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Synopsis of Biological Data on Tunas of the Genus *Euthynnus*

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National Oceanic and Atmospheric Administration
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U.S. DEPARTMENT OF COMMERCE
Juanita M. Kreps, Secretary

National Oceanic and Atmospheric Administration
Richard A. Frank, Administrator

National Marine Fisheries Service
Terry L. Leitzell, Assistant Administrator for Fisheries

CONTENTS

*No information available.

Synopsis of Biological Data on Tunas of the Genus *Euthynnus*

HOWARD O. YOSHIDA[1]

ABSTRACT

Biological and fisheries data on *Euthynnus affinis*, *E. alletteratus*, and *E. lineatus* from published and unpublished sources were compiled, synthesized, and summarized following the FAO species synopsis outline.

INTRODUCTION

The fishes of the genus *Euthynnus* are widely distributed in the warm and tropical waters of the world's oceans. In some localities they appear to be the dominant scombrid in the coastal, nearshore waters. *Euthynnus alletteratus* is one of the commonest scombrids in the western North Atlantic (Rivas 1951). In trolling surveys off the southeastern coast of the United States this species was caught most often (Anderson[2]). Ben-Tuvia (1957) stated that *E. alletteratus* seemed to be the only common scombrid along the coast of Israel in the Mediterranean. In Hawaiian waters *E. affinis* was one of the more common species taken by trolling (Welsh 1949; Tester and Nakamura 1957). Walford (1937) stated that *E. lineatus* was very abundant in the eastern tropical Pacific.

Although the species of *Euthynnus* are widely distributed and apparently abundant in some localities, generally the group as a whole is not commercially as important as the other tunas, e.g., skipjack tuna, *Katsuwonus pelamis*. Calkins and Klawe (1963) stated that *E. lineatus* was of no commercial value and Kikawa and staff (1963) noted that consumer demand for *E. affinis* was not very great in Japan. The world landings of *Euthynnus* ranged from 80,350 to 87,735 metric tons (t) and averaged about 84,674 t during the period from 1973 to 1976 (FAO 1977).

Because the world demand for tuna is steadily growing and since several of the commercially important tunas are at or near the level of maximum sustainable yield, the underexploited and presently commercially unimportant tuna and tunalike species are likely to attract more attention. Therefore it is important that the life history and biology of these species, including *Euthynnus*, be elucidated.

The purpose of this report is to collate and update all the information presently available on *Euthynnus*. All papers on *Euthynnus* published in the FAO Species Synopsis series (Calkins and Klawe 1963; Kikawa and staff 1963; Marchal 1963; Williams 1963) were relied on heavily in preparing this report.

1 IDENTITY

1.1 Nomenclature

1.11 Valid name

Collette (1978) discussed the relationships of the groups of fishes in the subfamily Scombrinae, including *Euthynnus*. He pointed out that some workers (Fraser-Brunner 1950; Collette and Gibbs 1963) placed the monotypic *Katsuwonus* in synonymy with *Euthynnus*, which he thought obscured the relationships of *Euthynnus* (sensu stricto) with *Auxis* and of *Katsuwonus* with *Thunnus*.

The status of the species within *Euthynnus* is clear; there are three allopatric species of *Euthynnus* throughout the world: *E. affinis* (Cantor) of the Indo-West Pacific, including Hawaii and the Red Sea; *E. alletteratus* (Rafinesque) of the Atlantic Ocean (including the Mediterranean Sea, the Caribbean Sea, and the Gulf of Mexico); and *E. lineatus* Kishinouye of the eastern Pacific.

Euthynnus affinis was originally described as *Thynnus affinis* Cantor 1850. The holotype was from Penang, most likely from the Strait of Malacca. It was 536 mm (FL) long and is preserved as a dried skin in the British Museum as BMNH 1860.3.19.214 (Collette[3]).

The little tuna from the eastern Pacific was originally described as *Euthynnus lineatus* Kishinouye 1920 and still retains that name.

Euthynnus alletteratus has long been accepted as the valid name of the Atlantic little tuna. It was first described as *Scomber alletteratus* Rafinesque 1810. It was claimed recently by Postel (1973), however, that the fish described and figured by Rafinesque is actually *Auxis rochei* and that the specific name for the Atlantic little tuna should be *Euthynnus quadripunctatus* of Geoffroy

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[2]Anderson, W. W. 1954. Progress report, South Atlantic Fishery Investigations, Appendix SA-2. *In* Atlantic States Marine Fisheries Commission, 13th Annu. Meet., Baltimore, Part 2, p. 211-213.

[3]B. B. Collette, Systematics Laboratory, National Marine Fisheries Service, NOAA, Washington, DC 20560, pers. commun. March 1978.

Saint Hilaire (1817). However, Tortonese (1975) argued for the retention of the name *alletteratus*. It was also pointed out that Rafinesque (1810) described *Sarda sarda* (as *Scomber palamitus*), *Auxis rochei* (as *S. bisus*), and *E. alletteratus* (as *S. alletteratus*) and that he could not have confused "bisu" (*Auxis*) with "alletterata" (*Euthynnus*) (Tortonese 1976). Thus *Scomber quadripunctatus* of Geoffroy Saint Hilaire (1817) is listed herein as a junior synonym of *Euthynnus alletteratus*.

1.12 Synonymy

The synonymies given below make no distinction between objective and subjective synonyms. The synonymies for *Euthynnus affinis* and *E. alletteratus* are based on synonymies given by Jones and Silas (1964) and Fraser-Brunner (1949), respectively. There are no synonyms for *E. lineatus*.

Euthynnus affinis

Thynnus affinis Cantor 1850 (Penang).
Thynnus thunnina. Temminck and Schlegel 1850 (Japan).
Auxis taso (not of Cuvier) Bleeker 1850 (Java).
Euthynnus alletteratus. Jordan, Tanaka, and Snyder 1913 (Japan).
Euthynnus yaito Kishinouye 1923 (Japan).
Gymnosarda alletteratus. Meek and Hildebrand 1923 (Panama).
Wanderer wallisi Whitley 1937 (New South Wales, Australia).
Euthynnus affinis affinis. Fraser-Brunner 1949 (Aden, Seychelles, Thailand).
Euthynnus affinis yaito. Fraser-Brunner 1949 (Japan, Hawaii, Pacific islands).
Euthynnus affinis. Rosa 1950 (in part).
Euthynnus alletteratus affinis. de Beaufort 1951 (in part) (Indo-Pacific).
Euthynnus wallisi. Whitley 1964 (Australia).

Euthynnus alletteratus

Scomber alletteratus Rafinesque 1810 (Sicily).
Scomber quadripunctatus Geoffroy Saint Hilaire 1817 (Egypt).
Thynnus leachianus Risso 1827 (Nice).
Thynnus thunnina Cuvier 1829 (Mediterranean).
Thynnus brevipinnis Cuvier in Cuvier and Valenciennes 1831 (Mediterranean).
Thynnus brasiliensis Cuvier in Cuvier and Valenciennes 1831 (Brazil).
Euthynnus alletteratus. Jordan, Evermann, and Clark 1930 (western Atlantic).
Euthynnus thunnina. Nobre 1935 (Portugal).
Euthynnus alletteratus alletteratus. Fraser-Brunner 1949 (North Atlantic).
Euthynnus alletteratus aurolitoralis. Fraser-Brunner 1949 (Gold Coast).

1.2 Taxonomy

1.21 Affinities

— Suprageneric

Phylum Chordata
Subphylum Vertebrata
Superclass Gnathostomata
Class Osteichthyes
Subclass Actinopterygii
Order Perciformes
Suborder Scombroidei
Family Scombridae
Subfamily Scombrinae
Tribe Thunnini

— Generic

Genus *Euthynnus* Jordan and Gilbert 1882.

The generic concept of *Euthynnus* as given below follows that of Godsil (1954a) and Collette (1978).

The species of *Euthynnus* are fusiform, streamlined, and have a lunate caudal fin similar to all tunalike fishes. The body is naked except for the scaly corselet. A series of oblique or longitudinal black markings above the lateral line distinguishes *Euthynnus* from *Katsuwonus,* which has black longitudinal stripes on the belly. The contiguous or nearly contiguous dorsal fins distinguishes *Euthynnus* from *Auxis,* which has widely separated dorsal fins. The concave distal margin of the first dorsal fin separates *Euthynnus* from *Sarda,* which has a nearly straight first dorsal margin. The species of *Euthynnus* usually have eight dorsal and seven anal finlets. Palatine teeth are present in all and vomerine teeth in two of the species. The intestine is straight. There are 37-39 vertebrae. Godsil (1954a) gave a detailed description of the generic skeletal characters.

Unlike *Auxis, Euthynnus* has a common trunk for the dorsal and ventral branches of the cutaneous artery. However, *Euthynnus* is more primitive than *Katsuwonus* in that the cutaneous artery's ventral branch is short and dendritic (Godsil 1954a) and much less developed than the dorsal branch. *Euthynnus* also differs from *Auxis* wherein the dorsal cutaneous artery lies dorsal to the corresponding vein and not ventral. In *Euthynnus* the aorta is moved ventrally a distance greater than the depth of the centrum owing to the development of the trelliswork, a distance less than in *Auxis* and more than in *Katsuwonus* (Collette 1978).

— Specific

Euthynnus affinis (Cantor) (Fig. 1).

The folowing description is based on that given by Godsil (1954a).

The dorsal black markings that are superimposed over a blue to indigo background are most accentuated in the

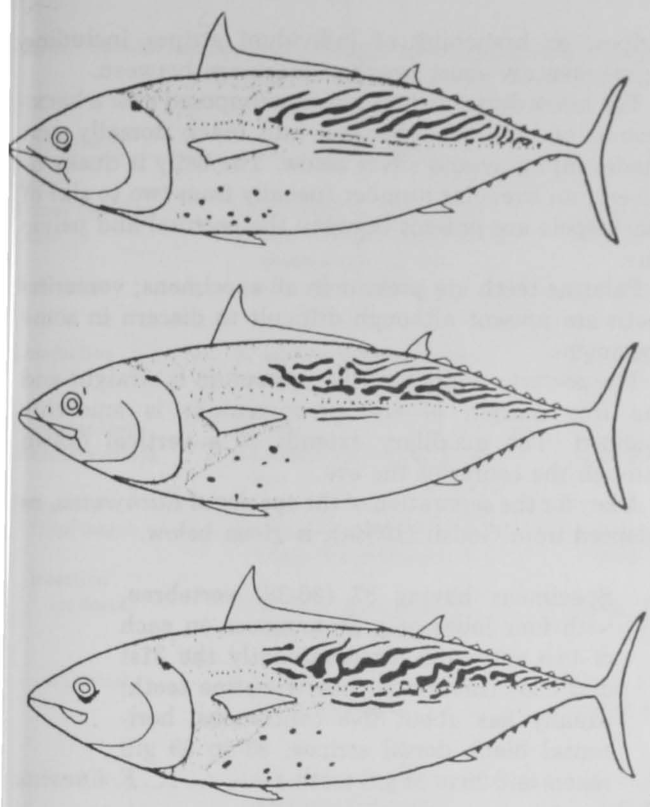


Figure 1.—Variations in the markings of three *Euthynnus affinis*. (From Godsil 1954a, fig. 65.)

anterior region and are more oblique in *E. affinis* than in the other two species. Black or dusky spots are scattered over a relatively wide area on the belly below the pectoral. These spots are variable and cannot be regarded as a specific character.

The crest or rise of the lateral line above the pectoral fin is minimal. The crest or rise, when present, is always gentle at its anterior slope. In many specimens the lateral line is almost horizontal from the opercular margin over the anterior third of the pectoral fin, from where it slopes gently downward.

The caudal keels are not conspicuously developed and are evident externally only by a dorsoventral flattening of the peduncle.

The operculum is relatively straight at the posterior margin and a small dark or black elongated spot is generally present at the dorsal extremity of this margin. The posterior outline of the preoperculum is gently and smoothly rounded. A small irregular dark spot or area is present below the posteroventral margin of the eye.

The maxillary extends to or slightly beyond the vertical through the middle of the eye and, depending on the size of the specimen, 24 to 35 teeth are on each side of the lower jaw. Vomerine teeth are present but palatine teeth, though always present, may not be as prominent.

The dorsal fin is contiguous, is about twice the height of the second dorsal fin, and is roughly half the head length; its dorsal outline is strongly concave. The insertion of the anal fin is on a vertical through the origin of the first dorsal finlet, or between this and the end of the second dorsal base. There usually are eight dorsal and seven anal finlets.

The gill rakers are fully developed on the first arch only and there is invariably a raker at the angle of the arch including a basal process extending both dorsally and ventrally. The raker count (first arch, left side) is 7 (7-9) + 1 + 24 (22-24) = 32 (29-34) (sic). Gill teeth (posterior rakers) are present on all arches and are most developed on the first arch.

Euthynnus alletteratus (Rafinesque) (Fig. 2).

The following description is based on Godsil (1954a). *Euthynnus alletteratus* is distinguished from *E. affinis* and *E. lineatus* by the absence of vomerine teeth and by the dorsal markings. The pattern of dorsal markings includes broken, longitudinal black or dark bars running irregularly from the corselet towards the caudal region and are more continuous and regular posteriorly. Anteriorly, short irregularly curved lines, blotches, or spots, replace the bars.

The markings are superimposed over a background of blue which shades dorsally into the deep blue and black of the middorsal line. The blue fades into silver below the lateral line and the entire belly is silvery or dusky; an irregular number of black or dark spots are present between ventral and pectoral fins, and slightly posterior to the pectorals.

The ventral projection of the corselet is variable but generally short, extending posterior to the tip of the pectoral, a distance not exceeding one-fourth (or occasionally more) the length of the pectoral fin in most specimens. The maxillary extends posteriorly to a vertical drawn through the middle of the eye.

The posterior margin of the operculum is relatively straight and the preoperculum smoothly rounded. The teeth are moderate, individually distinct, and number from approximately 25 to 35 on each side of the lower jaw. The palatine teeth are sharp and conspicuous.

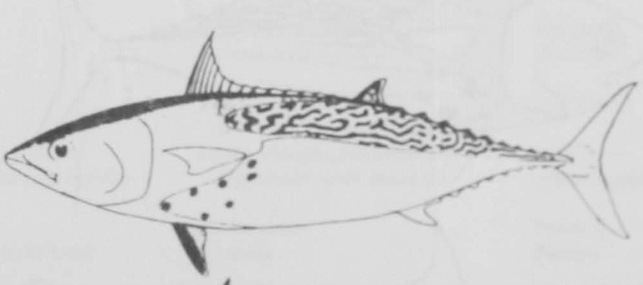


Figure 2.—Variations in the dorsal markings of *Euthynnus alletteratus*. (From Fraser-Brunner 1949, fig. 2.)

Euthynnus lineatus Kishinouye (Fig. 3).

The following description is also based on Godsil (1954a).

This species can in most instances be readily identified by the dorsal markings, which generally consist of a series of three, four, or five broad continuous black stripes running horizontally on the back from the corselet to the caudal fin. The most ventral stripe starts anteriorly below the lateral line and generally crosses it in its path to the caudal region. Variations in the pattern consist mainly of interruptions in the continuity of the

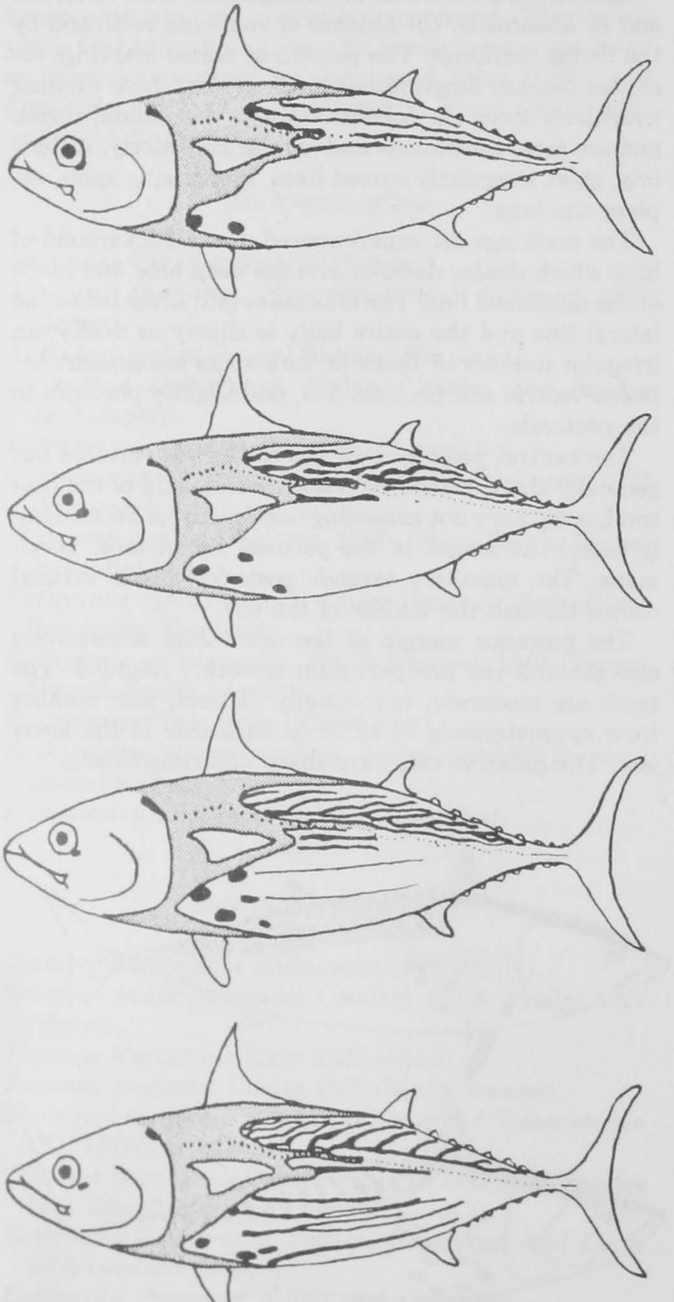


Figure 3.—Variations in the dorsal markings of *Euthynnus lineatus*. Upper figure represents the typical pattern and the lowest figure shows an extreme variant. (From Godsil 1954a, fig. 56.)

stripes, or branching of individual stripes including supplementary short irregular markings between.

The black dorsal stripes are superimposed over a background of blue that deepens into black dorsally and shades into grey and silver below. The belly is dusky or silvery; an irregular number (usually from two to six) of black spots are present between the pectoral and pelvic fins.

Palatine teeth are present in all specimens; vomerine teeth are present although difficult to discern in some specimens.

The posterior margin of the operculum is straight and the free margin of the preoperculum is smoothly rounded. The maxillary extends to a vertical drawn through the center of the eye.

A key for the separation of the species of *Euthynnus*, as adapted from Godsil (1954a), is given below.

A. Specimens having 37 (36-38) vertebrae, with four lobes or protuberances on each of two vertebrae, predominantly the 31st and 32d. (Invariably has vomerine teeth; usually has about five continuous, horizontal black dorsal stripes; 33 to 39 gill rakers and 29 to 31 gill teeth.) . . . . *E. lineatus*

B. Specimens having 39 vertebrae.
   1. Vomerine teeth present. No indication of lobes on 33d or 34th vertebrae. (Usually has oblique broken dorsal markings; from 29 to 33 gill rakers and 28 or 29 gill teeth.) . . . . *E. affinis*
   2. Vomerine teeth absent, although a longitudinal bony ridge can be felt in this area. Incipient lobes or protuberances occur on the 32d and 34th vertebrae. (Usually has broken horizontal dorsal markings; from 37 to 40 gill rakers and 31 or 32 gill teeth; width of snout between anterior margin of eyes less than distance of this plane from tip of upper jaw.) . . . . *E. alletteratus*

1.22 Taxonomic status

See also section 1.11.

Godsil (1954a) made a detailed comparison of the three species of *Euthynnus* (Table 1). He indicated that while the specific identity of *E. affinis*, *E. alletteratus*, and *E. lineatus* appeared to be well established, most of the differences that distinguish each species were relative. He noted that all the characters that positively separate the species were skeletal and that only the absence of the dentigerous vomerine plate in *E. alletteratus* could be used for superficial identification. However, it should be pointed out that *E. alletteratus* (37-40) is separable from *E. affinis* (29-33) on the basis of gill raker counts.

Euthynnus lineatus is clearly separated from *E. affinis* and *E. alletteratus* by having 37 (36-38) vertebrae as opable 1.—Tabular comparison and evaluation of suggestive differences in three species of *Euthynnus*. (From Godsil 1954a, table 17.) The terms used under the column, "nature of difference" are subjective and were not precisely defined by Godsil.

Character	*E. lineatus*	*E. alletteratus*	*E. affinis*	Nature of difference
xternal				
Dorsal markings	Continuous, horizontal bars	Broken horizontal bars	Broken oblique bars	Indicative
Color	Darker or deeper hued than in *alletteratus* or *affinis*	As in *affinis*	As in *alletteratus*	Relative
Belly spots	Larger than in *affinis*	Not recorded	Consistently smaller than in *lineatus*	Relative
Lateral line	a. Dip below second dorsal	No dip below second dorsal	No dip below second dorsal	Indicative
	b. Relatively steep rise above pectoral	Gentle rise above pectoral	No pronounced rise above pectoral	Relative
Vomerine teeth	Present	Absent	Present	Positive
Maxillary extent	To vertical through center of eye	As in *lineatus*	To or beyond vertical through center of eye	Indicative
Proportions:				
Head length	3.13 to 3.62, as in *affinis*, longer than *alletteratus*	3.65 to 3.89, shorter than *affinis* and *lineatus*	3.44 to 3.60, as in *lineatus*, longer than *alletteratus*	Biometrical
Insertion				
1st dorsal	2.82 to 3.33, more posterior than *alletteratus*, as in *affinis*	3.37 to 3.55, more anterior than in *affinis* and *lineatus*	3.11 to 3.23, as in *lineatus*, more posterior than in *alletteratus*	Biometrical
2d dorsal	1.51 to 1.79, includes *affinis* and *alletteratus*	1.72 to 1.77, as in *lineatus*, more anterior than in *affinis*	1.65 to 1.70, as in *lineatus*, more posterior than in *alletteratus*	Biometrical
anal fin	1.37 to 1.55, as in *affinis*, more posterior than in *alletteratus*	1.57 to 1.61, more anterior than in *affinis* and *lineatus*	1.48 to 1.52, as in *lineatus*, more posterior than in *alletteratus*	Biometrical
ventral fin	2.76 to 3.25, as in *affinis*, more posterior than in *alletteratus*	3.27 to 3.46, more anterior than in *affinis* and *lineatus*	3.07 to 3.24, as in *lineatus*, more posterior than in *alletteratus*	Biometrical
Ventral insertion to vent	2.62 to 3.01, includes *affinis* and overlaps *alletteratus*	2.57 to 3.12, overlaps *lineatus* less than *affinis*	2.75 to 2.95, as in *lineatus*, greater than *alletteratus*	Biometrical
Width between anterior margin of eye	Less than distance from tip of upper jaw to plane through anterior margin of eye	Less than distance from tip of upper jaw to plane through anterior margin of eye	Greater than distance from tip of upper jaw to plane through anterior margin of eye	Biometrical
Gill rakers	7 to 10 +1 +24 to 28 Total count 33 to 39	10 to 11 +1 +26 to 28 Total count 37 to 40	7 to 8 +1 + 22 to 24 Total count 29 to 33	Biometrical
Gill teeth	8 to 10 +21 to 23 Total count 29 to 31	9 +22 to 23 Total count 31 to 32	8 +20 to 21 Total count 28 to 29	Biometrical
Anal rays	11 to 12	11 to 15	13 to 14	Biometrical
nternal				
Ventral view of viscera				
1. Mosaic	Absent	Absent	Present, generally	Indicative
2. Right lobe of liver	Lateral, as in *affinis*	Mesial	Lateral, as in *lineatus*	Doubtful
3. Fat organ	Absent	Absent	Present, generally	Indicative
Ureter				
1. Branches	Large, straight, few collecting tubules as in *affinis*	Generally small, erratic, numerous collecting tubules	Large, straight, few collecting tubules as in *lineatus*	Relative—questionable
keleton				
Vertebral column	37 vertebrae	39 vertebrae	39 vertebrae	Positive
Protuberances	4 large lobes on each, 31st and 32d vertebrae	Incipient lobes on 33d and 34th vertebrae	No trace	Positive

osed to 39. It is further differentiated by the presence of our characteristic lobes on each of the 31st and 32d ertebrae and by having the major portion of the caudal ony keel on these two vertebrae. The major portions of he caudal bony keels are on the 33d and 34th vertebrae n *E. affinis* and *E. alletteratus*.

Euthynnus affinis and *E. alletteratus* are specifically ifferent in several structural features: the absence of vomerine teeth in *E. alletteratus*, the presence of incipient lobes on the 33d and 34th vertebrae in *E. alletteratus* and their absence in *E. affinis*. Identification of *E. affinis* and *E. alletteratus* could be made by the presence of vomerine teeth, together with the broken oblique dorsal markings in *E. affinis* and the broken horizontal markings in *E. alletteratus*, and the number of gill rakers.

Godsil (1954a) also noted that *E. affinis* differed slightly from *E. alletteratus* in many of the body proportions. In summing the ratios resulting from dividing the body length (fork length) in each case by the head length, first dorsal insertion, second dorsal insertion, anal insertion, and ventral insertion, he obtained figures ranging from 12.86 to 13.23 for *E. affinis* (eight specimens 378-643 mm FL) and 13.64 to 14.19 for *E. alletteratus* (seven specimens 503-763 mm FL). He found that these values were independent of fish size for both species so that mean values, 13.046 for *E. affinis* and 13.996 for *E. alletteratus*, could be used to define the species. The head of *E. affinis* was proportionately larger and the fins were more posteriorly inserted.

Table 2.—Common and vernacular names of *Euthynnus affinis*, *E. alletteratus*, and *E. lineatus*.

Country	Standard common name(s)	Vernacular name(s)
	Euthynnus affinis	
Australia	Mackerel tuna, little tuna	—
Sri Lanka	Lesser bonito, mackerel tuna	Atavalla, Ragodura, Sureya (Sinhalese), Shurai (Tamil)
China	—	Tow chung
Comoro Island	Bonito	Mibassi, Mpassi
East Africa	Bonito, little tuna	Sehewa (Kiswahili)—also refers to *Auxis* spp. and *Katsuwonus pelamis*
Hawaii, U.S.A.	Little tuna	Bonito, kawakawa
India	—	Choori min, suraly (Tamil); ohaman, chuki (Marathi)
Indochina	—	Ca ngu
Indonesia	—	Tongkol, diverg-bonito, tongkol komo, poetilai
Japan	Yaito	Suma, hiragatsuwo, obosogatsuwo segatsuwo, sumagatsuwo, watanabe
Madagascar	Bonite	Thonnine
Malaysia	—	Tongkol; Ikanayer, Sembak, Choreng, Kembel-mas, Tombal-mas (Malay)
Mauritius	Bonito	Bonite
Mirjurtein coast	—	Shirwa, shirwi (Arabic)
Mogadiscio	—	Maba'adi (Somali); Jeidha (Somali), also refers to small *Thunnus albacares* and *Megalaspis cordyla*
New Guinea	Kababida	—
Pakistan (West)	Dwarf bonito	Dawan, Chooki, Jukko
Philippines	Oceanic bonito	Katsarita, turingan, yaito bonito
Seychelles	Little tunny, bonito	Bonite
Somalia	—	—
	Euthynnus alletteratus	
Abidjan	Bonita	—
Angola	—	Merma
France	Thonine	—
Ghana	—	El'la (Apollonien), Poponkou (Keta)
Guinea	—	Makreni
Ivory Coast	—	Klewe (Kru), bokou-bokou (Alladian)
Mauritania	—	Corrinelo (Vermeulen)
Portugal	Atun	Fule-fule
Senegal	—	Walaz (Ouolof), dolo-dolo (Lebau)
South Africa	Little tunny, little tuna, mackerel tuna	Merma
Spain	Bacoreta	—
Tunisia	—	R'zem
United States	Little tunny	False albacore
	Euthynnus lineatus	
Ecuador	—	Negra, bonito negro
Mexico	—	Barrilete negro
Peru	—	Barrilete negro
United States	Black skipjack	Cross-bred mackerel

1.23 Subspecies

No subspecies are recognized.

1.24 Standard common names, vernacular names

The common and vernacular names of the three species of *Euthynnus* are given in Table 2.

1.3 Morphology

1.31 External morphology

The pattern of markings may vary, sometimes considerably, in the three species of *Euthynnus* (Fraser-Brunner 1949; Godsil 1954a). (See Figs. 1-3.)

Euthynnus affinis

Godsil (1954b) made morphological studies on *E. affinis* from Hawaii and Japan (Table 3). He found several minor differences in the body proportions of fish from the two areas but concluded that these differences merely indicated population differences.

Meristic data on *E. affinis* from various areas are given in Table 4.

Table 3.—Body proportions of *Euthynnus affinis* from Japan and Hawaii. (From Godsil 1954b, table 1.)

Proportions	Range in ratios	
	Japan	Hawaii
Head length	3.66-3.72	3.44-3.60
1st dorsal insertion	3.07-3.27	3.11-3.23
2d dorsal insertion	1.64-1.67	1.65-1.70
Anal insertion	1.53-1.54	1.48-1.52
Ventral insertion	3.33-3.43	3.07-3.24
Greatest body length	—	3.55-3.99
Dorsal-ventral distance	3.97-4.18	3.86-4.18
Dorsal-anal distance	2.31-2.37	2.28-2.38
Ventral insertion to vent	2.75-2.86	2.75-2.95
Length of 1st dorsal base	3.24-3.41	3.23-3.53
Length of 2d dorsal base	14.07-15.96	14.29-15.53
Length of anal base	13.76-14.46	14.02-17.38
Pectoral length	6.23-6.88	5.54-6.05
Height of 1st dorsal	6.86-7.00	6.41-7.00
Height of 2d dorsal	13.83-14.78	12.10-14.15
Height of anal	13.83-15.00	11.91-14.15
Diameter of iris[1]	7.27-7.82	6.06-8.00
Maxillary length[1]	2.49-2.53	2.31-2.51
Snout to posterior margin of eye[1]	2.35-2.38	2.14-2.34

[1]Ratio of this measurement is to head length. All other measurements are related to fork length.

Table 4.—Enumerative data on *Euthynnus affinis*.

Area	First dorsal fin	Second dorsal fin	Dorsal finlets	Anal fin	Anal finlets	Pectoral fin	Gill rakers
Sri Lanka							
Deraniyagala (1952)	14-15	12	8	14-15	7	28	22-24 (lower arch)
Munro (1955)	15	20	8	14	7	26	24 (lower arch)
East Africa							
Morrow (1954)	14-15	11-12	8	12-14	6-7	—	—
Williams (1956, 1964)	15-16	11-13	8	13-14	6-7	—	(7-10) + (22-23) = 29-33
India							
Jones and Silas (1964)	14	11-14	8-9	12-15	6-8	24-28	(7-10) + (22-25) = 29-35
Indonesia							
De Beaufort and Chapman (1951)	15	13	8	14	7	24	24 (lower arch)
Indo-Pacific							
Fraser-Brunner (1949, 1950)	—	—	—	—	—	—	(7-10) + (22-23) = 29-33
Madagascar							
Fourmanoir (1957)	15	11-13	8	13-15	7-8	—	25 (lower arch)
[Pakistan.] (west)							
Central Fish Department (1955)	15	13-14	8	14	8	26	—
Red Sea							
Steinitz and Ben-Tuvia (1955)	15-16	—	8-9	—	7	—	23-24 (lower arch)
Réunion							
Blanc and Postel (1958)	—	—	—	—	—	—	8+1+24 = 33
South Africa							
Smith (1961)	15-16	11-13	8	12-15	6-8	—	25 (lower arch)
Japan							
Godsil (1954b)	15	12-13	8	14	7	—	8+1+(22-24) = 31-33
Hawaii							
Godsil (1954b)	14-15	12-13	8	13-14	7	—	(7-9)+1+(22-24) = 29-34

Euthynnus alletteratus

Based on body proportions of *E. alletteratus* taken along the eastern Atlantic, Marchal (1963) indicated that there were no noteworthy differences in the samples from Cap Vert, Senegal, to Ghana.

Postel (1956) compared body proportions and meristic data of *E. alletteratus* from the Mediterranean Sea (Tunisia) and the eastern Atlantic Ocean (Senegal). He noted that the Tunisian sample was characterized by a shorter head and a shorter predorsal (snout to insertion of first dorsal) and preventral (snout to insertion of ventral) distance (Table 5). The Tunisian specimens also had a smaller number of gill rakers (36-41) than the Senegalese specimens (<38-47).

Body proportions of *E. alletteratus* from the U.S. Atlantic coast are given by Godsil (1954a) (Table 6). He also presented meristic data from these fish, which are shown below.

Meristic character	*Counts*
First dorsal spines	10-15
Second dorsal rays	12-13
Dorsal finlets	8
Anal rays	11-15
Anal finlets	7
Gill rakers	(10-11) + (0-1) + (26-28) = 37-40

Mansueti and Mansueti (1962) prepared a "topographic" osteology of a specimen captured in Chesapeake Bay (Fig. 4).

Euthynnus lineatus

Body proportions of *E. lineatus* are given in Table 7. Meristic data, from Godsil (1954a), are given below.

Meristic character	*Counts*
First dorsal spines	13-15
Second dorsal rays	11-12
Dorsal finlets	8-9
Anal rays	11-13
Anal finlets	7-8
Gill rakers	(7-11) + 1 + (23-29) = 31-41

Table 5.—Body proportions of *Euthynnus alletteratus* from Tunisia and Senegal (Postel 1955b: 132-133; 1956: 54). Ratios indicate fork length divided by length of body parts.

