

Synopsis of Biological Data on Striped Marlin, *Tetrapturus audax* (Philippi), 1887

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1 IDENTITY

1.1 Nomenclature

1.1.1 Valid Name

Tetrapturus audax (Philippi), 1887 is the name adopted by the most recent review of the family (Nakamura, Iwai, and Matsubara, 1968). The original combination was *Histiophorus audax* Philippi, 1887. Anal. Univ. Chile 71:34-39.

1.1.2 Objective synonymy

All synonyms are assumed to be subjective without consulting original papers and are listed under section 1.21.

1.2 Taxonomy

1.2.1 Affinities

Suprageneric

Phylum Chordata
Subphylum Vertebrata
Superclass Gnathostomata
Class Osteichthyes
Subclass Actinopterygii
Order Perciformes
Suborder Xiphoidei
Family Istiophoridae

Generic

Genus *Tetrapturus* Rafinesque, 1810.

Caratteri di alcuni nuovi generi e nuove specie di animali [principalmente di pesci] e piante della Sicilia, con varie osservazioni sopra i medisimi. Palermo, 105 p.

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Type-species *Tetrapturus belone* Rafinesque, 1810.

Robins and de Sylva (1960, 1963) placed the striped marlin in *Tetrapturus*, following the works of hierarchical classification of the family by Hirasaka and Nakamura (1947) and Nakamura (1949). This placement of *audax* in *Tetrapturus* is supported by Ueyanagi (1963b), Howard and Ueyanagi (1965), and Nakamura et al. (1968).

We follow the generic concept of Nakamura et al. (1968), who described the genus as follows:

The height of the dorsal fin is greater than the body depth. The ventral fin rays are rather long, the fin membrane not well developed. The body is compressed (flat) and except for the striped marlin (Makajiki) and the white marlin (Nishimakajiki), extends in a straight line from the pre-ocular area to the base of the dorsal fin. The cranium is long and narrow. The neural and haemal spines of the central vertebrae form a parallelogram. There are 24 vertebrae (12 + 12 = 24). The lateral appophysis³ is not well developed.

These authors include the following species in the genus: *T. angustirostris* Tanaka, 1914; *T. belone* Rafinesque, 1810; *T. pfluegeri* Robins and de Sylva, 1963; *T. albidus* Poey, 1861; *T. audax* (Philippi, 1887).

Specific

Identity of type specimen:

Species *T. audax* (Philippi, 1887).

Type specimen: Apparently one of the two deposited in the Museo Nacional de Historia Natural, Santiago, Chile by Rudolfo A. Philippi.

Type Locality: Iquique, Chile.

Diagnosis: Ventral fins and two caudal keels are present; snout cross section is nearly circular; first dorsal fin anteriorly is about same height as body depth or greater⁴ and is not saillike but slopes abruptly

³See Ueyanagi and Watanabe (1965) for usage of this term.

⁴Due to allometric growth of the dorsal fin relative to body depth the fin height may be less than body depth in fish larger than 360 cm FL (Royce, 1957).

posteriorly, the middle rays being much shorter than the anterior; snout is fairly long; vent is located very close in front of first anal fin; pectoral fins are fairly broad and long and fold against body; and the tips of pectorals, first dorsal, and first anal fins are pointed.

Subjective synonymy:

<i>Histiophorus audax</i>	Philippi, 1887
<i>Istiophorus audax</i>	Delfin, 1901
<i>Tetrapterus mitsukurii</i>	Jordan and Snyder, 1901
<i>Tetrapturus ectenes</i>	Jordan and Evermann, 1926
<i>Makaira audax</i>	Jordan and Evermann, 1926
<i>Makaira grammatica</i>	Jordan and Evermann, 1926
<i>Makaira holei</i>	Jordan and Evermann, 1926
<i>Makaira mitsukurii</i>	Jordan and Evermann, 1926
<i>Makaira zelandica</i>	Jordan and Evermann, 1926
<i>Marlina mitsukurii</i>	Grey, 1928
<i>Marlina zelandica</i>	Whitley, 1937
<i>Kajikia mitsukurii</i>	Hirasaka and Nakamura, 1947
<i>Kajikia formosana</i>	Hiraska and Nakamura, 1947
<i>Tetrapturus tenuirostratus</i>	Deraniyagala, 1951
<i>Tetrapturus acutirostratus</i>	Deraniyagala, 1952
<i>Makaira formosana</i>	Matsubara, 1955
<i>Tetrapturus brevirostris</i>	Munro, 1955
<i>Marlina audax</i>	Smith, 1956a, b
<i>Marlina jauffreti</i>	Smith, 1956b
<i>Tetrapturus audax</i>	Robins and de Sylva, 1960
<i>Makaira jauffreti</i>	Jones and Silas, 1964

Artificial key to genus (Nakamura et al., 1968):

- A. Anterior fin rays of first dorsal fin fairly high, posterior rays about same height; vent situated decidedly anterior to origin of the first anal fin; second anal fin anterior to second dorsal fin.
 - B. Pectoral fin narrow and short
 - C. Snout very short. . . Shortbill spearfish (Furaikajiki) *T. angustirostris* Tanaka.
 - CC. Snout fairly long Mediterranean spearfish (Chichukaifurai). *T. belone* Rafinesque.
 - BB. Pectoral fin wide and long Longbill spearfish (Kuchinagufurai) *T. pfluegeri* Robins and de Sylva.
- AA. Height of anterior portion of first dorsal fin about same as the body depth but gradually decreasing in height posteriorly; vent directly anterior to the origin of the first anal fin; second dorsal fin and second anal fin in parallel positions.
 - D. Pectoral fin wide and its tip rounded. The tip of the first dorsal fin and first anal fin

- rounded White marlin (Nishimakajiki) *T. albidus* Poey.
- DD. Pectoral fin narrow, and its tip pointed; the tips of the first dorsal fin and first anal fin pointed Striped marlin (Makajiki) *T. audax* (Philippi).

1.22 Taxonomic status

The species is established on the basis of morphology without breeding data. The species may be polytypic (see 1.31 below).

1.23 Subspecies

No subspecies are recognized.

1.24 Standard common names and vernacular names

Country	Standard common name	Vernacular name(s)
Sri Lanka		Seraman Koppara
Chile		Pez aguja
China		Chi zuo fo yii
Japan	Makajiki	Maka, Kajiki, Kajikimaguro, Nairagi, Nairage, Nairanbo
Kenya		Nduaro
Mexico	Marlin rayado	Marlin, agujon, pez puereo
New Zealand	Striped marlin	New Zealand marlin
Philippines		Spearfish
Russia		Polosatii marlin
Taiwan	Hung ju chi yii	Hung ju ting pan
United States	Striped marlin	Pacific striped marlin, barred marlin, Pacific marlin, striped swordfish, spearfish, spikefish
Vietnam		Ca co Mitsukurii

1.3 Morphology

1.31 External morphology (for description of spawn, larvae, and adolescents, see 3.17, 3.22, 3.23).

Generalized: Gregory and Conrad (1939) provide a scale diagram of the striped marlin outline based on modal body proportions of 30 specimens from New Zealand and Australia using standard length as the basic body measurement. Thirty-eight measurements were made on each specimen and are published in absolute and as percentage of standard length along with total body weight.

Nakamura et al. (1968) provide the following description:

External Characters. The first dorsal fin has 37-42 fin rays. The second dorsal fin has 6 soft rays. The first anal fin has 13-18 fin rays. The second anal fin has 5-6 soft rays. The pectoral fin has 18-22 soft rays. The ventral fin has one spine and 2 soft rays. The

body is elongated (the body length is about 5.9-7.3 times the body depth) and is rather thick. The snout is long (the head length is about 0.88-0.99 times the length of the maxillary), and its cross-section is almost round. The body is densely covered with scales; the tips of the scales are pointed. Scales from specimens less than 1 meter in length do not have this species characteristic. There are small file-shaped teeth on both jaws and on the palate. The lateral lines on the sides curve over the pectoral fin and then continue in a straight line to the area of the caudal fin. The head is large (the body length is 3.6-3.8 times the length of the head). The eyes are moderately large. There is a relatively conspicuous crest on the outer edge of the head between the pre-ocular region and the origin of the first dorsal fin. There are 2 scutes on each side of the tail near the caudal peduncle; the tail is strong and deeply forked. The pectoral fin, has a pointed tip and is located rather low on the body; it is shorter than the head (the head length is about 1.14-1.99 times the length of the pectoral fin). The first dorsal fin begins above the posterior end of the pre-opercle bone; its first few rays are larger than the body depth, but as it progresses towards the back, it gradually becomes shorter, ending just in front of the origin of the second dorsal fin. The tip of the first anal fin is pointed, large and sickle-shaped. The second dorsal fin and the second anal fin are about the same size and shape. The latter is located a little further forward on the body than the former. In spite of the fact that the ventral fin is longer than the pectoral fin in smaller specimens, the opposite is true for larger specimens. The fin membrane of the first dorsal fin is dark blue. The back of the body is dark blue with splotches of black on it; towards the ventral side of the body, 10 or more rows of cobalt-colored stripes are clearly visible. The other fins are blackish brown, or sometimes a dark blue. The bases of the first and second anal fins are silvery-white.

Morrow (1952a) published morphometric data on 49 specimens from New Zealand and later (Morrow, 1957) published extensive morphometric data and anal ray counts on 39 fish from Peru. These data include standard length as the basic body length measurement. Ueyanagi (1957b) presented morphometric data on young specimens, 80- to 180-cm eye-fork length, from the western North Pacific. Royce (1957) reported extensive morphometric data of 25 specimens from the central Pacific using fork length as the basic measurement but also giving standard length and eye-fork lengths for some specimens. He also published more limited data on 30 specimens measured by the Hawaii Division of Fish and Game. Kamimura and Honma (1958) published morphometric data on five characters using eye-fork length as the basic body measure for 56 fish south of the equator and 124 fish north of the equator in the western Pacific. Williams (1967) presented dorsal and anal fin ray counts of 13 specimens from East Africa. Merrett (1971) gives fin measurements on about 23 other specimens.

Counts have been given by several authors and are shown in Table 1.

Geographic variation: Geographic variation appears to be considerable. Morrow (1957) concluded that striped marlin from Peru and northern New

Zealand represented separate and distinct populations based on significant differences in 11 morphometric and meristic characters as follows: average absolute lengths of pelvic fins, counts of spines and rays in the first anal fin, and the regressions of the following measurements on standard length: greatest body depth, length of base of second dorsal fin, length of base of first anal fin, width of base of pectoral fin, snout tip to origin of first dorsal fin, snout tip to origin of second dorsal fin, snout tip to origin of first anal fin, snout tip to posterior edge of operculum, snout tip to posterior end of maxillary. By a character index (CI) in which

$$CI = \frac{\text{pelvic length}}{10} - \frac{100}{SL} (\text{Depth} + \text{Length}$$

of anal base + Width of pectoral base), Morrow could separate correctly about 72% of the 69 specimens from which the index was derived. The New Zealand specimens tended to have character indices of considerably lower numerical value than the Peru specimens.

In the western Pacific (west of long. 170°W) Kamimura and Honma (1958) found a remarkable difference in the lengths of the pectoral fins between northern (lat. 30°-35°N) and southern (lat. 18°-25°S) striped marlin. Covariance analysis of regression of pectoral fin on eye-fork length showed no significant difference in slope of regression but a highly significant (0.01) difference in adjusted means. Also significant differences (0.05) were found for both regression coefficients and adjusted means for regressions of eye-to insertion of second dorsal on eye-fork length. From these differences these authors concluded northern and southern populations in the western Pacific were extremely separated. In intermediate waters of the northern hemisphere (lat. 5°-25°N) all but three fish had pectoral lengths clustered about the regression line for the northern population. The pectoral lengths of the other three fish, which were taken from lat. 5° to 15°N, were close to the regression line for the southern population and were presumed to have strayed from that population.

Honma and Kamimura (1958) supported the hypothesis of separate north and south populations in the western Pacific with the following observations:

- a) a zone of low hook-rate along the equator separates the populations;
- b) the main spawning grounds are widely separated and spawning seasons are a half-year apart;
- c) the maximum size attained is much larger in the southern population;
- d) adaptations of the two populations to environmental circumstances do not coincide in details, differing with growth stages.

