak swimmers. However, in the case of the tunas—fishes which possess tremendous swimming speed and range—the actual spawning site could be some distance from the locality in which adult females with nearly ripe gonads are taken. A more-nearly ideal approach to the problem of locating the spawning sites of these fishes would be to examine the less-motile stages in the life cycle, specifically the planktonic eggs and newly hatched larvae.

The present investigation was limited to the larval stages because it has not been possible to identify the eggs of the several tunas. Early larvae can be considered planktonic, and while they have limited powers of movement, it is reasonable to suspect that they do not stray very far from the actual spawning grounds. If this is so, then it can be hypothesized that the localities where tuna larvae are taken should represent the approximate spawning sites.

Three factors must be evaluated before this reasoning can be applied to our data to estimate the location of spawning grounds: (1) The size of the larvae at hatching; (2) the duration of the incubational period, throughout which the eggs are planktonic; and (3) the direction and velocity of the currents.

Determination of size of larvae at hatching.—Sanzo (1932, 1933), who observed the development of the embryo in the eggs of *Orcynus thynnus* and *Orcynus germo*,[3] reported that the larvae measured from 2.44 to 3.04 mm. in total length at hatching. The egg diameters for these two species were from 1.00 to 1.12 mm. for the former, and 0.84 to 0.94 mm. for the latter. Comparatively, the eggs from ripe gonads collected during POFI cruises measured from 0.83 to 1.08 mm. for *N. macropterus*, and from 1.00 to 1.21 mm. for *P. sibi*. *K. pelamis* eggs were from 0.55 to 0.80 mm. in diameter, but it is believed that this may represent a somewhat earlier stage of maturity. The largest egg that Brock (1954) found during his investigation of the biology of *K. pelamis* measured 1.125 mm. in diameter, and should be close to the size of the fully ripe eggs. If egg size has any bearing on size of the larvae at hatching, then newly hatched *N. macropterus* and *K. pelamis* should fall within the size ranges given by Sanzo for two species of tuna, that is, 2.44–3.04 mm.

Determination of duration of incubational period.—The embryonic development of six California fishes (Budd 1940) indicates that various pelagic species have incubational periods ranging from 90 to 264 hours, and that the eyed-embryo stage regularly appears at about the middle of the developmental period or slightly earlier. The latter observation is supported by illustrations presented by Kuntz and Radcliffe (1918) for the pelagic eggs of six species of fish. It seems that the appearance of the eyed-embryo is fixed rather definitely at about the middle of the incubational period. If this holds true for all pelagic eggs, then the incubational period for tunas could be approximated at not more than 4 days, since the eyed-embryo eggs collected by Sanzo (1932, 1933) hatched in less than 2 days.

[3] Sanzo probably followed Lütken's terminology. If so, *O. thynnus* (Linnaeus) represents "the more or less 'short-finned' genuine tunafish" and *O. germo* (Lacépède) represents the "more or less 'long-finned' " tunas (Lütken 1880). Thus, *O. thynnus* could be bluefin tuna and *O. germo* could be either yellowfin or albacore.

Direction and maximum velocities of currents in the central Pacific.—As stated previously, the North and South Equatorial Currents flow westward and the Equatorial Countercurrent flows eastward in this area. The maximum velocity of the North Equatorial Current during 1950–52 was 0.56 knots, while that of the South Equatorial Current was 1.55 knots, as measured on POFI cruises. The eastward-flowing Countercurrent showed a maximum velocity of 1.16 knots. (Current speed in knots was converted from figures in Cromwell 1951, 1954; Austin 1954; and Stroup 1954.) It is well to bear in mind that the velocity of each current varies considerably throughout the width of the current and at different longitudes (Cromwell 1954, figs. 21 and 27).

The implications in the foregoing discussions are that larvae measuring between 2.44 and 3.04 mm. would have been adrift a maximum of 4 days prior to their hatching, and that these larvae could have drifted westward a distance of about 50 or 150 miles, depending on whether they were in the North or the South Equatorial Current, or they could have drifted eastward a distance of about 100 miles if they were in the Equatorial Countercurrent. The maximum drift in terms of longitudinal distance is about 2½° westward and about 2° eastward.

In the present investigation larvae measuring between 2.50 and 3.90 mm. (which approximates the size of newly hatched larvae), presumed to be *K. pelamis* and *N. macropterus*, were taken at nearly all latitudes from 25° N. to 14½° S. (fig. 35), and also at nearly all longitudes sampled (fig. 36). They were caught at stations which generally were 5 to 10 longitudinal degrees apart and beyond the maximum drift to which these larvae could have been subjected. Thus, the presence of these newly hatched larvae along the various longitudes from 120° W. to 180° provides evidence that some spawning occurs throughout the area sampled.

TIME OF SPAWNING OF *KATSUWONUS PELAMIS* AND *NEOTHUNNUS MACROPTERUS*

Larval-catch data from equatorial waters for the years 1950–52 were segregated by months for each species, and the average catches from three bands of 10° of latitude, 5° N. to 14° N., 5° S. to 4° N., and 14° S. to 6° S. were then plotted to produce figure 37. The area was separated into such bands in order to see if there were seasonal spawning trends from north to south.

The plots show that *K. pelamis* larvae were found throughout the year and in fairly equal numbers each month between 5° N. and 14° N.

