遠洋水研報第3号　昭和45年7月
Bull. Far Seas Fish. Res. Lab., No. 3. July, 1970

STUDIES ON THE EARLY LIFE HISTORY OF THE RAINBOW RUNNER, *ELAGATIS BIPINNULATUS* (QUOY & GAIMARD) IN THE INDO-PACIFIC OCEANS*

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ツムブリの初期生活史

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要　約

昭和 43 年度流動研究としておこなった「熱帯インド・太平洋海域における表層性稚仔魚の同定と分布に関する研究」の結果明らかとなったツムブリの初期生活史について報告した。その概要は次の通りである。

(1) 体長 3.5～76.0 mm におよぶ合計 178 尾（うち1尾は破損個体）のツムブリ幼期が同定された。この中から各発育段階を代表する7尾について，その外部形態に関する図示（Fig. 1～7）と記載をおこなった。

(2) この種の幼期は外部形態においていくつかの特徴——顕著な頭部骨質隆起，巨大で，かつ鋸歯状突起を有する前鰓蓋骨隅角棘，鰭上における色素胞の分布状態および離鰭の出現など——を有するが，いずれも幼期を通しての特徴ではないので，同定にあたっては常に各形質の適用範囲を考慮する必要がある。なお，後期仔魚期においては，肩帯縫合部周辺の色素胞分布型が同定上有効な特徴となる。

(3) 体長に対する体各部分長の相対成長は前鰓蓋隅角棘を除き極めて直線的である。

(4) 離鰭の形成はこの種において最も特徴的な点であるが，その形成過程（Fig. 9）から推して二次的な獲得形質と考えられる。多分，遊泳力の増加に伴って生じた尾柄部の細長化がこの形質の発達と関連しているものであろう。

(5) 胃内容物調査によると，この種は幼期を通じてほぼ小型橈脚類を主要な餌料としているものと思われる。摂餌量は成長につれて急激に増加する。

(6) 今回同定された個体の採集域は2例を除き，すべて 2 月における表面水温が 27°C 以上の海域に限定される。成魚における分布状態からみて，この種は熱帯西太平洋の沿岸水域で産卵し，成長につれて大きな海流系との関連のもとに生息域を拡大するものと予想される。海洋における幼期の分布は特に大きく集群することは予想されないが，その量は極めて大きいものと思われる。外洋表層性アジ科の幼期中ではツムブリが卓越することから考えて，この種は外洋における有力な未利用資源としての可能性がある。

The rainbow runner, *Elagatis bipinnulatus* (QUOY & GAIMALD), is one of the commonest oceanic carangids and is widely distributed in tropical and subtropical seas throughout the world (Briggs, 1960). It also appears occasionally in the temperate regions including the southern Japanese waters (Okada, 1955), whereas no record of this species seems to be available from the eastern Pacific off the American continents (Parin, 1963).

* Received 1 Nov. 1969. Far Seas Fisheries Research Laboratory Contribution No. 27.

Despite some confusions in the systematics of the family Carangidae, it is almost certain that this fish alone constitutes the distinct monotypic genus *Elagatis* under the subfamily Naucratinae*, which is characterized by such features as the brilliant yellow stripes along the body, the presence of the small finlets closely behind the dorsal and anal fins, and the absence of the detached anal spines.

As far as I am aware, however, informations concerning this fish is extremely scarce except for the faunal records or the taxonomical remarks, and little is known of the early life history. This situation shows the clear contrast with that in the another typical representative of the oceanic carangids, *Naucrates ductor* LINNAEUS, since the larval stages of the latter had already been described in Lütken's classic work (Lütken, 1880) for about ninety years ago.

During the study on " The systematics and distributions of the epipelagic fish larvae and juveniles of the Indo-Pacific Oceans, 1967–1968 ", carried out at the Far Seas Fisheries Research Laboratory, last autumn (1968), not infrequent occurrences of the certain carangid larvae attracted my attention. Careful examination of these animals proved the majority of them to be represented by the same species probably referable to *Elagatis bipinnulatus* (QUOY & GAIMARD). The series of these larval and juvenile fishes provide the excellent opportunity for studying the early life history.

Although the present work is a part of the forthcoming much larger article with the title mentioned above, I think it much advisable to publish herewith the criteria for the identification of this species of seemingly potential commercial importance, and thus to facilitate its further life history study.

Materials and Methods

The specimens used in this study were transferred from the plankton samples taken by many research vessels belonging to the Prefectural public agencies such as the Fisheries High School and the Fisheries Experimental Station, on their ways to or around the fishing grounds for tunas in the Indo-Pacific Oceans, during the periods from March 1967 to June 1968. Consequently, the sampling stations of the larval fishes were distributed too irregularly in time and space to afford the reliable quantitative estimate.

All collections were made principally by means of the Maruchi larval net with 1.4 meter in mouth diameter which was towed at the surface layer for 15 minutes during the night time at about 2 knots. Total 178 larval and juvenile stages of *E. bipinnulatus* were identified from 51 successful hauls.

Measurements were made according to Berry (1959) under the binocular

*The opinion that the genus *Elagatis* comprises two species (Smith, 1950) does not seem to be currently recognized. In this paper, therefore, all specimens are referred to *E. bipinnulatus*.

dissecting microscope by using the ocular micrometer, but for the several larger specimens the divider and 30 cm rule were used in measuring to the nearest 0.5 mm. Meristic characters were examined on the specimens stained by Arizarin-red S and for the observation of the detailed structure of the skeleton, specimens were cleared by glycerin.

All figures were illustrated with the aid of the Hamano-shiki drawing apparatus.

Descriptions of the early developmental stages

Measurements and counts of seven specimens described and illustrated are presented in Table 1.

Table 1. Data on the capture and the measurements of the seven specimens described and illustrated

Specimen No.	1	2	3	4	5	6	7
Date	1967-10-6	1968-2-5	1968-2-1	1968-2-1	1967-12-5	1968-6-18	1967-9-25
Locality	11°-10′S 154°-04′E	9°-47′S 42°-19′E	8°-11′S 45°-43′E	8°-11′S 45°-43′E	2°-27′N 164°-13′E	6°-14′S 50°-11′E	3°-51′N 136°-23′E
Measurements in mm:							
Total length	3.75	5.94	9.3	12.4	21.3	27.8	95.5
Standard length	3.63	5.50	7.7	10.4	16.3	22.6	76.0
Preanus distance	2.18	2.88	4.90	6.55	9.8	13.5	46.5
Maximum body depth	1.41	2.12	2.63	3.19	4.90	7.0	20.5
Head length	1.23	2.06	2.81	3.69	5.49	7.5	22.5
Snout length	0.25	0.54	0.70	0.72	1.19	1.69	6.3
Diameter of eye	0.40	0.69	0.89	1.23	1.94	2.38	4.6
Diameter of orbit	0.44	0.77	1.01	1.36	2.06	2.50	4.5
Maxillary length	0.52	0.89	1.03	1.56	2.12	2.81	6.9
Counts:							
Dorsal fin rays	—	(Ⅲ, Ⅰ, 24)*	(Ⅴ, Ⅰ, 26)	Ⅵ, Ⅰ, 28	Ⅵ, Ⅰ, 27	Ⅵ, Ⅰ, 24 +2**	Ⅵ, Ⅰ, 26 +2
Anal fin rays	—	(14)	(Ⅰ, 20)	Ⅰ, 21	Ⅰ, 20	Ⅱ, 17+2	Ⅱ, 17+1
Pectoral fin rays	—	(7)	(17)	20	20	21	21
Ventral fin rays	—	—	(5)	Ⅰ, 5	Ⅰ, 5	Ⅰ, 5	Ⅰ, 5
Branchiostegal rays	—	—	7	7	7	7	7

* Counts in pharenthesis indicate the unfinished form

** Figures in bold-face indicate the detached fin rays

(1) Early postlarval stage: Specimen No. 1; 3.63 mm in SL (Fig. 1).

