

Juvenile *Euthynnus lineatus* and *Auxis thazard* from the Pacific Ocean off Central America

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IN A PREVIOUS PAPER (Schaefer and Marr, in press), juvenile stages of two commercially important tunas, *Neothunnus macropterus* (Temminck and Schlegel) and *Katsuwonus pelamis* (Linnaeus) were described. They were taken, with dip nets at night, under flood lights, in the oceanic waters of the Pacific off Costa Rica and northern Panama. At some of the same stations where these were taken, and at others, juveniles of two other species of scombroid fishes which have been identified as *Euthynnus lineatus* Kishinouye, the black skipjack, and *Auxis thazard* (Lacépède), the frigate mackerel, were captured by the same means. Neither of these is utilized by the American commercial fishery in the Pacific. The black skipjack of the Asiatic side of the Pacific, *E. yaito* Kishinouye, however, is of considerable commercial importance to the Japanese fishery and it may be expected that *E. lineatus* will eventually be similarly exploited. Commercial catches of frigate mackerel in the middle Atlantic states averaged slightly over 100 tons in 1942-44 (Fiedler, 1945; Anderson and Power, 1946, 1947).

Euthynnus lineatus Kishinouye 1920

Adults of this species are occasionally captured in Central American waters incidentally to the tuna fishery. Four specimens were examined by us in the early spring of 1947. Two of these were captured in a bait-net in the Gulf of Nicoya, Costa Rica, on February 22; these fish, one male and one female, had

gonads in a very advanced stage of maturity. A female with running-ripe eggs was taken on a trolled feather jig off Quepos Point, Costa Rica, on April 4. A ripe male was taken in a purse seine haul off Cape Blanco, Costa Rica, on April 29. It is thus apparent that this species spawns in Central American waters during the early spring. The capture of juveniles further confirms this.

Juveniles were taken at the following stations on the dates indicated: 08° 20' N., 84° 10' W., March 18, 1947; 8 specimens, 48 to 86 mm. total length. 09° 20' N., 85° 20' W., March 19, 1947; 10 specimens, 29 to 56 mm. total length. 09° 10' N., 85° 20' W., March 20, 1947; 1 specimen, 61 mm. total length. (All total lengths in this paper are from tip of snout to tip of shortest median caudal ray.)

In Figures 1 and 2 representative specimens of these juveniles are depicted. They are relatively less deep bodied than the juveniles of *Neothunnus* of the same sizes, being similar in this regard to *Katsuwonus*, from which, however, they may easily be distinguished by the pigmentation of the first dorsal fin. The entire first dorsal is heavily pigmented in *Euthynnus* of all sizes collected, while in *Katsuwonus*, up to 44 mm. at least, there is only a light pigmentation of the anterior margin and of the distal edge of the fin.

The second dorsal fin remains completely unpigmented in fish up to about 45 mm. total length, at which size the fin begins to show some pigment at the bases of the rays. In our largest specimen, 86 mm. total length, the second dorsal is fairly dark about half way to the tips of the rays, the distal half remaining unpigmented. The pigmentation of the head and body is similar to that of *Katsuwonus* at