Length class (cm)	*N*	Ratios: Head length	First dorsal insertion	Ventral insertion	Pectoral length
		Tunisia			
40-45	1	4.27	3.40	3.40	7.06
45-50	2	4.21	3.57	3.48	6.99
50-55	11	4.22	3.50	3.46	6.99
55-60	30	4.24	3.55	3.50	6.95
60-65	10	4.29	3.56	3.53	6.90
65-70	16	4.28	3.53	3.53	6.70
70-75	13	4.29	3.55	3.53	6.82
75-80	3	4.21	3.59	3.55	6.86
80-85	5	4.29	3.60	3.57	6.88
85-90	5	4.33	3.58	3.55	6.88
90-95	3	4.40	3.67	3.59	6.81
95-100	1	4.37	3.65	3.62	7.06
		Senegal (Males)			
30-35	1	3.82	3.25	3.15	—
35-40	7	3.84	3.28	3.18	6.12
40-45	81	3.85	3.30	3.20	6.08
45-50	62	3.85	3.30	3.22	6.14
50-55	13	3.87	3.33	3.24	6.31
55-60	0	—	—	—	—

Table 6.—Body proportions of seven *Euthynnus alletteratus* from the western Atlantic (Atlantic coast of United States). Fork length the numerator except those indicated by an asterisk, where head length is the numerator. (From Godsil 1954a, table 15.)

Proportions	Ratios
Head length	3.65-3.89
1st dorsal insertion	3.37-3.55
2d dorsal insertion	1.72-1.77
Anal insertion	1.57-1.61
Ventral insertion	3.27-3.46
Greatest body depth	3.91-4.16
Greatest body width	6.07-6.12
Dorsal-ventral distance	4.08-4.36
Dorsal-anal distance	2.37-2.50
Ventral insertion to vent	2.87-3.12
Length of first dorsal base	3.30-3.57
Length of second dorsal base	14.16-17.25
Length of anal base	13.80-16.05
Pectoral length	5.89-6.50
Height of 1st dorsal	6.90-7.74
Height of 2d dorsal	10.78-13.55
Height of anal	10.78-12.74
Diameter of iris	*7.81-8.35
Maxillary length	*2.54-2.74
Snout to posterior margin of eye	*2.43-2.45

1.33 Protein specificity

The erythrocytes of two *E. lineatus* were tested with a series of 540 bean extracts as part of a preliminary work on a program for typing fish blood. On the basis of agglutinations, it was determined that the blood of *E. lineatus* can be differentiated from that of six other scombrids in the eastern tropical Pacific (Calkins and Klawe 1963).

2 DISTRIBUTION

2.1 Total area

In general the species of *Euthynnus* are coastal fishes found in tropical and subtropical waters of the world. Of the three species, *E. lineatus* has the most restricted distribution, occurring only in the eastern tropical Pacific Ocean. *Euthynnus affinis* and *E. alletteratus* are

Table 7.—Measurements (millimeters) and proportions of *Euthynnus lineatus*. Fork length the numerator except those indicated by an asterisk, where head length is the numerator. (From Godsil 1954a, table 10.)

Proportions	Fish number: 19	20	24	26	28	29	30	31	32	33	34	35	36	37	38	Ratios
Body length	520	574	583	492	472	446	427	613	514	432	476	455	484	ca. 443	462	
Head length	150	167	170	157	137	138	123	176	148	116	136	132	137	132	134	3.13- 3.72
1st dorsal insertion	165	186	183	Broken	150	158	133	197	160	129	146	142	145	145	143	2.82- 3.35
2d dorsal insertion	306	345	340	326	283	293	252	367	299	249	278	267	280	ca. 269	272	1.51- 1.79
Anal insertion	336	384	386	359	308	315	281	408	339	280	305	295	316	292	302	1.37- 1.56
Ventral insertion	164	182	—	178	154	153	137	198	167	132	153	146	168	147	154	2.76- 3.27
Greatest body depth	132	157	—	148	ca. 123	131	—	—	128	—	—	—	—	—	—	3.32- 4.58
Greatest body width	ca. 85	—	—	—	ca. 79	—	—	—	ca. 85	—	—	—	—	—	—	5.93- 6.17
Dorsal-ventral distance	128	147	—	—	116	127	—	—	120	—	—	—	—	—	—	3.51- 4.55
Dorsal-anal distance	210	241	—	—	192	204	—	—	210	—	—	—	—	—	—	2.19- 2.50
Ventral insertion to vent	180	206	—	187	157	170	144	205	175	147	149	153	153	143	150	2.62- 3.19
Length 1st dorsal base	146	168	—	Broken	137	143	—	—	145	—	—	—	—	—	—	3.12- 3.86
Length 2d dorsal base	32	33	—	—	30	34	—	—	31	—	—	—	—	—	—	13.12-18.84
Length of anal base	31	31	—	—	24	30	—	—	31	—	—	—	—	—	—	14.87-20.10
Pectoral length	84	88	—	89	78	84	—	—	87	—	—	—	—	—	—	5.31- 6.99
Height of 1st dorsal	66	72	—	Broken	64	71	—	—	76	—	—	—	—	—	—	6.28- 7.97
Height of 2d dorsal	33	Broken	—	—	33	35	—	—	36	—	—	—	—	—	—	12.74-16.63
Height of anal	34	ca. 45	—	—	36	35	—	—	35	—	—	—	—	—	—	12.74-18.29
Diameter of iris	23	ca. 20	—	20	—	20	—	—	19.5	—	—	—	—	—	—	*6.00- 7.85
Maxillary length	59	65	—	57	53	52	—	—	57	—	—	—	—	—	—	*2.48- 2.75
Snout to posterior margin of eye	—	—	—	—	ca. 58	—	—	—	62	—	—	—	—	—	—	*1.97- 2.39

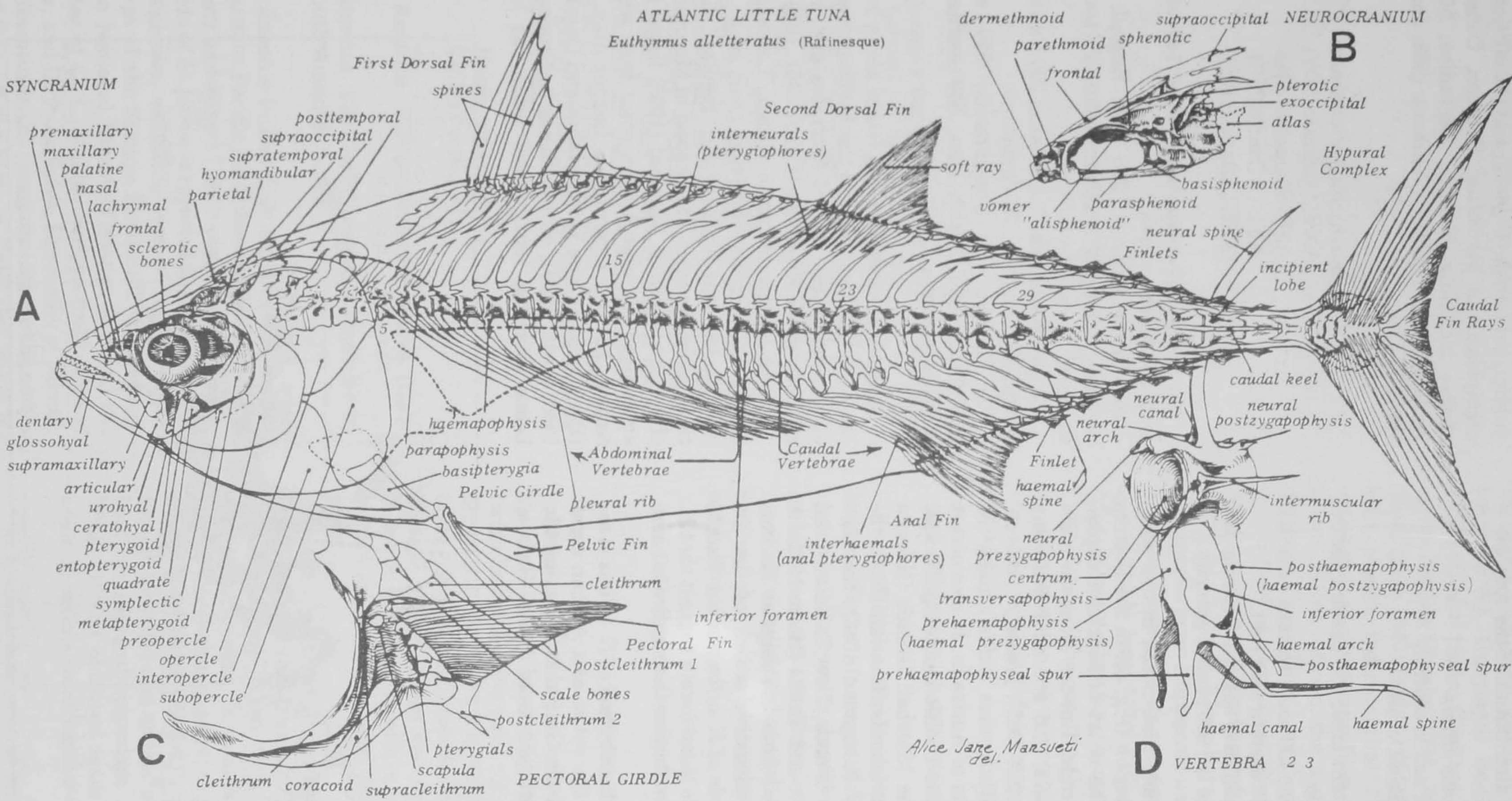


Figure 4.—Topographic osteology of *Euthynnus alletteratus*. A. Syncranium, axial, and appendicular skeleton. B. Neurocranium. C. Pectoral girdle. D. Parts of vertebra 23 and its unique trellis. (From Mansueti and Mansueti 1962, fig. 2.)

more widely distributed in the world's oceans. The geographic classification and codes from Rosa (1965) were used in part to describe the distribution of the species.

Euthynnus affinis
ISEW (Indo-Pacific, central)
ISW (Indian Ocean)

100 Africa. 120 northeastern area; 130 eastern central area; 156 Malagasy Republic.

400 Asia. 420 central area; 430 southeastern area; 440 eastern area (mainland); 450 eastern area (is.).

600 Oceania. 610 Australia; 640 eastern Oceania; 660 U.S.A. (Hawaii); 670 Pacific Is.; 680 central groups.

Euthynnus affinis is widely distributed in the warm waters of the Indo-Pacific region (Fig. 5). In the western Pacific it is found from the coast of southern Japan, throughout the Ryukyu Islands, Taiwan, along the coast of Indochina, the Philippines, and around Borneo and New Guinea (Kikawa and staff 1963). Whitley (1964) reported its occurrence (as *Euthynnus wallisi*) along the west, north, and east coasts of Australia. It also occurs around oceanic islands of the Pacific including the east and west Carolines and the Marshall Islands (Kikawa and staff 1963), the Gilbert Islands (Randall 1955), the Hawaiian Islands, Midway (Chapman 1946), the Line Islands and the Marquesas Islands, New Caledonia and New Hebrides (Angot 1959), and Tahiti (Herre 1932). A stray *E. affinis* was recorded from Los Angeles Harbor, Calif. (Fitch 1953). No exhaustive search of the literature was made for records of *E. affinis* in the Pacific Ocean. However, the records listed herein suggest that *E. affinis* may have a wider distribution than indicated here and in Figure 5.

In the Indian Ocean the distribution of *E. affinis* is essentially continuous along the entire east African coast including the Red Sea and the Gulf of Aden, along the coast of Pakistan and both coasts of India, Burma, Malaysia, and Indonesia, and to the west coast of Australia. It occurs around Madagascar (Malagasy Republic), Sri Lanka (Ceylon), and the offshore islands and archipelagos of Mauritius, Reunion, Comoro, the Seychelles including Aldabra, Laccadive, Maldives, and Andaman and Nicobar (Williams 1963; Jones and Silas 1964).

Euthynnus alletteratus
ANW (Atlantic, NW)
ASW (Atlantic, SW)
ANE (Atlantic, NE)
ASE (Atlantic, SE)

100 Africa. 110 northwestern area; 140 western central area; 150 southern area.

200 North America. 236 New Englad; 237 Middle Atlantic States; 235 southern states; 238 southern Atlantic states.

300 Latin America. 311 Mexico; 320 Caribbean Is.; 351 Brazil; 352 Uruguay; 353 Argentina.

500 Europe. 510 Scandinavia; 520 western area (mainland); 530 British Isles; 540 southern area; 550 southeastern area.

Euthynnus alletteratus is found along both coasts of the Atlantic Ocean and in the Mediterranean Sea. It is also found in the Sea of Marmara and it occurs sporadically in the Black Sea (Demir 1961, 1963) (Fig. 6).

In the eastern Atlantic Ocean, Laevastu and Rosa (1963), in their distributional chart of *E. alletteratus*, indicate that the limits of the "regular" distribution of this species are from off the coast of Morocco to the coast of northwest Africa. Marchal (1963) listed the following areas along the west African coast from which *E. alletteratus* has been recorded: Levrier Bay, Mauritania (Postel 1950); Cape Verde Islands and Gambia (Cadenat 1950; Postel 1950); off the Bissagos, Guinea, and Sierra Leone (Marchal 1961; Postel 1962); the length of the

Figure 5.—Distribution of *Euthynnus affinis* in the Indo-Pacific region. (Adapted from Kikawa and staff 1963, fig. 2, and Laevastu and Rosa 1963, fig. 4.)

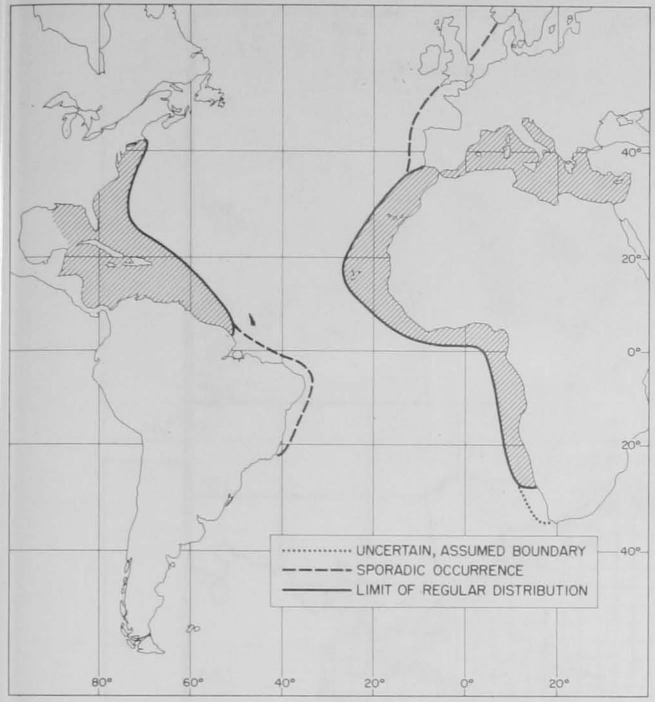


Figure 6.—Distribution of *Euthynnus alletteratus*. (Adapted from Laevastu and Rosa 1963, fig. 4.)

coast of Liberia, the Ivory Coast and Ghana; St. Thomas and Principe Islands (da Costa and Frade 1958); and Pointe-Noire (Roux 1957).

The distributional chart of *E. alletteratus* in the western Atlantic given by Laevastu and Rosa (1963) shows the limits of its distribution from the coast of Maine to the northern boundary of Brazil. Briggs (1958) stated that in the western Atlantic *E. alletteratus* is distributed from "Bermuda and the Gulf of Maine to Ilha Victoria, Brazil, and the northern and eastern Gulf of Mexico." Fraser-Brunner (1949) also recorded the species from Rio de Janeiro, Brazil.

Euthynnus lineatus
ISE (Pacific, SE)

200 North America. 232 southwestern states (California).

300 Latin America. 310 Central America (mainland); 340 western South America.

Euthynnus lineatus is found in the tropical coastal waters of the eastern Pacific from about lat. 35°N to 12°S (Fig. 7). Calkins and Klawe (1963) constructed this figure from records of *E. lineatus* reported in the literature, tuna vessel logbooks, scientific logs of oceanographic cruises by ships of the Scripps Institution of Oceanography and the National Marine Fisheries Service, and field-book notes of C. L. Hubbs, Scripps Institution of Oceanography, and D. P. de Sylva, University of Miami. Records of *E. lineatus* in the literature include the northernmost record from off San Simeon, Calif. (lat. 35°20'N, long. 120°40'W) (Nowell 1961), specimens from California waters (Roedel 1948; Fitch 1952), Baja California (Godsil 1954a), the Tres Marias Islands (Fowler 1944), Acapulco, Mexico (Mais and Jow 1960), Costa Rica (Schaefer and Marr 1948), Colombia Bank (lat. 2°N, long. 79°W), Guayaquil Bank (lat. 3°35'S, long. 80° 55'W) (Godsil 1954a; Clemens 1957), and from the Galapagos Islands (Fowler 1938, 1944; Schmitt and Schultz 1940; Seale 1940; Godsil 1954a). Logbooks of commercial tuna vessels indicate that *E. lineatus* has been encountered nearly everywhere along the coastline from about halfway down the coast of Baja California to northern Peru. They have been frequently encountered in the Gulf of California, the Revillagigedo Islands, all along the coast of Mexico and Central America, and the Galapagos Islands. There have been occasional reports of this species from Clipperton and Cocos Islands and there is a single report of its occurrence from Shimada Bank (lat. 16°52'N, long. 117°30'W) (Calkins and Klawe 1963). More recently, they have been recorded as far as 2,000 mi (3,200 km) off the coast in the eastern Pacific (Klawe[4]). In addition there are two records of *E. lineatus* from the Hawaiian Islands (Matsumoto and Kang 1967; Matsumoto 1976).

2.2 Differential distribution

From all indications it appears that the distribution of all the different life stages of *E. affinis* and the other two species of *Euthynnus* appears to be similar. As noted earlier the adults are generally coastal fishes and judging from the distribution of the various life stages of these species, the entire life cycle is completed within the coastal province.

2.21 Spawn, larvae, and juveniles

Euthynnus affinis

Larval and juvenile *E. affinis* are widely distributed in the Indo-Pacific area (Fig. 8). As many investigators have observed in the past, e.g., Matusmoto (1959), it appears that larval and juvenile *E. affinis* are generally taken close to land masses and less frequently around oceanic islands. There also are a few captures of larval fishes in midocean localities but chances are these were carried away from coastal areas by the prevailing currents.

In the coastal waters of southern Japan Yabe et al. (1953) indicate that preadults ranging in length from 150 to 250 mm are taken from August to October near Aburatsu, Kyushu. Preadults also constitute a regular part of the commercial catch in other areas. In the fishery for *E. affinis* off the southwest coast of Sri Lanka, fish smaller than 240 mm appear regularly in the commercial landings (Sivasubramaniam 1970). In the Philippines Wade (1950a) obtained many of his juvenile and preadult *E. affinis* from various fish markets.

[4] W. L. Klawe, Inter-American Tropical Tuna Commission, Scripps Institution of Oceanography, La Jolla, CA 92037, pers. commun. to Tamio Otsu, National Marine Fisheries Service, Southwest Fisheries Center, Honolulu, HI 96812, November 1977.

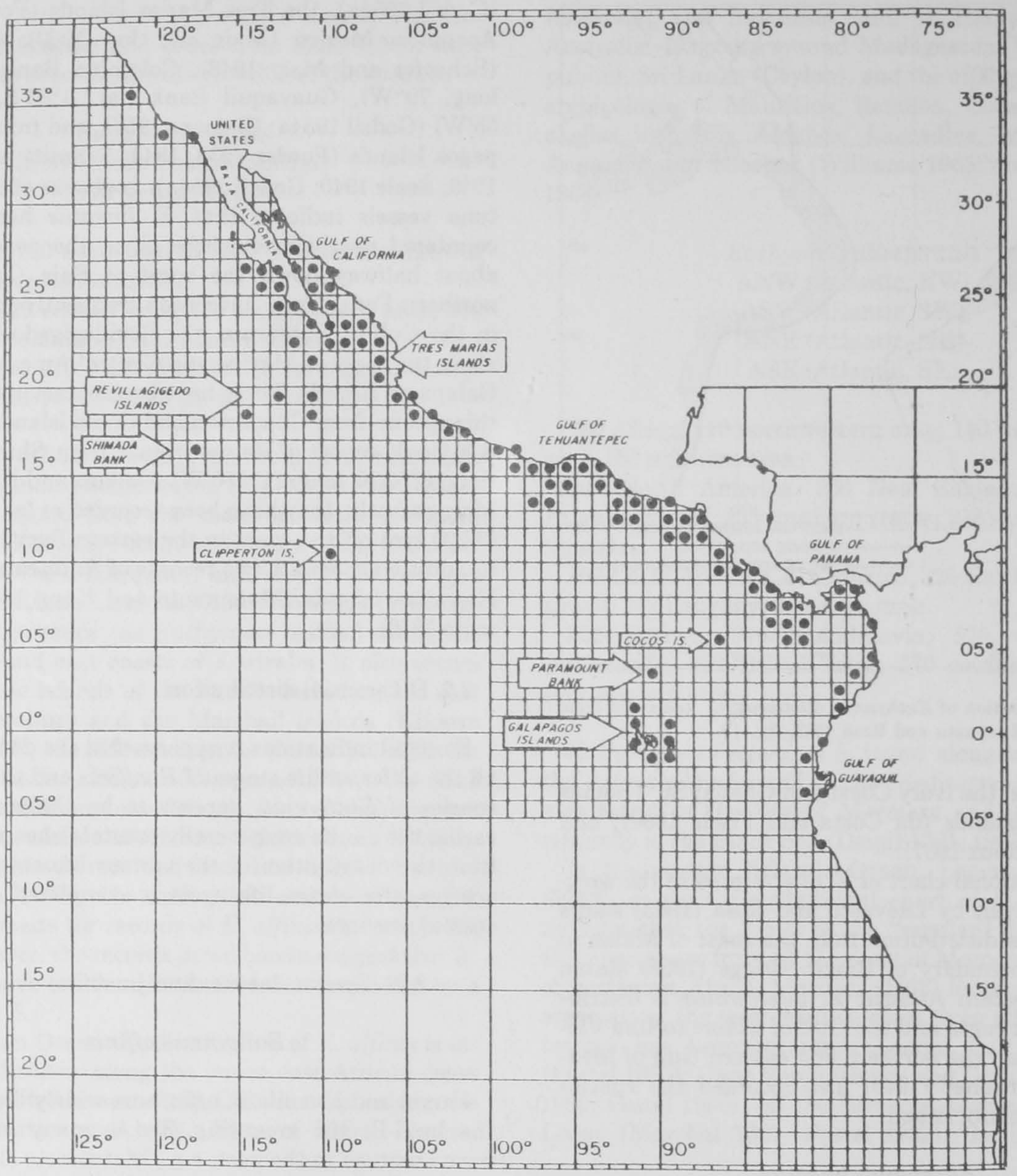


Figure 7.—Distribution of *Euthynnus lineatus* in the eastern Pacific Ocean. (From Calkins and Klawe 1963, fig. 2.)

Euthynnus alletteratus

The distribution of larval and juvenile *E. alletteratus* is shown in Figure 8. They have been recorded from both sides of the Atlantic Ocean, the Mediterranean Sea including the Black Sea and Sea of Marmara, and from the Gulf of Mexico. In the eastern Atlantic along the west African coast, the northernmost record of larval *E. alletteratus* is from off the northern coast of Morocco. There are numerous records of larval *E. alletteratus* from the Gulf of Guinea. The absence of records from farther south along the coast of Africa may merely reflect lack of sampling effort. In the western Atlantic, larval *E. alletteratus* has been collected as far north as lat. 35°42′N off the North Carolina coast of the United States and as far south as lat. 10°S off the coast of Brazil. Although most of the larvae have been collected relatively close to shore, there are a few midocean records of *E. alletteratus* larvae.

Richards and Simmons (1971) suggested some sort of vertical stratification in the distribution of larval *E. alletteratus*. They noted that the larvae were collected more often at the surface at night. They also tentatively concluded that there was greater net avoidance by larval *E. alletteratus* during the day. However, they attributed the higher frequency of capture at night to vertical migration.

Marchal (1963) stated that along the coasts of the Ivory Coast and Ghana postlarval and juvenile *E. alletteratus* were found at the surface from 2 mi (3.2 km) to around 100 mi (160 km) off the coast. Marchal made the observation that those postlarval and juvenile fish found out to 100 mi (160 km) offshore were probably taken out by the currents because no adults were found beyond the

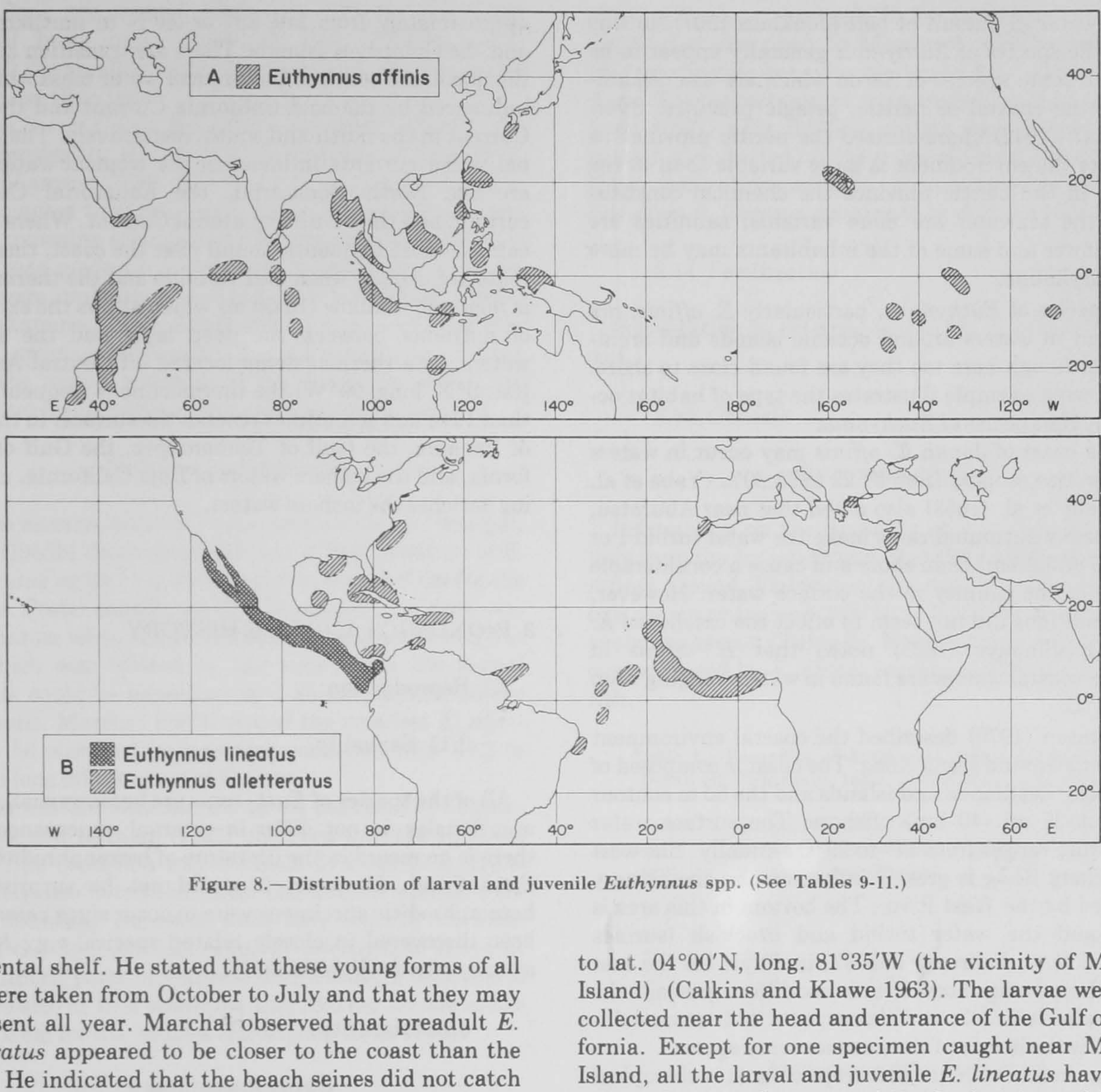


Figure 8.—Distribution of larval and juvenile *Euthynnus* spp. (See Tables 9-11.)

continental shelf. He stated that these young forms of all sizes were taken from October to July and that they may be present all year. Marchal observed that preadult *E. alletteratus* appeared to be closer to the coast than the adults. He indicated that the beach seines did not catch fish over 40 cm long.

In the Mediterranean Sea in Haifa Bay, Oren et al. (1959) captured preadults 80 to 240 mm long from the end of June to the middle of August. Also in the Mediterranean area, Demir (1963) reported the catch of preadult *E. alletteratus* ranging from 145 to 220 mm long in the Sea of Marmara during the period from the last week of August to the second half of September. He also reported 180 to 250 mm long preadults in the Dardanelles from the middle of August to the end of the first week in October.

In the Gulf of Mexico juvenile and preadult *E. alletteratus* 15 to 172 mm long have been commonly found beyond the edge of the continental shelf throughout the summer months (Bullis 1955).

Euthynnus lineatus

Larval and postlarval *E. lineatus* are almost as widely distributed as the adults in the eastern tropical Pacific Ocean (Fig. 8). They have been recorded as far north as lat. 29°45'N (Point Antonio, Baja California) and south to lat. 04°00'N, long. 81°35'W (the vicinity of Malpelo Island) (Calkins and Klawe 1963). The larvae were also collected near the head and entrance of the Gulf of California. Except for one specimen caught near Malpelo Island, all the larval and juvenile *E. lineatus* have been collected within about 150 mi (240 km) of the mainland.

2.22 Adults

See section 5.3.

2.3 Determinants of distribution changes

The three species of *Euthynnus* seldom occur more than a few hundred miles from land. They are usually found around land masses and island chains generally between lat. 35°N and 35°S (Blackburn 1965). Godsil (1954a) noted that *E. lineatus* along the west coasts of Baja California and Central America appeared to be localized in distribution and confined to certain inshore areas. He also noted that *E. affinis* in the Hawaiian Islands were confined within the 20 or 30 fathom (36.5 or 54.8 m) contour. In the western Pacific near New Guinea *E. affinis* were abundant and distributed in inshore waters throughout the area (Mori et al. 1969). Around the Maldive Islands in the Indian Ocean *E. affinis* are found close to the islands and they often venture into shallow water in pursuit of bait (Jonklaas 1967). In this respect the species of *Euthynnus* generally appear to be similar to some species of *Sarda* which are also inhabitants of the coastal or neritic, pelagic province. Sverdrup et al. (1942) characterized the neritic province as one where the environment is more variable than in the oceanic. In the neritic province the chemical constituents of the seawater are more variable: salinities are usually lower and some of the inhabitants may be more or less euryhaline.

The species of *Euthynnus*, particularly *E. affinis*, are also found in waters around oceanic islands and archipelagos although here too they are found close to shore. The following example illustrates the type of habitat occupied by the species of *Euthynnus*.

Off the coast of Japan *E. affinis* may occur in waters with salinities ranging from 31.22 to 33.80‰ (Yabe et al. 1953). Yabe et al. (1953) also noted that near Aburatsu, Japan, heavy autumnal rains make the water turbid 1 or 2 mi (1.6 or 3.2 km) from shore and cause a considerable lowering of the salinity in the surface water. However, these conditions did not seem to affect the catches of *E. affinis*. Kishinouye (1923) noted that *E. affinis* in Japanese coastal waters are found in waters ranging from 18° to 28°C.

Williamson (1970) described the coastal environment of *E. affinis* around Hong Kong. The coast is composed of steep, rocky headlands and islands and the 50 m contour lies about 25 mi (40 km) offshore. The surface water temperature ranges from 14° to 29°C annually. The west side of Hong Kong is greatly influenced by the estuary waters fed by the West River. The bottom in this area is muddy and the water turbid and brackish (surface salinity, 33‰ in February and 6‰ in July). On the east side of Hong Kong more oceanic conditions prevail: the surface salinity is 34‰ in February and 26‰ around July, which is the height of the summer rainy season.

In the Indian Ocean the tropical and subtropical waters are generally characterized by a scarcity of plankton offshore except in areas where vertical mixing of water masses occurs, e.g., off Somalia, where upwelling takes place. Strong development of phytoplankton and the ensuing zooplankton is confined to the immediate coastal areas (Williams 1963).

Along the Atlantic coast of the United States most of the *E. alletteratus* are taken in "green water" and are seldom taken in the "blue water," or slope water of the Florida Current (de Sylva and Rathjen 1961). As de Sylva and Rathjen pointed out, *E. alletteratus* typically occupy the inshore turbid waters. Morice and Cadenat (1952) made a similar observation in Guadeloupe, and Whiteleather and Brown (1945) noted that this species appeared to be a coastal fish in areas around Trinidad, Tobago, and Guyana.

