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SYNOPSIS ON THE BIOLOGY OF LITTLE TUNA Euthynnus yaito Kishinouye 1923

Exposé synoptique sur la biologie de la thonine Euthynnus yaito Kishinouye 1923

Sinopsis sobre la biología del atunito Euthynnus yaito Kishinouye 1923

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1 IDENTITY

1.1 Taxonomy

1.1.1 Definition

Phylum VERTEBRATA
Superclass Gnathostomata
Class Osteichthyes
Subclass Teleostomi
Superorder Teleostei
Order Percida
Suborder Scombrina
Family Scombridae
Subfamily Katsuwoninae
Genus Euthynnus Jordan and Gilbert 1882
Species Euthynnus yaito Kishinouye 1923

1.1.2 Description

- Genus Euthynnus Jordan and Gilbert

"Body plump, rounded and naked outside of the corselet. Mouth rather large, maxillary reaching the vertical from the centre of the eye. Teeth more developed in size and number than in the other genera of the Katsuwonidae. They are found not only in both jaws, but also on the palatines and sometimes on the vomer too. Teeth on the palatines are in single row. The right lobe of the liver much elongated as in the genus Auxis. It is remarkable that the chief cutaneous artery runs along the dorsal external side of the chief cutaneous vein, quite contrary to the case in all the other forms of the plecostean fishes, and the dorsal segmental branches of the chief cutaneous vein pass over the accompanying artery, which is a little more or less deeply imbedded in the muscle. The degenerated hypaxial cutaneous artery lies ventral, that is external, and similarly the accompanying vein. Hypaxial, cutaneous blood-vessels are bent in a zigzag line. They have no connection with the vascular plexus, nourishing the dark red portion of the lateral muscle. The subspinal rod of the vascular plexus is also well developed, but the rod is separated from the vertebral column by the development of the epihaemal process, between the vertebral column and haemal canal. Thus the inferior foramen is remarkably larger than in the genus Katsuwonus.

"Dark marking in the naked part of the back, and generally some greyish spots in the pectoral region above the ventral.

'Fishes of this genus attaind about the same size as the striped bonito. They are degenerated forms, derived from the genus Katsuwonus. Voracious fishes of temperate and tropical seas, not forming large schools, and often approaching the coast. Until recently only one species was known, but I have found other two species in the Pacific, quite different from the Atlantic species" (Kishinouye 1923).

- Euthynnus yaito Kishinouye 1923

"D. 15-16, 12-13, 8. A. 13, 7. Gill rakers 8-10 + 22-24. Vomerine teeth present. This character clearly separates this species from the allied species of the Atlantic, with which it has been hitherto confounded, as the presence of the vomerine teeth in this species had been overlooked. Vomerine teeth are arranged in one row on a longitudinal ridge. Palatine teeth are also on one row only. The upper jaw has 27-30 teeth, while the lower has 24-27. Gill rakers in this species are fewer in number than in the allied species of the Atlantic. The latter has 11-28.

'The cutaneous artery send arterioles from the inner and lower side in one row, while the venules to the cutaneous vein are arranged in two rows, alternate on the inner side. To the epaxial cutaneous blood vessels both the upper and lower segmentary branches are connected.

"Skull broad, its breadth is contained 1-1/3 in its length. The alisphenoid and prootic meet, and form a bridge over the groove of the prootic. Two pairs of the auxilary intermuscular bones are found on the dorsal surface of the exoccipitals, one pair of which is situated just above the foramen of the spinal cord, and the other at the lower end of paired vertical ridges continued from the top of the epiotic. The supraoccipital crest is very broad, and its vertical side meets the fused median ridge of the exoccipitals.

"Black blueish-black with many dark oblique bands. Belly silvery with three or more greyish spots below the pectorals. Fins black or greyish, the ventrals are partly black and fringed with chalk-white. Iris silvery with beautiful reflection, a

black spot under each eye.