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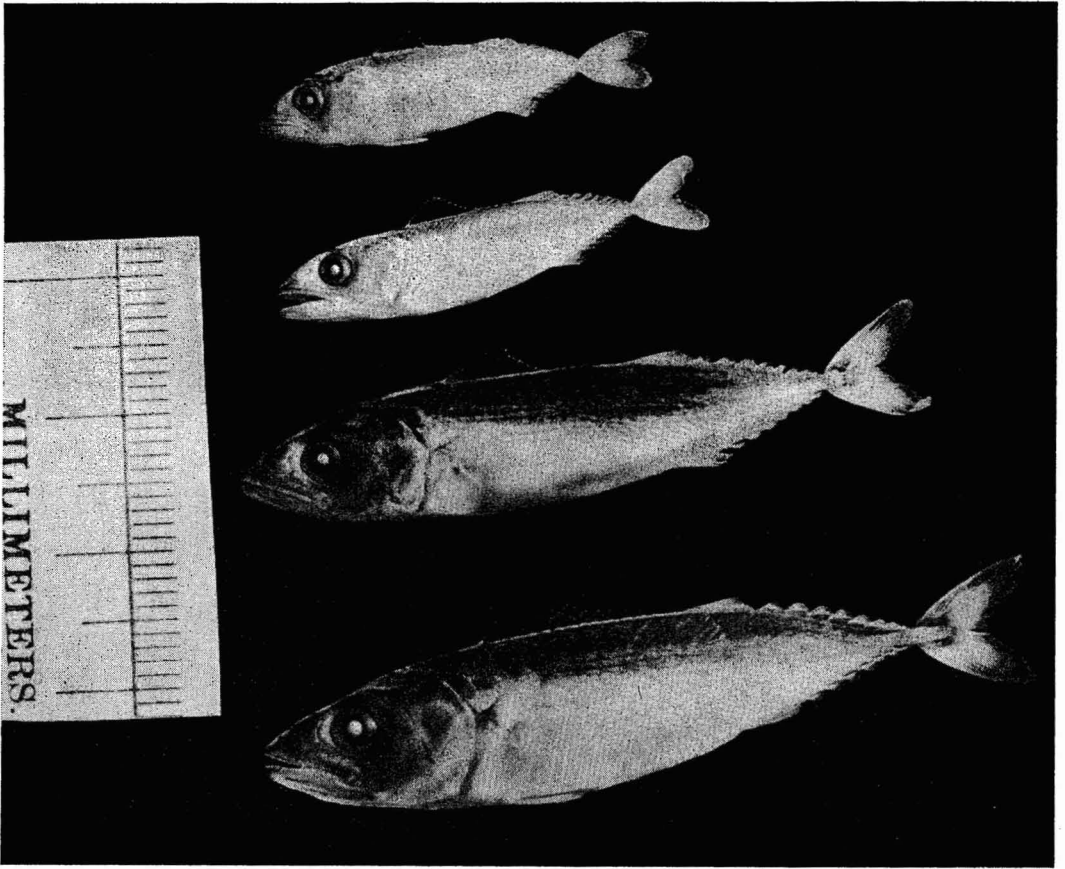


FIG. 1. Photograph of juvenile *Euthynnus lineatus* Kishinouye.

the smaller sizes, but the snout and anterior part of the head is rather more extensively pigmented in the smaller *Euthynnus* of these collections than in either *Katsuwonus* or *Neothunnus* of similar sizes. On the smaller of our specimens of *Euthynnus* the lateral pigmentation does not extend far below the mid-line, but there is a conspicuous series of black spots along the bases of the anal fin and following finlets. As the fish increase in size the pigmentation extends further down the sides, particularly posteriorly, until at about 45 mm. the pigmentation at the level of the anal fin extends the entire depth of the fish, although shading off ventrally. By the time the fish has reached 55 mm. the entire head is rather dark, the body is almost black dorsally, shading off

gradually to a white belly. In some specimens of about 45 mm. to 60 mm. the pigment on the upper sides is concentrated to form 8 or 9 extremely faint vertical bars. In the 86 mm. specimen these are not visible. The peritoneum bears numerous large dark spots dorsally which are visible through the body wall in small specimens. The caudal fin begins to exhibit some pigmentation in fishes of about 50 mm. total length.

In addition to the examination of specimens preserved in alcohol, two specimens of 54 mm. and 56 mm. were prepared for study of bony parts by staining with alizarin and clearing, after the method of Hollister (1934). The pectoral fin in the two stained specimens has 29 rays and 27 rays, respectively. These rays