The body is deep and laterally compressed. The fin folds are continuous throughout but poor in development. The head is as long as deep and 0.3 in standard length. In the dorsal profile of the head, anterior to the eye is almost straight, then gently arched posteriorly, terminating in a well produced bony cranial crest. The trunk rapidly tapers to the still nearly straight tip of the notochord, while a few hypural plates are visible on the ventral side of it. The scales are not seen. The mouth is terminal, large and oblique. The premaxillary excludes completely the maxillary with expanded end from the gape, and its posterior tip extends below the middle of the eye. The teeth and the gill rakers are indistinct. The eye is prominent, about one-third the head length and with a small fissure ventrally. The head armatures are conspicuous in the preopercular series; 8 spines in the inner series and 3 in the outer are counted. As seen in Fig. 1, the angular spine of the former is remarkably strong, being about one half the head length and serrated more numerously on the ventral side than on the opposite side. None of the other spines has such a serration. The ocular crest is bluntly produced above the middle of the eye. The nasal pore is present merely as an elongated shallow hole closely in front of the eye. Compared with the broad space of the brain cavity common to the most carangid larvae, the brain is small and occupied greatly by the lobus opticus. The auditory vesicle is poorly defined externally. The air bladder is visible as a small peritoneal space above the larval pectoral through the overlying tissue.

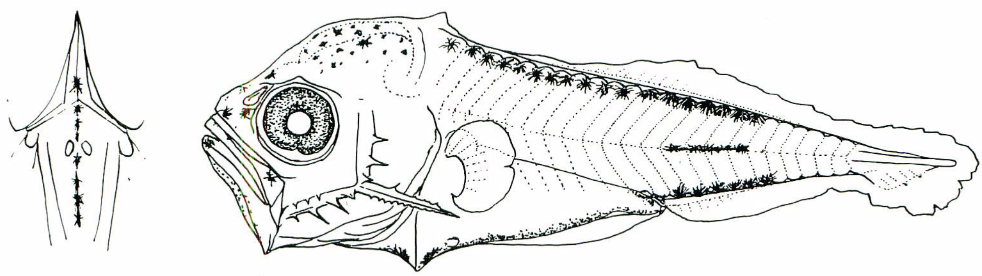

Fig. 1. Specimen No. 1.

As a whole, the pigmentation is poor in development. The body surface is striped with three rows of well expanded chromatophores located along the dorsal and ventral contours of the body and on the lateral midline, the last of which being least prominent. In the head regions, the eye is quite darkly pigmented but the other parts such as the brain, the nasal area, the ventral surface of the lower jaw and the tip of the lower and posterior parts of the maxillary have but a few dots. A group of well spaced small chromatophores around the symphysis of the pectoral girdle provides the useful key for the identification of the early larvae of this species.

(2) Middle postlarval stage: Specimen No. 2; 5.50 mm in S. L. (Fig. 2).

The larva at this size shows considerable developmental changes especially in the fin and the pigmentation.

The larval finfold becomes discontinuous with the caudal fin while its remnants are still distinct in the preanal part along the ventral edge. All fins except the ventral are in the process of differentiation. The anterior portion of the dorsal fin where the first spinous dorsal develops is already decidedly lower and has no spinous

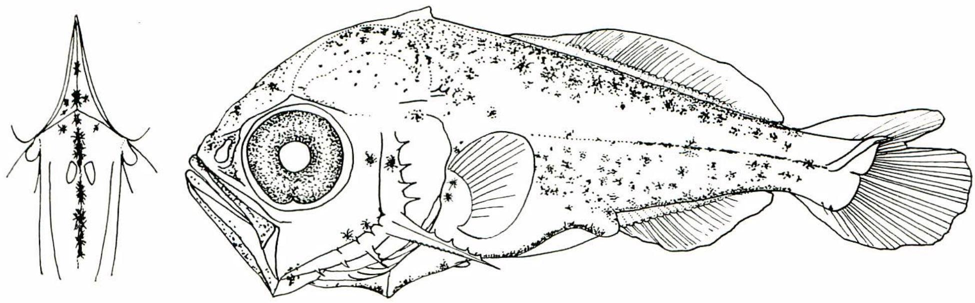

Fig. 2. Specimen No. 2.

elements at all. About 14 dorsal and about 7 anal rays are counted. The gill rakers are developing and 4+11 rakers are stained on the first arch. As is characteristic for the subfamily Naucratinae (Matsubara, 1955), the anteriormost ray of the second dorsal originates above far in advance of the anal fin origin. The caudal fin is distinct, rounded posteriorly and equipped with 15 rays. The head armatures become much more prominent than in the previous specimen, especially in the preopercular angle spine. It grows longer and stouter so that its tip extends beyond the ventral fin base. The smaller spine immediately ventral to this also bears two small denticulations dorsally. There are two new spines at the temporal. The nasal opening is still an elongated single hole.

The chromatophores are spread strikingly over the body surface except for the fins. Several pigments now appear on the preopercle and the base of the pectoral fin. The pigmentation pattern around the symphysis of the pectoral girdle shows little change principally.

(3) Late postlarval stage: Specimen No. 3; 7.7 mm in SL (Fig. 3).

Postlarva of this size is characterized by the appearance of the full complement of the fin rays exclusive of the ventral which is still very small and immature in condition. The remarkable increase in the chromatophores and the furcation of the caudal fin are very conspicuous in this specimen. The snout is slightly protruded. The preopercular spines numbering 11 in total are reducing in relative size and consequently the tip of the largest angular spine never reaches beyond the border of the opercular flap. On the other hand, there appear two new spines at the uppermost corner of the gill cleft and just behind the eye. The nasal is still a single opening but the septum is clearly forming. The brain case over the mid-and fore-brain, and the midlateral portion of the caudal peduncle possess the the pigment accumulations. In addition, there is a marked increase in the chromatophores over the opercular region. However, none of the fins are still provided with any chromatophores.

(4) Transforming stage: Specimen No. 4; 10.4 mm in SL. (Fig. 4).