"Found chiefly in the southern part of our empire. The northern limit of distribution seems to be near Chiba-ken on the Pacific coast. Lately Mr. K. Nomura sent me a specimen of this species, caught near Tsuruga, Fukui-ken, in October 1921. This is the first specimen from the Japan Sea. Among specimens of scombroid fishes from the Dutch Indies, kindly sent by Mr. Gobee, I found three immature forms of this species, but the southern limit of distribution is not yet determined.

"This species is rather rare, and is not found in schools. As it approaches the shore, a few examples are sometimes caught in drag seines and pound-nets. Also caught with rods and lines associated with bonito and immature tunnies" (Kishinouye 1923).

1.2 Nomenclature

1.2.1 Valid scientific name(s)

Euthynnus yaito Kishinouye 1923

1.2.2 Synonyms (according to Fraser-Brunner 1949)

Thynnus thunnina Temminck and Schlegel 1850 Fauna Japonica Poiss., p. 95, pl. 48.

Euthynnus alleteratus Jordan, Tanaka and Snyder 1913. Jour. Coll. Sci. Tokyo, xxxiii, p. 348 fig. 88.

Gymnosarda alleteratus Meek and Hildebrand 1923. Publ. Field Mus. Nat. Hist. Zool., xv, pt. 1 p. 311.

Euthynnus alleteratus Fowler 1928. Mem. B.P. Bishop Mus. x. pl. ix, A.

Euthynnus affinis affinis (Cantor 1850). Fraser-Brunner 1949. Ann. Mag. Nat. Hist., 2(20):622-628.

Fraser-Brunner regards E. affinis affinis as the valid name and E. yaito as its synonym. However, the latter has been taken as the valid name here, the reason for which will be explained later (see section 1.3.1).

1.2.3 Standard common names, vernacular names

TABLE I

Common and vernacular names

Country	Standard common name	Vernacular name(s)
Australia	mackerel tuna	
Ceylon	lesser bonito	atevalla, raguduva, sureya (Sinhalese); shurai (Tamil)
China		Tow chung
Hawaii	little tuna	bonito, kawakawa, kawakawa kinau
India		choori min, suraly (Tamil); ohaman, chuki (Marathi)
Indochina		Ca ngu
Indonesia		Tongol, diverg-bonito, tongol komo, poetilai
Japan	yaito	suma, hiragatwuwo, obosogatsuwo, segatsuwo, sumagatsuwo, watanabe
New Guinea	kababida	
Philippines	oceanic bonito	katsarita, turingan, yaito bonito.

1.3 General variability

1.3.1 Subspecific fragmentation (races, varieties, hybrids)

- Varieties

There are still some questions regarding the classification of the genus Euthynnus, and opinions about the subspeciations differ with the scientists.

Fraser-Brunner (1949) reviewed the fishes of the genus Euthynnus and established a new system. He placed yaito and lineatus as the subspecies of affinis. Therefore, according to him, Euthynnus from the seas of the East Indies and southwest Pacific are E. affinis affinis