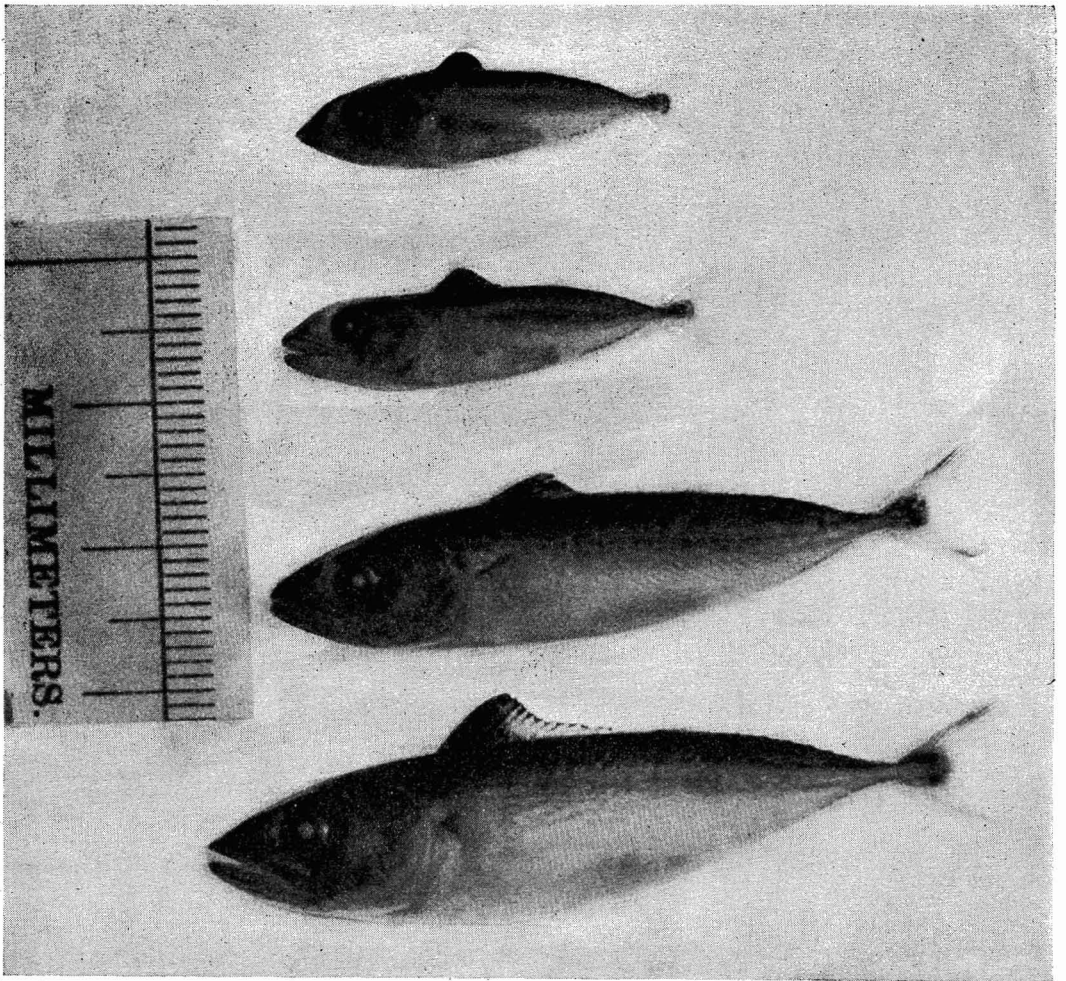


FIG. 2. Juvenile *Eubynnus lineatus*; photographed against a white background to illustrate pigmentation of dorsal fin.

cannot be counted accurately in unstained individuals because of the small size of the most inferior rays. The dorsal fin has 15 spines in six specimens examined and 14 in a seventh, the first or second anterior spines, which are of nearly equal length, being the longest and the remaining spines decreasing in length rapidly and successively. The first dorsal reaches almost to the insertion of the second. The second dorsal fin rays, counted in 5 specimens, are 12 in number, and there are in each case 8 dorsal finlets. The anal fin has 11 or 12 rays, and there are 7 anal finlets. The rays of the second dorsal

and anal are difficult to count except in stained material because of the shortness of the first one or two rays. The finlets are connected to each other and to the fin by a thin membrane which extends less and less far toward the tips of the finlets as the fish grow until in the largest specimen of 86 mm. it is only a vestige between the bases of the finlets.