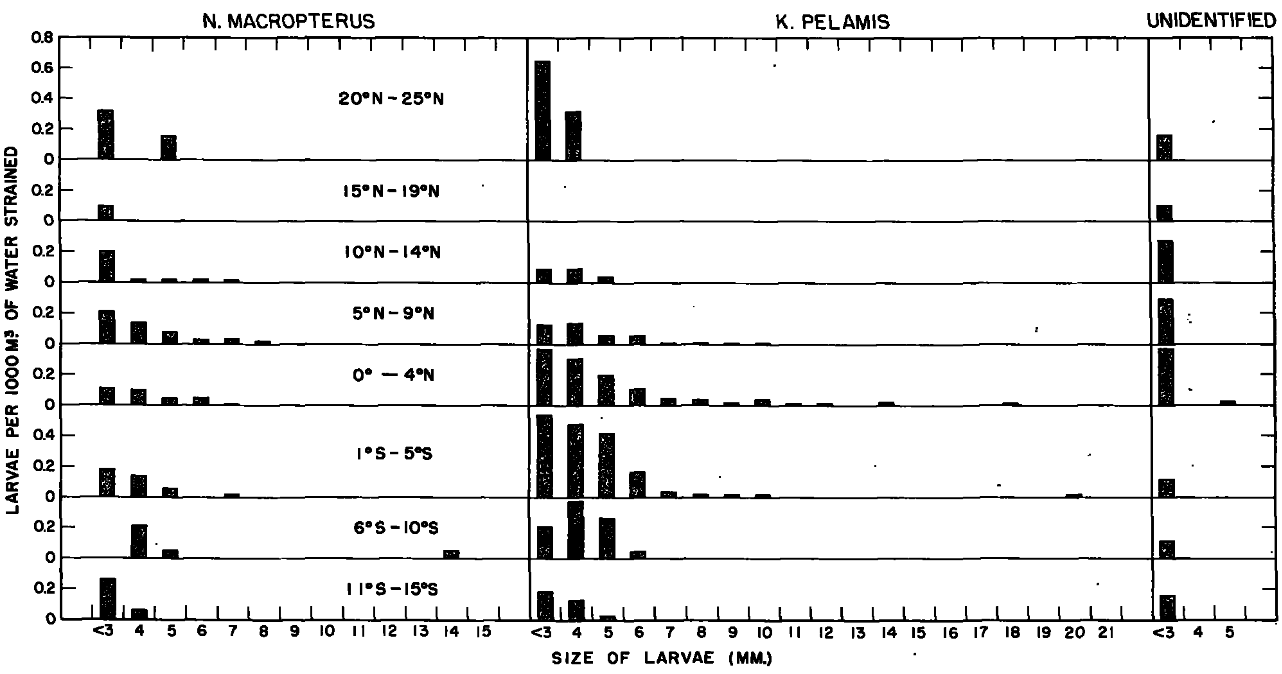

FIGURE 35.—Latitudinal variation in size composition of tuna larvae caught between 120° W. and 180° longitude.

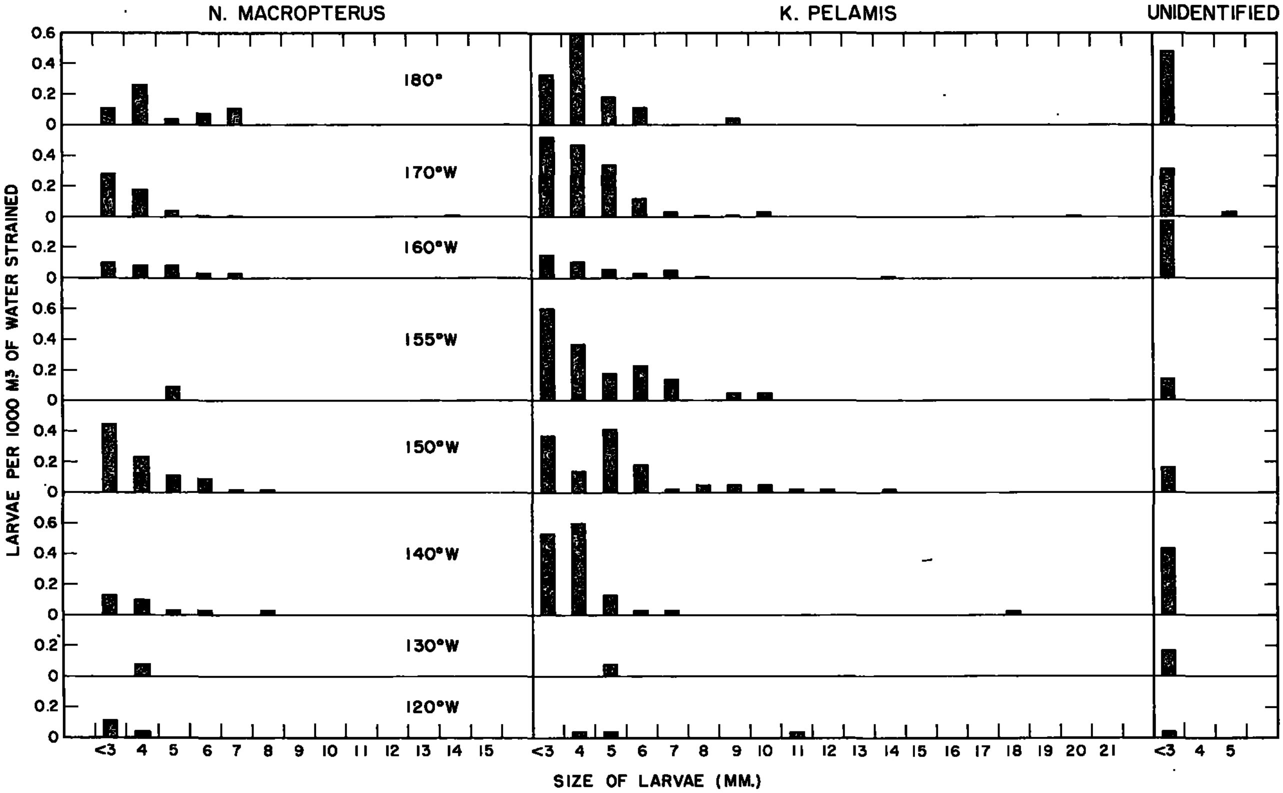

FIGURE 36.—Longitudinal variation in size composition of tuna larvae caught between 14° N. and 14° S. latitude.