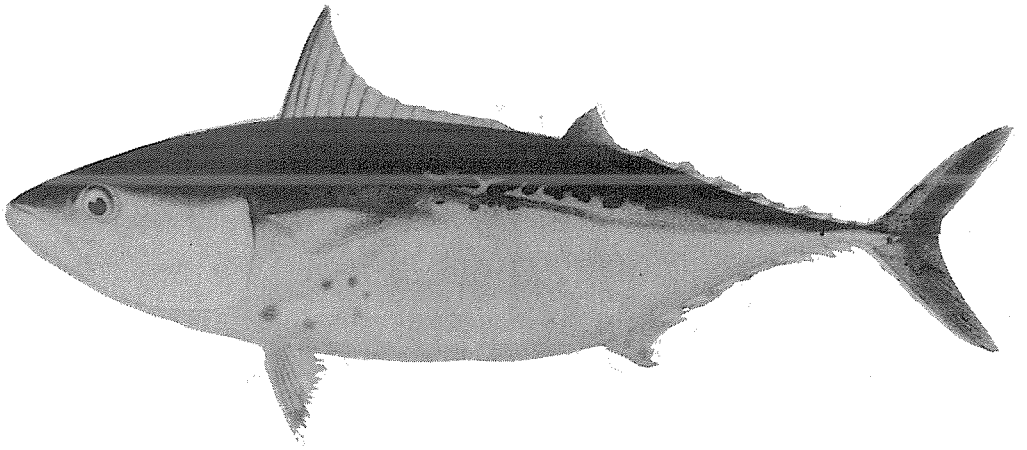


Fig. 1 Euthynnus yaito Kishinouye

(Cantor) and E. affinis yaito (Kishinouye).

Information on Euthynnus is given below.

Herre (1940) says that: "Whether Euthynnus alleterata, the Atlantic or striped bonito, occurs in the Pacific, is not clear to me. Jenkins, Jordan, Fowler, Günther, and others have recorded it from the tropical Pacific, all the way from Tahiti, Australia, and Hawaii to New Guinea and Japan, but the very few specimens I have been able to examine critically have proved to be Euthynnus yaito. However, I have not examined Polynesian or Australian specimens, but have seen in Polynesia fishes which I thought were probably E. alleterata, but which may well have been E. yaito like the Philippine examples."

Fraser-Brunner (1949) stated that: "For many years it has been customary for the majority of authors to consider the genus Euthynnus (Luetken) Jordan and Gilbert, to include a single variable, widely distributed species. A study of the material preserved in the British Museum (Nat. Hist.), however, combined with an examination of numerous freshly caught specimens in the Gulf of Aden, provided good reason to believe that there are at least two species, each with local subspecies or race."

Serventy (1950) reported that: "This widely distributed species appears to have differentiated into two geographical forms, E. a. alleteratus from the Atlantic Ocean and Mediterranean Sea and E. a. yaito from the Pacific Ocean. The two main characteristics by which these races can be distinguished are color pattern and gill-raker counts. The black skipjack, Euthynnus lineatus, from the tropical Pacific coast of central America is a near ally but shows some striking differences."

LaMonte (1950) stated that: "Confusion occurs in reports of the presence of these fish because in many cases the species have been undetermined. There appears to be at least three distinct species, looking very much alike."

As the result of the detailed comparative anatomy on E. lineatus, E. yaito and E. alleteratus, Godsil (1954) stated that in his opinion Kishinouye's classification was the most reasonable.

As to Thynnus affinis (Cantor), Cantor's original description is the only authority, and has never compared anatomically with E. yaito. Matsumoto (1959), who made identification of Euthynnus larvae from the East Indies, held the following view:

"The author believes that Kishinouye's suspicion concerning the similarity of E. yaito and T. affinis may be correct. If so, the specific name affinis would have priority over yaito. However, because the description of affinis is inadequate, and because neither the type specimen nor other adult specimens of this species were available for examination, no definite statement concerning the nomenclature can be made. Therefore, the Indo-Pacific species is designed as yaito in this paper."

- Meristic counts

TABLE II
Meristic counts of Euthynnus yaito

Meristic characters	1/	2/	3/	4/
1st dorsal rays	15-16	16	15	14-15
2nd dorsal rays	12-13	12-14	9-12	12-13
Dorsal finlets	8	8	8	8
Anal rays	13	13-14	10-13	13-14
Anal finlets	7	7	6-7	7
Gill rakers:				
upper limb	8-10	7-8	7-11	7-9
angle		1		0-1
lower limb	22-24	22-23	21-23	22-24

1/ Adult specimens from Japan (Kishinouye 1923)
2/ Juveniles, smaller than 178 mm from the Phillipines (Wade 1950)
3/ Young fish, between 159 and 235 mm, from Japan (Yabe et al. 1953)
4/ Adults from Hawaii (Godsil 1954)