Howard and Ueyanagi (1965) extended the

Area and author	First dorsal fin	dorsal fin	First anal fin	anal fin	Pelvic fins	Pectoral fins
Chile						
Philippi, 1887	38	5	12	5	1	
Western Pacific						
Nakamura, 1938, 1949	37-43 (III+12-15+XXII-XXV)	6	14-15 (II+12-13')	6	1+2	
Western Pacific						
Ueyanagi, 1959	37-44					
New Zealand						
Morrow, 1957			12-16			
Peru						
Morrow, 1957			14-17			
East Africa						
Williams, 1967	35-41	5-7	11-15	5-6		
Peru						
Morrow (unpubl.) (after Williams, 1967)	37-44	5-7	14-17	5-7		
East Africa						
Morrow (unpubl.) (after Williams, 1967)	36-41	5-7	11-15	5-6		
East Africa						
Merrett, 1971	38-42	5-7	13-16	5-6		19-23
Eastern North Pacific						
Wares and Sakagawa, 1974		5-7		5-7		

¹The figure of 25 which appears here in the translation of the 1949 paper is evidently a misprint.

hypothesis by including eastern Pacific fish in the southern population and demonstrating that growth of the pectoral fin is allometric with an inflection at about 185-cm eye-fork length. They pointed out that mixing of the two populations occurs in the tropics and suggested that Mexican fish belong principally to the southern-eastern group and that southern California fish are derived from both groups but dominated by the northern.

Merrett (1971) found striped marlin of the tropical western Indian Ocean to have relatively long pectoral fins indicating a closer relation to the southern-eastern population than to the northern.

There has been little mention in the literature of geographical variation in color pattern, but the striking almost zebra-like bars on the freshly caught New Zealand specimen in the photo published by Gregory and Conrad (1939) appears more pronounced than in fish from other regions.

To date, the knowledge of subpopulations, if they truly exist, is insufficient for morphological definition.

The morphological changes of larvae and adolescent phases are of course remarkable. See 3.22 and 3.23.

Morrow (1952a) found significant ($P < 0.001$) negative allometry in the dorsal and ventral lobes of the caudal fin and a slight but not statistically significant ($P = 0.065$) negative allometry in the length of the pectoral fin of 49 adult fish from Cape Brett, New Zealand. The pelvic fins show extreme negative

allometry appearing to cease growth after reaching a certain size (Morrow, 1957; Royce, 1957). Negative allometry was found in Peruvian specimens for body depth and snout tip to origin of first anal fin (Morrow, 1957). Ueyanagi (1957b) found extreme negative and positive allometry, respectively, in central dorsal rays relative to body depth and pectoral length relative to body depth in young specimens (85-175 cm) which proved the synonymy of *Kajikia formosana* and *T. audax*. Royce (1957) also found similar allometry.

Ontogenetic change in body form is shown in Figure 1. The morphological change of the snout (its growth relative to the body length) from the postlarval to adult stage of striped marlin is relatively small in comparison with those of other istiophorid species. However, the change of the dorsal fin shape during growth is remarkable in this species (Ueyanagi, 1963b).

In relation to functional morphology, Fierstine (1968) found an average aspect ratio (span/surface area of one side of fin) of 9.0 for the caudal fin of three striped marlin from the eastern Pacific. This high ratio, indicating relative efficiency as a hydrofoil, was greater than that for seven other scombroid species but less than that for the sailfish, *Istiophorus platypterus*, and the white marlin, *T. albidus* (10.0 and 10.3, respectively).

Published weight-length regression constants are summarized in Table 2.

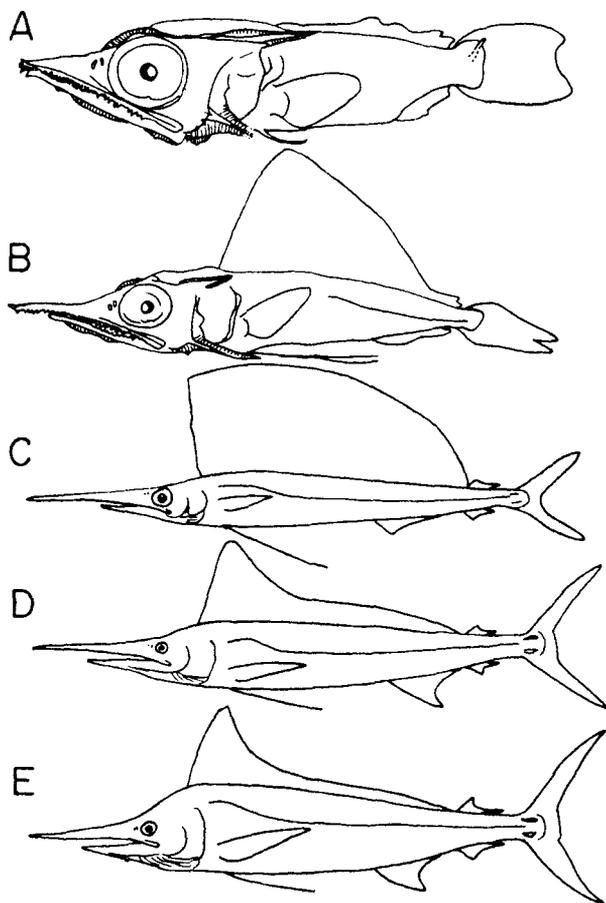


Figure 1.—Ontogenetic change in body form of striped marlin. A. 7.9 mm SL, B. 21.2 mm SL, C. 121.5 mm body length, D. 1,050 mm body length, E. 1,882 mm body length. (From Nakamura, 1968.)

1.32 Cytomorphology

No data available.

1.33 Protein specificity

No data available.

2 DISTRIBUTION

2.1 Total Area

In the eidological classification of Parin (1968) the striped marlin is holoeipipelagic, i.e., it inhabits the isothermic surface pelagic layer of the ocean at all stages of its life cycle. Such species are chiefly limited

in distribution to the tropics, where a permanent thermocline exists, but penetrate higher latitudes in the warm season. Atypical of the distribution of most scombroids, the striped marlin seems to prefer the more temperate waters. In the Pacific the distribution resembles that of the albacore, *Thunnus alalunga*, and bluefin tuna, *T. thynnus*, in contrast to that of the other billfishes and tunas (Howard and Ueyanagi, 1965; Parin, 1968), however, in the Indian Ocean the striped marlin distribution is centered in warmer waters.

Striped marlin occur throughout the warmer waters of the Indian and Pacific oceans. The species ranges eastward to the coast of the American continents and westward to the African coast. Off South Africa they are found a slight distance into Atlantic waters (Talbot and Penrith, 1962). Extreme poleward distribution has been recorded to lat. 40°-45° in both hemispheres. In the north this occurs in the Kuroshio extension, primarily between long. 165°E and 180°, but also at long. 150°W (Fisheries Agency of Japan, Research Division, 1969-71). In the southern hemisphere this occurs in the Agulhas Current (Talbot and Penrith, 1962; Fisheries Agency of Japan, Research Division, 1969-72) and also rarely at long. 105°E (Fisheries Agency of Japan, Research Division, 1969), which appears to be West Wind Drift water. On the eastern perimeter of the Pacific, Point Conception (lat. 35°N) and Chañaral, Chile (lat. 29°S) appear to be the northern and southern limits of distribution.

The broad geographical distribution of this species makes it difficult to generalize on the physical and biological characteristics of the areas inhabited. Temperature, however, is one parameter which has been considered to influence total distribution. The 20° and 25°C isotherms tend generally to bound the total distribution at least in the western Pacific (Howard and Ueyanagi, 1965).

2.2 Differential Distribution

2.21 Spawn, larvae, and juveniles

Although information is lacking on the distribution of eggs, there are several reports (Ueyanagi, 1959, 1964; Jones and Kumaran, 1964; Nishikawa and Ueyanagi, 1969) pertaining to the distribution of larvae.

In the Pacific, larvae have been observed in the northwestern Pacific (west of long. 180°) between lat. 10° and 30°N; and in the South Pacific (west of long. 130°W) between lat. 10° and 30°S. The larvae are most abundant in early summer, with the peak occurrence in the northwestern Pacific during May-June, and in the South Pacific in November-December. The seasonal occurrence of mature females coincides with that of the larvae (Ueyanagi, 1964). While the distribution of larvae is not known for the

Table 2.—Weight-length constants for *Tetrapturus audax* ($\log W = \log a + b \log L$).

Location	Weight	Units of		Length	Units of length	Num-ber	Approximate length range of specimens	a	b	s	Source
		weight	length								
New Zealand and Australia	Whole	lb	cm	FL ¹	cm	27	265-310	-6.515	3.624	0.045	Gregory and Conrad, 1939 (after Royce, 1957)
	Whole	lb	cm	FL ¹	cm	48	218-310	-5.024	3.011	0.056	Morrow, 1952a (after Royce, 1957)
Central Pacific Hawaii	Whole	lb	cm	FL	cm	13	142-304	-6.648	3.691	0.502	Royce, 1957
	Whole ²	lb	cm	FL ³	cm	30	166-253	-6.110	3.446	0.048	Hawaii Division of Fish and Game (after Royce, 1967)
East Africa Fiji area	Whole	lb	cm	FL	cm	98	170-270	-4.629	2.844	?	Williams, 1967
	Gilled and gutted	kan ⁴	cm	Eye-fork ²	cm	562	160-260	-6.737	3.504	?	Koga, 1967
Equatorial west Indian Ocean Eastern Pacific Eastern Pacific Eastern Pacific Eastern Pacific Eastern Pacific	Whole	lb	cm	Eye-fork	cm	156	120-196	-4.782	3.062	?	Merrett, 1968c
	Whole	kg	cm	Eye-fork	cm	51	108-211	-5.255	3.089	?	Kume and Joseph, 1969b
	Whole	lb	cm	Eye-fork	cm	1,982	110-215	-4.816	3.072		Wares and Sakagawa, 1974
	Whole	kg	cm	Eye-fork	cm	1,982	110-215	-5.157	3.071		Wares and Sakagawa, 1974
	Whole	lb	cm	FL	cm	535	153-271	-5.007	2.986		Wares and Sakagawa, 1974
	Whole	kg	cm	FL	cm	535	153-271	-5.340	2.982		Wares and Sakagawa, 1974

¹The original measurement was SL which apparently Royce converted to FL on the basis of regression for nine Hawaiian specimens and mislabeled "total" length in caption to Appendix Table 3-A.

²Presumed.

³The original measurement was naris to fork which Royce converted to FL on the basis of regression for 21 Hawaiian specimens.

⁴1 kan = 3.75 kg = 8.287 lb.

⁵±0.197.

eastern Pacific (east of long. 120°W), mature fish are reported to occur there between lat. 5° and 20°N, largely in May-June (Kume and Joseph, 1969b).

In the Indian Ocean, larvae have been reported to occur in the Banda and Timor seas during January to February (Ueyanagi, 1959), and in the western Indian Ocean during December to January between lat. 10°S and 18°S and in the eastern Indian Ocean during October to November between lat. 6°N and 6°S (Jones and Kumaran, 1964). Mature females are reported to occur in March-May in the Bay of Bengal although larval occurrence is not yet known there (Ueyanagi, 1964).

The lower temperature limit in the distribution of larvae is approximately 24°C both in the Indian and Pacific oceans. However, the distributions differ in that in the Pacific the larvae are scarcely found in equatorial waters. It is noted that striped marlin larvae are not likely to appear in the Kuroshio area, while sailfish larvae occur there exclusively (Ueyanagi, 1959).

Information is very sparse on the distribution of the juveniles. Nakamura (1968) reported on two juveniles (body length, 12.15 and 14.5 cm) found in stomachs of a yellowfin tuna, *Thunnus albacares*, and a dolphin, *Coryphaena hippurus*, taken by longline. One juvenile was found on 13 January 1955 at lat. 23°52'S, long. 175°49'W and the other on 21 December 1964 at lat. 17°57'S, long. 67°29'E. These two occurrences coincide with larval distributions in the South Pacific and Indian Ocean, respectively.

2.22 Adults

Major areas of high abundance are the western Arabian Sea, the central North Pacific (lat. 15°-30°N)

and the eastern Pacific as shown in Figure 2. This figure shows distributions based on highest quarter-year hook rates by 5° squares for the years 1967-69 (Fisheries Agency of Japan, Research Division, 1969-72). Lesser areas of abundance occur off South Africa, northern Madagascar, northern Sumatra, Sri Lanka, eastern and western Australia, central Pacific coast of Japan, and the south central Pacific.

The high density in the Arabian Sea appears to be seasonal, occurring in the second quarter of the year. However, fishing effort in other seasons has been very slight. Off East Africa (lat. 0°-12°S) where striped marlin are the most abundant marlin, the works of Merrett (1968a, b) showed highest hook rates occurred between lat. 2° and 4°S. The hook rate was six times higher in the northeast monsoon (Nov.-Mar.) than in the southeast monsoon (Apr.-Oct.).