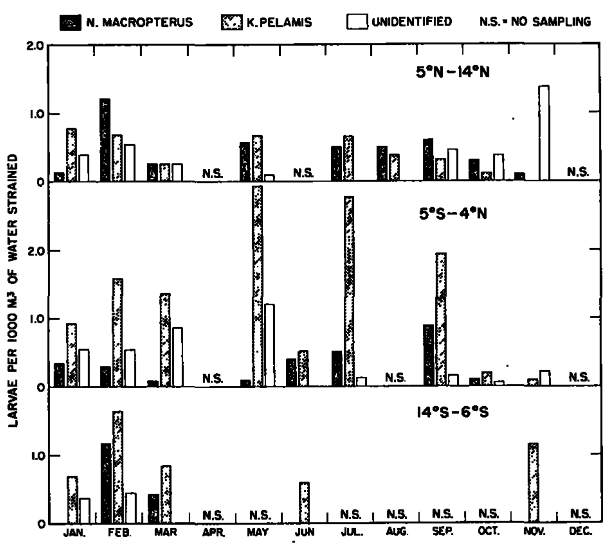

FIGURE 37.—Monthly catches of larvae in equatorial waters for three latitudinal zones, 1950 to 1952.

latitude. Substantially greater numbers of larvae occurred, however, between 4° N. and 5° S. latitude. Although this equatorial region produced *K. pelamis* larvae throughout the year, it showed a definite peak from May through September. South of 6° S. latitude larval *K. pelamis* were rather uniformly abundant; however, the catches do not represent enough months to permit a more specific interpretation. In general, it can be hypothesized that while year-round *K. pelamis* spawning occurs throughout the area between 4° N. and 5° S. latitude, the spawning activity is greatest from May through September.

There are no significant peaks of *N. macropterus* spawning between 14° N. and 5° S. latitude. However, a striking difference exists between the catches of *N. macropterus* and *K. pelamis* larvae in the area south of 5° S. latitude. Here, larvae of the former species were caught only in February and March, none being taken in January, June, and November. Seasonal spawning may occur in more southern waters, but here again data were obtained for too few months to form a definite opinion. As far as *N. macropterus* is concerned, it can be hypothesized that this species spawns throughout the area and throughout the year at a uniform intensity.

SUMMARY

1. Four species of tuna larvae, yellowfin (*Neothunnus macropterus*), skipjack (*Katsuwonus pelamis*), little tunny (*Euthynnus yaito*), and frigate mackerel (*Auxis thazard*), are described from plankton catches taken in central Pacific waters between 23° N. and 15° S. latitude and 120° W. and 180° longitude and from the East Indies and the Gulf of Panama.

2. The most conspicuous, specific characters that distinguish the larvae are as follows:

a. *Neothunnus macropterus:* Absence of chromatophores on the trunk, except over the visceral mass, until the larvae approach 14 mm.

b. *Katsuwonus pelamis:* Presence of a distinct chromatophore on the ventral midline of the caudal region, and no chromatophore at the symphysis of the pectoral girdle.

c. *Euthynnus yaito:* A series of chromatophores along the midventral line of the trunk, from the vicinity of the anal fin base to the caudal region; presence (usually) of a chromatophore at the symphysis of the pectoral girdle.

d. *Auxis thazard:* Three short series of closely set chromatophores on the middorsal, midlateral, and midventral lines of the caudal region; presence (usually) of a chromatophore at the symphysis of the pectoral girdle.

3. Larvae of *Katsuwonus pelamis* and *Neothunnus macropterus* were found in the waters north of the Hawaiian Islands to approximately 25° N. latitude and as far south as the Samoan Islands near 15° S. latitude. The areas rich in larval *Neothunnus macropterus* coincided with the areas where the adults were frequently taken by longlining. Along the Equator, larvae were found between longitudes 120° W. and 180°, the east-west limits of the area investigated, with a decidedly rich area between 140° W. and 180°. The close adult-larva relationship suggests the possibility of a transoceanic distribution of these larvae along the Equator.

4. Larvae were found to be concentrated at or near the surface, especially at night. It seems likely that even in the daytime the bulk of the larvae occur at less than 50 meters. Diurnal migration probably occurs within this shallow zone.

5. The abundance of *Katsuwonus pelamis* larvae in the area implied that a sizeable stock of adult *Katsuwonus pelamis* occurred in equatorial waters.

6. Recently hatched larvae were found in nearly all latitudes, longitudes, and seasons, suggesting widespread, continuous spawning throughout the area sampled.

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APPENDIX

The following tables list by species the number of tuna larvae collected from the POFI research vessel *Hugh M. Smith* on 8 cruises in the equatorial Pacific in 1950–52. The tables include only those cruises or parts of cruises, from which material for this study was obtained.

APPENDIX TABLE 1.—*Tuna larvae collected on* Hugh M. Smith *cruise 5 in equatorial waters*

[All hauls were oblique from 0 to 200 meters, of 30 minutes' duration]