TABLE III

A tabular comparison of skeletal differences

Character	E. lineatus	E. alleteratus	E. yaito	Nature of difference
Vertebral column	37 vertebrae	39 vertebrae	39 vertebrae	Positive
Protuberance	4 large lobes on each 31st and 32nd vertebrae	Incipient lobe on 33rd and 34th vertebrae	No trace	Positive
Caudal keels mainly on	31st and 32nd vertebrae	33rd and 34th vertebrae	33rd and 34th vertebrae	Positive
Cranium	1. Dentigenous plate on vomer, as in yaito	Sharp longitudinal ridge on vomer	Dentigenous plate on vomer as in lineatus	Positive
	2. Supraoccipital crest at lowest point in same horizontal planeas temporal crests, as in yaito	Supraoccipital crest at lowest point, appreciably higher than temporal crest	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 present in orbit	Longitudinal bridge of bone in orbit, absent	Relative

2 DISTRIBUTION

2.1 Delimitation of the total area of distribution and ecological characterization of this area

The occurrence of yaito has been reported from: Hawaiian archipelago, Japan, Ryukyu, Taiwan, Indochina, Philippines, East Indies archipelago, East and West Caroline Is., Marshall Is. and California.

According to Kishinouye (1923), the northern limit of its distribution, in the adjacent seas of Japan, is considered to be around 34°N on the Pacific coast, and the occurrence is quite rare in the Japan Sea (Kishinouye 1922). Yabe et al (1953) reported that the fishing grounds in the Southern Seas of Kagoshima are within 10 miles from the coast and the fish is caught together with bluefin, yellowfin and skipjack. It occurs also in the offing of Tosa. According to Kawasaki (1960), this species is caught in the shallows of Izu Island.

In September 1952, a specimen of E. yaito was caught in the port of Los Angeles, California. Up to that time E. yaito had not been recorded on the Pacific coast of U.S.A; however, examination showed the fish to be E. yaito (Fitch 1953).

The main distribution of E. yaito is in the western Pacific, west of the Hawaiian Islands and near the East Indies. It extends from the middle of Japan through Taiwan, Indochina and the Philippines as far as Australia. E. yaito also lives near islets in the ocean, but has not yet been recorded in pelagic basins far distant from islands or continents.

2.2 Differential distribution

2.2.1 Areas occupied by eggs, larvae and other junior stages: annual variations in these patterns, and seasonal variations for stages persisting over two or more seasons. Areas occupied by adult stages: seasonal and annual variations of these

- Eggs

No information on planktonic eggs is available.

- Larval stages

Postlarvae of E. yaito have been obtained around Kyushu, near the Philippine Islands, in the Sulu Sea, the Celebes Sea (Wade 1951) and in waters around the East Indies (Matsumoto 1958, 1959). They have not been caught in the Indian Ocean except on the west coast of Sumatra. According to the reports of the Dana trans-Pacific survey, the postlarvae were collected exclusively near coasts, but not in the central parts of the Ocean. The water temperature ranged from 24.5°C to 29.0°C in the points where collections were obtained. Matsumoto (1959) says, "Although there is no assurance that these values truly represent the lower and upper limit of temperatures tolerated by the young of Euthynnus, they at least give us an idea of the wide temperature range throughout which these larvae can exist".

Wade (1951) reports postlarva collection near the Philippine Islands as shown in Table IV.

- Juvenile stages

Kishinouye (1923) reported a 115 mm specimen of E. yaito from the port Keelung of Taiwan. Wade (1950) collected specimens of 33.5 to 175 mm near Batangas of Luzon Island, Manado of Celebes Island and Cape Maragabato of Mindanao Island. According to Wade, many of these juveniles enter into the large bays of Batangas and Balayan, which face the open sea.

- Young fish

According to Yabe et al (1953), from August to October many young of 150 to 250 mm length, which are presumed to be in their first year, come to the waters near Aburatsu in southern Kyushu and are fished. The catch of yaito young reported by Yabe et al is given in Table V.