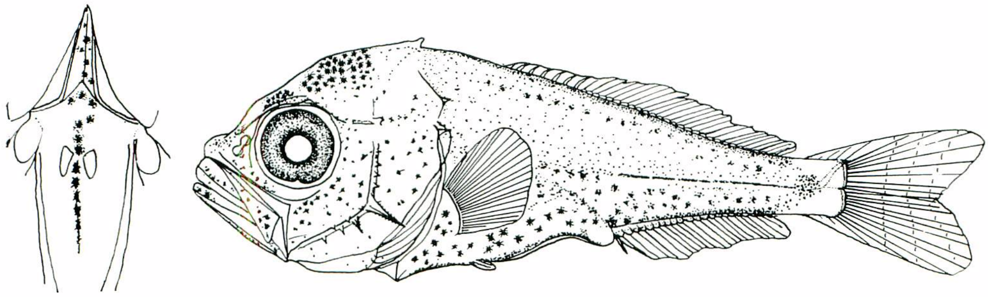

Fig. 3. Specimen No. 3.

The specimen of this size resembles well with the foregoing specimen, but the ventral fin is well elongated and has the full complements of rays. It appears therefore that the larva advances to the juvenile at around this size. The nasal opening is completely paired. The development of the teeth is too poor to be detected superficially. The eye fissure is still discernible. The scale now appears along the lateral midline slightly ahead the caudal peduncle. There is a distinct notch between the first and the second dorsal fins.

The remarkable increases in pigmentations are achieved but all fins and the base of the caudal are still unpigmented. Besides the pigment concentration over the head, there is a denser distribution of chromatophores on the body surface which parallel each myotomes. The larger chromatophores are found linearly along the base of the dorsal and anal fin and sparsely on the belly. Noteworthy is the finding of a pair of short but distinct linear area lacking the pigments on the lateral surface of the caudal peduncle.

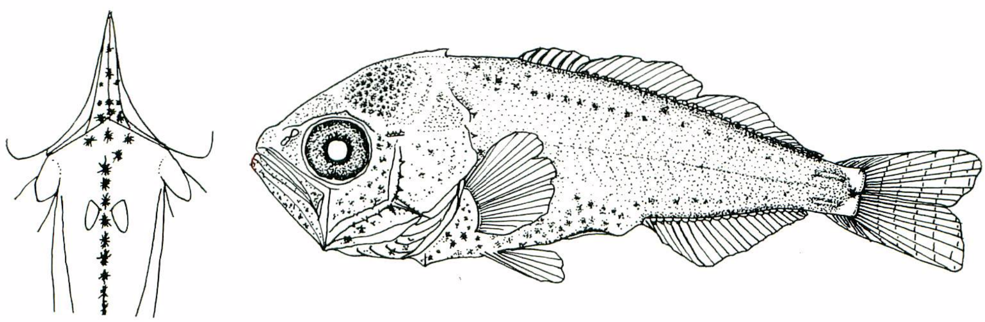

Fig. 4. Specimen No. 4.

(5) Early juvenile stage: Specimen No. 5; 16.3 mm in SL. (Fig. 5).

By this size, most of the head armatures disappear, but the preopercular angle and the temporal spines, while both markedly reduced in size, are still discernible. The nostril is completely separated into two openings; the anterior pore is slightly larger and equipped with the low membraneous flap post-dorsally. Aside from the lateral line which runs along the midlateral of the body with gentle arch in the anterior half of it, the canal system develops over the head, too.

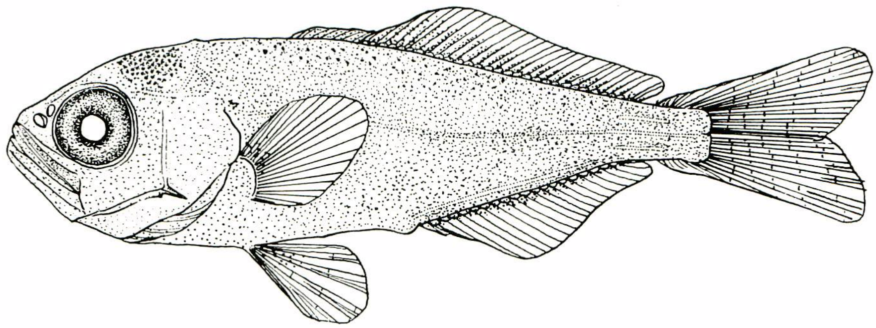

Fig. 5. Specimen No. 5.

There is an increase of chromatophores in all areas of the fish except for the caudal fin. The first dorsal fin is entirely pigmented but the second dorsal is black only at about the basal half. A few pigments are present at the base of the anal fin. On the pectoral and the ventral fins, chromatophores are very scarce and likewise restricted to the basal portions. The unpigmented linear area similar to that mentioned before is added to the ventral side of the full length of the anal fin.

(6) Juvenile stage: Specimen No. 6; 22.6 mm in SL. (Fig. 6).

The body becomes much slender and the snout is pointed. The head armatures are completely disappeared. The sensory canal of the head bears numerous openings; the supraorbital and the postorbital canals are most conspicuous. All fins are elongated and the caudal fin is deeply furcated. The last two rays of the anal and the dorsal fins are slightly detached from the preceding rays, although the membraneous connections are still distinct.

The fin chromatophores show the rapid spreading; the caudal fin which alone remained unpigmented so far, is now crowded with the numerous small chromatophores leaving the periphery. Similarly, the peripheral areas in all fins are more or less transparent.

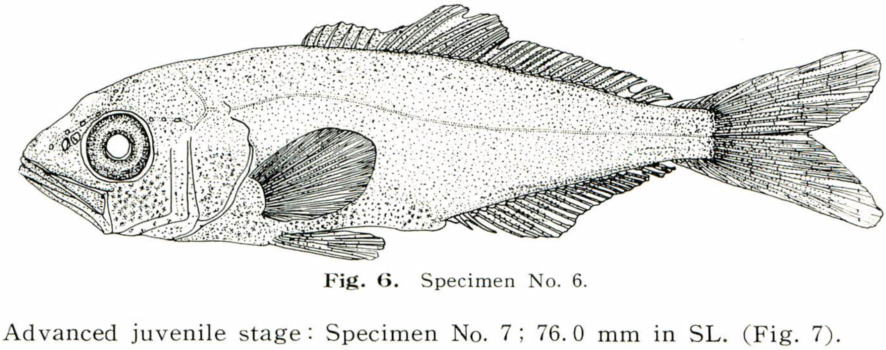

Fig. 6. Specimen No. 6.

(7) Advanced juvenile stage: Specimen No. 7; 76.0 mm in SL. (Fig. 7).

The body shape of this specimen is becoming much more like that of the adult due to the elongation of the body. The maximum body depth in standard length becomes 3.70 but still slightly smaller than 3.83–4.21 in the adults observed by Suzuki (1962). The gape reduces the relative size, so that the posterior end of the maxillary never attains the vertical alignment with the anterior rim of the eye. The opening of the eye is surrounded with the cartilaginous tissue, thus causing the displacement of the nasal opening forward on the middle point of the nasal area. The preopercular bone is broadly formed. The clearly defined finlets and the well pointed fins are striking.