The gill rakers of our smallest specimens are very tiny projections on the gill arches and are difficult to count accurately. On such a specimen, of 32 mm. total length, they were counted on the first gill arch as 7 + 20. As the

fish increase in size the gill rakers not only increase rapidly in length, but their number apparently increases. Counts of rakers on the first arch on specimens of various sizes are as follows:

48 mm.	8 + 25
52 mm.	9 + 25
61 mm.	10 + 26
86 mm.	11 + 27

The vertebrae, counting the urostyle, are 19 + 18 in one stained specimen and 20 + 17 in the other. They bear large inferior foramina on the last three or four precaudal vertebrae and on the first nine or ten caudal vertebrae. The haemal canal is very large, being broader than the body of the vertebrae beneath the precaudal and anterior caudal vertebrae. The lateral processes of the posterior caudal vertebrae are well developed in both specimens; there are no lateral processes on the anterior precaudal vertebrae. The first complete haemal arch was found to be on the 15th vertebra by dissection of the 56 mm. specimen.

Specimens of all sizes in our collection have about 20 to 30 conical, inwardly curved teeth on each side of each jaw. The palatines each bear a row of eight to ten rather large conical teeth. The vomer bears four or five rather small teeth which may be easily overlooked.

Our very smallest specimens, of about 30 mm., have visible the remnants of three spines at the lower posterior angle of the preopercle. In larger specimens the growth of the bone has completely obliterated these. Smaller specimens than those in our collection may be presumed, by analogy with *Neothunnus*, to have more prominent and perhaps more numerous preopercular spines.

The intestine of these specimens, as is characteristic of the Katsuwonidae, is relatively straight and is not folded. It runs back along the right inferior portion of the stomach. The liver is in three lobes, the right lobe being very much longer than the other two. In seven specimens examined, the right lobe of the liver

extended posteriorly three-fourths or more of the length of the body cavity.

That these specimens belong to either the genus *Euthynnus* or *Katsuwonus* is indicated by the morphology of the vertebral column. The well-developed inferior foramina on some precaudal as well as caudal vertebrae, forming with the very large haemal arches the so-called "trellis," is characteristic of these genera (Starks, 1910; Kishinouye, 1923).

These specimens have several characters agreeing with *Euthynnus* but not *Katsuwonus*. The very great elongation of the right lobe of the liver is definitive. In *Katsuwonus*, both in adults described by Kishinouye (1923: 363, 450, and 453, Fig. N) and by Godsil and Byers (1944: 11, 30), and in juveniles described by Schaefer and Marr (in press), the right lobe, although much larger than the other two, is not nearly as large as that of these specimens, which corresponds to Kishinouye's description of the liver of *Euthynnus*. The first closed haemal arch of *Katsuwonus* occurs on the 12th vertebra according to both Kishinouye and Godsil and Byers, whereas Kishinouye states that *Euthynnus* has the first complete haemal arch further back, on the 16th vertebra. The low vertebral count of our specimens is also definitive, although this was a matter of some concern at first because it does not agree with the literature. Kishinouye (1923: 338, 452) found that *Euthynnus* has 39 vertebrae counting the urostyle, probably based on *E. yaito* alone. He described *E. lineatus* from a single specimen from Manzanillo, Mexico, but probably did not dissect the fish to count the vertebrae. (Kishinouye: in the *Suisan Gakkwai Ho*, III, 113, 1920. We have been unable to examine this reference and our information is from Kishinouye, 1923.) He differentiates this species from *E. yaito* on the coloration and the relative size of the head. In his discussions he assumes all species of *Euthynnus* to have 39 vertebrae. This matter was cleared up through the kind cooperation of C. R. Clothier of the

California State Fisheries Laboratory, who has examined the skeletons of four adults identified from Kishinouye's description as *E. lineatus*. He has sent us the following data regarding these specimens, the first three of which were from tuna-clipper landings from unknown points somewhere south of the Mexican border, and the fourth of which was captured off Espiritu Santo Island in the Gulf of California:

Specimen number.....	1	2	3	4
Vertebra bearing 1st haemal arch.....	—	16	15	16
Total vertebrae (including urostyle).....	37	39	37	37
Abdominal vertebrae.....	—	21	19	20
Caudal vertebrae.....	—	18	18	17