- Adult

Adult E. yaito are fished along the Pacific coast of Japan from Ryuku through Satsunan waters as far as Chiba Prefecture. Fishing near Izu Islands begins in May and continues till November. The catch is reported to be of schools striking the shallows (Kawasaki 1960).

In the middle Pacific they are caught near the Hawaiian Islands, Line Islands and Phoenix

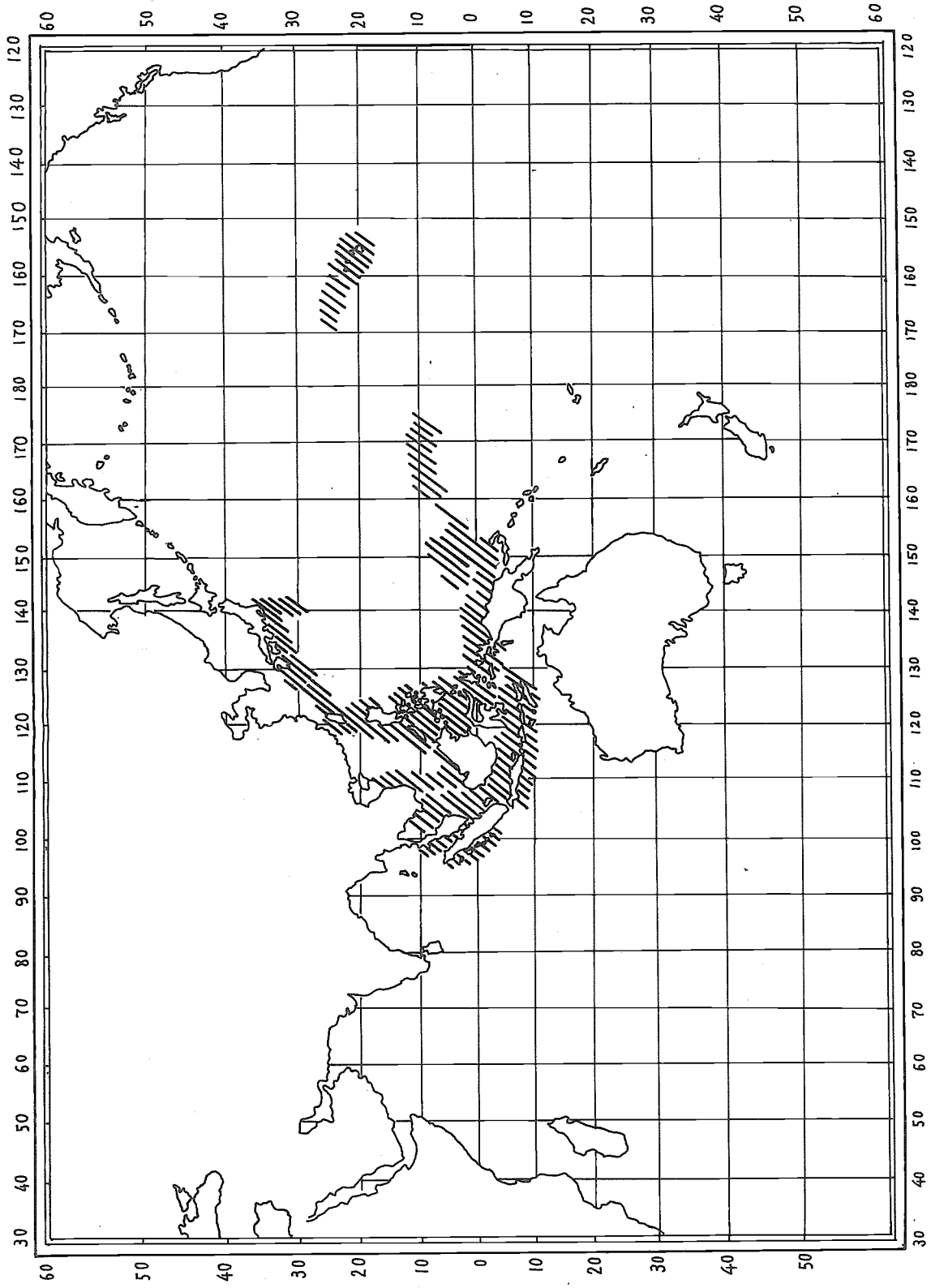


Fig. 2 Areas of capture of E. yaito, both adults and larvae

TABLE IV

Monthly catch of larval Euthynnus yaito taken in Philippine waters, 1947 - 1949

Month	Total number of Plankton tows	Tows with larvae		Larvae	
		Number	%	Number	Average catch per tow
1947					
October	21	3	14.2	6	0.28
December	15	3	20.0	49	3.27
1948					
February	10	2	20.0	16	1.67
March	18	5	27.8	12	0.67
April	27	3	11.1	17	0.63
June	27	-	-	-	-
July	25	2	8.0	8	0.32
August	17	3	17.6	35	2.06
September	28	6	21.4	25	0.89
1949					
January	30	11	36.7	141	4.70
February	43	11	25.6	681	15.70
May	38	3	7.9	5	0.13
June	25	-	-	-	-
July	18	-	-	-	-
August	50	4	8.0	152	3.40
September	35	2	5.7	3	0.09
October	20	-	-	-	-
November	16	2	12.5	14	0.87
TOTALS	463	60	13.0	1,164	2.51

Note: A specimen in Wade's collection, 10.5 mm long, has only 8 first dorsal spines and has three rows of chromatophores on the side of the caudal region. By these, Matsumoto (1959) presumes this to be Auxis. If his presumption is correct, it is possible that Auxis is mixed in the collection given in Table IV.

TABLE V

Catch of E. yaito young at Aburatsu Fish Market (1950)

Date 1950	No. of vessels	No. of fish
August 30	9	197
31	4	123
September 1	5	425
2	5	519
4	4	95
5	4	458
6	15	558
7	2	264