Station	Position		Date	Time started [1]	Water strained	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Auxis thazard*	Unidentified	Total
	Latitude	Longitude								
					1,000 m.³					
No. 1	27°00′ N.	175°11′ W.	6-30-50	0945	1.25					
No. 2	25°00′ N.	174°10′ W.	7- 1-50	0258	1.32	1	1			2
No. 3	22°58′ N.	173°00′ W.	7- 1-50	2315	1.34					
No. 4	21°00′ N.	172°00′ W.	7- 2-50	0415	0.74		3			3
No. 5	19°00′ N.	171°52′ W.	7- 3-50	0807	1.25					
No. 6	17°01′ N.	171°46′ W.	7- 3-50	1219	1.43					
No. 7	15°00′ N.	171°54′ W.	7- 4-50	1649	0.89				1	1
No. 8	14°00′ N.	171°57′ W.	7- 5-50	0123	0.85	1			1	2
No. 9	13°00′ N.	172°01′ W.	7- 5-50	0950	1.33					
No. 10	12°00′ N.	172°00′ W.	7- 5-50	1815	0.88					
No. 11	11°03′ N.	172°00′ W.	7- 6-50	0315	1.33		3			3
No. 12	9°54′ N.	172°02′ W.	7- 6-50	1213	1.78	1				1
No. 13	8°54′ N.	172°00′ W.	7- 6-50	2012	1.19	2				2
No. 14	7°59′ N.	171°57′ W.	7- 7-50	0350	1.62	1	4			5
No. 15	6°59′ N.	171°46′ W.	7- 7-50	1226	1.58	1				1
No. 16	6°02′ N.	171°56′ W.	7- 7-50	2130	1.38		2			2
No. 17	5°00′ N.	172°02′ W.	7- 8-50	0845	1.82	1				1
No. 18	4°00′ N.	172°03′ W.	7- 8-50	1659	1.35					
No. 19	3°00′ N.	172°01′ W.	7- 9-50	0036	1.06		1			1
No. 20	2°00′ N.	171°53′ W.	7- 9-50	0838	1.81				1	1
No. 21	0°54′ N.	172°12′ W.	7- 9-50	1746	1.59	2	1	2	2	7
No. 22	0°08′ S.	172°02′ W.	7-10-50	0143	1.94		8			8
No. 23	1°00′ S.	171°57′ W.	7-10-50	0925	1.26		24			24
No. 24	2°00′ S.	171°55′ W.	7-10-50	1740	1.41					
No. 25	2°59′ S.	171°59′ W.	7-11-50	0133	1.31	1	17			18
No. 26	4°05′ S.	171°56′ W.	7-11-50	1055	1.58	9	2			11
No. 27	5°04′ S.	171°58′ W.	7-11-50	2110	1.63					
No. 28	4°56′ S.	158°02′ W.	7-28-50	0556	1.38					
No. 29	4°00′ S.	158°03′ W.	7-28-50	1324	0.64					
No. 30	3°03′ S.	158°00′ W.	7-28-50	2137	0.87					
No. 31	2°03′ S.	158°00′ W.	7-29-50	0550	0.65					
No. 32	1°00′ S.	158°01′ W.	7-29-50	1418	1.00		1			1
No. 33	0°02′ S.	157°58′ W.	7-29-50	2221	0.77					
No. 34	0°57′ N.	157°57′ W.	7-30-50	0646	1.53					
No. 35	2°00′ N.	158°07′ W.	7-30-50	1532	0.85		1			1
No. 36	3°00′ N.	157°58′ W.	7-30-50	2302	0.97		6			6
No. 37	4°00′ N.	158°03′ W.	7-31-50	0640	1.65		6			6
No. 38	5°00′ N.	158°00′ W.	7-31-50	1750	1.18		1			1
No. 39	6°00′ N.	157°57′ W.	8- 1-50	0144	1.31	1				1
No. 40	7°00′ N.	157°57′ W.	8- 1-50	0854	0.95					
No. 41	8°00′ N.	157°50′ W.	8- 1-50	1620	3.36	1				1
No. 42	9°00′ N.	157°55′ W.	8- 2-50	0020	1.14	2	1			3
No. 43	10°00′ N.	157°53′ W.	8- 2-50	0744	1.60	1	2			3
No. 44	11°00′ N.	157°55′ W.	8- 2-50	1546	1.14					
No. 45	11°59′ N.	158°04′ W.	8- 2-50	2343	1.03	1	4			5
No. 46	13°00′ N.	157°58′ W.	8- 3-50	0800	1.46		1			1
No. 47	14°00′ N.	157°54′ W.	8- 3-50	1639	1.31					
No. 48	14°58′ N.	157°55′ W.	8- 4-50	0253	0.59	2				2
No. 49	17°00′ N.	158°08′ W.	8- 4-50	1741	0.93					
No. 50	19°02′ N.	157°59′ W.	8- 5-50	1006	1.03					
No. 51	20°53′ N.	158°02′ W.	8- 5-50	2300	0.85	3	2	2		7

[1] +11 zone time on stations 1 to 27; + 10 zone time on stations 28 to 51.

APPENDIX TABLE 2.—*Tuna larvae collected on* Hugh M. Smith *cruise 6 in Hawaiian waters*

[All hauls were 1-hour horizontal tows at depth indicated]