Calkins and Klawe (1963) characterized the general habitats of *E. lineatus* based on published studies (Holmes et al. 1957; Brandhorst 1958; Cromwell 1958; Cromwell and Bennett 1959; Sund and Renner 1959). Calkins and Klawe (1963) noted that *E. lineatus* occurs in the equatorial Pacific water mass which extends approximately from lat. 23° or 24°N to northern Peru and the Galapagos Islands. There are transition zones to the north and south of the tropical water mass which are influenced by the cold California Current and the Peru Current in the north and south, respectively. The principal warm currents influencing the tropical water mass are the North Equatorial, the Equatorial Countercurrent, and the South Equatorial Current. Where *E. lineatus* is most frequently found near the coast, these currents are usually weak and variable and the thermocline is relatively shallow (10-50 m) which allows the exchange of nutrients between the deep layer and the surface waters. In a thermal dome located off Central America (lat. 9°N, long. 90°W) the thermocline is frequently less than 10 m and sometimes reaches the surface. In the Gulf of Panama, the Gulf of Tehuantepec, the Gulf of California, and the inshore waters of Baja California, upwelling enriches the inshore waters.

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

All of the species of *Euthynnus* are heterosexual, males and females do not differ in external appearance, and there is no record in the literature of hermaphroditism in these fishes. However, it would not be surprising if hermaphroditic specimens were to occur since cases have been discovered in closely related species, e.g., *Katsuwonus pelamis* (Uchida 1961).

3.12 Maturity

Euthynnus affinis

Euthynnus affinis apparently attains sexual maturity at a relatively small size, at least in certain areas of its distributional range. Buñag (1958) examined a total of 30 *E. affinis* 44.4 to 62.2 cm long in Philippine waters and found that the smallest female with mature gonads was a specimen 49 cm long. A 47.7 cm female was found to have spent ovaries. In an earlier study in Philippine waters, a sample of 205 females included a ripe specimen between 40 and 40.9 cm long that was determined to be spent. In yet another study comprising a sample of 144 fish 33.4 to 50.8 cm long, it was found that the smallest mature female was around 38.5 cm long (Ronquillo 1963).

Euthynnus affinis in the Indian Ocean appears to reach sexual maturity later than those occurring in the Philippines. Based on a sample of 75 specimens taken near the Seychelles, Ommanney (1953) reported that *E. affinis* attained sexual maturity between 50 and 65 cm TL (total length), probably in the third year of life. Williams (1956, 1963) examined 37 specimens from east Africa and noted that fish there attained sexual maturity between 55 and 60 cm TL. In Mauritius waters *E. affinis*

55 cm long are mature (Baissac[5]). Off the southwest coast of India near Vizhingam (lat. 08°22′N, long. 76°59′E) the smallest female with ripe ovaries was found to be 48 cm (Rao 1964).

In the South China Sea off Kwangtung, China, *E. affinis* presumably attains sexual maturity at around 50 cm (Williamson 1970). Elsewhere in this paper Williamson also noted that two distinct size-groups of fish made up the spawning schools and that the smaller of the size groups was made up of fish with a mean size of 44 cm which were probably a year old. Around Hawaii, Tester and Nakamura (1957) determined the sex and maturity of 93 *E. affinis* caught by trolling. However, they did not relate the sexual maturity of the fish to its size. They found that five females in their sample were ripe.

Euthynnus alletteratus

In the eastern Atlantic in the area off Dakar, Senegal, Postel (1955b) determined the size of first maturity of *E. alletteratus* as 39.7 cm for the males and 38.6 cm for the females. Postel considered that *E. alletteratus* were sexually mature when the gonadosomatic index reached 3 to 4%, which was related to the time when the sexual products could be expressed by a slight pressure on the body walls. Marchal (1963) stated the smallest *E. alletteratus* he observed in spawning condition were 44.2 to 44.7 cm long off the coast of Guinea.

In the western Atlantic Ocean off the coast of Florida, de Sylva and Rathjen (1961) observed that the smallest fish in ripe condition was a female 27.2 cm long. However, they also noted that most fish in their sample were not in spawning condition until they were 35 cm long. And in the Spanish fishery for *E. alletteratus* based at the southern ports of Barbate and Tarifa, it was found that the size at first spawning was 56.5 cm for the males and 57.0 cm for the females (Rodríguez-Roda 1966).

Euthynnus lineatus

The size at first spawning for *E. lineatus* is not known. There are only fragmentary observations on the gonadal development of this species in the eastern tropical Pacific where it occurs. Mead (1951) reported two females 54.4 and 55.0 cm long, which had swollen and turgid ovaries, from the waters off Central America. Schaefer and Marr (1948) reported two adults from the Gulf of Nicoya, Costa Rica, in an advanced stage of maturity but did not give their size.

3.13 Mating

Although the reproductive behavior of *Euthynnus* has not been positively observed in the natural environment or in experimental tanks and ponds, Hunter and Mitchell (1967) observed a high frequency of wobbling and chasing by three ripe male *E. lineatus* in a manner similar to that described by Magnuson and Prescott (1966) as reproductive behavior of Pacific bonito, *Sarda chiliensis*. These observations were made by Hunter and Mitchell (1967) near drifting objects under which *E. lineatus* had collected off the coast of Costa Rica. Whether these observations actually represented reproductive behavior by *E. lineatus* remains to be demonstrated.

3.14 Fertilization

Fertilization is external in all the species of *Euthynnus*.

3.15 Gonads

Euthynnus affinis

Information on the fecundity of *E. affinis* is available only from the Indian Ocean. Rao (1964) indicated that *E. affinis* around Vizhingam spawned 210,000 to 680,000 ova per spawning and 790,000 to 2,500,000 ova during the spawning season (Table 8). He noted that the number of ova produced by *E. affinis* increased with the size of the fish.

Table 8.—Fecundity of *Euthynnus affinis* in the Indian Ocean off Vizhingam, India. (From Rao 1964, table 1.)

Fork length (cm)	Weight of fish (kg)	No. of ova per spawning (millions)	No. of ova per spawning season (millions)
48.0	1.37	0.21	0.79
52.5	2.06	0.31	0.88
55.5	2.35	0.30	1.31
58.2	3.20	0.50	2.14
65.0	4.57	0.68	2.50

Euthynnus alletteratus

Not much information is available on the fecundity of *E. alletteratus*. Postel (1955b) determined that the fecundity of a 75 cm fish from off the coast of Dakar, Senegal, was 1,750,000 eggs.

Euthynnus lineatus

The fecundity of *E. lineatus* has yet to be investigated.

3.16 Spawning

Euthynnus affinis

Euthynnus affinis in the Philippines apparently spawn all year round as indicated by the presence of fish in all stages of sexual development throughout the year (Wade 1950b; Buñag 1958). Wade (1950b) stated that his sample was not sufficiently large to discern possible seasonal variations in spawning intensity. Ronquillo (1963) determined the gonad index for a sample of 144 *E. affinis* in

[5]Baissac, J. de B. 1960. Indian Ocean section - genus *Euthynnus*. Mimeogr. rep., 2 p. CCTA/CSA, Colloque sur les Thonides, Dakar, 12-17 Decembre 1960, Tunny (60) 5.

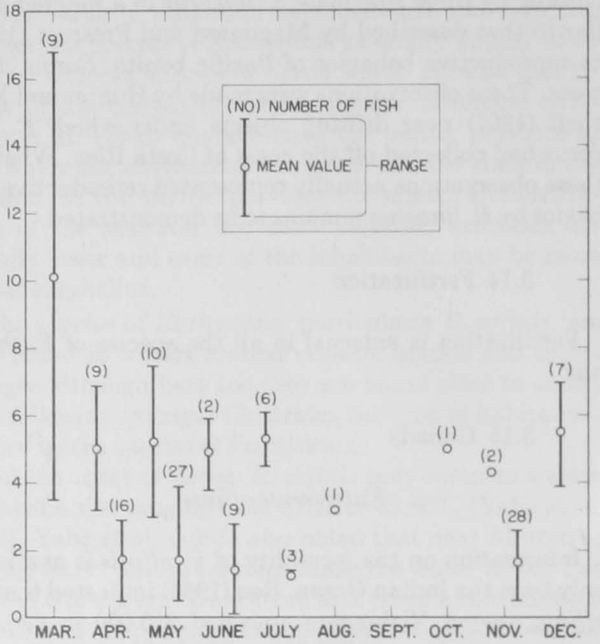


Figure 9.—Seasonal distribution of *Euthynnus affinis* gonad index in the Philippines. (From Ronquillo 1963, table 16.) Gonad index $= \frac{W_o}{L^3} \times 10^3$, where W_o is the weight of the paired ovaries in grams and L is fork length in millimeters.

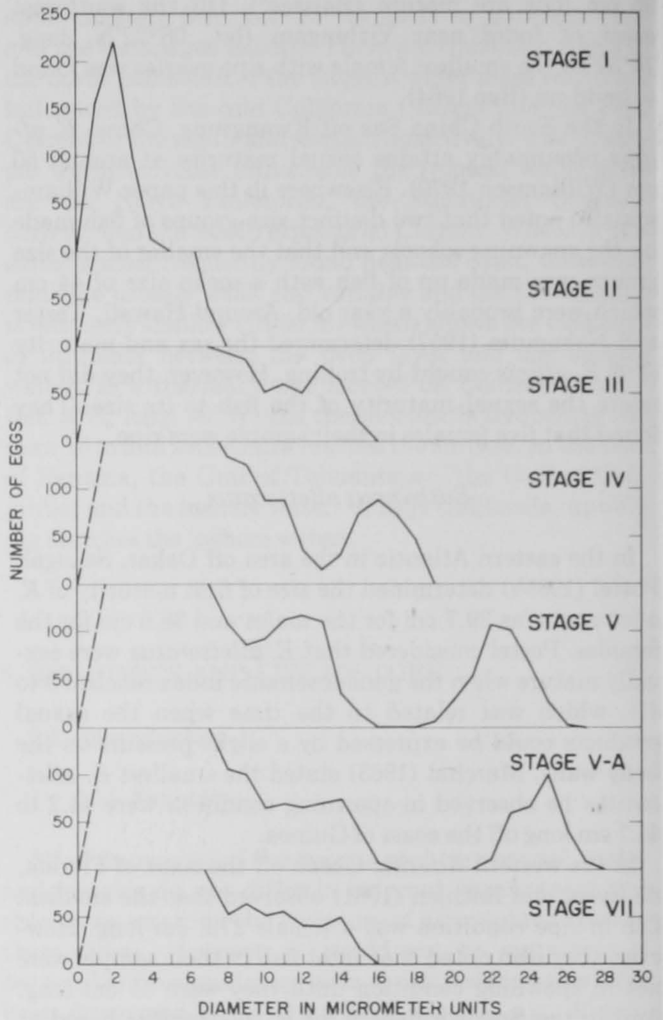


Figure 10.—Ova diameter frequency polygons of *Euthynnus affinis* showing the various stages of development of the ova to maturity: I, immature; II, early maturing; III, late maturing; IV, V, V-A, mature; VI, ripe; VII, spent. (From Buñag 1958, fig. 3.)

Philippine waters to define the spawning season (Fig. 9). His results were essentially the same as those obtained by Wade (1950b) and Buñag (1958) in that no clear seasonality in spawning was evident. Ronquillo (1963), however, noted that the highest gonad indices were found from March to May. Based on the development of ovarian ova, Buñag (1958) concluded that *E. affinis* in the Philippines spawns more than one batch of eggs during a spawning season (Fig. 10). Although he did not encounter any fully ripe ovaries in his samples, Buñag (1958) speculated that ripe eggs of *E. affinis* would probably be between 0.8775 and 1.1050 mm in diameter.

On the basis of the distribution of larval *E. affinis* in Philippine waters, Wade (1951) indicated that spawning may have seasonal peaks. Matsumoto (1959), however, indicated that Wade may have misidentified the larvae and that what Wade identified as *E. affinis* were more likely *Auxis*. Based on an earlier study reporting the capture of juveniles, Wade (1950a) stated that *E. affinis* spawn in the vicinity of Manado, Celebes, East Indies; near Marigabato Point, Cotabato Province, Mindanao; and Batangas and Balayan Bays, Luzon, Philippines.

In the western Indian Ocean near the Seychelles, the spawning season for *E. affinis* is during the period of the northwest monsoon, from October-November to April-May including a peak from January to March (Ommanney 1953). Off the coast of east Africa the spawning season extends from January to July, the middle of the northwest monsoon to the beginning of the southeast monsoon (Williams 1963). The capture of larval *E. affinis* in the western Indian Ocean during the months of December and January (Jones and Kumaran 1964) corroborates the above observations. In other close-by areas in the western Indian Ocean, fish in spawning condition were taken in November and December around Madagascar (Fourmanoir 1957) and in December around Mauritius (Baissac see footnote 5).

Off the southwest coast of India near Vizhangam, Rao (1964) indicated that *E. affinis* spawns from April to September. He did not discount spawning also in other months of the year and noted the possibility that individual fish may mature and spawn several batches of ova during the spawning season. The capture of juveniles up to 200 mm in the months of January, May, June, September, October, and November near Vizhingam and Calicut, India (Jones 1960; Table 9) suggests a rather lengthy spawning season for *E. affinis* in these waters.

In the eastern equatorial Indian Ocean, larval *E. affinis* have been captured from August to October in Indonesian waters (Matsumoto 1959; see Table 8) which suggested spawning during these months.

Larval and juvenile *E. affinis* have been recorded from many other areas in the Indo-Pacific (Table 9; see also

Table 9.— Records of larval and juvenile *Euthynnus affinis* in the Indo-Pacific.

Date	Locality		Marine area code [see Rosa (1965)]	Number		Length (mm)	Reference	Remarks
	Lat.	Long.		Larvae	Juveniles			
Apr. 1929	04°03′N	123°26′E	ISEW	1	—	—	Matsumoto (1959)	
	04°03′N	123°26′E		3	—	—	Matsumoto (1959)	
	06°55′N	114°02′E	ISEW	15	—	—	Matsumoto (1959)	
	06°55′N	114°02′E		23	—	—	Matsumoto (1959)	
	06°55′N	114°02′E		25	—	—	Matsumoto (1959)	
	08°02′N	109°36.5′E	ISEW	1	—	—	Matsumoto (1959)	
	08°02′N	109°36.5′E		2	—	—	Matsumoto (1959)	
	08°02′N	109°36.5′E		42	—	—	Matsumoto (1959)	
May 1929	12°15′N	109°26′E	ISEW	1	—	—	Matsumoto (1959)	
	20°30.5′N	125°28′E	ISEW	2	—	—	Matsumoto (1959)	
	20°30.5′N	125°28′E		2	—	—	Matsumoto (1959)	
June 1929	14°37′N	119°52′E	ISEW	1	—	—	Matsumoto (1959)	
July 1929	00°41.5′S	134°14.5′E	ISEW	1	—	—	Matsumoto (1959)	
	00°41.5′S	134°14.5′E		3	—	—	Matsumoto (1959)	
	00°41.5′S	134°14.5′E		2	—	—	Matsumoto (1959)	
	00°40.5′S	134°15′E	ISEW	7	—	—	Matsumoto (1959)	
	00°40.5′S	134°15′E		3	—	—	Matsumoto (1959)	
	00°40.5′S	134°15′E		10(?)	—	—	Matsumoto (1959)	
	00°40.5′S	134°15′E		4	—	—	Matsumoto (1959)	
	00°40.5′S	134°15′E		4	—	—	Matsumoto (1959)	
	00°33′S	134°00′E	ISEW	11	—	—	Matsumoto (1959)	
	00°33′S	134°00′E		3	—	—	Matsumoto (1959)	
	00°33′S	134°00′E		1(?)	—	—	Matsumoto (1959)	
	01°01′S	137°20′E	ISEW	2	—	—	Matsumoto (1959)	
	01°01′S	137°20′E		3	—	—	Matsumoto (1959)	
	01°20′S	138°42′E	ISEW	1	—	—	Matsumoto (1959)	
	01°20′S	138°42′E		1	—	—	Matsumoto (1959)	
Aug. 1929	07°53′S	116°18′E	ISEW	1	—	—	Matsumoto (1959)	
	07°53′S	116°18′E		2(?)	—	—	Matsumoto (1959)	
	09°09′S	114°47′E	ISEW	2	—	—	Matsumoto (1959)	
Sept. 1929	06°22′S	105°12′E	ISEW	7(?)	—	—	Matsumoto (1959)	
	06°22′S	105°12′E		13(?)	—	—	Matsumoto (1959)	
	04°38′S	99°24′E	ISW	1	—	—	Matsumoto (1959)	
	02°00′S	98°59′E	ISW	1	—	—	Matsumoto (1959)	
	02°00′S	98°59′E		1	—	—	Matsumoto (1959)	
	02°00′S	98°59′E		2	—	—	Matsumoto (1959)	
	02°07′S	99°53′E	ISW	1	—	—	Matsumoto (1959)	
	01°29′S	100°07′E	ISW	2	—	—	Matsumoto (1959)	
	01°29′S	100°07′E		10	—	—	Matsumoto (1959)	
	00°52′S	99°25′E	ISW	1	—	—	Matsumoto (1959)	
	00°52′S	99°25′E		11	—	—	Matsumoto (1959)	
	00°52′S	99°25′E		7	—	—	Matsumoto (1959)	
Oct. 1929	02°57′S	99°36′E	ISW	1	—	—	Matsumoto (1959)	
	03°12′S	99°26′E	ISW	1	—	—	Matsumoto (1959)	
Dec. 1929	01°45′N	71°05′E	ISW	1	—	7.08	Jones and Kumaran (1963)	Length not defined
	00°35′N	66°09′E	ISW	1	—	—	Jones and Kumaran (1963)	Length not defined
	03°45′S	56°33′E	ISW	2	—	6.05, 7.14	Jones and Kumaran (1963)	Length not defined
	05°01′S	54°46′E	ISW	1	—	5.94	Jones and Kumaran (1963)	Length not defined
	08°27′S	50°54′E	ISW	1	—	5.59	Jones and Kumaran (1963)	Length not defined
	11°55′S	49°55′E	ISW	2	—	4.7	Jones and Kumaran (1963)	Length not defined
	12°09′S	49°34′E	ISW	8	—	6.62-12.72	Jones and Kumaran (1963)	Length not defined
	09°10′S	45°17′E	ISW	1	—	6.58	Jones and Kumaran (1963)	Length not defined
	08°24′S	42°54′E	ISW	3	—	5.14-7.94	Jones and Kumaran (1963)	Length not defined
	07°24′S	41°51′E	ISW	56	—	4.68-8.75	Jones and Kumaran (1963)	Length not defined
	04°45′S	40°10′E	ISW	15	—	5.42-12.16	Jones and Kumaran (1963)	Length not defined
Jan. 1930	03°26′S	42°58′E	ISW	34	—	4.74-8.69	Jones and Kumaran (1963)	Length not defined
	04°21′S	42°56′E	ISW	2	—	6.11	Jones and Kumaran (1963)	Length not defined
	14°16′S	41°48′E	ISW	3	—	6.79	Jones and Kumaran (1963)	Length not defined
	16°12′S	42°04′E	ISW	14	—	4.79-9.14	Jones and Kumaran (1963)	Length not defined
	18°30′S	42°18′E	ISW	1	—	—	Jones and Kumaran (1963)	Length not defined
	21°13′S	42°26′E	ISW	3	—	5.69-5.88	Jones and Kumaran (1963)	Length not defined
	23°11′S	42°54′E	ISW	2	—	7.08-8.39	Jones and Kumaran (1963)	Length not defined
	25°14′S	36°21′E	ISW	29	—	4.62-7.42	Jones and Kumaran (1963)	Length not defined
Mar. 1948	Manado, Celebes, Netherlands, East Indies		ISEW	—	1	115	Wade (1950a)	Fork length

Table 9.— Continued.

Date	Locality		Marine area code [see Rosa (1965)]	Number		Length (mm)	Reference	Remarks
	Lat.	Long.		Larvae	Juveniles			
Apr. 1948	Batangas, Luzon, Philippines		ISEW	—	7	143-178	Wade (1950a)	Fork length
May 1948	7°02′N	124°12′E	ISEW	—	2	33.5, 35	Wade (1950a)	Fork length
	Taal, Batangas Province, Luzon, Philippines		ISEW	—	4	127-175	Wade (1950a)	Fork length
	Batangas, Luzon, Philippines		ISEW	—	2	40, 44	Wade (1950a)	Fork length
Mar. 1949	Batangas, Luzon, Philippines			—	2	40, 68.4	Wade (1950a)	Fork length
	Batangas, Luzon, Philippines			—	1	80	Wade (1950a)	Fork length
Apr. 1949	Batangas, Luzon, Philippines			—	1	76.5	Wade (1950a)	Fork length
	Batangas, Luzon, Philippines			—	18	73-112	Wade (1950a)	Fork length
	Batangas, Luzon, Philippines			—	2	117.5-131	Wade (1950a)	Fork length
Aug.-Oct. 1950	Off southern Kyushu, Japan		ISEW	—	Numerous	150-250	Yabe et al. (1953)	Fork length
Sept. 1956	Calicut, India		ISW	—	6	72.0-140.0	Jones (1960)	Length given by Jones is standard length. Jones reported capture of larger juveniles not included here.
Oct. 1956	Vizhingam, India		ISW	—	1	116.5	Jones (1960)	
Nov. 1956	Vizhingam, India			—	1	162.0	Jones (1960)	
Jan. 1957	Vizhingam, India			—	8	34.3-75.0	Jones (1960)	
May 1958	Vizhingam, India			—	2	24.5, 40.6	Jones (1960)	
June 1958	Vizhingam, India			—	1	96.0	Jones (1960)	
Aug. 1956	00°01′S	133°02′W	ISEW	—	1	—	Strasburg (1960)	
	12°31′S	132°04′W	ISEW	—	2	—	Strasburg (1960)	
Jan. 1957	07°55′S	110°02′W	ISEW	—	1	—	Strasburg (1960)	
Feb. 1957	02°58′S	129°55′W	ISEW	—	1	—	Strasburg (1960)	
	14°57′S	146°20′W	ISEW	—	2	—	Strasburg (1960)	
Mar. 1957	08°12′S	145°12′W	ISEW	1	—	—	Strasburg (1960)	
June 1957	21°11′N	158°17.5′W	ISEW	1	—	—	Strasburg (1960)	
	21°25′N	157°21′W	ISEW	1	—	—	Strasburg (1960)	
	21°24.5′N	159°00′W	ISEW	1	—	—	Strasburg (1960)	
Dec. 1957	09°34′S	139°50′W	ISEW	2	—	—	Nakamura and Matsumoto (1967)	
Oct. 1960	12°29′N	43°03′E	ISEW	215	—	—	Parin (1967)	
July-Aug. 1960-61	Gulf of Tonkin		ISEW	22	—	3.5-6.0	Gorbunova (1965a)	Length not defined
July-Sept. 1967	Hawaii		ISEW	—	25	—	Higgins (1970)	
July-Sept. 1968-71	21°30′- 24°45′N 03°30′- 12°00′N	119°28′-121°30′E 102°45′-115°15′E	ISEW	24	—	—	Chen and Tan (1973)	

Fig. 8). Larvae and juveniles have been reported from Hawaii (Strasburg 1960; Higgins 1970), near the Marquesas and Tuamotus and surrounding areas (Strasburg 1960; Nakamura and Matsumoto 1967), in the Gulf of Tonkin (Gorbunova 1965a), in the Gulf of Aden (Gorbunova 1965b; Parin 1967), around Taiwan and adjacent waters (Matsumoto 1959; Chen and Tan 1973), and off the coast of southern Japan (Yabe et al. 1953). These records suggest that *E. affinis* probably spawns throughout its range.

Euthynnus alletteratus

Based on the records of occurrence of postlarval and juvenile *E. alletteratus*, Padoa (1956) indicated that spawning in the Mediterranean occurred in the springtime and in the summer. The summer spawning conclusion was based on postlarval material reported on by Ehrenbaum (1924); however, Matsumoto (1959) indicated that the identification of *E. alletteratus* by Ehrenbaum was erroneous. On the other hand, Belloc (1955) noted that spawning takes place in different parts of the Mediterranean chiefly in July-August. Ben-Tuvia (1957) indicated that young *E. alletteratus* 8 to 16 cm long are taken by "light fishing" from June to September along the Mediterranean coast of Israel, which, according to him, suggested summer spawning. Postel (1964) also indicated that the spawning season for *E. alletteratus* in the Mediterranean is in the summer (June-July-August).

In the eastern Atlantic, Postel (1950) noted that the spawning season was from April to November, including a peak from June to September along the coast of Dakar, Senegal. Further south along the coast of western Africa, Marchal (1963) indicated that peak spawning took place in October and November. Along the Ivory Coast, Marchal (1963) indicated that the spawning season is very extended, at least from October to June. He noted an interruption of spawning during July to September coinciding with a cooling of the sea in the Ivory Coast area. Of interest is the series of larval tuna surveys conducted in the northwestern Gulf of Guinea in 1964 and 1965 by the Miami Laboratory, NMFS (National Marine Fisheries Service) (Richards et al. 1969a, 1969b, 1970). The cruises were made in the winter-spring "warm season" in the Gulf of Guinea (February-April 1964 and March-April 1965) and in the summer-fall "cool season" (August-October 1964). Larval *E. alletteratus* were caught during the cool season as well as the warm season (Table 10). Although the surveys did not cover all the months of the year, the results, together with observations made by Marchal (1963), suggest year-round spawning in the northwestern Gulf of Guinea. Around São Tomé and Principe the spawning season extends from October to December (Frade and Postel 1955; da Costa and Frade 1958).

The development of *E. alletteratus* gonads indicates an extended spawning season beginning in March and continuing to about November off the coast of Florida (de Sylva and Rathjen 1961). Potthoff and Richards (1970) also concluded that *E. alletteratus* spawns over a long period in Florida waters. They based their conclusion on the occurrence of juveniles in the regurgitated food of seabirds in the Dry Tortugas, Fla.

Klawe and Shimada (1959) reported the capture of juvenile *E. alletteratus* during the months of March, April, June, July, and August in the Gulf of Mexico (Table 11) and suggested reproductive activity at least during these months if not also in other months of the year. The records of other larval and juvenile *E. alletteratus* shown in Table 11 suggest spawning in those areas also.

Marchal (1963) concluded that in the Mediterranean and along the west coast of Africa, *E. alletteratus* spawns during periods of the year when the water is warmest and that this species apparently reproduces throughout its range.

Euthynnus lineatus

Klawe (1963) found that *E. lineatus* spawning in the northern part of its distribution is limited to the summer months. He also noted that farther south, *E. lineatus* spawns throughout the year including a possible peak in early spring (Table 12).

Table 10.—Records of larval *Euthynnus alletteratus* in the northwestern Gulf of Guinea and off Sierra Leone (ASE[1]). (From Richards et al. 1969a, 1969b, 1970.)

Date	Locality		No. of larvae	Date	Locality		No. of larvae
	Lat.	Long.			Lat.	Long.	
February 1964	04°20'N	08°09'W	78	October 1964	04°23'N	01°04'E	3
	04°51'N	05°30'W	1		02°53'N	01°02'W	1
	05°02'N	03°53'W	2		03°38'N	02°00'W	1
	04°15'N	01°32'W	1		04°00'N	02°38'W	4
	02°45'N	01°30'W	4		04°09'N	03°10'W	5
	02°51'N	01°25'W	1	February 1965	07°57'N	16°53'W	1
	04°20'N	01°30'W	1		06°29'N	16°28'W	5
	04°30'N	00°54'W	5		06°15'N	16°29'W	1
	04°34'N	00°49'W	1		09°00'N	16°02'W	1
	05°31'N	00°10'E	2		06°11'N	15°30'W	1
	05°28'N	00°10'E	2		07°30'N	15°00'W	2
	04°48'N	00°01'E	4	February 1965	08°30'N	15°27'W	1
	04°59'N	01°00'E	15		08°14'N	15°00'W	7
	04°30'N	01°30'E	3		07°26'N	15°01'W	1
March 1964	04°31'N	01°55'E	2		07°00'N	14°29'W	1
	05°01'N	03°58'W	1		07°01'N	14°28'W	1
April 1964	04°32'N	05°01'W	5	March 1965	07°08'N	13°30'W	1
	04°56'N	01°11'W	11		07°03'N	13°06'W	1
	04°54'N	00°30'W	33		06°49'N	13°04'W	4
	04°15'N	00°33'W	1		04°35'N	02°32'W	3
	03°52'N	01°03'W	1		04°06'N	02°33'W	1
	02°55'N	02°04'W	10		04°20'N	01°59'W	1
	03°31'N	02°04'W	10		04°08'N	01°28'W	1
August 1964	04°20'N	06°59'W	2		04°10'N	00°29'W	1
	04°32'N	06°19'W	1		04°22'N	00°06'W	9
	05°00'N	04°30'W	1		05°35'N	00°32'E	3
	04°21'N	02°02'W	1		05°05'N	00°25'E	1
	04°18'N	01°09'W	1		05°59'N	01°30'E	2
	04°27'N	01°44'W	8		05°45'N	01°30'E	1
	06°00'N	01°39'E	1		05°53'N	01°58'E	1
	06°09'N	02°37'E	1		04°15'N	02°30'E	2
September 1964	02°30'N	07°57'W	1				
	03°50'N	06°41'W	5				

[1]Marine area code. See Rosa (1965).

Table 11.—Records of larval and juvenile *Euthynnus alletteratus* in the Atlantic and Mediterranean.

Date	Locality		Marine area code [see Rosa (1965)]	Number		Length (mm)	Reference	Remarks
	Lat.	Long.		Larvae	Juveniles			
June 1920	18°00'N	64°14'W	ASW	1	—	—	Matsumoto (1959)	
July 1920	33°07'N	77°00'W	ASW	4	—	—	Matsumoto (1959)	
	33°07'N	77°00'W		5	—	—	Matsumoto (1959)	
May 1921	17°55'N	64°48'W	ASW	1	—	—	Matsumoto (1959)	
Nov. 1921	07°22'N	46°51'W	ASW	1	—	—	Matsumoto (1959)	
	05°35'N	51°08'W	ASW	1	—	—	Matsumoto (1959)	
	05°35'N	51°08'W		2	—	—	Matsumoto (1959)	
	05°35'N	51°08'W		10	—	—	Matsumoto (1959)	
	05°06'N	51°35'W	ASW	1	—	—	Matsumoto (1959)	
	05°06'N	51°35'W		14	—	—	Matsumoto (1959)	
	05°06'N	51°35'W		2	—	—	Matsumoto (1959)	
May 1922	35°42'N	73°43'W	ASW	5(?)	—	—	Matsumoto (1959)	
June 1953	25°35'N	79°25'W	ASW	—	1	8.8	Klawe (1960)	(1)
July 1954	34°35'N	75°15'W	ASW	—	2	25, 35	Klawe (1961)	(1)From stomach of *Euthynnus*
	28°59'N	88°07'W	ASW	—	4	27-41	Klawe and Shimada (1959)	(1)
	28°36'N	87°58'W	ASW	—	4	28-33	Klawe and Shimada (1959)	(1)
	29°05'N	88°10'W	ASW	—	86	21-44	Klawe and Shimada (1959)	(1)
	27°34'N	89°00'W	ASW	—	3	26-38	Klawe and Shimada (1959)	(1)
	27°58'N	88°03'W	ASW	—	2	76-80	Klawe and Shimada (1959)	(1)
Aug. 1954	29°28'N	87°30'W	ASW	—	38	11-47	Klawe and Shimada (1959)	(1)
	28°59'N	88°02'W	ASW	—	4	56-108	Klawe and Shimada (1959)	(1)
	28°46'N	88°40'W	ASW	—	5	24-36	Klawe and Shimada (1959)	(1)
	29°12'N	88°34'W	ASW	—	29	22-174	Klawe and Shimada (1959)	(1)
June 1955	28°40'N	88°58'W	ASW	—	10	21-31	Klawe and Shimada (1959)	(1)
Aug. 1955	28°50'N	87°50'W	ASW	—	4	3.5-5.3	Klawe and Shimada (1959)	(1)
	28°50'N	87°48'W	ASW	—	88	30-53	Klawe and Shimada (1959)	(1)
	28°47'N	87°57'W	ASW	—	16	31-55	Klawe and Shimada (1959)	(1)
	28°45'N	87°56'W	ASW	—	4	6.2-8	Klawe and Shimada (1959)	(1)
	28°55'N	88°00'W	ASW	—	90	29-65	Klawe and Shimada (1959)	(1)
	28°55'N	87°57'W	ASW	—	116	4-80	Klawe and Shimada (1959)	(1)
	29°01'N	87°48'W	ASW	—	60	17-68	Klawe and Shimada (1959)	(1)
	28°12'N	88°43'W	ASW	—	11	49-86	Klawe and Shimada (1959)	(1)
	28°17'N	88°37'W	ASW	—	12	32-94	Klawe and Shimada (1959)	(1)
Sept. 1955	29°27'N	86°55'W	ASW	—	52	24-49	Klawe and Shimada (1959)	(1)
—	Gulf of Mexico		ASW	—	8	19-29	Klawe and Shimada (1959)	(1)
Aug. 1956	28°50'N	87°50'W	ASW	—	33	21-82	Klawe and Shimada (1959)	(1)
Oct. 1957 Dec. 1958	Off Takoradi, Ghana		ASE	Single specimen	—		Kazanova (1962)	Length not defined
July 1960	Off Dakar, Senegal		ASE	Up to 60 specimens per catch	—	4.14-6.10	Kazanova (1962)	Length not defined
Aug.-Sept. 1964	Around Cuba		ASW	20	—	3.0-5.4	Gorbunova and Salabarrí (1967)	Length not defined
Feb.-Mar. 1963	06°18'N	23°20'W	ASE	2	—	3.8, 3.7	Zharov and Zhudova (1969)	Length not defined
	04°40'N	24°28'W	ASE	1	—	4.4	Zharov and Zhudova (1969)	Length not defined
	10°00'S	34°33'W	ASW	1	—	8.7	Zharov and Zhudova (1969)	Length not defined
	03°00'N	30°00'W	ASW	1	—	4.2	Zharov and Zhudova (1969)	Length not defined
	03°37'S	30°04'W	ASW	1	—	4.4	Zharov and Zhudova (1969)	Length not defined
Apr.-July 1960-67	24°30'N	82°50'W	ASW	—	47	29-135	Potthoff and Richards (1970)	Standard length
Oct. Dec. Feb. 1964-66	07°S 05°N 04°30'N	12°E 04°30'W 04°30'W	ASE	4	—	4.2-10.2	Zhudova (1969a)	Approximate locations Length not defined
Aug.-Oct. 1964	09°20'N	19°41'W	ASE	No numbers given	—	—	Zhudova (1969b)	
Throughout the year	Ivory Coast and Ghana		ASE	—	Numerous	—	Marchal (1963)	
June-Aug.	Haifa Bay		ASE	—	Numerous	80-240	Ben-Tuvia (1957)	Length not defined
Aug.-Oct. 1959	Dardanelles		ASE	—	Numerous	145-220	Demir (1963)	Fork length
Aug.-Sept. 1959	Sea of Marmara		ASE	—	Numerous	180-250	Demir (1963)	Fork length

[1]Total length measured from tip of snout to shortest median ray of caudal fin.

