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SYNOPSIS OF BIOLOGICAL DATA ON TUNAS OF THE GENUS EUTHYNNUS

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THE BIOLOGY AND RESOURCES OF THE SPECIES OF EUTHYNNUS

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CONTENTS

		Page
I.	Introduction	1
II.	Identity	3
	A. *Euthynnus affinis* (Cantor)	5
	B. *Euthynnus alletteratus* (Rafinesque)	8
	C. *Euthynnus lineatus* (Kishinouye)	10
	D. Similarities and differences among the species of *Euthynnus*	12
III.	Distribution	14
	A. *Euthynnus affinis*	14
	B. *Euthynnus alletteratus*	15
	C. *Euthynnus lineatus*	16
	D. Ecological characteristics of areas	17
IV.	Biology and ecology	21
	A. Reproduction	21
	1. *Euthynnus affinis*	21
	2. *Euthynnus alletteratus*	26
	B. Life history	30
	1. Eggs	30
	2. Larvae, juveniles, and pre-adults	31
	a. *Euthynnus affinis*	31
	b. *Euthynnus alletteratus*	37
	c. *Euthynnus lineatus*	44
	3. Adults	49
	a. Hardiness	49

Page

b. Competitors 50

c. Parasites 51

d. Biochemistry 51

e. Body temperature and other observations

4. Age and growth 55

a. Euthynnus affinis 55

b. Euthynnus alletteratus 57

c. Euthynnus lineatus 59

5. Nutrition 59

E. Behavior 64

V. Resource 72

A. Description of fisheries 72

1. Euthynnus affinis 72

2. Euthynnus alletteratus 78

3. Euthynnus lineatus 81

B. Population structure 82

1. Euthynnus affinis 82

2. Euthynnus alletteratus 85

3. Euthynnus lineatus 88

C. Landings 88

D. Abundance 91

E. Subpopulations 93

Literature cited 94

THE BIOLOGY AND RESOURCES OF THE SPECIES OF EUTHYNNUS

I. INTRODUCTION

The fishes of the genus Euthynnus are widely distributed in the warm and tropical waters of the world's oceans. In some localities it appears to be the dominant scombrid in the coastal, nearshore waters. For example, the Atlantic form, Euthynnus alletteratus, is reported to be 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 1954). Along the coast of Israel in the Mediterranean, Ben-Tuvia (1957) stated that E. alletteratus seemed to be the only common scombrid. Around the inshore waters of Hawaii Euthynnus affinis was one of the more common species taken by trolling (Welsh 1949; Tester and Nakamura 1957), and in the eastern tropical Pacific Walford (1937) stated that Euthynnus lineatus was very abundant.

Although the species of Euthynnus are widely distributed and apparently are abundant in some localities, generally the group as a whole is not commercially important. Calkins and Klawe (1963) stated that E. lineatus were 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 E. affinis and E. alletteratus ranged from 14,500 to 45,400 metric tons (MT) and averaged about 31,100 MT during the period from 1965 to 1973 (FAO 1974a). The FAO Yearbook of Fishery Statistics (FAO 1974a) does not list any landings of E. lineatus.

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 the Euthynnus be elucidated.

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

II. IDENTITY

In their preliminary review of the fishes of the family Scombridae Collette and Gibbs (1963) summarized the status of the species in the genus Euthynnus as follows:

> "Fraser-Brunner (1949, 1950) recognized two species, *E. affinis* (Cantor) and *E. alletteratus* (Rafinesque) in addition to the skipjack *E. pelamis* (Linnaeus). Fraser-Brunner (1949) divided *E. affinis* into three subspecies: *E. affinis affinis* (Cantor) from the Red Sea, Indian Ocean, Australia, Thailand, and Formosa; *E. a. yaito* Kishinouye from Japan, Hawaii, and Pacific islands; and *E. a. lineatus* Kishinouye from the Pacific Ocean off Central America. Present evidence indicates that *E. lineatus* may be a valid species while *E. yaito* may best be considered as a synonym of *E. affinis*. Fraser-Brunner (1949) described a new subspecies *E. alletteratus aurolitoralis* from Ghana. This appears to be a color variant within the range of variations in *E. alletteratus* and should be synonymized with it."

Subsequently, the status of the species in Euthynnus has been further clarified and it is now generally believed that there are three allopatric species of Euthynnus throughout the world. The three species are 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.

The classification of the species of Euthynnus within the family Scombridae as given by Collette and Chao (1975) is given below.

Family Scombridae

Subfamily Scombrinae

Tribe Thunnini

Genus Euthynnus

Species Euthynnus affinis

Euthynnus alletteratus

Euthynnus lineatus

Genus Euthynnus Jordan and Gilbert 1882.

The fishes 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 distinguish 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 the species and vomerine teeth in two of the species in Euthynnus. The intestine is straight. There are usually 39 vertebrae. Godsil (1954) gives a detailed description of the generic skeletal characters.

Fig. 1

A. EUTHYNNUS AFFINIS (Cantor) (Fig. 1).

The following description is taken from Godsil (1954).

The dorsal black markings are more oblique in E. affinis than in the other two species. "The above pattern is superimposed upon a blue to indigo background which is most accentuated in the anterior region. On the belly below the pectoral there are a number of black or dusky spots, scattered over a relatively wide area. They are variable in number, position, and extent, and cannot be regarded as a specific character."

The crest or rise of the lateral line above the pectoral fin is minimal. The rise or crest, 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.

"As in the other species of this genus the caudal keels are not conspicuously developed and are evidenced externally only by a dorso-ventral flattening of the peduncle.

"The posterior margin of the operculum is relatively straight. At the dorsal extremity of this margin there is generally a small dark or black elongated spot. The preoperculum is gently and smoothly rounded in posterior outline, as in the other species of this genus. There is a small irregular dark spot or area below the posteroventral margin of the eye.

"The maxillary extends to or slightly beyond the vertical through the middle of the eye. There are from 24 to 35 teeth on each side of the lower jaw, depending on the size of the specimen. The smallest number occurred on the smallest fish and the greatest on the largest fish. Vomerine teeth were invariably sharp and obvious to the touch, but palatine teeth, though present in all, were prominent in about half the specimens.

"The dorsal fins are contiguous and the first dorsal is high, being about twice the height of the second dorsal fin and roughly half the head length. The first two rays of the first dorsal are roughly equal in length, and succeeding rays are progressively and appreciably shorter so that the dorsal outline of the fin is strongly concave. The anal fin is inserted on a vertical though the origin of the first dorsal finlet, or between this and the end of the second dorsal base. There were eight dorsal and seven anal finlets in all specimens. The plaque of scales surrounding the ventral fins extends from one to two centimeters in fish of 40 to 60 cm. body length posterior to the tip of the ventral fins.

"Gill rakers are fully developed on the first arch only. There is invariably a raker at the angle of the arch with a basal process extending both dorsally and ventrally. On subsequent arches there may be occasional and scattered rakers. Thus in one specimen there were two short stubby rakers at the angle of the second arch, and one such raker at the angle of the third arch. Moreover, on the upper limb of the third and fourth arches there were respectively three and five such short stubby rakers. The raker count (first arch, left side) was 7(7-9) + 1 + 21 (22-24) = 32 (29-34).

"Gill teeth, or posterior rakers, are present on all arches. They are most developed on the first arch, on which the modal count was 8 + 20 = 28, with a variation in total count ranging only from 27 to 29 (seven specimens). On the first arch the longest teeth measured roughly nine mm., while the longest tooth on the last arch was roughly three mm.

A partial synonymy, based primarily on synonymies presented by Fraser-Brunner (1949) and Jones and Silas (1964) is given below.

?Scomber quadripunctatus Geoffroy St. Hilaire, 1827

?Thynnus brevipinnis Cuvier and Valenciennes, 1831

Thynnus affinis Cantor, 1850

Thynnus thunnina Temminck and Schlegel, 1850

Auxis taso (not of Cuvier) Bleeker, 1850

Euthynnus alletteratus Jordan, Tanaka and Snyder, 1913

Euthynnus yaito Kishinouye, 1923

Gymnosarda alletteratus Meek and Hildebrand, 1923

Wanderer wallisi Whitley, 1937

Euthynnus affinis affinis Fraser-Brunner, 1949

Euthynnus affinis yaito Fraser-Brunner, 1949

Euthynnus affinis (in part) Rosa, 1950

Euthynnus alletteratus affinis (in part) de Beaufort, 1951

Euthynnus wallisi Whitley 1964

Table 1 Table 1 lists the common and vernacular names of E. affinis.

Fig. 2

B. EUTHYNNUS ALLETTERATUS (Rafinesque) (Fig. 2).

The following description is based on the one given by Godsil (1954).

E. alletteratus can be distinguished from the other two species in the genus by the absence of vomerine teeth and the pattern of dorsal markings. The pattern of dorsal markings "consists of broken, longitudinal black or dark bars running irregularly from the corselet towards the caudal region. The markings are more continuous and regular posteriorly. Anteriorly the bars are replaced by short irregularly curved lines, blotches or spots.

"The markings are superimposed upon a background of blue, shading dorsally into the deep blue and black of the mid-dorsal line. Below the lateral line the blue fades into silver and the entire belly is silvery or dusky, with an irregular number of black or dark spots between ventral and pectoral fins, and slightly posterior to the pectorals.

"The ventral projection of the corselet is variable but generally short. It extends posterior to the tip of the pectoral a distance not exceeding one-fourth the length of the pectoral fin in most specimens, but is occasionally longer. The lateral line curves gently upward above the pectoral fin, and is of no diagnostic value. The maxillary extends posteriorly to the vertical through the middle of the eye.

"The posterior margin of the operculum is relatively straight, that of the preoperculum smoothly rounded. The teeth are moderate in size and individually distinct. There are approximately 25 to 35

teeth on each side of the lower jaw, and they are similar to those of the other described species of this genus. The palatine teeth are sharp, strong, and quite conspicuous."

Table 2 Meristic counts for E. alletteratus are given in Table 2. Mansueti and Mansueti (1962) presented a "topographic" osteology of a

Fig. 3 specimen captured in Chesapeake Bay (Fig. 3).

The partial synonymy given below was taken from Fraser-Brunner (1949) and Jones and Silas (1964).

Scomber alletteratus Rafinesque, 1810

Scomber quadripunctatus Geoffroy St. Hilaire, 1827

Thynnus leachianus Risso, 1827

Thynnus thunnina Cuvier and Valenciennes, 1831

Thynnus brasiliensis Cuvier and Valenciennes, 1831

Euthynnus alletteratus Jordan, Evermann, and Clark,1930

Euthynnus thunnina Nobre, 1935

Euthynnus alletteratus alletteratus Fraser-Brunner, 1949

Euthynnus alletteratus aurolitoralis Fracer-Brunner, 1949

The common and vernacular names of E. alletteratus are given

Table 3 in Table 3.

Fig. 4

C. EUTHYNNUS LINEATUS (Kishinouye) (Fig. 4).

"This species can in most instances be readily identified by the dorsal markings. The general pattern consists 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 of these stripes invariably starts anteriorly below the lateral line and generally crosses this in its path to the caudal region. Variations consist mainly of interruptions in the continuity of the stripes, or branching of individual stripes with supplementary short irregular markings between.

"These black dorsal stripes are superimposed upon a background of blue, deepening into black dorsally and shading into grey and silver below. The belly of the fish is dusky or silvery with an irregular number (usually from 2 to 6) of black spots between the pectoral and pelvic fins. Such spots are not diagnostic or invariable, for specimens are occasionally seen with no apparent spots. At the other extreme many specimens have distinct and unmistakable oblique black or dark stripes running on the belly from below the pectoral toward the caudal region.

"The lateral line is not specifically distinct. There is a gentle rise or a slight peak above the pectoral fin. Posterior to this the line subsides and runs as a relatively straight line to the caudal peduncle without regular conspicuous undulations.

"Palatine teeth are present in all specimens and conspicuous in most. Vomerine teeth are likewise present in all specimens, though in some they are difficult to discern, and in one specimen no teeth could be felt, but the longitudinal ridge of bone supporting the teeth was apparent to the touch.

"The posterior margin of the operculum is straight, with an angular posteroventral edge, as in all species of this genus. Similarly, the free margin of the preoperculum is smoothly rounded. The maxillary extends to the vertical through the center of the eye, but not beyond." (Godsil, 1954.)

Table 4

Meristic counts of E. lineatus are given in Table 4. E. lineatus can be differentiated from the other two species in the genus by the possession of 37 (36-38) vertebrae as against the customary 39 in the other two species. It is further differentiated by the presence of four characteristic lobes on each of the 31st and 32d vertebrae.

Calkins and Klawe (1963) list only one synonym for E. lineatus: Euthynnus affinis lineatus Fraser-Brunner, 1949.

Standard common names and vernacular names of E. lineatus include: negra, bonito negro (Ecuador); barrilete negro (Mexico, Peru); black skipjack, cross-bred mackerel (United States). Kishinouye (1920) referred to it as the Mexican little tunny.

D. SIMILARITIES AND DIFFERENCES AMONG THE SPECIES OF EUTHYNNUS.

Godsil (1954) made a detailed comparison of the three species of Euthynnus (Table 5). Godsil indicates that while the specific identity of E. affinis, E. alletteratus, and E. lineatus appears to be well established, most of the differences that distinguish each species are 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 in the superficial identification of the species in Euthynnus. Thus in the absence of positive external characters, the superficial identification of the species must rely on the assemblage of relative characters, which in turn is subject to final confirmation by the positive skeletal characters.

Table 5

E. lineatus is clearly differentiated from the other two species by the possession of 37 (36-38) vertebrae as opposed to 39 vertebrae in E. affinis and E. alletteratus. It is further differentiated by the presence of four characteristic lobes on each of the 31st and 32d vertebrae and by having the major portion of the caudal keel on these two vertebrae. The major portions of the caudal bony keels are on its 33d and 34th vertebrae in E. affinis and E. alletteratus.

E. affinis and E. alletteratus are specifically different in only minor 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. The superficial separation 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 37 to 40 gill rakers and 31 or 32 gill teeth on the first arch of E. alletteratus compared with 29 to 33 gill rakers and 28 or 29 gill teeth in E. affinis.

Godsil (1954) also noted that E. affinis differed slightly from E. alletteratus in many of the body proportions. The ratios were lower in E. affinis because the head was proportionately larger and the fins were more posteriorly inserted in E. affinis. Godsil found that while the differences were individually small they were all in the same direction and suggested that all the ratios could be summed to yield an index of these characters to characterize the species. In summing the ratios resulting from dividing the body 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 (8 specimens) and 13.64 to 14.19 for E. alletteratus (7 specimens). He found that these values were independent of fish size so that mean values, 13.046 for E. affinis and 13.996 for E. alletteratus, could be used to define the species.

III. DISTRIBUTION

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. E. affinis and E. alletteratus are more widely distributed in the world's oceans.

A. EUTHYNNUS AFFINIS

E. 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) reports its occurrence as Euthynnus wallisi along the west, north, and east coast 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, n.d.), the Hawaiian Islands; Midway (Chapman, 1946); the Line Islands and the Marquesas Islands; New Caledonia and New Hebrides (Angot 1959) and Tahiti (Herre 1932). 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 are widely distributed around the oceanic islands of the Pacific and it would not be surprising to discover that E. affinis is even more widely distributed than the records indicate. A stray E. affinis has also been recorded from Los Angeles Harbor, California (Fitch 1953).

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, Malaya, Indonesia, and to the west coast of Australia. It occurs around Madagascar (Malagassy Republic) Ceylon (Sri Lanka), and the offshore islands and archipelagos: Mauritius, Reunion, Comoro, the Seychelles including Aldabra, Laccadive, Maldives, and Andaman and Nicobar (Williams 1963; Jones and Silas 1964).

B. EUTHYNNUS ALLETTERATUS

E. alletteratus is found along both coasts of the Atlantic Ocean and in the Mediterranean Sea. It is also found in the Sea of Marmara (Demir 1961) and it occurs sporadically in the Black Sea (Richards and Klawe 1972) (Fig. 6).

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 is from off the coast of Morocco to the coast of northwest Africa. Marchal (1963) listed the following localities along the west African coast from which E. alletteratus has been recorded: Levrier Bay, Mauritania by Postel (1950); Cape Vert Islands and Gambia by Cadenat (1950) and Postel (1950); off the Bissagos, Guinea, and Sierra Leone by Marchal (1961) and Postel (1962); the length of the coast of Liberia, the Ivory Coast and Ghana; St. Thomas and Principe Islands by da Costa and Frade (1958); and Pointe-Noire by 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) states 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 records the species from Rio de Janeiro, Brazil.

C. EUTHYNNUS LINEATUS

E. lineatus is found in the tropical coastal waters of the eastern Pacific from about lat. 35°N to 12°S (Fig. 7). Calkins and 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 Dr. C. L. Hubbs, Scripps Institution of Oceanography and Dr. D. P. de Sylva, presently with the University of Miami. Records of E. lineatus in the literature include the northernmost record from off San Simeon, California (35°20'N, 120°40'W) (Nowell 1961); specimens from California waters (Roedel 1948 and Fitch 1952); from Baja California (Godsil 1954); the Tres Marias Islands (Fowler 1944); Acapulco, Mexico (Mais and Jow 1960); Costa Rica (Schaefer and Marr 1948); Colombia Bank (2°N, 79°W), Guayaquil Bank (3°35'S, 80°55'W) (Godsil 1954 and Clemens 1957) and from the Galapagos Islands (Fowler 1938 and 1944; Schmitt and Schultz 1940; Seale 1940; and Godsil 1954). Logbooks of commercial tuna vessels

Fig. 7

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 Revilla Gigedo 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 Coccos Islands and there is a single report of its occurrence from Shimada Bank (16°52'N, 117°30'W) (Calkins and Klawe, 1963). In addition there are two records of E. lineatus from the Hawaiian Islands (Matsumoto and Kang 1967 and Matsumoto 1976).

D. ECOLOGICAL CHARACTERISTICS OF AREAS

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 (1954) 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 (Jonklass 1967). In this respect the species of Euthynnus generally appear to be similar

to the species of Sarda which are also inhabitants of the coastal or neritic pelagic province. Sverdrup, Johnson, and Fleming (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 such that some of the inhabitants may be more or less euryhaline. "Plant nutrients, nitrates, phosphorus, and so on are more readily available in the shallower inshore water because of the greater possibility of return by vertical currents after they have been regenerated from the disintegrating organisms on the bottom or in the deeper water." (Sverdrup et al. 1942). 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°/$_{oo}$ to 33.80°/$_{oo}$ (Yabe, Anraku, and Mori 1953). Yabe et al. also noted that near Aburatsu, Japan, heavy autumnal rains make the water turbid 1 or 2 miles 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 miles offshore. The surface water temperature ranged 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°/₀₀ in February and 6°/₀₀ in July). On the east side of Hong Kong more oceanic conditions prevail: the surface salinity is 34°/₀₀ in February and 26°/₀₀ 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 occupies the inshore turbid waters wherever they are found. Morice and Cadenat (1952) made this observation of E. alletteratus in Guadelupe and Whiteleather and Brown (1945) noted that this species appeared to be a coastal fish in areas around Trinidad, Tobago, and British Guiana.

Calkins and Klawe (1963) characterized the general habitats of E. lineatus based on published studies (Holmes, Schaefer, and Shimada 1957; Brandhorst 1958; Cromwell 1958; Cromwell and Bennett 1959; Sund and Renner 1959). They noted that the major portion of the waters in which E. lineatus occurs is tropical, that is the Equatorial Pacific water mass which extends approximately from lat. 23° to 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.

In the areas inhabited by E. lineatus 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.

IV. BIOLOGY AND ECOLOGY

A. REPRODUCTION

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 do occur since cases of hermaphroditism have been discovered in closely related species, e.g., Katsuwonus pelamis. 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 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.

1. Euthynnus affinis

E. affinis apparently attains sexual maturity at a relatively small size, at least in certain areas of its distributional range. Bunag (1956) examined a total of 30 E. affinis 444 to 622 mm long in Philippine waters and found that the smallest female with mature gonads was a specimen 490 mm long. A female 477 mm long was found to have spent ovaries. In an earlier study in Philippine waters, a sample of 205 females included a ripe specimen that was between 400

and 409 mm long that was determined to be spent. In yet another study comprising a sample of 144 fish 334 to 508 mm long, it was found that the smallest mature female was around 385 mm long (Ronquillo 1963).

E. 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 total length, probably in their third year of life. Williams (1956 and 1963) examined 37 specimens from East Africa and noted that fish there attained sexual maturity between 55 and 60 cm total length. In Mauritius waters E. affinis 55 cm long are mature (Baissac 1960). 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 48.0 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 notes 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 with its size. They found that five females in their sample were ripe.

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
Table 6 790,000 to 2,500,000 during the spawning season (Table 6). Rao noted that the number of ova produced by E. affinis increased with the size of the fish.

E. 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 1956). Wade 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 Philippine waters to
Fig. 8 determine the spawning season (Fig. 8). His results were essentially the same as those obtained by Wade and Buñag in that no clear seasonality in spawning was evident. Ronquillo, however, noted that the highest gonad indices were found from March to May. Based on the development of ovarian ova Buñag concluded that E. affinis in the Philippines
Fig. 9 spawns more than one batch of eggs during a spawning season (Fig. 9). Although he did not encounter any fully ripe ovaries in his samples, Buñag 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, Netherlands East Indies; near Mariga-bato 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 with 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 1960).

North of the equator in the Indian Ocean, off the southwest coast of India near Vizhangam, E. affinis spawns from April to September (Rao 1964). Rao 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, and September to November near Vizhingam and Calicut, India (Jones 1960 and Table 7) 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 7) which suggested spawning during these months.

Larval and juvenile E. affinis have been recorded from many other areas in the Indo-Pacific (Table 7; see also Fig. 13). 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 distributional area.

2. Euthynnus alletteratus

In the eastern Atlantic in the area off Dakar, Senegal, Postel (1955b) determined the size of first maturity of E. alletteratus as 397 mm for the males and 386 mm 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. Off the coast of Guinea Marchal (1963) stated the smallest E. alletteratus he observed in spawning condition were 442-447 mm long.

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 272 mm long. However, they also noted that most fish in their sample did not reflect a spawning condition until they were 350 mm 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 (Rodriguez-Roda 1966).

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

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 8-16 cm long are taken by "light fishing" from June to September along the Mediterranean coast of Israel, which 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 with 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 areas. 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 and 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 to October 1964). Larval E. alletteratus were caught during the cool season as well as the warm season (Table 8). 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 Saint Thomas and Principe the spawning season extends from October to December (Frade and Postel 1955; and da Costa and Frade 1958).

Off the coast of Florida in the western Atlantic the development of E. alletteratus gonads indicates an extended spawning season beginning in March and continuing up to about November (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 sea birds in the Dry Tortugas, Florida (Table 9).

Table 9

Klawe and Shimada(1959) reported the capture of juvenile E. alletteratus during the months of March, April, and June-August in the Gulf of Mexico (Table 9) 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 9 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 wherever it is found.

3. 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 in an advanced stage of maturity from the Gulf of Nicoya, Costa Rica but did not give the size of the specimens. The fecundity of E. lineatus also has yet to be investigated.

E. lineatus spawning in the northern part of its distribution is limited to the summer months (Klawe 1963). Klawe also noted that farther south E. lineatus spawns throughout the year with a possible peak in the early spring (Table 10).

Table 10

Records of larval and juvenile E. alletteratus from the eastern Pacific and from near Costa Rica are shown in Tables 11 and 12, respectively. The records indicate the probable spawning periods and localities in the eastern tropical Pacific Ocean.

Tables 11, 12

B. LIFE HISTORY

1. Eggs

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 kanagurta. Delsman noted that the egg diameters were 0.85-0.95 mm and that the diameter of the oil globule ranged from 0.21-0.24 mm. Sanzo (1932) described some fertilized eggs which he tentatively identified as belonging to Euthynnus alletteratus. The eggs were buoyant, spherical, 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 embryo 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. Houde and Richards 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) state that the fertilized eggs of E. lineatus are pelagic but they have never been specifically identified in plankton collections.

2. Larvae, juveniles, and pre-adults

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.

a. Euthynnus affinis

Delsman (1926), as stated earlier, described some fertilized eggs of Scomber kanagurta which he later redesignated 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 larva of various stages of development (Fig. 10). Whether these are actually larvae of E. affinis has not been verified.

Fig. 10

The smallest specimen identified by Matsumoto (1958) as E. affinis measured 4.6 mm in total length (Fig. 11). The head length is moderate (33.9% of the total length), 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

Fig. 11

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.

"Most of the median fins show very little development, there being about 4 or 5 rays in the caudal and only strong striations representing rays in the region of the future anal and dorsal fins. The pectoral fins also show only striations, and the pelvic fins are absent.

"The pigmentation on the head consists of 3 small chromatophores over the forebrain and about 15 chromatophores over the midbrain. There is a single small chromatophore at the middle of the mandible and another at the symphysis of the pectoral girdle, which is not shown in the drawing. There is no pigmentation along the dorsal edge of the trunk, but 5 chromatophores are present along the ventral margin of the trunk near the caudal region." (Matsumoto 1958.)

A 5.5-mm specimen is shown in Fig. 11.

"The mouth now contains 13 and 15 teeth in the upper and lower jaws, respectively, and the preopercular spines have increased to 6.

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

"Pigmentation is more extensive over the midbrain and over the abdominal sac. There is also an increase in the number of chromatophores at the tip of the snout and lower jaw, and the single chromatophore at the middle of the mandible and that at the pectoral symphysis are still evident. In addition, 2 small chromatophores are present on the ventral midline just anterior to the anus, and a single conspicuous chromatophore is present in the first dorsal fin. The dorsal midline of the trunk is still free from pigmentation, while the ventral midline shows 3 well-separated chromatophores in the region of the future anal finlets." (Matsumoto 1958.)

A 7.6-mm specimen, shown in Figure 11 exhibits some striking changes, particularly in pigmentation.

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

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

The first dorsal fin has 8 spines, the length of the longest spine being slightly less than half the distance between the dorsal-fin insertions. The second dorsal and anal fin rays are beginning to form and, while the rays themselves are not clearly

evident, there appear to be about 11 radials in the second dorsal and 12 in the anal. The radials of the first 7 dorsal finlets and first 6 anal finlets are also evident. The caudal fin shows 9+9 rays, and the pelvin fins, although very small, are complete with 1 spine and 5 rays. Only about 5 rays are noticeable in the pectoral fins. The myomeres remain the same (40 or 41) as in the previous specimen." (Matsumoto 1958.)

A 9.6-mm specimen is also shown in Figure 11.

"The first dorsal fin is heavily pigmented, and the pigmentation at the tip of the snout is more extensive. The number of chromatophores along the lower jaw has increased and chromatophores now extend over two-thirds of the length of the mandible. The chromatophore at the symphysis of the pectoral girdle still persists, and the pigmentation over the rest of the body remains unchanged.

"There are 13 spines in the first dorsal fin, the length of the longest spine being greater than half the distance between the dorsal-fin insertions. The second dorsal and anal fins each contains 13 rays. The finlets are poorly developed, but 8 and 7 finlet radials are clearly evident in the dorsal and anal, respectively. The rest of the fins also show an increase in the number of rays." (Matsumoto 1958.)

Wade (1950a) and Jones (1960) described juvenile

Fig. 12 E. affinis ranging in length from 24.5 to 156 mm (Fig. 12). In the 24.5 mm specimen 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 specimen and in the 33.5 mm (Fig. 12b) is light brown dorsally and becomes paler toward the midline. A dark longitudinal band is present along the lateral midline.

"The body is pale ventrally and the pigmentation extends only slightly below the midline of the sides. The first dorsal is uniformly dark brown for the first three or four anterior spines. On the remaining spines the dark color is confined to the distal margin of the fin and approaches the base only near the posterior spine. Basally, the rest of the fin varies from almost entirely colorless to a light brown. The first dorsal is never uniformly colored and the other fins are colorless. The head is lightly colored with dark areas on the nape, operculum, and anterior half of the snout. There is a conspicuous crescent-shaped, light area behind the eye." (Wade 1950a.)

According to Wade the color of the body and the head darkens as the fish grows larger. "From 9 to 13 darker vertical bars begin to develop dorsally on the body at about 60 mm. fork length. These bars extend downward on the sides, becoming lighter laterally In some specimens they reach only to the midline of the sides, while in others they extend well below the midline. The head becomes almost

uniformly dark except for a light area posterior to the eye. The first dorsal retains the color pattern of the smaller specimens. The anterior spines and the tips of the posterior spines are dark brown, and the basal part of the fin is lighter in color. The second dorsal is lightly pigmented on the basal half of the fin at about 70 mm. and becomes slightly darker as the fish grows larger. Pectøral and caudal fins are progressively more pigmented as the size increases. The remaining fins are colorless.

"There are 16 spines in the first dorsal and the posterior spine almost reaches the base of the second dorsal. The second dorsal has 12 to 14 rays (mostly 13) and 8 finlets. The anal fin has 13 or 14 rays (13 in one specimen) and 7 anal finlets. In the smallest specimens the interradial membrane partly connects the finlets. This connecting membrane has almost disappeared by the time the fish is 70 mm. in length, and is absent in the large specimens.

"The gill rakers are small and difficult to count in the smaller specimens, and the full complement has not yet developed. The gill-raker count on a 35 mm. specimen was 4+1+20, increasing to 7-8+1+22-23 in specimens of 127 to 175 mm." (Wade 1950a.)

From all indications it appears that the distribution of all the different life stages of E. affinis and the other two species of Euthynnus appear 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.

Larval and juvenile E. affinis are widely distributed in the Indo-Pacific area (Fig. 13). As many investigators have observed in the past (e.g., Matsumoto 1959) it appears that generally larval and juvenile E. affinis are taken close to land masses. However, adult E. affinis do occur around oceanic islands and the larvae have also been taken in these areas. There also are a few captures of larval fishes in mid-ocean localities but the chances are these were carried away from coastal areas by the prevailing currents.

Fig. 13

In the coastal waters of southern Japan Yabe et al. (1953) indicate that pre-adults ranging in length from 150 to 250 mm are taken from August to October near Aburatsu, Kyushu. Pre-adults also constitute a regular part of the commercial catch in other areas. In the fishery for E. affinis off the southwest coast of Ceylon (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 pre-adult E. affinis from various fish markets.

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

Fig. 14

In a 4.6 mm specimen of E. alletteratus (Fig. 14), "there is no visible indication of spine or ray development in the unpaired fins. Instead, the fins are represented by a continuous membrane which starts in the region of the nape and extends around the caudal end of the body to the anal opening. The body contains 40 myomeres including the urostyle; the urostyle itself is undeveloped and extends posteriorly in line with the longitudinal axis of the body.

"Chromatophores are present at the symphysis of the pectoral girdle and along the midventral line immediately anterior to the anal opening. The head is fairly well pigmented, with about 3 chromatophores over the forebrain and about 12 over the midbrain. A row of 3 or 4 well-spaced chromatophores is already evident over the middle two-thirds of the length of the lower jaw. About 11 are more or less evenly spaced along the midventral line in the posterior half of the body." (Matsumoto 1959.)

A 5.5-mm specimen (Fig. 14) shows the development of four short spines in the first dorsal fin. "The second dorsal, anal, and caudal fins are beginning to develop, and the urostyle has turned upward. The chromatophores along the margin of the lower jaw have increased in number, and they extend over the anterior two-thirds of the jaw length. There are 9 chromatophores on the midventral line from the anal fin orgin to the caudal peduncle. Each ramus of the upper and lower jaws bears about 14 teeth." (Matsumoto 1959.)

A 7.5-mm specimen (Fig. 14) "has 9 very long spines in the first dorsal fin, compared with only 6 spines on a 6.5-mm. specimen. Other fins are also well developed, with 12 or 13 rays in the second dorsal, 14 rays in the anal, and about 17 rays in the caudal fin. Although it is difficult to distinguish each ray, the basal elements or pterygiophores are clearly formed and can be counted accurately. Each ramus of the upper and lower jaws contains about 16 teeth. There are about 40 myomeres in the body.

"A marked increase in pigmentation is noted on the first dorsal fin. 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 in number, and they now appear closer together. Seven chromatophores are present over the forebrain, and 25 over the midbrain. The row of pigmentation along the midventral edge of the body consists of about 11 regularly spaced chromatophores. On some specimens there are as many as 15 chromatophores. In addition to these, several small chromatophores are present at the tips of the snout and lower jaw." (Matsumoto 1959.)

The most noticeable change in a 9.3-mm specimen (Fig. 14) "is the extremely long spines in the first dorsal fin. As in lineatus of comparable size, the length of the longest spine almost equals the body depth measured at the origin of the second dorsal fin. Both the second dorsal and anal fins have 13 rays, the pterygiophores of which are clearly visible. Similarly, the pterygiophores of the dorsal

and anal finlets are clearly noticeable. The caudal fin rays are well developed, and the posterior edge of the fin now shows signs of becoming forked. The pectoral fins consist of about 9 completely formed rays, and the ventral fins, which were present on the 5.5-mm specimen as small fleshy buds, are beginning to enlarge with the development of a definite outer spine.

"Pigmentation on the first dorsal fin is restricted to the outer half of the fin membrane, but the number of chromatophores has increased to 22 and they extend over 8 interspinous membranes. An increase in pigmentation over the midbrain is also noted, and 4 light, well-spaced chromatophores are evident on the side of the head posterior to the eye. The rest of the head pigmentation appears unchanged from the previous specimen. The series of chromatophores along the midventral line shows some variation, and on this specimen only 6 chromatophores are present; 4 located along the posterior part of the anal fin base and 2 evenly spaced chromatophores located at the bases of the fourth and sixth anal finlets. Each ramus of the upper jaw now bears 20 teeth, and that of the lower jaw has 18; the number of myomeres is identical with that of the previous specimens." (Matsumoto 1959.)

Matsumoto noted many changes in a 10.6-mm and 11.5-mm specimen. Both specimens had 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 was more clearly forked and the pelvic fins were longer. The 11.5-mm specimen had 20+19 vertebrae.

"The increase in pigmentation is evident in several places. The margin of the lower jaw bears two rows of chromatophores and the upper jaw has a single row of chromatophores along two-thirds of its length. The larger of the 2 specimens has a third row of chromatophores along the anterior half of the lower jaw. About 4 or 5 closely grouped chromatophores are seen at the angle of the jaws, and about 8 large chromatophores are present on the surface of the opercle posterior to the eye. A band of pigment, about 4 chromatophores wide, is seen along the dorsal edge of the body. This band tapers to a single row of chromatophores at about the twelfth dorsal spine and continues to the origin of the second dorsal finlet. The first sign of pigmentation, 1 or 2 chromatophores along the midlateral line of the body, is seen between verticals through the anterior and posterior end of the second dorsal fin. About 10 chromatophores are present along the bases of the anal fin and the first 4 anal finlets." (Matsumoto 1959.)