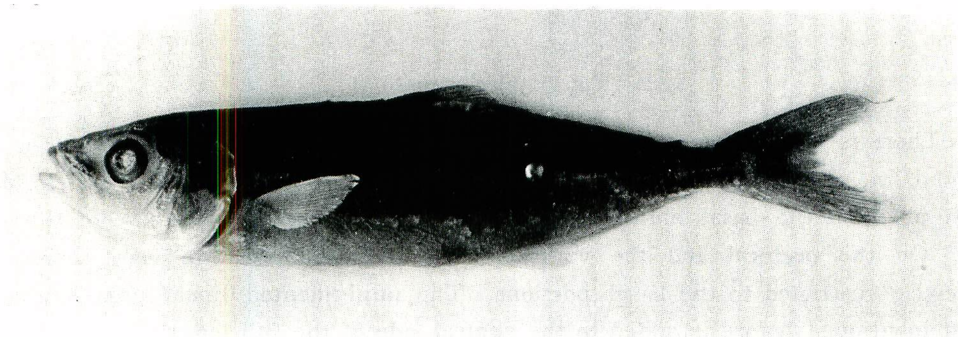

Fig. 7. Specimen No. 7.

The appearance of the lateral stripes is the most significant change in this specimen. They are dark brownish in colour in this preserved material. There is little increase in chromatophores in all fins and thus the anal as well as the pectoral fins are almost colourless superficially.

Identification and Comparison

The juvenile specimen of 22.6 mm illustrated in Fig. 6 has already possessed the significant adult characters to permit the positive identification. Therefore, its characteristics possibly diagnostic to *Elagatis* were traced down to the smaller specimens. The results concerning the diagnosis of *Elagatis* are summarized in Table 2, together with the relevant characters of the other two genera belonging to the subfamily Naucratinae. The genus *Seriolina* is not included here, since we have little informations on the life history of this seemingly rather rare member except for a short remark on the juvenile specimen (Nakamura, 1935).

At first sight of this table, one may notice at once that the larvae and juveniles of *Elagatis* are readily discriminated from those of the other naucratid carangids in the combination of several characters such as the bony cranial crest, the prominent preopercular angle spine with denticulations, the pigmentation patterns especially on the fins and the presence of the finlets, although no single one of them is diagnostic throughout the early stages and each is subject to be qualified by sizes.

In addition, as often remarked in the preceding chapter, the pigmentation pattern

Table 2. Comparisons of the larval and juvenile stages of the genus *Elagatis* with those of the other two genera belonging to the subfamily Naucratinae

Genus	*Elagatis*	*Naucrates**	*Seriola***
Body form	Rather deep and flattened in early postlarvae	Rather deep but not flattened in the postlarvae and early juveniles	Variable from elongate to deep, but generally flattened
Finlet	Present in juveniles	Absent	Absent
Head armatures in postlarvae:			
Cranial crest	Present; prominent	Absent	Absent
Orbital spine	Single; small; blunted	2–3; prominent; pointed	Indistinct
Temporal spine	Small	Very large	Small
Preopercular angle spine	Prominent; serrated throughout	Rather large; smooth	Rather large; smooth
Otic crest	Distinct; serrated	Distinct; smooth	Indistinct
Pigmentation:			
In postlarvae	Rather sparse	Very heavy	Rather heavy
Cross-band	Absent throughout the life	Present; 5–7; in more than ca. 2 cm specimens	Present; 6–11; in juveniles
Longitudinal stripe	Present; 3; in juveniles (also in young and adults)	Absent throughout the life	Absent (but present; 1: in young and adults)
On dorsal and anal fins	Spread throughout the bases	At interval; closely associated with the crossbands on body	Clustered; never extending throughout the bases

*From Padoa (1956). **From Padoa (1956) and Uchida et al. (1958).

around the symphysis of the pectoral girdle is also very useful in identifying the early postlarvae missing the preopercular spine, along with the prominent bony cranial crest.

Here it must be remembered that these characters that distinguish *Elagatis* from the other two naucratid genera do not always hold for the other carangids, because, for example, the bony cranial crest, although that of *Elagatis* seems to be most prominent, is duplicated with varying degrees in many other carangid genera such as *Trachurus*, *Decapterus*, and *Caranx* (Ahlstrom & Ball, 1954; McKenney & Alexander, 1958; Uchida, et al, 1958; Berry, 1959; Shojima, 1962), and the finlet is also common to *Decapterus* and *Megalaspis* (Smith. 1950; Shojima, 1962).

The superficial resemblance of the finlet characters between *Elagatis* and *Decapterus* was formerly considered to indicate the close relation of these two genera (Matsubara, 1955). Recently, however, Suzuki (1962) proposed the quite different picture of their relationships on the basis of the detailed osteological study of the Japanese carangidae; he placed *Decapterus* in the most distant form from the Naucratinae.

In fact, we have too little information on the larval taxonomy at present to elucidate any reliable conclusion concerning the phylogenetic problem of the fishes, but the close similarity of the larval stages between the above mentioned two genera seems not to be convincingly explained as a parallel or convergent adaptation to a similar environments. Anyhow, I think it worthy to review the carangid fishes from the view point of the comparative study of the larval features.

Analysis of Several Aspects

(1) General development

The relative growth of the eight bodily parts against the standard length is presented in Fig. 8, where the declining border lines separating the two graphs represent the isoauxesis ($k=1$). Therefore, by comparing with these oblique lines, one can easily determine whether the relative growth is the tachyauxesis ($k<1$) or the bradyauxesis ($k<1$).

Because of the considerable individual variations, it is difficult to fit the simple allometric growth equation to some of these bodily portions. Generally speaking, however, these portions in *Elagatis* present the very regular growth throughout the larval and the juvenile stage with the exception of the preopercular angle spine.

So far as the present materials are concerned, the preanal distance shows approximately the isoauxesis, but the others including the body depth, the head length, the eye diameter and the maxillary length are apparently referred to the bradyauxesis, with descreasing value of k in this order. The remaining portions such as the caudal fin length and the snout length are referable to the tachyauxesis.