Table 12.—Average numbers of *Euthynnus lineatus* larvae caught per hour of surface plankton tow off Cape Blanco, Costa Rica. (From Klawe 1963:465.)

Month	No. of larvae	Month	No. of larvae
January	1.5	July	0.1
February	0.1	August	0.2
March	3.2	September	1.4
April	14.9	October	0.0
May	0.6	November	0.2
June	0.0	December	0.7

Records of larval and juvenile *E. lineatus* from the eastern Pacific and from near Costa Rica are shown in Tables 13 and 14, respectively. The records indicate the probable spawning periods and localities in the eastern tropical Pacific Ocean.

3.17 Spawn

There is very little information on the fertilized eggs of *Euthynnus* in the literature. Delsman (1931) described the eggs of *Thynnus thunnina* (= *E. affinis*) which he had earlier identified as eggs of *Scomber* (= *Rastrelli-*

Table 13.—Records of larval and juvenile *Euthynnus lineatus* in the eastern tropical Pacific Ocean (ISE[1]). The lengths of the specimens were given as total or fork length in the various references listed in the table; however, both were taken in the same manner, i.e., from the tip of the snout to the shortest median ray in the caudal fin.

Date	Locality		Number		Total or fork length (mm)	Collector or reference
	Lat.	Long.	Larvae	Juveniles		
Jan. 1922	06°49′N	80°25′W	4	1	—	Matsumoto (1959)
	06°49′N	80°25′W	1	—	—	Matsumoto (1959)
	06°49′N	80°25′W	1	—	—	Matsumoto (1959)
	06°49′N	80°25′W	13	—	—	Matsumoto (1959)
	06°40′N	80°47′W	4	—	—	Matsumoto (1959)
	06°40′N	80°47′W	1	—	—	Matsumoto (1959)
	06°40′N	80°47′W	1	—	—	Matsumoto (1959)
	06°40′N	80°47′W	2	—	—	Matsumoto (1959)
	06°40′N	80°47′W	2	—	—	Matsumoto (1959)
	06°40′N	80°47′W	58	—	—	Matsumoto (1959)
	06°48′N	80°33′W	1	—	—	Matsumoto (1959)
	06°48′N	80°33′W	2	—	—	Matsumoto (1959)
	06°48′N	80°33′W	2	—	—	Matsumoto (1959)
	06°48′N	80°33′W	1	—	—	Matsumoto (1959)
	06°48′N	80°33′W	1	—	—	Matsumoto (1959)
	08°24′N	79°23′W	13	—	—	Matsumoto (1959)
	08°40′N	79°23′W	25	—	—	Matsumoto (1959)
Sept. 1928	07°06′N	79°55′W	2	—	—	Matsumoto (1959)
	07°16′N	78°30′W	1	—	—	Matsumoto (1959)
	07°55′N	79°02′W	1	—	—	Matsumoto (1959)
Mar. 1947	08°20′N	84°10′W	—	8	48-86	Schaefer and Marr (1948)
	09°20′N	85°20′W	—	10	29-56	Schaefer and Marr (1948)
	09°10′N	85°20′W	—	1	61	Schaefer and Marr (1948)
May 1949	10°58′N	89°56′W	—	2	7.5, 10.5	Mead (1951)
	11°20′N	87°20′W	—	23	14-18	Mead (1951)
	12°50′N	89°40′W	—	2	18, 24	Mead (1951)
Oct. 1951	24°35′N	112°05′W	—	1	9.7	Sefton, Jr.[2]
Jan. 1955	12°34′N	89°50′W	—	8	25 (mean)	Clemens (1956)
	08°43′N	84°11′W	—	34	17-38	Clemens (1956)
Nov. 1955	07°42′N	79°20′W	—	1	30	Eastropac Expedition[2]
	03°01′N	82°15′W	—	6	27-38	Eastropac Expedition[2]
Dec. 1955	11°48′N	88°25′W	—	1	46	Eastropac Expedition[2]
Nov. 1955	08°31.3′N	79°32′W	2	—	—	Klawe (1963)
Aug. 1956	26°04.5′N	112°48′W	1	—	7.0	La Jolla Lab., NMFS[2]
Sept. 1956	15°05′N	93°54′W	—	3	15-27	Klawe (1963)
Oct. 1956	12°51′N	93°05′W	—	1	51	Klawe (1963)
Nov. 1956	14°00′N	96°11′W	—	1	30	Schaefer and Shimada[2]
Feb. 1957	17°24′N	102°04′W	—	1	21	Renner and Hark[2]
Aug. 1957	29°12′N	115°39′W	—	1	—	La Jolla Lab., NMFS[2]
	31°11′N	114°15′W	—	2	29.5, 353	La Jolla Lab., NMFS[2]
May 1958	05°34′N	81°29′W	—	1	60	Klawe (1963)
	08°28′N	84°21′W	1	—	—	Klawe (1963)
	15°15′N	95°23′W	11	—	—	Klawe (1963)
June 1958	18°44′N	104°21′W	—	5	20-27	Klawe (1963)
	17°49′N	103°38.5′W	—	99	7.5-45	Klawe (1963)
	21°36′N	106°44′W	—	3	18-48	Klawe (1963)
	16°39′N	100°05′W	1	—	—	Klawe (1963)
	17°24′N	101°25′W	6	—	—	Klawe (1963)
	18°44′N	104°21′W	1	—	—	Klawe (1963)

Table 13.—Continued.

Date	Locality		Number		Total or fork length	Collector or
	Lat.	Long.	Larvae	Juveniles	(mm)	reference
Nov. 1958	14°56.5′N	93°06.5′W	11	—	—	Klawe (1963)
	15°39′N	93°59.5′W	1	—	—	Klawe (1963)
	14°18′N	95°02.8′W	1	—	—	Klawe (1963)
	15°02′N	95°07.5′W	1	—	—	Klawe (1963)
	14°21′N	97°01′W	3	—	—	Klawe (1963)
	14°21′N	97°01′W	24	—	—	Klawe (1963)
	15°31′N	97°44′W	5	—	—	Klawe (1963)
Dec. 1958	15°31′N	97°44′W	15	—	—	Klawe (1963)
	15°36′N	99°23.5′W	1	—	—	Klawe (1963)
Jan. 1959	15°29.5′N	98°32.5′W	4	—	—	Klawe (1963)
	15°29.5′N	98°32.5′W	4	—	—	Klawe (1963)
Feb. 1959	19°46′N	105°44′W	5	—	—	Klawe (1963)
Apr. 1959	08°12′N	83°15.5′W	—	6	12-18	Broadhead and Chatwin[2]
	08°12′N	83°17′W	—	1	7.5	Broadhead and Chatwin[2]
	08°15′N	83°23′W	—	6	13-28	Broadhead and Chatwin[2]
Sept. 1959	15°39′N	97°00′W	2	—	—	Klawe (1963)
	14°20′N	95°59′W	6	—	—	Klawe (1963)
	14°20′N	95°59′W	6	—	—	Klawe (1963)
	14°54.8′N	95°07.1′W	36	—	—	Klawe (1963)
	14°21.5′N	94°01′W	5	—	—	Klawe (1963)
	16°28′N	99°32.5′W	2	—	—	Klawe (1963)
Feb. 1961	12°35′N	93°40′W	—	3	7.5-9.5	Vann[2]
Oct. 1966	Entrance, Gulf of California		2	—	—	Klawe et al. (1970)
Nov. 1966	Entrance, Gulf of California		3	—	—	Klawe et al. (1970)
	Off Tres Marias Is.		1	—	—	Klawe et al. (1970)
Dec. 1966	Entrance, Gulf of California		1	—	—	Klawe et al. (1970)

[1]Marine area code. See Rosa (1965).
[2]As reported in Klawe (1963).

ger) kanagurta. Delsman noted that the egg diameters were 0.85 to 0.95 mm and that the diameter of the oil globule ranged from 0.21 to 0.24 mm. Sanzo (1932) described some fertilized eggs which he tentatively identified as belonging to *Euthynnus alletteratus*. The eggs were buoyant, spherical, and transparent, and were about 1.08 mm in diameter with an oil globule 0.28 mm in diameter. The dimensions of the fertilized eggs were very similar to that of *Auxis* and *Thunnus* eggs, but the embryos did not show yellow pigmentation as in those species. The yolk sac was rich in black pigment.

Houde and Richards (1969) reported on the collection of some fertilized eggs which were later determined to be from *E. alletteratus*. The eggs were collected from May through August 1969 in the Straits of Florida off Miami and returned to the laboratory for incubation. In a successful attempt at hatching some of the fertilized eggs, examination of the resulting larvae reared to 12 days past hatching revealed that the larvae were those of *E. alletteratus*. They noted that the larvae hatched within 12 h of collection and probably within 24 h after the eggs were fertilized. They did not include a description of the fertilized eggs.

Calkins and Klawe (1963) stated that the fertilized eggs of *E. lineatus* are pelagic but they had never been specifically identified in plankton collections.

3.2 Preadult phase

3.21 Embryonic phase

Euthynnus affinis

Delsman (1926), as stated earlier, described some fertilized eggs of *Scomber* (= *Rastrelliger*) *kanagurta* which he later reidentified as *Thynnus thunnina* (= *E. affinis*). He noted that the eggs took less than 24 h to hatch. Delsman's drawing of a newly hatched larva indicates a size of approximately 2.1 mm at hatching. He counted a total of 39-41 "myotomes" in larvae of various stages of development (Fig. 11). Whether these were actually larvae of *E. affinis* has not been verified.

Euthynnus alletteratus

Houde and Richards (1969) collected the fertilized eggs of *E. alletteratus* and were successful in hatching the eggs and rearing the larvae up to 18 days past hatching. The larvae were slightly less than 3 mm long at hatching. The newly hatched larvae had a large yolk sac that contained a single prominent oil globule, the eyes were unpigmented, and the mouth and gut were not functional. The yolk was absorbed, the eyes became pigmented, and

Table 14.—Larval and juvenile *Euthynnus lineatus* captured off Cape Blanco, Costa Rica (ISE[1]). (From Klawe 1963, table 5.)

Date	Location from Cape Blanco	Number Larvae	Number Juveniles	Total length (mm)
Nov. 1958	20 mi S	1	—	6.5
	20 mi S	1	—	9.0
	20 mi SSW	1	—	6.0
	20 mi SSW	2	—	5.0
Jan. 1959	20 mi S	—	8	21-39
	20 mi S	—	43	14-25
Feb. 1959	20 mi S	—	8	25-50
	20 mi S	1	—	5.0
Mar. 1959	20 mi S	3	—	5.1-6.7
	20 mi S	1	—	6.7
	5 mi SE	2	—	6.2,8.2
	5 mi SE	6	—	5.2-9.2
	5 mi SE	1	—	5.3
Apr. 1959	20 mi S	—	4	11-25
	5 mi SE	—	77	16-25
	20 mi S	2	—	6.5-7.7
	20 mi S	7	—	5.0-8.2
	20 mi SE	12	—	4.1-7.1
	5 mi SE	23	—	4.5-7.5
	5 mi SE	25	—	4.4-7.5
	5 mi SE	12	—	4.4-7.2
	5 mi SE	88	—	4.4-14.2
May 1959	10 mi SE	—	11	16-25
	10 mi SE	5	—	5.5-8.0
	10 mi SE	1	—	8.5
	10 mi SE	2	—	6.0-13.0
June 1959	10 mi W	—	2	ca.17
Aug. 1959	12 mi SE	3	—	4.6-8.8
	6 mi SE	—	3	15-17
Sept. 1959	20 mi S	4	—	4.8-5.7
	10 mi S	5	—	6.1-7.4
	10 mi S	4	—	5.0-7.3
	10 mi S	5	—	4.4-7.5
Nov. 1959	20 mi S	—	4	11.5-53
	20 mi S	1	—	4.4
Jan. 1960	10 mi S	9	—	4.1-5.5
	10 mi S	2	—	4.6-4.8
Feb. 1960	20 mi SSW	—	1	18
Mar. 1960	10 mi S	—	12	15-28
	20 mi S	6	—	3.3-6.3
	20 mi S	19	—	4.3-8.6
	10 mi S	6	—	3.7-6.7
	10 mi S	4	—	6.6-8.3
May 1960	20 mi S	—	14	13-21
	10 mi S	—	6	9.5-24
	10 mi S	1	—	6.5
July 1960	10 mi S	—	4	13-17
	10 mi S	—	62	10-24
	10 mi S	1	—	7.0
Aug. 1960	10 mi S	1	—	6.0
	20 mi S	—	1	19
	10 mi S	—	3	12-18
Sept. 1960	10 mi S	—	51	12.5-24
Oct. 1960	10 mi S	1	—	7.5

[1]Marine area code. See Rosa 1965.

the mouth and gut were functional within 48 h after hatching.

Euthynnus lineatus

No information.

3.22 Larvae and adolescent phases

The larvae and juveniles of all three species of *Euthynnus* have been described in detail (e.g., Schaefer and Marr 1948; Wade 1950a; Mead 1951; Matsumoto 1958, 1959; Jones 1960). The following descriptions of young *Euthynnus* are taken primarily from the above references.

Euthynnus affinis

The smallest specimen identified by Matsumoto (1958) as *E. affinis* measured 4.6 mm TL (Fig. 12a). The head length is moderate (33.9% TL), there are 40 myomeres, and the abdominal sac is nearly triangular. The mouth is fairly large (about 71.9% of the head length) and contains 12 teeth on the upper jaw and 9 teeth on the lower jaw. The distance from the tip of the snout to the anterior edge of the orbit is almost equal to the orbit diameter. Three long spines are present on the posterior edge of the preopercle; the longest spine is the one at the angle. Generally, a single chromatophore is found at the middle of the lower jaw and at the symphysis of the pectoral girdle.

The median fins show very little development; there are 4 or 5 rays in the caudal fin and only strong striations representing rays in the incipient anal and dorsal fins. The pelvic fins are undeveloped and the pectoral fins show only striations.

There are 13 and 15 teeth in the upper and lower jaws, respectively, and the preopercular spines have increased to 6 in a 5.5 mm TL specimen (Fig. 12b).

Five short spines are present in the first dorsal fin and about nine rays in the caudal; the other median fins and the pectorals still show only strong striations and the pelvic fins are just emerging as small buds.

The single chromatophore at the middle of the mandible and that at the pectoral symphysis are still evident.

A 7.6 mm TL specimen exhibits some striking changes, particularly in pigmentation. A series of four or five chromatophores is present on the anterior half of the mandible and the first dorsal fin is almost completely pigmented.

The head comprises 39.8% of the total length and the snout length is much greater than the diameter of the orbit. About 16 teeth are present on both the upper and lower jaws, and 7 spines are noticeable on the posterior edge of the preopercle.

There are 8 spines in the first dorsal fin; the length of the longest spine is less than half the distance between the dorsal fin insertions. The second dorsal and anal fin rays are further developed and, although the rays are not clearly evident, about 11 radials in the second dorsal and 12 in the anal are present. The first 7 dorsal and 6 anal finlet radials are also evident. There are 9 + 9 rays in the caudal fin and the pelvic fins are complete with 1 spine and 5 rays; about 5 rays are noticeable in the pectoral fins.

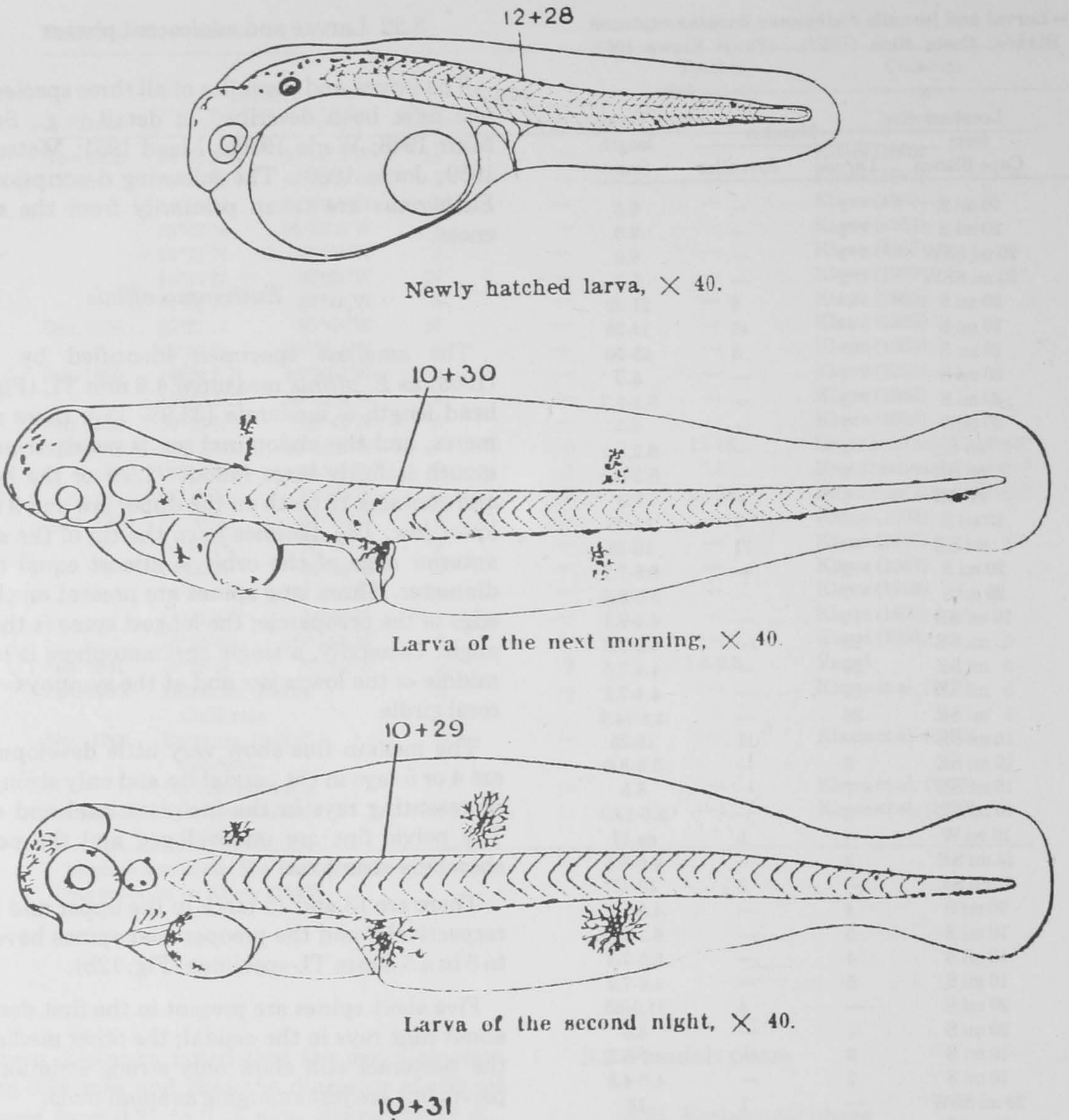
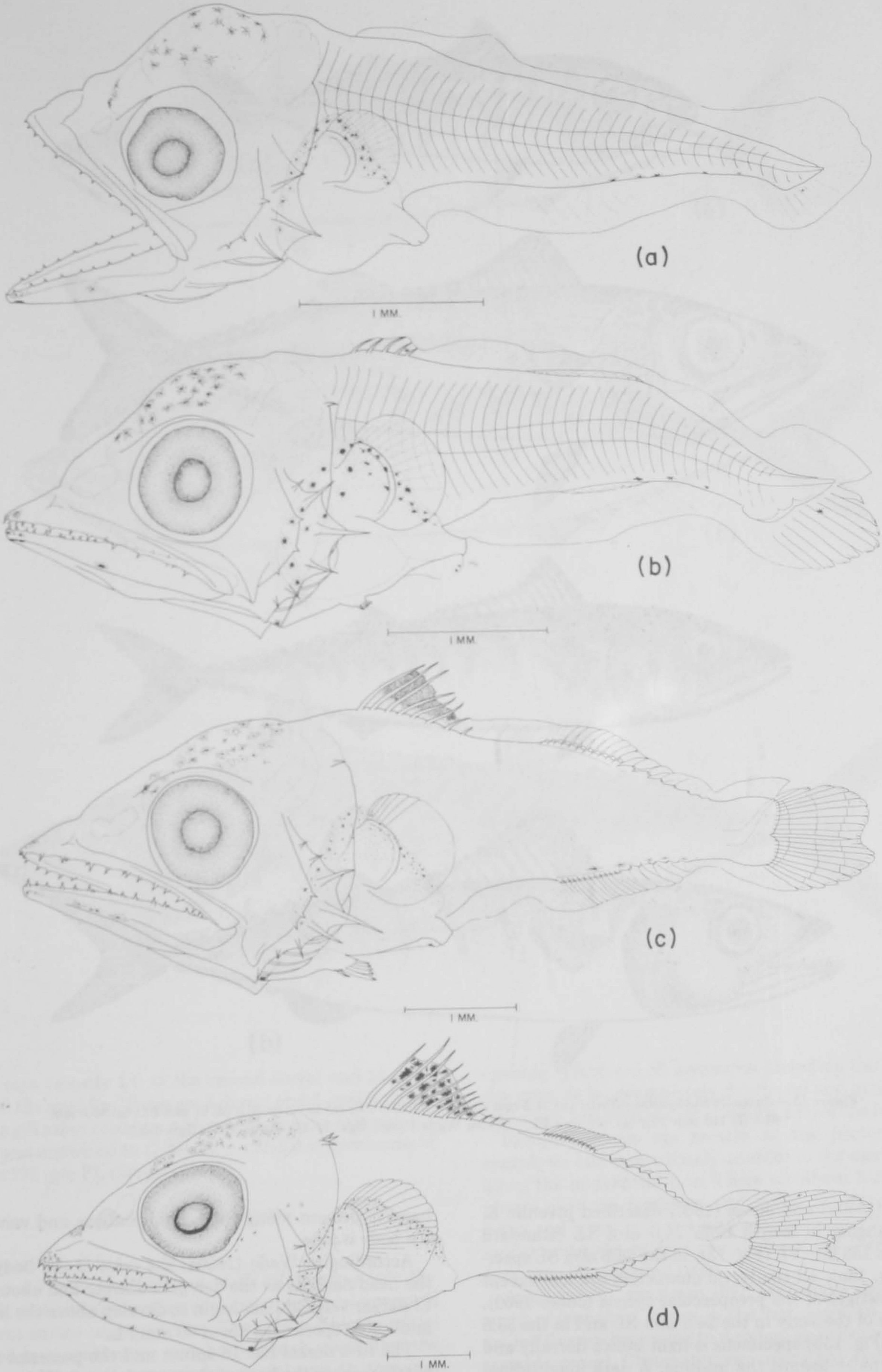


Figure 11.—Larvae of *Euthynnus affinis*. (From Delsman 1926, figs. 3-6.)

The first dorsal fin is heavily pigmented, and the pigmentation at the tip of the snout is more extensive in a 9.6 mm TL specimen (Fig. 12d). Chromatophores now extend over two-thirds of the length of the mandible and the chromatophore at the symphysis of the pectoral girdle still persists.

The first dorsal fin now has 13 spines and the length of the longest spine is greater than half the distance between the dorsal fin insertions. There are 13 rays in the second dorsal and anal fins.

Figure 12.—*Euthynnus affinis* larvae: (a) 4.6 mm; (b) 5.5 mm; (c) 7.6 mm; (d) 9.6 mm. (From Matsumoto 1958, figs. 15-17.) The body length, total or fork length, was measured from the tip of the snout to the fork of the tail when the tail was forked, and to the tip of the longest ray when the tail was not forked.


(a)
1 MM.
(b)
1 MM.
(c)
1 MM.
(d)
1 MM.

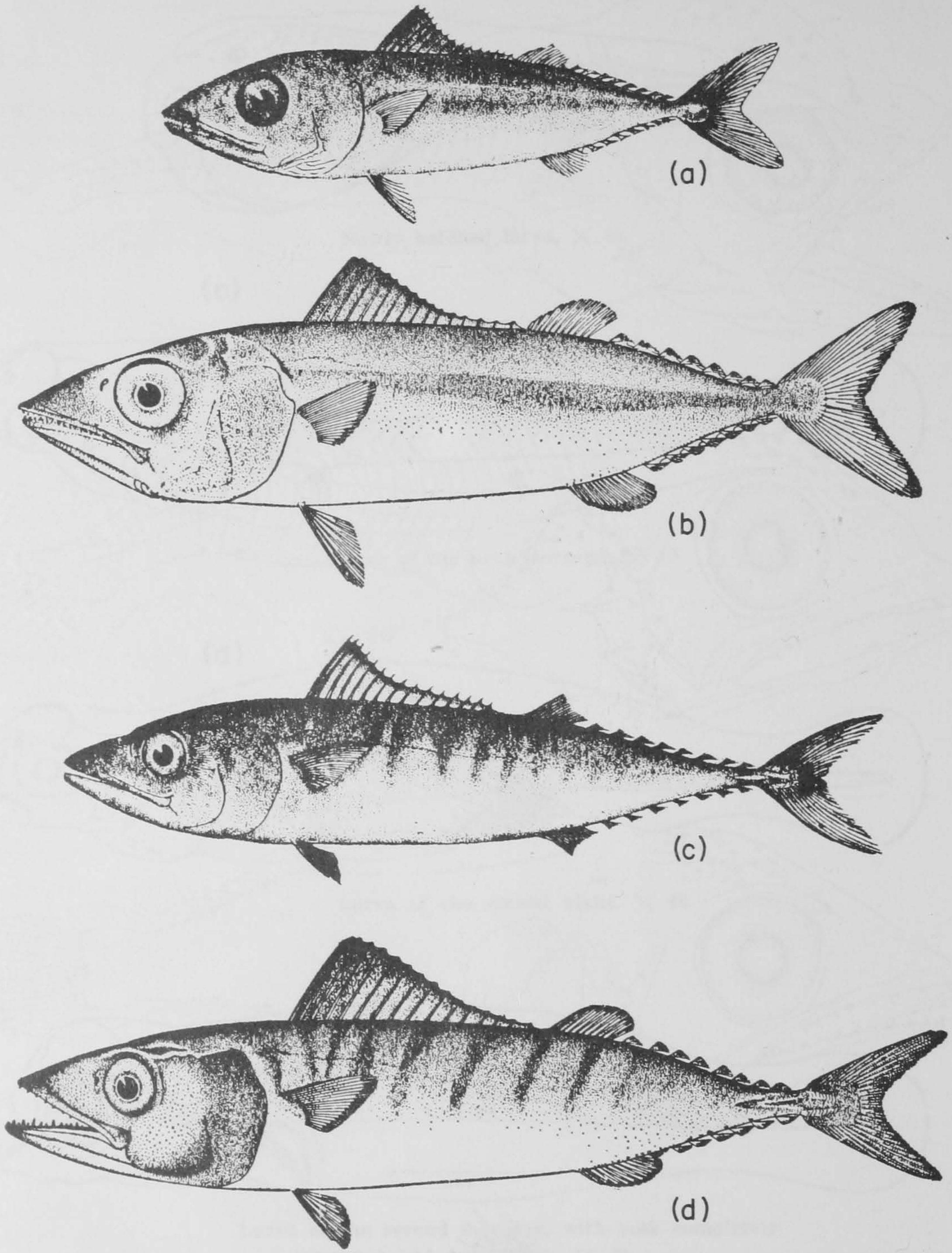
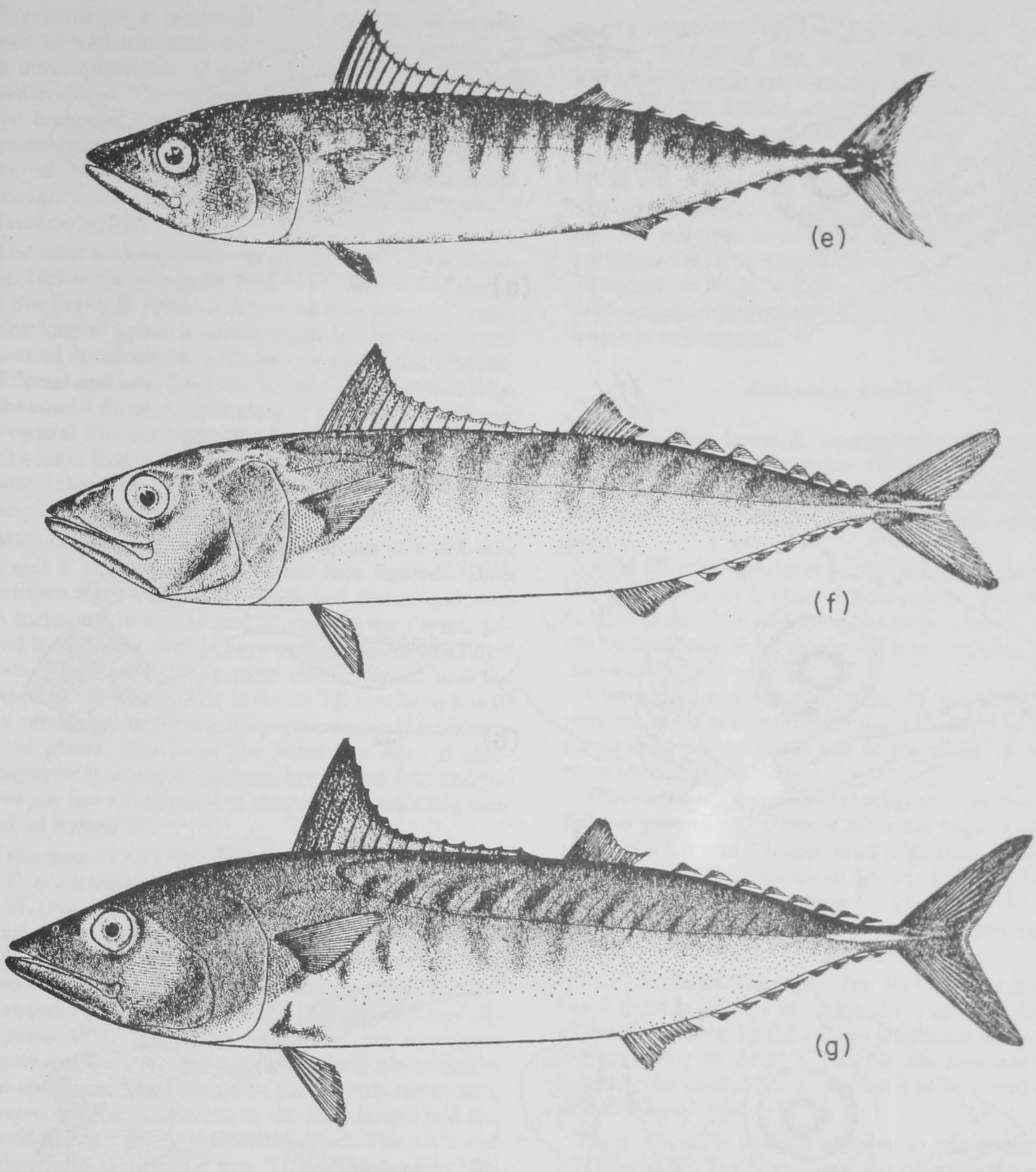


Figure 13.—Juvenile *Euthynnus affinis:* (a) 24.5 mm SL; (b) 33.5 mm FL; (c) 56.6 mm SL; (d) 67 mm FL; (e) 96.0 mm SL; (f) 110 mm FL; (g) 156 mm FL. (From Wade 1950a, figs. 10-13; Jones 1960, figs. 1-3.)

Wade (1950a) and Jones (1960) described juvenile *E. affinis* ranging in length from 24.5 mm SL (standard length) to 156 mm FL (Fig. 13). In the 24.5 mm SL specimen (Fig. 13a), all the larval characters are lost except for the vestiges of the preopercular spines (Jones 1960). The color of the body in the 24.5 mm SL and in the 33.5 mm FL (Fig. 13b) specimens is light brown dorsally and becomes paler toward the midline. A dark longitudinal band is present along the lateral midline and ventrally the body is pale.

According to Wade (1950a) the color of the body and the head darkens as the fish grows larger and about 9 to 13 darker vertical bars begin to develop above the lateral midline on specimens about 60 mm FL.

The first dorsal has 16 spines and the posterior spine nearly reaches the base of the second dorsal. There are 12



to 14 rays (mostly 13) in the second dorsal and 13 or 14 rays in the anal fin. There are 8 dorsal and 7 anal finlets.