Matsumoto (1959) also described postlarval and juvenile

Fig. 15 E. alletteratus ranging in length from 12.0 to 58.0 mm (Fig. 15). The pigmentation along the dorsal and ventral edges of the body and along the mid-lateral line noted in the 10.6- and 11.5-mm specimen was also evident in the 12.0-mm specimen. Distinctive changes occurred between the 12.0- and 18.5-mm specimen. 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

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 specimen resembles that of an adult and the body is narrower, relative to the total length than in the 18.5-mm specimen. For specimens larger than 26.0 mm the only noticeable change is in the increased pigmentation on the body. At about 40 mm in total length, 1 to 3 very faint spots or ventral bars appear along the dorsal third of the body. The number of bars increase to about 10 in a 58.0-mm specimen and to 13 on a 94.3-mm fish.

Richards and Dove (1971) described in detail the internal development of young E. alletteratus ranging in length from 3.5 to 24.0 mm. Anatomical features of E. alletteratus were described and compared with that 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 and 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 and VL is vertebral column length.

The distribution of larval and juvenile E. alletteratus is shown in Figure 13. 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 lack of records of larval E. alletteratus from further 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 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 mid-ocean records of E. alletteratus larvae.

Richards and Simmons (1971) suggest 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 of the larvae at night to the vertical migration of the larvae to the surface at night.

Marchal (1963) states that along the coast of the Ivory Coast and Ghana postlarval and juvenile E. alletteratus are found on the surface from 2 to around 100 miles off the coast. Marchal makes the observation that thos postlarval and juvenile fish found out to

100 miles offshore were probably taken out by the currents because no adults were found beyond the continental shelf. He states that these young forms of all sizes were taken from October to July and that they may be present all year. Marchal observed that pre-adult 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, Ben Tuvia, and Gottlieb (1959) captured pre-adults 80-240 mm long from the end of June to the middle of August. Also in the Mediterranean area Demir (1963) reported the catch of pre-adult 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 pre-adults in the Dardanelles from the middle of August to the end of the first week in October.

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

c. Euthynnus lineatus

The smallest larval E. lineatus identified by Matsumoto (1959) measured 5.0 mm (Fig. 16). The head is relatively large (about 37% of total length) and the mouth is also large and contains about 8 teeth on each side of both jaws.

Fig. 16

"The abdominal sac is short and triangular, and the anus is located near the middle of the body. No indications of spine or ray development in the first dorsal and other fins are noticeable, and the pelvic fins are just emerging as small, fleshy buds. The body contains 38 or 39 myomeres including the urostyle which is just beginning to turn dorsally.

"Pigmentation consists of chromatophores at the symphysis of the pectoral girdle and anterior to the anal opening. Each side of the brain is well pigmented with 12 to 15 chromatophores over the midbrain and 3 over the forebrain. Two chromatophores are present on the midventral line of the body along the base of the anal fin, and 2 more are seen faintly in the region of the middle anal "finlets". The lower jaw is unpigmented at this stage of development." (Matsumoto 1959.)

A 6.0-mm specimen is also shown in Figure 16. "Five short spines are visible in the region of the first dorsal fin and posterior to these, 2 more are beginning to develop. The second dorsal and anal fin rays are poorly developed and are difficult to distinguish, but about 11 pterygiophores are observable. The caudal fin consists of 17 rays.

"The chromatophores over the forebrain and midbrain have increased in number, but the pigmentation on the caudal region remains unchanged. Three or 4 chromatophores are present near the middle of the lower jaw." (Matsumoto 1959.)

Figure 16 shows a 7.1-mm specimen. "The first dorsal fin consists of 7 definite spines, the 6 anterior ones being the slightly greater in length. Three additional weak spines are beginning to develop. The fin rays are poorly formed, but 11 pterygiophores are developed in the second dorsal fin and 12 in the anal fin. Similarly, about 5 indistinct basal elements of the dorsal finlets and 2 basal elements of the anal finlets are beginning to develop. The caudal fin, which is beginning to fork, has 18 well-developed rays, and the number of myomeres (38-39) is identical with that of the previous specimens.

"Some striking changes are seen in the pigmentation. The first dorsal fin now has 6 large chromatophores between the second and sixth spines, and the first interspinal membrane is lightly tinged. In addition to the chromatophores at the tips of the upper and lower laws, there are 7 more along the anterior two-thirds of the lower jaw. Pigmentation over the forebrain and midbrain is more extensive, and several small chromatophores are present on the opercle posterior to the angle of the jaw. Although the figure does not show them, 2 small chromatophores are present at the symphysis of the pectoral girdle." (Matsumoto 1959.)

Compared to the 7.1-mm specimen, a 9.1-mm specimen (Fig. 16) has a well-developed dorsal fin. "The first dorsal fin consists of 12 well-developed spines; the longest one being about 78 percent of the body depth at the origin of the second dorsal fin.

"The second dorsal fin consists of 11 rays and the 8 finlets following it are not fully developed; each finlet being attached to its neighbor by persistent elements of the median fin membrane. The first finlet is also attached to the last ray of the second dorsal fin. The anal fin, with 12 rays, and the 7 finlets following it are also connected in a similar way. The enlarged pelvic fins are almost completely developed, and the pectorals now have about 14 distinct rays.

"Pigmentation on the first dorsal fin extends over the first 8 interspinal membranes and is generally concentrated on the outer two-thirds of the fin. A single small chromatophore is present near the base of the last ray of the second dorsal fin, and pigmentation on other parts of the body remain relatively unchanged. The myomere count is 38 or 39." (Matsumoto 1959.)

A 10.6-mm postlarval E. lineatus is shown in Figure 17. "The abdominal sac has elongated, and the anal opening is only slightly anterior to the anal fin origin. The unpaired fins are almost fully developed and consist of 15 spines, 12 rays, and 8 finlets in the dorsal, and 11 rays and 7 finlets in the anal. The caudal fin contains the same number of rays, whereas the pectoral fin now consists of 20 well-developed rays.

"Pigmentation over the forebrain and midbrain is more intense, but remains generally unchanged on other parts of the head, on the first dorsal fin, and at the bases of the second dorsal and anal fins. The only new pigmentation is along the base of the first dorsal fin, where a row of small, close-set chromatophores is now evident." (Matsumoto 1959.)

The 18.6-mm juvenile shown in Figure 17 is already similar in body shape to larger juveniles. "This is due mostly to a gradual reduction in the head depth relative to the body length and to the elongation of the abdominal sac, so that the anal opening is closer to the anal fin origin. Other changes, though not quite as prominent, can be seen in the more forward termination of the posterior margin of the upper jaw. In smaller specimens the end of the maxillary extends beyond a vertical through the posterior margin of the pupil. On the 18.6-mm. specimen, however, the end of the maxillary does not quite reach the vertical through the posterior margin of the pupil.

"On the 18.6-mm specimen the fins and finlets are more clearly defined. The dorsal fins consist of the full adult complement of 15 spines and 12 rays, followed by 8 finlets, whose tips are free from each other. The bases of the finlets, however, are still connected by a membrane. The anal fin, consisting of 12 rays, is followed by 7 finlets which are developed similarly to their dorsal counterparts. The caudal fin is well developed and more deeply forked, and the pelvic fins are longer. The pectorals, with 24 completely formed rays, are comparable to the full developed fins (24 to 26 rays) of the adults.

"Further additions of pigmentation are noted on this specimen. The dorsal part of the body has a wide band of chromatophores which tapers posteriorly to the base of the fifth dorsal finlet. A row of small chromatophores is also present along the midlateral line

of the body. These chromatophores extend from the tip of the pectoral fin to a vertical through the base of the fourth dorsal finlet. The series of chromatophores along the bases of the anal fin and finlets and also along the lower jaw remains relatively unchanged. Two widely separated chromatophores are seen near the middle of the upper jaw, and the snout, forebrain, midbrain and the surface of the opercle posterior to the eye show increased pigmentation." (Matsumoto 1959.)

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

Larval and postlarval E. lineatus are almost as widely distributed as the adults in the eastern tropical Pacific Ocean (Fig. 13). They have been recorded as far north as lat. 29°45'N (Point Antonio, Baja California) to the vicinity of Malpelo Island (04°00'N, 81°35'W) (Calkins and Klawe 1963). The larvae have also been 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 miles of the mainland.

3. Adults

a. 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 1 to 3 lb (0.4-1.4 kg) 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 the National Marine Fisheries Service in Honolulu E. affinis have survived for more than 14 months (Magnuson 1965). Stevens and Fry (1971) reported making body temperature determinations on E. affinis that had been in captivity for 2 years. These observations perhaps demonstrate the hardiness or adaptability of E. affinis. Calkins and Klawe (1963) state that the hardiness of E. lineatus is similar to that of other tunalike fishes and that "Fishes are hardy enough to be successful in their natural environment, but they can only stand a minimum of handling."

b. Competitors

The competitors of E. affinis in east African waters include skipjack tuna, K. pelamis, small yellowfin tuna, frigate mackerel, Auxis thazard, and a carangid, Megalaspis cordyla (Williams 1963). These fishes are found schooled together with E. affinis off east Africa in the Indian Ocean. In waters around Ceylon (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) states that E. alletteratus competes with the species with which it is found such as A thazard and S. sarda. He also suggests the dolphins, Delphinus and other cetaceans, Grampus and Globicephalus, which feed on anchovy, as probable competitors.

In the eastern tropical Pacific E. lineatus is found in close association with yellowfin tuna, skipjack tuna, and dolphin fish, Coryphaena, among others and all these species undoubtedly compete with E. lineatus for food (Calkins and Klawe 1963).

c. Parasites

Silas (1967a) and Silas and Ummerkutty (1967) made detailed surveys on, among others, parasitism in Euthynnus. They found that the three species of Euthynnus were parasitized by various copepods, digenetic trematodes, and monogenetic trematodes (Table 13). Calkins and Klawe (1963) also found that E. lineatus was parasitized by a trematode Hirudinella marina, which was found in the stomach. Postel (1954) also listed the parasites of E. alletteratus (Table 14). Thomas (1968) described a new parasitic copepod, Caligus krishnai from the gills of E. affinis.

Table 13

Table 14

d. Biochemistry

Malvin and Vander (1967) determined the plasma renin activity in E. affinis. They pointed out that there is general ageement that fresh-water fishes contain renin in their kidney 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 enzymetic action of renin.

It was determined that the renin activity, expressed as angiotensin-equivalents, was 23.3 and 15.8 nanograms per milliliter of plasma for two specimens of E. affinis. Graham (1973) determined the thermal profile of E. lineatus, which uses a centrally located vascular heat exchanger to maintain core body temperatures warmer than ambient temperature of seawater. He also described the structure of the central heat exchanger and the effect of temperature changes in blood-gas relationships in E. lineatus. Graham found a warm central core in E. lineatus which was related to the distribution of red muscle in the fish. The warmest body temperatures occurred along the vertebral column between the first and second dorsal fins. The heat exchanger 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 Cary 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 fish probably achieves a marked independence from environmental temperature that permits them to make rapid horizontal and vertical migrations without the necessity of thermal acclimation.

Stevens and Fry (1971) determined the body temperatures of two E. affinis that had been held in captivity for 2 years (Table 15). They found that captivity reduced the excess temperature of E. affinis.

Table 15

Magnuson (1970) made a detailed study of the hydrostatic equilibrium of E. affinis. The study was based on morphometric and body density measurements of fish 31.6-67.8 cm long and on 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 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 his model (Magnuson 1970) 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 the 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.

Klawe, Barrett, and Klawe (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 with 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 in the blood of E. lineatus was somehow related to its complex cutaneous vascular system which S. japonicus and S. chiliensis lack.

e. Body temperature and other observations

Carey et al. (1971) state that the tunas, including E. alletteratus, have evolved a countercurrent heat-exchanger 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.

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 kg (mean) and ranged from 1.55 to 1.88 liter/min 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.kg/liter and ranged from 0.90 to 1.20. Oxygen uptake was determined to be 503 mg/h kg (mean) and ranged from 400 to 643. The calculated utilization 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 discussed its possible function as a light receptor to control phototactic movements of the fish.

4. Age and growth

a. 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 months old. Wade (1950a) speculated that a 115 mm long specimen from the Celebes Sea was 3 or 4 months old and that a 175 mm specimen may have been spwaned as long as 6 months before its capture. These observations suggest a growth rate of 1.0 to 1.3mm/day.

Yabe et al. (1953) presented length data of pre-adult E. affinis landed at the port of Aburatsu, Japan during August-October 1950 (Table 16, 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. It is of interest that this growth rate is not very different from that suggested for E. affinis juveniles in the Philippines.

Table 16
Fig. 18

Ommanney (1953) made observations on 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.

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 17. Landau, using the graphical method, estimated that the L_∞ for E. affinis in the Red Sea was 580 mm (standard length).

Table 17

On the basis of annular marks on the first dorsal spine of E. affinis Shabotiniets (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

The length-weight relationships determined for E. affinis from various locations in the Indo-Pacific are given in Table 18.

Table 18

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 weigh 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 19 lb (8.6 kg). 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 years old. The fish was 620 mm long (standard length) and weighed a little over 5 kg (11 lb).

b. Euthynnus alletteratus

Houde and Richards (1969) made observations on the growth of larval E. alletteratus under laboratory conditions. They collected fertilized eggs in the western edge of the Gulf Stream near Miami, Florida and incubated and hatched the eggs in 20- and 140-gal aquaria. The growth in length of the larvae in one of their rearing
Fig. 19 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 year (Group 0)	<30 cm
1 to 2 years (Group 1)	30-45 cm
2 to 3 years (Group 2)	45-60 cm
3 to 4 years (Group 3)	60-75 cm
Over 4 years	>75 cm

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 diameter 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 19. Landau also estimated L_∞ for E. alletteratus as 840 mm using the graphical method on size obtained by back-calculations.

Table 19

The length-weight relationships determined for E. alletteratus from various localities are given in Table 18.

With regard to the maximum size of E. alletteratus, Fowler (1936) in his description of the species based on specimens from the West Indies indicates that they grow to 1,220 mm. The largest specimen measured by Postel (1956) in the Mediterranean Sea off Tunisia was 1,015 mm but he noted that he had seen many exceeding a meter in length. In the tropical eastern Atlantic the largest specimen measured by Postel (1955a) in Senegal was 946 mm. Landau (1965) noted that the oldest E. alletteratus in her samples belonged to age group X and was estimated to be about 860 mm (standard length). The world record sport catch for E. alletteratus is a specimen 92.07 cm long and weighing 9.12 kg (20 lb) (International Game Fish Association no date).

c. 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 20).

Table 20

The length-weight relationship for E. lineatus computed by Klawe and Calkins (1965) is given in Table 18. The largest E. lineatus collected by Calkins and Klawe was a male 636 mm long which weighed 10.5 lb (4.8 kg).

5. Nutrition

Observations on various aspects of feeding and related observations have been made on species of 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. This phalanx attacked the ball of dwarf herring without altering their tight

orientation. 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 make a move 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 aginst 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 fishes 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 6:00 p.m. and returned at 10:30 a.m. the next day.

Wicklund's (1968) observations have similarities and differences from observations made by Hiatt and Brock (1948). Hiatt and Brock observed a group of three E. affinis herding a closely packed school of several hundred scads, Decapterus sanctae-helenae over a large

coral head in Rongerik lagoon in the northern Marshall Islands. Hiatt and Brock 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 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 their 3-h observational period. Wicklund's observations are 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 aggressively attacked their prey whereas the E. affinis observed by Hiatt and Brock merely picked off the stragglers. In this regard Wicklund's observations are more similar to those made by Kishinouye (1923). Kishinouye noted that E. affinis is a voracious feeder and described their feeding method whereby they dart swiftly into a school of small fish and scatter them. As Kishinouye 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/sec while feeding with an observed maximum of 10.0 body lengths/sec. 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 observed that the feeding mechanism is drag-free and that E. affinis feeds by swimming over its prey rather than by sucking it in. 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 mm. They noted that, in terms of gill-raker gap, E. affinis was intermediate (ranked fifth, going from small to large) compared with K. pelamis, Auxis rochei, A. thazard, Scomber japonicus, Thunnus albacares, T. alalunga, T. obesus, Sarda chiliensis, Sarda orientalis, Coryphaena equiselis and C. hippurus, ranked from small to large, respectively. Magnuson and Heitz 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.

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, for E. affinis, Ronquillo (1954) found that they fed about equally on crustaceans (56.2% by number) and fish (43.8% by number) in Philippine waters. Ronquillo found no squid in the stomachs. Around Hawaii Tester and Nakamura (1957) also found that squid was negligible in the diet of E. affinis but unlike the Philippine area, fish was much more important (91.8% by volume) than crustaceans (8.2% by volume) in the diet. In the Indian Ocean Kumaran (1964) found that squid (56.5% by volume) was most important, followed by fish (38.3% by volume) and crustaceans (5.2% by volume) 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 fish (22% by number) and squid (11% by number). Heteropods and tunicates made up 4% by number of the diet.

Table 21

Table 21 presents examples of food items found in stomachs of Euthynnus from various areas. It can be seen in Table 21 that Postel (1954) listed E. alletteratus, presumably a juvenile from the stomach of adult E. alletteratus.

E. BEHAVIOR

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/sec while feeding with a maximum of 10.0 body lengths/sec. The non-feeding swimming speed, with food present, averaged 4.5 body lengths/sec and ranged from 2.9 to 12.5 body lengths/sec.

Magnuson (1969) investigated the swimming activity of captive E. affinis as related to search for food in outdoor tanks. He determined that the average swimming speed of E. affinis averaging about 35 cm long was 80 cm/sec during the day and 83 cm/sec 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 months 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/sec) and the mean speed during the night (72 cm/sec). Magnuson also measured the swimming speed of E. affinis in tanks containing several thousand live prey fish. These fish appeared to swim faster than those without food, averaging 108 cm/sec during the day and 92 cm/sec at night. Magnuson notes that the higher day speeds were caused from intermittent high-speed pursuit of the prey. E. affinis did not prey on the baitfish at night.

Magnuson 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 Magnuson 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 with the requirements for maintaining hydrostatic equilibrium and gill ventilation than for food search.

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

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 visual acuity the 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 conducted these experiments on K. pelamis also and noted that

Fig. 20

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 lowest mean threshold was 7 db/1 microbar at 500 Hz. At 100 Hz the threshold was 30 db/1 microbar higher than at 500 Hz and at 1,100 Hz it was 23 db/1 microbar 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.

Fig. 21

Footnote 2

Steffel et al. (MS)[2] conducted experiments on captive E. affinis to determine their ability to discrimate 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.

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, Yuen, Takata 1954; Hsiao and Tester 1955; Tester, Van Weel, and Naughton 1955; and 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 ft candles). E. 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 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 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 the E. affinis were feeding. Nakamura and Magnuson suggested that these transient color patterns may act as social releasers to signal the presence of food to other members of the school.

The many experiments conducted on E. affinis suggests that this species is quite adaptable to various environmental conditions. It is not known whether the other species of Euthynnus have been subjected to similar experimental conditions as E. affinis. However, it would not be surprising of E. alletteratus and E. lineatus were as adaptable as E. affinis.

Aspects of the schooling behavior of Euthynnus relative to feeding have been discussed in an earlier section. Other observations on the schooling behavior of Euthynnus indicate 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, A. thazard, and a carangid Megalaspis cordyla (Williams 1963). Williams noted, however, that all the individuals in the schools were of much the same size. He also found that with small E. affinis (size?) "the schooling is strong and disciplined."

Elsewhere in the Indian Ocean Williams (1963) noted that in waters around Ceylon (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 other catches are almost always mixed. Fourmanoir (1957) observed that around Madagascar schools of E. affinis were almost always distinct from 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 Ceylon (Sri Lanka) as many as 5,000 individuals (mixed E. affinis and Auxis spp.) may be taken in one haul of a beach seine.

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 are often schooled with other species, including A. thazard, Sarda sarda, and Selar crumenophthalmus. All the individuals in these mixed schools tend to be of the same size (Marchal 1963).

E. lineatus in Peruvian waters are frequently found schooled 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 the E. lineatus will frequently collect around drifting or anchored tuna boats. Calkins and Klawe noted that T. albacares and K. pelamis also exhibit this type of behavior but they believe that this behavior pattern is 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 object only for short periods and they did not swim as close to the objects as did the other small fishes associated with the objects. They could not ascertain whether the schools of E. lineatus were truly associated with a particular object.

Wickham, Watson, and Ogren (1973) investigated the efficacy of midwater artificial structures for attracting pelagic sport fish in the Gulf of Mexico near Panama City, Florida. With equal experimental fishing effort they obtained significantly greater catches of E. alletteratus around the artificial structures than in adjacent control areas. However, Wickham et al. 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.

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. E. 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. Cahn concluded that hydrodynamic contact is essential for the typical spacing and positional orientation in schooling and that the lateral line, as the water turbulence detector, plays a prime regulatory role.

V. RESOURCE

It was noted earlier that the species of Euthynnus generally has little or no commercial value. In many localities it appears that the typical fishery for Euthynnus is a multi-species fishery. It is not very clear whether the Euthynnus or the other species of tunas that are taken with them are the main objective of these fisheries. Euthynnus are usually schooled together with other species of tunas and sometimes non-tunas and the use of non-selective gear and fishing methods probably accounts for the mixed catches. However, there is some evidence of differential schooling habits by size 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 be schooled with other species (Williams 1963). Williams also noted that in Madagascar, Somalia, Seychelles, West Pakistan, Sri Lanka and the west coast of India E. affinis are prime objectives of fisheries and specific attempts are made to catch this species.

A. DESCRIPTION OF FISHERIES

1. Euthynnus affinis

Based on the FAO Yearbook of Fishery Statistics (FAO 1974a) only five countries have fisheries for E. affinis, two in the western Pacific and three in the Indian Ocean, probably including the Red Sea. It appears, however, that there are other countries bordering the Indian Ocean with fisheries for E. affinis that somehow are not listed in the FAO Yearbook (FAO 1974b). Consolidating the

listings of both sources (FAO 1974a, 1974b) countries with E. affinis fisheries in the Indian Ocean include Bangladesh, India, Israel (probably Red Sea) Maldives, Pakistan, Sri Lanka (Ceylon) and Yemen. In the western Pacific the Philippines and Malaysia have fisheries for E. affinis (FAO 1974a).

Silas (1967b) described the "multiple trolling" tuna fishery off the southeast coast of India (Gulf of Mannar). This is a multi-species fishery and in addition to E. affinis, a number of other species are taken (Table 22). The vessels used in the fishery are known as Tuticorin-type boats which are small sail-boats ranging in length from 27 to 34 feet (8.2 to 10.4 m). 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.

Table 22

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, Thomas, and Pillay 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 25-40 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 tuna are taken in this fishery. The other species are A. thazard, A. thynnoides, S. orientalis, Thunnus tonggol, T. albacares and K. pelamis. Bennet states that E. affinis is one of the most important commercial species at Vizhingam. The principal gear used were cotton and nylon drift nets and hook and line. Shore seines were occasionally used also. During a period from July 1960 to October 1961, Bennet noted that 71.4% of the landings of E. affinis was made by drift nets and 24.3% by hook and line. Only 4.3% was made 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, longlines and beach seines (Sivasubramaniam 1966, 1970). In West Pakistan the fishing methods used are trolling, longlines, handlines and beach seines (Qureshi 1952). In Madagascar, 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 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 by trolling 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, a fish marketing organization in Hong Kong 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 MT of E. affinis were landed in the two years 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 only incidentally in the live-bait pole-and-line K. pelamis fishery.

In the higher latitudes of the southern hemisphere Indian Ocean, specifically around coastal South Africa and southwest Australia, E. affinis occurs and is fished only 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° to 30°C). In northern Somalia the fishery is conducted during the northeast monsoon at the time of minimum surface temperature. In West Pakistan, west coast of India and Sri Lanka, E. affinis is taken throughout the year with slight local variations (Williams 1963). Bennet (1964) found that good landings of E. affinis occur during the eight months from October to May and the period of low catches is from June to September (Table 23) 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) describes a somewhat more complex situation of the seasonality of the E. affinis fishery in Sri Lanka (Fig. 22). The seasonal picture around Sri Lanka is complicated by two 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.

Table 23

Fig. 22

Off east Africa, around the Comoro Island and Madagascar E. affinis is taken throughout the year (Williams 1963). E. 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 150 to 250 mm 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. 23) 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.

Fig. 23

In troll fishing conducted off the northeast coast of Oahu, Hawaii from 1951-1955 Tester and Nakamura (1957) reported that no E. affinis were taken during December to April. Their data showed a peak in the catch rate (catch per hour) in October. However, Tester and Nakamura cautioned that the fact that no E. affinis were taken during December to April cannot be regarded as significant because 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 indicates higher landings from October to April (Fig. 24). The results obtained by Tester and Nakamura (1957) and Welsh (1949) are not inconsistent with

Fig. 24

those shown in Fig. 24. Thus it appears that around Hawaii E. affinis may be less available during May to September and more available from October to April.

2. Euthynnus alletteratus

In the Atlantic Ocean and the Mediterranean Sea the FAO Yearbook of Fishery Statistics (FAO 1974a) lists the following countries that had landings of E. alletteratus: Angola, Bulgaria, Cyprus, Israel, Liberia, Romania, Spain, Turkey, United States of America, Venezuela, and Yugoslavia.

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

The fisheries for E. alletteratus along the east coast of Africa apparently are not well developed (Marchal 1963). E. alletteratus 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). In the islands of Saint Thomas 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 U.S. 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 1951-1961 E. alletteratus has been harvested commercially in pound nets and hand seines. However, the annual landings statistics given by Mansueti and Mansueti were minimal (less than 6 MT 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).

In the Gulf of Gobés, 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). And in Morocco Postel states 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. 25) indicate

Fig. 25

that this species is caught throughout the year with two peaks in landings, one in May and the other in October. Rodriguez-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 24). The various seasonal peaks in the Mediterranean fisheries suggest that this species may make seasonal migratory movements.

Table 24

Off the coast of Senegal in the eastern Atlantic E. alletteratus arrives in large numbers in January-February and May-June (Postel 1955b). They are present all year round in the region of Cape Vert (Marchal 1963). Off the Ivory Coast Marchal states that E. alletteratus are found throughout the year along the coastline but that the catches peak in February. And in Angola he states that E. alletteratus are caught starting in October, the catches peak in February and March and the catches become nonexistent in May-June.

In the eastern Atlantic Chilton (1949) suggests that E. alletteratus makes seasonal migrations along the U. S. coast. Although E. alletteratus appear to be found throughout the year in southern waters, in the winter they have been seen in large schools off South Carolina, Georgia, and Florida. In May and June they have been reported moving north to North and South Carolina and in August and September they have been caught on the coast of New Jersey and New York. Observations made during September 1952 to August 1953 on anglers' catches landed at Miami, Florida

indicate that 87% of the catches were made from March through August with a peak in July (de Sylva and Rathjen 1961). De Sylva and Rathjen state 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 northward along the coast during the summer.

3. Euthynnus lineatus

E. lineatus are not fished commercially in the eastern tropical Pacific except for the small numbers that are 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. E. lineatus has been taken by tuna purse seines, by line bait pole-and-line fishing, commercial and sport trolling gear, and by trolled hand lines. E. lineatus are taken by commercial tuna vessels of all sizes, from small albacore trollers to large purse seiners and bait boats, and by Ecuadorian and Peruvian canoe and raft fishermen (Calkins and Klawe 1963).

E. lineatus are 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) cite 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.

B. POPULATION STRUCTURE

1. 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 Fig. 26. The E. affinis taken by the commercial fishery ranges from 20 to 65 cm. Occasionally fish in the 15-20 cm and 65-68 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 size 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 4"-6" (10.2-15.2 cm) in Sri Lanka made these nets less selective. Sivasubramaniam indicated that the use of 4"-6" (10.2-15.2 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 40-55 cm, this fishing method tends to select E. affinis of the same size range which are found together with K. pelamis. Finally, Sivasubramaniam 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

Fig. 26

the gear used. This probably holds true for the other two species in Euthynnus which are also coastal fishes.

The length-frequency distribution of E. affinis caught
Fig. 27 by trolling along the southeast coast of India is shown in Figure 27. 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
Table 25 coast of India is given by Bennet (1964) (Table 25). The gear used in this fishery includes drift nets and hook and line (presumably trolling gear). Shore seines are occasionally used. The fish caught during the sampling period measured from 15 to 70 cm. Bennet noted that the smallest fish were taken in October 1960 by shore seine. He further stated that the smaller size 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
Table 26 Williams (1963) are shown in Table 26.

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. 28).

Fig. 28

During the abortive E. affinis fishing and marketing experiment described earlier E. affinis measuring 23-73 cm were taken by the 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 to 7.0 kg) and the other less numerous group was composed of fish 38-44 cm long (1.2-2.5 kg) (Williamson 1970).

In the Philippines the size of E. affinis taken by trolling on research vessels is shown in Figure 29. 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 E. affinis much smaller. Wade (1950a) reported finding E. affinis as 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 1975[3]) is given below:

Fig. 29

Footnote 3

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 30 and 31, respectively.

Figs. 30,31

The sex ratios of E. affinis in various localities are given in Table 27. 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.

2. Euthynnus alletteratus

The length-frequency distributions of juvenile E. alletteratus caught in the Sea of Marmara and the Dardanelles are shown in Figure 32. These juveniles were taken in 1959 and apparently were the first records of juvenile E. alletteratus in Turkish waters (Demir 1963). The juveniles caught in the Sea of Marmara were slightly smaller (mode at 20 cm) than the fish taken in the Dardanelles (mode at 23 cm).

Fig. 32

Rodriguez-Roda (1966) presented length-frequency distributions of E. alletteratus landed at Barbate and Tarifa, Spain in 1963 and 1964 (Fig. 33). Rodriguez-Roda smoothed the percentage frequency of the various length classes by the formula, $f_n = \frac{f_{n-1} + 2 f_n + f_{n+1}}{4}$. 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
Fig. 34 9 kg (Fig. 34). Thus, in 1963 both the length- and weight-frequency distributions indicated only a single size group in the fishery but in 1964, in terms of length, three size groups were represented in the landings and only two size groups in terms of weight.

Postel (1955b) presented the length-frequency distribution
Fig. 35 of E. alletteratus taken in the eastern Atlantic off Senegal (Fig. 35). He stated that the fish in the length group from 30 to 45 cm were 1 to 2 years old and those from 60 to 75 cm were 3 to 4 years old. He noted that fish 45-60 cm long (2 to 3 years old) were not found in the area off Cape Vert, Senegal. However, Marchal (1963) stated that E. alletteratus from 50 to 70 cm were found in normal proportion off the coast of Guinea.

The length-frequency distribution of E. alletteratus caught by sport fishermen on charter boats off Miami, Florida is shown
Fig. 36 in Figure 36. In Figure 37 is shown the length-frequency distribution
Fig. 37 of E. alletteratus taken by commercial trolling gear between North Carolina and northern Florida. The length range of fish generally landed by the Miami sport fishery (Fig. 36) 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 of mortality beginning at that size between

the sexes. They also found that the E. alletteratus taken by commercial trolling gear 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. De Sylva and Rathjen suggested several causes for the disparity in the length-frequency distributions from the two areas. They suggested that the commercial trolling gear possibly selected a certain size range of fish by the use of only a certain range of hook sizes. Carlson (1951) suggested that the commercial trolling gear possibly selected a certain size range of fish by the use of only a certain range of hook sizes. He indicated that the selectivity was possibly due to the loss of smaller fish caused by the hooks pulling free more easily from smaller fish. De Sylva and Rathjen 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. 38). These fish were sampled at a Florida taxidermy firm during a period from September 1967 to September 1968. Beardsley and Richards 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.

Fig. 38

A comparison of the length-frequency data presented by de Sylva and Rathjen (1961) (Fig. 36) with that of Beardsley and Richards (Fig. 38), however, does not clearly indicate that larger fish were being selected in the samples obtained by Beardsley and Richards.

The sex ratio of E. alletteratus in various localities
Table 28 is given in Table 28.

3. Euthynnus lineatus

There is almost no information on the size of E. lineatus. The length-frequency distribution of E. lineatus used by Godsil
Fig. 39 (1954) in his study of the Euthynnus is given in Figure 39. No information is available on the sex ratio of E. lineatus.

C. LANDINGS

With the exception of the Philippines where a fair amount of E. affinis is landed, the species of Euthynnus are nowhere the basis of important or large commercial fisheries. To illustrate the magnitude of the fisheries for Euthynnus, from 1965 to 1973 the total world landings for all the species fluctuated from 14,500 to 45,400 MT
Fig. 40 (Fig. 40). In comparison, the annual world production of K. pelamis has been from 300,000 to 350,000 MT in 1966-71 (Matsumoto 1974).

In Fig. 39 is also plotted the total world landings of E. affinis and E. alletteratus from 1965 to 1973. The world landings of E. affinis varied from 6,700 to 37,300 MT annually and that of E. alletteratus from 4,600 to 12,900 MT. E. affinis constituted 46.2% to 85.8% of the total annual world landings of Euthynnus during this period. The FAO Yearbook of Fishery Statistics (e.g., FAO 1974a) does not include any landings figures for E. lineatus.

It should be pointed out, however, that the world production of Euthynnus as indicated by the statistics given above is probably underestimated. At least two factors contribute to this underestimate. First, the FAO Yearbook of Fishery Statistics does not include country landings that are less than 100 MT. Therefore the landings of Euthynnus from fisheries which are typically small in many areas are not included in the FAO statistics. Secondly, it may happen that because the landings of Euthynnus are small, they are lumped together with other species of tunas or together with other miscellaneous species so that the landings are not identifiable to species. Other problems associated with collecting catch statistics in the Indian Ocean are discussed in FAO (1973). Thus the landings figures of Euthynnus are probably not only underestimated but are subject to inaccuracies.