The season of high abundance off western and eastern Australia is the fourth quarter (Fisheries Agency of Japan, Research Division, 1969-72). Koga (1967) states, however, that good catches occur in winter off western Australia. In the South Pacific, Koga states that it is a remarkable feature that the main fishing areas, which show good catches from August to December, show very poor catches from January to July.

In the northwestern Pacific, striped marlin are abundant in Formosan waters, both in the Kuroshio and in the South China Sea, during the whole northeast monsoon season with a peak in the middle of that season. Later in the spring, they move north into the waters of Japan where they appear at about the same time as the albacore do (Nakamura, 1949).

In the Hawaiian area, striped marlin occur from fall through spring with the seasonal distribution being

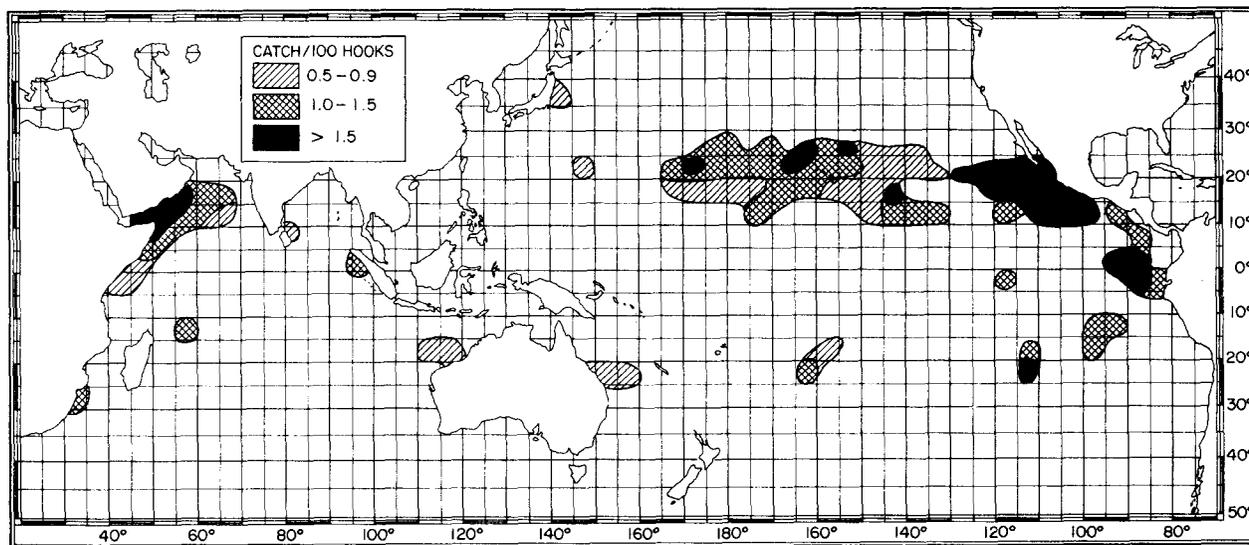


Figure 2.—Areas of high apparent abundance of striped marlin, 1967-69. (After Fisheries Agency of Japan, Research Division, 1969-72.)

complimentary to that of the blue marlin, *Makaira nigricans*, which occurs primarily in the summer (Strasburg, 1970).

In the eastern Pacific, striped marlin are present throughout the year from lat. 30°N to 30°S. High abundance is maintained throughout the year in the areas of the Revilla Gigedo Islands, Baja California, Ecuador, the Galapagos Islands, and in the high-sea area bounded by long. 90°-110°W and lat. 10°-30°S (Kume and Joseph, 1969b). Seasonal changes in apparent density are marked. The concentration between Baja California and the Revilla Gigedo Islands, which is restricted to a narrow band in the first quarter, expands southeast along the coast and seaward to long. 115°W during the second quarter, and then north to lat. 28°N, south to lat. 3°N and seaward to long. 125°W during the third quarter. During the fourth quarter the southern extension expands further to long. 130°W. Another seasonal concentration develops in the second and third quarters in the offshore area between long. 100° and 115°W centered at about lat. 8°-13°N. The area of high density around the Galapagos Islands extends eastward to the coast of Ecuador in the third and fourth quarters and then recedes again in the first.

The sport fisheries for striped marlin off Mexico and southern California are seasonal. In southern California it is highly seasonal with almost all fish being taken between August and October. In Mexico some fish may be taken year round, but the best fishing occurs from December through March at Mazatlán and April through August near the tip of Baja California (Eldridge and Wares, 1974).

In addition to differential distribution in density, there is also some differential distribution in size. In the eastern Pacific, fish on the southern spawning grounds are larger than those on the northern. The length frequency of the southern group has a single mode at 180-200 cm whereas that of the northern group has two modes, one at 140 cm and one at 180 cm (Kume and Joseph, 1969b). In the western Pacific latitudinal stratification occurs. Honma and Kamimura (1958) show small marlin occurring in equatorial waters; these small fish are absent in the region of lat. 5°-16°S. In mid-latitudes (15°-30°S) of the central South Pacific longitudinal stratification is apparent; larger fish (> 180 cm) occur in the western Pacific (Koga, 1967). There may also be some vertical stratification. Furukawa, Koto, and Kodama (1958) found harpooned fish to be larger than longline-caught fish in the East China Sea. The harpooned fish were also fatter at a given length.

Off Formosa the smaller fish, which were long thought to be the separate species *Kajikia formosana*, occur with the shortbill spearfish, *Tetrapturus angustirostris*, offshore from the center of the Kuroshio, while the larger fish occur inshore (Nakamura, 1949).

2.3 Determinants of Distribution Changes

Probably behavioristic factors related to feeding and reproduction are the primary determinants of changes in distribution. These in turn are affected by the seasonal cycle of warming of the surface waters, development of thermoclines and currents, and seasonal cycles in abundance of food organisms. The subject of the factors and relationships causing concentration of striped marlin has not received much discussion in the literature.

Nishimura and Abe (1971) have found a correlation between the position of the Kuroshio as indicated by the latitude at which the current crosses 139°30'E, and the catch made off Izu.

Kume and Joseph (1969b) noted that the appearance of the area of high hook rate centered at lat. 8°-13°N from long. 100° to 115°W is associated with the strong development of the Equatorial Countercurrent. They noted further that a diagonal band of high abundance extending from lat. 5°S, long. 120°W to lat. 8°S, long. 95°W was in the general region of the eastern extension of the South Equatorial Countercurrent.

In the area west of Australia, both the striped marlin and southern bluefin tuna grounds are centered at the boundary of currents which run along long. 115° E meridian in winter (Koga, 1967).

Manning (1957) states that off Chile, striped marlin are found in the green water that is normally found from shore to 10 to 25 miles offshore. Their occurrence in these waters was in common with bonito, sardines, and anchovies and in contrast to swordfish which occurred farther offshore in the blue and white waters.

Furukawa et al. (1958) show the fishing ground in the western Pacific associated with the surfacing of the 20°C isotherm over the edge of the continental shelf.

Nakamura (1938) states that surfacing of fish is associated with high waves generated by opposing wind and current as in the case of the Kuroshio and the northeast monsoon.

2.4 Hybridization

No record.

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

Striped marlin are heterosexual with no reported intersexuality or hermaphroditism.

Sexual dimorphism has not been reported in this species and the sexes are indistinguishable externally. Nakamura (1949) mentioned the sexual difference in body size is not great in the genus *Tetrapturus* in contrast to the case in *Makaira*. Differences in greatest

size or modal size between the sexes are small. Ueyanagi (1953) found, in the northwestern Pacific, that the modal size of males is about 10 cm smaller than that of females. Koga (1967) showed a length-frequency distribution by sex for 210 fish from the Fiji area in which the modal lengths for males and females were 195 and 205 cm, respectively. In a sample of 105 striped marlin taken by longline off East Africa, Williams (1967) found males did not exceed 240 cm fork length (equivalent to 182 cm eye-fork length from regression of Merrett, 1971). About 16 females were taken above this length to a size of about 270 cm (205 cm eye-fork length). Merrett (1971), however, found males up to 193 cm eye-fork length off East Africa. Modal size differences between the sexes were not found in Hawaiian fish (Strasburg, 1970) nor in the eastern Pacific (Kume and Joseph, 1969b).

3.12 Maturity

As has been found in other pelagic species such as albacore and dolphin, quantitative measure of maturity for males is difficult. There is only a small increase in testis size during the maturation cycle. Merrett (1971) found little correlation between relative testis size and maturity-stages based on microscopic examinations. In fact, Merrett (1970) suggests that there is continuous availability of spermatozoa in mature males based on differential maturation of the testicular lobules and the possession of a muscular seminal vesicle.

In the female, maturation is synchronous throughout the ovary and seasonal maturation is accompanied by marked increase in relative size of the gonads. Data from Kume and Joseph (1969b) showed a twentyfold increase. Moreover, there is good correlation of relative ovary weight and mean maximum egg diameter (Merrett, 1971; Eldridge and Wares, 1974).

Williams (1967) concluded from longline data in East Africa that first maturity was reached between 180 and 200 cm fork length (50-80 lb) which is equivalent to 141-157 cm eye-fork length (Merrett, 1971). Merrett reported similar results, 140-160 cm or 62-93 pounds. Ueyanagi (1957b) mentioned that 154 cm eye-fork length was the smallest size found in the spawning group of the northwestern Pacific. Kume and Joseph (1969b), using a gonad index, reported that individuals from the eastern Pacific do not regularly enter the spawning group until reaching about 160 cm eye-fork length but found one as small as 148 cm. Other data from the eastern Pacific (Eldridge and Wares, 1974) agree with these conclusions.

Since age at specific size is not known for striped marlin, age at maturity is also unknown. Koga (1967), however, stated "it is likely that growth rate of this species shows different values between the Indian Ocean and the Pacific Ocean and the groups in the In-

dian Ocean attain maturity earlier than those in the Pacific."

3.13 Mating

Nothing has been published relating to mating habits of this species.

3.14 Fertilization

Fertilization is externally.

3.15 Gonads

Merrett (1970) has described the gonads of billfish in detail. The following description is taken from his work.

The gonads are paired organs lying in the posterior half of the body cavity, on each side of the stomach and intestine. They are suspended from the lateral edges of the chambered air bladder by mesenteries . . . the gonads are almost bilaterally symmetrical and both terminate at their point of discharge to the exterior in the urino-genital papilla . . . which lies posterior to, and in a common groove with, the anus . . . The urinary and genital systems are closely linked.

The ovaries are elongate sausage-shaped organs, which taper at both ends, and joined only at their posterior ends . . . A strong muscular sheath binds the ovaries to the urino-genital papilla and the basal part of the intestine. They are invested in thick layers of connective tissue which sometimes contain deposits of fat; fat is also occasionally found in the mesovarium. Beneath the connective tissue the ovaries are pale flesh-pink to wine red in colour, depending upon the stage of maturity. Internally, at certain stages, a central lumen runs the length of the ovary . . . the ovaries have been found to be unequal in length . . . either ovary can be the longer of a pair.

. . . Immediately posterior to . . . [the anal papilla] . . . is the urino-genital papilla. In the female this carries only the urinary duct. The point of discharge of the ovaries is situated between the bases of the anal papilla and the urino-genital papilla.

This opening between the anal and urino-genital papillae which is absent in the males should serve as an external characteristic in distinguishing the sexes. But in the experience of the junior author this difference is difficult to observe consistently in this species. It is more obvious in the sailfish.

Nakamura (1949) stated that the fecundity of billfishes ranges from 1 to 1.2 million eggs, depending on fish size and species. Morrow (1964) estimated 2 million eggs for New Zealand marlins. These appear to be low estimates, however. Merrett (1971) reported an estimated fecundity of 12 million for one Indian Ocean specimen of 182 cm eye-fork length, 126 pounds with ovary weight of 1.53 kg, and mean maximum egg diameter of 0.470 mm. Eldridge and Wares (1974) reported fecundity estimates of three eastern Pacific specimens which ranged from 11 to 29 million eggs. These fish ranged in size from 150 to 180 cm eye-fork length but the fecundities showed no relation to size of the fish. Gosline and Brock (1960) estimated 13.8

million eggs were contained in one ovary of a 154-pound striped marlin landed in Honolulu. The other ovary of this fish was immature.

3.16 Spawning

Examination of size-frequency distributions of egg diameters (Eldridge and Wares, 1974) indicates only one spawning per season.

In the western Indian Ocean it appears that the high catch rates during the northeast monsoon period which peak from December to February are associated with a postspawning feeding migration (Williams, 1967; Merrett, 1971). Spawning must occur elsewhere in the Indian Ocean.