8	19	1,120
9	17	1,164
20	7	335
October 25	1	13
6	4	56
11	3	9
13	5	24
TOTAL:	104	5,360

Islands (Eckles 1949; Smith and Schaefer, 1949). They are fished in the waters within two miles of the east coast of Oahu Island and Mokumanu Island from May to October (Tester 1952).

Around the Philippine Islands they are caught with trolling all the year round (Wade 1950).

2.3 Behavioristic and ecological determinants of the general limits of distribution and of the variations of these limits and of differential distribution

Kishinouye (1923) says that E. yaito is found within the temperature range of 18°C to 28°C, the lower limit being a little higher than that for other fishes of Katsuwonidae and Thunnidae. Near Izu Islands, where the E. yaito is caught during May to November, the surface temperature in May 1960 was 21° - 23°C and in November 22° - 24°C, the highest being attained in August at 29°C. From this, the water temperature of their habitat is reckoned as being 20°C to 29°C, which nearly coincides with Kishinouye's results.

According to Yabe et al (1953), it is suggested that E. yaito has a great adaptability to salinity. In 1950 the salinity of surface sea water near Aburatsu was 31.22 to 33.80 o/oo, and many young were caught in a salinity range of 31.22 to 31.31 o/oo. Near Aburatsu, heavy autumnal rains are supposed to make turbid the water belt one or two miles from shore and to cause a considerable low salinity of surface water, but these conditions do not greatly affect the catch.

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.1.1 Sexuality (hermaphroditism, heterosexuality, intersexuality)

Heterosexual.