Station	Depth of haul	Position		Date	Time started [1]	Water strained	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Auxis thazard*	Unidentified	Total
		North latitude	West longitude								
	Meters					*1,000 m.³*					
No. 1	0	23°31′	161°05.5′	8-25-50	1405	2.05	1				1
	50					1.99	1	1			2
	150					3.14				1	1
No. 1A	0	22°45′	161°15′	8-25-50	2030	2.63	5	9	1	4	19
	50					2.81		2		3	5
	150					3.32				3	3
No. 2	0	21°57′	161°05′	8-26-50	0315	2.26	12				12
	100					3.07		3		1	4
	200					4.01	1	1			2
No. 3	0	21°09.5′	161°03′	8-26-50	1042	2.15					
	50					2.07				1	1
	150					2.60					
No. 4	0	20°20′	161°05′	8-26-50	1750	2.25		8		5	13
	100					2.80		1			1
	200					3.57		1			1
No. 5	0	19°25.5′	161°05′	8-27-50	0042	2.31	2	13		10	25
	150					3.11					
	300					3.70		1		1	2
No. 6	0	19°26′	159°50′	8-27-50	0950	2.39	2				2
	100					2.48					
	200					3.98					
No. 7	0	20°16.5′	159°44′	8-27-50	1853	3.03	4		1		5
	50					3.22		3			3
	150					4.30	1	1			2
No. 8	0	20°54′	159°47′	8-28-50	0507	2.84		5	1	2	8
	100					2.66					
	200					3.68	1	4	3		8
No. 9	0	21°05.1′	159°50.5′	8-28-50	1350	2.46					
	50					2.49				1	1
	150					3.06					
No. 10	0	22°48.5′	159°51′	8-24-50	2239	2.33	10	21	2	22	55
	150					3.61		3	7		10
	300					5.80	2	5	1	1	9
No. 11	0	23°27′	159°45.7′	8-25-50	0500	2.37	5	9	2		16
	50					2.85				1	1
	150					4.21					
No. 12	0	22°43.3′	158°26′	8-24-50	1250	2.71					
	100					2.90					
	200					3.95					
No. 13	0	21°50′	158°30.6′	8-24-50	0528	2.01	4		7	3	14
	50					3.14	2	10	4	6	22
	150					3.56		2	1	2	5
No. 14	0	20°50′	158°32′	8-18-50	1720	2.29	11			2	13
	100					2.17	2				2
	200					2.25				1	1
No. 15	0	20°15′	158°24′	8-19-50	2340	2.72	5	8			13
	150					3.81		1			1
	300					5.28	2	4			6
No. 16	0	19°24′	158°23′	8-19-50	0750	3.38	3				3
	100					3.48					
	200					3.06	1	6			7
No. 17	0	18°30′	158°29′	8-19-50	1522	2.24				1	1
	100					3.31					
	150					4.09					
No. 18	0	18°22′	157°07.5′	8-20-50	0210	1.61	13	22		11	46
	100					2.43	2				2
	200					3.61	1	5		3	9
No. 19	0	19°31′	157°10′	8-20-50	2311	2.73	1				1
	100					3.93		1			1
	150					4.78	1	2			3
No. 20	0	20°23′	157°07′	8-21-50	0815	2.11				1	1
	150					3.15		1			1
	300					4.29		1			1
No. 21	0	20°55.5′	157°10.3′	8-21-50	1412	2.77	7				7
	100					2.45	1				1
	150					2.81					
No. 22	0	21°50′	157°10.5′	8-23-50	1754	2.59		1		1	2
	100					3.07				1	1
	200					4.07		1			1
No. 23	0	22°39′	157°13′	8-23-50	1020	2.84				1	1
	50					2.99					
	150					3.64					
No. 24	0	22°40′	155°47′	8-22-50	2149	2.90	1			1	2
	100					3.34					
	200					5.03	1	3			4
No. 25	0	21°56.3′	155°45.3′	8-22-50	1500	2.82	14				14
	150					3.43					
	300					3.92	1	1			2
No. 26	0	21°03.5′	155°50′	8-22-50	0711	2.11	6				6
	100					3.07				1	1
	200					4.69				2	2
No. 27	0	20°30′	155°47.2′	8-22-50	0140	2.18	6	4		2	12
	50					2.30					
	150					3.88					
No. 28	0	18°32.5′	156°07′	8-20-50	1136	2.22				3	3
	100					2.58					
	200					4.08				1	1

[1] Local civil time corresponding to +10 zone time.

APPENDIX TABLE 3.—*Tuna larvae collected on* Hugh M. Smith *cruise 7 in equatorial waters*

[All hauls were oblique tows from 0 to 200 meters, of 30 minutes' duration]

Station	Position		Date	Time started [1]	Water strained	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Auxis thazard*	Unidentified	Total
	Latitude	Longitude								
					1,000 m.[3]					
No. 1	20°30′ N.	158°00′ W.	10-17-50	1925	0.95					
No. 2	19°10′ N.	158°02′ W.	10-18-50	0532	0.90				2	2
No. 3	18°13′ N.	158°00′ W.	10-18-50	1326	1.11					
No. 4	17°10′ N.	158°00′ W.	10-18-50	2159	0.68					
No. 5	16°11′ N.	157°57′ W.	10-19-50	0506	0.70	(2)	(2)	(2)	(2)	(2)
No. 6	15°02′ N.	157°58′ W.	10-19-50	1250	1.00					
No. 7	14°03′ N.	157°59′ W.	10-19-50	1921	1.22				3	3
No. 8	12°57′ N.	157°57′ W.	10-20-50	0330	0.73					
No. 9	12°25′ N.	158°00′ W.	10-20-50	1729	1.22					
No. 10	11°08′ N.	158°01′ W.	10-21-50	1526	1.37					
No. 11	10°01′ N.	157°55′ W.	10-22-50	0724	1.43					
No. 12	8°52′ N.	157°45′ W.	10-23-50	0742	0.96					
No. 13	8°05′ N.	157°15′ W.	10-24-50	0742	1.41				2	2
No. 14	7°17′ N.	157°04′ W.	10-25-50	0727	1.70					
No. 15	5°57′ N.	157°05′ W.	10-26-50	0737	1.57				1	1
No. 16	5°19′ N.	157°20′ W.	10-27-50	0725	2.21	1	1		3	5
No. 17	4°23′ N.	157°30′ W.	10-28-50	0912	1.87		2			2
No. 18	3°17′ N.	157°53′ W.	10-29-50	0802	1.31				1	1
No. 19	2°01′ N.	157°34′ W.	11- 1-50	0812	1.59		1			1
No. 20	6°07′ N.	162°06′ W.	11- 6-50	0950	1.93					
No. 21	6°13′ N.	163°05′ W.	11- 7-50	0810	1.57				1	1
No. 22	6°59′ N.	163°54′ W.	11- 8-50	0808	1.75				4	4
No. 23	7°24′ N.	164°25′ W.	11- 9-50	0806	1.44					
No. 24	6°31′ N.	165°45′ W.	11-10-50	0813	1.52	1			10	11

[1] +10 zone time on stations 1 to 21; +11 zone on stations 22 to 24. [2] Sample missing.