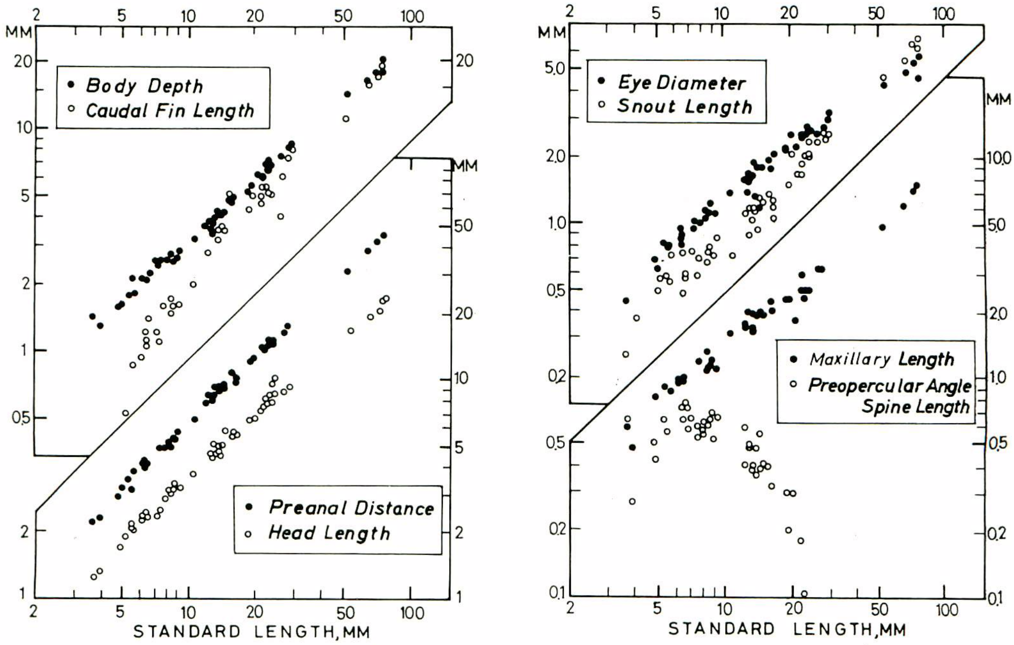

Fig. 8. Relative growth of eight bodily parts against standard length during the postlarvae and juvenile stages of *E. bipinnulatus*.

Among these proportional patterns, the caudal fin is unique in having a distinct point of growth inflection when the fish gets about 20 mm in length. A similar inflection, while less prominent, is also observed in the eye diameter at about the same size as the previous feature.

The change in the preopercular angle spine accompanying growth is very striking. Although it is difficult to determine at what size it ceases to increase in length and is absorbed completely, the greatest size appears to be acquired before the fish attains 7–8 mm and it disappears at about 25 mm in standard length. This kind of growth may be ascribed to the so-called "enantiometry". In this connection, Berry's observation (Berry, 1959) on *Caranx crysos* would be worthwile to note: Above approximately 10 mm, the length of this(=preopercular angle) spine decreased due to expansion of the posterior margin of the preoperculum.

It is well known that the larval characters exhibit occasionally unexpected sequential changes but the most specialized forms are generally achieved during the late postlarval stage (Uchida, 1937). The behaviour of the above mentioned preopercular angle spine and perhaps the bony cranial crest may be a typical example of this nature.

On the associations between the growth inflection and the ecological feature, the present materials only suggest that former two inflections which occur just in the early stage of the finlet formation may be correlated with the change in the mode of life peculiar to this fish.

(2) Fin formation

Ossifications of the fin seem to occur simultaneously at approximately 4 mm in length except for the ventral fin which is visible as a freshy bud at this stage. Although the exact sequential pattern of the fin formation during the early larval stages is not clarified, the fin development seems to be similar to that described for *Trachurus symmetricus* (Ahlstrom & Ball, 1954); the pectoral, the soft dorsal and the anal are early in developing and the spinous dorsal and the ventral are last to be stained.

The full complement of the various fins were achieved approximately at the following sizes: Dorsal 7.5; anal 7.5; pectoral 10.5; ventral 10.5; and caudal 9.3, all in mm of standard length.

One of the most conspicuous features of the fin formation in this species may be the differentiation of the finlets. Fig. 9 presents the osteological details of the

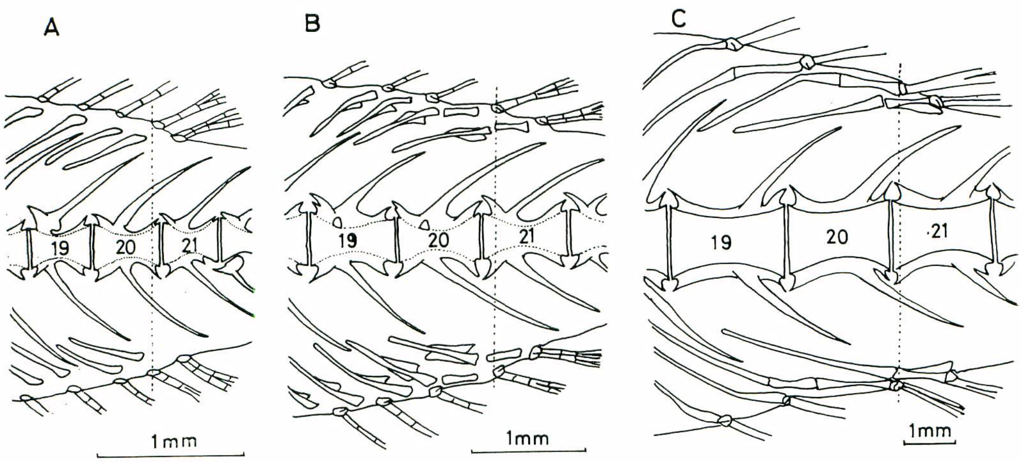

Fig. 9. Three stages of the finlet formation showing the details of the osteological features.

three specimens on the process of the finlet formation. Its primary feature is recognized as the posteriormost two rays slightly detached from the preceding one in both the dorsal and the anal fins in the postlarva as small as 12.8 mm in length. Little changes are noticed in this respect in the much larger specimen of 16.3 mm illustrated in Fig. 9A except for the full branching of the rays. In this stage the finlets stand almost opposite each other and originate at the posterior part of 20th vertebra. The pterygiophores relevant to these detached rays are inserted between the neural as well as the haemal spines of the 19th and the 20th vertebrae, and have no actual connection with the rays.

In much advanced specimen of 22.6 mm (Fig. 9B), the rays are displaced posteriorly thus line connecting the origin of the anal and the dorsal finlets being on the 21th vertebra. Surprisingly, the rodlike ossicles (medial radials) appear between the posterior most two rays and the relevant primary pterygiophores without actual conjunction one another. All the pterygiophores are furnished with the membraneous keels of roughly triangle in outline along the distal portions of their posterior edges and at the same time the posteriormost two bear the similar ornaments on the opposite side, too.

A series of these elements, viz., the soft rays, the intermediate ossicles, and the pterygiophores, are united to form a functional rays in 71 mm specimen (Fig. 9C). The finlets are quite distinct but membraneous connections with the preceding rays are still faintly present. The location of these finlets relative to the vertebra well agrees with that in the preceding specimen. The accessory keels on the pterygiophores had already disappeared, and in turn, the intermediate ossicles of the last rays bear the similar structure on their posterior edge. The posteriormost pterygiophores are nearly straight but immediately preceding bones have unique shape with inflection at about the middle point of their length, thus forming the triangular frameworks for the basal finlet support.