Table 29

The landings of E. affinis from 1965 to 1973 in the Pacific and Indian Oceans are given in Table 29. As noted earlier, the Philippines has one of the larger fisheries for Euthynnus. The Philippine landings of E. affinis fluctuated from 8,900 to 32,800 MT during 1965 to 1973. (Apparently, no landings were reported in 1972.) The landings in Malaysia fluctuated between 3,100 and 5,600 MT during the same period. Although the FAO Yearbook of Fishery Statistics does not show any E. affinis landings, according to Bennet (1964) landings of this species in Vizhingam, India ranged from 85.7 to 205.8 MT during 1956 to 1960 (see Table 23). In Hawaii where E. affinis is taken incidentally in the pole-and-line fishery for K. pelamis, the

landings fluctuated between 8.0 and 22.0 MT during the 11-year period from 1964 to 1974. In Japan landings figures for E. affinis are not readily available because they are combined with the landings of other species (Kikawa and staff 1963).

The world landings of E. alletteratus during 1965 to 1973 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 1965 to 1973 the total annual landings of E. alletteratus in the western Atlantic did not exceed 300 MT. In the eastern Atlantic during the same period the total annual landings fluctuated between 4,600 and 12,000 MT, and in the Mediterranean-Black Sea area the landings did not exceed 900 MT during the same period.

Although the FAO Yearbook of Fishery Statistics does not show any landings of E. alletteratus for Tunisia or Morocco, Postel (1964) indicated 400-500 tons of this species are landed in Tunisia and 200-300 tons in Morocco. In the Ivory Coast Marchal (1963) reported that 113 tons were landed in 1957, 268 tons in 1958 and 267 in 1959.

As already noted no landings of E. lineatus appear in the FAO Yearbook of Fishery Statistics. Calkins and Klawe (1963) stated that most of the landings of E. lineatus are probably made by small boats in Latin America and that these landings 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).

D. ABUNDANCE

Probably because of the relative unimportance of the species of Euthynnus as commercial species very little 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 that the catch rates of E. affinis showed a high degree of variability within four subareas along the southwest coast which he attributed to the seasonal changes in the 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 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 the 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 in the southwest coast of Sri Lanka. These landings did not include those made by the non-mechanized boats. Sivasubramaniam indicated that there is evidence of differential distribution of E. affinis by size and that it could be possible to alter the size of first capture by avoiding areas occupied by small fish. He indicated that the annual yield of the fishery could be considerably increased by doing this.

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

Marchal (1963) indicated that the catches of E. alletteratus that have been made has had no effect on the populations of this species. He noted that the manner in which this species is fished has little impact on the existing stocks. Rodriguez-Roda (1966) presented long-term landings data of E. alletteratus in the Spanish fishery covering a period from 1929 to 1964 (Fig. 41). The landings are given in numbers of fish and show wide annual fluctuations but no significant trends.

E. 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 status of the species in the genus, very little has been done to investigate the subpopulation problem within this group. Based on various published works on 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 Cape 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, spills over into the Atlantic south to Morocco and perhaps extends as far north as the Gulf of Gascony, France.

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 variations 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.

LITERATURE CITED

ANDERSON, W. W.

1954. Progress report, South Atlantic Fishery Investigations, Appendix SA-2. In Atlantic States Marine Fisheries Commission, 13th Annual Meeting, Baltimore, Part 2, p. 211-213. [Mimeogr.]

ANGOT, M.

1959. Tuna fishing investigations in the South Pacific. South Pac. Comm. Quart. Bull., Oct., 7 p.

BAISSAC, J. de B.

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

BEARDSLEY, G. L., JR., and W. J. RICHARDS.

1970. Size, seasonal abundance, and length-weight relation of some scombrid fishes from southeast Florida. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 595, 6 p.

BELLOC, G.

1955. Mediterranean tunas. Part 2. Little tunas and striped-bellied bonito. [In Fr., Engl. abstr.] Proc. Tech. Pap. Gen. Fish. Counc. Mediter. 3:471-485.

BENNET, P. S.

1964. Euthynnus affinis affinis (Cantor) in the Vizhingam fisheries. Part II. Proc. Symp. Scombroid Fishes, p. 708-711. Mar. Biol. Assoc. India, Mandapam Camp.

BEN-TUVIA A.

1957. Pelagic fisheries in Israel. Proc. Tech. Pap. Gen. Fish. Counc. Mediter. 4:383-391.

BINI, G.

1952. Osservazioni sulla fauna marina delle coste del Cile e del Peru con speciale riguardo alle specie ittiche in generale ed ai tonni in particolare. Boll. Pesca Piscic. Idrobiol. 7:11-60.

BLACKBURN, M.

1965. Oceanography and the ecology of tunas. In H. Barnes (editor), Oceanography and marine biology--an annual review 3:299-322, George Allen and Unwin, Lond. [Summ. Jap. transl. by M. Uda, In Bull. Jap. Soc. Fish. Oceanogr. 8:109-119.]

BRANDHORST, W.

1958. Thermocline topography, zooplankton standing crop, and mechanisms of fertilization in the eastern tropical Pacific. J. Cons. Cons. Int. Explor. Mer 24:16-31.

BRIGGS, J. C.

1958. A list of Florida fishes and their distribution. Bull. Fla. State Mus. 2(8):223-318.

BULLIS, H. R., JR.

1955. Observations on schooling juvenile tuna, Euthynnus alletteratus, in the Gulf of Mexico. Copeia 1955:153.

BULLIS, H. R., JR., and R. JUHL.

1967. Phalanx orientation in feeding behavior of the little tuna Euthynnus alletteratus. Trans. Am. Fish. Soc. 96:122-125.

BUNAG, D. M.

1956. Spawning habits of some Philippine tuna based on diameter measurements of the ovarian ova. Philipp. J. Fish. 4:145-177.

CADENAT, J.

1950. Poissons de mer du Sénégal. Init. Afr. 3, 345 p.

CAHN, P. H.

1972. Sensory factors in the side-to-side spacing and positional orientation of the tuna, Euthynnus affinis during schooling. Fish. Bull., U.S. 70:197-204.

CALKINS, T. P., and W. L. KLAWE.

1963. Synopsis of biological data on black skipjack Euthynnus lineatus Kishinouye 1920. FAO Fish. Rep. 6, 2:130-146.

CAREY, F. G., J. M. TEAL, J. W. KANWISHER, K. D. LAWSON, and J. S. BECKETT.

1971. Warm-bodied fish. Am. Zool. 11:137-145

CARLSON, C. B.

1951. Exploratory fishing for the little tuna, Euthynnus alletteratus, off the coast of the United States. Proc. Gulf Carib. Fish. Inst., 4th Annu. Sess., p. 89-94.

CHACKO, P. I., S. D. THOMAS, and C. M. PILLAY.

1967. Scombroid fisheries of Madras State, India. Proc. Symp. Scombroid Fishes, Part III, p. 1006-1008. Mar. Biol. Assoc. India, Mandapam Camp.

CHAPMAN, W. M.

1946. Observations on tuna-like fishes in the tropical Pacific. Calif. Fish Game 32(4):165-170.

CHEN, S.-C., and T.-H. TAN.

1973. A preliminary report on occurrence of tuna larvae in waters adjacent to Taiwan and South China Sea. Rep. Inst. Fish. Biol. Minis. Econ. Affairs and Natl. Taiwan Univ. 3(1): 158-171.

CHILTON, C. H.

1949. "Little tuna" of the Atlantic and Gulf coasts. Fish. Leafl., Wash. 353:1-5.

CLEMENS, H. B.

1956. Rearing larval scombrid fishes in shipboard aquaria. Calif. Fish Game 42(1):69-79.

1957. Fishes collected in the tropical eastern Pacific. Calif. Fish Game 43(4):299-307.

COLLETTE, B. B., and L. N. CHAO.

1975. Systematics and morphology of the bonitos (Sarda) and their relatives (Scombridae, Sardini). Fish. Bull., U.S. 73: 516-625.

COLLETTE, B. B., and R. H. GIBBS, JR.

1963. A preliminary review of the fishes of the family Scombridae. FAO Fish. Rep. 6, 1:23-32.

CROMWELL, T.

1958. Thermocline topography, horizontal currents and "ridging" in the eastern tropical Pacific. [In Engl. and Span.] Inter-Am. Trop. Tuna Comm., Bull. 3:133-164.

CROMWELL, T., and E. B. BENNETT.

1959. Surface drift charts for the eastern tropical Pacific Ocean. [In Engl. and Span.] Inter-Am. Trop. Tuna Comm., Bull. 3:214-237.

CUSHING, J. E.

1956. Observations on serology of tuna. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 183, 14 p.

da COSTA, F. C., and F. FRADE.

1958. Investigações sobre os peixes de superficie e a pesca nas ilhas de Sao Thomé e do Principe. Commun. Int. W. Afr. Conf. 6(4):151-168.

DELSMAN, H. C.

1926. Fish eggs and larvae from the Java Sea. 9. Scomber kanagurta. Treubia 8:395-399.

1931. Fish eggs and larvae from the Java Sea. 18. The genus Cybium, with remarks on a few other Scombridae. Treubia 13(304): 401-410.

DEMIR, M.

1961. Note on Germo alalunga Gml. and Euthynnus alletteratus Raf. in the Sea of Marmara. Proc. Tech. Pap. Gen. Fish. Counc. Mediter. 6:219-220.

DEMIR, M.

1963. On the juveniles of Euthynnus alletteratus Raf. appeared in Turkish waters in 1959. Rapp. P.-V. Reun. Comm. Int. Explor. Scient. Mer Mediter. 17:375-377.

de SYLVA, D. P., and W. F. RATHJEN.

1961. Life history notes on the little tuna, Euthynnus alletteratus, from the south-eastern United States. Bull. Mar. Sci. Gulf Caribb. 11:161-190.

EHRENBAUM, E.

1924. Scombriformes. Rep. Dan. Oceanogr. Exped. Mediter. (Biology) 2(8):1-42. (In German. Partial translation, pp. 1-11 and 31-42 not translated. Transl. available U.S. Dep. Interior, English Translations of Fishery Literature. Mis. Ser. 112.)

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS.

1973. Report of the first session of the IPFC/IOFC ad hoc working party of scientists on stock assessment of tuna, Rome, 7-9 June 1972. FAO Fish. Rep. 137, 17 p.

1974a. Yearbook of fishery statistics. Catches and landings, 1973. FAO 36, 590 p.

1974b. Report of the second session of the IPFC/IOFC ad hoc working party of scientists on stock assessment of tuna. FAO Fish. Rep. 152.

FITCH, J. E.

1952. Distributional notes on some Pacific coast marine fishes. Calif. Fish Game 38(4):557-564.

1953. Extensions to known geographical distributions of some marine fishes on the Pacific coast. Calif. Fish Game 39(4): 539-552.

FOURMANOIR, P.

1957. Poissons téléostéens des eaux malgaches du Canal de Mozambique. Mém. Inst. Sci. Madagascar (F), 1:1-316.

FOWLER, H. W.

1936. The marine fishes of West Africa based on the collection of the American Museum Congo Expedition, 1909-1915. Bull. Am. Mus. Nat. Hist. 70:607-1493.

1938. The fishes of the George Vandebilt South Pacific Expedition, 1937. Monogr. Acad. Nat. Sci. Phila. 2:31-33, 253, 277.

1944. Results of the Fifth George Vanderbilt Expedition (1941). Monogr. Acad. Nat. Sci. Phila. 6:349, 373-374, 378, 498.

FRADE, F., and E. POSTEL.

1955. Contribution a l'étude de la reproduction des scombridés et thonidés de l'Atlantique tropical. Rapp. P.-V. Reun. Cons. Int. Explor. Mer 137:33-35.

FRASER-BRUNNER, A.

1949. On the fishes of the genus Euthynnus. Ann. Mag. Nat. Hist. Ser. 12, vol. 2:622-627.

FRASER-BRUNNER, A.

1950. The fishes of the family Scombridae. Ann. Mag. Nat. Hist. Ser. 12, vol. 3:131-163.

GODSIL, H. C.

1954. A descriptive study of certain tuna-like fishes. Calif. Dep. Fish Game, Fish Bull. 97, 185 p.

GORBUNOVA, N. N.

1965a. O nereste skumbrievidnykh ryb (Pices, Scombroidei) v Tonkinskom zalive Yuzhno-Kitaiskogo moria. [In Russ., Engl. summ.] [On spawning of scombroid fishes (Pisces, Scombroidei) in the Gulf of Tonkin, South China Sea.] Trudy, Inst. Okeanol. 80:167-176.

1965b. Sroki i usloviya razmnozheiya skumbrievidnykh ryb (Pisces, Scombroidei). [In Russ.] [The spawning seasons and conditions of scombroid fishes (Pisces, Scombroidei.] Trudy Inst. Okeanol. 80:36-61. (Engl. transl. available National Marine Fisheries Service, Washington, D. C., 28 p.)

GORBUNOVA, N. N., and D. SALABARRIA.

1967. Razmnozhenie skumbrievidnykh ryb (Pisces, Scombroidei) vzapadnykh rayonakh Atlanticheskogo okeana. [In Russ., Span. summ.] [Reproduction of scombroid fishes (Pisces, Scombroidei) in western Atlantic, p. 120-131.] In Sovetsuo-kubinskie Rybokhozyaistvennye Issledovaniya. Pishchevaya Promyshlennost', Moscow, 263 p. (Engl. transl. by W. L. Klawe, Inter-American Tropical Tuna Commission.)

GRAHAM, J. B.

1973. Heat exchange in the black skipjack and the blood-gas relationship of warm-bodied fishes. Proc. Natl. Acad. Sci. U.S.A. 70:1964-1967.

1975. Heat exchange in the yellowfin tuna, Thunnus albacares, and skipjack tuna, Katsuwonus pelamis, and the adaptive significance of elevated body temperatures in scombrid fishes. Fish. Bull., U.S. 73:219-229.

HERRE, A. W.

1932. A check list of fishes recorded from Tahiti. Pac. Res. Inst., J. 7(1):2-6, Pan Pacific Union, Honolulu, Hawaii.

HIATT, R. W., and V. E. BROCK.

1948. On the herding of prey and schooling of the black skipjack, Euthynnus yaito Kishinouye. Pac. Sci. 2:297-298.

HIGGINS, B. E.

1970. Juvenile tunas collected by midwater trawling in Hawaiian waters, July-September 1967. Trans. Am. Fish. Soc. 99:60-69.

HOLMES, R. W., M. B. SCHAEFER, and B. M. SHIMADA.

1957. Primary production, chlorophyll and zooplankton volumes in the eastern tropical Pacific Ocean. [In Engl. and Span.] Inter-Am. Trop. Tuna Comm., Bull. 2:127-169.

HOUDE, E. D., and W. J. RICHARDS.

1969. Rearing larval tunas in the laboratory. Commer. Fish. Rev. 31(12):32-34.

HSIAO, S. C.

1952. Reaction of tuna to stimuli--1951. Part III. Observations on the reaction of tuna to artificial light. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 91:36-58.

HSIAO, S. C., and A. L. TESTER.

1955. Reaction of tuna to stimuli--1952-53. Part 2. Response of tuna to visual-chemical stimuli. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 130:63-76.

HUNTER, J. R., and C. T. MITCHELL.

1967. Association of fishes with flotsam in the offshore waters of Central America. U.S. Fish Wildl. Serv., Fish. Bull. 66: 13-29.

INOUE, M., Y. IWASAKI, R.AMANO, M. AOKI, and M. YAMAUTI.

1970. Ecology of various tunas under captivity--II. Behaviour of tuna shown against light and darkness. [In Jap., Engl. abstr.] J. Coll. Mar. Sci. Technol. Tokai Univ. 4:53-58.

INTERNATIONAL GAME FISH ASSOCIATION.

n.d. 1975 world record marine fishes. Compiled and published by the International Game Fish Association, 3000 East Las Olas Blvd., Fort Lauderdale, Fla.

IVERSEN, R. T. B.

1967. Response of yellowfin tuna (Thunnus albacares) to underwater sound. In W. N. Tavolga (editor), Marine Bio-Acoustics 2:105-119, discussion, p. 119-121. Proceedings of the Second Symposium on Marine Bio-Acoustics held at the American Museum of Natural History, N.Y., April 13-15, 1966. Pergamon Press, Oxford and New York.

IVERSEN, R. T. B.

1969. Auditory thresholds of the scombrid fish Euthynnus affinis, with comments on the use of sound in tuna fishing. In A. Ben-Tuvia and W. Dickson (editors), Proceedings of the FAO Conference on Fish Behaviour in Relation to Fishing Techniques and Tactics, Bergen, Norway, 19-27 October 1967. FAO Fish. Rep. 63, 3:849-859.

JONES, S.

1960. Notes on eggs, larvae and juveniles of fishes from Indian waters--V. Euthynnus affinis (Cantor). Indian J. Fish. 7:101-106.

JONES, S., and M. KUMARAN.

1964. Eggs, larvae and juveniles of Indian scombroid fishes. Proc. Symp. Scombroid Fishes, Part I, p. 343-378. Mar. Biol. Assoc. India, Mandapam Camp.

JONES, S., and E. G. SILAS.

1964. A systematic review of the scombroid fishes of India. Proc. Symp. Scombroid Fishes, Part I, p. 1-105. Mar. Biol. Assoc. India, Mandapam Camp.

JONKLAAS, R.

1967. Scombroid fishes and fisheries of the Maldive Islands with special reference to the tuna fishery. Proc. Symp. Scombroid Fishes, Part III, p. 1132-1138. Mar. Biol. Assoc. India, Mandapam Camp.

KAZANOVA, I. I.

1962. Lichinki tuntsov tropicheskoi zony Atlanticheskogo okeana (Tuna larvae of the tropical zone of the Atlantic Ocean.) [In Russ.] Vop. Ikht. 2(3)(24):451-461. (Translated by Kr. Fr. Wiborg, Branch of Reports, U.S. Bur. Commer. Fish., Wash., D.C.)

KIKAWA, S.,and STAFF OF THE NANKAI REGIONAL FISHERIES RESEARCH LABORATORY

1963. Synopsis of the biology of little tuna Euthynnus yaito Kishinouye 1923. FAO Fish. Rep. 6, 2;218-240.

KISHINOUYE, K.

1920. Mexican little tunny. [In Jap.] Suisan Gakkai Hō. Proc. Sci. Fish. Assoc., Tokyo 3(2):113.

1923. Contributions to the comparative study of the so-called scombroid fishes. J. Coll. Agric., Tokyo Imp. Univ. 8:293-4575.

KLAWE, W. L.

1960. Larval tunas from the Florida Current. Bull. Mar. Sci. Gulf Caribb. 10:227-233.

1961. Young scombroids from the waters between Cape Hatteras and Bahama Islands. Bull. Mar. Sci. Gulf Caribb. 11:150-157.

1963. Observations on the spawning of four species of tuna (Neothunnus macropterus, Katsuwonus pelamis, Auxis thazard, and Euthynnus lineatus) in the eastern Pacific Ocean, based on the distribution of their larvae and juveniles [In Engl. and Span.] Inter-Am. Trop. Tuna Comm., Bull. 6:448-540.

KLAWE, W.L., I. BARRETT, and B. M. H. KLAWE.

1963. Haemoglobin content of the blood of six species of scombroid fishes. Nature 198:96.

KLAWE, W. L., and T. P. CALKINS.

1965. Length-weight relationship of black skipjack tuna, Euthynnus lineatus. Calif. Fish Game 51:214-216.

KLAWE, W. L., J. J. PELLA, and W. S. LEET.

1970. The distribution, abundance and ecology of larval tunas from the entrance to the Gulf of California. [In Engl. and Span.] Inter-Am. Trop. Tuna Comm., Bull. 14:507-544.

KLAWE, W. L., and B. M. SHIMADA.

1959. Young scombrid fishes from the Gulf of Mexico. Bull. Mar. Sci. Gulf Caribb. 9:100-115.

KUMARAN, M.

1964. Studies on the food of Euthynnus affinis affinis (Cantor), Auxis thazard (Lacépède), Auxis thynnoides Bleeker and Sarda orientalis (Temminck & Schlegel). Proc. Symp. Scombroid Fishes, Part II, p. 599-606. Mar. Biol. Assoc. India. Mandapam Camp.

LAEVASTU, T., and H. ROSA.

1963. Distribution and relative abundance of tunas in relation to their environment. FAO Fish. Rep. 6, 3:1835-1851.

LANDAU, R.

1965. Determination of age and growth rate of Euthynnus alletteratus and E. affinis using vertebrae. Rapp. P.-V. Reun. Comm. Int. Explor. Scient. Mer Mediter. 18:241-243.

MAGNUSON, J. J.

1965. Tank facilities for tuna behavior studies. Progr. Fish-Cult. 27:230-233.

1969. Swimming activity of the scombrid fish, Euthynnus affinis as related to search for food. In A. Ben-Tuvia and W. Dickson (editors), Proceedings of the FAO Conference on Fish Behaviour in Relation to Fishing Techniques and Tactics, Bergen, Norway, 19-27 October 1967. FAO Fish. Rep. 63, 2:417-429.

1970. Hydrostatic equilibrium of Euthynnus affinis, a pelagic teleost without a gas bladder. Copeia 1970:56-85.

1973. Comparative study of adaptations for continuous swimming and hydrostatic equilibrium of scombroid and xiphoid fishes. Fish. Bull., U.S. 71:337-356.

MAGNUSON, J. J., and J. G. HEITZ.

1971. Gill raker apparatus and food selectivity among mackerels, tunas, and dolphins. Fish. Bull., U.S..69:361-370.

MAGNUSON, J. J., and J. H. PRESCOTT.

1966. Courtship, locomotion, feeding and miscellaneous behaviour of Pacific bonito (Sarda chiliensis). Anim. Behav. 14:54-67.

MAIS, K. F., and T. JOW.

1960. Exploratory longline fishing for tunas in the eastern topical Pacific, September, 1955 to March, 1956. Calif. Fish Game 46(2):117-150.

MALVIN, R. L., and A. J. VANDER.

1967. Plasma renin activity in marine teleosts and Cetacea. Am. J. Physiol. 213:1582-1584.

MANSUETI, R. J., and A. J. MANSUETI.

1962. Little tuna, Euthynnus alletteratus, in northern Chesapeake Bay, Maryland, with an illustration of its skeleton. Chesapeake Sci. 3:257-263.

MARCHAL, E.

1961. Quelques observations complementaires sur les dur les Scombridae peches par le PYRRUS. Bull. Inst. Franc. Afr. Noire 23A:102-107.

1963. Expose synoptique des connees biologiques sur la thonine Euthynnus alletteratus (Rafinesque) 1810 (Atlantique Oriental et Mediterranee). [In Fr.] FAO Fish. Rep. 6, 2:647-662.

MATSUMOTO, W. M.

1958. Description and distribution of larvae of four species of tuna in central Pacific waters. U.S. Fish Wildl. Serv., Fish. Bull. 58:31-72.

1959. Descriptions of Euthynnus and Auxis larvae from the Pacific and Atlantic Oceans and adjacent seas. Dana Rep. 50:1-34.

1974. The skipjack tuna, Katsuwonus pelamis, an underutilized resource. Mar. Fish. Rev. 36(8):26-33.

1976. Second record of black skipjack, Euthynnus lineatus from the Hawaiian Islands. Fish. Bull., U.S.

MATSUMOTO, W. M., and T. KANG.

1967. The first record of black skipjack, Euthynnus lineatus, from the Hawaiian Islands. Copeia 1967:837-838.

MEAD, GILES W.

1951. Postlarval Neothunnus macropterus, Auxis thazard, and Euthynnus lineatus from the Pacific coast of Central America U.S. Fish Wildl. Serv., Fish. Bull. 52:121-127.

MIYAKE, I.

1952. Reaction of tuna to stimuli--1951. Part IV. Observations on sound production and response in tuna. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 91:59-68.

MIYAKE, I., and W. R. STEIGER.

1957. The response of tuna and other fish to electrical stimuli. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 223, 23 p.

MORGANS, R.

1956. World sea fisheries. Mondon, Methuen and Co., Ltd., 307 p.

MORI, K., Y. MORITA, Y. NISHIKAWA, and Y. FURUYA.

1969. Chapter 4. Research on distribution of coastal fishes. In Report on Fishing Survey in the Bismarck-Solomon Seas by Shunyo-maru, October-December, 1968. [In Jap., Engl. synop.] Far Seas Fish. Res. Lab. S Ser. 1:18-97 and 166-170.

MORICE, J., and J. CADENAT.

1952. Distribution of fish species in the French West Indies. In Fisheries of the Caribbean, Caribbean Comm., Rep. Fish. Conf., Kent House, Trinidad, March 24-28, p. 102-122.

MORROW, J. E., JR.

1954. Data on dolphin, yellowfin tuna, and little tuna from East Africa. Copeia 1954:14-15.

NAKAMURA, E. L.

1968. Visual acuity of two tunas, Katsuwonus pelamis and Euthynnus affinis. Copeia 1968:41-49.

NAKAMURA, E. L., and J. J. MAGNUSON.

1965. Coloration of the scombrid fish Euthynnus affinis (Cantor). Copeia 1965:234-235.

NAKAMURA, E. L., and W. M. MATSUMOTO.

1967. Distribution of larval tunas in Marquesan waters. U.S. Fish Wildl. Serv., Fish. Bull. 66:1-12.

NOWELL, J. C.

1961. New northern record for black skipjack (Euthynnus lineatus). Calif. Fish Game 47(4):415.

OGILVIE, H. W., A. FRASER-BRUNNER, and D. L. BYRD.

1954. Report to the government of Italy as the administering authority for the trust territory of Somalia on the exploratory fishery survey in Somalia - 1952/53. Rep. FAO/ETAP 288, 83 p.

OMMANNEY, F. D.

1953. The pelagic fishes and a note on two nettings. In Report on the Mauritius-Seychelles fisheries survey 1948-49. Part II. G. B. Colonial Off. Fish. Publ. 1(3):58-104.

OREN, O. H., A. BEN-TUVIA, and E. GOTTLIEB.

1959. Experimental tuna fishing cruise in the eastern Mediterranean. Proc. Tech. Pap. Gen. Fish. Counc. Mediter. 5:269-279.

PADOA, E.

1956. Divisione; Scombriformes. [In Ital.] In 38. Monografia--Uova, larve e stadi giovanili di Teleostei. Fauna Flora Golfo Napoli, p. 471-521. [Eggs, larvae, and juvenile stages of the Scombriformes (in part) of the Gulf of Naples.] (Engl. transl. by J. P. Wise and G. M. Ranallo, 1967, 49 p., transl. No. 12; Tropical Atlantic Biological Laboratory, Bur. Commer. Fish., Miami.)

PARIN, N. V.

1967. O sutochnykh izmeneiiakh vstrechaemosti lichinok nekotorykh okeanicheskikh ryb u poverkhnosti vody. [In Russ.] Okeanologiia 7(1):148-156. Diurnal variations in the larval occurrence of some oceanic fishes near the ocean surface. Oceanology 7(1): 115-121.

POSTEL, E.

1950. Peche sur les cotes d'Afrique occidentale. Rapport et note sur quelques poissons de surface de la presquiile de Cap-Vert. Inspection generale de l'elevage, Dakar, French West Africa 2:1-77.

1954. Contribution a l'etude des Thonides de l'Atlantique tropical. J. Cons. Cons. Int. Explor. Mer 19:356-362.

POSTEL, E.

1955a. Contribution a l'etude des Thonides de l'Atlantique tropical (deuxieme note). Rapp.P.-V. Reun. Cons. Int. Explor. Mer 137:31-32 (SS/1c).

1955b. Contribution a l'etude de la biologie de quelques Scombridae de l'Atlantique tropico-oriental. Ann. Sta. Oceanogr. Salammbo 10, 168 p. (SS/1b and 15c).

1956. Donnees biometriques sur quelques Scombrides tunisiens. Bull. Sta. Oceanogr. Salammbo 53:50-61 (SS/1a).

1962. L'evolution de la peche au thons les japonais dans l'Atlantique. Peche Marit. 1013:579-583.

1964. Les thonides d'Afrique du nord. Proc. Symp. Scombroid Fishes, Part I, p. 211-220. Mar. Biol. Assoc. India, Mandapam Camp.

POTTHOFF, T., and W. J. RICHARDS.

1970. Juvenile bluefin tuna, Thunnus thynnus (Linnaeus), and other scombrids taken by terns in the Dry Tortugas, Florida. Bull. Mar. Sci. 20:389-413.

QURESHI, M. R.

1952. Fishes of Medran coast. Agric. Pakist. 3(4):1-20.

RANDALL, J.

n.d. Fishes of the Gilbert Islands. Dep. Zool. Ent., Univ. Hawaii. Submitted as a report for t e Office of Naval Research Contract No. 695(00), 243 p.

RAO, K. V. N.

1964. An account of the ripe ovaries of some Indian tunas. Proc. Symp. Scombroid Fishes, Part II, p. 733-743. Mar. Biol. Assoc. India, Mandapam Camp.

RICHARDS, W. J., and G. R. DOVE.

1971. Internal development of young tunas of the genera Katsuwonus, Euthynnus, Auxis, and Thunnus (Pisces, Scombridae). Copeia 1971:72-78.

RICHARDS, W. J., and W. L. KLAWE.

1972. Indexed bibliography of the eggs and young of tunas and other scombrids (Pisces, Scombridae), 1880-1970. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-652.

RICHARDS, W. J., and D. C. SIMMONS.

1971. Distribution of tuna larvae (Pisces, Scombridae) in the northwestern Gulf of Guinea and off Sierra Leone. Fish. Bull., U.S. 69:555-568.

RICHARDS, W. J., D. C. SIMMONS, A. JENSEN, and W. C. MANN.

1969a. Tuna larvae (Pisces, Scombridae) collected in the northwestern Gulf of Guinea, Geronimo Cruise 3, 10 February to 26 April 1964. U.S. Fish Wildl. Serv., Data Rep. 36, 10 p. on 1 microfiche.

1969b. Larvae of tuna and frigate mackerel (Pisces, Scombridae) collected in the northwestern Gulf of Guinea, Geronimo Cruise 4, 5 August to 13 October 1964. U.S. Fish Wildl. Serv., Data Rep. 37, 17 p. on 1 microfiche.

RICHARDS, W. J., D. C. SIMMONS, A. JENSEN, and W. C. MANN.

1970. Larvae of tuna and frigate mackerel (Pisces, Scombridae) in the northwestern Gulf of Guinea and off Sierra Leone, Geronimo Cruise 5, 10 February to 19 April 1965. U.S. Fish Wildl. Serv., Data Rep. 40, 24 p. on 1 microfiche.

RIVAS, L. R.

1951. A preliminary review of the western North Atlantic fishes of the family Scombridae. Bull. Mar. Sci. Gulf Caribb. 1:209-230.

1953. The pineal apparatus of tunas and related scombrid fishes as a possible light receptor controlling phototactic movements. Bull. Mar. Sci. Gulf Caribb. 3:168-180.

RODRIGUEZ-RODA, J.

1966. Estudio de la bacoreta, Euthynnus alletteratus (Raf.) bonito, Sarda sarda (Bloch) y melva, Auxis thazard (Lac.) capturados por las almadrabas expanolas. [Engl. summ.] Investigaciones Pesq. 30:247-292.

ROEDEL, P. M.

1948. Occurrence of black skipjack (Euthynnus lineatus) off southern California. Calif. Fish Game 34(1):38-39.

RONQUILLO, I. A.

1954. Food habits of tunas and dolphins based upon the examination of their stomach contents. Philipp. J. Fish. 2:71-82.

1963. A contribution to the biology of Philippine tunas. FAO Fish. Rep. 6, 3:1683-1752.

ROUGHLEY, T. C.

1951. Fish and fisheries of Australia. Sydney, Angus and Robertson, Ltd., 343 p.

ROUX, C.

1957. Poissons marins. In Mollusques, crustaces, poissons marins des cotes d'A.E.F. en collection au Centre d'Oceanographie et Plinte Noire, par J. Collignon, M. Rossignol et Ch. Roux, Paris, ORSTOM, 369 p.

SANZO, L.

1932. Uova e primi stadi larvali di Pelamys sarda C. V. [In Ital.] Memorie R. Com. Talassogr. Ital. 188:3-9.

SCHAEFER, M. B., and J. C. MARR.

1948. Juvenile Euthynnus lineatus and Auxis thazard from the Pacific Ocean off Central America. Pac. Sci. 2:262-271.

SCHMITT, W. L., and L. P. SCHULTZ.

1940. List of the fishes taken on the presidential cruise of 1938. Smithson. Misc. Coll. 98(25), 10 p.

SEALE, A.

1940. Report on fishes from Allan Hancock Expeditions in the California Academy of Sciences. Allan Hancock Pac. Exped. 9(1):17-18.

SHABOTINIETS, E. I.

1968. Opredelenie vozrasta tuntsov Indiiskogo okeana. Trudy VNIRO, vol. 64, Trudy AzcherNIRO, vol. 28:374-376. (Age determination of Indian Ocean tunas) (Engl. transl. by W. L. Klawe, 1968, Inter-American Tropical Tuna Commission, La Jolla, California.)

SILAS, E. G.

1967a. Parasites of scombroid fishes. Part I. Monogenetic trematodes, digenetic trematodes, and cestodes. Proc. Symp. Scombroid Fishes, Part III, p. 799-875. Mar. Biol. Assoc. India, Mandapam Camp.

1967b. Tuna fishery of the Tinnevelly Coast, Gulf of Mannar. Proc. Symp. Scombroid Fishes, Part III, p. 1083-1118, 3 plates. Mar. Biol. Assoc. India, Mandapam Camp.

SILAS, E. G., and A. N. P. UMMERKUTTY.

1967. Parasites of scombroid fishes. Part II. Parasitic copepoda. Proc. Symp. Scombroid Fishes, Part III, p. 876-993. Mar. Biol. Assoc. India, Mandapam Camp.

SIVASUBRAMANIAM, K.

1966. Distribution and length-weight relationship of tunas and tuna-like fishes around Ceylon. Bull. Fish. Res. Sta. Ceylon 19:27-46.

1970. Biology of the exploited stock of mackerel tuna E. affinis Cantor off the south west region of Ceylon. Bull. Fish. Res. Sta., Ceylon 21, No. 1.

STEVENS, E. D.

1972. Some aspects of gas exchange in tuna. J. Exper. Biol. 56:809-823.

STEVENS, E. D., and F. E. J. FRY.

1971. Brain and muscle temperatures in ocean caught and captive skipjack tuna. Comp. Biochem. Physiol. 38A:203-211.

STRASBURG, D. W.

1960. Estimates of larval tuna abundance in the central Pacific. U.S. Fish Wildl. Serv., Fish. Bull. 60:231-255.

SUND, P. N., and J. A. RENNER.

1959. The Chaetognatha of the Eastropic Expedition, with notes as to their possible value as indicators of hydrographic conditions. [In Engl. and Span.] Inter-Am. Trop. Tuna Comm., Bull. 3:393-436.