APPENDIX TABLE 4.—*Tuna larvae collected on* Hugh M. Smith *cruise 8 in equatorial waters*

[All hauls were oblique tows from 0 to 200 meters, of 30 minutes' duration]

Station	Position		Date	Time started [1]	Water strained	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Auxis thazard*	Unidentified	Total
	Latitude	Longitude								
					1,000 m.[3]					
No. 1	20°48′ N.	157°30′ W.	1-14-51	2012	0.94				1	1
No. 2	18°47′ N.	158°01′ W.	1-15-51	1449	0.63					
No. 4	14°30′ N.	158°00′ W.	1-17-51	0925	0.43				3	3
No. 6	12°57′ N.	157°58′ W.	1-17-51	2251	0.82					
No. 7	11°59′ N.	157°50′ W.	1-18-51	0811	1.36					
No. 8	11°00′ N.	157°53′ W.	1-18-51	1633	1.40				3	3
No. 9	10°00′ N.	157°56′ W.	1-19-51	0224	1.83	2				2
No. 10	9°00′ N.	157°58′ W.	1-19-51	1154	0.99					
No. 11	8°04′ N.	157°58′ W.	1-19-51	2024	1.24		3			3
No. 12	7°08′ N.	157°58′ W.	1-20-51	0615	1.30					
No. 13	5°59′ N.	158°00′ W.	1-20-51	1505	1.81					
No. 14	5°00′ N.	158°00′ W.	1-20-51	2338	0.98					
No. 15	3°55′ N.	157°54′ W.	1-21-51	1100	0.98					
No. 16	3°02′ N.	157°57′ W.	1-21-51	2135	1.02	1				1
No. 17	2°00′ N.	158°01′ W.	1-21-51	0802	1.63				1	1
No. 18	0°58′ N.	158°07′ W.	1-22-51	1730	1.53					
No. 19	0°01′ N.	158°02′ W.	1-23-51	0328	1.93					
No. 20	0°55′ S.	157°54′ W.	1-23-51	1208	1.51		1			1
No. 21	2°00′ S.	158°00′ W.	1-23-51	2312	1.27	1				1
No. 22	3°00′ S.	158°05′ W.	1-24-51	0744	1.27	1			1	2
No. 23	4°00′ S	158°00′ W.	1-24-51	1550	1.07					
No. 24	5°00′ S.	158°00′ W.	1-24-51	2330	0.89	5				5
No. 25	6°01′ S.	158°06′ W.	1-25-51	0741	1.23		2		1	3
No. 26	7°00′ S.	158°01′ W.	1-25-51	1548	1.35					
No. 77	14°30′ S.	171°51′ W.	2. 26-51	1931	1.88	6	8		4	18
No. 78	11°56′ S.	171°59′ W.	2-27-51	1129	1.92	4	2		1	7
No. 79	10°05′ S.	171°52′ W.	2-28-51	0245	1.74	2	5		1	•8
No. 80	8°00′ S.	171°56′ W.	2-28-51	1821	1.45		2			2
No. 81	7°01′ S.	171°54′ W.	3- 1-51	0238	1.05		2			2
No. 82	5°59′ S.	172°00′ W.	3- 1-51	1118	1.40	1				1
No. 83	5°00′ S.	172°15′ W.	3- 1-51	1930	1.51					
No. 84	4°00′ S.	172°06′ W.	3- 2-51	0735	1.51		4			4
No. 85	3°00′ S.	171°50′ W.	3- 2-51	1537	1.51	1	1		2	4
No. 86	2°00′ S.	172°02′ W.	3- 3-51	1612	1.59					
No. 87	0°57′ S.	172°00′ W.	3- 4-51	0047	1.39		1		1	2
No. 88	0°09′ N.	171°58′ W.	3- 4-51	0926	1.07		1		1	2
No. 89	1°04′ N.	172°00′ W.	3- 4-51	1702	0.98		1		2	3
No. 90	1°54′ N.	172°02′ W.	3- 5-51	0034	1.85		8		5	13
No. 91	2°48′ N.	172°04′ W.	3- 5-51	0834	1.33		3		1	4
No. 92	3°57′ N.	172°02′ W.	3- 5-51	1816	1.22					
No. 93	4°56′ N.	171°54′ W.	3- 6-51	0249	1.62	1	1			2
No. 94	5°55′ N.	171°50′ W.	3- 6-51	1105	1.43	1	1		1	3
No. 95	6°58′ N.	171°49′ W.	3- 6-51	.1939	1.91		2			2
No. 96	7°56′ N.	171°51′ W.	3- 7-51	0407	1.50					
No. 97	9°00′ N.	171°58′ W.	3- 7-51	1315	1.54	1				1
No. 98	10°02′ N.	171°56′ W.	3- 7-51	2147	1.54					
No. 99	11°02′ N.	171°52′ W.	3- 8-51	0602	1.58				1	1
No. 100	12°00′ N.	171°52′ W.	3- 8-51	1417	1.51				2	2
No. 101	13°01′ N.	171°48′ W.	3- 8-51	2236	1.72	1				1
No. 102	13°58′ N.	171°24′ W.	3- 9-51	0650	1.27					
No. 103	15°00′ N.	170°52′ W.	3- 9-51	1557	1.31					
No. 104	16°58′ N.	169°42′ W.	3-10-51	0913	1.99				1	1
No. 105	18°58′ N.	168°27′ W.	3-11-51	0207	1.94					

[1] +10 zone time on stations 1 to 26; +11 zone time on stations 77 to 105.

APPENDIX TABLE 5.—*Tuna larvae collected on* Hugh M. Smith *cruise 11 in equatorial waters*

[All hauls were oblique tows from 0 to 200 meters, of 30 minutes' duration]