3.1.2 Maturity (age and size)

According to the survey made by Wade (1950) near the Philippines, females of the spawning stage are found among individuals more than 450 mm in body length, and males at the corresponding stage among those over 400 mm. Again, females and males in the "spent" stage are seen among those over 430 mm and 510 mm in body length respectively. From these figures their biological minimum can be presumed, which nearly coincides with the results obtained by Buñag (1956). Buñag stated that females of the mature and the spent stage are found among individuals over 490 mm and 500 mm in body length, respectively. The maturity stages that these investigators give may not correspond perfectly with each other, but it can be supposed that many females attain spawning ability when they are 400 to 500 mm in body length. As for maturity body lengths for male and female, Wade (1950) states: "The immature females averaged larger than the males, which may have been the result of an inadequate sample. Again, it may indicate that the females grow more rapidly or reach maturity at a greater age and a larger size than the males, if the growth rate of the two sexes is equal".

3.1.3 Mating (monogamous, polygamous, promiscuous)

Mating of E. yaito has not been observed, but it is supposed to be promiscuous.

3.1.4 Fertilization (internal, external)

External.

3.1.5 Fecundity

Buñag (1956) studied the frequency distribution of egg diameter for many ovaries at different stages of maturity and showed the development of the matured egg lump which is to be spawned. The total number of eggs which a female spawns during the spawning period is about 100, 000, but so far no attempt has been made to estimate the number of eggs to be spawned.

3.1.6 Spawning

- Spawning seasons (beginning, end, peak)

Kishinouye (1923) states that near Taiwan the spawning of E. yaito takes place about May. But in some areas individuals at different stages of maturity can be found all the year round. According to Wade (1951), the collection of larvae around the Philippines suggests that spawning activity is great during December to February and declines somewhat in summer, although in August the number of collected larvae has increased a little. Wade, however, does not think that such results of larva collection show the general tendency of spawning activity in the waters near the Philippines. According to Buñag E. yaito in this area has no well-defined spawning season, but the individual fish has a distinct spawning periodicity with a well-established rest period.

- Number of spawnings per year, frequency

Buñag (1956), based on his study of the change of egg-diameter composition accompanied by maturation, presumes that an individual spawns more than once during the spawning period, but he does not define the period of a spawning cycle.

3.1.7 Spawning grounds

- Coastal (surface, vegetation, shore, shoal, sand, shelter); bottom

Spawning grounds of E. yaito, if we assume them roughly to coincide with the distribution areas of the larvae, extend from the tropical to the subtropical zone, but are restricted to near shore. Wade (1950) gives the main spawning grounds as being near the Philippines, Manado of Celebes Island, Marigabats point of Mindanao Island, Batangas Bay and Balagan Bay of Luzon Island.

3.1.8 Eggs: structure, size, hatching type, parasites and predators

Forms and structures of a fully matured

ovarian egg or of a spawned fertilized egg are not known. Buñag (1956) has described residual eggs which are found in the ovary after spawning: "The largest measurable degenerating eggs of Euthynnus yaito were 33 micrometer units (1.07 mm) in diameter, translucent, with a single oil globule measuring from 7 to 8 micrometer units (0.23 - 0.26 mm), and a granular, light orange yolk." He also mentions: "It is probable, therefore, that mature eggs begin to ripen when they have grown to 27 micrometer units (0.88 mm) in diameter." From these data, it is supposed that mature eggs of this species may be floating eggs about 1 mm in diameter and with an oil globule whose diameter is about one-fourth of that of the egg itself.

3.2 Larval history

3.2.1 Account of embryonic and juvenile life (prelarva, larva, postlarva, juvenile)

- Postlarva

The postlarva of yaito has a comparatively large head, mouth and eyes, short and triangular abdominal sac, and anus located underneath and anteriorly of the body. The general body form resembles that of other fishes of Katsuwonidae or Thunnidae.

According to Matsumoto (1959), the morphological features of postlarva can be recognized mainly in the pigmentation of the body. First, in individuals of less than 10 mm body length, there are one to several chromatophores at the middle lower jaw. These chromatophores are well separated from each other and found in the anterior one-half to two-thirds of the lower jaw. Second, there are three to five chromatophores along the ventral edge of the body near the caudal region. In a specimen 12.2 mm, four additional chromatophores are found along the base of the posterior end of the second dorsal fin and the first three dorsal finlets, which are not present in smaller individuals.