Three of these four specimens have 37 vertebrae, corresponding with our juveniles, and disagreeing with Kishinouye. Mr. Clothier has also advised us that, in addition, H. C. Godsil of the same laboratory, has examined two specimens from near Magdalena Bay each of which had 37 vertebrae. It appears that *E. lineatus* has 37 vertebrae as a rule. The vertebrae counts of our juveniles agree, then, with those of adult *E. lineatus* identified from other characters. All other characters examined agree well enough with Kishinouye's descriptions, and it was therefore concluded that these were juveniles of *E. lineatus*.

There are few references to juvenile *Euthynnus* in the literature. Kishinouye's (1923: 388) smallest specimens, 13 cm. in length, from the Asiatic side of the Pacific, were larger than any of ours. He described them as follows: "They are very slender and have eight or more transverse bands on the side. These bands are nearly vertical and fade toward the ventral median line. When they grow to a total length of 19 cm. the body becomes very broad, the thoracic spots appear, the bands gradually disappear from the ventral part and the dorsal part of the bands becomes oblique."

Ehrenbaum (1924) found among the Mediterranean collections of the Danish Oceanographical Expeditions six young tunas, 5.9 to

10.1 mm. in length, which he referred to *Euthynnus alliteratus* (Raf.). He differentiated these specimens from those of *Auxis thazard* only with great difficulty, on the basis of the first dorsal rays. The identification seems doubtful, but, since none of our specimens of *Euthynnus* are as small as Ehrenbaum's, we cannot verify it.

Auxis thazard (Lacépède) 1802

As is the case with many of the scombroids, there is some doubt as to whether there is a single cosmopolitan species of *Auxis* or whether different species occur in different parts of the world. The solution of this problem is beyond the scope of this paper and our juveniles are referred to *Auxis thazard*. No adult specimens were examined by us during this voyage, but the capture of juveniles indicates that this species spawns in Central American Pacific waters during the early spring. Juveniles were taken at the following stations on the dates indicated: 08° 20' N., 84° 10' W.; March 18, 1947; 2 specimens, 67 and 68 mm. total length. 09° 43' N., 85° 54' W.; March 19, 1947; 52 specimens, 21 to 53 mm. total length. 08° 7' 30" N., 83° 8' 30" W.; May 7, 1947; 3 specimens, 23 to 41 mm. total length. 09° 43' N., 85° 54' W.; May 17, 1947; 1 specimen, 42 mm. total length. Through the courtesy of Dr. J. T. Nichols, we were also able to examine 5 specimens, 22 to 31 mm. in total length, taken under a light at night from the "Askoy" at 04° 01' N., 80° 26' W. on March 24, 1941. Nichols and Murphy (1944: 241) suggest that these may be young *Euthynnus*, but they are undoubtedly *Auxis*.

Representative specimens of juvenile *A. thazard* are shown in Figures 3 and 4. In the smaller specimens the prominent areas of pigmentation are on the upper and lower jaws, above the snout, around the postero-ventral margin of the orbit, on the upper operculum, between the orbits, along the mid-line of the body, along the bases of the dorsal and anal fins



FIG. 3. Photograph of juvenile *Auxis thazard* (Lacépède).

including the finlets, and around the posterior end of the urostyle. Large chromatophores in the peritoneum show through the body wall along the upper half of the body cavity. None of the fins or finlets bears pigment spots, with the exception of the first dorsal. The first dorsal bears a few scattered chromatophores, largely distributed along the spines. However, the first dorsal in general appearance is virtually colorless, as may be seen in Figure 4, especially as contrasted with *Euthynnus* or *Neothunnus*. With increasing size the local areas of pigmentation expand. In our largest specimens the head is well pigmented. The dorsal half of the

body is uniformly dark. This dark area extends below the mid-line on the caudal peduncle. The chromatophores in the peritoneum are no longer visible through the thickened body wall, and the ventral surface is unpigmented. Even in our largest specimens none of the fins is heavily pigmented; the caudal is more pigmented than the others.