Station	Position		Date	Time started [1]	Water strained	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Auxis thazard*	Unidentified	Total
	Latitude	Longitude			*1,000 m.*^{3}					
No. 1	14°37′ N.	150°12′ W.	8-24-51	0854	1.44		1			1
No. 2	13°06′ N.	149°58′ W.	8-25-51	0828	1.22					
No. 3	11°31′ N.	150°02′ W.	8-26-51	0832	1.90					
No. 4	9°41′ N.	150°01′ W.	8-27-51	0801	1.36	2				2
No. 5	8°58′ N.	150°08′ W.	8-28-51	0722	1.85					
No. 6	7°59′ N.	149°51′ W.	8-29-51	0754	2.84	2	1			3
No. 7	6°55′ N.	149°50′ W.	8-30-51	0734	1.69					
No. 8	5°59′ N.	149°55′ W.	8-31-51	0742	1.54	4				4
No. 9	4°49′ N.	150°02′ W.	9- 1-51	0743	1.95	4	1			5
No. 10	4°02′ N.	150°04′ W.	9- 2-51	0852	0.70	2	1		2	5
No. 11	2°55′ N.	150°09′ W.	9- 3-51	0739	1.70	7	6			13
No. 12	1°59′ N.	150°04′ W.	9- 4-51	0740	1.94	2	1			3
No. 22	2°00′ N.	151°18′ W.	9-19-51	0743	1.29	3	2			5
No. 23	0°55′ N.	149°54′ W.	9-20-51	0742	1.31	1	1			2
No. 24	0°01′ S.	149°56′ W.	9-21-51	0743	1.47		2			2
No. 25	1°03′ S.	150°16′ W.	9-22-51	0746	1.13					
No. 26	2°01′ S.	150°08′ W.	9-23-51	0737	1.19		2		1	3
No. 27	3°34′ S.	150°05′ W.	9-24-51	0740	1.55		3			3
No. 28	4°57′ S.	150°04′ W.	9-25-51	0906	1.34					
No. 29	4°00′ S.	150°00′ W.	9-25-51	2352	1.88		21			21
No. 30	3°00′ S.	149°57′ W.	9-26-51	0858	1.64					
No. 31	2°00′ S.	150°02′ W.	9-26-51	1719	1.39		7		1	8
No. 32	1°00′ S.	149°58′ W.	9-27-51	0210	1.51	(2)	(2)	(2)	(2)	(2)
No. 33	0°02′ N.	150°00′ W.	9-27-51	1300	1.12	1	1			2
No. 34	1°02′ N.	150°01′ W.	9-27-51	2332	1.57	(2)	(2)	(2)	(2)	(2)
No. 35	2°01′ N.	149°53′ W.	9-28-51	0840	1.54	1				1
No. 36	3°00′ N.	150°03′ W.	9-28-51	1715	1.63	1	1			2
No. 37	3°58′ N.	150°00′ W.	9-29-51	0152	1.53	2	3			5
No. 38	4°59′ N.	149°56′ W.	9-29-51	1038	1.07		1			1
No. 39	5°56′ N.	150°00′ W.	9-29-51	1919	1.66					
No. 40	6°51′ N.	149°57′ W.	9-30-51	0343	1.63	3				3
No. 41	7°51′ N.	150°57′ W.	9-30-51	1257	1.93		1		3	4
No. 42	8°57′ N.	149°58′ W.	9-30-51	2233	1.47	1	1			2
No. 43	10°00′ N.	150°13′ W.	10- 1-51	0709	1.79		1			1
No. 44	10°58′ N.	150°02′ W.	10- 1-51	1554	1.73					
No. 45	11°59′ N.	150°03′ W.	10- 2-51	0042	1.47					
No. 46	13°00′ N.	149°56′ W.	10- 2-51	0907	1.60	4				4
No. 47	14°01′ N.	150°03′ W.	10- 2-51	1733	1.78					
No. 48	15°02′ N.	150°01′ W.	10- 3-51	0144	1.60	(2)	(2)	(2)	(2)	(2)
No. 49	17°00′ N.	150°42′ W.	10- 3-51	1653	1.94					
No. 50	19°00′ N.	151°19′ W.	10- 4-51	0750	1.97					

[1] +10 zone time on all stations.
[2] No sample.

APPENDIX TABLE 6.—*Tuna larvae collected on* Hugh M. Smith *cruise 14 in equatorial waters*

[All hauls were oblique tows from 0 to 200 meters, of 30 minutes' duration]

Station	Position		Date	Time started [1]	Water strained	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Auxis thazard*	Unidentified	Total
	Latitude	Longitude								
					1,000 m.³					
No. 1	7°57′ N.	154°57′ W.	1-27-52	1158	1.01					
No. 2	6°55′ N.	154°57′ W.	1-27-52	2132	1.33		9			9
No. 3	5°53′ N.	154°55′ W.	1-28-52	0813	1.13					
No. 4	4°55′ N.	154°51′ W.	1-28-52	1707	1.53		1		1	2
No. 5	3°54′ N.	154°51′ W.	1-29-52	0207	1.32					
No. 6	2°56′ N.	154°59′ W.	1-29-52	1057	1.03					
No. 7	1°54′ N.	155°03′ W.	1-29-52	2010	1.15		1		1	2
No. 8	0°54′ N.	155°11′ W.	1-30-52	0837	1.33		1			1
No. 9	0°06′ S.	155°14′ W.	1-30-52	1905	2.05		14		1	15
No. 10	1°10′ S.	155°08′ W.	1-31-52	0452	1.65		2			2
No. 11	2°00′ S.	155°03′ W.	1-31-52	1200	1.48					
No. 12	3°00′ S.	154°58′ W.	1-31-52	2124	1.51	1	4			5
No. 13	4°00′ S.	155°07′ W.	2- 1-52	0707	1.39					
No. 14	4°58′ S.	155°00′ W.	2- 1-52	1920	1.25	1	3			4
No. 15	5°53′ S.	155°03′ W.	2- 2-52	0455	1.33					
No. 16	6°50′ S.	155°05′ W.	2- 2-52	1407	1.32					
No. 17	7°56′ S.	179°53′ W.	2-15-52	0116	1.89		2			2
No. 18	7°01′ S.	179°49′ W.	2-15-52	1053	1.67		3			3
No. 19	6°05′ S.	179°58′ W.	2-15-52	1800	1.55	3				3
No. 20	5°04′ S.	179°58′ W.	2-16-52	0529	1.76	1	7			8
No. 21	4°03′ S.	179°58′ W.	2-16-52	1506	1.31	2	8			10
No. 22	2°56′ S.	180°00′	2-17-52	0040	1.39	1	2			3
No. 23	1°52′ S.	179°54′ E.	2-17-52	1107	1.34					
No. 24	0°59′ S.	179°57′ E.	2-17-52	1932	1.64		1			1
No. 25	0°52′ N.	179°59′ E.	2-18-52	0520	1.21		2		3	5
No. 26	1°03′ N.	179°58′ W.	2-18-52	1615	1.51			1	4	5
No. 27	2°07′ N.	179°57′ W.	2-19-52	0210	1.07					
No. 28	3°06′ N.	179°57′ W.	2-19-52	1105	1.74					
No. 29	4°05′ N.	179°55′ W.	2-19-52	2008	1.47		4	1	2	7
No. 30	5°06′ N.	179°50′ W.	2-20-52	0505	1.70	4	4		1	9
No. 31	6°06′ N.	179°44′ W.	2-20-52	0211	1.45	2				2
No. 32	7°04′ N.	179°59′ E.	2-20-52	1108	1.61	3	1		3	7
No. 33	8°03′ N.	179°58′ W.	2-21-52	0759	1.39					
No. 34	8°54′ N.	179°55′ W.	2-21-52	1720	1.33					