The gill raker count on a 35 mm FL specimen was 4 + 1 + 20 and increased to (7-8) + 1 + (22-23) in specimens of 127 to 175 mm FL (Wade 1950a).

Euthynnus alletteratus

See section 3.21.

In a 4.6 mm TL specimen of *E. alletteratus* (not figured), no visible indication of spine or ray development is evident in the unpaired fins. The future fins are represented by a continuous membrane which starts near the nape and extends around the caudal end to the anal opening. There are 40 myomeres including the urostyle; the urostyle is incompletely developed and extends posteriorly in line with the longitudinal axis of the body.

Chromatophores are present at the pectoral girdle symphysis and immediately anterior to the anal opening along the midventral line. There are about 3 chromatophores over the forebrain and about 12 over the midbrain and a row of 3 or 4 well-spaced chromatophores is evident over the middle two-thirds of the length of the lower jaw (Matsumoto 1959).

A 5.5 mm TL specimen (Fig. 14a) shows the development of four short spines in the first dorsal fin. The unpaired fins are beginning to develop, and the urostyle has turned upward. Chromatophores along the margin of the

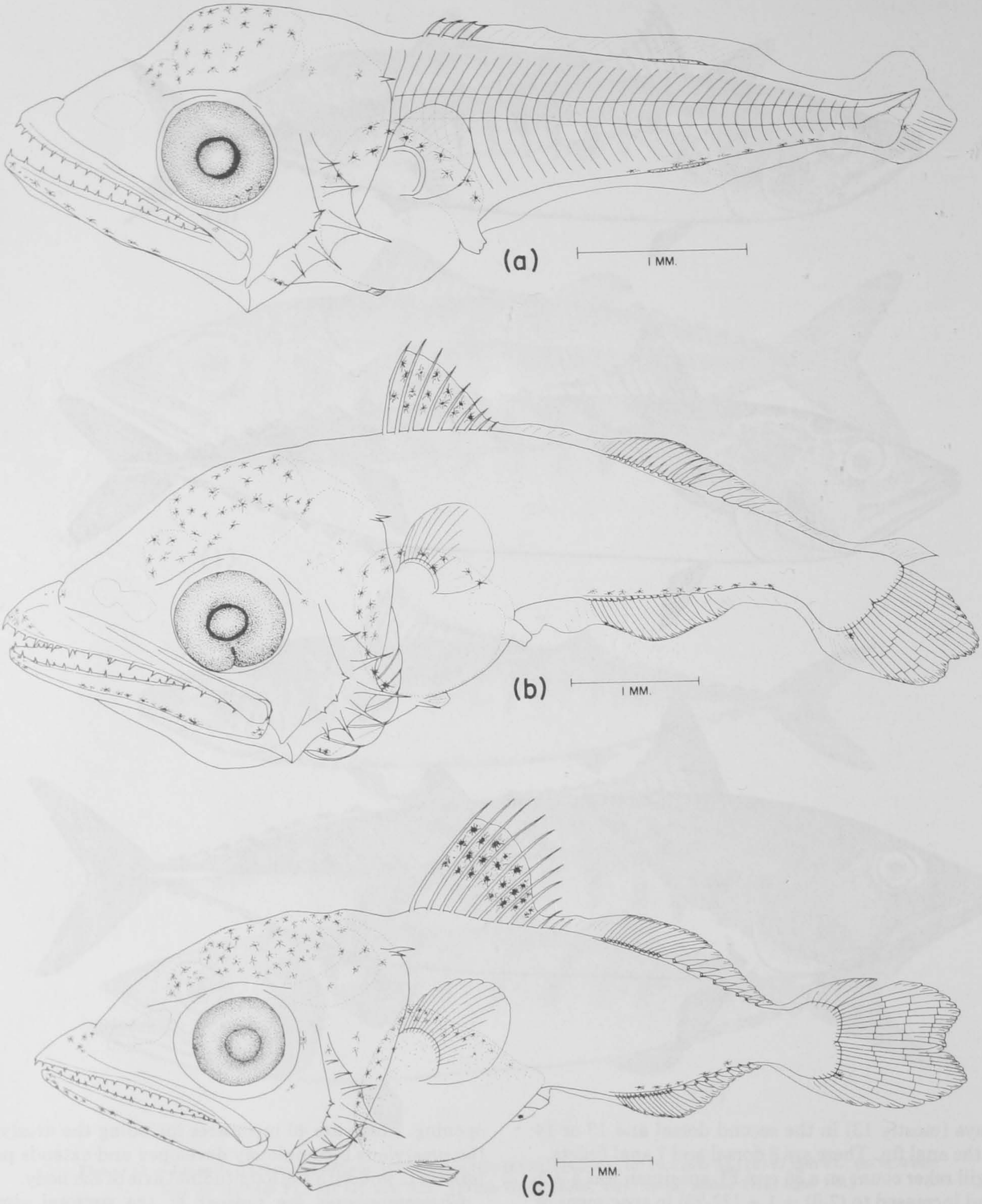


Figure 14.—*Euthynnus alletteratus* larvae: (a) 5.5 mm; (b) 7.5 mm; (c) 9.3 mm. (From Matsumoto 1959, figs. 8-10.) (See Fig. 12 for definition of body length.)

lower jaw have increased and cover the anterior two-thirds of the jaw length. Nine chromatophores are present on the midventral line from the anal fin origin to the caudal peduncle (Matsumoto 1959).

A 7.5 mm TL specimen (Fig. 14b) has 9 very long spines in the first dorsal fin. There are 12 or 13 rays in the second dorsal, 14 rays in the anal, and about 17 rays in the caudal fin.

Pigmentation is increased on the first dorsal fin and about 13 well-scattered chromatophores are present on the outer two-thirds of the fin between the first and seventh spines. The chromatophores along the lower jaw have increased and now appear closer together. The pigmentation along the midventral edge of the body consists of about 11 regularly spaced chromatophores although some specimens may have as many as 15 (Matsumoto 1959).

The most noticeable change in a 9.3 mm TL specimen (Fig. 14c) is the extremely long spines in the first dorsal fin. Similar to *E. lineatus* of comparable size, the length of the longest spine is about equal to the body depth measured at the origin of the second dorsal fin. The second dorsal and anal fins have 13 rays. The posterior edge of the caudal fin now shows signs of becoming forked and the ventral fins are beginning to enlarge. Pigmentation on the outer half of the first dorsal fin membrane has increased; there are 22 chromatophores extending over 8 interspinous membranes (Matsumoto 1959).

Matsumoto (1959) noted many changes in a 10.6 mm TL and a 11.5 mm TL specimen (not figured). Both specimens have completely developed dorsal and anal fins including 16 spines and 13 rays in the dorsal, followed by 8 finlets, and 14 rays in the anal followed by 7 finlets. The caudal fin is more clearly forked and the pelvic fins are longer. The 11.5 mm TL specimen has 20 + 19 vertebrae. An increase in pigmentation is evident in several places. The lower jaw bears two rows of chromatophores (the larger specimen has a third row) and the upper jaw has a single row of chromatophores along two-thirds of its length.

Matsumoto (1959) also described postlarval and juvenile *E. alletteratus* ranging in length from 12.0 to 58.0 mm TL (Fig. 15). The pigmentation along the dorsal and ventral edges of the body and along the midlateral line noted in the 10.6 and 11.5 mm TL specimens was also evident in the 12.0 mm TL specimen (Fig. 15a). Distinctive changes occurred between the 12.0 and 18.5 mm TL specimens (Fig. 15b). The abdominal sac was more elongate and the anus was more posteriorly placed in the larger specimen. The head parts, particularly the mouth, appeared smaller in relation to the total length and the fins and finlets were more clearly defined. The outline of the dorsal fin in the 26.0 mm TL specimen (Fig. 15c) resembles that of an adult and the body is narrower, relative to the total length than in the 18.5 mm TL specimen. For specimens larger than 26.0 mm TL the only noticeable change is in the increased pigmentation on the body. At about 40 mm TL one to three very faint spots or ventral bars appear along the dorsal third of the body. The number of bars increases to about 10 in a 58.0 mm TL specimen (Fig. 15d) and to 13 on a 94.3 mm TL fish (not figured).

Richards and Dove (1971) described in detail the internal development of young *E. alletteratus* ranging in standard length from 3.5 to 24.0 mm. Anatomical features of *E. alletteratus* were described and compared with those of *K. pelamis, Thunnus albacares, T. obesus, T. thynnus, T. alalunga, T. atlanticus,* and *Auxis* spp. The following anatomical features were examined: the sensory organs including the eyes, olfactory organs and acoustico-lateralis systems, the nervous system (brain), swim bladder, kidney, gonads, liver, pancreas, spleen, digestive system, cardiovascular system, gills, skeleton, musculature, and pigmentation. Potthoff and Richards (1970) also made observations on the development of the axial skeleton of *E. alletteratus* and also computed a regression equation to estimate the standard length of a specimen based on the length of the vertebral column. The equation is, $SL = 3.66 + 1.22\ VL$, where SL is standard length in millimeters, and VL is vertebral column length in millimeters.

Euthynnus lineatus

The smallest larval *E. lineatus* identified by Matsumoto (1959) measured 5.0 mm TL (Fig. 16a). The head is relatively large (about 37% TL) and the mouth is also large and contains about eight teeth on each side of both jaws.

As in the other species of *Euthynnus* at the same stage, the abdominal sac is short and triangular, and the anus is located near the middle of the body. Spines and rays are undeveloped in all the fins. There are 38 or 39 myomeres including the urostyle.

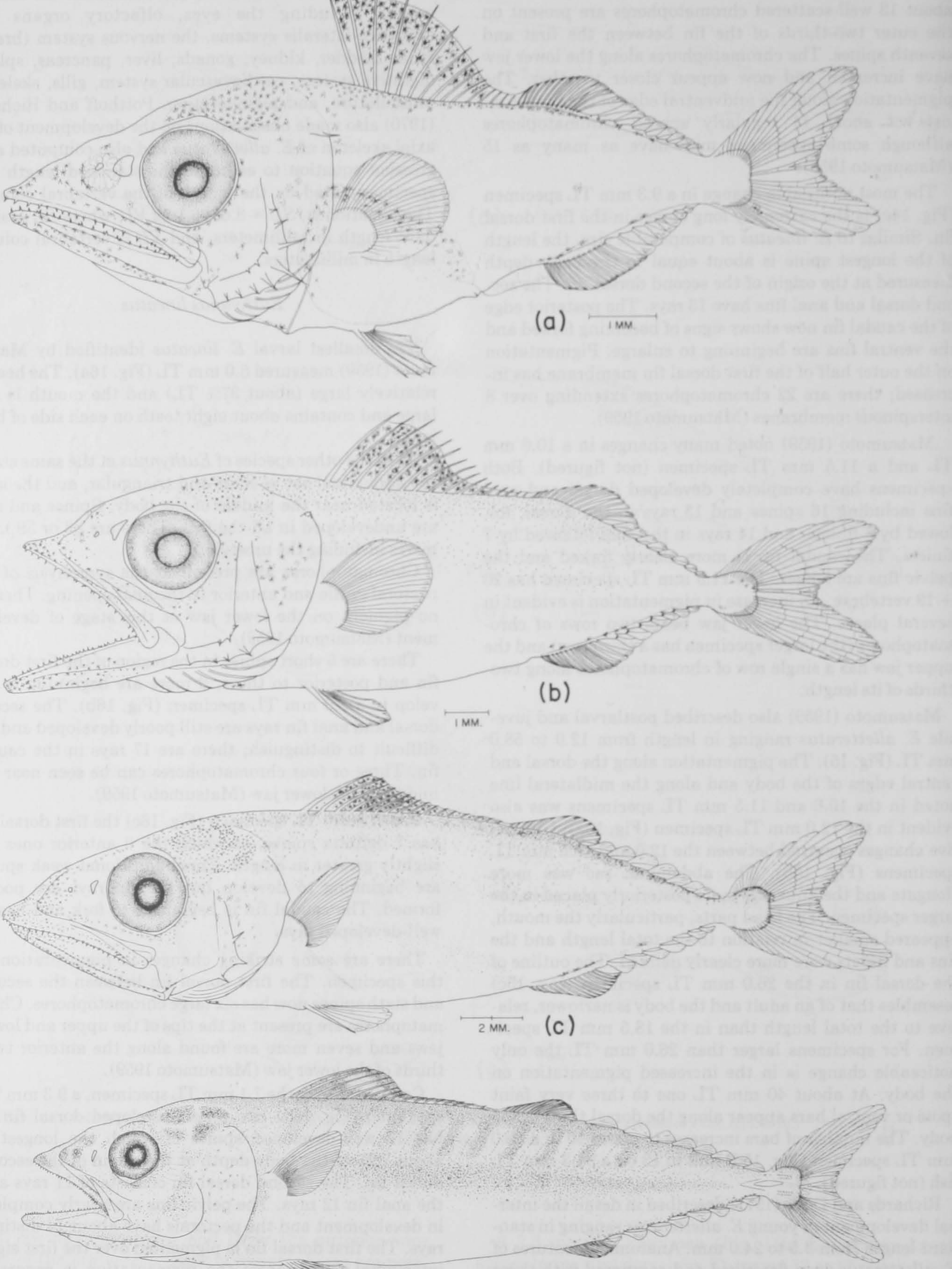
Chromatophores are present at the symphysis of the pectoral girdle and anterior to the anal opening. There is no pigment on the lower jaw at this stage of development (Matsumoto 1959).

There are 5 short spines in the region of the first dorsal fin and posterior to these, 2 more are beginning to develop in a 6.0 mm TL specimen (Fig. 16b). The second dorsal and anal fin rays are still poorly developed and are difficult to distinguish; there are 17 rays in the caudal fin. Three or four chromatophores can be seen near the middle of the lower jaw (Matsumoto 1959).

In a 7.1 mm TL specimen (Fig. 16c) the first dorsal fin has 7 definite spines, of which the 6 anterior ones are slightly greater in length. Three additional weak spines are beginning to develop but the fin rays are poorly formed. The caudal fin is beginning to fork and has 18 well-developed rays.

There are some striking changes in pigmentation in this specimen. The first dorsal fin between the second and sixth spines now has six large chromatophores. Chromatophores are present at the tips of the upper and lower jaws and seven more are found along the anterior two-thirds of the lower jaw (Matsumoto 1959).

Compared with the 7.1 mm TL specimen, a 9.3 mm TL specimen (Fig. 16d) has a well-developed dorsal fin. It has 12 well-developed spines of which the longest is about 78% of the body depth at the origin of the second dorsal fin. The second dorsal fin consists of 11 rays and the anal fin 12 rays. The pelvic fins are nearly complete in development and the pectorals have about 14 distinct rays. The first dorsal fin is pigmented over the first eight interspinal membranes; the pigmentation is generally concentrated on the outer two-thirds of the fin (Matsumoto 1959).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(c)
3 MM.
(d)

The abdominal sac is more elongate and the anal opening only slightly anterior to the anal fin origin in a 10.6 mm TL postlarval *E. lineatus* (Fig. 17a). The dorsal fin consists of 15 spines and 12 rays, and there are 8 dorsal finlets; the anal fin consists of 11 rays and there are 7 anal finlets (Matsumoto 1959).

The 18.6 mm TL juvenile (Fig. 17b) is already similar in body shape to larger juveniles due mostly to a gradual reduction in the head depth relative to body length and to the elongation of the abdominal sac, wherein the anal opening is closer to the anal fin origin.

The fins and finlets are more clearly defined in the 18.6 mm TL specimen. The dorsal fins have the full adult complement of 15 spines and 12 rays, followed by 8 finlets. The anal fin also has the full adult complement of 12 rays followed by 7 finlets. The caudal fin is well developed and more deeply forked, the pelvic fins are longer, and the pectorals have 24 completely formed rays which are comparable to the fully developed fins (24-26 rays) of the adults (Matsumoto 1959).

In the 21.0 mm TL specimen (Fig. 17c), except along the area of the lower jaw, the pigmented areas are more widespread (Matsumoto 1959).

3.3 Adult phase

3.31 Longevity

See sections 3.43 and 4.13.

The maximum size and longevity of *E. affinis* are not well defined. Kishinouye (1923) stated that *E. affinis* from Japanese waters grow to be 60 cm and 3.5 kg, and that on rare occasions, specimens over 100 cm long and 10 kg in weight are found. Ommanney (1953) reported that the largest *E. affinis* caught during a survey in the Mauritius-Seychelles area was a specimen 87 cm long, which weighed 8.6 kg (19 lb). Around the Marquesas Islands, *E. affinis* as large as 79 cm have been taken on surveys conducted by the NMFS Honolulu Laboratory. Landau (1965) estimated the age of the oldest fish from a sample collected in the Red Sea as 6 yr old. The fish was 62 cm SL and weighed a little over 5 kg (11 lb).

Fowler (1936) indicated that *E. alletteratus* from the West Indies grow to 122 cm. The largest specimen measured by Postel (1956) in the Mediterranean Sea off Tunisia was 101.5 cm, but he noted seeing many exceeding a meter in length. In the tropical eastern Atlantic, the largest specimen measured by Postel (1955a) in Senegal was 94.6 cm. Landau (1965) noted that the oldest *E. alletteratus* in her Mediterranean samples belonged to age group X and was estimated to be about 86 cm SL (defined as the distance from snout to insertion of caudal fin). The world record sport catch for *E. alletteratus* is a specimen 92.07 cm long and weighing 12.24 kg (20 lb) (International Game Fish Association undated).

Figure 15.—Postlarvae and juvenile *Euthynnus alletteratus:* (a) 12.0 mm (b) 18.5 mm; (c) 26.0 mm; (d) 58.0 mm. (From Matsumoto 1959, figs. 11-14.) (See Fig. 12 for definition of body length.)

There is no information on the longevity of *E. lineatus*.

3.32 Hardiness

Not much is known on the hardiness of the three species of *Euthynnus*. In establishing tunas in tanks and ponds for experimental purposes, Tester (1952a) noted that small *E. affinis* 0.4 to 1.4 kg (1-3 lb) became established in these enclosures more readily than yellowfin tuna, *T. albacares*. Once a school of *E. affinis* became established, newly introduced fish started to feed during the second day of confinement. In the experimental tanks maintained by NMFS in Honolulu, *E. affinis* have survived for more than 14 mo (Magnuson 1965). Stevens and Fry (1971) took body temperatures of *E. affinis* that had been in captivity for 2 yr. Calkins and Klawe (1963) stated that the hardiness of *E. lineatus* is similar to that of other tunalike fishes and that "They are hardy enough to be successful in their natural environment, but they can only stand a minimum of handling."

3.33 Competitors

The competitors of *E. affinis* in east African waters include skipjack tuna, small yellowfin tuna, *Auxis thazard*, and a carangid, *Megalaspis cordyla* (Williams 1963). These fishes school together with *E. affinis* off east Africa in the Indian Ocean. In waters around Sri Lanka, *E. affinis* are found in schools together with *A. thazard*, and presumably these two species are direct competitors for food (Williams 1963).

Marchal (1963) stated the *E. alletteratus* competes with species with which it is found such as *A. thazard* and *S. sarda*. He also suggests the dolphins (*Delphinus*) and other cetaceans, *Grampus* and *Globicephala*, as probable competitors.

In the eastern tropical Pacific, *E. lineatus* is found in close association with yellowfin tuna, skipjack tuna, and dolphin fish (*Coryphaena*) that undoubtedly compete with it for food (Calkins and Klawe 1963).

3.34 Predators

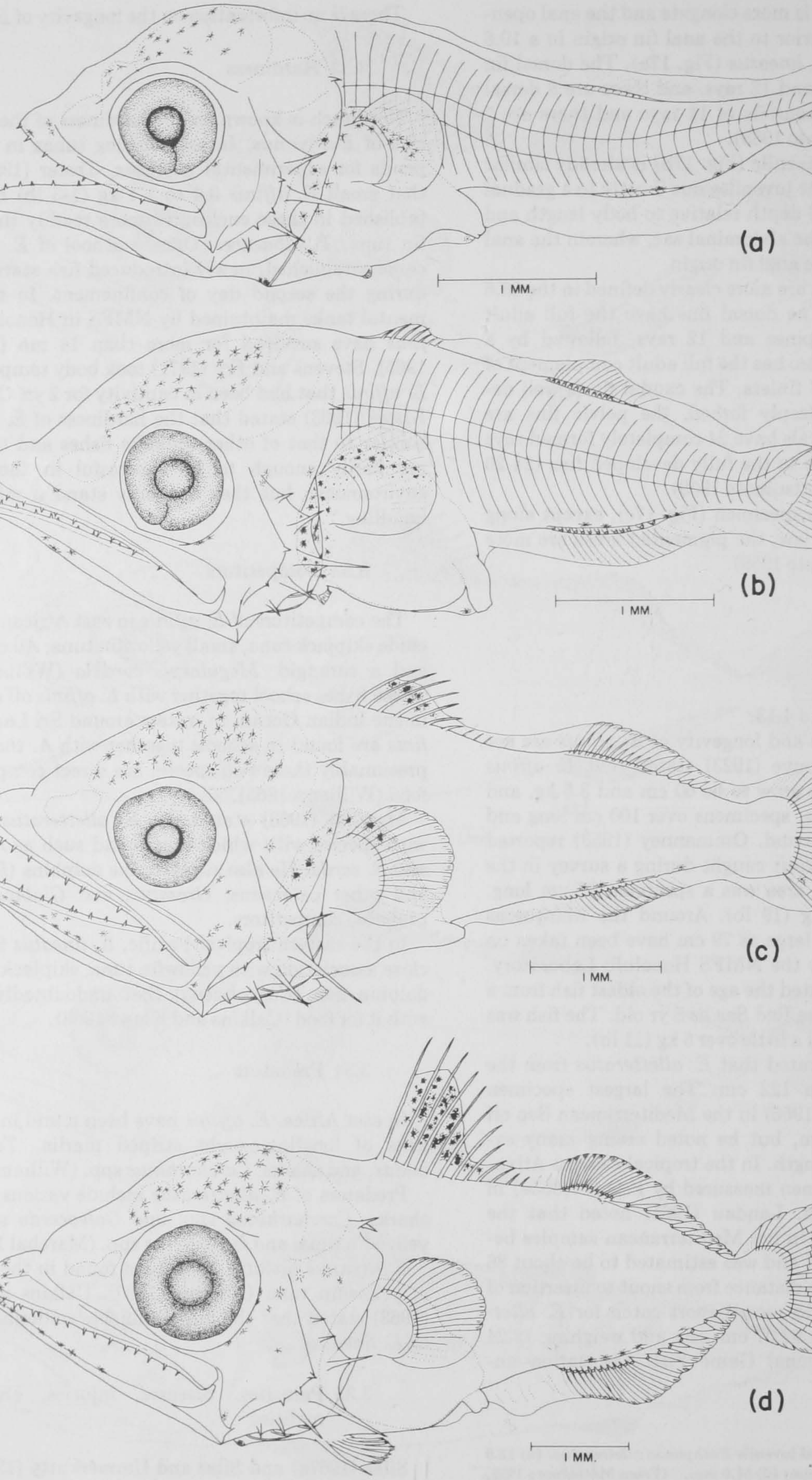
In east Africa, *E. affinis* have been found in the stomachs of longline-caught striped marlin, *Tetrapturus audax*, and sharks, *Carcharhinus* spp. (Williams 1963).

Predators of *E. alletteratus* include various species of sharks, *Carcharhinus* spp. and *Galeocerdo* spp., large yellowfin tuna, and *Istiophorus* spp. (Marchal 1963).

Euthynnus lineatus have been found in the stomachs of yellowfin tuna (Alverson 1963). Calkins and Klawe (1963) stated that the large billfishes undoubtedly prey on *E. lineatus*.

3.35 Parasites, diseases, injuries, and abnormalities

Silas (1967a) and Silas and Ummerkutty (1967) made detailed surveys on parasitism in *Euthynnus* and other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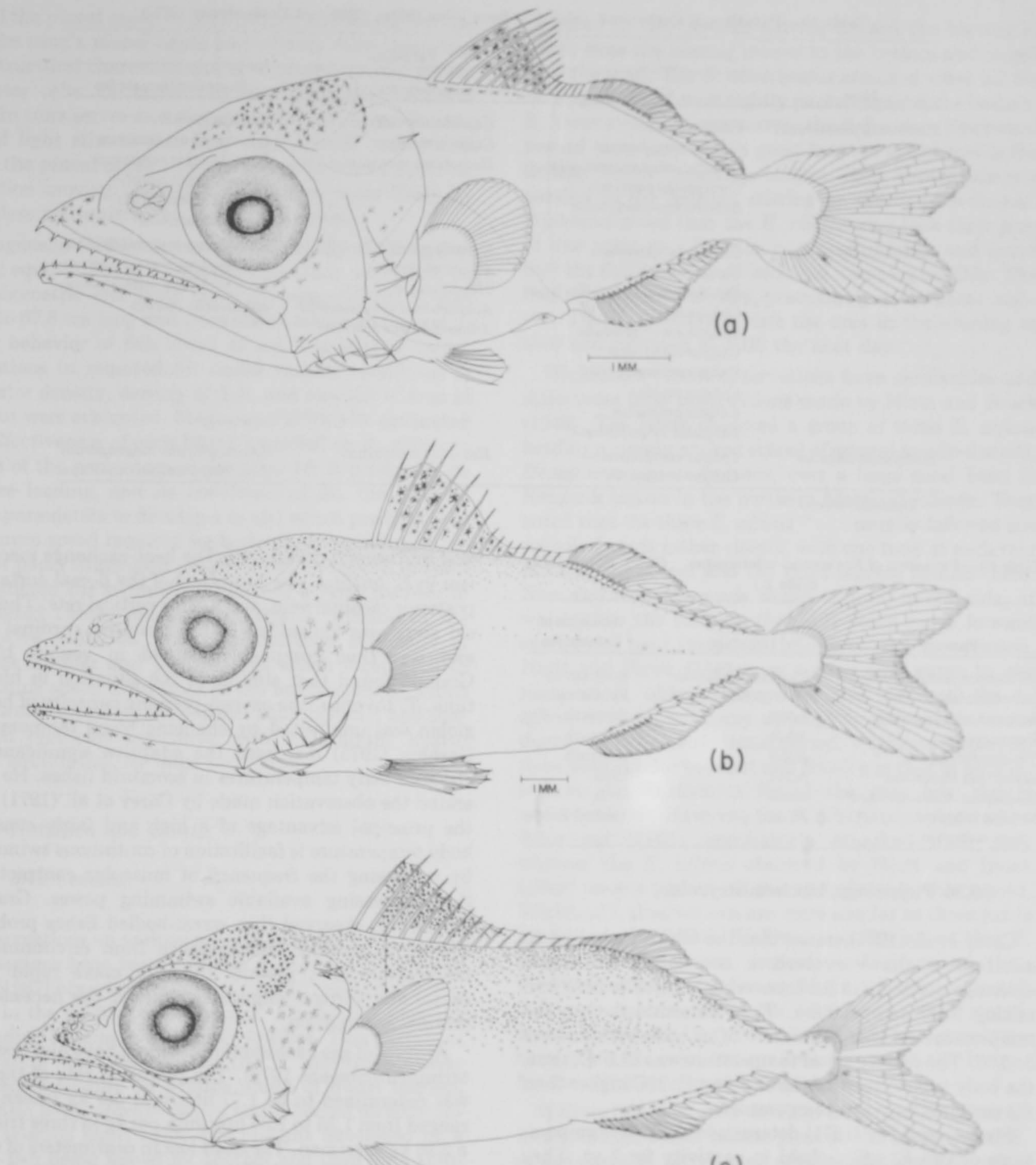

Figure 17.—Postlarval and juvenile *Euthynnus lineatus*: (a) 10.6 mm; (b) 18.6 mm; (c) 21.0 mm. (From Matsumoto 1959, figs. 5-7.) (See Fig. 12 for definition of body length.)

scombrids. They found that the three species of *Euthynnus* were parasitized by various copepods, digenetic trematodes, and monogenetic trematodes (Table 15).

Figure 16.—*Euthynnus lineatus* larvae: (a) 5.0 mm; (b) 6.0 mm; (c) 7.1 mm; (d) 9.3 mm. (From Matsumoto 1959, figs. 1-4.) (See Fig. 12 for definition of body length.)

Calkins and Klawe (1963) also found that *E. lineatus* was parasitized by a trematode *Hirudinella marina*, which was found in the stomach. Postel (1964) also listed the parasites of *E. alletteratus* (Table 16). Thomas (1967) described a new parasitic copepod, *Caligus krishnai*, from the gills of *E. affinis*.

Table 15.—Parasites of *Euthynnus*. (Modified from Silas 1967a; Silas and Ummerkutty 1967.)

Host	Parasites		
	Copepods	Monogenetic trematodes	Digenetic trematodes
Euthynnus alletteratus	*Caligus bonito* *Caligus coryphaenae* *Pseudocycnus appendiculatus* *Ceratocolax euthynni* *Bomolochus anonymous*	*Capsala maccallumi* *Capsala manteri* *Hexostoma macracanthum*	*Dinurus scombri* *Lecithochirum texanum* *Rhipidocotyle capitatum* *Rhipidocotyle nagatyi* *Sterrhurus monticelli* *Tergestia laticollis*
Euthynnus affinis	*Caligus coryphaenae* *Caligus regalis* *Pseudocycnus appendiculatus* *Caligus bonito* *Caligus amblygenitalis* *Caligus euthynnus* *Caligus asymmetricus* *Caligus savala* *Caligus productus* *Caligulus longispinosus*	*Capsala gouri* [1]*Pricea minimae* [1]*Hexostoma euthynni* *Allopseudaxine katsuwonis* *Allopseudaxine macrova*	*Rhipidocotyle septapapillata* [1]*Lecithochirum magnaporum* [1]*Lecithochirum microstomum* *Hirudinella marina*
Euthynnus lineatus	*Caligus coryphaenae* *Caligus macarovi*	*Hexostoma euthynni*	[1]*Lecithochirum magnaporum* [1]*Lecithochirum microstomum*

[1]Doubtful record.

Table 16.—Parasites of *Euthynnus alletteratus*. (From Postel 1954, table 2.)

Parasite	Life stage	Location of infestation
Callitetrarhynchus gracilis	Plerocercoid larvae	Body cavity
Otobothriidae	Plerocercoid larvae	Pyloric caeca
Radinorhynchus pristis	Adult	Stomach
Sterrhurus sp.	Adult	Stomach
Hirudinella clavata	Adult	Stomach
Hexostoma thunninae	Adult	Gills
Hexostoma macrocanthum	Adult	Gills
Nerocila orbignyi form *maculata*	Adult	Ventral finlets

3.36 Physiology, biochemistry, etc.

Carey et al. (1971) stated that the tunas, including *E. alletteratus*, have evolved a countercurrent heat-exchange mechanism for conserving metabolic heat and raising body temperature. They determined that the temperature of one specimen of *E. alletteratus* was 31.2°C. The surface water temperature was 19.9°C; thus, the body temperature of the fish was 11.3°C higher than the surrounding water temperature.

Stevens and Fry (1971) determined the body temperatures of two *E. affinis* held in captivity for 2 yr. They found that captivity reduced the excess temperature (defined as the body temperature minus ambient water temperature) of *E. affinis*. Graham (1973) determined the thermal profile of *E. lineatus*, which uses a centrally located vascular heat-exchange mechanism similar to that of *E. alletteratus* to maintain core body temperatures warmer than ambient temperature of seawater. He also described the structure of the central heat-exchange mechanism and the effect of temperature changes in blood-gas relationships in *E. lineatus*. Graham found that a warm central core in *E. lineatus* was related to the distribution of red muscle. The warmest body temperatures occurred along the vertebral column between the first and second dorsal fins. The heat-exchange mechanism in *E. lineatus* was composed of the dorsal aorta, the posterior cardinal vein, and a large vertical rete. The dorsal aorta was embedded in the posterior cardinal vein and was thus completely bathed in venous blood. Graham found that similar to the situation in bluefin tuna, *T. thynnus*, the oxygen-carrying capacity of hemoglobin was unaffected by changing blood temperature. Graham (1975) discussed the adaptive significance of elevated body temperatures in scombrid fishes. He reiterated the observation made by Carey et al. (1971) that the principal advantage of a high and fairly constant body temperature is facilitation of continuous swimming by increasing the frequency of muscular contractions, thus increasing available swimming power. Graham (1975) also observed that warm-bodied fishes probably achieve a marked independence from environmental temperature that permits them to make rapid horizontal and vertical migrations without the necessity of thermal acclimation.

Aspects of gas exchange in *E. affinis* have also been determined (Stevens 1972). The perfusion rate of the gills was determined to be 1.77 liter/min per kg (mean) and ranged from 1.55 to 1.88 liter/min per kg in three trials on a 2.26 kg specimen. The head loss in centimeters of water averaged 1.8. The calculated resistance to water flow offered by the gills averaged 1.03 cm of water/min per kg per liter and ranged from 0.90 to 1.20. Oxygen uptake was determined to be 503 mg/h per kg (mean) and ranged from 400 to 643. The calculated utilization (fraction of oxygen removed from the water) averaged 0.79 and ranged from 0.69 to 0.95.

Rivas (1953) determined that scombrid fishes, including *Euthynnus*, possessed a pineal apparatus. He gave a description of the pineal apparatus and hypothesized that it might function as a light receptor to control phototactic movements of the fish. Support for Rivas' hypothesis was provided by Murphy (1971) who investigated the pineal organ in bluefin tuna and found that the bluefin tuna's pineal organ had sensory cells possessing the structural characteristics of vertebrate retinal photoreceptor cells. He concluded that the pineal organ in bluefin tuna serves as a photoreceptor which receives external light stimuli and that such stimuli may travel from the pineal organ to a site of action via an apocrine secretion moving through capillaries or more likely by impulses transmitted by the pineal nerve.