These sequential scopes suggest that the finlet in the genus *Elagatis* is established secondarily as a result of the adaptation to the peculiar mode of life and surely serves to form the slender but strong caudal peduncle.

It is generally known that the finlet is unique within the typical oceanic forms. More precisely, aside from the family Scomberesocidae, this characteristic is restricted to occur in certain suborders including Scombrina and Carangina. Such a taxonomical integrity may provide a good evidence on the close correlation between this character and the generic affinity and even the similar way of life. The another integrity that the majorities are fast swimmers who have the slender tail in common should be mentioned. Possibly, the strong flexture of body as a main propulsive force and the the adaptation to minimize the hydrodynamic resistance may be particularly responsible for this common nature.

In contrast, there is no sign of any specialized structure in the finlets of *Cololabis saira* (Chapman, 1943), one of the representative of the family Scomberesocidae, that accounts for the phylogenetically rather distant and exceptional occurrence of this character.

(3) Food and the structure of the digestive canal

In order to clarify the feeding habit of the early stages the stomachs of 17 specimens ranging from 3.6 to 75 mm in standard length were dissected. At the same time, some morphological aspects of the digestive canal including the gill structure were studied and the results are summarized in Table 3.

The gill rakers first appear in 5.5 mm specimen and thereafter rapidly increase

Table 3. Development of digestive canal and the gut contents of larvae and juveniles of *Elagatis bipinnulatus*

SL (mm)	No. of gill rakers	Shape of digestive canal		Food items
		Stomach*	Intestine	
3.6	undeveloped	Ia-shape	straight	2 copepods
5.5	4+11	Ia	straight	3 copepods
5.8	4+15	Ia	straight	3 copepods
6.5	5+13	Ia	straight	8 copepods
7.9	5+15	Ia	straight	5 copepods
8.7	6+18	Ib	straight	6 copepods
9.7	7+18	Ib	straight	6 copepods
10.4	6+20	Ib	straight	14 copepods
12.0	8+19	V	straight	13 copepods
13.6	8+18	V	straight	17 copepods
14.5	9+19	V	straight	undetermined
16.0	9+22	V	looped	undetermined
24.0	9+23	V	looped	empty
25.5	10+21	V	looped	empty
28.0	11+25	Y	looped	ca. 200 copepods
52.0	11+23	Y	looped	ca. 20 copepods; 1 amphipod
75.0	11+23	Y	looped	1 fish egg; 1 copepod

*Shape of stomach is classified chiefly according to the standards given by Suyehiro (1942); a and b denote the absence and presence of the rudimentary blind sac respectively.

in number as growth proceeds. The full complement seems to be acquired at about 25 mm in length. According to the standard of Suyehiro (1942), the sequence of the stomachal development is diagrammed as follows: I→I→V→Y. The intestinal loop is formed during the V stage but no pyrolic caecum is found in these materials.

It may be said with certainty that the copepods play the most important part in the diet of the postlarvae and the juveniles and the amounts of foods taken by a single specimen increase roughly proportionately with the growing size. Among these copepods, the calanoid copepods (mostly copepodid larvae) and *Corycaeus* predominated in the diet and a single specimen of *Sapphirina* was detected in 13.6 mm specimen. Furthermore, a single fish egg and a small amphipod crustacea were identified.

The differences of the feeding condition in the present materials are likely due to the differences in the sampling stations rather than in the size of the predators. In addition, neither size preference nor strong selection for foods were observed at all.

These results coincide well with the observation by Anraku & Azeta (1965) for the amber fish, *Seriola quinqueradiata*, that states as follows: "Copepodid larva of the small copepods are the most important food for the early stage of the larvae and the juveniles."

Distribution and Relative Abundance

The localities of the larvae and the juveniles of *Elagatis bipinnulatus* (QUOY & GAIMARD) at my disposal are plotted in Fig. 10.

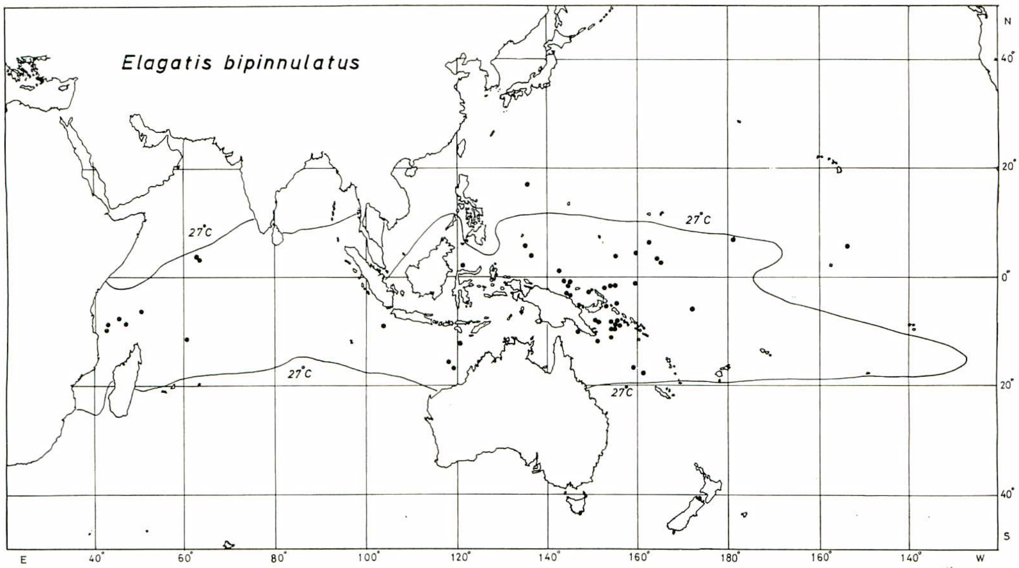

Fig. 10. Localities of larvae and juveniles of *Elagatis bipinnulatus* at my disposal and correlation with the surface isotherm for 27° C in February (after Sverdrup, et al., 1942).

Although the surface water temperature for these specimens are 26.5 to 29.9°C, and most abundant specimens are found in 28 degree (Fig. 11), it is clear from this map that occurrences are restricted to the somewhat coastal areas of the equatorial regions in the western Pacific where the temperature in February is higher than 27°C, with the exceptions of two specimens; one at 16°-48′N, 135°-54′E, and another at 05°-35′N, 153°-40′W, each representing the northernmost and easternmost records in the present materials, respectively. In view of the most numerous occurrences of the larvae in March collections, this 27°C isotherm appears to have some ecological significances on the reproduction of this fish.

These distributional features may reflect partly the sampling intensity but there seems to be a significant differrence in the horizontal ranges between the early stages and the adult specimens.