[1] +10 zone time on stations 1 to 16; +12 zone time on stations 17 to 34.

APPENDIX TABLE 7.—*Tuna larvae collected on* Hugh M. Smith *cruise 15 in equatorial waters*

[All hauls were oblique tows from 0 to 200 meters, of 30 minutes' duration]

Station	Position		Date	Time started [1]	Water strained	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Auxis thazard*	Unidentified	Total
	Latitude	Longitude								
					1,000 m.³					
No. 1	8°59′ N.	139°56′ W.	5-28-52	0731	1.42					
No. 2	7°51′ N.	139°46′ W.	5-28-52	1839	1.62					
No. 3	7°00′ N.	140°00′ W.	5-29-52	0315	1.73			1		1
No. 4	6°36′ N.	139°44′ W.	5-29-52	1035	1.87					
No. 5	6°00′ N.	140°00′ W.	5-29-52	1727	2.06	4				4
No. 6	5°02′ N.	139°58′ W.	5-30-52	0208	1.90	2	7		1	10
No. 7	4°05′ N.	139°58′ W.	5-30-52	1003	2.17	1	10		2	13
No. 8	3°09′ N.	139°53′ W.	5-30-52	1838	1.51		10		10	20
No. 9	1°57′ N.	140°03′ W.	5-31-52	0344	2.46		8			8
No. 10	0°53′ N.	140°02′ W.	5-31-52	1237	1.70		1			1
No. 11	0°11′ S.	139°52′ W.	5-31-52	2138	2.06					
No. 12	1°02′ S.	139°52′ W.	6- 1-52	0515	1.95					
No. 13	2°00′ S.	139°50′ W.	6- 1-52	1257	1.57					
No. 14	3°00′ S.	139°52′ W.	6- 1-52	2026	1.52	1	3			4
No. 15	4°00′ S.	140°05′ W.	6- 2-52	0628	1.32	1	1			2
No. 16	5°30′ S.	139°57′ W.	6- 2-52	1839	1.36	1				1
No. 17	7°00′ S.	139°58′ W.	6- 3-52	0709	1.72		1			1

[1] +9 zone time on all stations.

APPENDIX TABLE 8.—*Tuna larvae collected on* Hugh M. Smith *cruise 18 in equatorial waters*

[All hauls were oblique tows from 0 to 200 meters, of 30 minutes' duration]

Station	Position		Date	Time started [1]	Water strained	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Auxis thazard*	Unidentified	Total
	Latitude	Longitude								
					1,000 m.³					
No. 2	9°00′ N.	120°50′ W.	10-19-52	0012	1.53					
No. 4	7°06′ N.	120°00′ W.	10-21-52	0200	1.24	2			2	4
No. 5	5°50′ N.	120°16′ W.	10-22-52	0217	3.29	2	1			3
No. 6	4°53′ N.	119°59′ W.	10-22-52	2325	1.45	1	1			2
No. 7	4°01′ N.	120°06′ W.	10-23-52	1200	1.53					
No. 8	3°03′ N.	120°05′ W.	10-25-52	0004	1.54	1				1
No. 9	1°55′ N.	120°14′ W.	10-26-52	0105	3.05					
No. 10	1°02′ N.	120°17′ W.	10-27-52	0111	1.46					
No. 11	0°39′ N.	120°14′ W.	10-28-52	0115	2.62					
No. 13	1°04′ S.	120°07′ W.	10-28-52	2309	1.62					
No. 15	3°06′ S.	120°10′ W.	10-29-52	2310	1.36					
No. 17	4°50′ S.	120°21′ W.	10-31-52	1206	0.77					
No. 19	6°37′ S.	120°24′ W.	10-31-52	2307	1.37					
No. 21	8°40′ S.	120°35′ W.	11- 1-52	2308	0.88		1			1
No. 24	4°12′ S.	130°14′ W.	11- 5-52	2311	0.87		1			1
No. 26	2°15′ S.	130°11′ W.	11- 6-52	2310	1.12					
No. 28	0°27′ S.	130°09′ W.	11- 7-52	2310	1.31					
No. 30	1°10′ N.	130°08′ W.	11- 9-52	0103	2.33					
No. 31	1°42′ N.	130°22′ W.	11- 9-52	2329	1.31			1		1
No. 32	3°15′ N.	130°14′ W.	11-11-52	0005	1.40				2	2
No. 33	4°37′ N.	130°26′ W.	11-12-52	0015	0.71					
No. 34	5°42′ N.	130°50′ W.	11-12-52	2308	0.87					
No. 36	7°56′ N.	131°11′ W.	11-14-52	0002	1.18					
No. 37	9°12′ N.	131°24′ W.	11-15-52	0103	0.60					

[1] +8 zone time on all stations.

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