SVERDRUP, H. U., M. W. JOHNSON, and R. H. FLEMING.

1942. The oceans. Prentice-Hall, Inc., N.Y., 1087 p.

TESTER, A. L.

1952a. Establishing tuna and other pelagic fishes in ponds and tanks. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 71, 33 p.

1952b. Reaction of tuna and other fish to stimuli-1951. Part I. Background and summary of results. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 91:1-7.

1959. Summary of experiments on the response of tuna to stimuli. In H. Kristjonsson (editor), Modern fishing gear of the world. Fish. News (Books) Ltd., Lond. p. 538-542.

TESTER, A. L., and E. L. NAKAMURA.

1957. Catch rate, size, sex, and food of tunas and other pelagic fishes taken by trolling off Oahu, Hawaii, 1951-55. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 250, 25 p.

TESTER, A. L., P. B. VAN WEEL, and J. J. NAUGHTON.

1955. Reaction of tuna to stimuli, 1952-53. Part 1: Response of tuna to chemical stimuli. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 130:1-62.

TESTER, A. L., H. YUEN, and M. TAKATA.

1954. Reaction of tuna to stimuli, 1953. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 134, 33 p.

THOMAS M. M.

1968. A new parasitic copepod, Caligus krishnai, from the mackerel tuna Euthynnus affinis affinis (Cantor). J. Mar. Biol. Assoc. India 9:137-140, 1 tab.

VAN WEEL, P. B.

1952. Reaction of tuna to stimuli--1951. Part II. Observations on the chemoreception of tuna. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 91:8-35.

WADE, C. B.

1950a. Juvenile forms of Neothunnus macropterus, Katsuwonus pelamis and Euthynnus yaito from Philippine Seas. U.S. Fish Wildl. Serv., Fish. Bull. 51:395-404.

1950b. Observations on the spawning of Philippine tuna. U.S. Fish Wildl. Serv., Fish. Bull. 51:

1951. Larvae of tuna and tuna-like fishes from Philippine waters. U.S. Fish Wildl. Serv., Fish. Bull. 51:445-485.

WALFORD, L. A.

1937. Marine game fishes of the Pacific coast-Alaska to the equator. Univ. California Press, Berkeley, 205 p., 69 plates.

WALTERS, V.

1966. On the dynamics of filter-feeding by the wavyback skipjack (Euthynnus affinis). Bull. Mar. Sci. Gulf Carib. 16:209-221

WARFEL, H. E.

1950. Outlook for development of a tuna industry in the Philippines. U.S. Fish Wildl. Serv., Res. Rep. 28:1-37.

WELSH, J. P.

1949. A trolling survey of Hawaiian waters. Hawaii (Terr.) Div. Fish and Game, Fish. Prog. Rep. I, No. 2, 26 p. (In Fish and Game, Spec. Bull. No. 2, 1950.)

WHITELEADER, R. T., and H. H. BROWN.

1945. An experimental fishery survey in Trinidad, Tobago and British Guinea. Anglo-Am. Caribb. Comm., Wash., 130 p.

WHITLEY, G. P.

1964. Scombroid fishes of Australia and New Zealand. Proc. Symp. Scombroid Fishes, Part I, p. 221-253, 4 plates. Mar. Biol. Assoc. India, Mandapam Camp.

WICKHAM, D. A., J. W. WATSON, JR., and L. H. OGREN.

1973. The efficacy of midwater artificial structures for attracting pelagic sport fish. Trans. Am. Fish. Soc. 102:563-572.

WICKLUND, R. I.

1968. Observations on the feeding behavior of the false albacore. Underwater Nat. 5(2):30-31.

WILLIAMS, F.

1956. Preliminary survey of the pelagic fishes of East Africa. G. B. Colonia Off. Fish. Publ. 8, 67 p.

1963. Synopsis of biological data on little tuna Euthynnus affinis (Cantor) 1850 (Indian Ocean). FAO Fish. Rep. 6, 2:167-179.

1964. The scombroid fishes of East Africa. Proc. Symp. Scombroid Fishes, Part I, p. 107-163. Mar. Biol. Assoc. India, Mandapam Camp.

WILLIAMSON, G. R.

1970. Little tuna Euthynnus affinis in the Hong Kong area. Jap. Soc. Sci. Fish. Bull. 36:9-18.

YABE, H., N. ANRAKU, and T. MORI.

1953. Scombroid youngs found in the coastal seas of Aburatsu, Kyushu, in summer. [In Jap.] Contrib. Nankai Reg. Fish. Res. Lab. 11, 10 p.

ZHAROV, V. L., and A. M. ZHUDOVA.

1969. Nekotorye dannye o vstrechaemosti lichinok skombroiknykh (otriad Perciformes, podotriad Scombroidei) v otkrytoi chast tropicheskoi Atlantiki. [Some data on occurrence of scombroid larvae (Order Perciformes, Suborder Scombroidei) in the open waters of the tropical Atlantic.] [In Russ.] Trudy AtlantNIRO 18:201-214. (Engl. transl. by W. L. Klawe, 1969, 21 p.; Inter-Am. Trop. Tuna Comm., La Jolla, California.)

ZHUDOVA, A. M.

1969a. Materialy po izucheniyu ikry i lichinok nekotorykh vidov ryb Gvineiskogo zaliva i prilegayushchikh vod othrytoi chasti okeana. [In Russ.] [Materials on the study of the eggs and larvae of some species of fish from the Gulf of Guinea and the adjacent waters of the open ocean.] Trudy AtlantNIRO 22:135-163. (Engl. transl. by W. L. Klawe, 1971, 38 p.; Inter-Am. Trop. Tuna Comm., La Jolla, California.)

ZHUDOVA, A. M.

1969b. Lichinki skombroidnykh ryb (Scombroidei, Perciformes) tsentral'noi chasti Atlanticheskogo okeana. [In Russ.] [Larvae of scombrid fishes (Scombroidei, Perciformes) from the central portion of the Atlantic Ocean.] Trudy AtlantNIRO 25:100-108. (Engl. transl. by W. K. Klawe, 1970, 17 p.; Inter-Am. Trop. Tuna Comm., La Jolla, California.)

TEXT FOOTNOTES

[2]STEFFEL, S., A. E. DIZON, J. J. MAGNUSON, and W. H. NEILL. Manuscript in preparation. "Temperature discrimination by captive free-swimming tuna, Euthynnus affinis. Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96812.

[3]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. South China Sea Fisheries Development and Coordinating Programme.

Table 1. Common and vernacular names of Euthynnus affinis.

Country	Standard common name(s)	Vernacular name(s)
Australia	Mackerel tuna, little tuna	-
Ceylon (Sri Lanka)	Lesser bonito, mackerel tuna	Atavalla, Ragodura, Sureya (Sinhalese), Shurai (Tamil).
China	-	Tow chung
Comoro Is.	Bonito	Mibassi, Mpassi
East Africa	Bonito, little tuna	Sehewa (Kiswahili) - also refers to Auxis and Katsuwonus spp.
Hawaii, USA	Little tuna	Bonito, kawakawa
India	-	Choori min, suraly (Tamil); ohaman, chuki (Marathi)
Indochina	-	Ca ngu
Indonesia	-	Tongol, diverg-bonito, tongol komo, poetilai
Japan	Yaito	Suma, hiragatsuwo, doosogatsuwo segatsuwo, sumagatsuwo, watanabe
Madagascar	Bonite	Thonnine
Malaya	-	Tongkol; Ikanayer, Sembak, Choreng, Kembel-mas, Tombalmas (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	-	-

Table 2. Meristic counts of Euthynnus alletteratus (from Godsil 1954).

Meristic character	Count		No. of specimens
	Range	Most common	
1st dorsal spines	10-15	15	7
2d dorsal rays	12-13	13	7
Dorsal finlets	8	8	7
Anal rays	11-15	13-14	7
Gill rakers:			
Upper limb	10-11	10	8
Angle	0-1	1	8
Lower limb	26-28	26	8
Total	37-40	37	8

Table 3. Common and vernacular names of Euthynnus alletteratus.

Country or language	Standard common names	Vernacular names
Abidjan	Bonita	-
Angola	-	Merma
French	Thonine	-
Ghana	-	El'la (Apollonien), Poponkou (Keta)
Guinea	-	Makreni
Ivory Coast	-	Klewe (Kru), bokou-bokou (Alladian)
Mauritania	-	Corrinelo (Vermeulen)
Portuguese	Atun	Fule-fule
Senegal	-	Walaz (Ouolof), dolo-dolo (Lebau)
South Africa	Little tunny, little tuna, mackerel tuna	Merma
Spain	Bacoreta	-
Tunisia	-	R'zem

Table 4. Meristic counts of Euthynnus lineatus (from Godsil 1954).

Meristic character	Count		No. of specimens
	Range	Most common	
1st dorsal spines	13-15	14-15	20
2d dorsal rays	11-12	11	10
Dorsal finlets	8-9	8	20
Anal rays	11-13	11-12	18
Anal finlets	7-8	7	20
Gill rakers:			
Upper limb	7-11	9-10	30
Angle	1	1	28
Lower limb	23-29	26-27	30
Total	32-41	35-38	30
Number of vertebrae	36-38	37	27
Precaudal vertebrae	19-20	20	24
1st complete haemal arch on vert. no.	15-17	15-16	23

TABLE 5

A Tabular Comparison and Evaluation of Suggestive Differences in Three Species of Euthynnus (from Godsil 1954

Character	*E. lineatus*	*E. alletteratus*	E. affinis	Nature differen-
A. EXTERNAL:				
Dorsal markings	Continuous, horizontal bars	Broken horizontal bars	Broken oblique bars	Indicative
Color	Darker or deeper hued than in *alletteratus* or *yaito*	As in *yaito*	As in *alletteratus*	Relative
Belly spots	Larger than in *yaito*	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 *yaito* longer than *alletteratus*	3.65 to 3.89 shorter than *yaito* and *lineatus*	3.44 to 3.60 as in *lineatus* longer than *alletteratus*	Biometrical
Insertion-first dorsal	2.82 to 3.33 more posterior than *alletteratus*, as in *yaito*	3.37 to 3.55 more anterior than in *yaito* and *lineatus*	3.11 to 3.23 as in *lineatus* more posterior than in *alletteratus*	Biometrical
Insertion-second dorsal	1.51 to 1.79 includes *yaito* and *alletteratus*	1.72 to 1.77 as in *lineatus* more anterior than in *yaito*	1.65 to 1.70 as in *lineatus* more posterior than in *alletteratus*	Biometrical
Insertion-Anal fin	1.37 to 1.55 as in *yaito* more posterior than in *alletteratus*	1.57 to 1.61 more anterior than in *yaito* and *lineatus*	1.48 to 1.52 as in *lineatus* more posterior than in *alletteratus*	Biometrical
Insertion-Ventral fin	2.76 to 3.23 as in *yaito* more posterior than in *alletteratus*	3.27 to 3.46 more anterior than in *yaito* 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 *yaito* and overlaps *alletteratus*	2.57 to 3.12 overlaps *lineatus* less than *yaito*	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
B. INTERNAL:				
Ventral view of viscera				
1. Mosaic	Absent	Absent	Present, generally	Indicative
2. Right lobe of liver	Lateral, as in *yaito*	Mesial	Lateral, as in *lineatus*	Doubtful
3. Fat organ	Absent	Absent	Present, generally	Indicative
Ureter				
1. Branches	Large, straight, few collecting tubules as in *yaito*	Generally small, erratic, numerous collecting tubules	Large, straight, few collecting tubules as in *lineatus*	Relative—Questionable
C. SKELETON:				
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
Caudal keels mainly on	31st and 32d vertebrae	33d and 34th vertebrae	33d and 34th vertebrae	Positive
Cranium	1. Dentigerous plate on vomer as in *yaito*	Sharp longitudinal ridge on vomer	Dentigerous plate on vomer, as in *lineatus*	Positive
	2. Supraoccipital crest at lowest point in same horizontal plane as temporal crests, as in *yaito*	Supraoccipital crest at lowest point appreciably higher than temporal crests	Supraoccipital crest at lowest point in same horizontal plane as temporal crests, as in *lineatus*	Relative
	3. Intermediate between *yaito* and *alletteratus*	Longitudinal bridge of bone (see page 162) present in orbit	Longitudinal bridge of bone in orbit, absent	Relative

Table 6. Fecundity of Euthynnus affinis in waters off Vizhingam, India (from Rao 1964).

Length cm	Weight 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

Table 7. Records of larval and juvenile Euthynnus affinis in the Indo-Pacific.

Date	Locality	Number larvae	Number juveniles	Total or fork length (mm)	Reference	Remarks
April 1929	4°03'N, 123°26'E	1	-	-	Matsumoto (1959)	
"	"	3	-	-	"	
"	6°55'N, 114°02'E	15	-	-	"	
"	"	23	-	-	"	
"	"	25	-	-	"	
"	8°02'N, 109°36.5'E	1	-	-	"	
"	"	2	-	-	"	
"	"	42	-	-	"	
May 1929	12°15'N, 109°26'E	1	-	-	"	
"	20°30.5'N, 125°28'E	2	-	-	"	
"	"	2	-	-	"	
June 1929	14°37'N, 119°52'E	1	-	-	"	
July 1929	0°41.5'S, 134°14.5'E	1	-	-	"	
"	"	3	-	-	"	
"	"	2	-	-	"	
"	0°40.5'S, 134°15'E	7	-	-	"	
"	"	3	-	-	"	
"	"	10(?)	-	-	"	
"	"	4	-	-	"	
"	"	4	-	-	"	
"	0°33'S, 134°00'E	11	-	-	"	
"	"	3	-	-	"	
"	"	1(?)	-	-	"	
"	1°01'S, 137°20'E	2	-	-	"	
"	"	3	-	-	"	
"	1°20'S, 138°42'E	1	-	-	"	
"	"	1	-	-	"	
Aug. 1929	7°53'S, 116°18'E	1	-	-	"	
"	"	2(?)	-	-	"	
"	9°09'S, 114°47'E	2	-	-	"	
Sept. 1929	6°22'S, 105°12'E	7(?)	-	-	"	
"	"	13(?)	-	-	"	
"	4°38'S, 99°24'E	1	-	-	"	
"	2°00'S, 98°59'E	1	-	-	"	

Sept. 1929	2°00'S, 98°59'E	1	-	-	"
"	"	2	-	-	"
"	2°07'S, 99°53'E	1	-	-	"
"	1°29'S, 100°07'E	2	-	-	"
"	"	10	-	-	"
"	0°52'S, 99°25'E	1	-	-	"
"	"	11	-	-	"
"	"	7	-	-	"
Oct. 1929	2°57'S, 99°36'E	1	-	-	"
"	3°12'S, 99°26'E	1	-	-	"
Dec. 1929	1°45'N, 71°05'E	1	-	7.08	Jones and Kumaran
"	0°35'N, 66°09'E	1	-	-	(1963) "
"	3°45'S, 56°33'E	2	-	6.05, 7.14	"
"	5°01'S, 54°46'E	1	-	5.94	"
"	8°27'S, 50°54'E	1	-	5.59	"
"	11°55'S, 49°55'E	2	-	4.7	"
"	12°09'S, 49°34'E	8	-	6.62-12.72	"
"	9°10'S, 45°17'E	1	-	6.58	"
"	8°24'S, 42°54'E	3	-	5.14-7.94	"
"	7°24'S, 41°51'E	56	-	4.68-8.75	"
"	4°45'S, 40°10'E	15	-	5.42-12.16	"
Jan. 1930	3°26'S, 42°58'E	34	-	4.74-8.69	"
"	4°21'S, 42°56'E	2	-	6.11	"
"	14°16'S, 41°48'E	3	-	6.79	"
"	16°12'S, 42°04'E	14	-	4.79-9.14	"
"	18°30'S, 42°18'E	1	-	-	"
"	21°13'S, 42°26'E	3	-	5.65-5.88	"
"	23°11'S, 42°54'E	2	-	7.08-8.39	"
"	25°14'S, 36°21'E	29	-	4.62-7.42	"
May 1948	7°02'N, 124°12'E	-	2	33.5, 35	Wade (1950a)
Mar. 1948	Manado, Celebes, Netherlands, East Indies	-	1	115	"
Apr. 1948	Batangas, Luzon, Philippines	-	7	143-178	"
May 1948	Taal, Batangas Province Luzon, Philippines	-	4	127-175	"
"	Batangas, Luzon, Philippines	-	2	40, 44	"
Mar. 1949	"	-	2	40, 68.4	"
"	"	-	1	80	"
Apr. 1949	"	-	1	76.5	"
"	"	-	18	73-112	"
"	"	-	2	117.5-131	"

Sept. 1956	Calicut, India	-	6	72.0-140.0	Jones (1960)	Length given by Jones
Oct. 1956	Vizhingam, India	-	1	116.5	"	is standard length.
Nov. 1956	"	-	1	162.0	"	Jones reported capture
Jan. 1957	"	-	8	34.3-75.0	"	of larger juveniles
May 1958	"	-	2	24.5, 40.6	"	not included here.
June 1958	"	-	1	96.0	"	
Aug. 1956	0°01'S, 133°02'W	-	1	-	Strasburg (1960)	
"	12°31'S, 132°04'W	-	2	-	"	
Jan. 1957	07°55'S, 110°02'W	-	1	-	"	
Feb. 1957	02°58'S, 129°55'W	-	1	-	"	
"	14°57'S, 146°20'W	-	2	-	"	
Mar. 1957	08°12'S, 145°12'W	1	-	-	"	
June 1957	21°11'N, 158°17.5'W	1	-	-	"	
"	21°25'N, 157°21'W	1	-	-	"	
"	21°24.5'N, 159°00'W	1	-	-	"	
Dec. 1957	9°34'S, 139°50'W	2	-	-	Nakamura and Matsumoto (1967)	
Oct. 1960	12°29'N, 43°03'E	215	-	-	Parin (1967)	
July-Aug.60-61	Gulf of Tonkin	22	-	3.5-6.0	Gorbunova (1965a)	
July-Sept. 67	Hawaii	-	25	-	Higgins (1970)	
1968-1971----	(21°30'N-24°45'N) (119°28'E-121°30'E) (03°30'N-12°00'N) (102°45'E-115°15'E)	24	-	-	Chen and Tan (1973)	
Aug.-Sept.	Off southern Kyushu, Japan	-	Numerous	150-250	Yabe et al.(1953)	

Table 8. Records of larval Euthynnus alletteratus in the northwestern Gulf of Guinea and off Sierra Leone (from Richards et al. 1969a, 1969b, and 1970).

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

Table 8. Records of larval Euthynnus alletteratus in the northwestern Gulf of Guinea and off Sierra Leone (from Richards, et al., 1969a, 1969b, and 1970).--continued

Date	Locality	No. of larvae
February 1965	08°30'N, 15°27'W	1
"	08°14'N, 15°00'W	7
"	07°26'N, 15°01'W	1
"	07°00'N, 14°29'W	1
"	07°01'N, 14°28'W	1
March 1965	07°08'N, 13°30'W	1
"	07°03'N, 13°06'W	1
"	06°49'N, 13°04'W	4
"	04°35'N, 02°32'W	3
"	04°06'N, 02°33'W	1
"	04°20'N, 01°59'W	1
"	04°08'N, 01°28'W	1
"	04°10'N, 00°29'W	1
"	04°22'N, 00°06'W	9
"	05°35'N, 00°32'E	3
"	05°05'N, 00°25'E	1
"	05°59'N, 01°30'E	2
"	05°45'N, 01°30'E	1
"	05°53'N, 01°58'E	1
"	04°15'N, 02°30'E	2

Table 9. Records of larval and juvenile Euthynnus alletteratus.

Date	Locality	Number		Total or fork length (mm)	Reference	Remarks
		Larvae	Juveniles			
June 1920	18°00'N, 64°14'W	1	-	-	Matsumoto (1959)	
July 1920	33°07'N, 77°00'W	4	-	-	"	
"	"	5	-	-	"	
May 1921	17°55'N, 64°48'W	1	-	-	"	
Nov. 1921	07°22'N, 46°51'W	1	-	-	"	
"	05°35'N, 51°08"W	1	-	-	"	
"	"	2	-	-	"	
"	"	10	-	-	"	
"	05°06'N, 51°35'W	1	-	-	"	
"	"	14	-	-	"	
"	"	2	-	-	"	
May 1922	35°42'N, 73°43'W	5(?)	-	-	"	
June 1953	25°35'N, 79°25'W	-	1	8.8	Klawe (1960)	
July 1954	34°35'N, 75°15'W	-	2	25, 35	Klawe (1961)	Frøm stomach of Euthynnus
"	28°59'N, 88°07'W	-	4	27-41	Klawe and Shimada (1959)	
"	28°36'N, 87°58'W	-	4	28-33	"	
"	29°05'N, 88°10'W	-	86	21-44	"	
"	27°34'N, 89°00'W	-	3	26-38	"	
"	27°58'N, 88°03'W	-	2	76-80	"	
Aug. 1954	29°28'N, 87°30'W	-	38	11-47	"	
"	28°59'N, 88°02'W	-	4	56-108	"	
"	28°46'N, 88°40'W	-	5	24-36	"	
"	29°12'N, 88°34'W	-	29	22-174	"	
June 1955	28°40'N, 88°58'W	-	10	21-31	"	
Aug. 1955	28°50'N, 87°50'W	-	4	3.5-5.3	"	
"	28°50'N, 87°48'W	-	88	30-53	"	
"	28°47'N, 87°57'W	-	16	31-55	"	
"	28°45'N, 87°56'W	-	4	6.2-8	"	
"	28°55'N, 88°00'W	-	90	29-65	"	
"	28°55'N, 87°57'W	-	116	4-80	"	
"	29°01'N, 87°48'W	-	60	17-68	"	
"	28°12'N, 88°43'W	-	11	49-86	"	
"	28°17'N, 88°37'W	-	12	32-94	"	
Sept. 1955	29°27'N, 86°55'W	-	52	24-49	"	
	Gulf of Mexico	-	8	19-29	"	

Table 9. Records of larval and juvenile Euthynnus alletteratus.--continued

Date	Locality	Number		Total or fork length (mm)	Reference	Remarks
		Larvae	Juveniles			
Aug. 1956	28°50'N, 87°50'W	-	33	21-82	Klawe and Shimada (1959)	
Oct. 1957) Dec. 1958)	Off Takoradi, Ghana	Single specimens	-	4.14-6.10	Kazanova (1962)	
July 1960	Off Dakar, Senegal	Up to 60 specimens per catch	-		Kazanova (1962)	
Aug. 1964) Sept. 1964)	Around Cuba	20	-	3.0-5.4	Gorbunova and Salabarria (1967)	
Feb.-Mar. 1963	(06°18'N, 23°20'W	2	-	3.8, 3.7	Zharov and Zhudova (1969)	
	(04°40'N, 24°28'W	1		4.4	"	
	(10°00'S, 34°33'W	1		8.7	"	
	(03°00'N, 30°00'W	1		4.2	"	
	(03°37'S, 30°04'W	1		4.4	"	
April-May) June-July) 1960-1967)	24°30'N, 82°50'W	-	47	29-135	Potthoff and Richards (1970)	
Oct.) Dec.)'64-'66 Feb.)	7°S 12°E) 5°N 4°30'W) 4°30'N, 4°30'W)	4	-	4.2-10.2	Zhudova (1969a)	Approx. locations
Aug-Oct. '64	9°-20°N, 19°-41°W	No numbers given	-	-	Zhudova (1969b)	
Throughout the year	Ivory Coast and Ghana	-	Numerous	-	Marchal (1963)	
June-Aug.	Haifa Bay	-	"	80-240	Ben-Tuvia (1957)	
Aug.-Oct. 1959	Dardanelles	-	"	145-220	Demir (1963)	
Aug.-Sept.1959	Sea of Marmara	-	"	180-250	"	

Table 10. Average numbers of Euthynnus lineatus larvae caught per hour of surface plankton tow off Cape Blanco, Costa Rica (from Klawe 1963).

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

Table 11. Records of larval and juvenile Euthynnus lineatus in the eastern tropical Pacific Ocean.

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

1/ As reported in Klawe (1963)

Table 11. Records of larval and juvenile Euthynnus lineatus in the eastern tropical Pacific Ocean.--continued

Date	Locality	Number		Total or fork length (mm)	Collector or reference
		Larvae	Juveniles		
May 1958	05°34'N, 81°29'W	-	1	60	Klawe (1963)
"	08°28'N, 84°21'W	1	-	-	"
"	15°15'N, 95°23'W	11	-	-	"
June 1958	18°44'N,104°21'W	-	5	20-27	"
"	17°49'N,103°38.5'W	-	99	7.5-45	"
"	21°36'N,106°44'W	-	3	18-48	"
"	16°39'N,100°05'W	1	-	-	"
"	17°24'N,101°25'W	6	-	-	"
"	18°44'N,104°21'W	1	-	-	"
Nov. 1958	14°56.5'N,93°06.5'W	11	-	-	"
"	15°39'N, 93°59.5'W	1	-	-	"
"	14°18'N, 95°02.8'W	1	-	-	"
"	15°02'N, 95°07.5'W	1	-	-	"
"	14°21'N, 97°01'W	3	-	-	"
"	14°21'N, 97°01'W	24	-	-	"
"	15°31'N, 97°44'W	5	-	-	"
Dec. 1958	"	15	-	-	"
"	15°36'N, 99°23.5'W	1	-	-	"
Jan. 1959	15°29.5'N,98°32.5'W	4	-	-	"
"	"	4	-	-	"
Feb. 1959	19°46'N,105°44'W	5	-	-	"
Apr. 1959	08°12'N, 83°15.5'W	-	6	12-18	Broadhead and Chatwin 1/
"	08°12'N, 83°17'W	-	1	7.5	"
"	08°15'N, 83°23'W	-	6	13-28	"
Sept. 1959	15°39'N, 97°00'W	2	-	-	Klawe (1963)
"	14°20-N, 95°59'W	6	-	-	"
"	"	6	-	-	"
"	14°54.8'N,95°07.1'W	36	-	-	"
"	14°21.5'N,94°01'W	5	-	-	"
"	16°28'N, 99°32.5'W	2	-	-	"
Feb. 1961	12°35'N, 93°40'W	-	3	7.5-9.5	Vann 1/
Oct. 1966	Entrance, Gulf of California	2	-	-	Klawe et al. (1970)
Nov. 1966	"	3	-	-	"
"	Off Tres Marias Is.	1	-	-	"
Dec. 1966	Entrance, Gulf of California	1	-	-	"

1/ As reported in Klawe (1963)

Table 12. Larval and juvenile Euthynnus lineatus captured off Cape Blanco, Costa Rica (from Klawe 1963).

Date	Location from Cape Blanco	Number Larvae	Number Juveniles	Total or fork length (mm)
Nov. 1958	20 mi S	1	-	6.5
"	"	1	-	9.0
"	20 mi SSW	1	-	6.0
"	"	2	-	5.0
Jan. 1959	20 mi S	-	8	21-39
"	"	-	43	14-25
Feb. 1959	"	-	8	25-50
"	"	1	-	5.0
Mar. 1959	"	3	-	5.1-6.7
"	"	1	-	6.7
"	5 mi SE	2	-	6.2,8.2
"	"	6	-	5.2-9.2
"	"	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
"	"	7	-	5.0-8.2
"	"	12	-	4.1-7.1
"	5 mi SE	23	-	4.5-7.5
"	"	25	-	4.4-7.5
"	"	12	-	4.4-7.2
"	"	88	-	4.4-14.2
May 1959	10 mi SE	-	11	16-25
"	"	5	-	5.5-8.0
"	"	1	-	8.5
"	"	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
"	"	4	-	5.0-7.3
"	"	5	-	4.4-7.5
Nov. 1959	20 mi S	-	4	11.5-53
"	"	1	-	4.4
Jan. 1960	10 mi S	9	-	4.1-5.5
"	"	2	-	4.6-4.8
Feb. 1960	20 mi SSW	-	1	18
March 1960	10 mi S	-	12	15-28
"	20 mi S	6	-	3.3-6.3
"	"	19	-	4.3-8.6
"	10 mi S	6	-	3.7-6.7
"	"	4	-	6.6-8.3
May 1960	20 mi S	-	14	13-21

Table 12. Larval and juvenile Euthynnus lineatus captured off Cape Blanco, Costa Rica (from Klawe 1963).--continued

Date	Location from Cape Blanco	Number		Total or fork length (mm)
		Larvae	Juveniles	
May 1960	10 mi S	-	6	9.5-24
"	"	1	-	6.5
July 1960	"	-	4	13-17
"	"	-	62	10-24
"	"	1	-	7.0
Aug. 1960	"	1	-	6.0
"	20 mi S	-	1	19
"	10 mi S	-	3	12-18
Sept. 1960	"	-	51	12.5-24
Oct. 1960	"	1	-	7.5

Table 13.--Parasites of Euthynnus (From Silas, 1967a and Silas and Ummerkutty, 1967)

Host	Parasites		
	Copepods	Monogenetic Trematodes	Digenetic Trematodes
Euthynnus alletteratus	Caligus bonito Caligus coryphaena Pseudocycnus appendiculatus	Capsala maccallumi Capsala manteri Hexostoma macracanthum	Dinurus scombri Lecithochirum texanum Rhipidocotyle capitatum Rhipidocotyle nagatyi Sterrhurus monticelli Tergestia laticollis
Euthynnus affinis	Caligus coryphaena Caligus regalis ?Anuretes branchialis Pseudocycnus appendiculatus	Capsala gouri ?Pricea minimae ?Hexostoma euthynni	Rhipidocotyle septapapillata ?Lecithochirum magnaporum Lecithochirum microstomum
Euthynnus lineatus	Caligus coryphaena Caligus macarovi	Hexostoma euthynni	?Lecithochirum magnaporum ?Lecithochirum microstomum

? indicates doubtful record.

Table 14.--Parasites of Euthynnus alletteratus (from Postel 1954).

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

Table 15. Excess body temperature (°C) of two Euthynnus affinis which had been held in captivity for 2 years (Stevens and Fry 1971).

	Fish No. 1	Fish No. 2
Excess brain temperature	3.12	4.33
Excess red muscle temperature	4.16	5.43
Excess white muscle temperature	1.71	2.86
Ambient water temperature	25.05	24.88
Fork length (cm)	46.5	48.5

Table 16. Average size of Euthynnus affinis landed at Aburatsu, Japan (data from Yabe et al. 1953).

Month	No. of fish measured	Body length (mm)	
		Ranges	Mean sizes
August 26	107	183 - 240	200
30	51	201 - 225	213
31	98	203 - 239	217
September 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
October 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

Table 17. Age-size relationships of Euthynnus affinis from the Red Sea (from Landau 1965).

Age	No. of fish	Length (LS) 1/ in mm Range	Mean	Approx. mean Wt. (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/ LS is standard length defined as the distance from the snout to the insertion of the caudal fin.

Table 18. Length-weight relationships of Euthynnus.

Species and locality	No. of fish	Size range of fish: Weight	Size range of fish: Length	log a	a	b	Wt. unit	Lg. unit	Source
Euthynnus affinis (Indian Ocean)	10	4-11.5 lb	52-71 cm		$1.63X10^{-6}$	3.16	lb	cm	Morrow (1954)
Euthynnus affinis (Indian Ocean)	201	-	12-58 cm	-3.3154	$4.838X10^{-4}$	3.0249	oz	cm	Sivasubramaniam (1966)
Euthynnus affinis (Indian Ocean	-	-	-	-7.5442		3.0287	lb	mm	Silas (1967b)
Euthynnus affinis (South China Sea)	226	-	-		0.008853	2.5649	kg	cm	Williamson (1970)
Euthynnus affinis (Hawaii)	101	1-15 lb	-	-4.6229		3.1544	lb	cm	Tester and Nakamura (1957)
Euthynnus affinis (males) (Philippines)	203		34.4-81.0 cm	-4.13317		2.83768	lb	cm	Ronquillo (1963)
Euthynnus affinis (females) (Philippines)	165		33.1-65.2 cm	-4.33240		2.94854	lb	cm	"
Euthynnus alletteratus (western Atlantic)	115	-	-		$6.73X10^{-3}$	3.10	oz	mm	de Sylva and Rathjen (1961)
Euthynnus alletteratus (western Mediterranean)	325	-	-		0.0000221842	2.914897	kg	cm	Rodriguez-Roda (1966)
Euthynnus alletteratus (eastern Atlantic)					15.2	3.0	kg	M	Postel (1950)
Euthynnus alletteratus	100	1,350-13,900g	473-1015 mm		16.3	3.0	g	M	Postel (1956)
Euthynnus alletteratus (Forida)	343	0.23-8.39 kg	23.1-85.8 cm		$4.956X10^{-6}$	3.26314	kg	cm	Beardsley and Williams (1970)
Euthynnus lineatus	109	2-13 lb 13 oz	365-667 mm	-7.6155	$2.4237X10^{-8}$	3.0817	lb	mm	Klawe and Calkins (1965)

Table 19. Age-length and age-weight relationships for Euthynnus alletteratus in the Mediterranean Sea (from Landau 1965).

Age	Length (LS)[1] in mm		Approx. mean wt. (kg)
	Range	Mean	
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]LS is standard length defined as the distance from the snout to the insertion of the caudal fin.

Table 20. Growth of postlarval Euthynnus lineatus (from Clemens 1956).

Number of fish	Hours*		Standard length, mm.		Fork length, mm.		Weight, gms.	
	Range	Average	Range	Average	Range	Average	Range	Average
23	0	0	17.0–37.5	26.8	13.5–40.0	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

* Hours of growth computed from time fish started feeding, 42 hours after capture.

Table 21. Food of Euthynnus.

Food of Euthynnus affinis (from Kumaran 1964).

Food items	Number of food organisms	Percentage of prevalence	Percentage by volume
Crustacea :	(140)	(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 :	(27)	(12.3)	(56.5)
Sepioteuthis sp.	25	10.9	55.7
Loligo sp.	2	1.4	0.8
Vertebrata (Pisces) :	(308)	(87.1)	(38.3)
Sardinella spp.	10	5.5	0.7
Anchoviella 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
Hemirhamphus 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 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).

Fish:
- *Sardinella aurita*
- *Sardinella* sp.
- *Engraulis* sp.
- *Aulorus* sp.
- *Saurida parri*
- *Myctophum* sp.
- *Fodiator acutus*
- *Cypselurus* sp.
- Hemiramphidae
- *Sphyraena* sp.
- *Galeoides polydactylus*
- *Scomber colias*
- *Auxis thazard*
- *Euthynnus alletteratus*
- *Caranx rhoncus*
- *Decapterus punctatus*
- *Vomer setipinnis*
- *Pagellus* sp.
- *Sargus* sp.
- *Box boops*
- *Smaris* sp.
- *Ammodytes* sp.