From larval occurrence, spawning was suggested to take place in the Banda and Timor seas during January to February (Ueyanagi, 1959). On the basis of larval occurrence, Jones and Kumaran (1964) stated that striped marlin spawn in the western Indian Ocean during December-January between lat. 10° and 18°S and in the eastern Indian Ocean during October-November between lat. 6°N and 10°S. Furthermore mature females are known to occur in March-May in the Bay of Bengal and in October-December in the waters south of the Lesser Sunda Islands (Ueyanagi, 1964).

In the western Pacific, mature females are found from lat. 15° to 30° (north and south) in early summer, from May to June and October to January in the northern and southern hemispheres, respectively. Larvae are also found in these areas (Ueyanagi, 1964). Nakamura (1949) stated that in the Formosa area, spawning is thought to take place mainly in the South China Sea with its peak occurring from April to May. Koga (1967) reported that the spawning areas (lat. 18°-30°S) in the western South Pacific is also the main fishing area and that the period of spawning corresponds to the season of northward migration which occurs from September to November.

In the eastern Pacific, the spawning season also appears to be the early summer in each hemisphere, quarters II and III in the northern and quarters IV and I in the southern. Highest frequencies of spawning fish occur from May to June in the north and November to December in the south (Kume and Joseph, 1969b). Evidence of spawning in the eastern Pacific is based only on relative gonad sizes of females. The northern spawning area appears to be isolated in a narrow band from long. 107° to 114°W extending from about lat. 6° to 19°N (Kume and Joseph, 1969b).

Ovaries of striped marlin caught in the Mexican sport fishery undergo rapid development in June; ripe fish were never observed (Eldridge and Wares, 1974). Japanese fishermen, however, have reported ripe and running ripe striped marlin in the waters around Socorro Island from June to October (J. L. Squire, Jr., Southwest Fisheries Center, National Marine Fisheries Service, NOAA, La Jolla, Calif., pers. commun.).

The southern spawning area appears fairly well confined to lat. 20°-25°S and long. 125°-130°W (Kume and Joseph, 1969b). Highest frequencies of the mature females occur in November and December.

Nakamura (1949) stated that sex ratios approached 1:1 at the peak of the spawning season. However, it was found that males dominate during the spawning season in the northwestern Pacific (Nakamura, Yabuta, and Ueyanagi, 1953). Kume and Joseph (1969b) also found a high proportion of males in the spawning groups in the eastern Pacific. Male:female ratios ranged from 1.8 to 6.6 in spawning groups, whereas in nonspawning groups they tended to be less than 0.5 and to decrease with increased size of fish.

3.17 Spawn

There is little information pertaining to the eggs of this species. Nakamura (1949) mentioned that the external morphology of the eggs of striped marlin closely resembles that of sailfish eggs which are spherical, transparent, and buoyant, with a single oil globule and with no special structure on the egg membrane. Morrow (1964) reported that the ovarian eggs of striped marlin from New Zealand average about 0.85 mm in diameter. Size of the ovulated eggs of this species is presumed to exceed 1 mm in diameter considering that the mean diameter of eggs for shortbill spearfish is 1.442 mm and for sailfish is 1.304 mm as reported by Merrett (1970).

3.2 Pre-Adult Phase

3.21 Embryonic phase

No information available.

3.22 Larval phase

The postlarval stage of striped marlin is described in detail by Ueyanagi (1959). The study was based on 40 specimens ranging from 2.9 to 21.2 mm in standard length, collected from the northwestern Pacific, South Pacific, and the Indian Ocean. These specimens were captured by surface tows of the larvae net. The morphology of the striped marlin postlarvae is similar to that of other istiophorid species in the development and degeneration of head spination, fin formation, pigmentation, etc. Figure 3 from Ueyanagi (1959, 1963a) represents the postlarval stage of this species from an early stage with short snout to an advanced stage with elongated jaws. The snout begins to lengthen at around 7 mm standard length. Head spination becomes most conspicuous at this size. Fin rays of each fin reach their full complement at around 20 mm standard length. Pigmentation extends almost all over the body surface and on the dorsal fin membrane at this size. The dorsal fin begins to increase its height at around 10 mm and stands very high like a sail in larvae exceeding 20 mm. The key diagnostic character for the striped marlin larvae was reported as

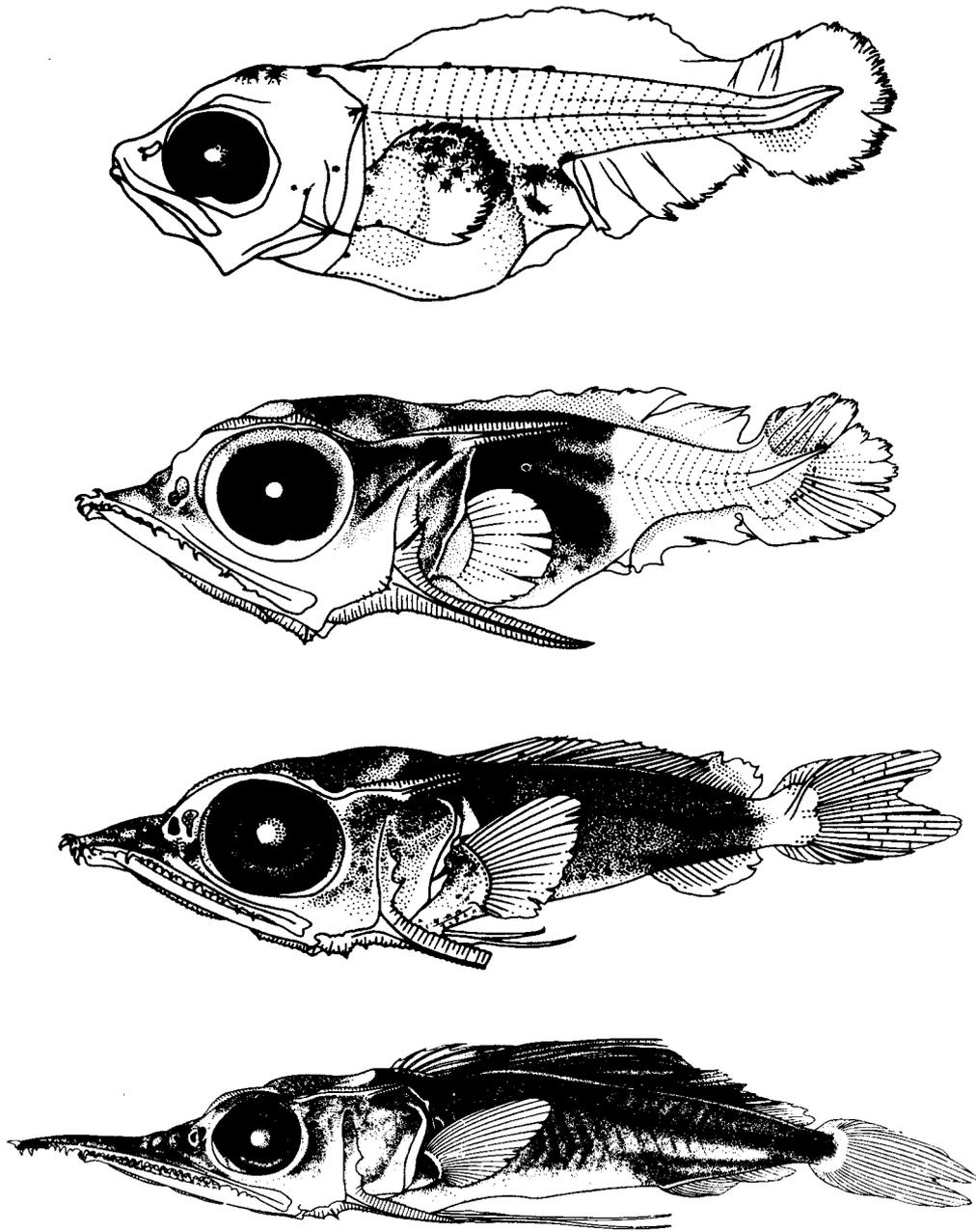


Figure 3.—Larvae of striped marlin. From top to bottom: 2.9, 5.0, 12.0, and 21.2 mm SL. (From Ueyanagi, 1959, 1963a.)

follows: “. . . the profile of head, tip of snout and center of eye are on a nearly equal level” (Ueyanagi, 1963a). In addition, the shape (arrangement) of the pterotic and preopercular spines is diagnostic for larval identification (Ueyanagi, 1974).

On the vertical distribution of billfish larvae, Ueyanagi (1964) indicated that larvae appear to be distributed most abundantly in the surface layer during the daytime and vertical, diurnal migration seems to occur in the upper 50 m of waters (Table 3). Billfish larvae appear from time to time in the stomach contents of the larvae and juveniles of sailfish and swordfish, *Xiphias gladius* (Arata, 1954; Gehringer, 1956). It is assumed that striped marlin larvae are therefore preyed upon by many surface feeding species, including the billfishes. Considering the very large numbers of eggs spawned by the striped marlin (see 3.15), it appears that mortality at the larval stage is extremely high.

Time of first feeding: No direct information is available. There is an observation that five copepods were seen in the stomach of a 3.9-mm sailfish larva (Gehringer, 1956).

Type of feeding: There is no information pertaining to the larvae of striped marlin. Of the larvae of sailfish in the Atlantic, Gehringer (1956) noted that “copepods constituted the food of specimens less than 6 mm. long. At this size fish larvae also were eaten, and no specimen exceeding 13 mm. had copepods in its stomach.” Furthermore, it is also known that sailfish larvae have consumed istiophorid larvae half as long as their own body length. It is believed that the larvae of striped marlin, like the sailfish, begin to feed on fish larvae after reaching a size of about 7 mm.

Table 3.—Comparison of numbers (and percentage) of tows from which istiophorid larvae were captured, showing the various depths and times of towing, in the western Pacific area. (From Ueyanagi, 1964.)

Depth (m)	32 day tows		31 night tows	
	Number	Percent	Number	Percent
0	22	68.8	12	38.7
ca. 20	8	25.0	12	38.7
40-50	2	6.2	10	32.3

3.23 Adolescent phase

Nakamura (1968) described the juveniles of striped marlin based on two specimens collected from the South Pacific and the western Indian Ocean (see 2.21). His drawing has been reproduced as Figure 4. In the juvenile stage the snout is very elongate and, in fact, is longest at this stage relative to body length. The shape of the first dorsal fin still differs from the adult configuration, being highest anteriorly and decreasing gradually in height posteriorly. The arrangement of the viscera is similar to that of the adult. Nakamura also mentioned that the juvenile of striped marlin is similar to that of the white marlin in many respects except that the former has no ocelli on the first dorsal fin.

It is believed that large, powerful pelagic fishes such as tunas, billfishes, dolphins, etc., are the principal predators of juvenile striped marlin.

Little is known about parasites in juvenile striped marlin.

Immature striped marlin (80-100 cm eye-fork

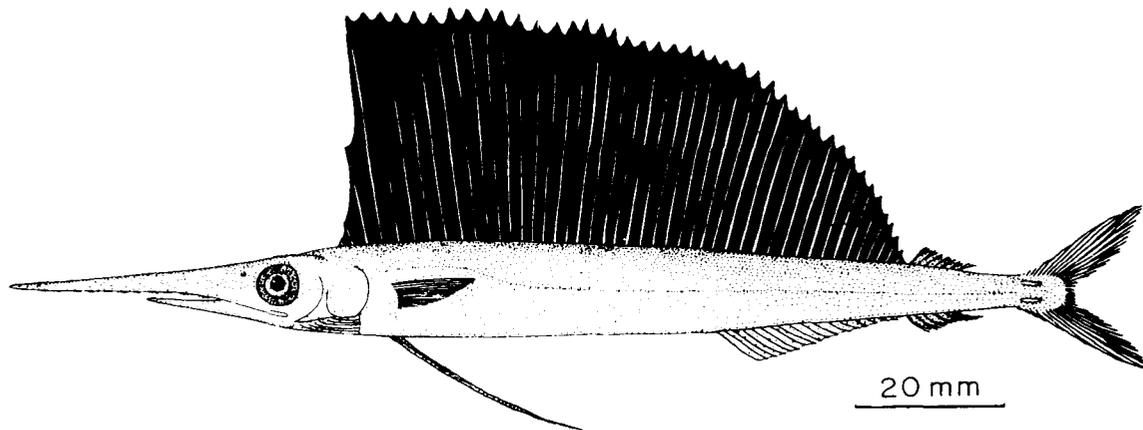


Figure 4.—Juvenile striped marlin (121.5 mm body length) collected from the southwestern Indian Ocean. (From Nakamura, 1968.)

length) are taken by longline. The shape of the first dorsal fin in these fish differs from the adults in that the posterior rays are still high (Ueyanagi, 1957b). Fish and squid are found in the stomachs, as in the adults.