Juvenile *Auxis* are rounder in cross section than *Euthynnus*, being relatively less compressed laterally. The head length and length of the caudal region in *Auxis* are less in comparison to the total length than is the case in *Euthynnus*. The maxillary in *Auxis* generally

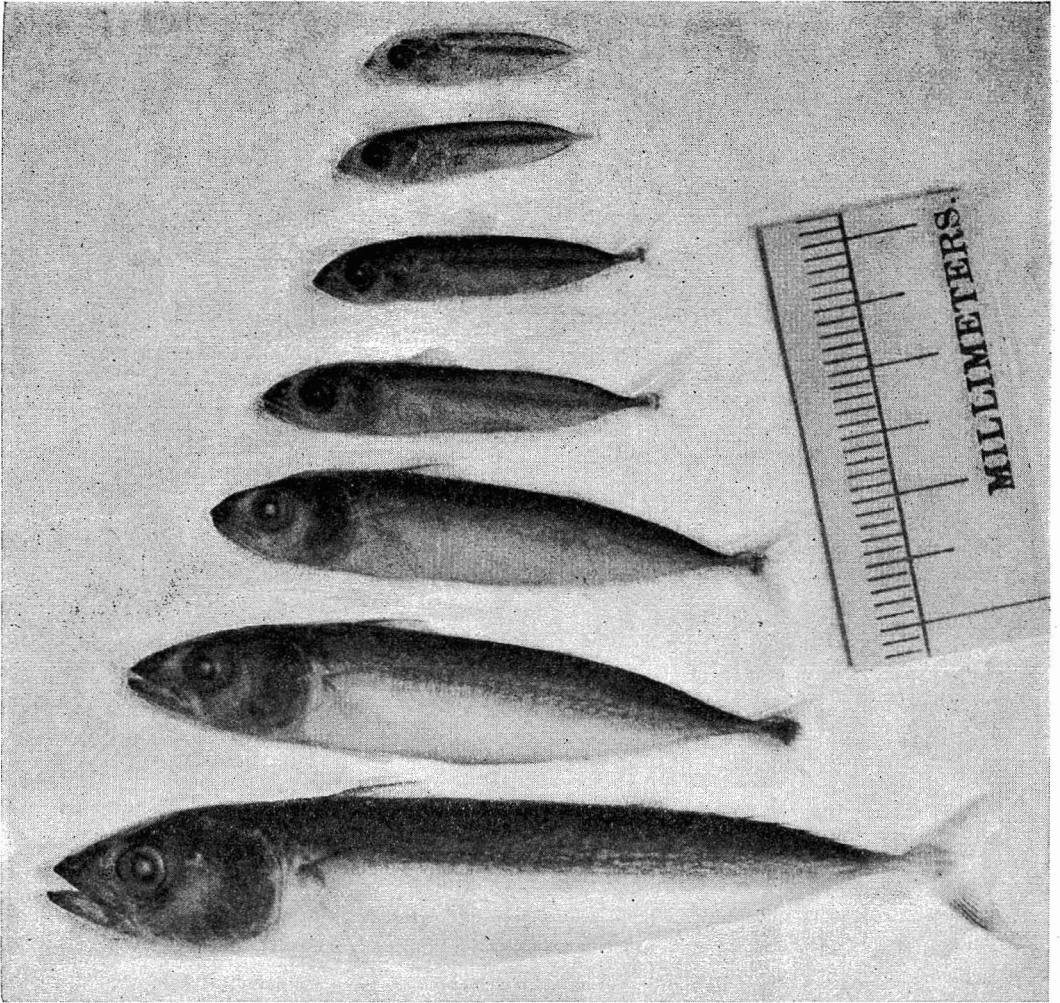


FIG. 4. Juvenile *Auxis thazard* photographed against a white background, illustrating lack of pigmentation of fins.

extends to a point between the anterior margin of the iris and the vertical bisector of the iris, whereas in *Euthynnus* it generally extends to a point between the vertical bisector of the iris and the posterior margin of the iris. In the smaller specimens the lower jaw is shorter than the upper, but the jaws become equal at about 50 mm. total length. The smallest specimens have three spines at the angle of the preopercle, but these are gradually grown over and disappear at about 35 to 40 mm. total length. There are indications, on alizarin-stained speci-

mens, that seven more spines are present in smaller individuals. Similarly, a figure of a 17.5 mm. specimen of *A. thazard* from the Mediterranean (deBuen, 1932: Fig. 27) shows a total of nine preopercular spines. The lateral keel along the caudal peduncle starts to develop at about 40 mm. total length.