Molluscs:
- Shelled (?) molluscs
- *Sepia* sp.
- *Loligo* sp.
- *Allotenthis africana*

Crustacea:
- Planktonic crustacea
- Euphausiaceae
- Sergestidae
- *Parapeneus longirostris*

Bryozoans

Madreporaires

Green algae

Table 22. Species of fish landed in the multiple trolling fishery at Tuticorin, India (from Silas 1967b).

Scientific name	Vernacular name (English name)	Remarks
Auxis thazard Lacépède	(short corseletted frigate mackerel)	Rare
Euthynnus affinis affinis (Cantor)	Suraimin (little tunny or mackerel tuna)	Common
Katsuwonus pelamis (Linnaeus)	(skijpack tuna)	Rare
Thunnus (Neothunnus) albacares macropterus (Temminck and Schlegel)	Kelavalai (yellowfin tuna)	Common
T.(Kishinoella) tonggol (Bleeker)	Ettalai (Northern bluefin tuna)	Common
Istiophorus gladius (Broussonnet)	Thalapathu (sailfish)	Common
Makaira indica (Cuvier)	Kopprai Kulla (black marlin)	Rare
Makaira nigricans Lacépède	Kola (blue marlin)	Rare
Tetrapturus audax Philippi	Kola (striped marlin)	Rare
Tetrapturus sp.	Kola	Rare
Scomberomorus commerson (Lacépède)	Chela (Seer)	Common
Scomberomorus lineolatus (Cuvier)	Nonachela (Seer)	Rare
Acanthocybium solandri (Cuvier)	Sawara (Wahoo)	Rare

Table 23. Monthly landings of Euthynnus affinis at Vizhingam, India (from Bennet 1964).

Months	1956	1957	1958	1959	1960	1961
			kilograms			
January	12091	8929	5725	6130	4360	8436
February	8827	3970	10843	2737	15998	16825
March	6198	25761	8022	8022	15501	24384
April	8444	10446	1957	4498	4623	32236
May	6151	4131	3602	7105	11192	27775
June	—	3937	3086	1501	2290	1259
July	—	13405	—	567	510	290
August	324	402	—	11952	5663	10072
September	—	—	19072	26957	7067	21999
October	4514	5394	25580	9499	81026	22537
November	26675	16267	15462	20560	34969	
December	12451	2621	32753	5009	22569	
Total	85675	95263	126102	104537	205768	165813

Table 24. Fishing seasons for Euthynnus alletteratus in Spain (Rodriguez-Roda, 1966).

Region		Fishing season	Months of peak catches
North coast	Atlantic Ocean	January to December	September and October
Northwest coast		June to December	October
Southwest coast		February to December	August to October
Canary Islands		January to December	December to March
Southern coast	Mediterranean Sea	January to December	September and October
Southeast coast		January to December	September and October
Eastern coast		April to December	July to October
Balearic Islands		January to December	May to July

Table 25. Size composition of Euthynnus affinis from the southwest coast of India (Bennet 1964).

Months	*Minimum Length in cm.*	*Maximum Length in cm.*
July 1960	45.0	60.5
August	43.5	64.0
September	43.0	60.0
October	15.0	62.3
November	24.7	55.0
December	26.3	62.7
January 1961	30.5	62.8
February	31.7	58.5
March	24.3	62.3
April	30.1	70.1
May	42.5	67.3
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

Table 26. Size composition of catches of Euthynnus affinis in various areas of the Ind an Ocean (Williams 1963).

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 - 2.2 kg 3.6 - 5.4 kg	40 - 78 cm at 1 - 7.3 kg
Madagascar		
Fourmanoir 1954	-	up to 80 cm
Seychelles		
Ommaney 1953	45 - 65 cm over 65 cm	43 - 87 cm at 1 - 8.6 kg
Somalia		
Ogilvie, Fraser-Brunner, and Byrd 1954	50 cm at 3 - 4 kg	up to 79 cm and 6 kg

Table 27. Sex ratio of Euthynnus affinis.

Locality	Sample size	Number (percent) Males	Females	Source
East Africa (western Indian Ocean)	11	6 (54.5)	5 (45.4)	Morrow 1954
"	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 28. Sex ratio of Euthynnus alletteratus.

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

Table 29. Landings of Euthynnus affinis (data from FAO 1974a).

	1965	1966	1967	1968	1969	1970	1971	1972	1973
	Thousand metric tons								
Pacific Ocean Total	27.8	37.3	20.5	32.2	30.7	21.1	13.6	6.1	30.9
Philippines	24.7	32.8	14.9	27.7	26.2	16.0	8.9	-	25.9
Malaysia	3.1	4.5	5.6	4.5	3.5	5.1	4.7	6.1	5.0
Indian Ocean Total	0.0	0.0	0.5	0.5	0.6	0.5	0.4	0.6	1.0
Maldives	0.0	0.0	0.5*	0.5*	0.6	0.5*	0.4	0.6	1.0
Total Landings Pacific and Indian Oceans	27.8	37.3	21.0	32.7	31.3	21.6	14.0	6.7	31.9

* Data estimated or calculated by FAO.

Table 30. Landings of Euthynnus alletteratus (data from FAO 1974a).

	1965	1966	1967	1968	1969	1970	1971	1972	1973
	Thousand metric tons								
Western Atlantic Ocean Total	-	-	-	0.1	0.1	0.3	0.3	0.3	0.3
United States	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Venezuela	-	-	-	0.1	0.1	0.2	0.3	0.3	0.3
Eastern Atlantic Ocean Total	4.6	8.1	8.9	8.0	7.5	12.0	8.0	7.5	6.6
Angola	3.7	3.3	4.0	3.0	2.0	6.4	2.4	1.3	1.0
Bulgaria	-	-	-	-	0.0	0.0	0.0	0.0	0.0
Liberia	0.9	4.8	4.9*	5.0*	5.5*	5.5*	5.5*	5.5*	5.5*
Romania	-	-	-	-	-	-	-	0.1	0.1
Spain	-	-	-	-	-	0.1	0.1	0.6*	-
Mediterranean and Black Sea Total	0.0	0.0	0.0	0.1	0.9	0.6	0.6	0.0	0.0
Cyprus	-	-	-	-	-	-	-	-	-
Spain	-	-	0.0	0.1	0.9	0.6	0.6	-	0.0
Turkey	-	-	-	-	-	-	-	-	-
Yugoslavia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total landings all oceans	4.6	8.1	8.9	8.2	8.5	12.9	8.9	7.8	6.9

* Data estimated or calculated by FAO.

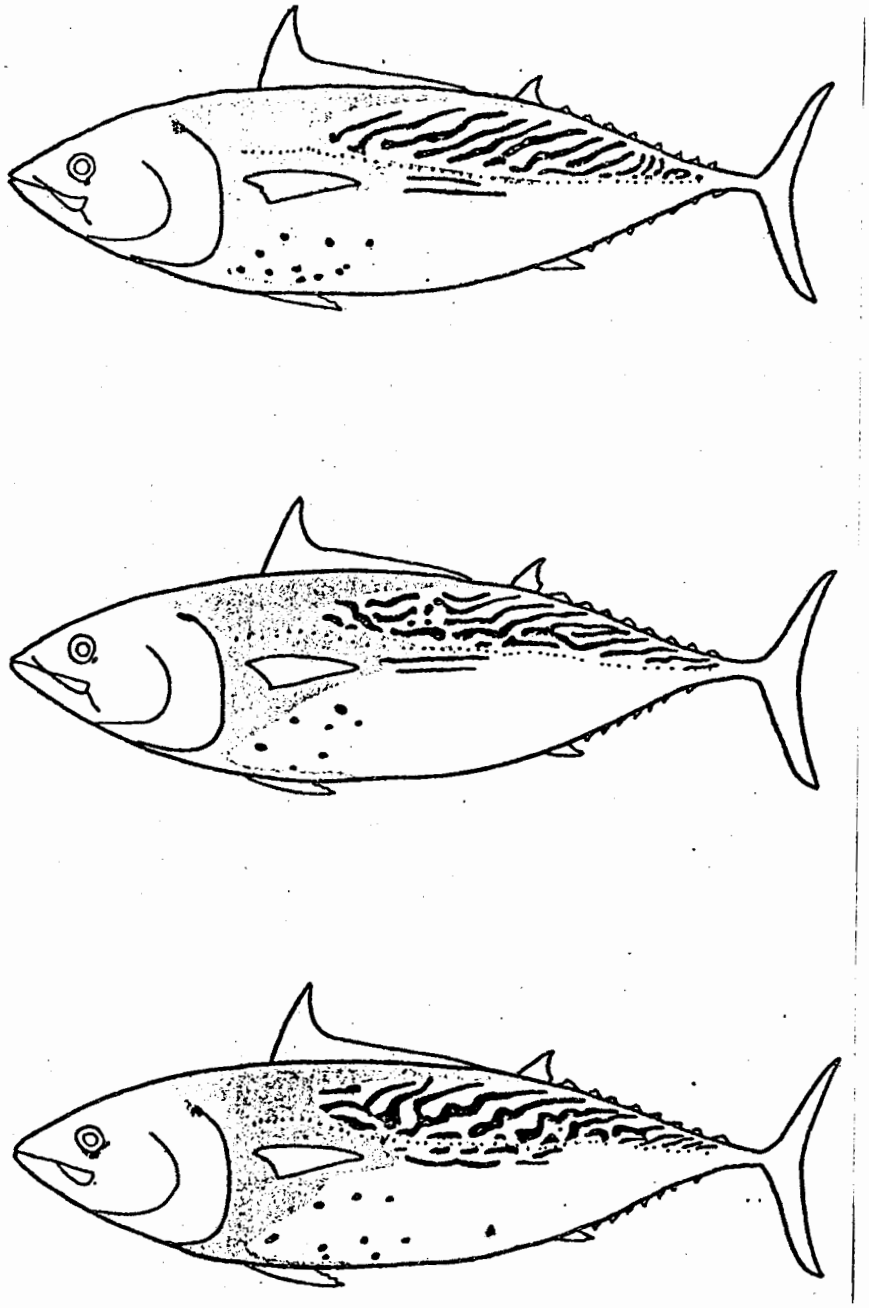

Figure 1.--Variations in the markings of three specimens of Euthynnus affinis (from Godsil 1954).

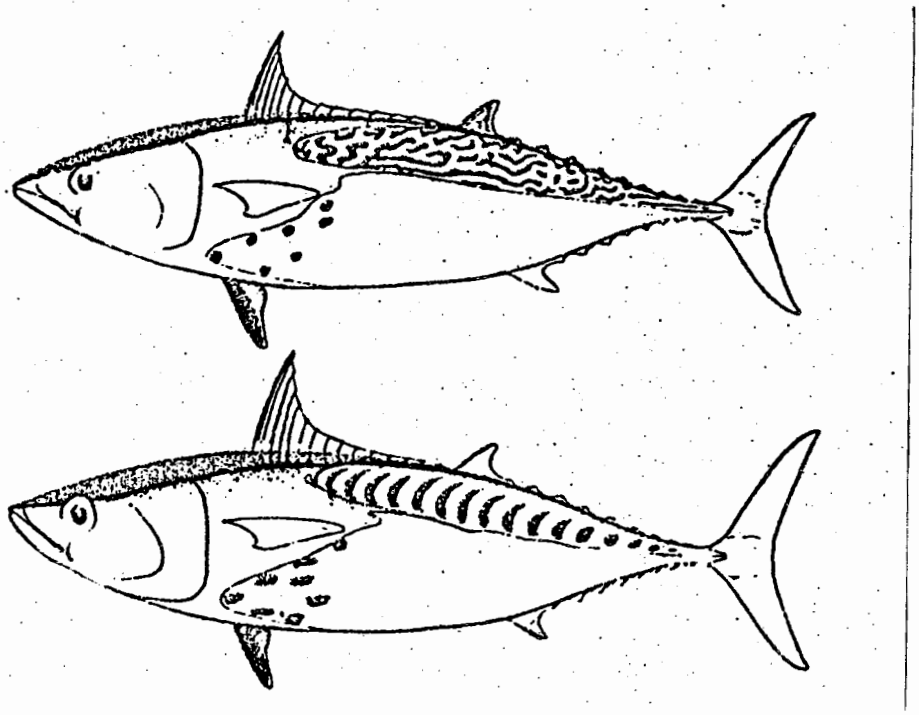

Figure 2.--Euthynnus alletteratus showing variations in the dorsal markings (from Fraser-Brunner 1949).

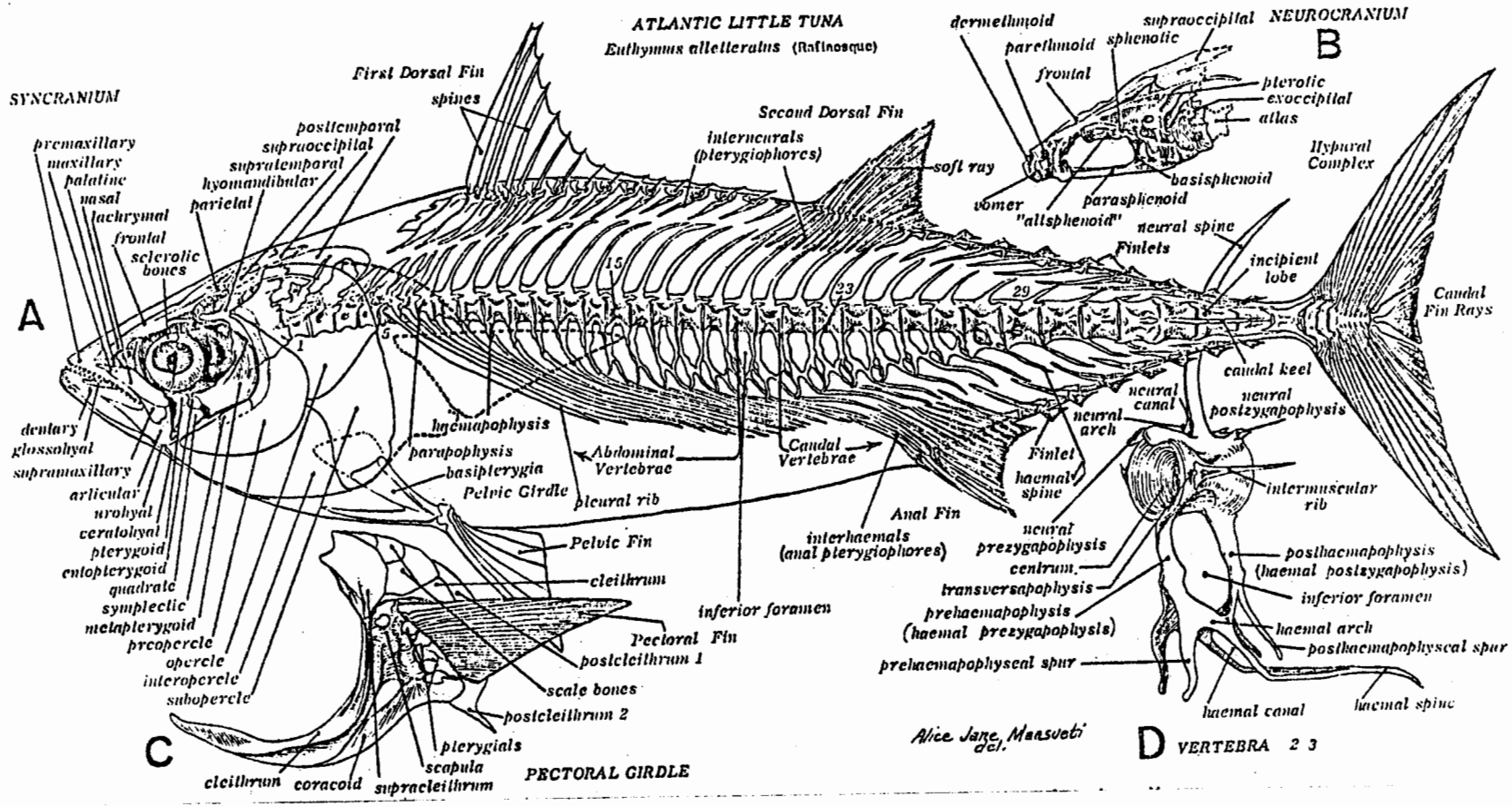

Figure 3.--Topographic osteology of Euthynnus alletteratus. A. syncranium, axial, and appendicular skeleton; B. neurocranium; C. pectoral girdle; and D. vertebra 23 to parts and how the unique trellis is formed (from Mansueti and Mansueti 1962).

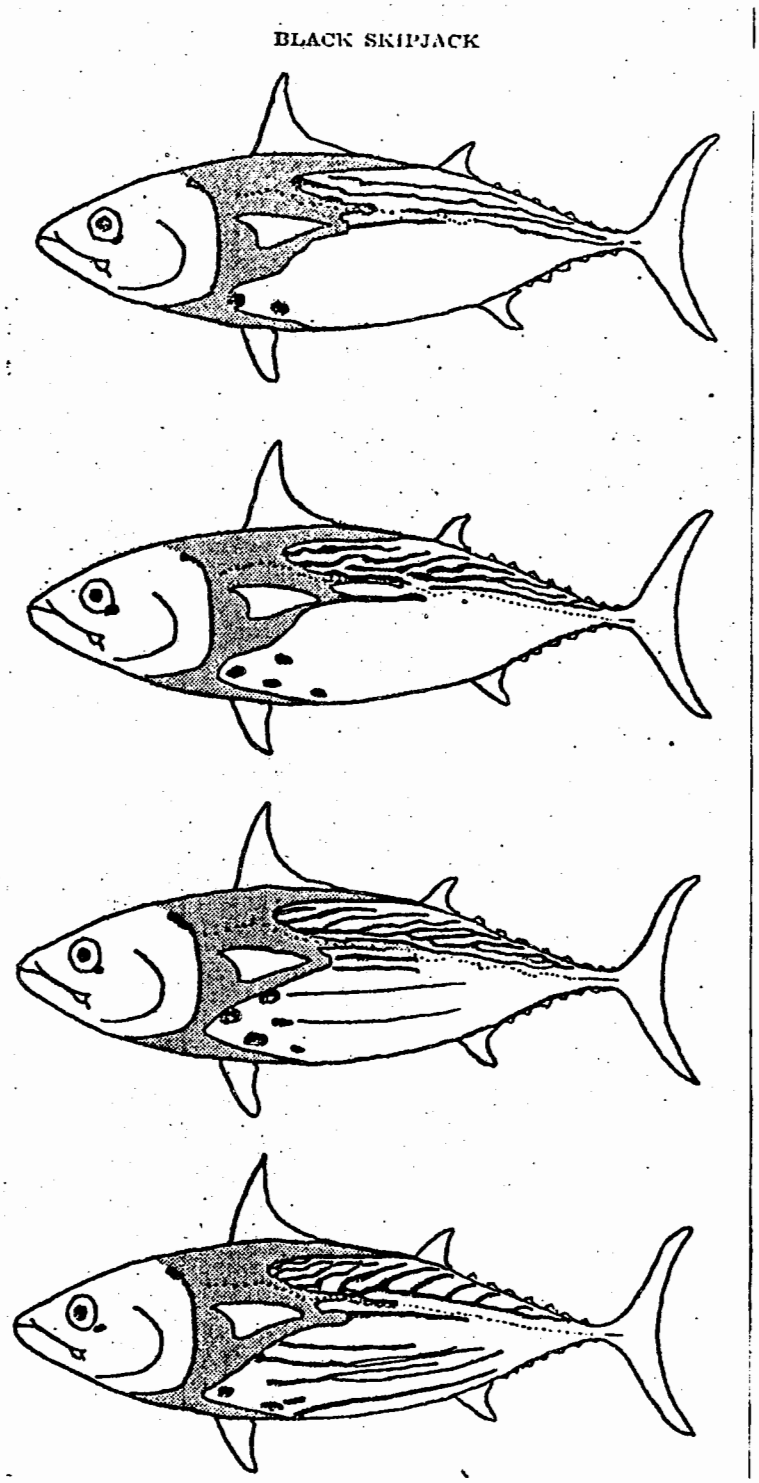

Figure 4.--Euthynnus lineatus showing variations in the dorsal markings. The upper figure represents the typical pattern and the lowest figure shows an extreme variant (from Godsil 1954).

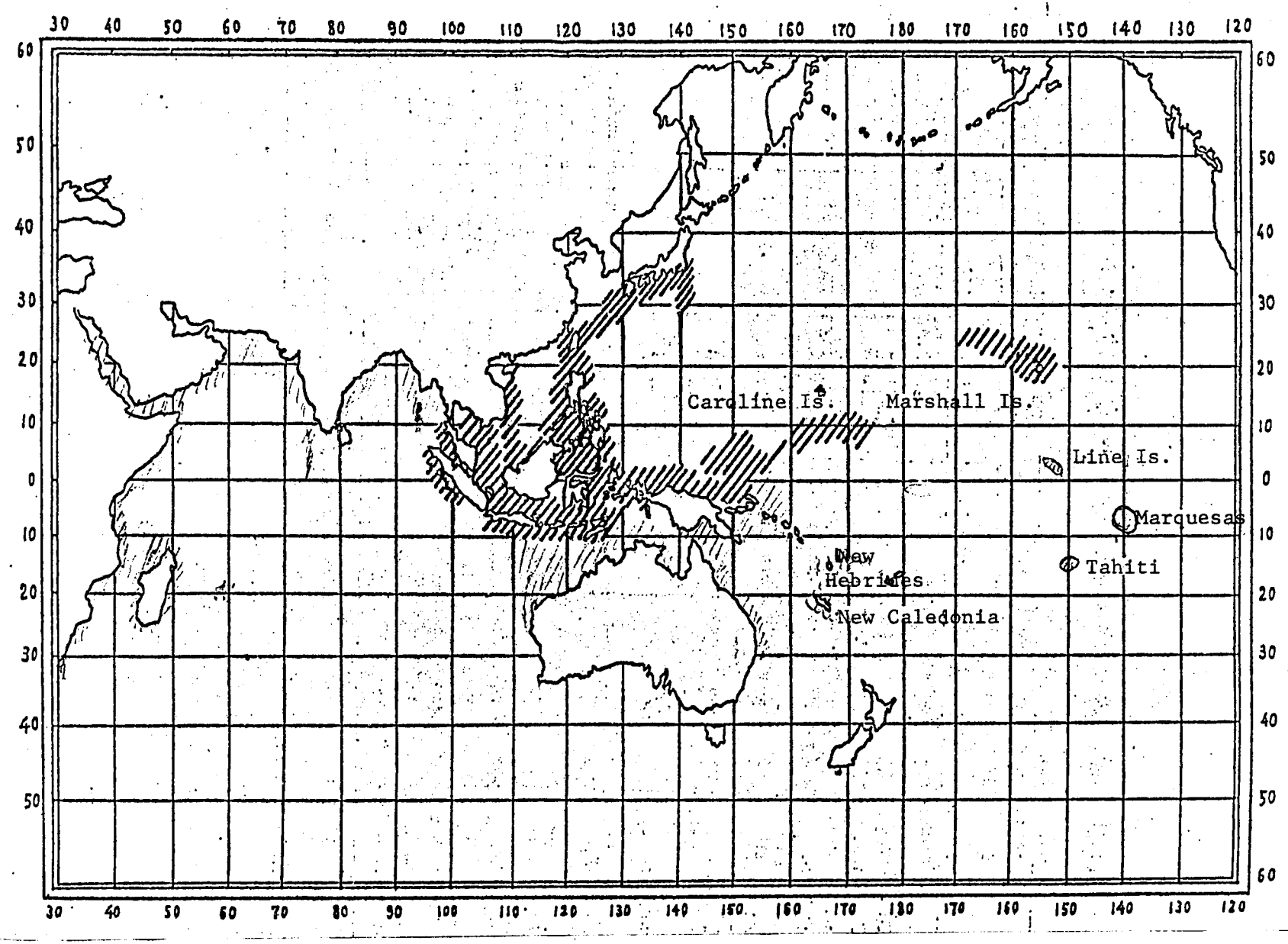

Figure 5.--Distribution of Euthynnus affinis in the Indo-Pacific region.

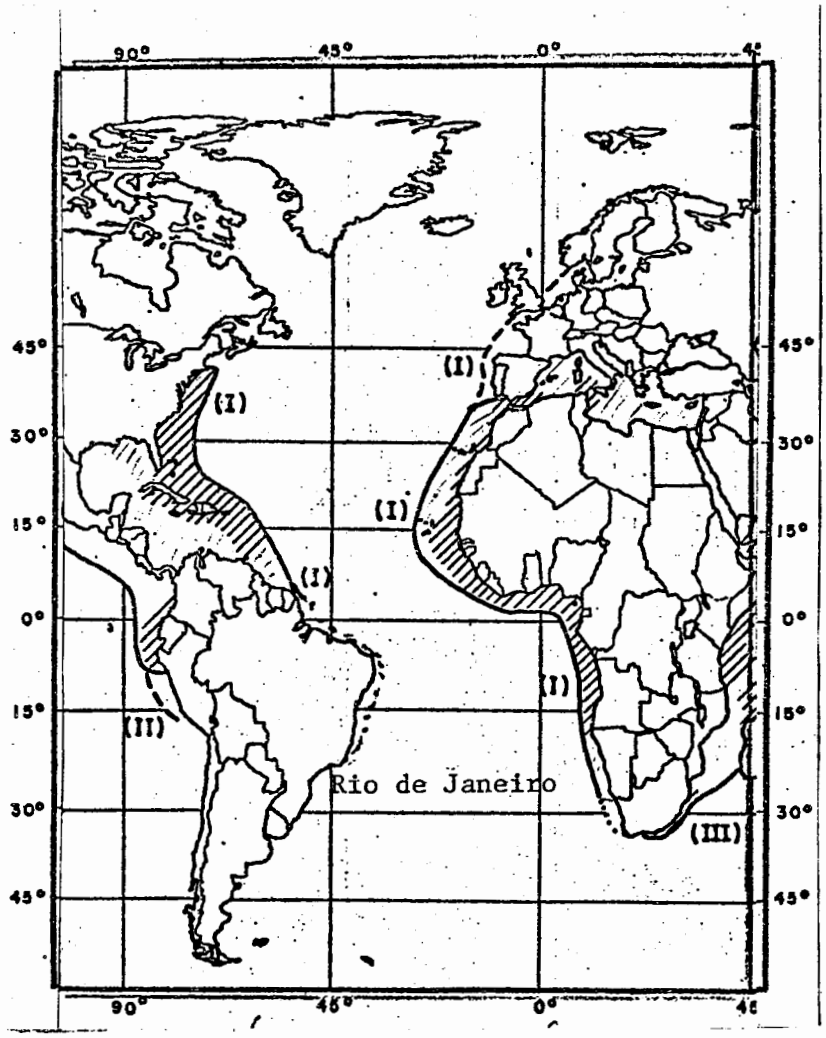

Figure 6.--Distribution of Euthynnus alletteratus.

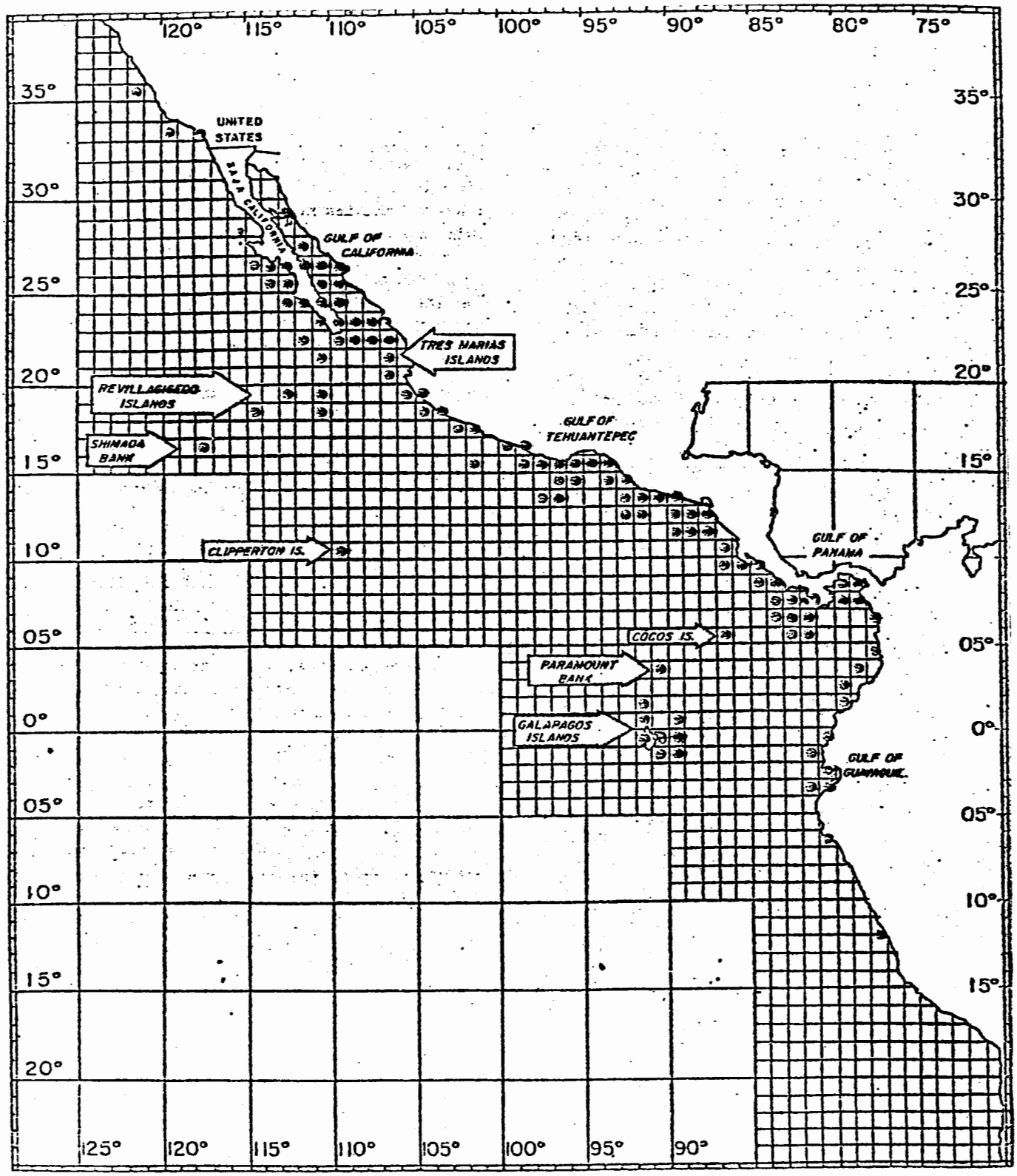

Figure 7.--Distribution of Euthynnus lineatus in the eastern Pacific Ocean (from Calkins and Klawe 1963).

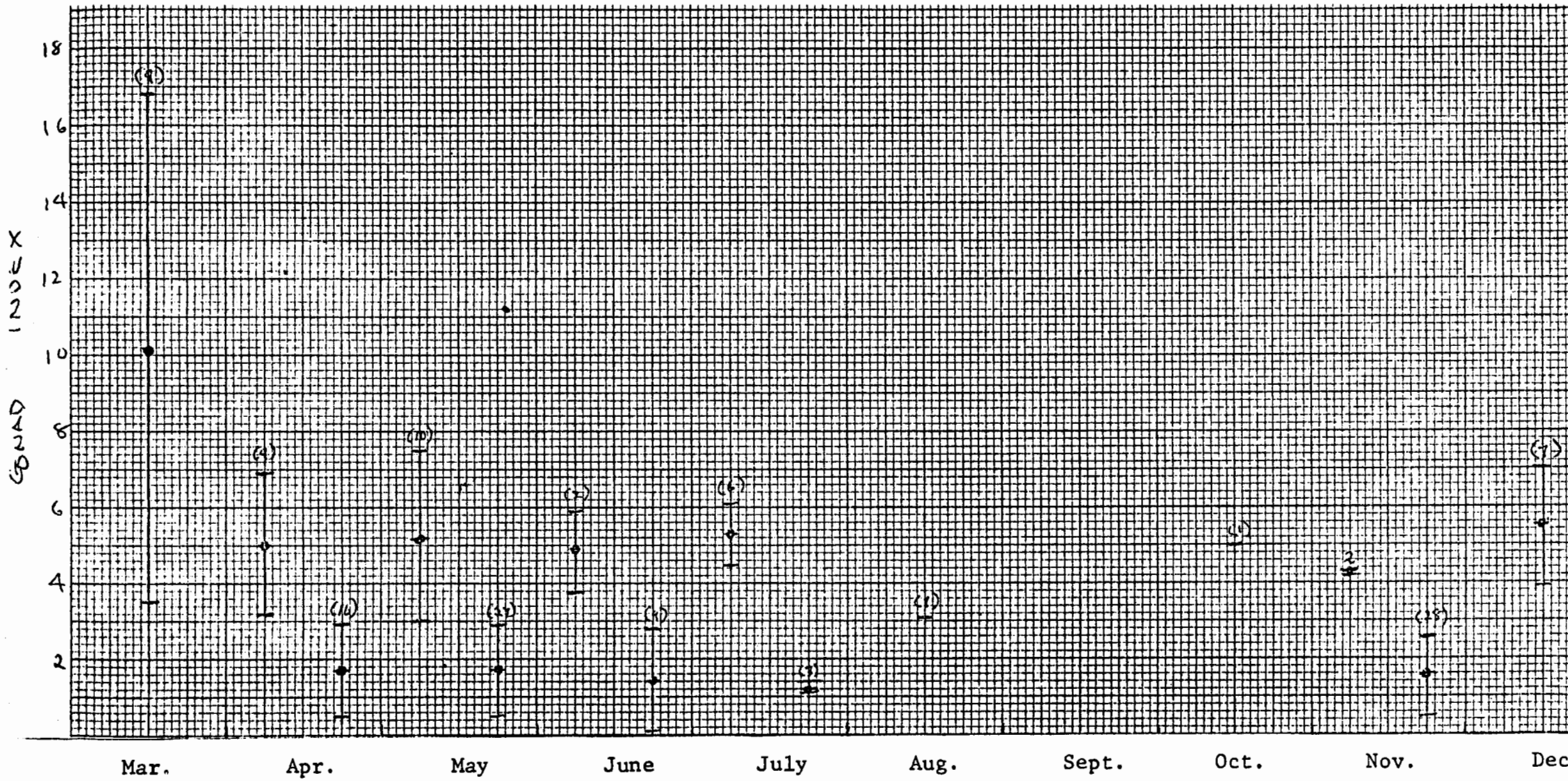

Figure 8.--Seasonal distribution of Euthynnus affinis gonad index in the Philippines (data from Ronquillo 1963).