Magnuson (1970) made a detailed study of the hydrostatic equilibrium of *E. affinis*. This study was based on morphometric and body density measurements of fish 31.6 to 67.8 cm long and from observations on the swimming behavior of fish about 42 cm long held in tanks. Variations in required lift under various conditions of seawater density, density of fish, and amount of food in the gut were evaluated. Magnuson (1970) also estimated the effectiveness of each lifting hydrofoil on *E. affinis* in terms of the percentage of the total lift it produced, its surface loading, and its coefficient of lift. He used all these parameters to develop a model which predicted the minimum speed required for hydrostatic equilibrium. In a later paper Magnuson (1973) tested this model to see if it predicted the swimming speeds of a large number of scombroid fishes, including *E. affinis;* considered the "adaptive radiation in the morphology especially of the gas bladder and pectoral fins which together with swimming speed contribute to the mechanism by which scombroids maintain hydrostatic equilibrium"; and considered problems associated with maintaining hydrostatic equilibrium by large body size.

3.4 Nutrition and growth

3.41 Feeding

Observations on various aspects of feeding and related observations have been made on *Euthynnus*. Bullis and Juhl (1967) observed what they called "phalanx orientation" in the feeding behavior of *E. alletteratus* near the Grenadine Islands in the Lesser Antilles. This pattern of orientation was observed as the *E. alletteratus* were apparently feeding on a large group of dwarf herring, *Jenkinsia lamprotaenia,* which had collected directly under a floating night light. The phalanx developed by a single fish being joined by another and then by a third fish. This phalanx took the form of a tightly packed three-fish aggregation evenly aligned side by side. The phalanx attacked the ball of dwarf herring without altering formation. The observers noted that the attack on the dwarf herring did not start until the phalanx had been formed. During the course of feeding, additional *E. alletteratus* were seen to join the phalanx until it was estimated that the phalanx contained 14 or 15 fish of about the same size.

Wicklund (1968) reported on daylight feeding patterns of *E. alletteratus* in Florida waters. He observed a school of 20 and a group of 4 fish feeding on bigeye scad, *Selar crumenophthalmus,* and herring, *Clupea* sp. Wicklund observed *E. alletteratus* moving toward the herring at which time the herring moved to the bottom and mixed with the scad. The *E. alletteratus* attacked when all the herring and scad were tightly packed against the bottom. In their attacking maneuver, the fish swam downward toward their prey with a great burst of speed and in the instant before reaching bottom they turned sharply parallel to the bottom, stirring up clouds of sediment. Wicklund noted that the *E. alletteratus* took their prey at this point or a fraction of a second later, and noted that the fish's jaws could be heard snapping audibly. The feeding continued all day, presumably in the same manner. The *E. alletteratus* left the area in the evening at 1800 and returned at 1030 the next day.

Wicklund's (1968) observations have similarities and differences from observations made by Hiatt and Brock (1948). The latter observed a group of three *E. affinis* herding a closely packed school of several hundred scads, *Decapterus sanctaehelenae,* over a large coral head in Rongerik lagoon in the northern Marshall Islands. They noted that the three *E. affinis* " . . . usually followed the school of scads rather closely, with one tuna at each rear flank of the school and the third lagging behind them. Now and then the scads would turn off to one side, at which time the tuna on that side could move forward swiftly and herd them back into line." On one occasion, Hiatt and Brock (1948) saw a stray scad eaten by the rearmost *E. affinis*. Except for this incident, the *E. affinis* did not make any attempt to prey on the scads during the 3-h observational period. Wicklund's observations were similar to Hiatt and Brock's in that in both instances the *Euthynnus* forced the prey into tightly packed schools. However, the *E. alletteratus* observed by Wicklund (1968) aggressively attacked their prey whereas the *E. affinis* observed by Hiatt and Brock (1948) merely picked off the stragglers. In this regard, Wicklund's observations are more similar to those made by Kishinouye (1923). Kishinouye (1923) noted that *E. affinis* were voracious feeders, and described their feeding method as darting swiftly into a school of small fish and scattering them. As Kishinouye (1923) stated, however, the feeding habits of *E. affinis* may vary throughout the year. Presumably, this could also be true for the other species of *Euthynnus*.

Walters (1966) studied the filter feeding of *E. affinis* by means of high-speed motion pictures. He showed that *E. affinis* traveled an average of 5.9 body lengths/s while feeding and observed a maximum speed of 10.0 body lengths/s. He found no change in speed and no increase in swimming effort as the fish opened its mouth and distended the orobranchial chamber to engulf its prey. Walters (1966) observed that the feeding mechanism is drag free and that *E. affinis* feeds by swimming over its prey rather than by sucking it into its mouth. He also pointed out that *E. affinis,* and scombrid fishes in general, are facultative filter-feeders in that they are able to feed in open water upon swimming organisms that are minute in comparison to the size of the predator, and noted the high gill-raker counts in these species to support his statement.

Magnuson and Heitz (1971) determined that the mean gill-raker gap for *E. affinis* was 1.4 mm and the filtering area of the first gill arch was 650 mm². They noted that in terms of gill-raker gap, *E. affinis* was intermediate (ranked fifth, going from small to large) compared with *Katsuwonus pelamis, Auxis rochei, A. thazard, Scomber japonicus, Thunnus albacares, T. alalunga, T. obesus, Sarda chiliensis, S. orientalis, Coryphaena equiselis,* and *C. hippurus,* ranked from small to large, respectively. Magnuson and Heitz (1971) related the gill-raker apparatus to food selectivity among these fishes and noted that despite the varied diet of scombrid fishes, selectivity in terms of size does exist in the scombrids. They observed that within a species, larger fish fed on relatively fewer crustaceans and more fishes.

3.42 Food

Observations on the diet of *Euthynnus* from various localities suggest that these fishes feed primarily on whatever is available at any particular place and time. As an example Ronquillo (1953) found that *E. affinis* fed about equally on crustaceans (56.2% by number) and fishes (43.8% by number) in Philippine waters. Ronquillo (1953) found no squids in the stomachs. Around Hawaii Tester and Nakamura (1957) also found that squids were negligible in the diet of *E. affinis,* but unlike the Philippine area, fishes were much more important (91.8% by volume) than crustaceans (8.2% by volume). In the Indian Ocean, Kumaran (1964) found that squids (56.5% by volume) were most important, followed by fishes (38.3% by volume), and crustaceans (5.2% by volume) were the least important.

For *E. alletteratus* in the Mediterranean Sea, Oren et al. (1959) found that crustaceans (63% by number) were most important followed by fishes (22% by number) and squids (11% by number). Heteropods and tunicates made up 4% by number of the diet.

Small fish; squid; *Auxis thazard;* a pelagic crab, *Pleuroncodes planipes;* and sierra mackerel, *Scomberomorus sierra,* have been found in the stomachs of *E. lineatus* (Calkins and Klawe 1963).

Table 17 presents examples of food items found in stomachs of *Euthynnus* from various areas. It can be seen in Table 17 that Postel (1954) listed *E. alletteratus,* presumably a juvenile, from the stomach of an adult *E. alletteratus.*

Table 17.—Food of *Euthynnus* spp.

Food items	Number of food organisms	Percentage prevalence	Percentage by volume
Food of *Euthynnus affinis.* (From Kumaran 1964, table 1.)			
Crustacea:		(20.4)	(5.2)
Isopods	7	2.8	—
Amphipods	9	2.8	—
Copepods	9	3.4	0.1
Penaeus sp.	3	1.4	0.1
Phyllosoma larvae	6	2.7	0.1
Megalopa larvae	8	2.0	0.1
Squilla sp.	2	0.7	—
Alima larvae	82	5.5	3.4
Unidentified crustaceans	17	5.5	1.1
Gastropoda:			
Pteropods	5	1.4	—
Cephalopoda:		(12.3)	(56.5)
Sepioteuthis sp.	25	10.9	55.7
Loligo sp.	2	1.4	0.8
Vertebrata (Pisces):		(87.1)	(38.3)
Sardinella spp.	10	5.5	0.7
Stolephorus commersonii	15	6.8	1.0
Anchoviella tri	56	23.7	3.4
Other clupeids	6	3.4	0.5
Saurida sp.	4	2.0	0.4
Leptocephalus	3	1.4	0.1
Hemiramphus sp.	1	0.7	—
Holocentrus sp.	3	1.4	0.6
Sphyraena sp.	5	2.7	—
Sillago sihama	7	4.1	0.4
Lactarius lactarius	1	0.7	0.1
Carangids	18	5.5	13.8
Leiognathus spp.	141	32.5	6.8
Sciaena sp.	1	0.7	—
Euthynnus affinis	1	0.7	—
Triacanthus sp.	1	0.7	0.2
Unidentified fish including larvae	36	14.9	9.5

Food of *Euthynnus alletteratus.* (From Postel 1954, table 1.)

Fish:	
Sardinella aurita	*Smaris* sp.
Sardinella sp.	*Ammodytes* sp.
Engraulis sp.	*Galeiodes polydactylus*
Aulopus sp.	*Scomber japonicus*
Saurida parri	*Auxis* sp.
Myctophum sp.	*Euthynnus alletteratus*
Fodiator acutus	*Caranx Rhoncus*
Cypselurus sp.	*Decapterus pundtatus*
Hemiramphidae	*Vomer Setipinnis*
Sphyraena sp.	*Pagellus* sp.
Box boops	*Sargus* sp.
Molluscs:	
Shelled (?) molluscs	
Sepia sp.	
Loligo sp.	
Allotenthis africana	
Crustacea:	
Planktonic crustacea	
Euphausiaceae	
Sergestidae	
Parapeneus longirostris	
Bryozoans	
Madreporaires	
Green algae	

3.43 Growth rate

Euthynnus affinis

The available information on the age and growth of *E. affinis* is sketchy and fragmentary. No data are available on the growth of the larvae. On the juveniles, Kishinouye (1923) suggested that a 115 mm specimen caught off Port Keelung in August may have been about 3 mo old. Wade (1950a) speculated that a 115 mm long specimen from the Celebes Sea was 3 or 4 mo old, and that a 175 mm specimen may have been spawned as long as 6 mo before its capture. These observations suggest a growth rate of 1.0 to 1.3 mm/day.

Yabe et al. (1953) presented length data of preadult *E. affinis* landed at the port of Aburatsu, Japan, during

August-October 1950 (Table 18; Fig. 18). Yabe et al. indicated that *E. affinis* between 150 and 250 mm were in their first year of life. Figure 18 suggests an average growth rate of 1.5 mm/day. This growth rate is not very different from that suggested for *E. affinis* juveniles in the Philippines.

Ommanney (1953) observed the age-size relationship of *E. affinis* caught near the Seychelles. Although the basis for determining the age-size relationship is not made clear, he suggested that postlarval to 25 cm fish were in their first year of life, 25 to 45 cm fish in their second year, 45 to 65 cm fish in their third year, and 65 cm and larger fish in their fourth year and over.

Table 18.—Average size of *Euthynnus affinis* landed at Aburatsu, Japan. (From Yabe et al. 1953, table 5.)

Month		No. of fish measured	Fork length (mm) Range	Mean
Aug.	26	107	183-240	200
	30	51	201-225	213
	31	98	203-239	217
Sept.	1	53	194-240	214
	2	19	199-268	218
	4	92	209-245	225
	5	78	204-290	224
	6	91	200-309	221
	7	79	203-307	235
	8	132	196-325	234
	9	149	200-271	222
	20	115	213-274	236
	25	13	223-255	236
Oct.	6	5	230-295	241
	11	9	252-278	262
	13	24	254-286	265
	16	138	244-313	270
	17	111	220-332	272

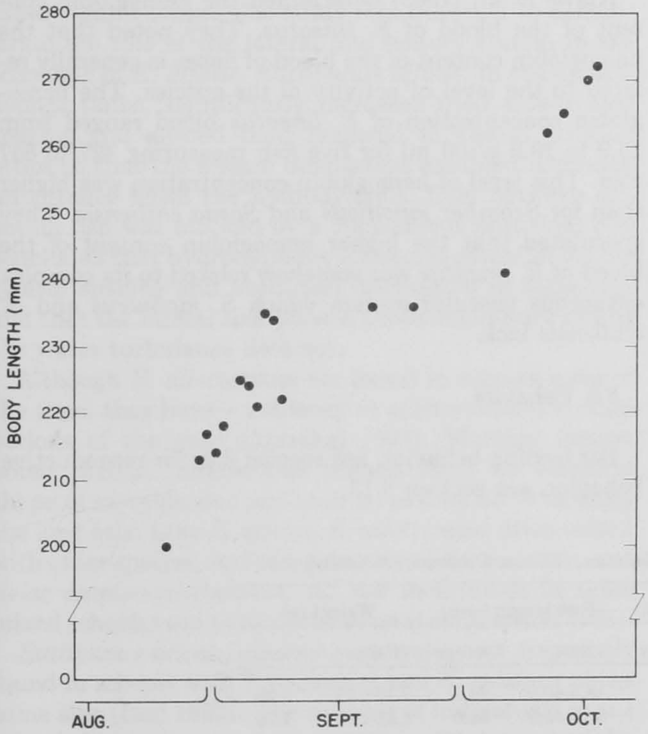

Figure 18.—Growth of preadult *Euthynnus affinis* off the southern coast of Japan. (Data from Yabe et al. 1953.)

Landau (1965) determined the ages of *E. affinis* from the southern Red Sea based on the annular marks on the vertebral centra. The age-size relationships are given in Table 19. Landau, using the graphical method, estimated that the L_∞ for *E. affinis* in the Red Sea was 580 mm SL.

Table 19.—Age-size relationships of *Euthynnus affinis* from the Red Sea. (From Landau 1965, tables 2, 3.)

Age	No. of fish	Length (SL)[1] in mm Range	Mean	Approximate mean weight (kg)
Southern Red Sea (April-June 1964)				
I	28	310-430	345	0.9
II	11	370-520	456	2.1
III	18	470-560	511	2.8
IV	25	520-590	544	3.3
V	10	520-600	554	3.5
Bay of Eilat, Red Sea (May 1964)				
I	78	320-340	370	1.0
II	2	505 and 525	—	3.0

[1]SL is standard length defined by the author as the distance from the snout to the insertion of the caudal fin.

On the basis of annular marks on the first dorsal spine of *E. affinis,* Shabotinets (1968) determined the age-size relationship of fish taken in the Gulf of Aden as shown below.

Age	*Size (cm)*
3	50-65
4	55-75
5	65-80
6	86

Euthynnus alletteratus

Houde and Richards (1969) observed the growth of larval *E. alletteratus* under laboratory conditions. They collected fertilized eggs in the western edge of the Gulf Stream near Miami, Fla., and incubated and hatched the eggs in 20- and 140-gal (75.5- and 530-liter) aquaria. The growth in length of the larvae in one of their rearing experiments is shown in Figure 19. As can be seen the larval fish grew from approximately 2.5 mm to a little less than 8.5 mm in 18 days. Houde and Richards noted that the growth of the larvae was probably not as fast as in the natural environment.

Based on modal groups in length-frequency distributions Postel (1955b) presented the following age-length relationships for *E. alletteratus* off Dakar in the eastern Atlantic:

Less than 1 yr (Group 0)	<30 cm
1 to 2 yr (Group 1)	30-45 cm
2 to 3 yr (Group 2)	45-60 cm
3 to 4 yr (Group 3)	60-75 cm
Over 4 yr	>75 cm

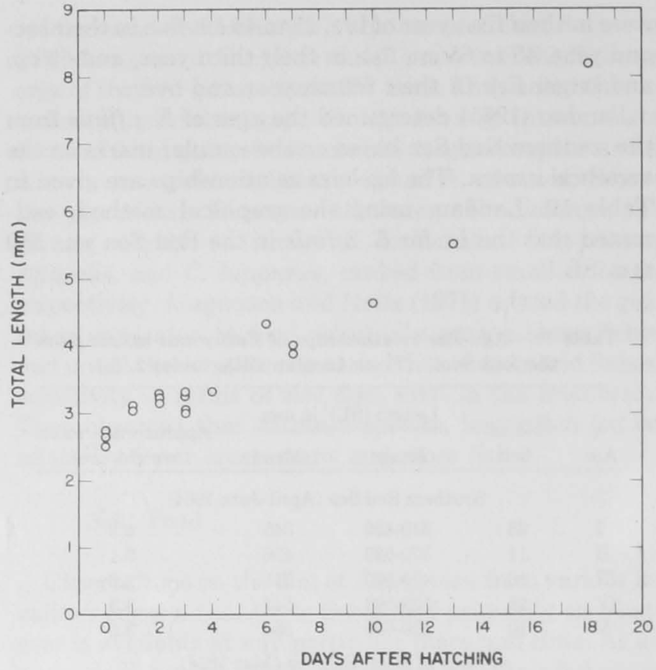

Figure 19.—Growth in length of *Euthynnus alletteratus* larvae oreared in the laboratory. (From Houde and Richards 1969, fig. 3.)

Landau (1965) determined the ages of *E. alletteratus* in the Mediterranean Sea by reading marks on the vertebral centra. Lengths of fish at various ages were back-calculated by relating the radius of annular marks on the vertebrae to the length by the regression:

$$LS = 45.85V + 72.62$$

where *LS* is standard length defined as distance from snout to insertion of caudal fin, and *V* is vertebral radius. The age-size relations determined by Landau are given in Table 20. Landau also estimated L_∞ for *E. alletteratus* as 840 mm, using the graphical method on size obtained by back-calculations.

Euthynnus lineatus

Except for some observations on the growth of juvenile *E. lineatus* there is nothing in the literature on the growth of this species. Clemens (1956) was able to rear juvenile *E. lineatus* for up to 10 days in shipboard aquaria. From the beginning of the holding experiment to the end 10 days later, the average weight of the juveniles increased 11 times and the average length increased approximately 1.4 times (Table 21).

Table 20.—Age-length and age-weight relationships for *Euthynnus alletteratus* in the Mediterranean Sea. (From Landau 1965, table 1.)

Age	Length (SL)[1] in mm Range	Mean	Approximate mean weight (kg)
I	28-49	358.4	0.8
II	46-68	539.1	2.8
III	54-75	637.2	4.5
IV	61-79	701.9	6.0
V	65-84	755.0	7.5
VI	74-86	801.5	8.5
VII	75-84	810	9.0

[1]SL is standard length defined by the author as the distance from the snout to the insertion of the caudal fin.

3.44 Metabolism

Malvin and Vander (1967) determined the plasma renin activity in *E. affinis*. They pointed out that there is general agreement that freshwater fishes contain renin in their kidneys but that this problem had not been resolved in marine fishes; furthermore, plasma renin had not been measured for marine species. Their results showed that certain characteristics in the plasma renin activity of *E. affinis* and *K. pelamis* were identical to that of the mammalian renin-angiotensin system which strongly indicated to them that the material being evaluated was angiotensin generated by the enzymatic action of renin. It was determined that the renin activity, expressed as angiotensin-equivalents, was 23.3 and 15.8 ng/ml of plasma for two specimens of *E. affinis*.

Klawe et al. (1963) determined the hemoglobin content of the blood of *E. lineatus*. They noted that the hemoglobin content of the blood of fishes is generally related to the level of activity of the species. The hemoglobin concentration of *E. lineatus* blood ranged from 16.9 to 19.9 g/100 ml for five fish measuring 427 to 657 mm. This level of hemoglobin concentration was higher than for *Scomber japonicus* and *Sarda chiliensis*. They speculated that the higher hemoglobin content of the blood of *E. lineatus* was somehow related to its complex cutaneous vascular system which *S. japonicus* and *S. chiliensis* lack.

3.5 Behavior

For feeding behavior, see section 3.4; for reproductive behavior, see section 3.13.

Table 21.—Growth of postlarval *Euthynnus lineatus*. (From Clemens 1956, table 1.)

Number of fish	Hours[1] Range	Hours Average	Standard length (mm) Range	Standard length Average	Fork length (mm) Range	Fork length Average	Weight (g) Range	Weight Average
23	0	0	17.0-37.5	26.8	18.5-40.0	28.3	0.10-0.57	0.29
3	171-175	173	48.0-52.0	49.3	51.0-55.0	52.0	1.51-1.91	1.70
3	194-200	197	54.0-55.0	54.3	58.0	58.0	1.94-2.37	2.14
4	244-248	246	59.0-71.5	63.6	63.0-75.0	67.5	2.61-4.72	3.46

[1]Hours of growth computed from time fish started feeding, 42 h after capture.

3.51 Migrations and local movements

See section 5.3.

3.52 Schooling

Aspects of the schooling behavior of *Euthynnus* relative to feeding have been discussed in section 3.41. Other observations on the schooling behavior of *Euthynnus* indicate that these species tend to school with other species. In the Indian Ocean off the east African coast, *E. affinis* were found in schools with small *T. albacares, K. pelamis, Auxis* sp., and a carangid, *Megalaspis cordyla* (Williams 1963). Williams noted, however, that all individuals in the schools were of much the same size. He also found that with small *E. affinis* "the schooling is strong and disciplined."

Elsewhere in the Indian Ocean, Williams (1963) noted that in waters around Sri Lanka, mixed schools of *Auxis* spp. and *E. affinis* are common. Sivasubramaniam (1970) stated that *K. pelamis, Auxis* spp., and young *T. albacares* occur together with *E. affinis* and that the catches are almost always mixed. Fourmanoir (1957) observed that around Madagascar, schools of *E. affinis* were almost always distinct from that of other species of tuna, except in June to the east of Nosy-Bé, where *T. albacares* were taken at the same time as *E. affinis.*

Williams (1963) noted that in east Africa, schools of *E. affinis* were composed of 100 to 1,000 or more individuals, and in Sri Lanka as many as 5,000 individuals (mixed *E. affinis* and *Auxis* spp.) may be taken in one haul of a beach seine.

Cahn (1972) investigated side-to-side spacing and positional orientation of *E. affinis* during schooling in experimental tanks. The study was designed to demonstrate the role of the lateral line sensory system in the schooling of *E. affinis. Euthynnus affinis,* in the experimental tanks, significantly increased their side-to-side spacing and altered their diagonal to abeam position ratios so that the abeam orientation assumed increased importance when the hydrodynamic field between orienting fish was blocked by a transparent partition. She concluded that hydrodynamic contact is essential for the typical spacing and positional orientation in schooling, and that the lateral line plays a prime regulatory role as the water turbulence detector.

Although *E. alletteratus* are found in schools most of the time, they have a tendency to scatter during certain periods of the year (Marchal 1963). Marchal further noted that *E. alletteratus* schools have an elliptical shape of variable size and may be as long as 30 m along the long axis. Like *E. affinis, E. alletteratus* often school with other species, including *Auxis* sp., *Sarda sarda,* and *Selar crumenophthalmus.* All the individuals in these mixed schools tend to be of the same size (Marchal 1963).

Euthynnus lineatus in Peruvian waters are frequently found in schools with *T. albacares* and *K. pelamis* of the same size (Bini 1952). The number of individuals in the school, however, was not as great as the commercially important species. Calkins and Klawe (1963) reported that commercial tuna fishermen have observed that *E. lineatus* will frequently collect around drifting or anchored tuna boats. They noted that *T. albacares* and *K. pelamis* also exhibit this type of behavior but believed this behavior pattern was more pronounced with *E. lineatus.* Hunter and Mitchell (1967) observed schools of *E. lineatus* beneath flotsam or drifting objects. However, these schools remained near the floating objects only for short periods and they did not swim as close to the objects as did other small fishes. They could not ascertain whether the schools of *E. lineatus* were truly associated with a particular object.

3.53 Responses to stimuli

Tester (1959) summarized the various experiments on the response of *E. affinis* and other tunas to stimuli (Hsiao 1952; Miyake 1952; Tester 1952a, 1952b; Van Weel 1952; Tester et al. 1954; Hsiao and Tester 1955; Tester et al. 1955; Miyake and Steiger 1957). It was found that *E. affinis* were attracted to continuous white light over a range of moderate intensity (about 70 to 450 fc). *Euthynnus affinis* were not attracted to a light of weaker intensity, and were repelled by a light of stronger intensity (Hsiao 1952). In experiments testing the reaction of *E. affinis* to moving objects of various colors, it was found that white lures were slightly more attractive than red, black, or silver (Hsiao and Tester 1955). Hsiao and Tester (1955) noted, however, that this may have been associated with greater visibility than color preference. Experiments on the chemoreception of *E. affinis* indicated that this species had a well-developed sense of smell or taste in that they were strongly attracted to clear colorless extracts of tuna flesh. It was further found that the attractant was contained in the protein rather than the fat fraction of the clear extract (Van Weel 1952; Tester et al. 1955). It was also determined that *E. affinis* became conditioned to the smell of juices exuded from the food which presumably contained common or similar substances which stimulated the feeding response (Tester et al. 1954).

Nakamura (1968) determined the visual acuity of *E. affinis.* Visual acuity was defined as the ability to see clearly the fine details of objects, especially as the objects become smaller and closer together. To determine the visual acuity, *E. affinis* were trained to discriminate between vertically and horizontally striped images that were projected on an opal glass plate in an experimental tank. The visual acuity of two *E. affinis,* 36.4 cm (0.9 kg) and 43.4 cm (1.6 kg), were determined at various levels of luminance (Fig. 20). Nakamura (1968) also conducted these experiments on *K. pelamis* and noted that at lower luminances the visual acuity of the two species were similar. At higher luminances, however, *K. pelamis* had a greater visual acuity than *E. affinis.*

Experiments have also been conducted to describe the hearing thresholds and frequencies audible to *E. affinis* (Iversen 1969). Based on experiments with two specimens, Iversen determined a threshold curve for acoustic sound pressure for *E. affinis* which showed that the fish perceived sounds from 100 to 1,100 Hz (Fig. 21). The

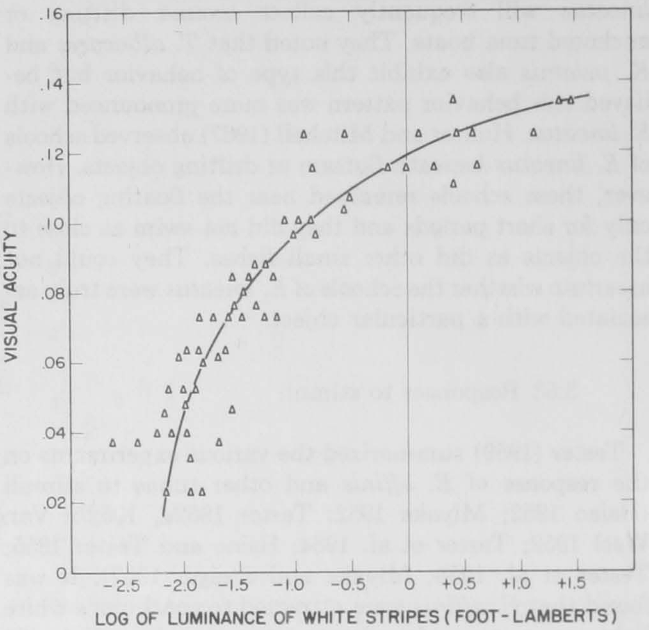

Figure 20.—Visual acuity curve of *Euthynnus affinis* at adaptive illumination of 170 luxes. Curve fitted by eye. (From Nakamura 1968, fig. 3.) (Although not explicitly stated, it is believed that visual acuity is plotted against $\log_e$ of luminance.)

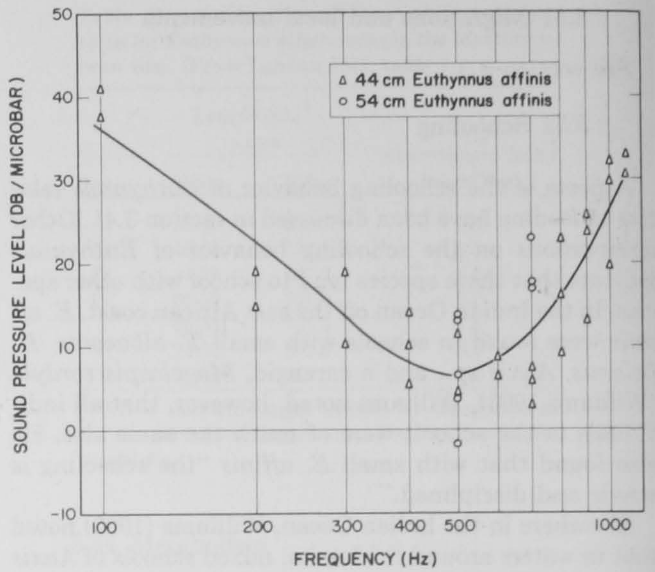

Figure 21.—Acoustic sound pressure thresholds of two *Euthynnus affinis*. (From Iversen 1969, fig. 1.)

lowest mean threshold was 7 dB/mbar at 500 Hz. At 100 Hz the threshold was 30 dB/mbar higher than at 500 Hz, and at 1,100 Hz it was 23 dB/mbar higher. The mean thresholds for *E. affinis* were consistently higher than those for *T. albacares* (Iversen 1967). Iversen (1969) noted that this difference could have resulted in part from the lack of a gas bladder in *E. affinis.*

Steffel et al. (1976) conducted experiments on captive *E. affinis* to determine their ability to discriminate temperature gradients. Tests on two fish yielded a discrimination threshold of 0.10° to 0.15°C. Their experiments indicated that the thermal sensitivity of *E. affinis* is no more acute than that of inshore fishes and appeared inadequate for direct sensing of weak horizontal temperature gradients at sea.

Walters (1966) determined the swimming speed of *E. affinis* by high-speed motion pictures. He observed that *E. affinis* traveled an average of 5.9 body lengths/s while feeding and a maximum of 10.0 body lengths/s. The nonfeeding swimming speed, with food present, averaged 4.5 body lengths/s and ranged from 2.9 to 12.5 body lengths/s.

Magnuson (1969) investigated the swimming activity of captive *E. affinis* as related to their search for food in outdoor tanks. He determined that the average swimming speed of *E. affinis,* averaging about 35 cm long, was 80 cm/s during the day and 83 cm/s at night in tanks containing no food. These fish had been in captivity for less than a month. Swimming speed measurements made after the fish had been in captivity for 5 to 6 and 8 mo showed that the speed was lower than that of fish held less than a month, but no marked difference was observed between the mean speed during the day (74 cm/s) and the mean speed during the night (72 cm/s). Magnuson (1969) also measured the swimming speed of *E. affinis* in tanks containing several thousand live prey fish. They appeared to swim faster than those without food, averaging 108 cm/s during the day and 92 cm/s at night. He noted that the higher day speeds were caused from intermittent high-speed pursuit of the prey. *Euthynnus affinis* did not prey on the baitfish at night.

Magnuson (1969) found that swimming speed was highest after a meal and decreased when the fish were deprived of food. He argued that if the level of swimming activity is regulated by search for food, swimming speed should be higher when motivation to feed is increased by deprivation of food. Because swimming speed decreased during deprivation, he concluded that swimming activity must be regulated in response to some biological need other than food search. He further concluded that swimming activity appeared to be more closely related to the requirements for maintaining hydrostatic equilibrium and gill ventilation, than for food search.

Inoue et al. (1970) also made observations on the swimming speed of *E. affinis.* They found that *E. affinis* swam at a speed of 0.30-1.27 m/s during the day and 0.33-0.75 m/s under artificial lights in their experimental tanks 4 m in diameter and 0.6 m deep.

Nakamura and Magnuson (1965) gave a detailed description of the coloration of living *E. affinis.* In addition to the permanent coloration, *E. affinis* exhibited three transient color patterns or markings that were related to feeding. These patterns or markings were black spots ventral to the pectoral fins, faint vertical bars on the flanks, and a yellowish middorsal stripe. These three color patterns were observed when *E. affinis* were feeding. Nakamura and Magnuson (1965) suggested that these transient color patterns may act as "social releasers" to signal the presence of food to other members of the school.

Wickham et al. (1973) investigated the efficacy of midwater artificial structures for attracting pelagic sport fishes in the Gulf of Mexico near Panama City, Fla. With equal experimental fishing effort they obtained significantly greater catches of *E. alletteratus* around the artificial structures than in adjacent control areas. However, they noted that *E. alletteratus* were seldom observed or captured at the structures unless baitfish were present. They concluded that *E. alletteratus* apparently were not attracted by the structures per se, but rather by the presence of the baitfishes that were attracted to the structures.

4 POPULATION

4.1 Structure

4.11 Sex ratio

The sex ratios of *E. affinis* in various localities are given in Table 22. Williamson (1970) estimated the sex ratio of *E. affinis* by size near Hong Kong. He found that for fish from 38 to 49 cm the sexes appeared to be represented in equal numbers but for fish from 50 to 73 cm, 67% of the fish were males.

The sex ratio of *E. alletteratus* in various localities is given in Table 23.

No information is available on the sex ratio of *E. lineatus*.

Table 22.—Sex ratio of *Euthynnus affinis*.

Locality	Sample size	Number (percent) Males	Number (percent) Females	Source
East Africa (western Indian Ocean)	11	6(54.5)	5(45.4)	Morrow (1954)
East Africa (western Indian Ocean)	37	22(59.4)	15(40.5)	Williams (1964)
Hawaii	93	45(48.4)	48(51.6)	Tester and Nakamura (1957)
Philippines	456	243(53.3)	213(46.7)	Wade (1950b)

Table 23.—Sex ratio of *Euthynnus alletteratus*.