Following the 1954 hydrogen bomb test in Bikini, it was reported that virtually all of the radioactively contaminated striped marlin found in the northwestern Pacific were fish under 130 cm long (Anon., 1955). It is not clear what the implications are with respect to ecological differences between young and adult fish.

3.3 Adult Phase (Mature Fish)

3.31 Longevity

The ability to determine age of individual striped marlin has not been developed and thus life tables cannot be developed and life expectancy and maximum age are unknown.

Koto (1963a), using size-frequency data from western Pacific catches, was able to discern six age classes (which he designates as n though $n + 5$) in fish greater than 100 cm eye-fork length. The Walford growth transformation of his data indicated an ultimate size of about 290 cm. Specimens of this size are apparently occasionally taken in the South Pacific (Honma and Kamimura, 1958). From the general pattern of growth indicated by Koto, fish of this size would be expected to be at least 10 yr old.

3.32 Hardiness

Very little is known. Because of the large size and activity of this species, physiological experimentation is difficult. The return rate for tagged fish is much higher for striped marlin than for sailfish (Squire, 1974), and this may indicate greater general hardiness for striped marlin. Healing of severely broken bills (Wisner, 1958) may also be an indication of hardiness. Sportsmen usually report that the striped marlin fights harder than the sailfish when hooked and tends not to die as easily as the sailfish.

3.33 Competitors

The other billfishes, particularly the smaller species (sailfish and probably the shortbill spearfish), swordfish, and the larger tunas are probably the closest competitors for food. Even the smaller scombrids share many forage species with the striped marlin. The dolphin and pelagic sharks such as *Prionace*, *Carcharhinus*, and *Isurus* utilize many of the same forage species (Parin, 1968). Striped marlin tend to feed more on epipelagic species and less on mesopelagic species than the oceanic tunas or the swordfish.

3.34 Predators

Predators of adults are probably extremely limited, the only likely candidates being some of the large pelagic sharks and the toothed whales.

Bills of billfishes have been found in floating objects and other fish. Occasionally bills of striped marlin are found to have been broken off, and the fish are known sometimes to ram fishing boats when hooked, but it is not certain that any of these occurrences have any relation to defense or aggressive action.

3.35 Parasites, diseases, injuries, and abnormalities

Parasites and diseases: The body surface usually harbors many caligid copepods which frequently congregate on the ventral surface, particularly in the area around the anal fin and on the head. Williams (1967) reports they may occur in the thousands. The skin surface in areas of concentration often appears red and irritated. Penellid copepods (*Penella fillosa*) are frequently found penetrating the skin and anchored in the muscle or sometimes in internal organs such as the gonads. Koga (1967) reports the percentage occurrence of caligid copepods and penellid copepods on striped marlin in Fiji waters was 100% and 20%, respectively. Eldridge and Wares (1974) report the percent occurrence of penellids above and below the lateral line on one side of the body as 26.2% and 22.8% with average infections of 3.3 and 2.3 copepods per fish. Stalked barnacles (*Conchoderma irgatum*) frequently are attached to the penellid copepods and often to the marlin skin, normally near the vent (Williams, 1967). Digenetic trematodes were reported found on the gills by Williams (1967). Monogenetic trematodes of the family Capsalidae are quite common on the surface of the skin (Eldridge and Wares, 1974).

Cestode worms resembling *Dibothrium manubrifformes* have been found in the intestines and nematodes (*Contracaecum incurvum*) are very common in the stomach occurring in densities greater than 200 per stomach (Morrow, 1952b). The copepod, *Philichthys xiphae*, has been found in the mucus canals of the preopercular and opercular bones, and capsalid trematodes are commonly found in the nasal capsule (Eldridge and Wares, 1974).

Injuries and abnormalities: Gastric ulcers were reported in 14% of 563 eastern Pacific striped marlin (Evans and Wares, 1972). These may be associated with the presence of nematodes (R. T. B. Iversen, Southwest Region, National Marine Fisheries Service, NOAA, Honolulu, Hawaii, pers. commun.). The small squaloid shark (*Isistius brasiliensis*), the probable cause of crater wounds on many pelagic fishes including istiophorids (Jones, 1971), probably parasitizes striped marlin.

There is evidently little ability for regeneration as

broken bills and pelvic fins are seen to heal over rather than regenerate. Striped marlin have recovered after losing almost all of the bill (Wisner, 1958).

3.4 Nutrition and Growth

3.41 Feeding

Most active feeding probably takes place in the morning. LaMonte (1955) reported that squid found in the stomachs of striped marlin off Peru and Chile were less digested in fish caught in the morning than those landed after noon. Kobayashi and Yamaguchi (1971), examining only fish caught after noon, found a decline in feeding activity toward sunset. Williams (1967), however, suggests that East African fish feed at any time of the day or night.

Apparently the food is usually captured by grasping with the mandibles rather than by spearing, slashing, or clubbing with the bill. Fish which have lost the bill completely survived well. Some food specimens are occasionally found, however, which have been neatly speared (Wisner, 1958; Evans and Wares, 1972).

3.42 Food

Several authors have reported on food habits. Table 4 gives an idea of the variety of food species which have been found most important in different studies. It is notable that, despite the large size and lack of gill rakers in striped marlin, relatively small forage items are commonly taken (Nakamura, 1949).

Food habits do not appear to vary appreciably with sex or size over the range of sizes commonly caught. Considerable variation in species composition of the diet occurs, however, with season and geographic location (Evans and Wares, 1972). Such variations probably reflect variations in availability of the food organisms in keeping with the generally accepted concept that these fish are broadly carnivorous, nonselective feeders. This is true of epipelagic fishes generally (Parin, 1968).

The average volume of food found in stomachs of striped marlin caught by the eastern Pacific sport fishery ranged from 14 to 23 fluid ounces per stomach (Evans and Wares, 1972). Yamaguchi (1969) reports that empty stomachs were found in 66% of striped marlin caught by longline. This percentage tends to be larger in billfish than in tunas. Evans and Wares (1972) found 19% empty stomachs.

3.43 Growth rate

Weight-frequency modal progressions in Hawaii landing data suggest an annual growth rate of about 30 pounds (Royce, 1957). Merrett (1971) found agreement with Royce's data in size-frequency distributions from East Africa. Possible modal lengths of about 152, 167, 177, and 197 cm eye-fork length were found in the length-frequency distribution for the total catch. Computed weights at modal lengths gave

Table 4.—Some reported major food species for striped marlin.

Area	Food species	Author
East Africa	<i>Fistularia</i> sp.	Williams, 1967
	<i>Auxis</i> sp.	
	Squid	
New Zealand	<i>Scomberesox saurus</i>	Morrow, 1952b
	<i>Arripis trutta</i>	
	<i>Loligo</i> sp.	
New Zealand	<i>Ommastrephes sloani</i>	Baker, 1966
	<i>Caranx lutescens</i>	
	<i>Scomber japonicus</i>	
Tasman Sea	<i>Alepisauridae</i>	Koga, 1968
	<i>Clupeidae</i>	
Bonin Islands	<i>Gempylus</i> sp.	Yabuta, 1953
	Cephalopods	
	<i>Pseudoscopelus</i> sp.	
	<i>Alepisaurus</i>	
	<i>Ostracion</i>	
California	<i>Cololabis saira</i>	Hubbs and Wisner, 1953
	<i>Engraulis mordax</i>	
	<i>Sardinops caerulea</i>	
California	<i>Engraulis mordax</i>	Evans and Wares, 1972
	<i>Trachurus symmetricus</i>	
Mazatlán, Mexico	Squid	Evans and Wares, 1972
	<i>Etrumeus teres</i>	
	<i>Fistularia</i>	
	<i>Argonauta</i> sp.	
Baja California, Mexico	Squid	Evans and Wares, 1972
	<i>Etrumeus teres</i>	
	<i>Scomber japonicus</i>	
	<i>Fistularia</i> sp.	
Peru-Chile	Squid	LaMonte, 1955
Chile	<i>Engraulis ringens</i>	de Sylva, 1962
	<i>Trachurus symmetricus</i>	
	Squid	

annual weight increments of 27, 21, and 23 pounds.

Koto (1963a) working with length-frequency data from the western North Pacific, found six modal groups (n through $n+5$). The monthly progression of these modes is shown in Figure 5. The designations of these modal groups are as follows:

Group	Lengths (cm)	Increment (cm)
n	100-120	?
$n+1$	120-160	35
$n+2$	160-185	27
$n+3$	185-205	19
$n+4$	205-220	16
$n+5$	220-233	13

There is a marked seasonal change in growth rate with rapid growth occurring from June to November and very little growth in the remainder of the year for age groups $n+1$, $n+2$, and $n+3$. Age group n appears

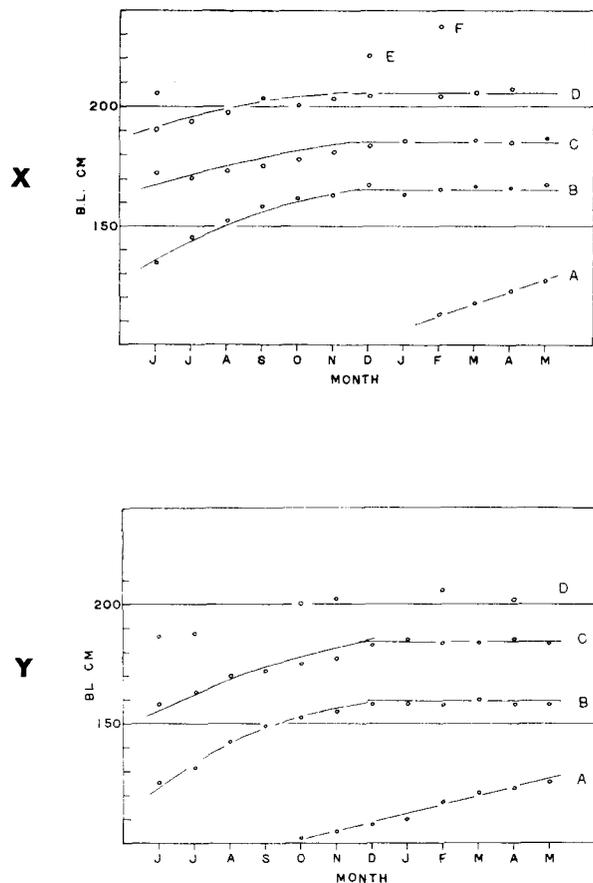


Figure 5.—Seasonal changes in modes derived from average year's length frequencies of longline-caught striped marlin. A. North Pacific Current area; B. East China Sea (long. 120°-130°E). (From Koto, 1963a.)

in the catch only after September, as fish larger than 100 cm and shows rapid growth right through the winter. The failure of the fishery to capture many fish below 100 cm makes it impossible to say what the absolute ages of the groups are.

The annual growths of the $n+1$ and $n+2$ age groups differ between areas and years. Koto (1963b) showed that in the North Pacific Current area the yearly differences in the length composition were caused by differences in the average length of the $n+1$ age group. In the North Equatorial Current area, however, these differences were probably caused by differences in age composition and the relative abundance of the n and $n+1$ age groups.

Koto (1963b) has shown growth rate to be affected by population density. The very close inverse relationship between growth of the $n+1$ age group and the total fish abundance, or especially the abundance of the n and $n+1$ groups is shown in Figure 6. The correlation coefficients between growth of the $n+1$ age group and total fish abundance were -0.958 ($df = 6$)

for the North Equatorial Current area and -0.737 ($df = 8$) for the North Pacific Current areas.

Royce (1957) suggested the maximum size reached by striped marlin is less than 226.8 kg (500 pounds). Records were given as follows: 172.8 kg (381 pounds) off New Zealand; 142.4 kg (314 pounds) from Pacific equator; a "questionable" record of 196.9 kg (434 pounds) from the Hawaiian market, where normally only occasional specimens approach 136.1 kg (300 pounds); a somewhat questionable record because of possible confusion with the blue marlin of 219.1 kg (483 pounds) from Chile; the world's record, taken off California, was 692 pounds, which was based on a misidentified blue marlin.

The theoretical maximum length of about 290 cm mentioned in section 3.31 is equivalent to 259.5 kg (572 pounds). A fish of 290 cm was taken by longline in the South Pacific (Honma and Kamimura, 1958).