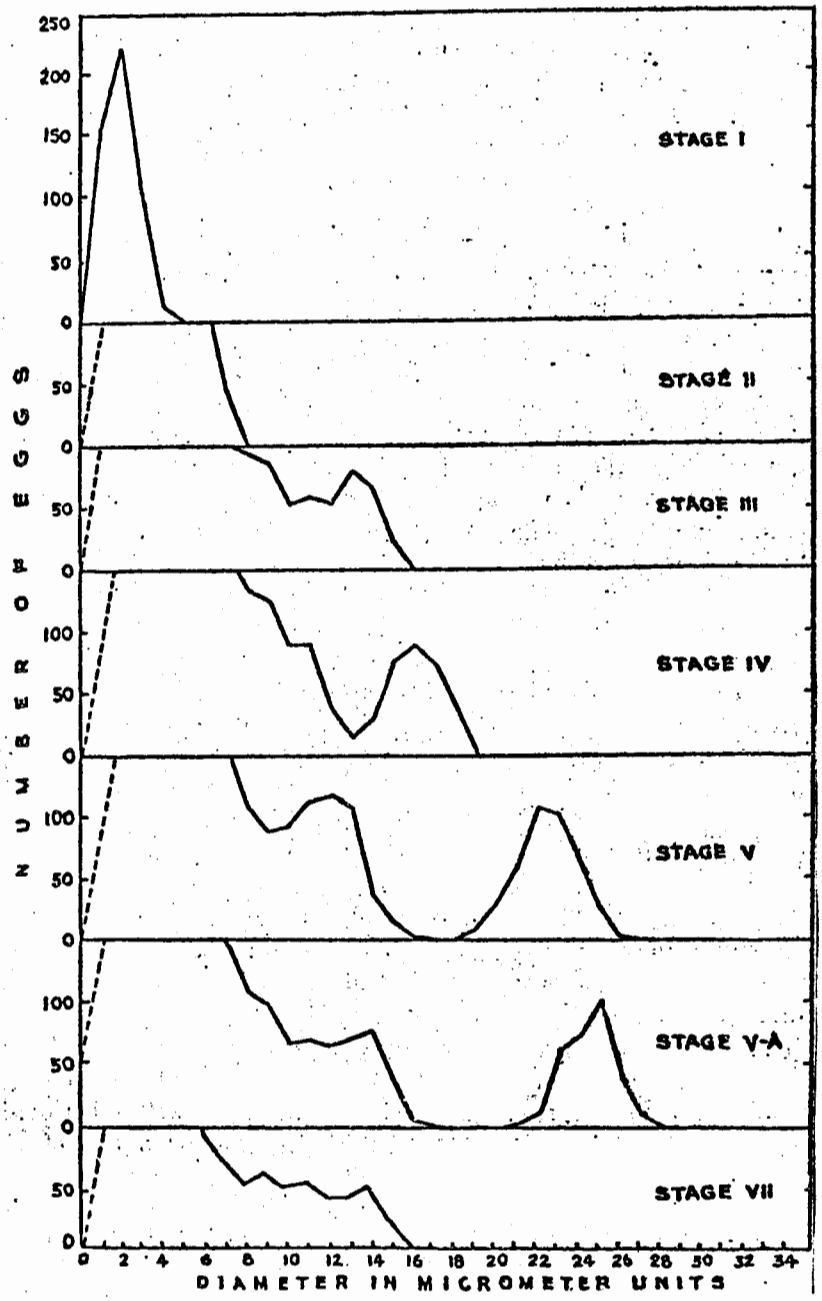

Figure 9.--Ova diameter frequency polygons of Euthynnus affinis showing the various stages of development of the ova to maturity (from Buñag 1956).

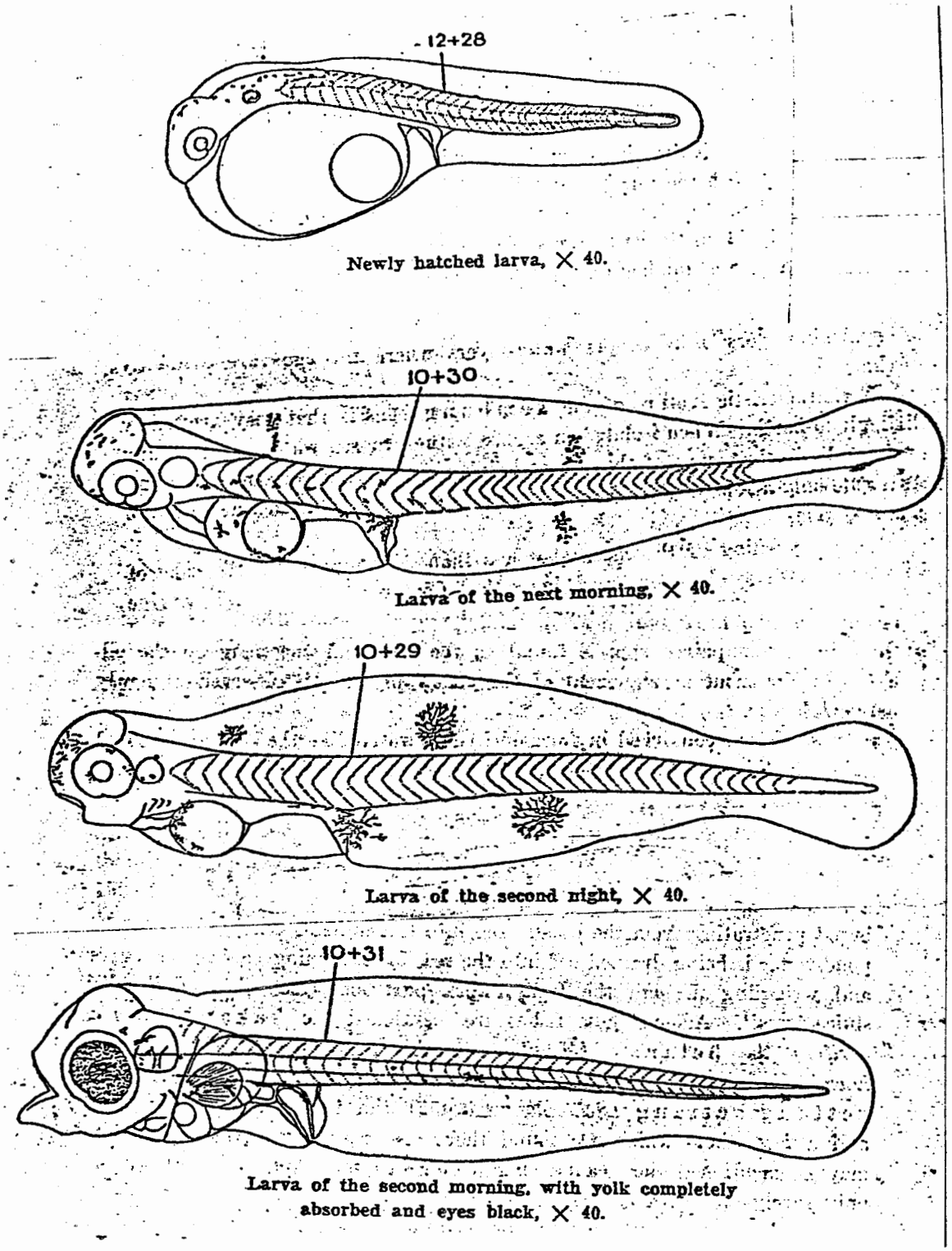

Figure 10.--Larvae of Euthynnus affinis (?) (from Delsman 1926).

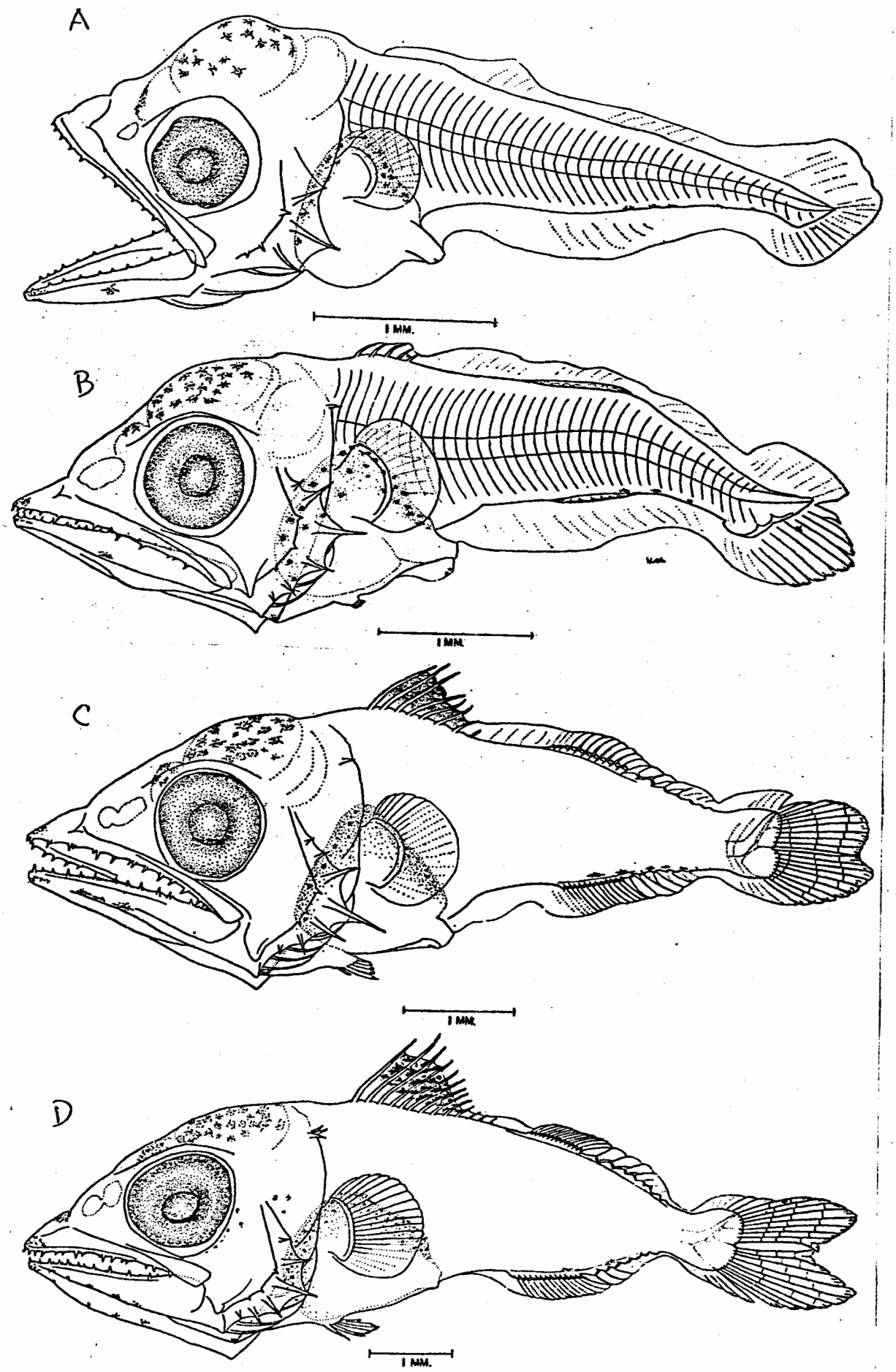

Figure 11.--Euthynnus affinis larvae, (A) 4.6 mm long; (b) 5.5 mm long; (C) 7.6 mm long; (D) 9.6 mm long (from Matsumoto 1958, 1959).

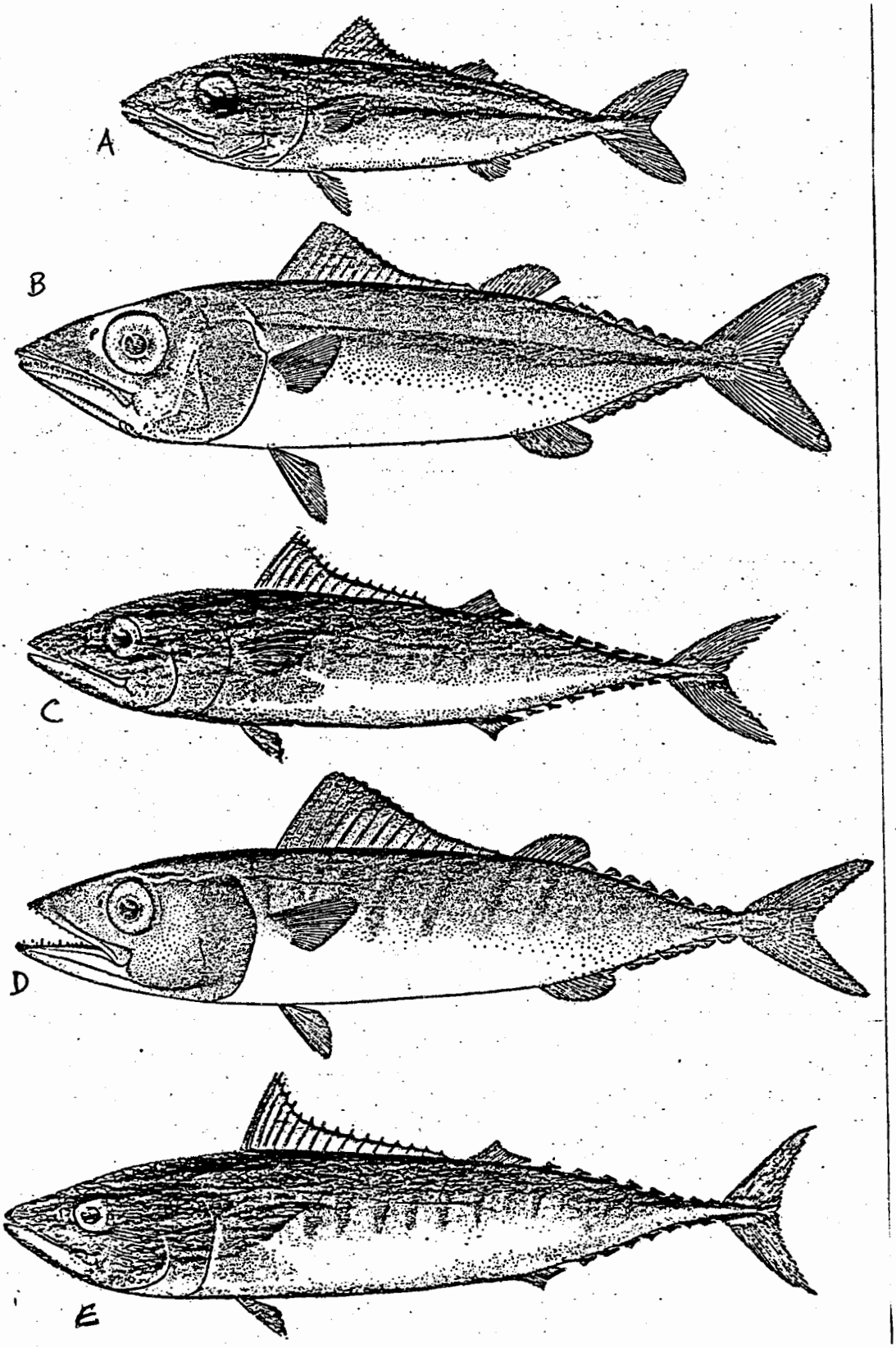

Figure 12.--Juvenile Euthynnus affinis, (A) 24.5 mm long; (B) 33.5 mm long; (C) 56.6 mm long; (D) 67 mm long; (E) 96.0 mm long; (F) 110 mm long; (G) 156 mm long (from Wade 1950a and Jones 1960).

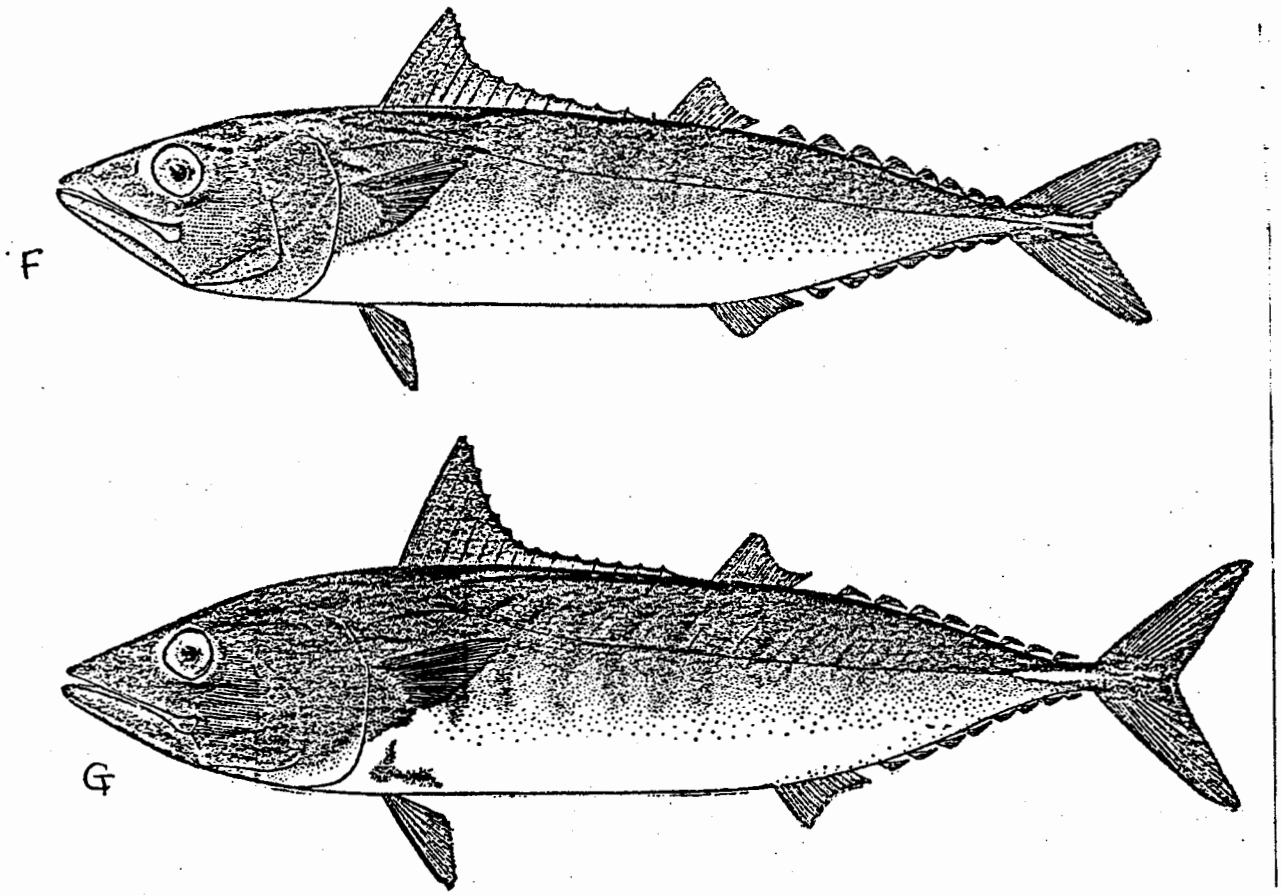

Figure 12.--Continued.

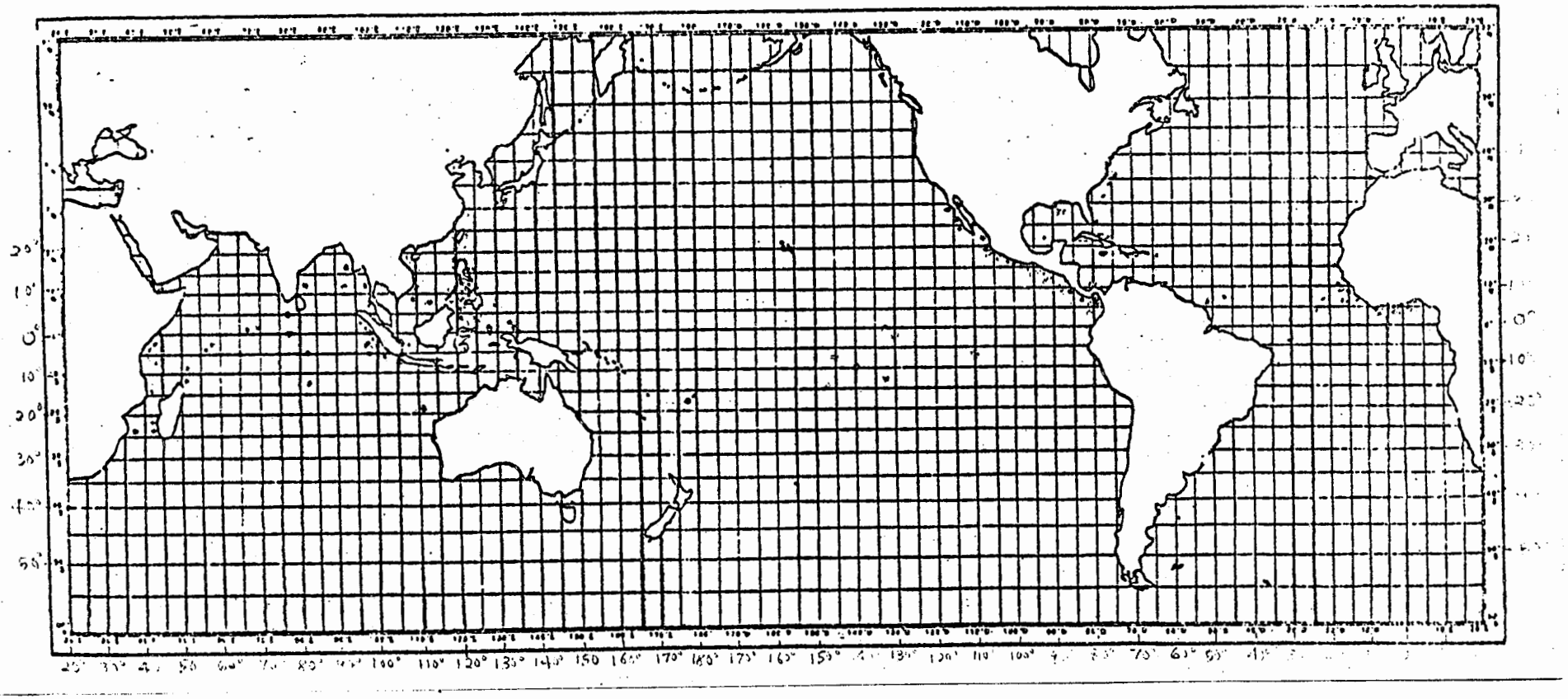

Figure 13.--Distribution of larval and juvenile Euthynnus spp.

- Euthynnus alletteratus
- Euthynnus affinis
- Euthynnus lineatus

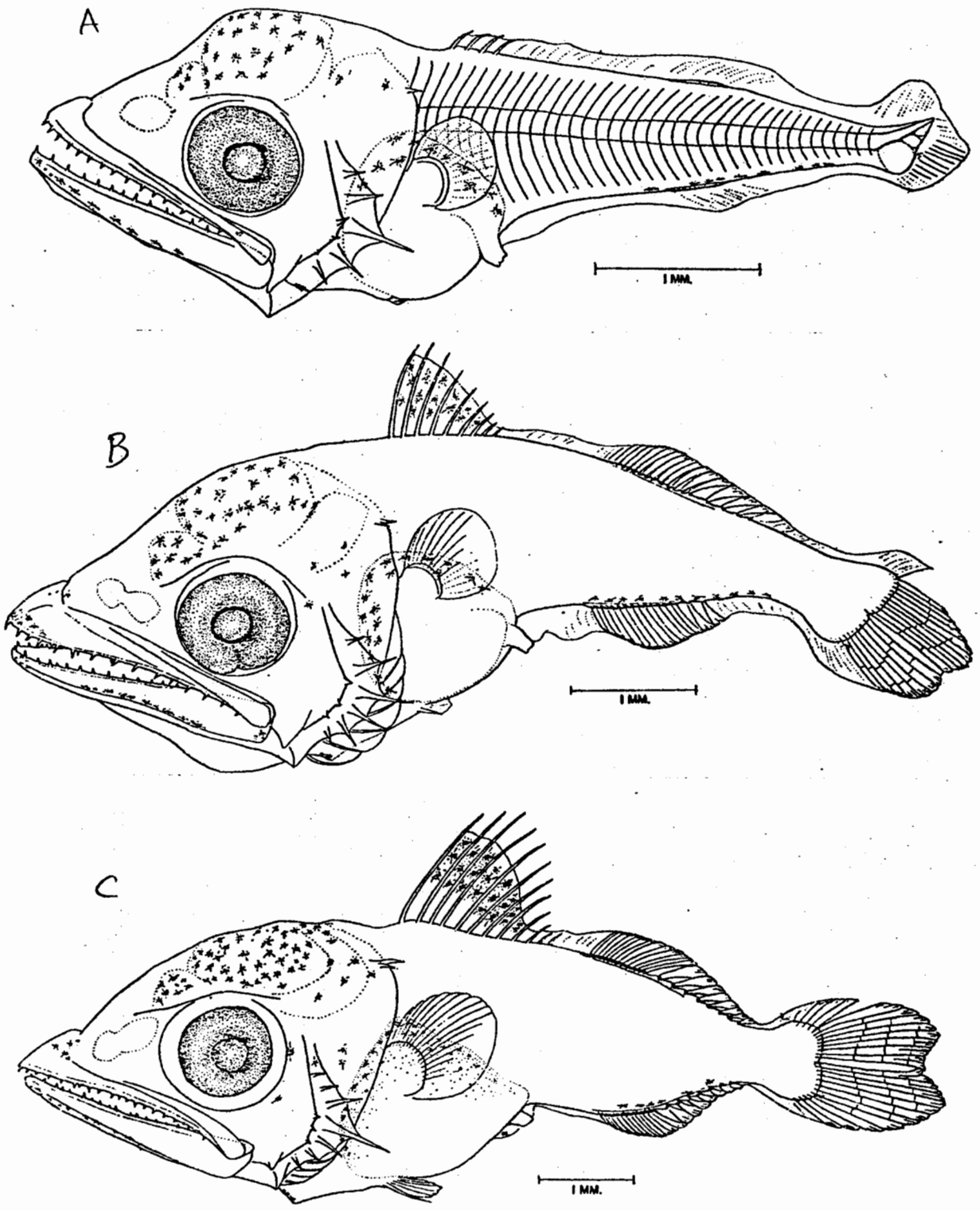

Figure 14.--Euthynnus alletteratus larvae (A) 5.5 mm long; (B) 7.5 mm long; (C) 9.3 mm long (from Matsumoto 1959).

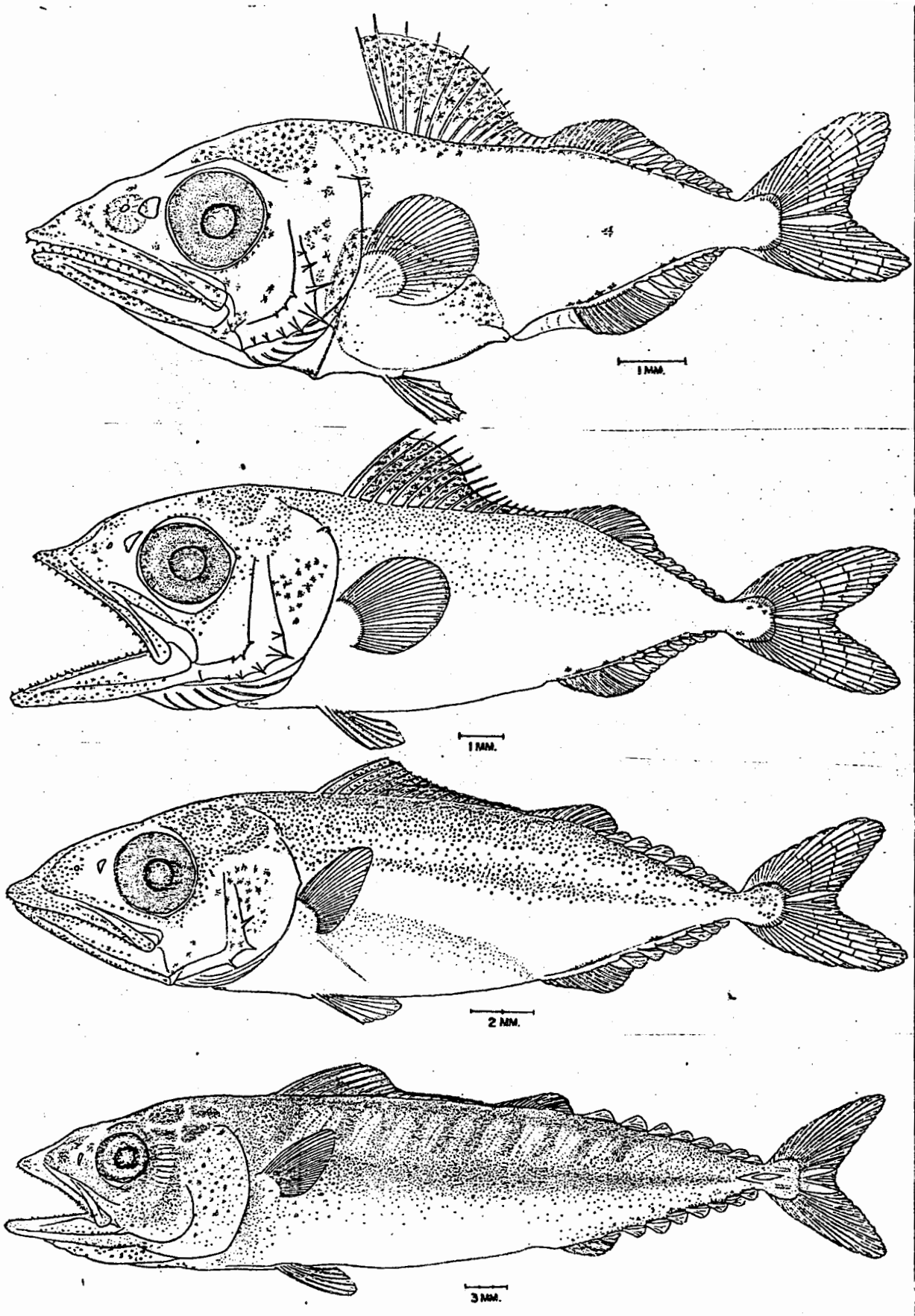

Figure 15.--Postlarvae and juvenile Euthynnus alletteratus (A) 12.0 mm long; (B) 18.5 mm long; (C) 26.0 mm long; (D) 58.0 mm long (from Matsumoto 1959).

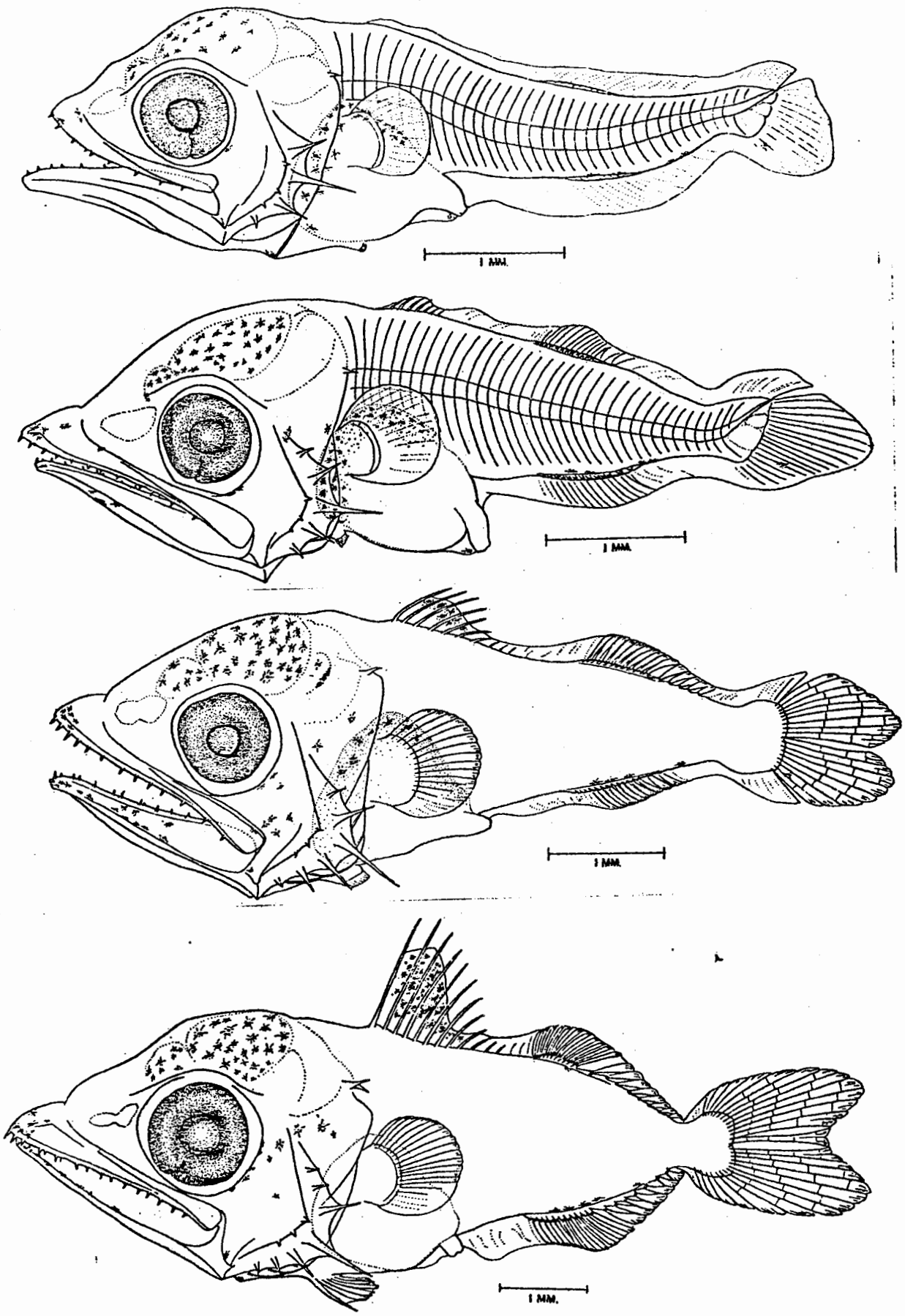

Figure 16.--Euthynnus lineatus larvae (A) 5.0 mm long; (B) 6.0 mm long; (C) 7.1 mm long; (D) 9.3 mm long (from Matsumoto 1959).