The large dorsal interspace characteristic of *Auxis* actually contains small spines or rays. These are usually subcutaneous. Even in our smallest specimens they are not visible unless the fish is cleared and stained or unless the

specimen is shrunken from the preservative so that the spines project above the dorsal profile. In adult *Auxis* from Culion, Philippine Islands, examined through courtesy of Dr. G. S. Myers of the Stanford University Natural History Museum, the interneural supports of the suppressed rays are well developed; the rays themselves are vestigial, however, and can be found only by staining and dissection. Fin ray counts on our stained juvenile specimens are as follows:

	mm.	mm.	mm.
Total length of specimen.....	25	31	46
First dorsal.....	11	11	11
Dorsal interspace.....	6	7	8
Second dorsal.....	12	11	11
Dorsal finlets.....	8	8	8
Anal.....	14	13	13
Anal finlets.....	7	7	7
Ventral.....	7	7	7
Pectoral.....	22	23	25

Other, unstained, specimens also have eight dorsal finlets and seven anal finlets. In the smaller specimens the finlets are joined by a membrane that extends completely or nearly to their distal ends. With increasing size this membrane becomes less prominent until in our longest specimens it is wanting or exists only between the bases of the finlets.

In all our specimens, each side of the upper jaw bears about 20 small, conical teeth; each side of the lower jaw about 25 small, conical teeth; each palatine 6 or 7 teeth; and the vomer none. The vomer and palatines are exposed. Starks (1910: 97), with reference to *Auxis thazard*, and Kishinouye (1923: 460), with reference to the genus *Auxis*, state that there are no palatine teeth, and this is apparently true in the adults. In the two adults from Culion, Philippine Islands, the vomer and palatines are toothless and are not exposed. These specimens are probably *Auxis bira* Kishinouye.

The gill rakers on the most anterior gill arch of our smallest specimens are very tiny projections and are difficult to count. They are first apparent near the angle of the arch. With an increase in the size of the fish, the rakers near

the angle of the arch increase in length and new rakers are added distally on each arm. The full complement of rakers is apparently attained at about 50 mm. total length, as judged by the following counts on specimens of various sizes:

21 mm.	4 + 18
24 mm.	5 + 21
27 mm.	6 + 24
32 mm.	9 + 26
42 mm.	9 + 30
46 mm.	10 + 31
52 mm.	12 + 36
54 mm.	11 + 35
68 mm.	11 + 31

Gill raker counts on the adult specimens referred to above are 12 + 34 and 11 + 32. Kishinouye (1923: 462-3) gives 9 + 30 as the gill raker count for *A. bira* and 10 + 36 as the count for *A. maru* Kishinouye. Possible variation in these counts is not mentioned. He does not list *A. thazard*, but *A. maru* is probably a synonym of *A. thazard*, as he tentatively suggests in his synonymy.

The nasal rosette is visible only in cleared specimens.

The vertebrae were counted as 20 + 19 (including the urostyle) in three cleared and stained specimens. This agrees with Kishinouye (1923: 452) and Frade and deBuen (1932: 70), but disagrees with Starks (1910: 97), who counted 22 + 15 vertebrae. On a specimen 46 mm. total length, small ventral foramina are present on the 9th to 15th caudal vertebrae. On smaller specimens of 25 and 31 mm. total length, these foramina are not discernible, if present. In our specimens, the pedicles (of Starks = epihaemal process of Kishinouye) of the caudal vertebrae, bearing the closed haemal arches, are extremely short or non-existent. In a specimen of 25 mm. total length, the haemal arches of the caudal vertebrae are long, wide, and elliptical. In a specimen of 46 mm. total length, the haemal arch