In the Indo-Pacific regions, this fish has been reported from as far north as the coast of Japan (Matsubara, 1955; Okada, 1955), the coast of Hawaii and the southern Africa (Gosline & Brock, 1960), and the Great Barrier Reef region is also included in its range (Marshall, 1965). As is well known, this fish is a common visitor in

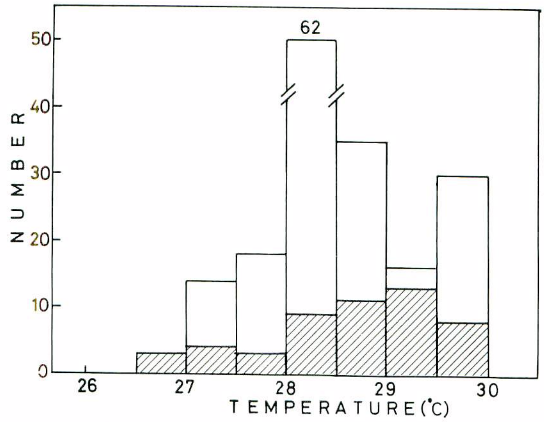

Fig. 11. Frequency of the successful hauls and the individuals of the larval and juvenile *Elagatis bipinnulatus* at temperature increments in the Indo-Pacific Oceans. Hatched area is number of successful hauls ($n=51$); clear area is number of individuals ($n=178$).

the Ryukyu Islands where the Kuroshio current remarkably prevails (Okada, 1955). It is worthy mentioning in this connection that 100 mm specimen in total length, probably the smallest one of *Elagatis* available in literature, has been recorded from the Japanese waters (Ida, 1967).

From these evidences, it seems reasonably safe to conclude that as pointed out by Parin (1967), the genus *Elagatis* is a typical epipelagic form of the coastal origin and this epipelagic nature is established through the close association with the prevailing water currents.

Here, an assumption is made that the presence of the specimens less than 20 mm in length is indicative of the recent spawning in an area at or near the time of capture. Monthly catch data by latitude (Table 4) then revealed that *Elagatis bipinnulatus* is a rather southern spawner and has a seasonal peak of spawning in March, while the small scale spawning may occur throughout the year. About 28 percent of the total specimens were taken during that month.

Table 4. Monthly catch of larvae and juveniles of *Elagatis bipinnulatus* by latitude

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	No. of sp./haul
10-20(N)	1	0	0	0	0	0	0	0	0	0	0	0	1.00
0-10(N)	5	2	5	0	3	2(1)*	0	0	4(4)	0	2	2	1.64
0-10(S)	50	17	35(5)	5(3)	0	12(6)	6(6)	1	0	0	5(2)	0	4.85
10-20(S)	3(1)	0	14(2)	0	0	0	0	1	0	2	0	0	2.22
No. of sp./haul	8.42	6.33	6.75	1.67	1.50	1.40	2.00	1.00	4.00	1.00	1.00	2.00	

*Figures in pharentheses indicate the number of specimens larger than 20 mm in standard length

Table 5. Catching condition of larvae and juveniles of *Elagatis bipinnulatus* by size

Range in SL (mm)	No. of sp.	No. of hauls	No. of sp./haul	
			Range	Mean
0- 9.9	97	17	1-27	5.71
10-19.9	50	22	1-10	2.27
20-29.9	22	15	1- 5	1.47
30-39.9	2	2	1	1.00
40-49.9	0	0	—	—
50-59.9	1	1	1	1.00
60-69.9	1	1	1	1.00
70-79.9	3	2	1- 2	1.50

In Table 5 and Fig. 12 are given the length composition and the catching condition of the present materials. Of total 177 specimens ranging from 3.5 to 76 mm in standard length, the postlarvae smaller than 10 mm make up more than half (54 percent) of them and the remainings are mostly occupied by 10–30 mm specimens. The number of specimens per successful haul tends to decrease with the increasing size of them, but such a trend becomes obscure for beyond 40 mm specimens.

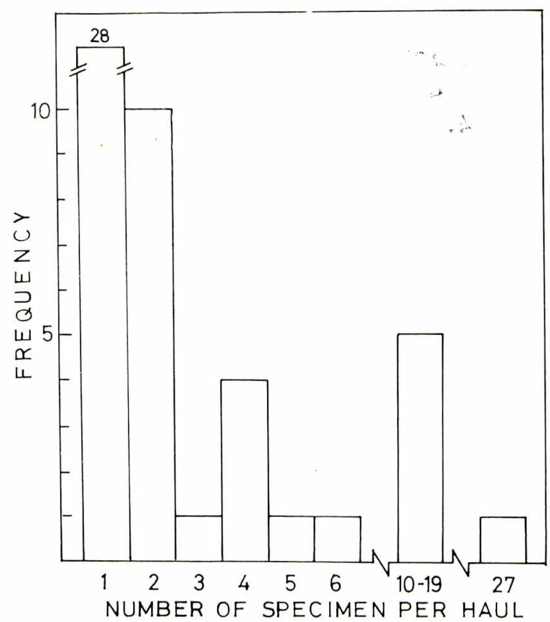

Fig. 12. Frequency distribution of the number of specimen per successful haul (n=51).

On the other hand, more than half of the successful hauls (28 stations) are represented by a solitary capture and the other 10 contain two specimens. Among the remaining 13 stations, however, 5 successful hauls provide more than 10 specimens.

The greatest production in a single haul is 27 postlarvae (4.9–8.7 mm in S.L.) recorded at 08°–16′S, 46°–26′E, in the Indian Ocean, on January 30th, 1968.

As regards the close association with the floating materials, such as the Coelenterates, the floating *Sargassum* weeds and occasionally the larger sharks, which is a very common as well as a peculiar habit of carangids (Shojima, 1962; Mansueti, 1963), there is a few observation in *Elagatis* as well (Ida, 1967; Parin, 1967), while seemingly less prominent than in *Seriola* and *Naucrates*.

Recently, in the review of the epipelagic fishes in the Pacific Ocean, Parin (1967) proposed to divide them into three groups and his opinion on the carangids is as follows: (1) the holoepipelagic group comprises *Naucrates*; (2) the meroepipelagic, *Elagatis*; (3) the xenoepipelagic, *Caranx*, *Decapterus* and *Seriola*. Fig. 13 is

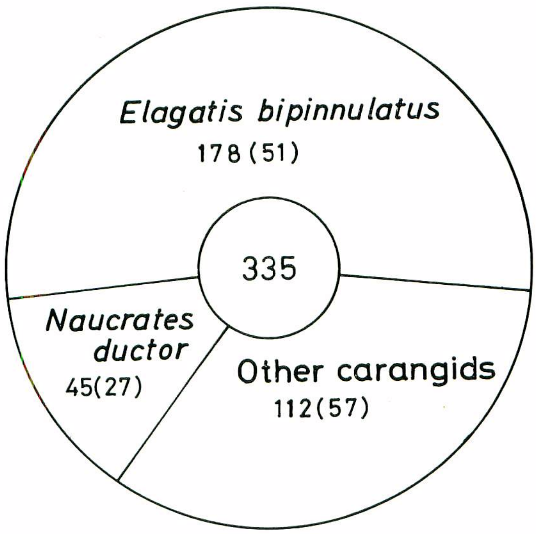

Fig. 13. Relative abundance of the epipelagic larvae and juveniles of carangid fishes compiled on my unpublished data.
Figure in the central circle represents the total number of specimens at my disposal. Figures before and in the parentheses indicate the actual total numbers of specimens and the successful hauls in each groups, respectively.

compiled according to this standard to reveal the relative abundance of the epipelagic larvae in the Indo-Pacific regions on my unpublished data. Taking it into consideration that majority of these specimens are collected near the fishing grounds of tuna which are typical representatives of the holoepipelagic forms, these materials might well reflect the actual abundance of the epipelagic fauna in the open seas.