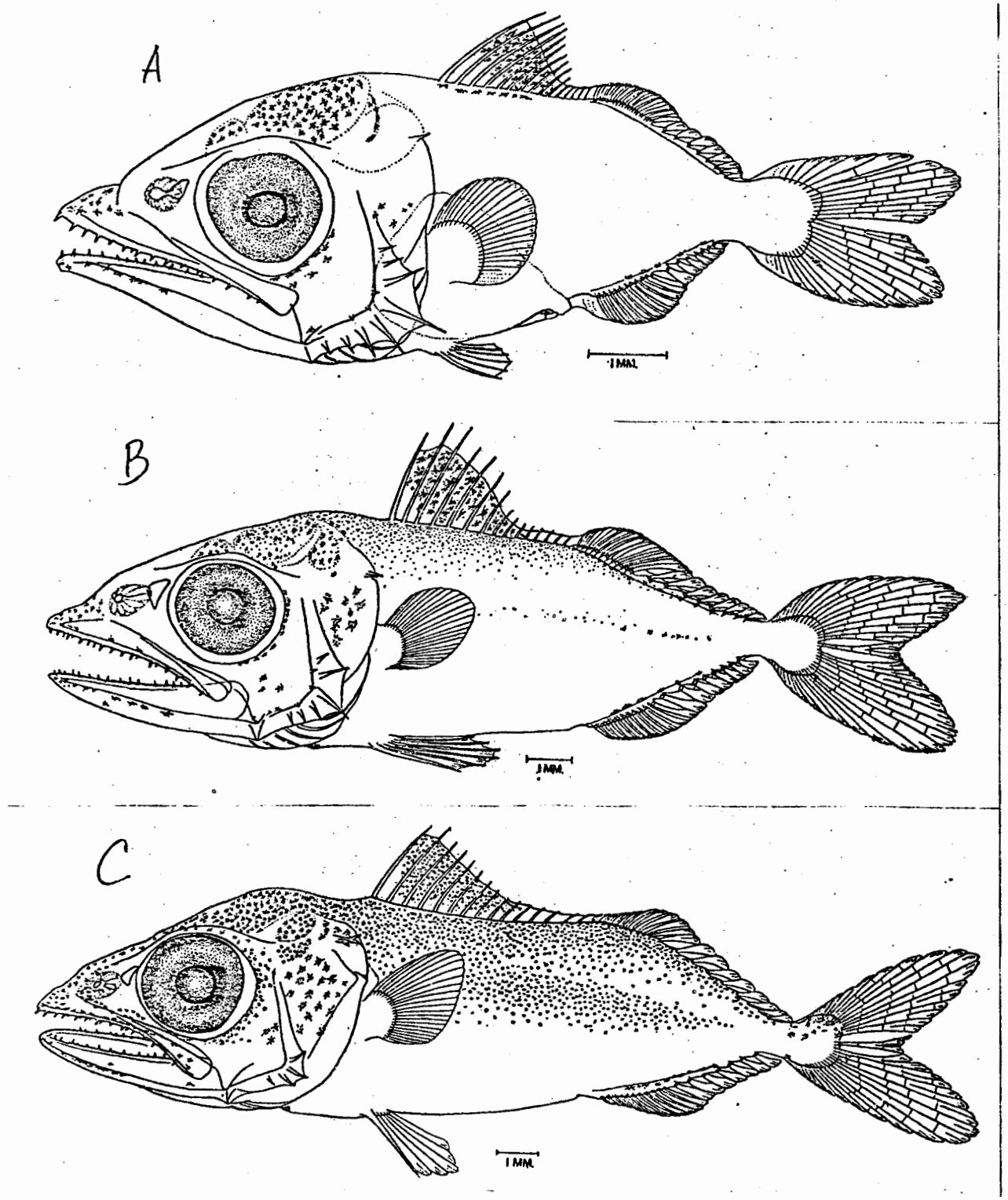

Figure 17.--Postlarval and juvenile Euthynnus lineatus (A) 10.6 mm long; (B) 18.6 mm long; (C) 21.0 mm long (from Matsumoto 1959).

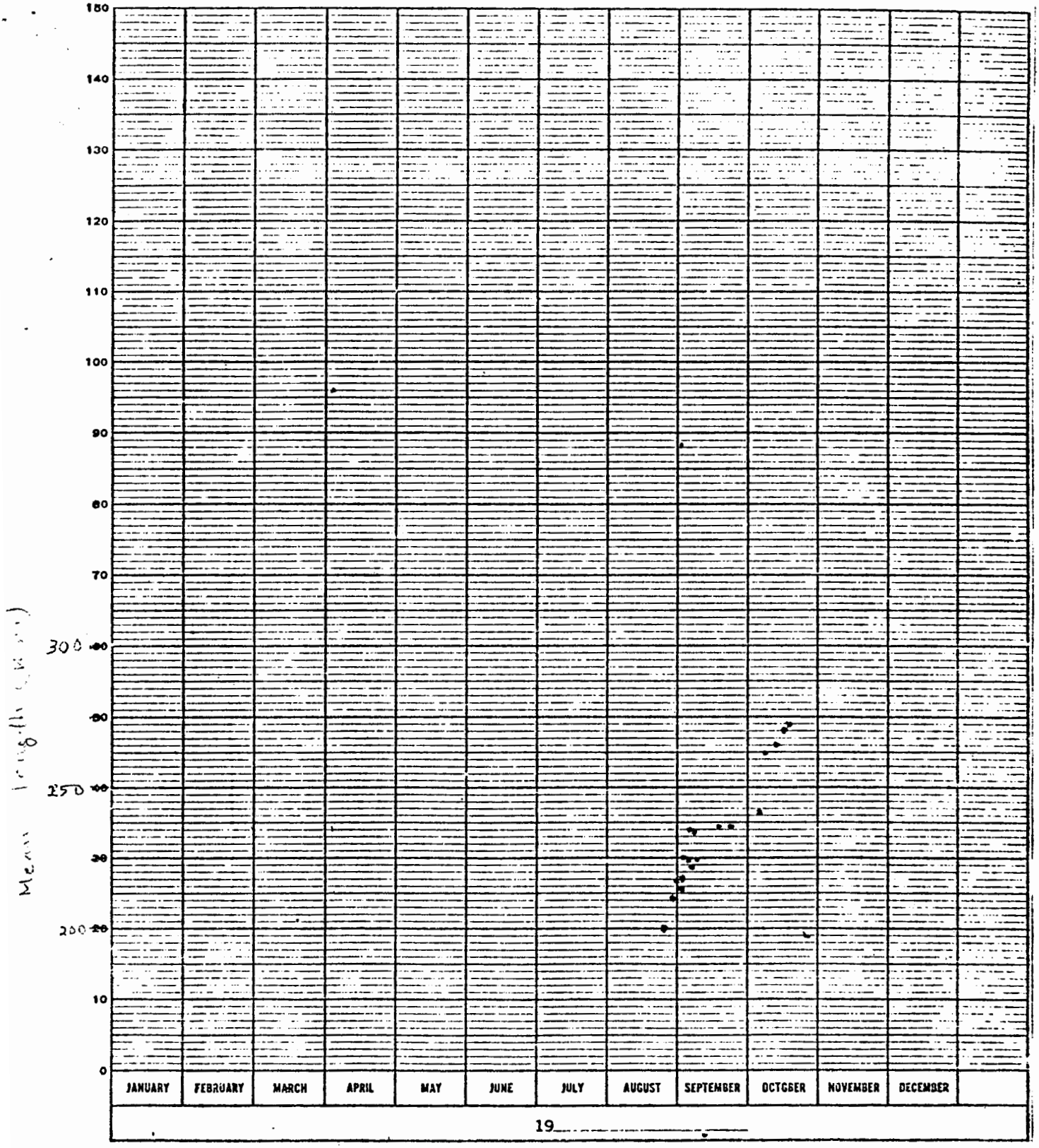

Figure 18.--Growth of pre-adult Euthynnus affinis off the southern coast of Japan (data from Yabe et al. 1953).

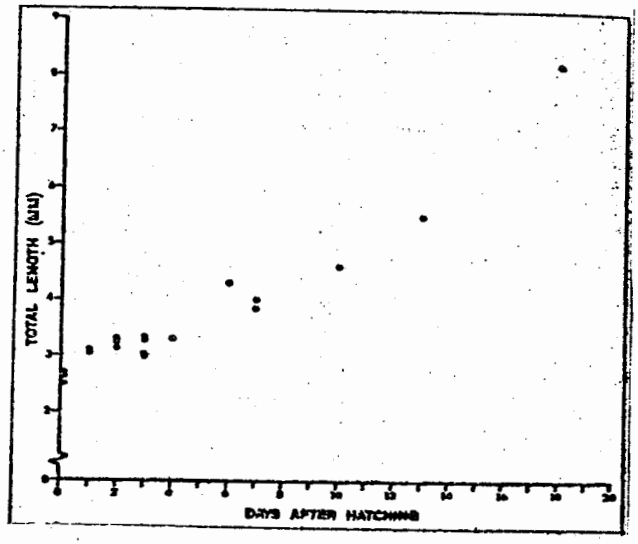

Figure 19.--Growth in length of Euthynnus alletteratus larvae reared in the laboratory (from Houde and Richards 1969).

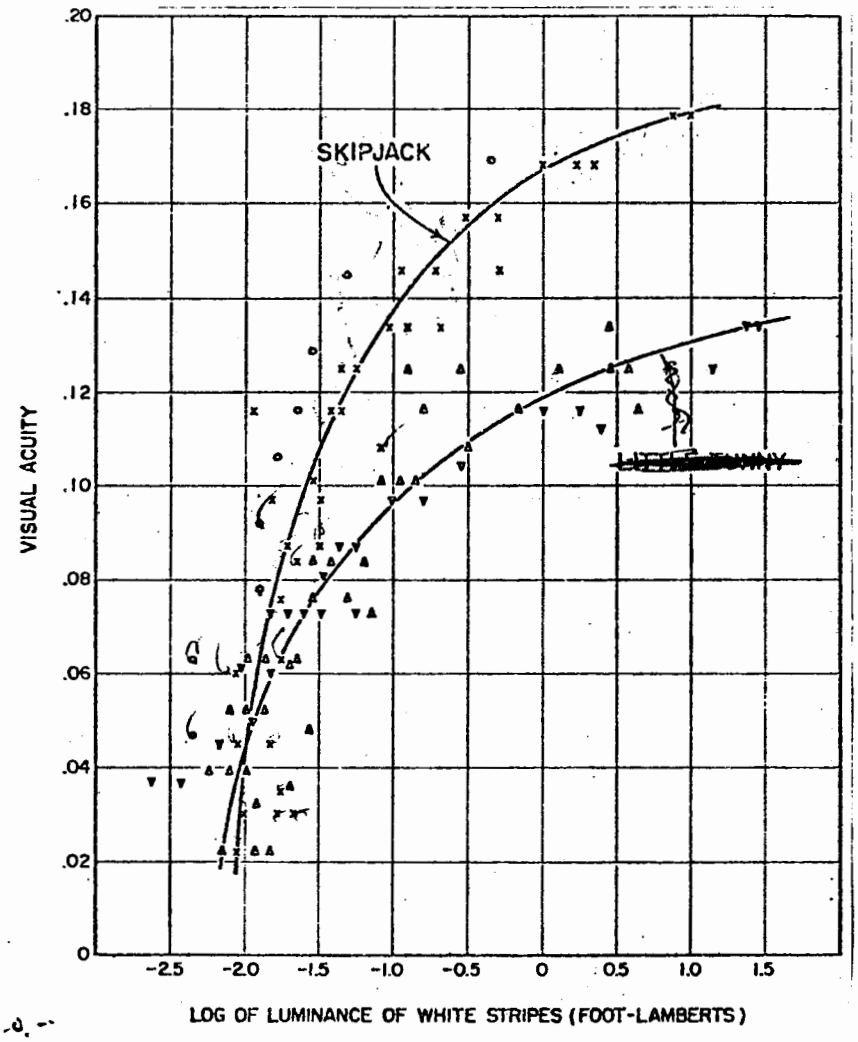

Figure 20.--Visual acuity curve of Euthynnus affinis at adaptive illumination of 170 luxes. Curve fitted by eye (from Nakamura 1968).

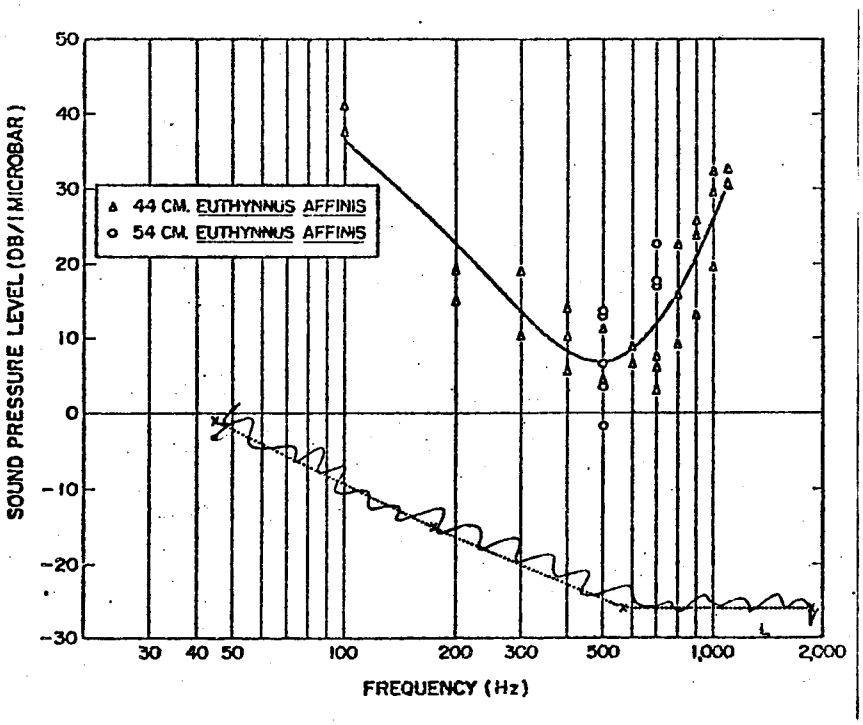

Figure 21.--Acoustic sound pressure thresholds of two Euthynnus affinis (from Iversen 1969).

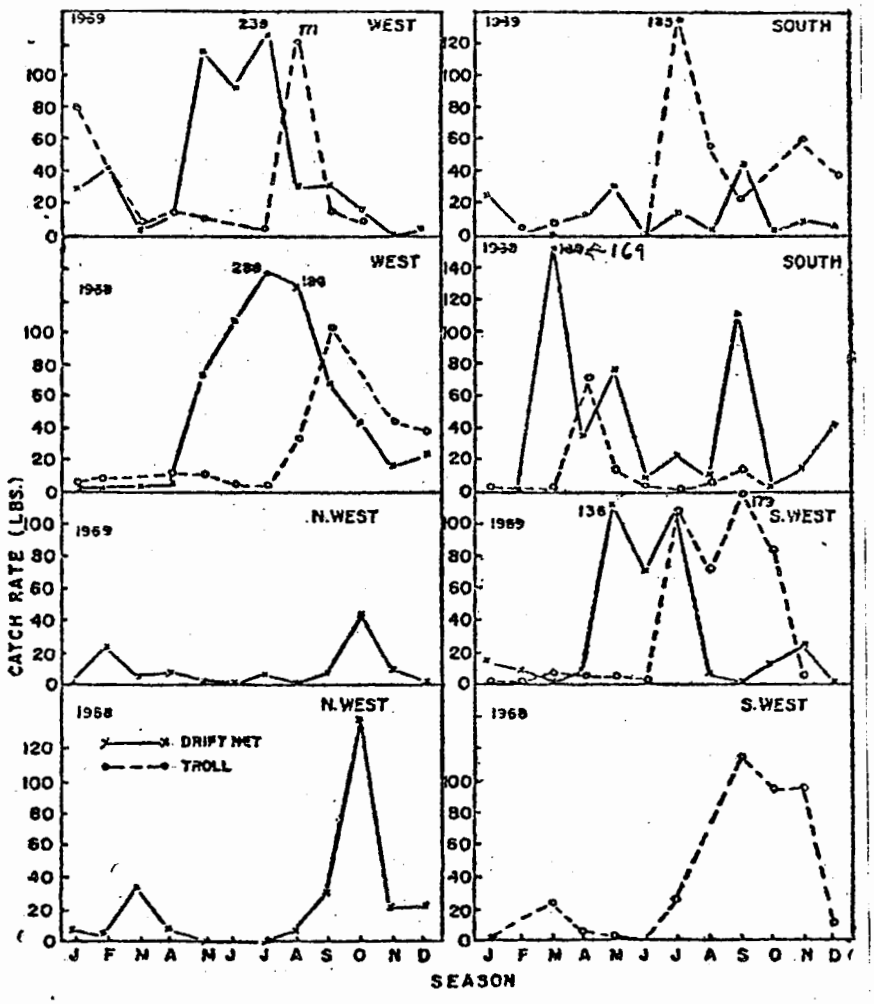

Figure 22.--Seasonal variation in the occurrence of Euthynnus affinis around Sri Lanka (from Sivasubramaniam 1970).

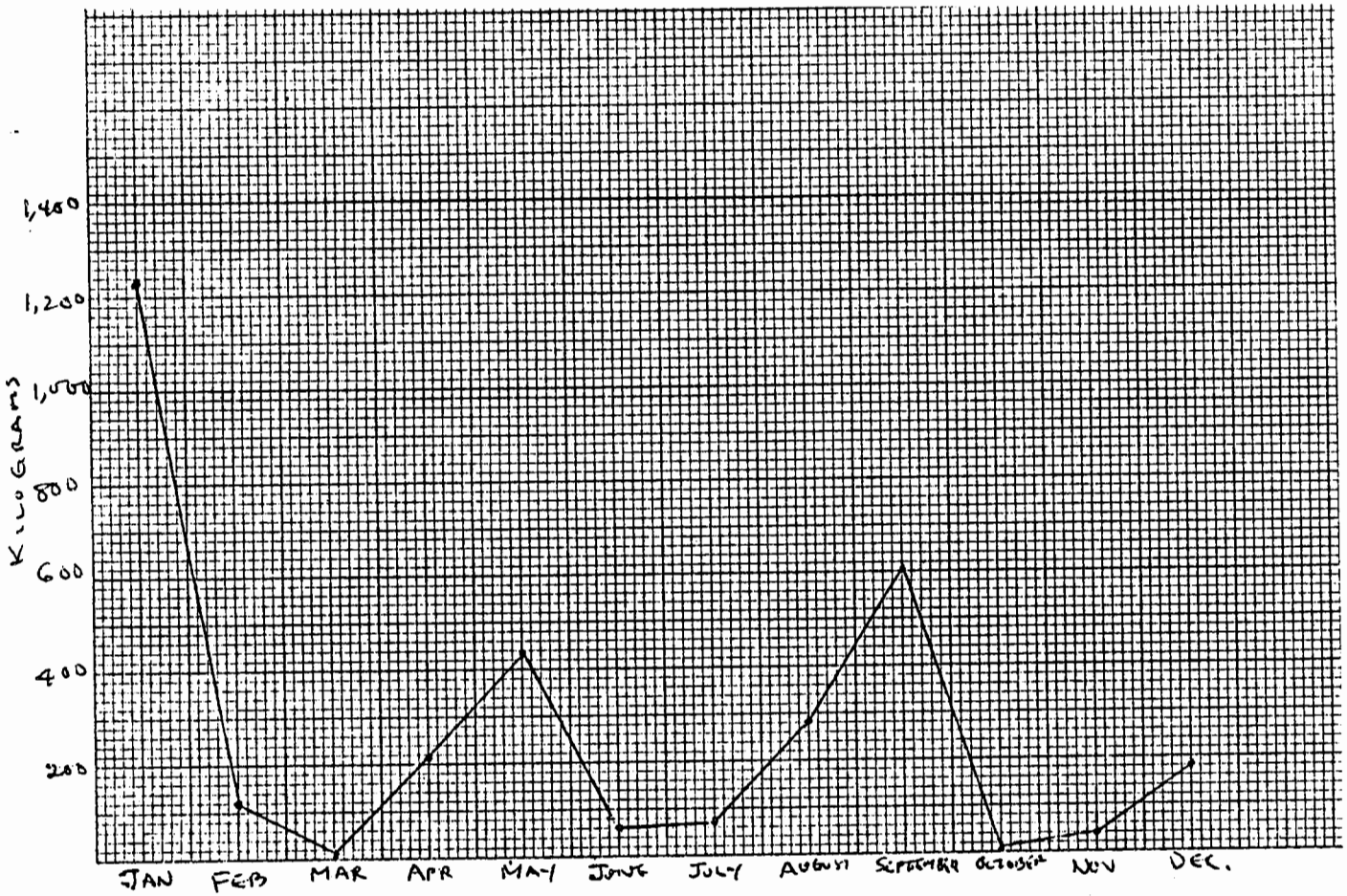

Figure 23.--Mean monthly landings of Euthynnus affinis in Kochi, Japan. (Data courtesy of Mr. T. Koto, Nansei Regional Fisheries Research Laboratory and Dr. S. Kikawa, Far Seas Fisheries Research Laboratory, Japan.)

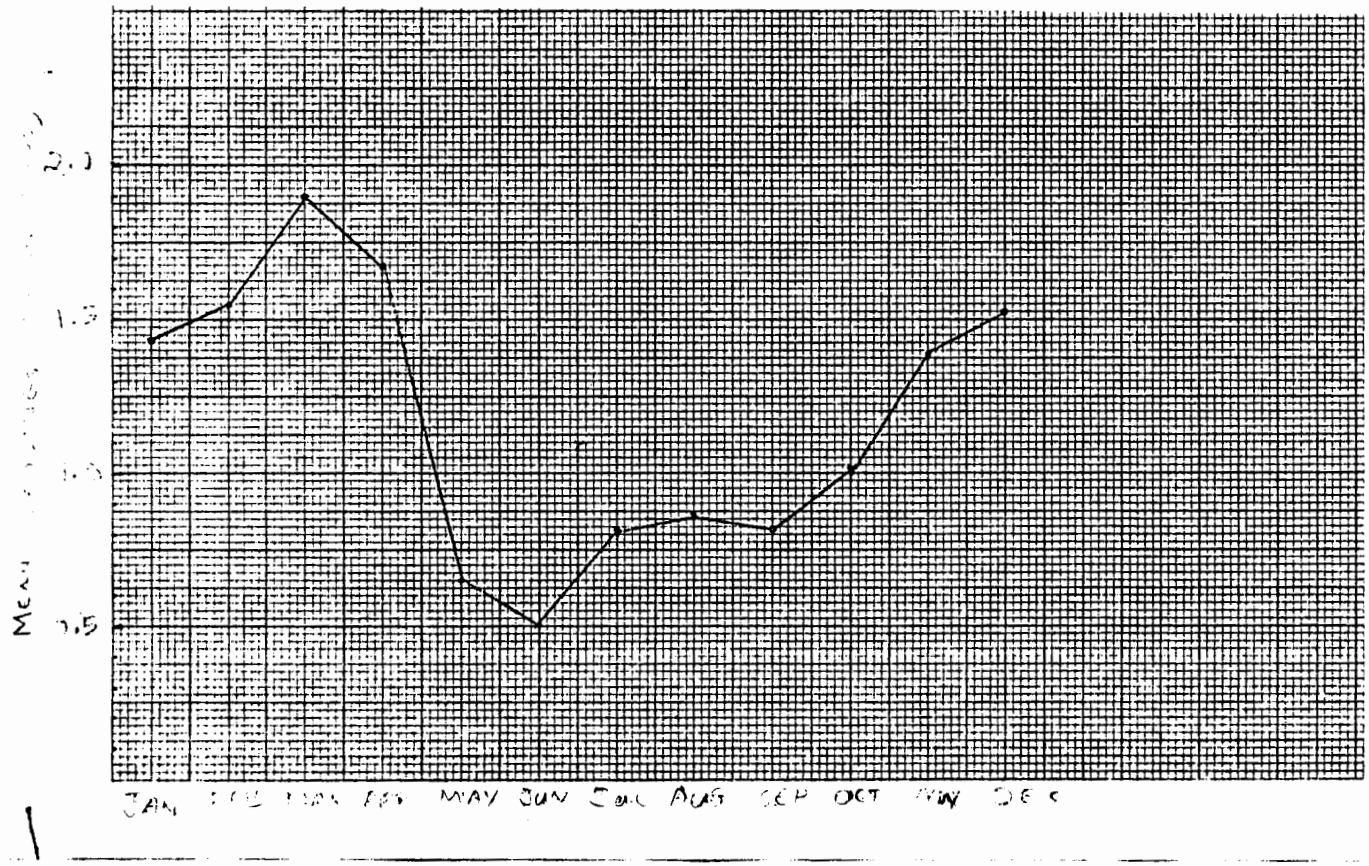

Figure 24.--Mean monthly landings of Euthynnus affinis in Hawaii, 1964-74.

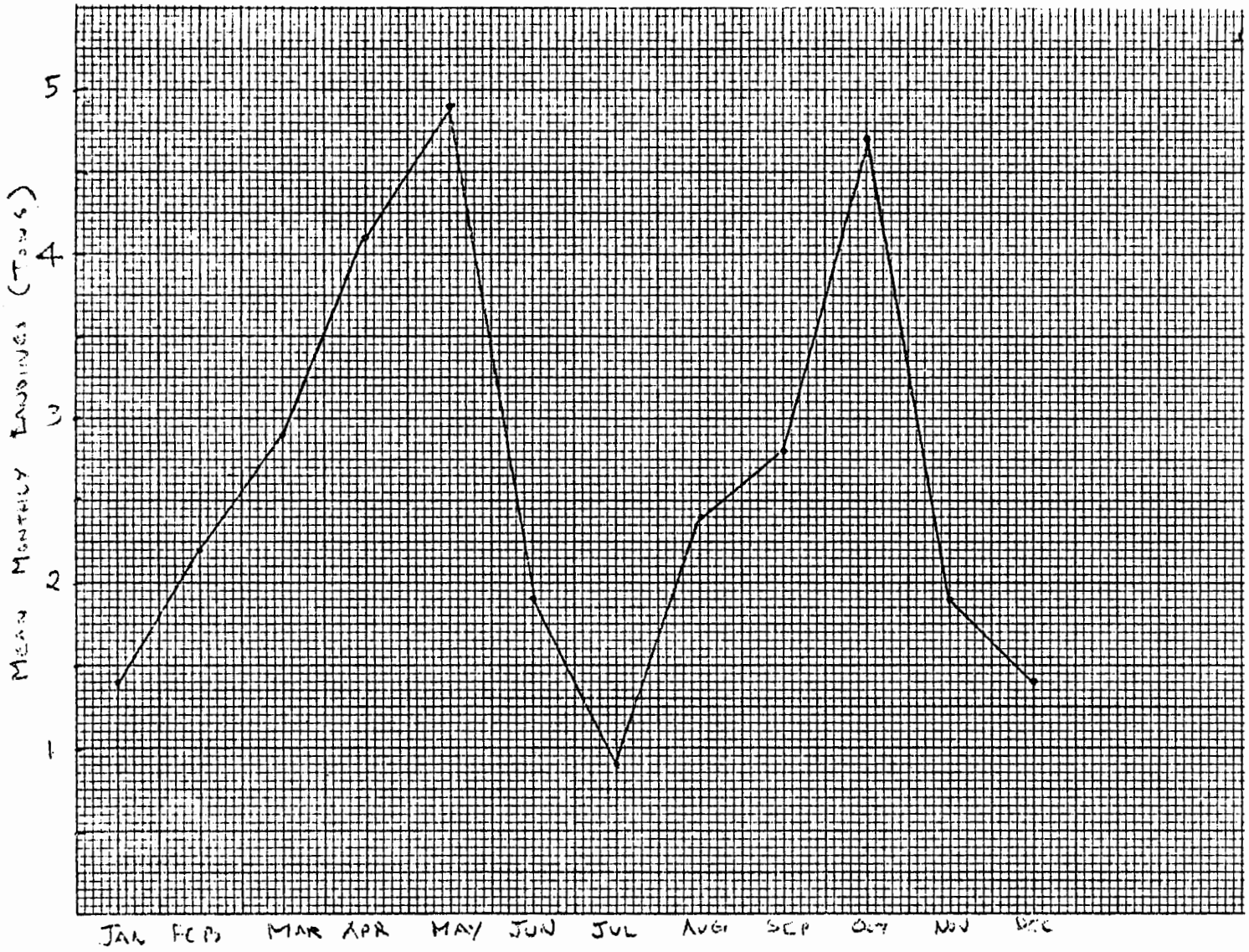

Figure 25.--Mean monthly landings of Euthynnus alletteratus from 1950-55 in Israel (from Ben-Tuvia 1957).

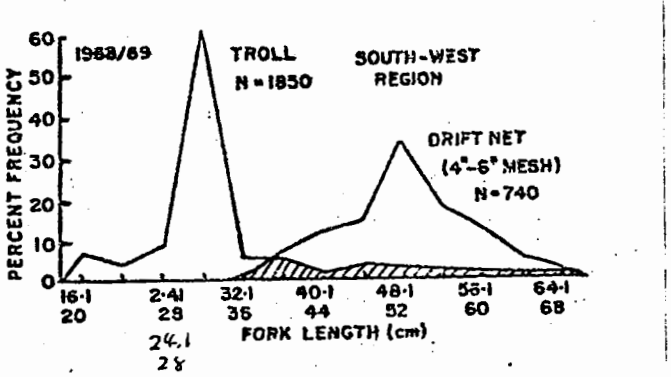

Figure 26.--Length-frequency distributions of Euthynnus affinis caught by drift nets and troll lines in the southwest regions of Sri Lanka (Sivasubramaniam 1970).

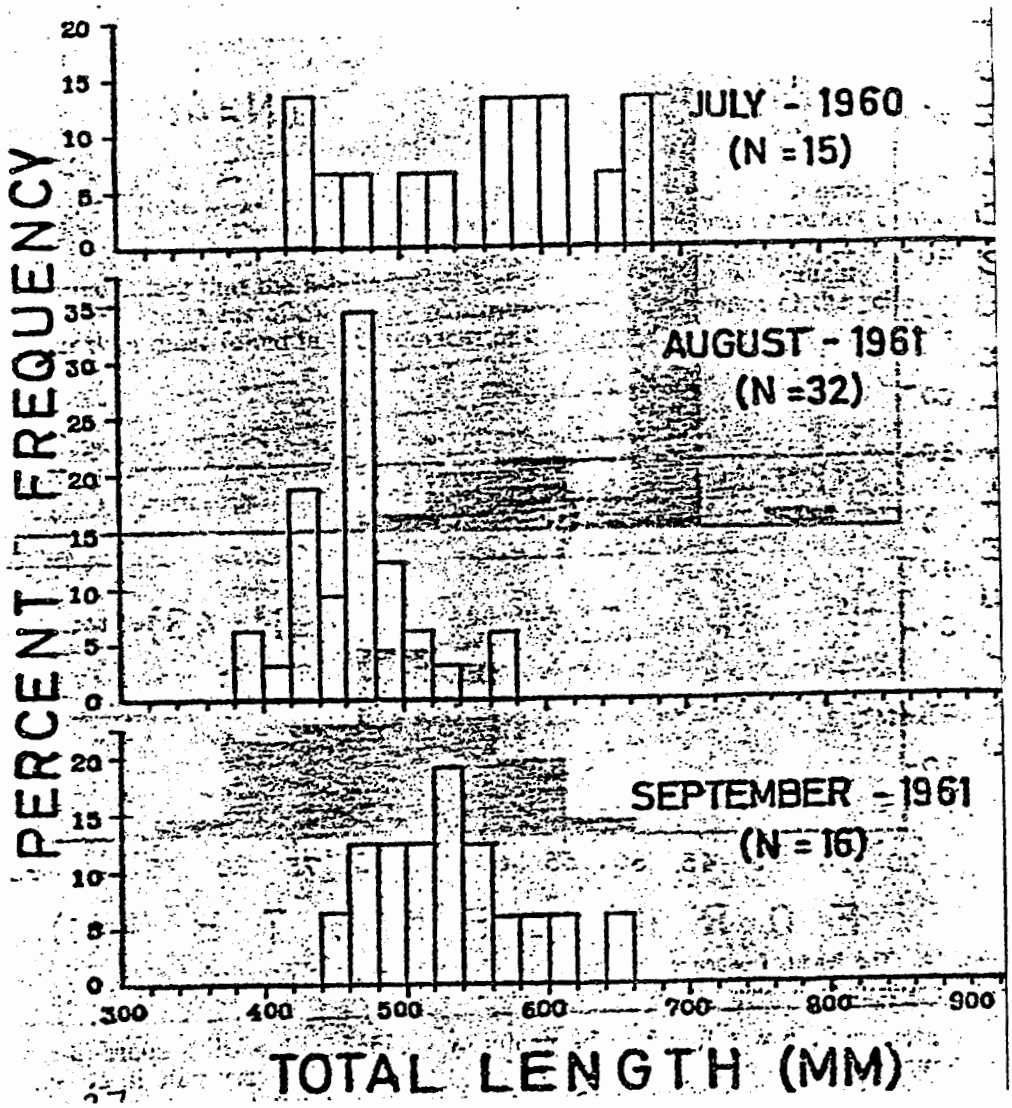

Figure 27.--The length-frequency distribution of Euthynnus affinis caught by trolling off the southeast coast of India (from Silas 1967b).

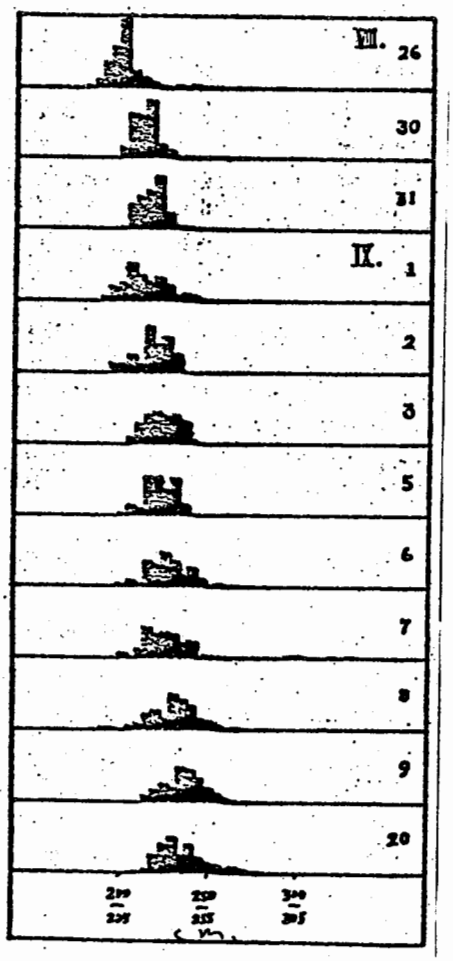

Figure 28.--Length-frequency distribution of Euthynnus affinis landed at Aburatsu, Kyushu, Japan in 1950 (from Yabe et al. 1953).