Average semimonthly condition factors (K) computed

$$K = \frac{W \times 10^5}{L^3}$$

where W is whole fish weight in kg
 L is eye-fork length in cm

for eastern Pacific fish ranged approximately from 0.80 to 1.26 (Eldridge and Wares, 1974).

In the East China Sea, condition factor

$$K = \frac{W}{L^3}$$

where W = gilled and gutted weight in kan (= 3.75 kg)

L = eye-fork length in m

was found to increase with body length from about 8 at 110 cm to a peak of about 10 at 180 cm and then to decline to about 9 with larger fish up to 230 cm

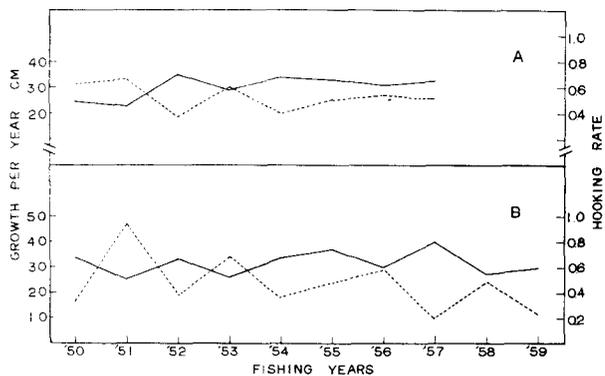


Figure 6.—Relation between total fish abundance and growth of the $n+1$ age group. A North Equatorial Current area; B. North Pacific Current area. — growth per year;hook rate. (From Koto, 1963b.)

(Furukawa et al., 1958). The condition factor also showed a seasonal drop from about 10.8 in December to about 8.7 in June for fish of body length 166-195 cm. The drop in condition factor before June was much more abrupt than the increase after June. A similar seasonal cycle was also apparent for fish of 136-165 cm.

3.44 Metabolism

There are no data on metabolic rates for this species. Lindsey (1968) found body muscle temperatures as much as 2.6°C higher than the surrounding seawater. The highest temperature recorded occurred near the center of the epaxial muscle mass with a lesser maximum slightly below the hypaxial muscle mass center. Red muscle was found to be lower than white muscle at comparable depths beneath the skin. Temperatures of the viscera exceeded seawater temperatures by 0.7-1.3°C.

Barrett and Williams (1965) report the mean hemoglobin content in 16 striped marlin was 11.3 ± 0.75 g Hb/100 ml and ranged from 5.8 to 16.8.

3.5 Behavior

For feeding behavior, see 3.41; for reproductive behavior see 3.13, 3.21.

3.51 Migrations and local movements

See also 2.22 and 2.3.

The migration pattern of striped marlin appears to be principally a simple latitudinal movement between spawning areas and productive feeding areas (Parin, 1968). The movement is toward higher latitudes in the summer of each hemisphere and back toward equatorial waters in winter. In the northern hemisphere the peak of the northward migration is August-September and the southward migration begins in October and continues through February. The northward movement is also accompanied by an eastward expansion in the eastern Pacific (Howard and Ueyanagi, 1965; Fisheries Agency of Japan, Research Division, 1969-72).

In the central North Pacific small fish of about 13.6 kg (30 pounds) appear in Hawaii in winter, grow to 22.7-27.2 kg (50-60 pounds) by May or June, then migrate north for several months, and return to Hawaii as larger fish the next year. A similar pattern of migration is common to areas west of long. 180° (Howard and Ueyanagi, 1965).

In the southern hemisphere west of long. 150°W fish migrate north from south of lat. 30°S from August through November and form concentrations which are exploited in the area lat. 18°-19°S. The period of this migration corresponds to the spawning season. After November the fish appear to migrate south (Koga, 1967).

In the eastern South Pacific a high density area,

which occurs in the area lat. 10°-17°S, long. 90°-115°W during the second and third quarters, appears to move southwest to the region of lat. 20°-28°S, long. 100°-110°W in the fourth and first quarters (Kume and Joseph, 1969a, b).

In the eastern North Pacific the seasonal north-south movements are apparent but less pronounced. Striped marlin do occur in their extreme northern range (southern California) during late summer and fall when surface temperatures reach a peak, but it is not clear whether these fish have come from the south or from the west (Howard and Ueyanagi, 1965). Data from fish tagged in the sport fisheries of southern California and Mexico provide evidence that striped marlin are capable of fairly long migratory movements up to 3,000 miles (Fig. 7). Some fish do move from California southward to the tip of Baja California and further, but there is no evidence of migration from Mexican waters to southern California (Squire, 1974).

Howard and Ueyanagi (1965) suggested on the basis of the appearance of an unusually small size group in California in 1958 and subsequent appearance 2 yr later of a small group in New Zealand, which was of a size expected for fish 2 yr older than the former, that there may be transpacific interchange between these remote areas.

Following the 1954 hydrogen bomb test in Bikini, contaminated fish were found only from the North Pacific, suggesting the possibility of separate populations in the two hemispheres (Nakamura, 1969).

In addition to the primary migratory trend, there are also lesser local movements reported. The area of high density off the central Mexican coast generally tends to expand westward seasonally reaching its maximum westward extent at about long. 130°W during the fourth quarter of the year (Kume and Joseph, 1969a, b). The region of high density around the Galapagos Islands during the second and third quarters expands eastward to the coast of Ecuador during the fourth and first quarters (Kume and Joseph, 1969a, b; Kume and Schaefer, 1966).

Nakamura (1949) mentions dense schools move from south to north along the coast of Vietnam in March and April.

In the western Pacific, Furukawa et al. (1958) report a gradual westward migration of fish from the vicinity of the Bonin Islands to the East China Sea in July and August where they stay until November after which a southward emigration takes place.

Migratory patterns in the Indian Ocean are unknown. The seasonal increase in density off East Africa during the northeast monsoon is believed to be a postspawning feeding migration (Williams, 1967; Merrett, 1971). The north-south type of seasonal movements that are typical in the Pacific are most evident off South Africa. A northward movement in the springtime (second quarter) is evident in the

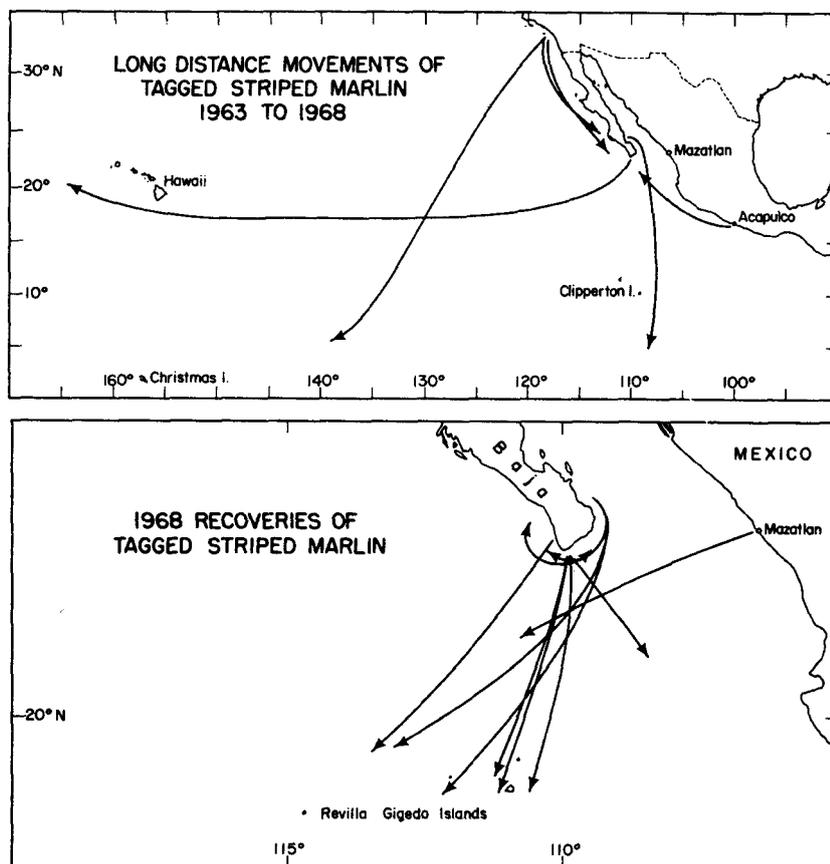


Figure 7.—Movements of tagged striped marlin in the eastern Pacific Ocean.

western Arabian Sea (Fisheries Agency of Japan, Research Division, 1969-72).

3.52 Schooling

Striped marlin, like the other istiophorids, do not form dense schools like the tuna, and the individuals are usually dispersed at wide intervals (Nakamura, 1949). Frequently, however, several fish are seen together; sometimes following one another, especially during the spawning season.

Surfacing is apparently more common when the wind and waves are high. When wind and current are moving in the same direction, the surface is calm and few fish are seen at the surface. When the wind runs counter to the current, high waves result, and fish are most often seen at the surface and are usually swimming in the direction of the wind, at least in Formosan waters (Nakamura, 1938).

When surfaced, the striped marlin usually is swimming very slowly with the upper caudal lobe above the surface and the dorsal fin retracted and not showing. This characteristic reportedly distinguishes them from swordfish which are unable to depress the dorsal fin and show both the dorsal and caudal fins when surfaced. Striped marlin swim faster and are less easi-

ly approached when surfaced than the swordfish (Philippi, 1887).

Little is known about how far the fish move vertically. Saito et al. (1972) report that striped marlin have been caught at 150- to 290-m depths by vertical longline experiments in Fiji waters.

For composition of stocks by size see also section 2.22. As mentioned previously, there is considerable variation in size composition between various regions and particularly between the northern and southern groups in the Pacific (see, for example, Howard and Ueyanagi, 1965; Koga, 1967; and Kume and Joseph, 1969b). As mentioned earlier, southern fish tend to be larger than northern fish throughout the Pacific. Size composition of striped marlin in the Indian Ocean resembles the North Pacific size distribution more than the South Pacific.

Striped marlin "schools" occur in waters in common with the schools of most of the Indo-Pacific scombroids, particularly albacore, yellowfin tuna, and bigeye tuna, *Thunnus obesus*.

3.53 Responses to stimuli

Very little is known of this subject as it relates to striped marlin. The possible response to temperature

has been mentioned previously. It may be pertinent to note here that when billfishes are caught by hook or harpoon, they first make several leaps into the air and then swim wildly in broad circles near the surface. Tunas, on the other hand, try to escape in a vertical direction by diving deep (Nakamura, 1949).

4 POPULATION

4.1 Structure

4.11 Sex ratio

Sex ratio of the population as a whole is unknown; but from the data of Williams (1967), Kume and Joseph (1969b), and Merrett (1971), females usually predominate in longline catches. The notable exception to this is on the spawning grounds, where males tend to predominate (Kume and Joseph, 1969b). The percentage of females tends to increase with size of fish (Kume and Joseph, 1969b). There is a tendency for spawning grounds to be dominated by larger fish than in nonspawning areas.

4.12 Age composition

Since age determination of individual fish is not possible at present, age composition of the population has not been studied. See 3.43 on growth rate.

4.13 Size composition

Size composition varies greatly between stocks and with seasons (see 3.52).

Size at first capture by tuna longline gear is about 80 cm eye-fork length.

Size at first maturity is between 140 and 160 cm eye-fork length.

Maximum size is probably about 290 cm eye-fork length or 258.6 kg (570 pounds).

See 1.31 for length-weight relationships.

4.2 Abundance and Density (of Population)

4.21 Average abundance

No data.

4.22 Changes in abundance

Relative abundance in terms of average CPUE (catch per unit of effort) for major ocean areas is shown in Table 5 for the years 1962-70. These data show no apparent trend for the eastern, northern or the Pacific Ocean at large, however, there is a general decline noted for the South Pacific and a slight decline in the Indian Ocean, the latter since 1966 (Fisheries Agency of Japan, Research Division, 1965-72).

Year-to-year changes in CPUE for the various

Table 5.—Catch statistics by major ocean areas of Japanese longline fishery for striped marlin for 1962-1970 (Fisheries Agency of Japan, Research Division, 1965-72).