On above composition, one may be of sure that *Elagatis* is the most abundant form of the epipelagic larval carangids in the tropical as well as in the subtropical Indo-Pacific. The rather small numbers of *Naucrates*, despite its extended ranges, are supposed to be due to the solitary nature in occurrences. Anyhow, it may be said with certainty that *Elagatis bipinnulatus* (QUOY & GAIMARD) is one of the hopeful latent fish resources at least in the Pacific Ocean.

I wish to express my heartfelt thanks to Drs. Hiroshi Yabe, Akira Suda, Yoshio Fukuda, and Shoji Ueyanagi of the Far Seas Fisheries Resarch Laboratory for their guidances and advices in many ways during the course of this work. My thanks are also due to Drs. Shiro Murakami and Sukekata Ito of the Japan Sea Regional Fisheries Research Laboratory who generously permitted me to leave the desk of the Laboratory for this work and also read the manuscript. Various staff members of the Prefectural Fisheries Experimental Stations and the Fisheries High Schools, assisted in collecting these enormous and precious materials. Their painstaking assistances are most deeply appreciated.

This work was made possible by a draft research fellowsihp of the Agriculture, Forestry & Fisheries Research Council, and was accomplished in the Far Seas Fisheries Research Laboratory.

References

AHLSTROM E. H., and O. P. BALL, 1954: Description of eggs and larvae of Jack mackerel (*Trachurus symmetricus*) and distribution and abundance of larvae in 1950 and 1951. U. S. Dept. Interior, Fish and Wildlife Service, Fish. Bull. 97, vol. 56: 209-245.

ANRAKU M., and M. AZETA, 1965: The feeding habits of larvae and juveniles of the yellowtail, *Seriola quinqueradiata* TEMMINCK et SCHLEGEL, associated with floating seaweeds. Bull. Seikai Reg. Fish. Res. Lab., (33): 13-45. (In Japanese)

BERRY, F. H., 1959: Young Jack crevalles (*Caranx* species) off the southeastern Atlantic coast of the United States. U. S. Dept. Interior, Fish and Wildlife Service, Fish. Bull. 152, vol. 59: 417-535.

BRIGGS, J. C., 1960: Fishes of worldwide (circumtropical) distribution. Copeia, 1963(3): 171-180.

CHAPMAN, W. M., 1943: The osteology of the Pacific saury, *Cololabis saira*. Ibid., 1943(3): 171-182.

GOSLINE, W. A. and V. E. BROCK, 1960: Handbook of Hawaiian fishes. Univ. of Hawaii Press, Hawaii: 372pp.

IDA, H., 1967: Study of fishes gathering around floating seaweeds II. Behaviour and feeding habit. Bull. Jap. Soc. Sci. Fish., 33(10): 930-936.

LÜTKEN, C. F., 1880: Spolia atlantica. Vid. Selsk. Skrifter Kjobenhavn, 5 ser., vol. 12: 409-613.

MANSUETI, R., 1963: Symbiotic behavior between small fishes and jellyfishes, with new data on that between the stromateid, *Peprilus alepidotus*, and the scyphomedusa, *Chrysaora quinquecirrha*. Copeia, 1963(1): 40-80.

MARSHALL, T. C., 1965: Fishes of the Great Barrier Reef and coastal waters of Queensland. Livingston Co., Narberth, Pennsylvania: xv+566pp.

MATSUBARA, K., 1955: Fish morphology and hierarchy, Part I. Ishizaki Shoten, Tokyo: 789pp. (In Japanese).

McKENNEY, T. W., E. C. ALEXANDER, and G. L. VOSS, 1958: Early development and larval distribution of the carangid fish, *Caranx crysos* (MITCHILL). Bull. Mar. Sci. Gulf and Carib., 8(2): 167-200.

NAKAMURA, S., 1935: Larval and juvenile stages of reef fishes occurring in the adjacent waters of Kominato (X). Yoshoku-Kaishi, 5(7/8): 127-132. (In Japanese).

OKADA, Y., 1955: Fishes of Japan. Marnzen Co., Tokyo: 434pp.

PADOA, E., 1956: Uova, larve e stadi giovanili di teleostei; Carangiformes. Fauna e Flora del Golfo di Napoli, Monogr., 38: 548-572.

PARIN, N. V., 1963: Results of studying pelagic ichthyofauna of the Pacific and Indian Oceans by use of electric light for attracting fishes. Trud. Inst. Okean., Tom. 62: 128-144. (In Russian).

--------------------, 1967: The general characteristics of the epipelagic ichthyofauna, in "Biology of the Pacific Ocean, Book III, Fishes of the open water". Inst. Acad. Sci. USSR. (After the Japanese translation by Y. Hirano, 1969)

SHOJIMA, Y., 1962: On the postlarvae and juveniles of carangid fishes collected together with the jelly-fishes. Bull. Seikai Reg. Fish. Res. Lab., (27): 47-58. (In Japanese).

SMITH, J. L. B., 1950: The sea fishes of southern Africa. Central News Agency, Ltd., South Africa: xvi+550pp.

SUYEHIRO, Y., 1942: A study of th digestive system and feeding habits of fish. Jap. Jour. Zool., (10): 1-303.

SUZUKI, K., 1962: Anatomical and taxonomical studies on the carangid fishes of Japan. Rep. Fac. Fish., Pref. Univ. Mie, 4(2): 43-232.

SVERDRUP, H. V., M. W. JOHNSON, and R. H. FLEMING, 1942: The oceans. New York, Prentice-Hall: 1087pp.

UCHIDA, K., 1937: On the floating mechanism appearing during the pelagic stages of fishes (I). Kagaku, 7(13): 540-546. (In Japanese).

UCHIDA, K., et al., 1958: Studies on eggs, larvae and juveniles of Japanese fishes, Ser. I. Second Lab., Fish. Biol., Fish. Dept. Fac. Agr., Kyushu Univ., Fukuoka: 89pp., Pls. 86. (In Japanese).

Addendum

After the manuscript of this paper had gone to press, an interesting paper by Berry [*Elagatis bipinnulata* (Pisces: Carangidae): Morphology of the fins and other characters, Copeia, 1969(3): 454-463] came to my attention. In this paper are given the comprehensive stuides on the fin structures and some other characters such as gill rakers and scales, chiefly from the view point of ontogeny. At the same time, the juvenile of 18.5 mm in SL from Florida Straits is illustrated for the first time.

The occurrence of this species in the Eastern Pacific off Central America is recorded in his specimens examined.