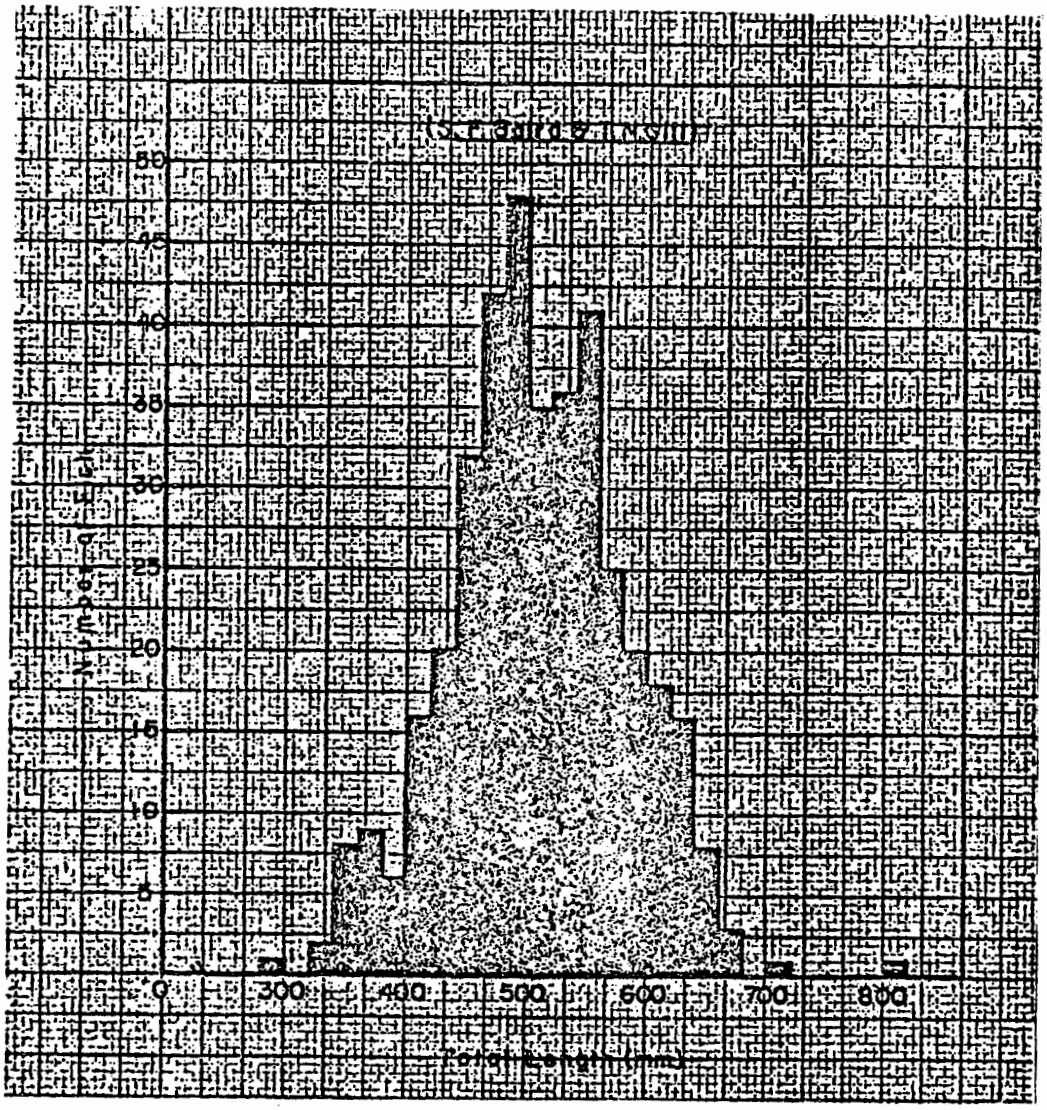

Figure 29.--Length-frequency distribution of Euthynnus affinis taken by trolling in Philippine waters 1947-49 (from Ronquillo 1963).

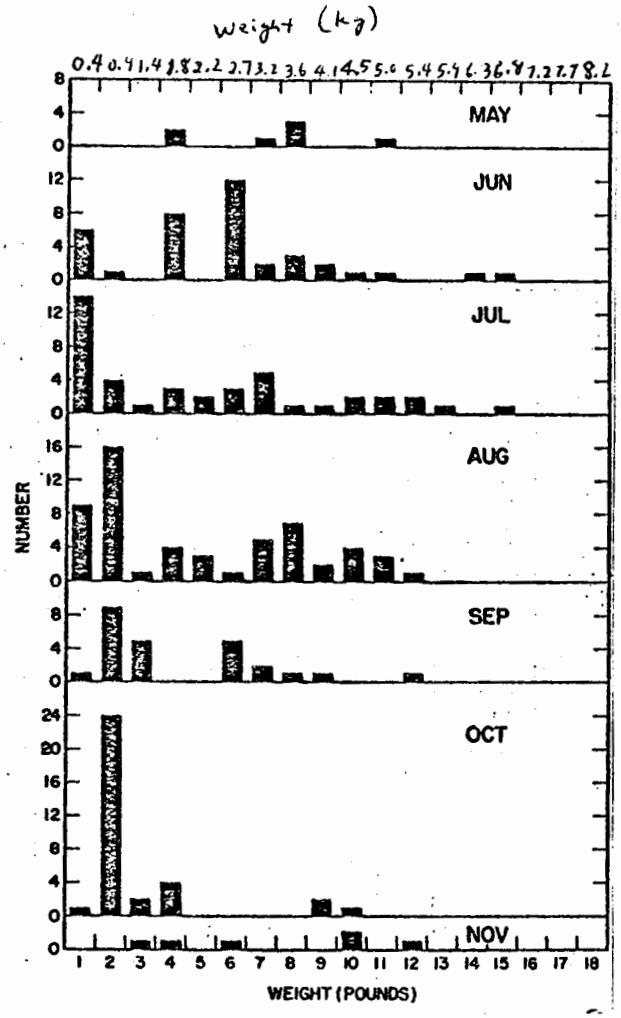

Figure 30.--Weight composition of Euthynnus affinis captured off Kaneohe, Oahu, Hawaii by months, 1951-55 (from Tester and Nakamura 1957).

Figure 31.--Length-frequency distribution of Euthynnus affinis taken by trolling around the Marquesas Islands.

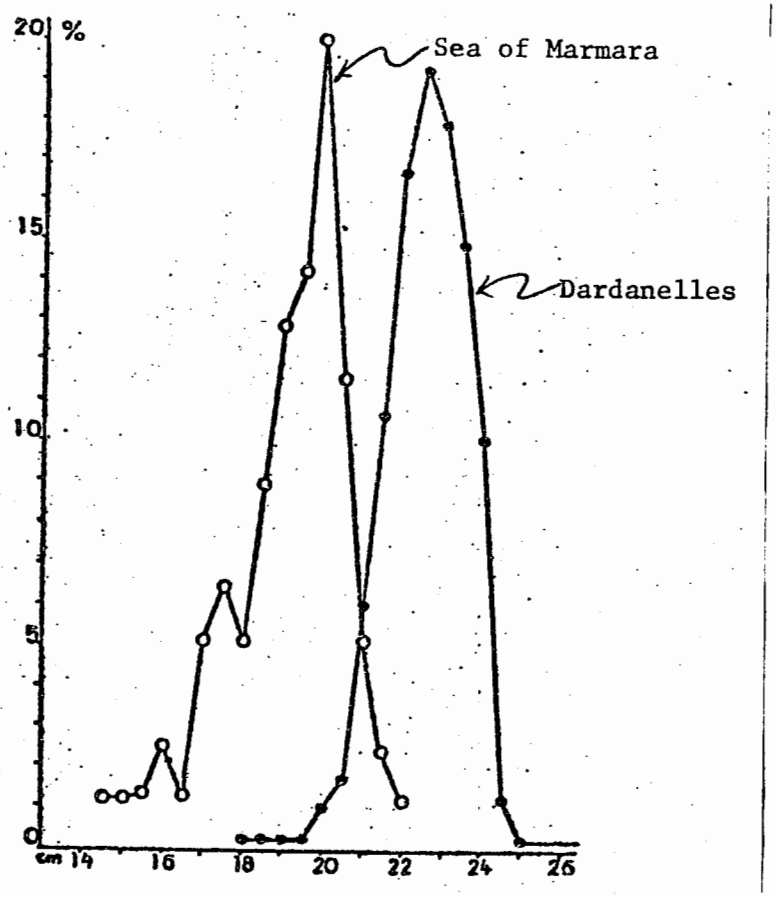

Figure 32.--Length-frequency distributions of juvenile Euthynnus alletteratus from the Sea of Marmara and the Dardanelles (Demir 1963).

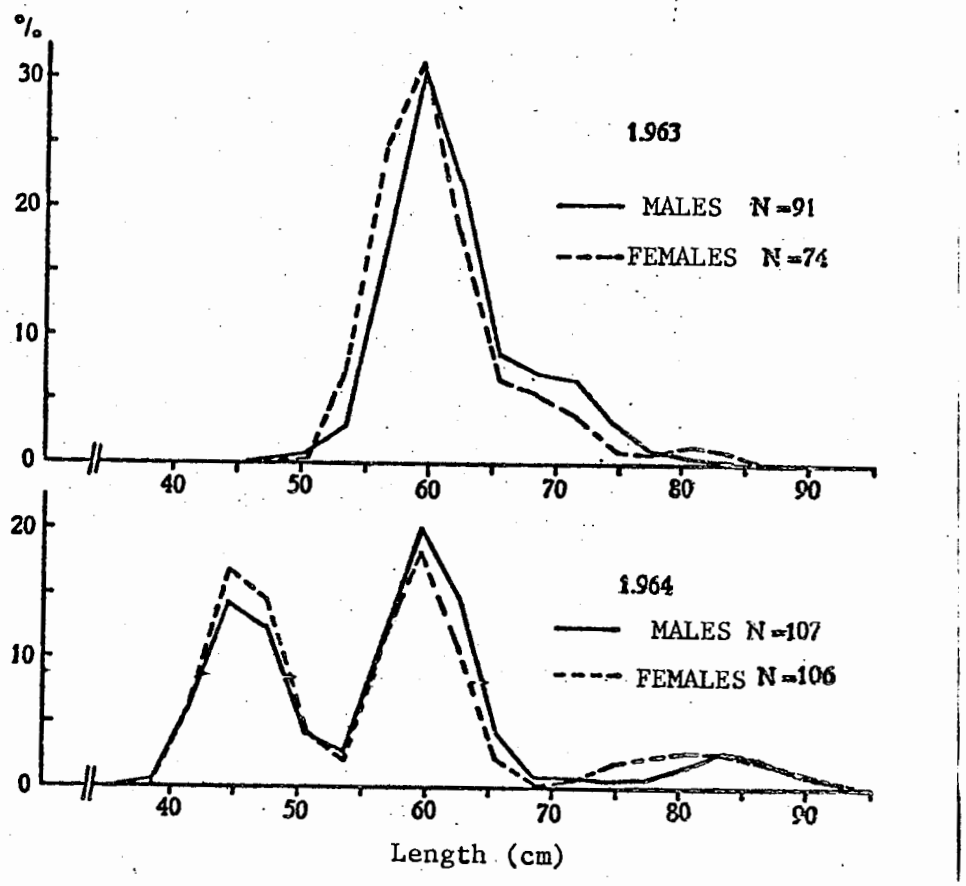

Figure 33.--Length-frequency distribution of Euthynnus alletteratus landed at Barbate and Tarifa, Spain in 1963 and 1964 (Rodriguez-Roda 1966).

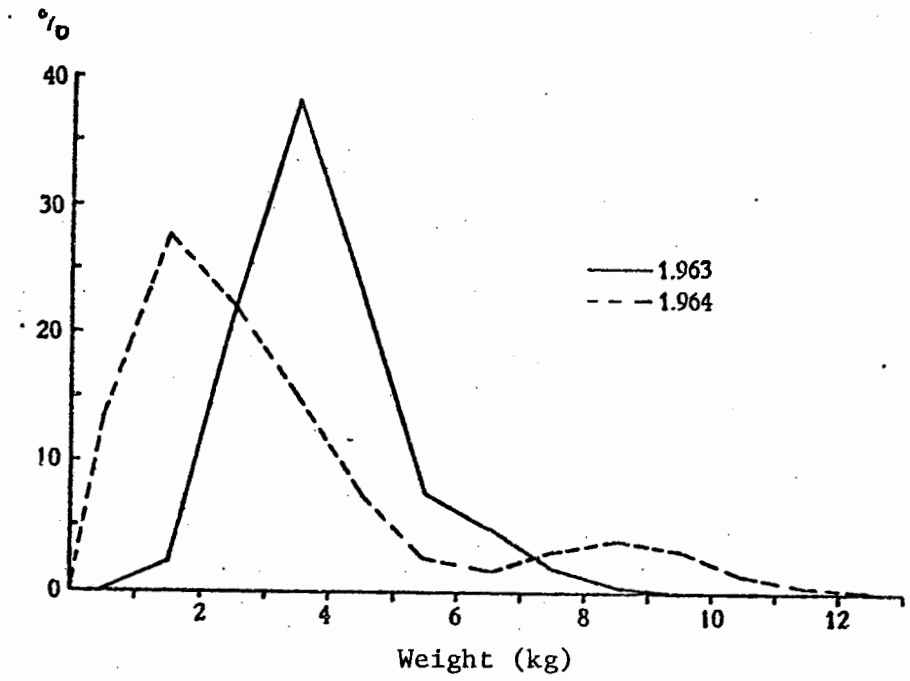

Figure 34.--Weight-frequency distribution of Euthynnus alletteratus landed at Barbate and Tarifa, Spain in 1963 and 1964 (Rodrigues-Roda 1966).

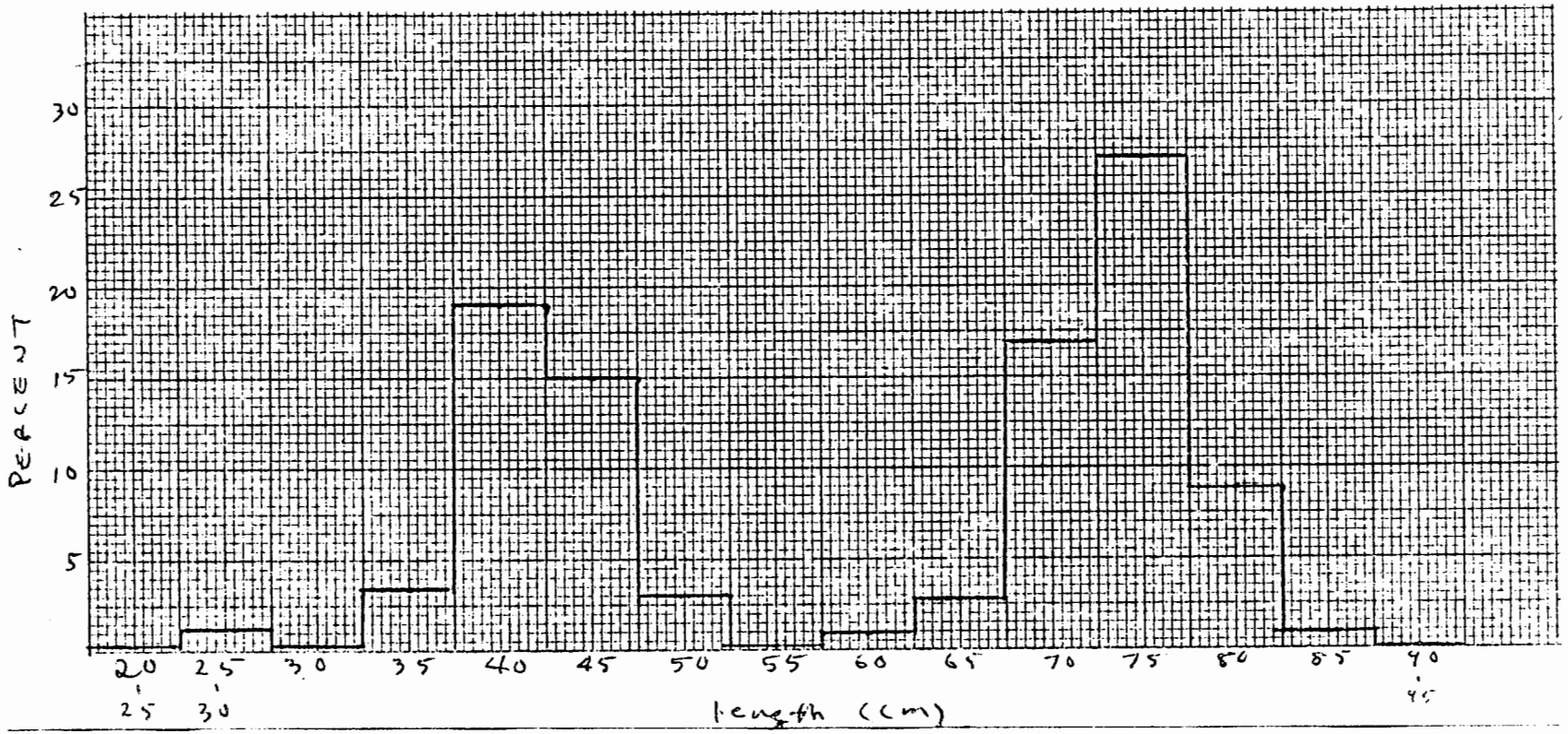

Figure 35.--Length-frequency distribution of Euthynnus alletteratus from Senegal (Postel 1955b).

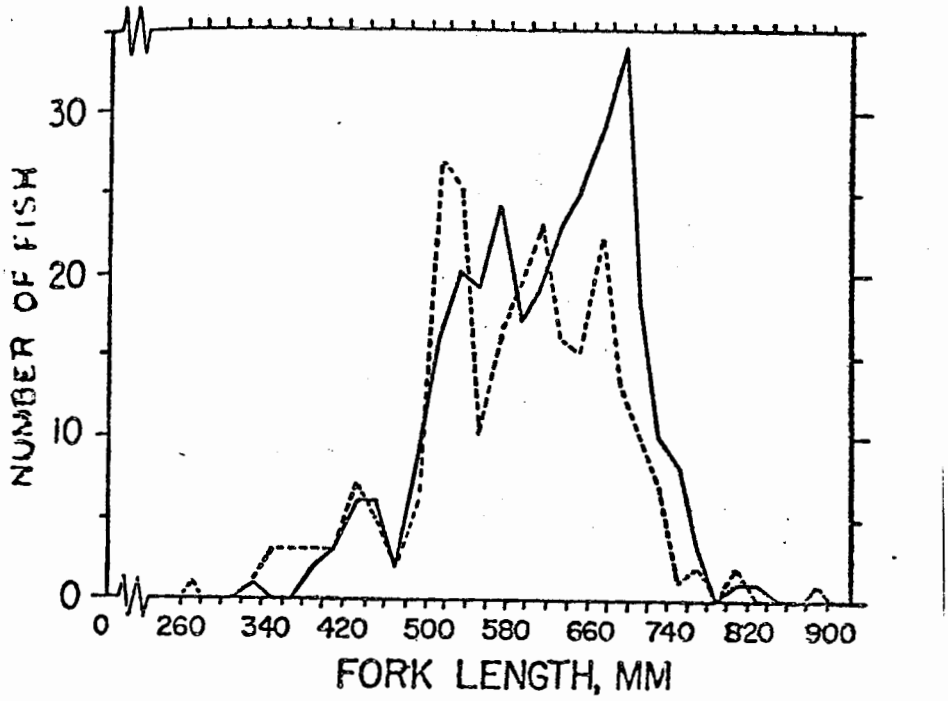

Figure 36.--Length-frequency distribution of male and female Euthynnus alletteratus caught by anglers off Miami, Florida, September 1952 to August 1953. Solid line represents males (N = 295); dashed line represents females (N = 242) (de Sylva and Rathjen 1961).

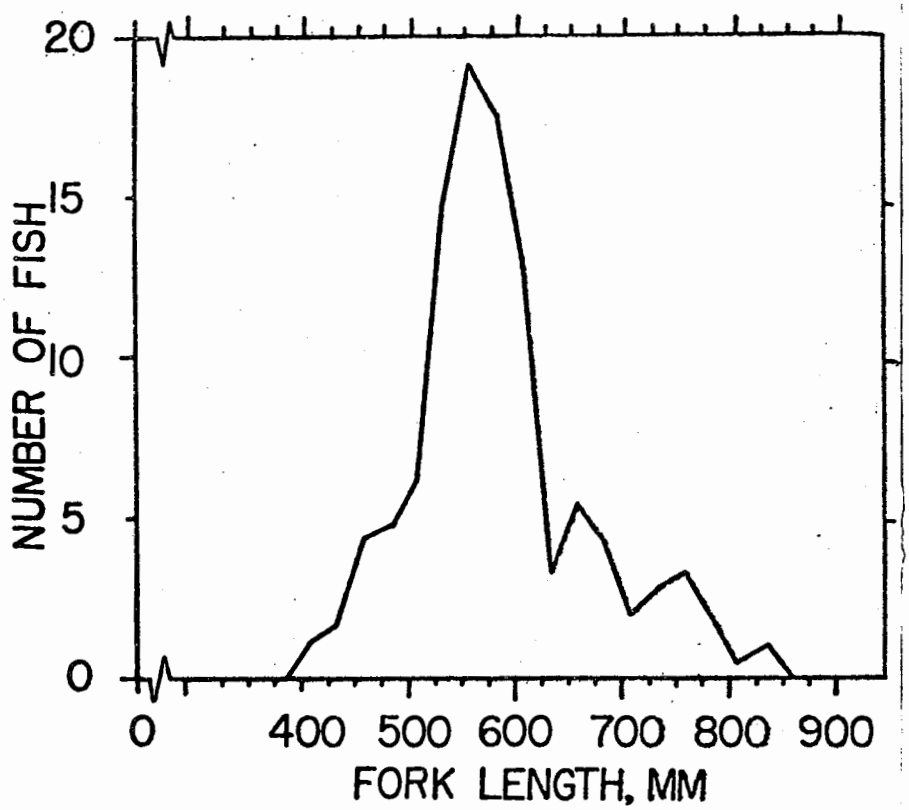

Figure 37.--Length-frequency distribution of 217 Euthynnus alletteratus caught by commercial trolling gear between North Carolina and northern Florida, July 1951 (de Sylva and Rathjen 1961).

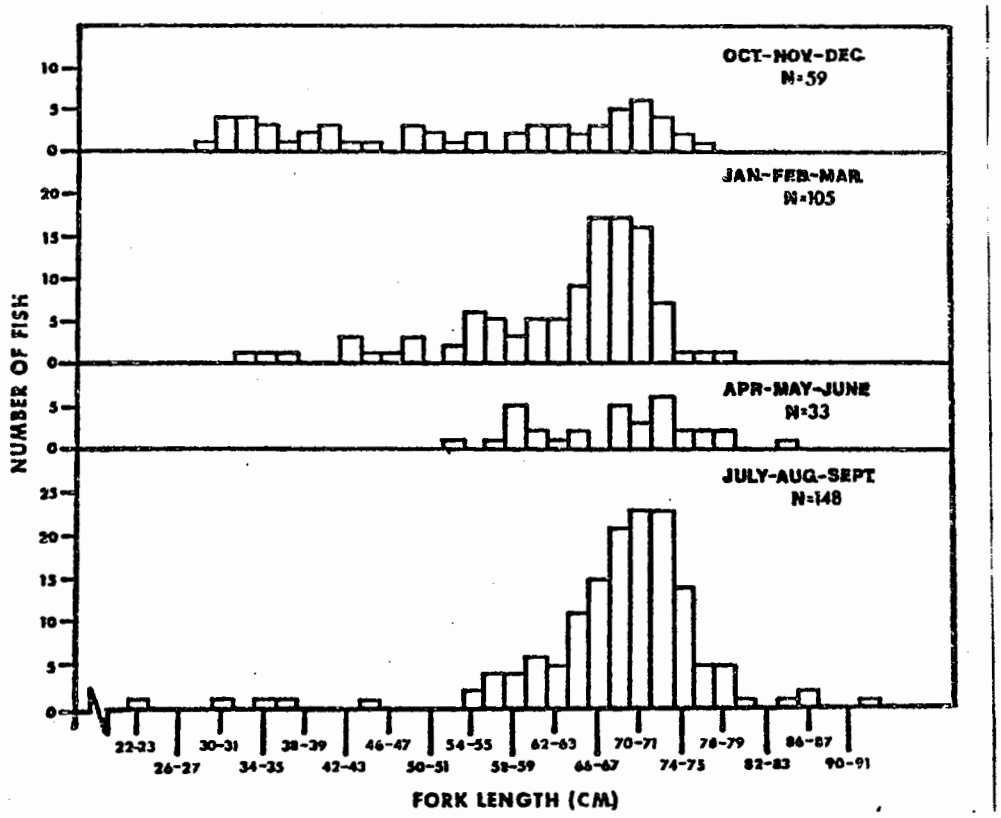

Figure 38.--Length-frequency distributions by quarters of the year for Euthynnus alletteratus sampled from a taxidermy plant in south Florida from September 1967 through September 1968 (Beardsley and Richards 1970).

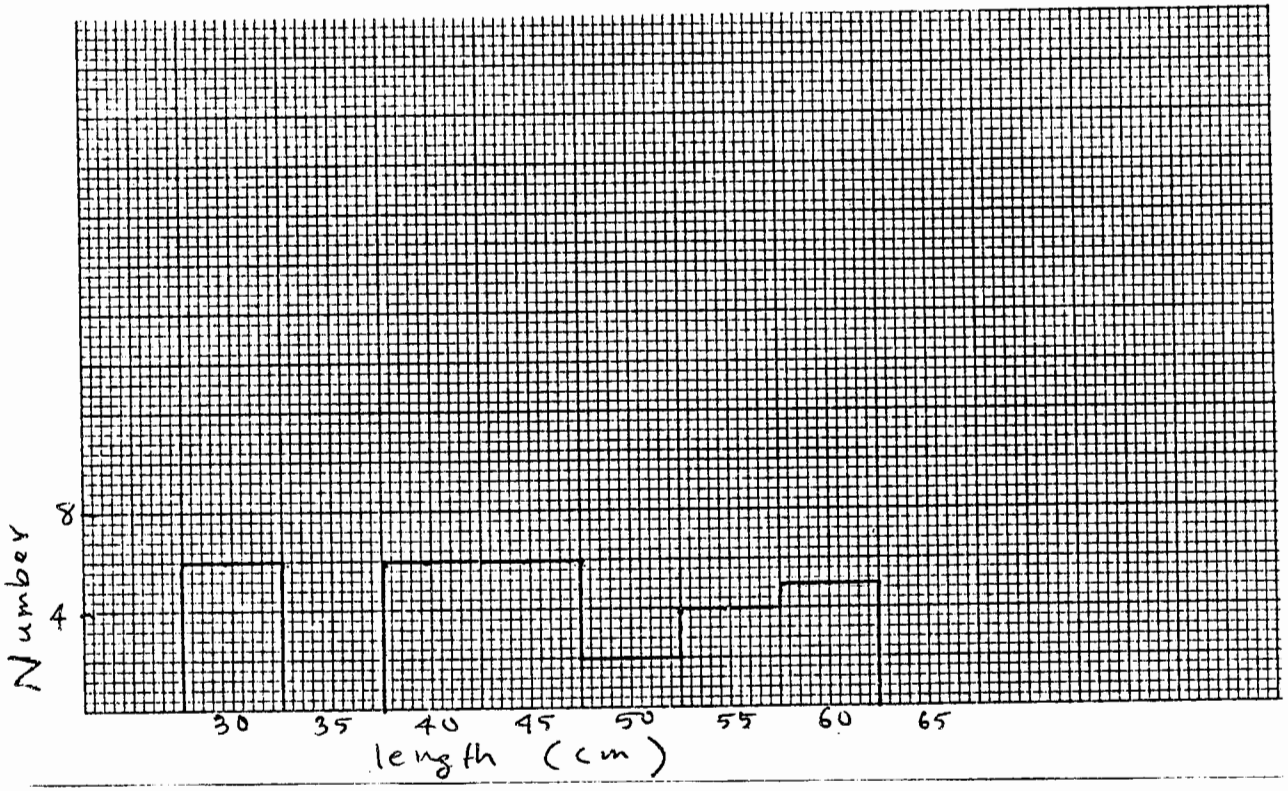

Figure 39.--Length-frequency distribution of Euthynnus lineatus (data from Godsil 1954).

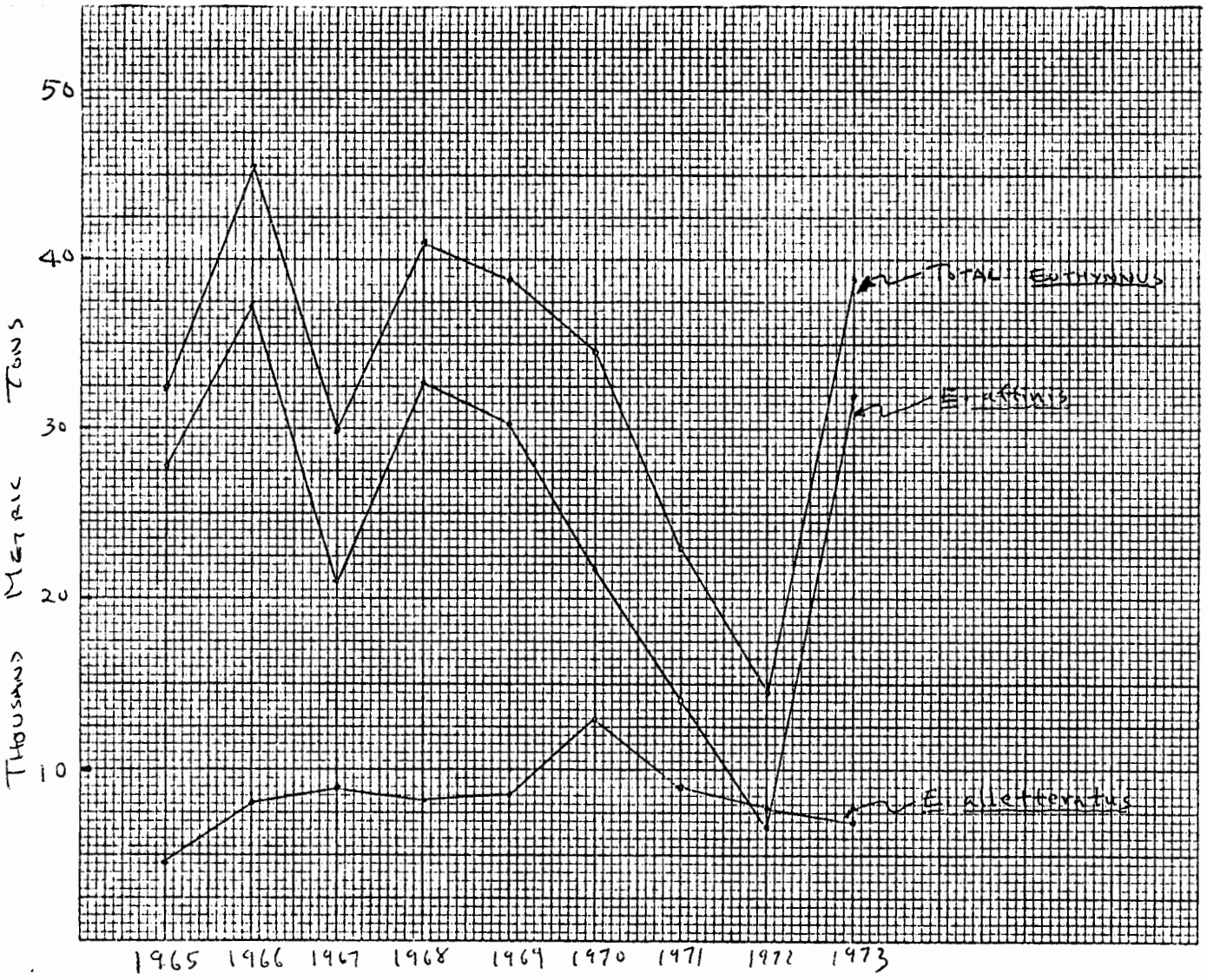

Figure 40.--World landings of Euthynnus (data from FAO 1974a).

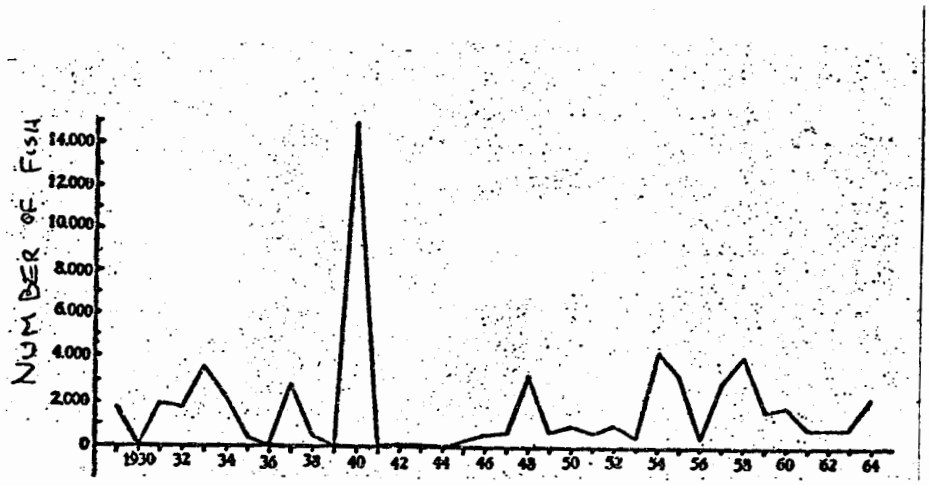

Figure 41.--Landings of Euthynnus alletteratus in the Spanish fishery (Rodriguez-Roda 1966).