	1962	1963	1964	1965	1966	1967	1968	1969	1970
Indian Ocean									
E ¹	68.4	57.3	68.9	79.9	89.6	126	119	101	78
C ²	48	34	38	81	106	114	63	59	45
CPUE ³	0.07	0.06	0.06	0.10	0.12	0.09	0.05	0.06	0.06
Whole Pacific									
E	290	337	283	288	301	306	286	306	282
C	287	338	508	421	351	406	506	323	450
CPUE	0.10	0.10	0.18	0.14	0.12	0.13	0.18	0.11	0.16
North Pacific									
E	156	154	140	153	150	193	165	169	163
C	144	123	210	156	98	159	154	101	242
CPUE	0.09	0.08	0.15	0.10	0.06	0.08	0.09	0.06	0.15
South Pacific									
E	109	131	81.2	92.2	104	70.6	71.0	70.1	67.7
C	59	49	28	29	30	17	14	14	32
CPUE	0.05	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.05
Eastern Pacific (E of 130°W)									
E	24.7	52.1	62.0	43.6	47.5	42.4	50.4	67.2	52.1
C	84	166	270	236	223	230	338	208	177
CPUE	0.34	0.32	0.44	0.54	0.47	0.54	0.67	0.31	0.34

¹E = Effort in hooks × 10⁴.

²C = Catch × 10⁴.

³CPUE = Catch/100 hooks.

regions of the Pacific and Indian oceans are examined in section 5.41.

Seasonal variations in available stock are marked. See 2.22 on differential distribution. Kume and Joseph (1969a) have shown that there is a threefold seasonal fluctuation in CPUE for the various regions in the eastern Pacific.

4.23 Average density

No data.

4.24 Changes in density

No data.

4.3 Natality and Recruitment

4.31 Reproduction rates

Annual egg production rates have not been estimated. Little is known of fecundity relationship with fish size. See 3.15 for some estimates.

Nothing is known of survival rates of eggs and larvae because they are so rarely collected.

4.32 Factors affecting reproduction

No data.

4.33 Recruitment

There is little information pertaining to the variation in annual recruitment (see 3.43 and 4.24).

4.4 Mortality and Morbidity

No work has been done on mortality rates or causes of mortality.

4.5 Dynamics of Population (as a Whole)

No work has been done.

4.6 The Population in the Community and the Ecosystem

There is no specific information on this subject available; some general information on distribution and life history is presented in sections 2 and 3.

5 EXPLOITATION

5.1 Fishing Equipment

5.11 Gear

Virtually all of the commercial catch of striped marlin is by longlining. The harpoon fishery for billfishes is responsible for less than 5% of the total catch.

The longline gear aims largely at tunas and billfishes which are distributed at depths of around 100-150 m. The gear consists of mainline, float lines, branch lines, hooks, and buoys. The construction of the longline gear differs according to the species of fish sought, but Morita (1969) presents an example of a "standard" gear (Table 6). Several hundred of these units (each unit is referred to as a "basket") are joined in a series to make up a set. The gear is retrieved with a longline hauler.

Suda and Schaefer (1965) gave examples of the various types of longline gear presently in use (Table 7), and indicated that types 1 through 5 are the more typical ones in use. They also included the estimated hook depths for the different types of gear.

Billfishes are generally found closer to the sea surface than tunas. Therefore, in fishing primarily for billfishes, the longline gear is modified by shortening the float line and the branch lines and also by adding another buoy in the middle of the mainline section, the latter bringing the hooks closer to the surface. Furukawa et al. (1957) reported that for fishing billfishes in the East China Sea, the combined length

Table 6.—General form of tuna longline. (From Morita, 1969.)

Name of part	Material	Length	Number used for 1 basket
Mainline	Cremona (20S, 55×3×3)	250 m ¹	1
Branch line	Cremona (20S, 55×3×3)	11 m	4
Sekiyama	Steel wire (27 # 3×3) and hemp yarn coiled with thread No. 5)	5.5 m	4
Kanayama	Steel wire (27 #, 3×3, Type M)	3 m	4
Hook	Steel	3.8 sun ²	4
Float Line	Cremona (20S, 55×3×3)	22 m	1
Flag buoy	Flag, bamboo, float (glass ball or synthetic resin ball)	—	1
Radio buoy			2 or 3 (for all basket)

¹Length per one basket.

²1 sun = 3.03 cm.

Table 7.—Some examples of Japanese tuna longline gear. (From Suda and Schaefer, 1965.)

Type no.	1	2	3	4	5	6	7	8
A. The structure of one basket of the line (unit of length: meters)								
Length of mainline	300	300	300	300	300	245	360	350
Length of branch line								
Cotton or vinyl rope	13.5	10.5	12.0	11.5	12.0	12.0	14.5	12.0
Ganged wire leader	6.0	6.0	8.0	6.0	7.0	8.0	7.0	7.0
Wire leader	1.5	2.0	2.5	1.5	2.0	2.0	3.5	2.5
Length of float line	18.5	19.5	20.0	16.5	22.0	18.0	22.5	25.0
Number of hooks	5	5	5	5	5	4	4	6
B. The estimated maximum depth of each hook of the lines shown above								
No. 1 hook	86.5	85.0	89.5	82.5	90.0	84.5	113.5	92.5
2	127.5	126.0	130.5	123.5	131.0	123.0	169.5	136.5
3	148.5	147.0	151.5	144.5	152.0	123.0	169.5	168.5
4	127.5	126.0	130.5	123.5	131.0	84.5	113.5	168.5
5	86.5	85.0	89.5	82.5	90.0			136.5
6								92.5

of the float line and branch line should not exceed 30 m.

As for the amount of gear fished per day, Yoshida (1966) reported that "Vessels of 39 to 99 gross tons fish 210 to 355 baskets; vessels 100 to 190 gross tons fish 355 to 400 baskets; and vessels 200 to 500 tons fish 400 to 450 baskets." Suda and Schaefer (1965) reported that Japanese vessels in the eastern Pacific fished an average of 2,000 hooks (about 400 baskets) per set.

The basic construction of the longline gear has remained unchanged over the years. However, due to manpower problems some effort has been directed towards developing laborsaving devices in longlining. Two examples are the reel-type and tub-type of longlining.

In the reel-type, the mainline is continuously reeled onto a drum, while in the tub-type, the retrieved line is coiled into a large tub. Important advances in addition to the line hauler, include the "slow-conveyor" (for line setting and line hauling), the "guide stand" and "guide roller" (for leading line), gear-transporting conveyor system, line-winder system, etc. In using these methods, the branch lines are joined to the mainline by the use of snaps (Katsuo-Maguro Nenkan, 1969).

The principal bait used in longlining is frozen Pacific saury, *Cololabis saira*. Squid is also commonly used. Mackerel, *Scomber* sp., as well as mackerel scad, *Decapterus* sp., have been used as alternate bait. In addition, experiments are underway to utilize silver carp, *Hypophthalmichthys molitrix*, as well as artificial preparations (e.g., infused with extracts of saury) as longline bait.

Depending on the location, certain baits have been reported to have advantages in catching billfishes. For instance, in the East China Sea fishing grounds, live mackerel were believed effective and were used extensively. However, Furukawa et al. (1957) reported that using live or dead mackerel did not significantly affect

the catches of white marlin (= black marlin), striped marlin, and broadbill.

The main piece of equipment in the harpoon fishery is the harpoon itself. The harpoon pole of oak is about 4 m long and at its tip is a three-pronged iron piece about 7 mm in diameter. The detachable harpoon of steel about 10 cm in length, connected to about 100 m of line, is placed over this iron tip. Recently the electric harpoon has been used in order to kill the fish quickly. When the harpoon enters the fish, a wire distributed along the harpoon line is charged with electricity.

5.12 Boats

The longline vessels fishing in the Indian and Pacific oceans for striped marlin are largely those from Japan. Other vessels are from Taiwan and Korea.

The details on the construction of longline vessels are given by Kanasashi (1960) and by Yoshida (1966). There are two types of longline vessels: those that use longline exclusively and those that use both longline and pole and line. The holds on longline vessels are not divided into small compartments to carry live bait. Thus, the hold space in the longliners is 20% to 40% greater than in the combination vessels.

Longline vessels are constructed of wood or steel; those larger than 100 gross tons are usually constructed of steel. Most of the longliners are 250 to 350 gross tons; at this stage of the fishery they appear to be the most economical and efficient size to operate. The specifications of typical longliners of this size class and those of some typical combination vessels are given in Yoshida (1966).

Other than the independently operating vessels, there is the mother ship operation in which several catcher boats are transported on the deck of a mother ship to the fishing grounds.

Small mother ships of 400 to 800 gross tons are able to carry only one portable catcher boat, but the larger 2,000- to 3,000-ton mother ships carry six catcher boats. The portable catcher boats measure about 15 m in length (Yoshida, 1966). To decrease the weight of the portable boats, recent constructions have been of fiber-reinforced plastic (FRP). The weight of a FRP boat is about 13 tons, or approximately two-thirds the weight of former catcher boats (Kazama, 1967).

Significant advances have also been made in preserving the catch of high-quality sashimi fish. Many vessels are equipped with refrigeration equipment capable of preserving the catch at very low temperatures of -40° to -45°C . In this way, the vessels are able to deliver fish in excellent condition and as a result, billfish prices have increased greatly in the Japanese market.

In addition, there have been advances in automating ship operations, fishing gear, and other equipment. Almost all longliners are equipped with fish detectors. Living conditions on the ships have also been improved considerably, and many vessels are now equipped with air conditioning for the crew's comfort (Katsuo-Maguro Nenkan, 1969).

Harpoon vessels are constructed with an extended prow where the harpooner is stationed. These vessels are constructed of wood, and range in size from about 10 to 40 tons. Billfishes taken by these vessels are kept in ice for delivery to the market.

5.2 Fishing Areas

5.2.1 General geographic distribution

The longline fishery now virtually covers the entire distribution of the species (see 2.1 and 2.22). The major sport fishing areas are southern California, Mexico, Panama, Ecuador, Peru, Chile, Hawaii, Tahiti, Fiji, New Zealand, Australia, and East Africa (not listed in order of importance).

5.2.2 Geographic ranges

See also 5.41.

Longlining is carried out across the high seas to within 5 miles of coastlines in places. The sport fishery is generally restricted to within about 75 miles of coastlines with the bulk of the fishing much closer.

The greatest fishing pressure is exerted in the North Equatorial Current in the Pacific and western Indian oceans, in the Kuroshio and Kuroshio extension, in the North Pacific Gyral northeast of the Hawaiian Islands, in the South Equatorial Current from about long. 90° to 140°W , and also off Mexico and Ecuador.

Regarding the development of the Japanese longline fishery, Suda and Schaefer (1965) report that prior to about 1952 the fishery was confined to the western and central Pacific. After this date it expanded into the Indian Ocean extending west of long. 80°E in 1954 and throughout the Indian Ocean by the end

of 1955. In the Pacific, the fishery expanded eastward between lat. 10°N and lat. 10°S reaching 130°W by late 1956 and long. 85°W by 1961. After 1963 the fishery in the eastern Pacific expanded rapidly poleward, the northward expansion being primarily for striped marlin (Kume and Joseph, 1969a).

The fishing grounds for the Japanese harpoon fishery are located in the waters of Sanriku (off northeast of Honshu), around Izu, and East China Sea.

5.2.3 Depth range

Little has been written regarding fishing effort by depth range. Merrett (1968a) reports almost half of the striped marlin caught during experimental longlining off East Africa were caught over less than 1,000 fathoms even though most of the effort was expended beyond this depth contour.

5.2.4 Conditions of the grounds

See sections 2.1, 2.2, and 2.3.

5.3 Fishing Seasons

For sections 5.31, 5.32, and 5.33 see section 2.22.

The fishing season for the Japanese harpoon fishery in the waters of the Sanriku fishing ground extends from June to November with the peak occurring from July through September; in the Izu area from December to August with its peak from February through April; and in the East China Sea from December to February.

5.4 Fishing Operations and Results

5.4.1 Effort and intensity

Type of unit of effort: Detailed data on fishing effort and catch in the Japanese tuna longline fishery are published in the "Annual report of effort and catch statistics by area on Japanese tuna longline fishery" by the Research Division, Fisheries Agency of Japan. Fishing effort is reported in terms of number of operations and number of hooks fished; catch is reported in terms of number of fish. The statistics are reported on a monthly basis by 5° units.

Since 1967, Taiwan has also begun to publish data from their tuna longline fishery, following the same format as the Japanese publication. The Taiwan data are published annually in "Report on survey of production and marketing of Taiwan's tuna longline fishery" by the Taiwan Fisheries Bureau. Publication of effort and catch statistics of the Korean longline fishery started in 1970 in "Yearbook of catch and effort statistics on Korean tuna longline fishery" issued by the Office of Fisheries, Korea.

Landings per unit of fishing effort: As noted above, the catch statistics are reported in terms of numbers

of fish taken in the various unit areas. Landings by weight can be estimated from the data along with average body weight data.