is still long, but less wide. In a specimen of 72 mm. total length, the haemal arch is still long, but even less wide. In fact, the pedicle is divided and contains a large part of the haemal arch. In the two smaller specimens, the haemal arch is certainly closed on the 18th abdominal vertebra and is probably closed on the 17th vertebra; it is definitely open on the 16th vertebra. In the 72 mm. specimen, the haemal arch is open on the 17th vertebra and closed on the 18th. Kishinouye (1923: 339) states that the first closed haemal arch of *Auxis* occurs on the 1st caudal vertebrae (= 21st). In an adult specimen examined through the courtesy of Dr. G. S. Myers, the first closed haemal arch is on the first caudal vertebra. This specimen is from Wakanoura, Japan, and is referred to *Auxis hira*. We have been unable to examine any adult *Auxis* from the eastern Pacific in order to attempt to resolve this apparent discrepancy. C. R. Clothier has informed us that one specimen from the vicinity of Sebastian Viscaino Bay and two from the vicinity of Espiritu Santu Island, all identified as *A. thazard*, have a total of 39 vertebrae with the first haemal arch on the 21st vertebra. It seems unlikely that haemal arches that are closed would, with growth, become open. Our specimens may, therefore, be juveniles of an undescribed species. It is not unlikely that the sides of the pedicle fuse with an increase in size of the fish so that the haemal arch becomes greatly reduced in size. The possibility exists, however, that it may remain divided in this form.

The liver is divided into three lobes. The right lobe is almost as long as the visceral cavity and bears a prominent hepatic vein on its outer surface; the other two lobes are small. The stomach is long and lies above the rest of the viscera. The caecal mass is considerably shorter than the stomach. The intestine is relatively short, straight, and not folded. It runs posteriorly along the right inferior side of the stomach. There is no air bladder.

The vertebral count, the great length of the right lobe of the liver, the presence of a caudal keel, and the absence of an air bladder indicate that these juvenile scombroids belong to the family Katsuwonidae. The large interspace between the dorsal fins and the low ray count of the first dorsal, as well as the absence of the elaborate "trellis" of the vertebrae, indicate that they are *Auxis*, rather than *Euthynnus* or *Katsuwonus*. In the larger specimens, gill raker and fin ray counts will also serve to separate *Auxis* from the other genera. Positive specific allocation must await examination of adult specimens from the area.

A specimen of *A. thazard*, 17.5 mm. long, from the Mediterranean, was described and figured by deBuen (1932: 36-38). This is somewhat smaller than our smallest specimen and the differences between them, such as differences in numbers of preopercular spines, etc., are probably due to the differences in size. Sparta (1933: 16) mentions that specimens of *Auxis bisus* Bonaparte (= *A. thazard* Lacépède) about 1 cm. in length have been collected under a light at night in the Straits of Messina. Ehrenbaum (1924: 33-38) reported on 132 juvenile *A. thazard* from the Mediterranean collections of the Danish Oceanographical Expeditions. His largest specimen was 12 mm. in length, or about 9 mm. shorter than our smallest specimen. Again, differences between his descriptions and our specimens may probably be attributed to differences in size. These specimens were apparently taken in May, July, August, and September. He states that Sanzo found ripe ovaries in June and July. Sella (1924) describes Mediterranean specimens of *A. bisus* Bonaparte (= *A. thazard* Lacépède) ranging from 3 to 10 mm. These are much smaller than our specimens. He states that juveniles up to 10 to 15 mm. in length are found from the second half of June to September 20. He also mentions that before a length of 12 to 15 mm. is attained, about six rays are formed in the membrane connecting the first and second dorsal

fins and that these rays subsequently become contained in the median furrow so that they are no longer visible. This is in accord with our findings. The dates of our collections indicate the possibility of a somewhat earlier spawning season for *Auxis* off the Pacific Coast of Central America.

We have been unable to examine papers by Sanzo (1909, 1910) which apparently contain information on larval and juvenile *Auxis*.

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