Locality	Sample size	Number (percent) Males	Number (percent) Females	Source
Between North Carolina and northern Florida	227	121(53.3)	106(46.7)	de Sylva and Rathjen (1961)
Miami, Fla.	550	261(47.5)	289(52.5)	de Sylva and Rathjen (1961)
Barbate and Tarifa, Spain	378	198(52.4)	180(47.6)	Rodríguez-Roda (1966)
Senegal	866	432(49.9)	434(50.1)	Postel (1955b)

4.12 Age composition

See section 4.13.

4.13 Size composition

Euthynnus affinis

The length-frequency distribution of *E. affinis* caught by trolling and drift nets in the southwest region of the Sri Lanka fishery is shown in Figure 22. The *E. affinis*

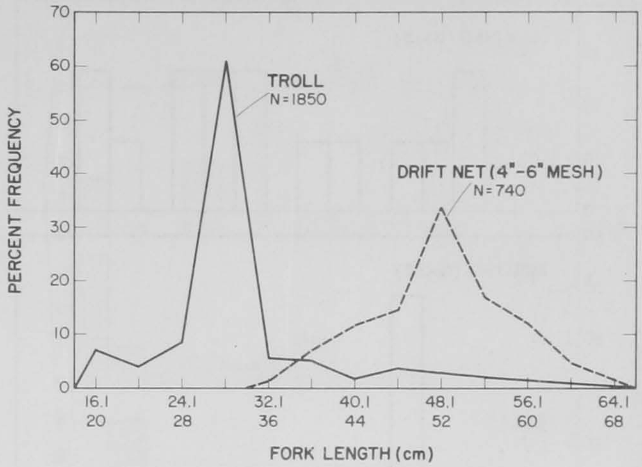

Figure 22.—Length frequencies of *Euthynnus affinis* caught by drift nets and troll lines in the southwest regions of Sri Lanka. (From Sivasubramaniam 1970, fig. 3.)

taken by the commercial fishery ranges from 20 to 65 cm. Occasionally fish in the 15 to 20 cm and 65 to 68 cm groups are also taken (Sivasubramaniam 1970). Sivasubramaniam discussed the size selectivity of the various gear used in the Sri Lanka fishery. He noted that the trolling gear sampled a wide range of sizes of *E. affinis*. However, he also stated that trolling gear selected a larger proportion of smaller sizes of fish in the stock. Although drift nets are highly selective, the use of a wider range of mesh sizes from 10.2 to 15.2 cm (4-6 in) in Sri Lanka made these nets less selective. He indicated that the use of 10.2 to 15.2 cm mesh nets resulted in the capture of a fairly wide size range of *E. affinis*. Since the pole-and-line fishing method is directed primarily at *K. pelamis* which range from 40 to 55 cm, this fishing method tends to select *E. affinis* of the same size range which are found together with *K. pelamis*. Finally, Sivasubramaniam (1970) pointed out that the selectivity of longline gear relative to the size and behavior of *E. affinis* eliminated this species from longline catches. It appears that in general all the various life stages of *E. affinis* occupy the same habitat, and the size of fish taken is primarily dictated by the gear used. This probably holds true for the other two species of *Euthynnus* which are also coastal fishes.

The length-frequency distribution of *E. affinis* caught by trolling along the southeast coast of India is shown in Figure 23. The *E. affinis* caught during July 1960 in this area ranged from about 42 to 68 cm. No modes were discernible in the length distribution. The August 1961 sample showed a mode at around 46 cm and the September 1961 sample at around 52 cm. As noted earlier, other fishing gear in addition to trolling gear are used to catch *E. affinis* along the southeast coast of India. Presumably, the length-frequency distribution of *E. affinis* caught by other gear would differ from that of fish caught by trolling.

The length range of *E. affinis* caught along the southwest coast of India is given by Bennet (1964) (Table 24). The gear used in this fishery includes drift nets and hook and line (presumably trolling gear). Shore seines are oc-

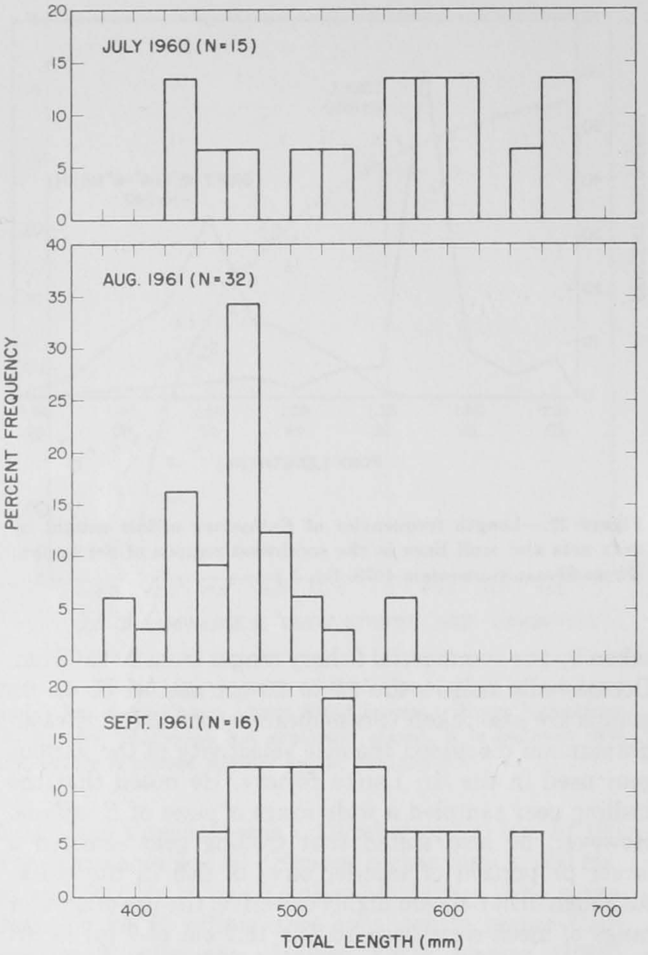

Figure 23.—Length frequencies of *Euthynnus affinis* caught by trolling off the southeast coast of India. (From Silas 1967b, fig. 15.)

Table 24.—Size composition of *Euthynnus affinis* from the southwest coast of India. (From Bennet 1965, table 3.)

Month	Minimum length (cm)	Maximum length (cm)	Month	Minimum length (cm)	Maximum length (cm)
1960			1961		
July	45.0	60.5	January	30.5	62.8
August	43.5	64.0	February	31.7	58.5
September	43.0	60.0	March	24.3	62.3
October	15.0	62.3	April	30.1	70.1
November	24.7	55.0	May	42.5	67.3
December	26.3	62.7	June	42.5	63.7
			July	48.2	66.1
			August	41.6	67.3
			September	42.2	61.0
			October	20.3	59.0

casionally used. The fish caught during the sampling period measured from 15 to 70 cm. Bennet (1964) noted that the smallest fish were taken in October 1960 by shore seine. He further stated that the smaller sizes are not represented in the commercial catches. The size range and the modal groups of *E. affinis* caught in various other localities in the Indian Ocean as summarized by Williams (1963) are shown in Table 25.

Length-frequency data on *E. affinis* caught in Japanese waters are scanty. Yabe et al. (1953) presented size data on young *E. affinis* landed at Aburatsu, Kyushu, Japan, in 1950 (Fig. 24).

During a fishing and marketing experiment (see section 5), *E. affinis* measuring 23 to 73 cm were taken by a

Table 25.—Size composition of catches of *Euthynnus affinis* in various areas of the Indian Ocean. (From Williams 1963, table 3.)

Area and author	Main size groups	Overall size
Australia		
Roughley (1951)	2.2-4.1 kg 5.4-6.6 kg	Up to 76 cm and 8.2 kg
East Africa		
Morrow (1954)	—	51-71 cm at 1.9-5.2 kg
Williams (1964)	1.0-2.2 kg 3.6-5.4 kg	40-78 cm at 1.0-7.3 kg
Madagascar		
Fourmanoir (1955)	—	Up to 80 cm
Seychelles		
Ommanney (1953)	45-65 cm Over 65 cm	43-87 cm at 1.0-8.6 kg
Somalia		
Ogilvie et al. (1954)	50 cm at 3-4 kg	Up to 79 cm and 6 kg

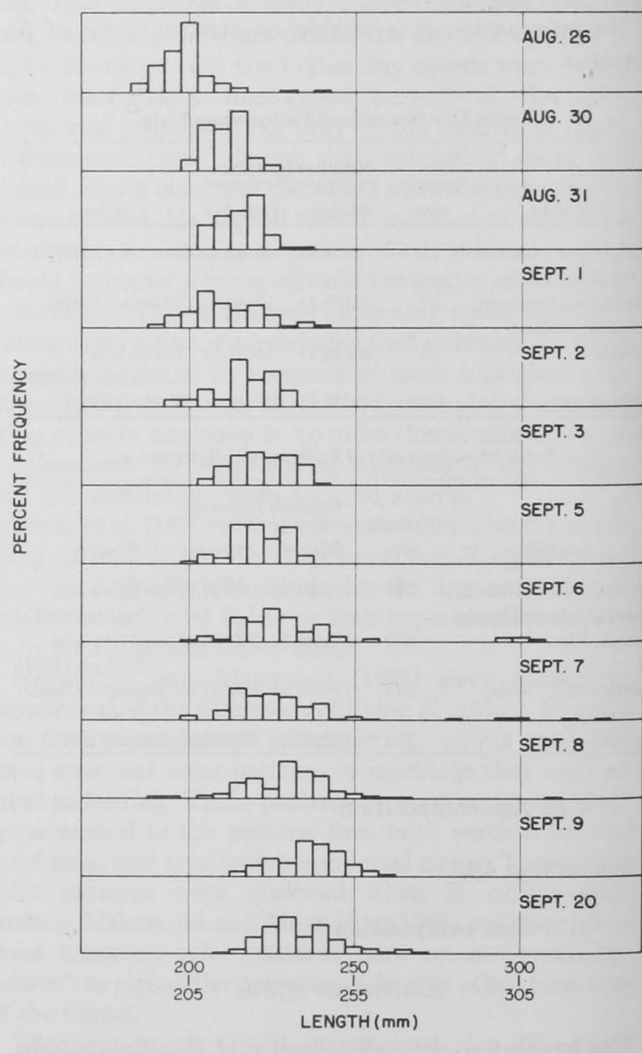

Figure 24.—Length frequencies of *Euthynnus affinis* landed at Aburatsu, Kyushu, Japan, in 1950. (From Yabe et al. 1953, fig. 1.)

modified purse seiner off Hong Kong. Two size groups were represented in the landings. The dominant group included fish from 50 to 73 cm long (2.5-7.0 kg) and the other less numerous group was composed of fish 38 to 44 cm long (1.2-2.5 kg) (Williamson 1970).

In the Philippines, the size of *E. affinis* taken by trolling by research vessels is shown in Figure 25. The fish ranged from about 30 to 80 cm and the length-frequency distribution showed a prominent mode at about 50 cm. Other commercial fishing methods capture much smaller *E. affinis.* Wade (1950a) reported finding *E. affinis* as

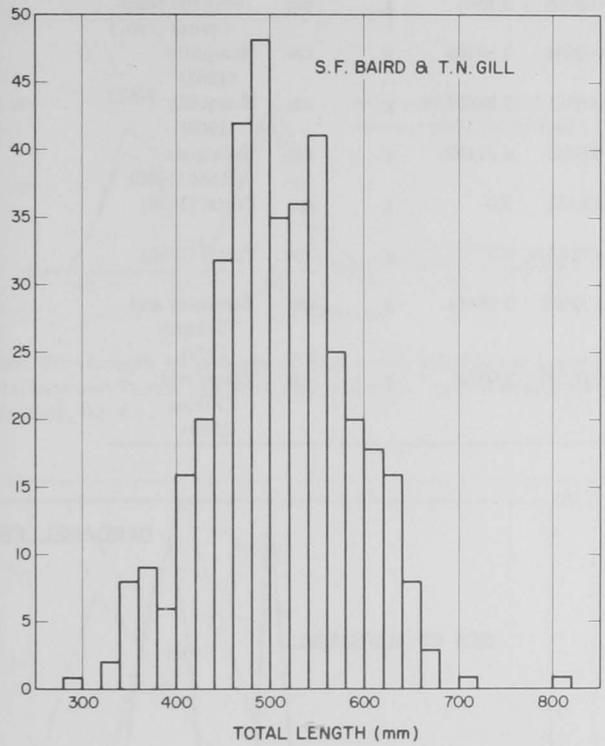

Figure 25.—Length frequency of *Euthynnus affinis* taken by trolling in Philippine waters, 1947-49. (From Ronquillo 1963, fig. 16.)

small as 40 mm in the fish markets in the Philippines. The length-frequency distribution of *E. affinis* taken in recent purse seine surveys near the Philippines (Rosenberg and Simpson[6]) is given below.

Length (cm)	*Number*	*Percent*
30	1	0.3
35	79	25.2
40	228	72.6
45	6	1.9
50	—	—

Elsewhere in the Pacific, size distribution of *E. affinis* taken by trolling around Hawaii and the Marquesas is shown in Figures 26 and 27, respectively. Length-weight relationships have been determined for *E. affinis* from various locations in the Indo-Pacific (Table 26).

[6]Rosenberg, K. J., and A. C. Simpson. 1975. Pelagic fisheries development - trip reports chartered purse seine vessels. Regional. 9 February 1975 to 26 March 1975, voyage 3, 28 p. South China Sea Fisheries Development and Coordinating Programme.

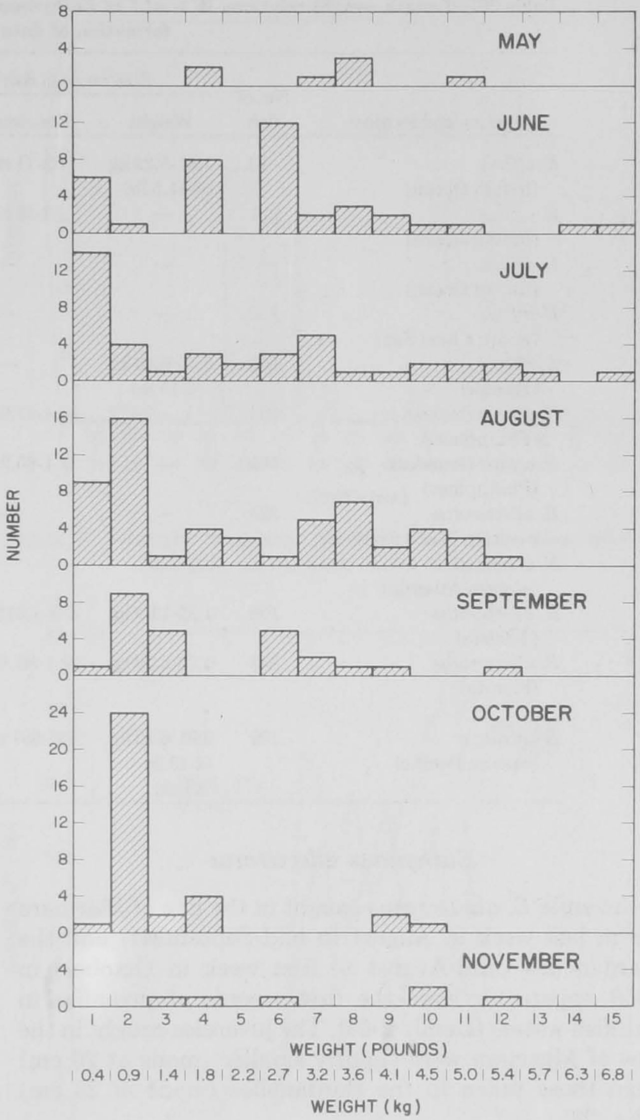

Figure 26.—Weight composition of *Euthynnus affinis* captured off Kaneohe, Oahu, Hawaii, by months, 1951-55. (From Tester and Nakamura 1957, fig. 6.)

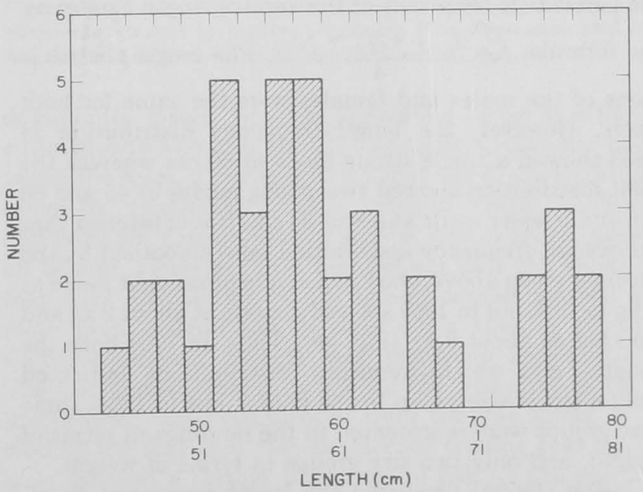

Figure 27.—Length frequency of *Euthynnus affinis* taken by trolling around the Marquesas Islands. (Data from files of Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96812.)

Table 26.—Length-weight relations $W = aL^b$ of *Euthynnus*. Predictive equations were fit throught logarithmic transformation of data (see Ricker 1973).

Species and locality	No. of fish	Size range of fish: Weight	Size range of fish: Fork length	a	b	Weight unit	Length unit	Source
E. affinis (Indian Ocean)	10	1.81-5.22 kg (4-11.5 lb)	52-71 cm	0.0166	2.963	g	cm	Morrow (1954)
E. affinis (Indian Ocean)	201	—	12-58 cm	0.0137	3.0249	g	cm	Sivasubramaniam (1966)
E. affinis (Indian Ocean)	—	—	—	0.0138	3.0287	g	cm	Silas (1967b)
E. affinis (South China Sea)	226	—	—	0.08853	2.5649	g	cm	Williamson (1970)
E. affinis (Hawaii)	101	0.45-6.80 kg (1-15 lb)	—	0.0108	3.1544	g	cm	Tester and Nakamura (1957)
E. affinis (males) (Philippines)	203	—	34.4-81.0 cm	0.0334	2.83768	g	cm	Ronquillo (1963)
E. affinis (females) (Philippines)	165	—	33.1-65.2 cm	0.0211	2.94854	g	cm	Ronquillo (1963)
E. alletteratus (western Mediterranean)	325	—	—	0.0222	2.914897	g	cm	Rodríguez-Roda (1966)
E. alletteratus (eastern Atlantic)	—	—	—	0.0152	3.0	g	cm	Postel (1950)
E. alletteratus (Tunisia)	100	1.35-13.9 kg	473-1,015 mm	0.0163	3.0	g	cm	Postel (1956)
E. alletteratus (Florida)	343	0.23-8.39 kg	23.1-85.8 cm	0.00496	3.26314	g	cm	Beardsley and Richards (1970)
E. lineatus (eastern Pacific)	109	0.91-6.26 kg (2-13 lb 13 oz)	365-667 mm	0.01327	3.0817	g	cm	Klawe and Calkins (1965)

Euthynnus alletteratus

Juvenile *E. alletteratus* caught in the Sea of Marmara (from last week in August to mid-September) and the Dardanelles (mid-August to first week in October) in 1959 apparently were the first records of juveniles in Turkish waters (Demir 1963). The juveniles caught in the Sea of Marmara were slightly smaller (mode at 20 cm) than those taken in the Dardanelles (mode at 23 cm) (Fig. 28).

Rodríguez-Roda (1966) presented length-frequency distributions of *E. alletteratus* landed at Barbate and Tarifa, Spain, in 1963 and 1964 (Fig. 29). He smoothed the percentage frequency of the various length classes by the formula, $f = \frac{f_{n-1} + 2f_n + f_{n+1}}{4}$. The length distributions of the males and females were the same for both years. However, the length-frequency distribution in 1963 showed a single strong mode at 60 cm whereas the 1964 distribution showed two strong modes at 45 and 60 cm and a lesser mode at about 85 cm. It is of interest that the weight-frequency distribution, also smoothed by the formula given above, showed a single prominent mode at 4 kg in 1963 but in 1964 showed a mode at about 2 kg and another at about 9 kg (Fig. 30). Thus, in 1963 both the length- and weight-frequency distributions indicated only a single size group in the fishery but in 1964, three size groups were represented in the landings in terms of length, and only two size groups in terms of weight.

Postel (1955b) presented the length-frequency distribution of *E. alletteratus* taken in the eastern Atlantic off Senegal (Fig. 31). He stated that the length group from 30 to 45 cm were 1 to 2 yr old fish and those from 60 to 75

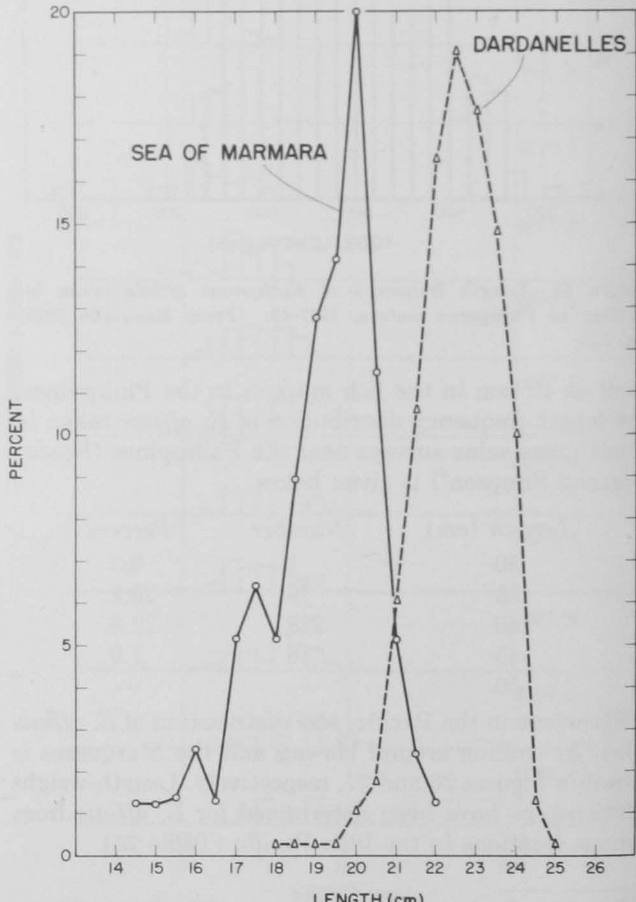

Figure 28.—Length frequencies of juvenile *Euthynnus alletteratus* from the Sea of Marmara and the Dardanelles. (From Demir 1963, fig. 2.)

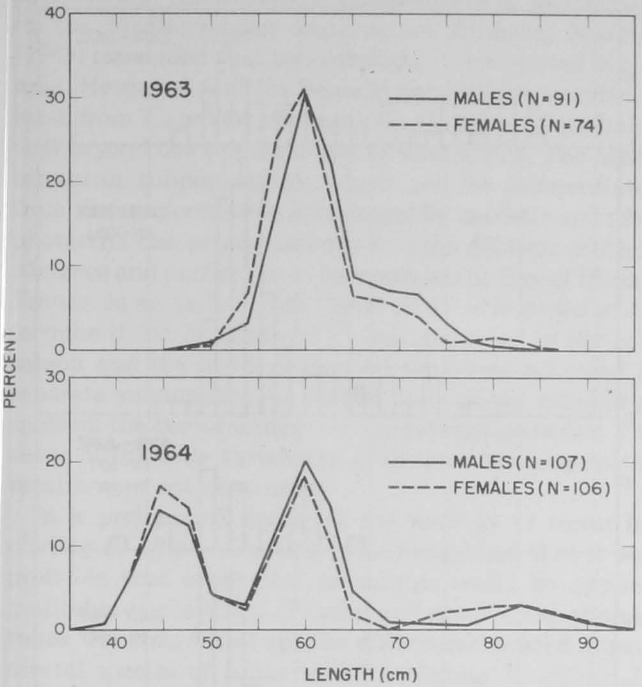

Figure 29.—Length frequencies of *Euthynnus alletteratus* landed at Barbate and Tarifa, Spain, in 1963 and 1964. (From Rodríguez-Roda 1966, fig. 6.)

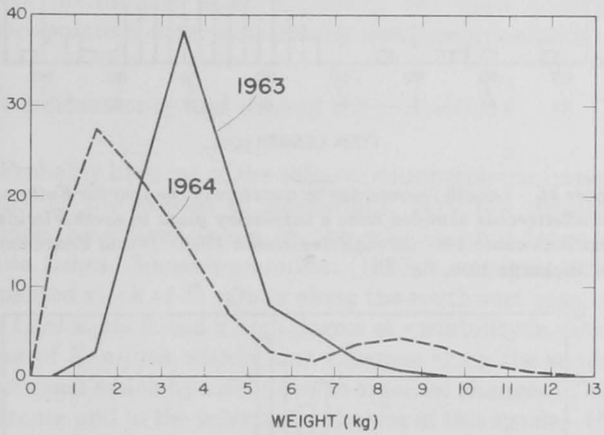

Figure 30.—Weight frequencies of *Euthynnus alletteratus* landed at Barbate and Tarifa, Spain, in 1963 and 1964. (From Rodríguez-Roda 1966, fig. 7.)

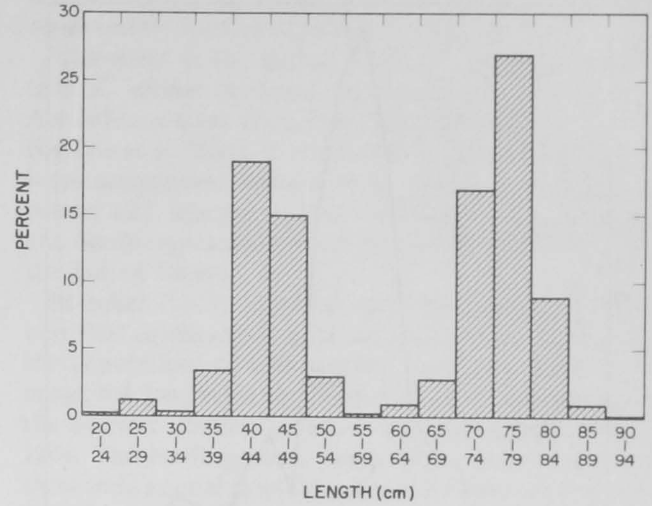

Figure 31.—Length frequency of *Euthynnus alletteratus* from Senegal. (Data from Postel 1955b.)

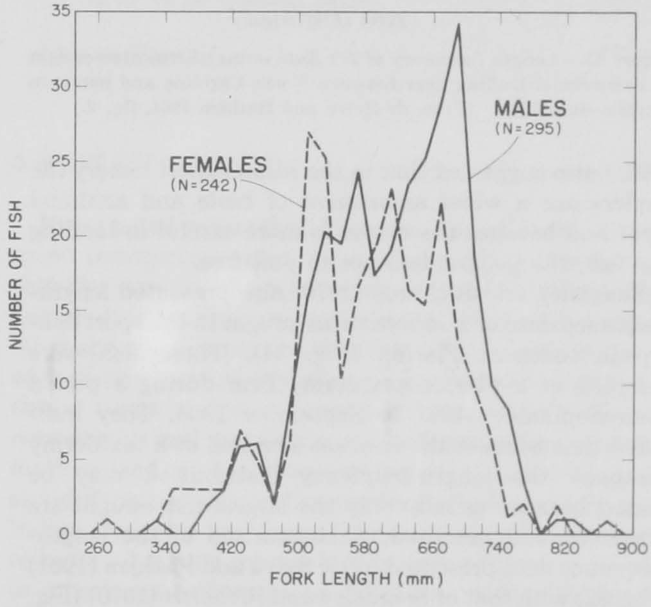

Figure 32.—Length frequencies of male and female *Euthynnus alletteratus* caught by anglers off Miami, Fla., September 1952 to August 1953. (From de Sylva and Rathjen 1961, fig. 1.)

cm were 3 to 4 yr old. He noted that fish 45 to 60 cm long (2-3 yr old) were not found in the area off Cap Vert, Senegal. However, Marchal (1963) stated that *E. alletteratus* from 50 to 70 cm were found in normal proportions off the coast of Guinea.

The length-frequency distribution of *E. alletteratus* caught by sport fishermen on charter boats off Miami, Fla., is shown in Figure 32. In Figure 33 is shown the length-frequency distribution of *E. alletteratus* taken by commercial trolling between North Carolina and northern Florida. The length range of fish generally landed by the Miami sport fishery (Fig. 32) was from about 500 to 750 mm (de Sylva and Rathjen 1961). de Sylva and Rathjen noted that only a very few large or very small fish were taken and that fish larger than 620 mm were predominantly males, possibly suggesting either a differential growth rate or mortality beginning at that size between the sexes. They also found that the *E. alletteratus* taken by commercial trolling between North Carolina and northern Florida were of similar size as those taken off Miami. However, they pointed out that the length-frequency distribution of the Miami sample showed a more even distribution of sizes while that of North Carolina-northern Florida was markedly leptokurtic. They suggested several causes for the disparity in the length-frequency distributions from the two areas, including the fact that the commercial trolling gear possibly selected a certain size range of fish by the use of only a certain range of hook sizes, as also suggested by Carlson (1952). Carlson indicated that the selectivity was possibly due to the loss of smaller fish caused by the hooks pulling free more easily. de Sylva and Rathjen

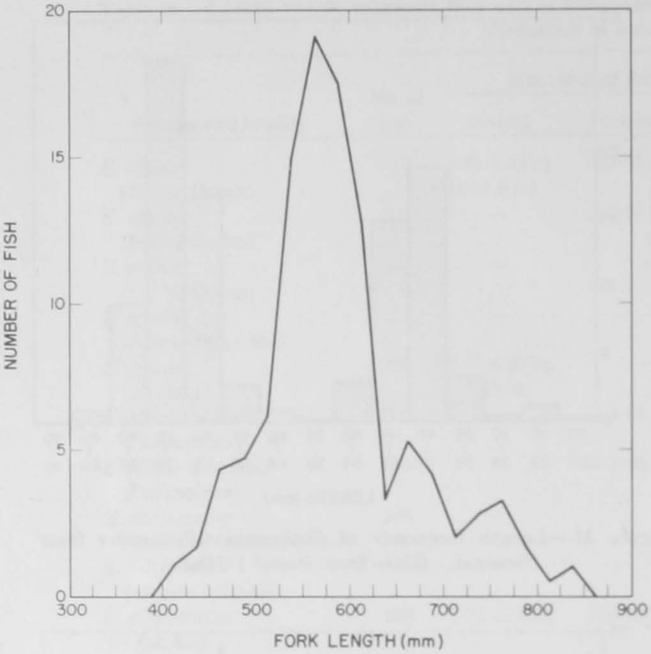

Figure 33.—Length frequency of 217 ***Euthynnus alletteratus*** caught by commercial trolling gear between North Carolina and northern Florida, July 1951. (From de Sylva and Rathjen 1961, fig. 2.)

(1961) also suggested that in the Miami sport fishery the anglers use a wider assortment of baits and artificial lures and because the angler is more careful in landing the fish, the hook is less apt to pull free.

Beardsley and Richards (1970) also presented length-frequency data of *E. alletteratus* caught in the sport fishery in southern Florida (Fig. 34). These fish were sampled at a Florida taxidermy firm during a period from September 1967 to September 1968. They indicated that because the fish was sampled at a taxidermy company the length-frequency distribution may be biased because usually only the largest fish caught are preserved and mounted. A comparison of the length-frequency data presented by de Sylva and Rathjen (1961) (Fig. 32) with that of Beardsley and Richards (1970) (Fig. 34), however, does not clearly indicate that larger fish were being selected.

The length-weight relationships determined for *E. alletteratus* from various localities are given in Table 26.

Euthynnus lineatus

The length-frequency distribution of *E. lineatus* taken between June 1972 and August 1975 in the Gulf of California and from Baja California to Ecuador is shown in Figure 35.

The length-weight relationship for *E. lineatus* computed by Klawe and Calkins (1965) is given in Table 26. The largest *E. lineatus* collected by Calkins and Klawe was a male 636 mm long which weighed 4.8 kg (10.5 lb).

4.14 Subpopulations

For various reasons, probably including the fact that 1) *Euthynnus* in general are commercially not very important and 2) investigators had been concerned primarily with clarifying the species status in the genus, very little has been done to investigate the subpopulation problem within this group. Based on various published works on

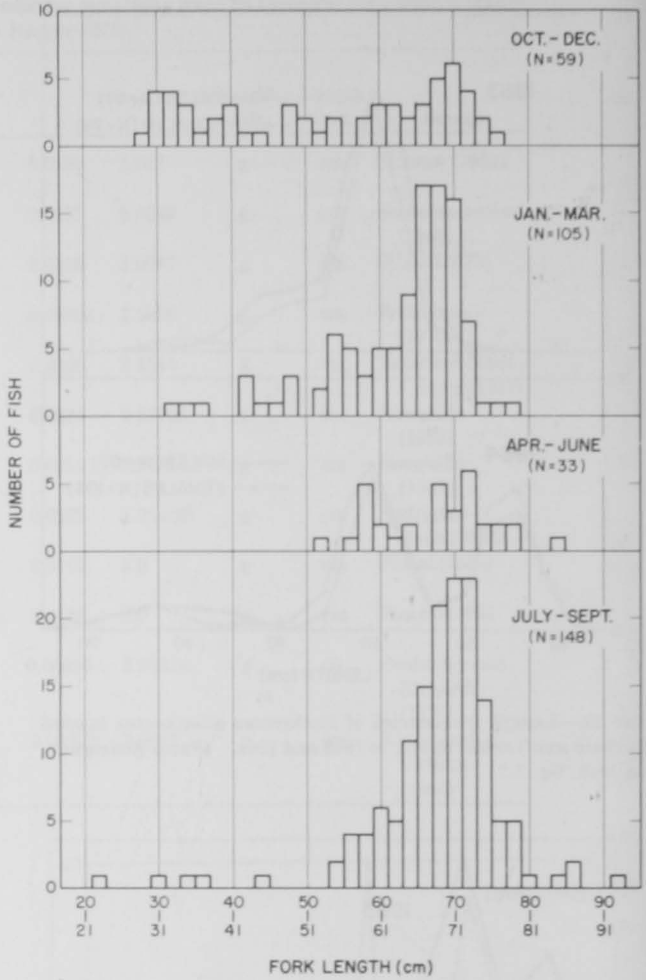

Figure 34.—Length frequencies by quarters of the year for ***Euthynnus alletteratus*** sampled from a taxidermy plant in south Florida from September 1967 through September 1968. (From Beardsley and Richards 1970, fig. 2.)