Catches per unit of fishing effort: The catch per unit of effort (CPUE) can be obtained in terms of catch in numbers per 100 or 1,000 hooks fished. Strasburg (1970) studied year-to-year changes in CPUE of billfishes in the Pacific by analyzing the 1953-63 Japanese longline data for quadrangles measuring 20° of latitude and longitude. He noted a progressive decline over the years in the CPUE for the striped marlin of western and central South Pacific (lat. 20°-40°S) areas. Strasburg (1970) concluded that while some workers have attributed the decline in CPUE to heavy fishing, "It is impossible to determine its real cause without more information on various biological features related to migration, reproduction, age, and year classes."

Honma and Suzuki (1969) studied the apparent abundance of striped marlin in the principal fishing grounds in the Pacific (northwestern Pacific, eastern Pacific, and waters east of Australia) for the years 1960-66. They noted no apparent trends in CPUE in the northwestern Pacific and eastern Pacific grounds. On the other hand, for waters east of Australia, they reported a definite decreasing trend; the CPUE has been at a low level of around 0.1 fish per 100 hooks since 1964.

Of the striped marlin in the Indian Ocean, Kikawa et al. (1969) examined the annual changes in CPUE (number of fish per 1,000 hooks) based on data for the years 1962-67. They reported CPUE of about 0.6 fish per 1,000 hooks between 1962 and 1964, followed by an increase to about 1.0 in 1965-67. The authors concluded that "An increasing trend in the CPUE for striped marlin in this period may probably represent the increase in effectiveness in catching fish."

Fishing effort per unit area: Figure 8 shows the distribution of fishing effort of the Japanese tuna longline vessels in 1970. The effort, in terms of

numbers of hooks fished, is shown by 5° quadrangles.

If we examine the data along with catch per unit area data of striped marlin (Fig. 9) it is apparent that the relatively large fishing effort in the eastern Pacific off Mexico and Ecuador is principally related to pursuit of striped marlin in those areas.

Total fishing intensity: The total fishing effort of the Japanese longline vessels in recent years (1965-69) for the Pacific and Indian oceans is estimated at about 400 million hooks fished per year. The efforts by areas are given in Table 5 (see 4.23).

Since 1963 there has been a significant increase in fishing effort in the eastern Pacific region. Correspondingly the fishing grounds for striped marlin also has increased during this period.

In the South Pacific region, however, effort has decreased from about 100 million hooks in 1965-66 to around 70 million hooks beginning in 1967.

5.42 Selectivity

Small striped marlin under 80 cm eye-fork length are virtually never taken by longline.

Furukawa et al. (1958) have reported that striped marlin taken by harpooning in the East China Sea fishing grounds are relatively heavier (higher fatness index) than fish taken by longline.

5.43 Catches

Total annual yields: The FAO "Yearbook of fishery statistics" reports the total annual yields of striped marlin; Table 8 summarizes the 1970 catch (FAO, 1971). The recent total annual landings of striped marlin have been around 25,000 tons from the Pacific and Indian oceans.

Total annual yields from different fishing grounds: As seen in Table 8, the striped marlin catches are high in the eastern Pacific; the catch from this area comprises about one-half of the total Pacific

Table 8.—Catches of striped marlin by fishing areas for 1964-70. (From FAO, 1971.)

Area	1964	1965	1966	1967	1968	1969	1970
<i>In thousands of metric tons</i>							
Indian Ocean	(2.4)	(3.8)	(3.8)	(6.2)	(3.8)	(4.3)	(3.1)
Western	1.2	2.1	3.2	4.9	2.2	2.5	2.1
Eastern	1.2	1.7	0.6	1.3	1.6	1.8	1.0
Pacific Ocean	(25.6)	(22.5)	(20.5)	(19.5)	(21.6)	(20.5)	(22.1)
Northwest	8.6	8.8	7.0	6.9	7.2	8.5	8.4
Eastern central	14.0	11.3	9.1	10.4	11.0	8.7	10.9
Southwest	1.4	1.3	2.3	0.9	1.7	1.6	1.6
Southeast	1.6	1.1	2.1	1.3	1.7	1.7	1.2
Total	28.0	26.3	24.3	25.7	25.4	24.8	25.2

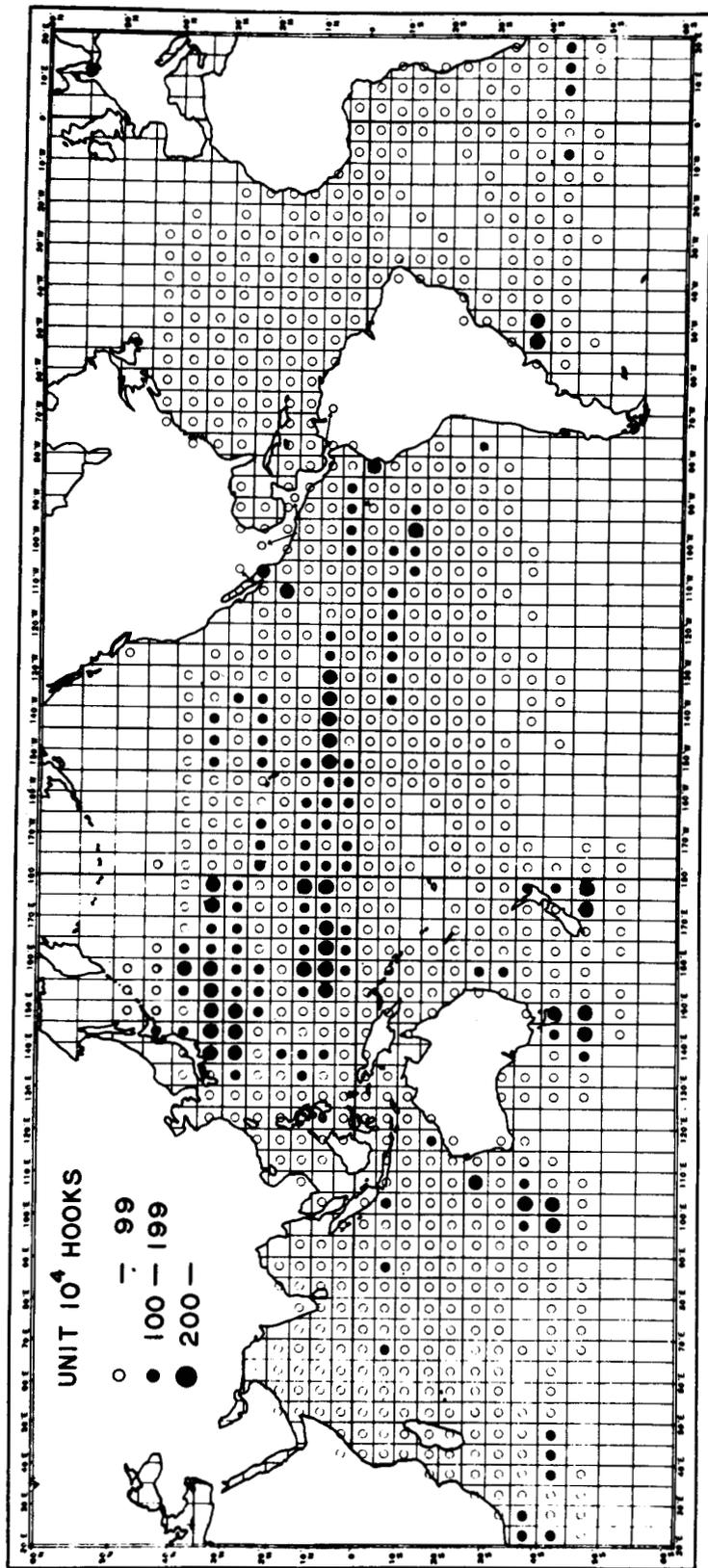


Figure 8.—Distribution of estimated total fishing effort, in numbers of hooks per unit area (1970).

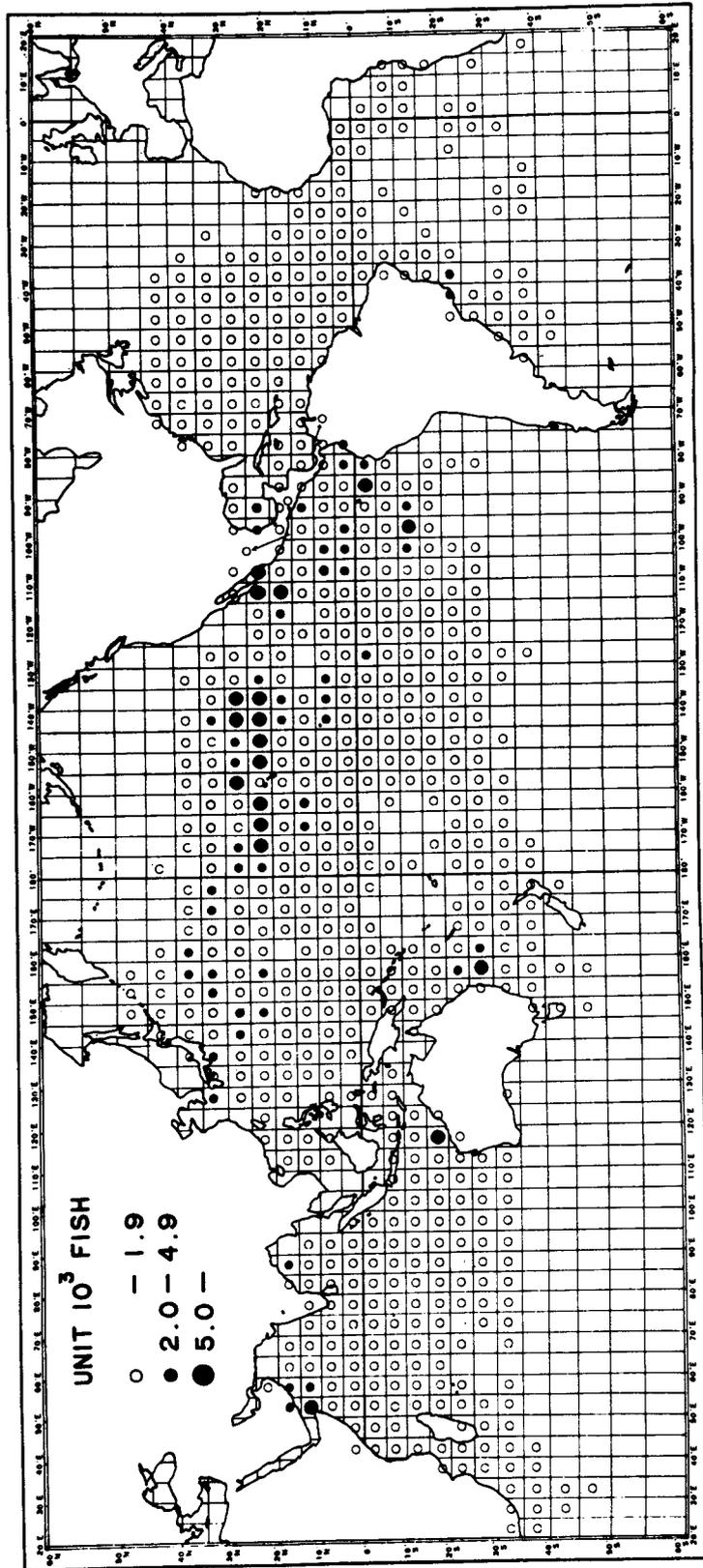


Figure 9.—Distribution of the catch of striped marlin in numbers per unit area (1970). Catch data in Atlantic Ocean area pertains to white marlin, *Tetrapturus albidus*.

landings. The Indian Ocean landings of striped marlin amount to approximately 20% of the Pacific landings.

Maximum equilibrium yield: Honma and Suzuki (1969) made some preliminary determinations of the maximum sustainable yield on the basis of 1960-66 data. They suggested that striped marlin catches in the Pacific can probably be increased about 60% over the recent average annual landings.

However, judging by the fact that catches have leveled off in recent years after fishing effort has virtually covered all of the known areas of striped marlin distribution, it appears that the present catches may be close to the maximum equilibrium yield level.

Obviously, further research is needed on this subject.

6 PROTECTION AND MANAGEMENT

6.1 Regulatory (Legislative) Measures

6.11 Limitation on reduction of total catch

The Japanese tuna longline fishery is regulated in terms of fleet size by the vessel licensing system. Licensing is reviewed at 5-yr intervals and fleet size is governed on the basis of the condition of the tuna resources. No increase in fleet size has been permitted since 1963. However, other countries such as Korea and Taiwan have increased the size of their longline fleet.

7 POND FISH CULTURE

Not applicable.

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