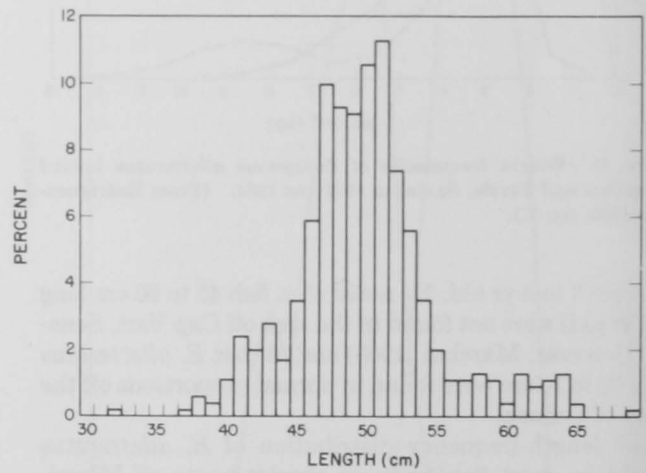

Figure 35.—Length frequency of ***Euthynnus lineatus***. (Data courtesy of W. Klawe, Inter-Am. Trop. Tuna Comm., La Jolla, Calif.)

meristic and morphometric characters of *E. alletteratus* in the Mediterranean and eastern Atlantic, Marchal (1963) concluded that two subpopulations existed in this area. He stated that the Senegal population extended at least from Cap Vert, Senegal, to Ghana and probably well beyond the tropical coast of west Africa. The Mediterranean subpopulation, which can be differentiated from the subpopulation off Senegal by meristic and morphometric characters, extends into the Atlantic south to Morocco and perhaps to as far north as the Bay of Biscay, France. In an earlier work Postel (1953) attempted to determine if the *E. alletteratus* that appeared in the cold season and the warm season off Cap Vert belonged to separate subpopulations on the basis of the number of spots on the pectoral region of the two groups of fish. Because of the wide variability of the number of spots the results were not conclusive.

In a preliminary study of the serology of tunas including *E. affinis*, Cushing (1956) indicated that it was probable that serological techniques could be applied profitably to the study of racial and specific variation in tunas. He stated that species differences existed among several species of tunas tested including *E. affinis*. In some preliminary experiments on two *E. lineatus*, it was found that the blood of this species could be differentiated from that of six other scombroids from the eastern tropical Pacific (Calkins and Klawe 1963). Other than these preliminary studies nothing has been done on subpopulation determination by serological methods.

4.2 Abundance and density (of population)

Probably because of the relative commercial unimportance of the species of *Euthynnus*, very few detailed studies have been made on the relative abundance of these fishes. Sivasubramaniam (1970) investigated the exploited stock of *E. affinis* along the southwest coast of Sri Lanka. He found a high degree of variability in catch rates of *E. affinis* within four subareas along the southwest coast which he attributed to seasonal changes in occurrence and to the schooling behavior of this species. He concluded that the best index of the relative density of *E. affinis* was an average taken from the mean catch rates obtained in the four subareas. The catch rate was given as the catch in pounds per operation or trip not exceeding 24 h. Sivasubramaniam (1970) found that the index of relative density was higher (35.3) in 1968 than in 1969 (31.1). He also indicated that the mean value of relative density obtained for the southwest subarea could indicate the relative strength of recruitment of *E. affinis* along the whole southwest coast. He noted that *E. affinis* are first recruited into the troll fishery in the southwest subarea along the southwest coast.

Sivasubramaniam (1970) estimated that a little over 600 tons of *E. affinis* were landed in 1969 on the southwest coast of Sri Lanka. These landings did not include those made by the nonmechanized boats. He noted that there is evidence of differential spatial distribution of *E. affinis* by size and that it could be possible to avoid capturing small fish by avoiding areas occupied by them. He indicated that the annual yield of the fishery could be considerably increased by doing this.

Elsewhere in the Indian Ocean it has been recorded that *E. affinis* occurred in commercial quantities in Australian waters (Roughley 1951) and around Somalia (Ogilvie et al. 1954). Williams (1964) noted that there are large unexploited schools of *E. affinis* in east African waters and Morgan (1956) estimated that *Euthynnus* and *Sarda* represented about 0.5% of all fish by weight in the Indian Ocean.

Marchal (1963) reported that the manner of fishing and total catches of *E. alletteratus* have had no effect on the populations of this species. Rodríguez-Roda (1966) presented long-term landings data of *E. alletteratus* in the Spanish fishery covering the period from 1929 to 1964. The landings were given in numbers of fish and show wide annual fluctuations but no significant trends.

4.3 Natality and recruitment

4.31 Reproduction rates

See section 3.1.

5 EXPLOITATION

It was noted earlier that *Euthynnus* generally has little or no commercial value. In many localities it appears that the typical fishery for *Euthynnus* is a multispecies fishery. It is not very clear whether the *Euthynnus* or the other species of tunas are the main targets of these fisheries. *Euthynnus* usually schools together with other species of tunas, and sometimes nontunas, and the use of nonselective gear and fishing methods probably accounts for the mixed catches. However, there is some evidence of size-differentiated schooling habits in *Euthynnus*. In the Indian Ocean, it was found that small *E. affinis* tended to be found in pure schools but the larger fish were found to school with other species (Williams 1963). Williams also noted that in Madagascar, Somalia, Seychelles, Pakistan, Sri Lanka, and the west coast of India, *E. affinis* is the prime objective of fisheries and specific attempts are made to catch this species.

The FAO Yearbook of Fishery Statistics (FAO 1977) indicates that nine countries had landings of *E. affinis* between 1973 and 1976. In the Indian Ocean, the following countries showed landings: Maldives, Pakistan, Seychelles, Yemen (Arab Republic), and Indonesia; in the western Pacific: Indonesia, Malaysia, Papua New Guinea, and Philippines; and in the central Pacific: United States. Other sources (FAO 1974a, 1974b) showed that Bangladesh, India, Israel, and Sri Lanka also at one time had landings of *E. affinis*.

In the Atlantic Ocean and the Mediterranean Sea, the following countries had landings of *E. alletteratus* between 1973 and 1976: Angola, Bulgaria, Cyprus, Ghana, Ivory Coast, Mauritania, Morocco, Poland, Romania, Spain, United States, Venezuela, and Yugoslavia (FAO 1977). An earlier list (FAO 1974a) showed that Israel, Liberia, and Turkey also at one time had landings of *E. alletteratus*.

Euthynnus lineatus landings for Panama and the United States between 1973 and 1976 are shown in the FAO Yearbook of Fishery Statistics (FAO 1977).

5.1 Fishing equipment

Silas (1967b) described the "multiple trolling" tuna fishery off the southeast coast of India (Gulf of Mannar). This is a multispecies fishery and in addition to *E. affinis*, a number of other species are taken. The vessels used in the fishery are known as Tuticorin-type boats which are small sailboats ranging in length from 8.2 to 10.4 m (27-34 ft). These vessels troll seven or nine lines and carry a crew of six or seven fishermen on the smaller boats and seven to nine fishermen on the larger boats. Brined *Sardinella* (*S. albela, S. gibbosa*, and *S. sirm*) are used almost exclusively as bait and only rarely are artificial lures used.

Other methods of fishing for *E. affinis* in the Gulf of Mannar include bottom-set nylon nets (150 mm mesh), shore seines, drift nets (pachuvalai) of 130-150 mm mesh, and longlines (Chacko et al. 1967). In the southern sector of the Gulf of Mannar, the drift nets are set in depths of about 30 m. The longline set is composed of up to 400 hooks baited with squid and the gear is set in depths of 25 to 40 m.

Off the southwest coast of India at Vizhingam, a tuna fishery is conducted almost exclusively by dugout canoes and catamarans (Bennet 1964). Including *E. affinis*, seven species of tunas are taken in this fishery. The other species are *Auxis rochei, A. thazard, Sarda orientalis, Thunnus tonggol, T. albacares*, and *Katsuwonus pelamis*. Bennet (1964) stated that *E. affinis* is one of the most important commercial species at Vizhingam. The principal fishing gears include cotton and nylon drift nets, hook and line, and occasionally shore seines. From July 1960 to October 1961, he noted that 71.4% of the landings of *E. affinis* were made by drift nets, 24.3% by hook and line, and only 4.3% by shore seines.

In the coastal waters of Sri Lanka, mechanized boats of 3.5-ton class and 11-ton class, in addition to the traditional outrigger canoes, are engaged in the mixed tuna fishery (Sivasubramaniam 1970). The fishing gear used includes drift nets, trolling lines, pole and line, longline, and beach seines (Sivasubramaniam 1966, 1970). In Pakistan the fishing gear or methods used are trolling, longlines, handlines, and beach seines (Qureshi 1952). In the Malagasy Republic, Comoro Island, east Africa, Somalia, Seychelles, and Australia the commonest fishing method for *E. affinis* is trolling with either natural bait or artificial lures. Handlines and longlines are also used in Somalia (Williams 1963).

In Japan no specialized fishery for *E. affinis* exists, apparently because consumer demand for this species is not great (Kikawa and staff 1963). Presumably, most of the *E. affinis* caught in Japan are taken incidentally with other species. Kikawa and staff (1963) stated that *E. affinis* are taken together with *Auxis*, juvenile *K. pelamis, T. albacares*, and *T. thynnus*. In the coastal waters of Japan, *E. affinis* are taken mainly from small sailing and motorized vessels. They are also taken by pole and line.

In an attempt to develop a tuna fishery in Hong Kong, the Hong Kong Fish Marketing Organization offered to buy *E. affinis* at a special high price in 1967 and 1968. Two boats switched to tuna fishing using a modified purse seine method. About 16 t of *E. affinis* were landed in the 2 yr but the fish could not be marketed at a profit and the project was abandoned (Williamson 1970).

Warfel (1950) stated that the most productive method of catching tuna in the Philippines is the fish trap, called corrals, or in Tagalog, baklad. The beach seine is the next most productive. Other methods used are a Philippine version of a purse seine called a talakop, trolling (sibid-sibid), and occasionally a drive-in net.

In Hawaii, *E. affinis* is taken incidentally in the live-bait pole-and-line *Katsuwonus pelamis* fishery and recreational troll fishery.

Euthynnus alletteratus

Like many of the fisheries for *E. affinis*, the fisheries for *E. alletteratus* appear to be multispecies fisheries. Along the coast of Tunisia in the Mediterranean, for example, Postel (1956) lists *T. thynnus, Sarda sarda, Auxis* sp., and *E. alletteratus* as species taken in specialized traps called madragues. Madragues are also used in the Moroccan fishery (Marchal 1963). The Tunisian fishery lands 400 to 500 tons and the Moroccan fishery 200 to 300 tons of *E. alletteratus* per year (Postel 1964).

Fisheries for *E. alletteratus* along the east coast of Africa are apparently not well developed (Marchal 1963). They are caught in beach seines in Senegal, the Ivory Coast, Ghana, and Angola. Off the Ivory Coast, *E. alletteratus* are also taken in sardine purse seines and in Angola they are also taken in traps similar to the madrague (Marchal 1963). On the islands of Sao Tomé and Principe, *E. alletteratus* are taken by a type of encircling gill net (Frade and Postel 1955).

In the western Atlantic and adjacent areas, Rivas (1951) stated that the flesh of *E. alletteratus* is good and of commercial importance throughout the West Indies. Chilton (1949) reported that for many years *E. alletteratus* has been caught in varying amounts along the Atlantic coast of the United States and along the coast of the Gulf of Mexico. Chilton's account of this species along the Atlantic and Gulf of Mexico coasts indicates that although *E. alletteratus* is frequently taken, and sometimes in fair amounts, no large-scale sustained fishery exists for this species in these areas. Mansueti and Mansueti (1962) reported on this species in Chesapeake Bay and stated that during 1951-61, *E. alletteratus* had been harvested commercially in pound nets and hand seines. However, the annual landings were minimal (less than 6 t per year). In addition to pound nets and hand seines, *E. alletteratus* in the western Atlantic has been taken by menhaden purse seines and trolling with artificial lures (Chilton 1949; de Sylva and Rathjen 1961).

Euthynnus lineatus

Euthynnus lineatus were not fished commercially in the eastern tropical Pacific before 1972 except for the small numbers that were taken and sold fresh in the local markets of Latin American countries. This species is taken incidentally by gear used to catch other species of fish. They have been taken by tuna purse seines, by live-bait pole-and-line fishing, commercial and sport trolling, and by trolled handlines. They are taken by commercial tuna vessels of all sizes, from small albacore trollers to large purse seiners and by bait boats, and by Ecuadorian and Peruvian canoe and raft fishermen (Calkins and Klawe 1963). Since 1972 the following commercial catches of *E. lineatus* have been reported in the Inter-American Tropical Tuna Commission's yellowfin tuna regulatory area (data courtesy of Calkins[7]):

Year	*Catch (tons)*
1972	660
1973	1,845
1974	4,043
1975	582
1976	1,673
1977	1,195

5.2 Fishing areas

See section 5.3.

5.3 Fishing seasons

Euthynnus affinis

Off the coast of South Africa and southwest Australia, *E. affinis* occur and are fished during the southern summer when surface water temperatures are at a maximum (Williams 1963). In the Seychelles, the fishery is highly seasonal and takes place during the northwest monsoon (October-November to April-May), when the surface water temperature is highest (29°-30°C). In northern Somalia, the fishery is conducted during the northeast monsoon at the time of minimum sea-surface temperature. In Pakistan, west coast of India, and Sri Lanka, *E. affinis* is taken throughout the year with slight local seasonal variations (Williams 1963). Bennet (1964) found that good landings of *E. affinis* occur during the 8 mo from October to May and the period of low catches is from June to September (Table 27) in the Vizhingam fishery (southwest coast of India). Bennet observed that the period of low catches coincides with the southwest monsoon when the seas are rough and very little fishing effort is expended. In contrast to the generalized statement made by Williams (1963) on the seasonal nature of the *E. affinis* fishery in Sri Lanka, Sivasubramaniam (1970) described a somewhat more complex situation of the seasonality of the *E. affinis* fishery (Fig. 36). The seasonal picture around Sri Lanka is complicated by two

Table 27.—Monthly landings (kilograms) of *Euthynnus affinis* at Vizhingam, India. (From Bennet 1964, table 1.)

Month	1956	1957	1958	1959	1960	1961
January	12,091	8,929	5,725	6,130	4,360	8,436
February	8,827	3,970	10,843	2,737	15,998	16,825
March	6,198	25,761	8,022	8,022	15,501	24,384
April	8,444	10,446	1,957	4,498	4,623	32,236
May	6,151	4,131	3,602	7,105	11,192	27,775
June	—	3,937	3,086	1,501	2,290	1,259
July	—	13,405	—	567	510	290
August	324	402	—	11,952	5,663	10,072
September	—	—	19,072	26,957	7,067	21,999
October	4,514	5,394	25,580	9,499	81,026	22,537
November	26,675	16,267	15,462	20,560	34,969	
December	12,451	2,621	32,753	5,009	22,569	
Total	85,675	95,263	126,102	104,537	205,768	165,813

factors: the differential selectivity of the gear used (trolling and drift net) and variation in recruitment by size in the various areas around Sri Lanka.

Off east Africa, around the Comoro Islands and the Malagasy Republic, *E. affinis* is taken throughout the year (Williams 1963). *Euthynnus affinis* is present around the Philippines throughout the year but the highest catches are made from October through December and April through May (Warfel 1950). Around Japan, *E. affinis* is taken near the Izu Islands from May to November (Kikawa and staff 1963). Young *E. affinis*,

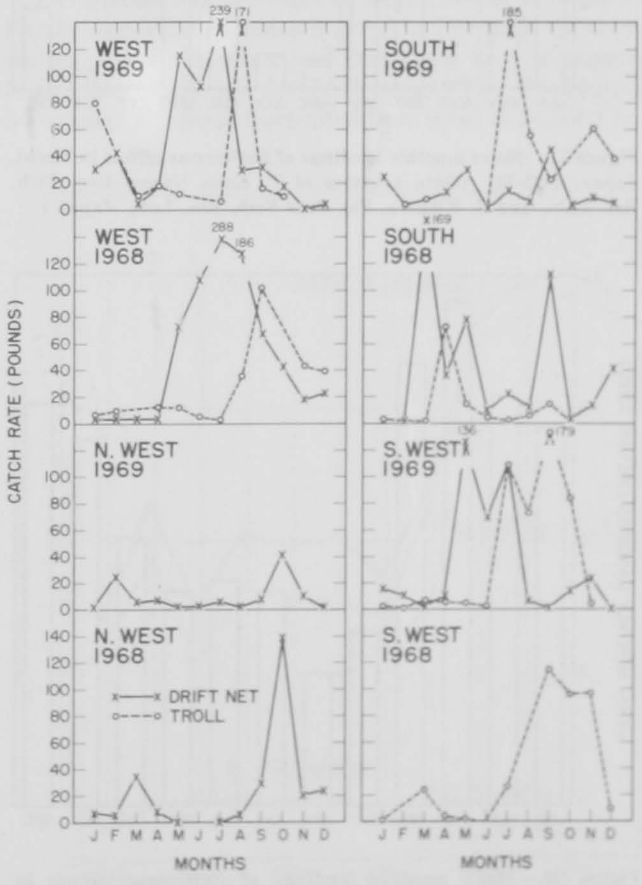

Figure 36.—Seasonal variation in catch of *Euthynnus affinis* around Sri Lanka. (From Sivasubramaniam 1970, fig. 4.)

[7]T. P. Calkins, Inter-American Tropical Tuna Commission, Scripps Institution of Oceanography, La Jolla, CA 92037, pers. commun. March 1978.

15 to 25 cm long, have been caught near Aburatsu in southern Kyushu from August to October (Yabe et al. 1953).

The mean monthly landings of *E. affinis* at two ports in Kochi Prefecture, Japan, in 1973 and 1974 (Fig. 37) indicate that *E. affinis* are present throughout the year near Kochi. Because of the sparse data, the significance of the three peaks in January, May, and September is not clear.

In troll fishing conducted off the northeast coast of Oahu, Hawaii, from 1951 to 1955, Tester and Nakamura (1957) reported that no *E. affinis* were taken between December and April. Their data showed a peak in the catch rate (catch per hour) in October. However, they cautioned that the fact that no *E. affinis* were taken from December to April cannot be regarded as significant since only a small number of hours were expended in fishing during that period. Welsh (1949) reported good catches of *E. affinis* during March, April, and May 1948 and during February and April 1949 in Hawaiian waters, including the same area fished by Tester and Nakamura (1957). The mean monthly landings of *E. affinis* in Hawaii from 1964 to 1974 indicate higher landings from October to April (Fig. 38). The results obtained by Tester and Nakamura (1957) and Welsh (1949) are not inconsistent with those shown in Figure 38. Thus it appears that around Hawaii, *E. affinis* may be less available from May to September and more available from October to April.

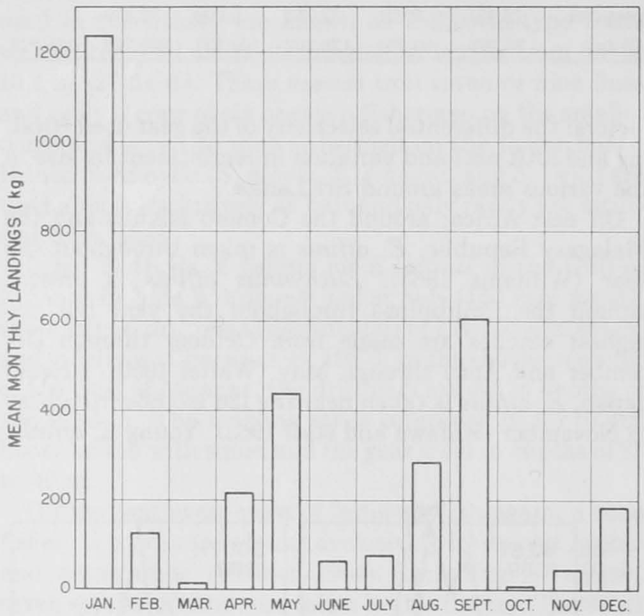

Figure 37.—Mean monthly landings of *Euthynnus affinis* in Kochi, Japan, 1973-74. (Data courtesy of T. Koto, Nansei Reg. Fish. Res. Lab., and S. Kikawa, Far Seas Fish. Res. Lab., Japan.)

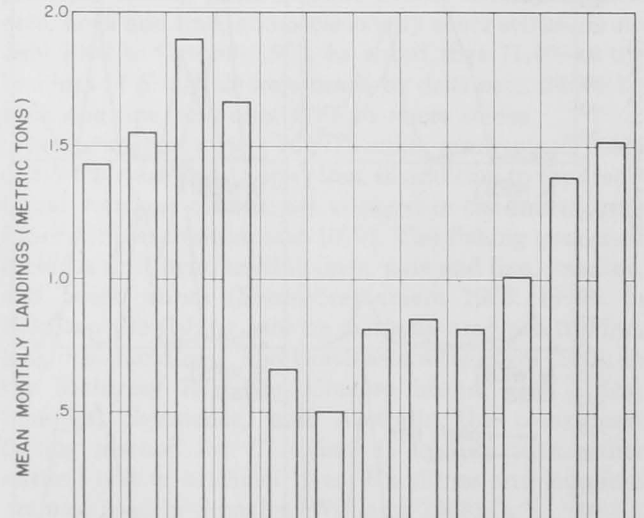

Figure 38.—Mean monthly landings of *Euthynnus affinis* in Hawaii, 1964-74. (Data from files of Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96812.)

Euthynnus alletteratus

In the Gulf of Gabès, Tunisia, *E. alletteratus* is found sporadically throughout the year. Off the northern coast of Tunisia, it appears in the spring and disappears in the autumn (Postel 1964). In Morocco, Postel stated that *E. alletteratus* appears in May and disappears at the end of November. Data presented by Ben-Tuvia (1957) on the mean monthly landings of *E. alletteratus* during 1950 to 1955 in Israel (Fig. 39) indicate this species is caught throughout the year and that the landings peak in May and October. Rodríguez-Roda (1966) gave a summary of the fishing seasons and the months of peak catches for *E. alletteratus* in the various Spanish fisheries in the Mediterranean and the Atlantic (Table 28). The various seasonal peaks in the Mediterranean fisheries suggest that this species may make seasonal migratory movements.

Off the coast of Senegal in the eastern Atlantic, *E. alletteratus* arrive in large numbers in January-February

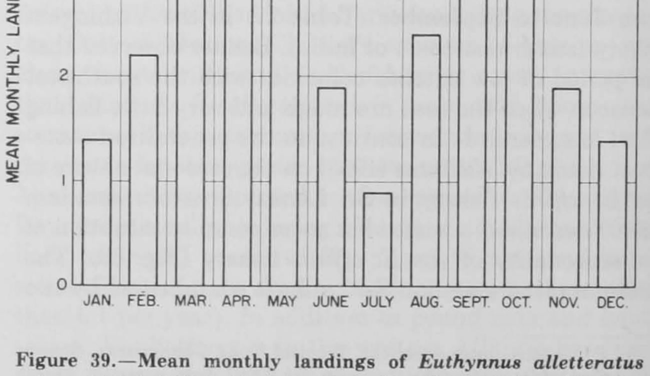

Figure 39.—Mean monthly landings of *Euthynnus alletteratus* from 1950 to 1955 in Israel. (From Ben-Tuvia 1957, table 3.)

Table 28.—Fishing seasons for *Euthynnus alletteratus* in Spain. (From Rodríguez-Roda 1966, table 3.)

Region		Fishing season	Months of peak catches
North coast	Atlantic Ocean	Jan. to Dec.	Sept. and Oct.
Northwest coast	Atlantic Ocean	June to Dec.	Oct.
Southwest coast	Atlantic Ocean	Feb. to Dec.	Aug. to Oct.
Canary Islands	Atlantic Ocean	Jan. to Dec.	Dec. to Mar.
Southern coast	Mediterranean Sea	Jan. to Dec.	Sept. and Oct.
Southeast coast	Mediterranean Sea	Jan. to Dec.	Sept. and Oct.
Eastern coast	Mediterranean Sea	Apr. to Dec.	July to Oct.
Balearic Islands	Mediterranean Sea	Jan. to Dec.	May to July

and May-June (Postel 1955b). They are present all year in the region of Cap Vert (Marchal 1963). Off the Ivory Coast, Marchal (1963) stated that *E. alletteratus* are found throughout the year along the coastline but that the catches peak in February. He stated that *E. alletteratus* are caught in Angola starting in October, the catches peak in February and March, and become nonexistent in May-June.

In the western Atlantic, Chilton (1949) suggested that *E. alletteratus* make seasonal migrations along the U.S. coast. In May and June they have been reported moving north to North and South Carolina and in August and September they have been caught along the coasts of New Jersey and New York. Observations made from September 1952 to August 1953 on anglers' catches landed at Miami, Fla., indicate that 87% of the catches were made from March through August including a peak in July (de Sylva and Rathjen 1961). de Sylva and Rathjen stated that there is evidence of a general drift of *E. alletteratus* out of the Miami area toward the south during the winter and that they occur further north along the coast during the summer.

Euthynnus lineatus

Euthynnus lineatus is taken throughout the year in all areas of its distributional range. Although information on the seasonal abundance is not very clear, Calkins and Klawe (1963) cited an Ecuadorian census of fishermen which indicated that *E. lineatus* was most abundant from May to September in the open coastal areas and from January to March in the Gulf of Guayaquil.

5.4 Fishing operations and results

5.42 Selectivity

The beach seines, principally used in the Sri Lanka fishery for *E. affinis*, are not size selective. Surface trolling, handlines, and longlines that are used in the Indian Ocean are also not selective (Williams 1963).

Calkins and Klawe (1963) stated that *E. lineatus* are taken by nonselective gear.

de Sylva and Rathjen (1961) suggested that the commercial trolling gear used to catch *E. alletteratus* may possibly be selective for a certain size range of fish (see section 4.13).

5.43 Catches

With the exception of the Philippines and Indonesia where a fair amount of *E. affinis* is landed, the species of *Euthynnus* are nowhere the basis of important large commercial fisheries. To illustrate the magnitude of the fisheries for *Euthynnus*, from 1965 to 1976 the total world landings for all the species fluctuated from 37,000 to 88,000 t (Fig. 40). In comparison, the annual world production of *K. pelamis* has ranged from 300,000 to 350,000 t in 1966-71 (Matsumoto 1974).

In Figure 40 is also plotted the total world production of *E. affinis* and *E. alletteratus* from 1965 to 1976. The world landings of *E. affinis* varied from 29,900 to 84,800 t annually and that of *E. alletteratus* from 4,600 to 9,500 t. *Euthynnus affinis* constituted 77.1 to 97.0% of the total for *Euthynnus* during this period. Only small amounts of *E. lineatus* have been reported in the statistics. It should be pointed out, however, that the world production of *Euthynnus*, as indicated by the statistics given above, is probably underestimated. It may happen that because only small amounts of *Euthynnus* are taken, they are lumped together with other species of tunas, or together with other miscellaneous species. Other problems associated with collecting catch statistics in the Indian Ocean are discussed in FAO (1973). Thus the figures for *Euthynnus* are probably not only underestimated but are also subject to inaccuracies.

The production of *E. affinis* from 1973 to 1976 in the Pacific and Indian Oceans is given in Table 29. As noted earlier, the Philippines and Indonesia have comparatively large fisheries for *Euthynnus*. The Philippines landings of *E. affinis* fluctuated from 9,447 to 24,000 t be-

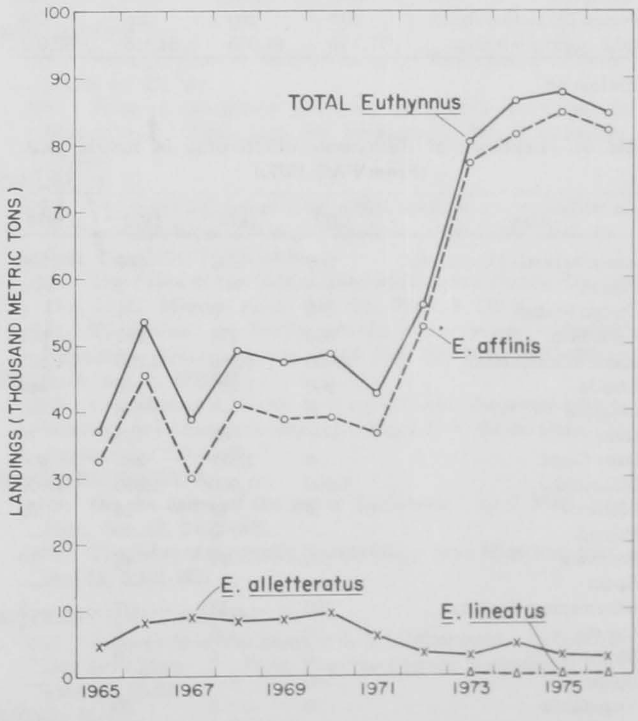

Figure 40.—World landings of *Euthynnus*. (Data from FAO 1974a, 1976, 1977.)

tween 1973 and 1976. The landings in Indonesia fluctuated between 31,600 and 41,616 t (Pacific Ocean) and 5,200 and 8,609 t (Indian Ocean) during the same period. Although the FAO Yearbook of Fishery Statistics does not show any landings of *E. affinis* in India from 1973 to 1976, according to Bennet (1964), 85.7 to 205.8 t were produced in Vizhingam, India, between 1956 and 1960 (see Table 26). In Hawaii, where *E. affinis* is taken incidentally in the pole-and-line fishery for *K. pelamis*, between 8.0 and 43.9 t were recorded during the 14-yr period from 1964 to 1977. In Japan, production figures for *E. affinis* are not readily available because they are combined with those of other species (Kikawa and staff 1963).

The world landings of *E. alletteratus* from 1973 to 1976 are shown in Table 30. It can be seen that only relatively small quantities of this species are taken in any of the fisheries. During the period from 1973 to 1976, the total annual production of *E. alletteratus* in the western Atlantic amounted to slightly over 500 t. In the eastern Atlantic, during the same period, the total annual landings fluctuated between 1,967 and 4,285 t, and in the Mediterranean Sea they did not exceed 700 t during the same period.

Although the FAO Yearbook of Fishery Statistics does not show any figures for *E. alletteratus* from Tunisia, Postel (1964) reported that 400-500 tons are landed annually in Tunisia.

Calkins and Klawe (1963) stated that most of the landings of *E. lineatus* are probably made by small boats in Latin America and that they go unrecorded. They further noted that landings are sometimes recorded in Mancora, Peru, but it is not known what proportion they make up of the actual total landings even in the immediate area of Mancora. Tuna purse seiners sometimes inadvertently set on *E. lineatus* but these catches are dumped overboard. However, estimates of the amount caught have been recorded in the vessels' logbooks which indicate that amounts from 1 to 100 tons have been caught (Calkins and Klawe 1963). In years when large amounts of tuna are caught by setting on schools, as opposed to setting on porpoises, large quantities of *E. lineatus* are dumped overboard (Klawe[8]).

Table 29.—Landings of *Euthynnus affinis* in metric tons. (From FAO 1977.)

Area	1973	1974	1975	1976
Pacific Ocean total	[1]60,850	58,233	61,654	59,003
Indonesia	31,600	38,507	39,625	41,616
Malaysia	5,000	8,145	9,963	7,810
Papua New Guinea	[1]250	250	30	100
Philippines	24,000	11,315	12,013	9,447
United States	0	16	23	30
Indian Ocean total	16,300	23,132	23,156	[1]23,028
Indonesia	5,200	8,609	7,710	7,927
Maldives	1,000	800	400	1,000
Pakistan	9,600	13,113	14,470	13,575
Seychelles	300	350	250	200
Yemen (Arab Republic)	200	260	326	[1]326
Total *E. affinis* landings	[1]77,150	81,365	84,810	[1]82,031

[1]Estimated.

Table 30.—Landings of *Euthynnus alletteratus* in metric tons. (From FAO 1977.)

Area	1973	1974	1975	1976
Western Atlantic Ocean total	300	382	360	506
Poland	—	—	2	—
United States	0	9	1	5
Venezuela	300	373	357	501
Eastern Atlantic total	2,000	[1]4,285	[1]2,515	[1]1,967
Angola	900	1,287	449	[1]449
Bulgaria	0	—	8	—
Ghana	—	66	138	76
Ivory Coast	0	1,583	860	400
Mauritania	1,000	[1]1,000	[1]1,000	[1]1,000
Morocco	0	46	14	32
Poland	—	6	—	—
Romania	100	297	46	10
Spain	—	—	—	—
Mediterranean Sea total	700	13	27	8
Cyprus	0	5	7	7
Morocco	0	5	0	—
Spain	700	—	—	—
Yugoslavia	0	3	20	1
Total landings	3,000	[1]4,680	[1]2,902	[1]2,481

[1]Estimated.

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