As to pigmentation by which larvae of genus Euthynnus may be separated from each other, Matsumoto (1959) writes: "Specifically, specimens of yaito and lineatus consistently bear fewer chromatophores along the lower jaw than comparable specimens of alleteratus. ... Another difference in pigmentation is seen in the row of chromatophores along the ventral margin of body in the region of the anal fin and finlets. E. yaito and lineatus have three to five chromatophores, whereas alletteratus has from six to eleven."

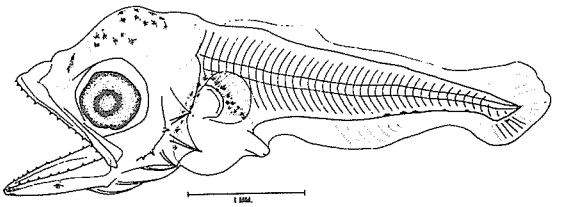
Yaito and lineatus resemble each other in pigmentation, but yaito and alletteratus have 40 or 41 myomeres, while lineatus has 38 or 39. The number of vertebrae reaches the adult's constant (20 + 19 = 39) in yaito over 9 to 10 mm in body length. Yaito has ordinarily 13 second dorsal rays and 13 or 14 anal rays (Matsumoto 1959).

- Juvenile

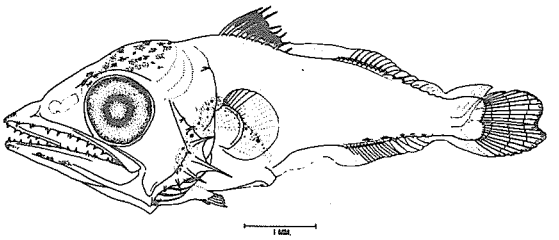
Wade (1950) describes juveniles of 33.5 to 178 mm. Wade shows that yaito differs from lineatus (Schaefer and Marr 1948) in vertebral and gill raker counts, color pattern and the number of dorsal and anal rays. A difference is also seen in their pigmentation. Schaefer and Marr stated that the entire first dorsal was heavily pigmented, but Wade says: "In Philippine specimens of E. yaito the heavy pigment is confined to the anterior part of the fin and to the outer ends of the posterior spines; and the basal part of the remainder of the fin is either almost colorless or lighter in color than the distal. The basal half of the second dorsal is less heavily pigmented, and there is no conspicuous series of dark spots along the anal base or on the following finlets. The ventral bars are more numerous in E. yaito and persist until the fish reaches a larger size. There is a pronounced pale, crescent-shaped area behind the eye of yaito which is not evident in lineatus."

- Feeding

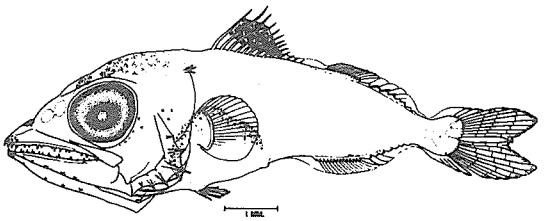
Kishinouye (1924) reported the fact that E. yaito of 36 mm body length had eaten one 10 mm and two 6 mm young of unidentified fish.



(a) E. yaito, 4.6 mm



(b) E. yaito, 7.6 mm



(c) E. yaito, 9.6 mm

Fig. 3 Euthynnus yaito - larval stages (after Matsumoto 1959)

3.3 Adult history

3.3.1 Longevity

According to Kishinouye (1923), yaito attains a total length of 60 cm and a body weight of 3.5 kg, and that on rare occasions individuals over 100 cm long and 10 kg in weight are found. Wade (1950) reported the body length distribution of catch in Philippine waters during October 1947 to November 1948 and showed that the largest was 66 cm long. Little is known about the life span of yaito.

3.3.2 Hardiness

Tester (1952), who reared yaito in tanks and ponds, recognized that small yaito, one to three pounds in weight were more readily established than larger individuals. Judging from the swimming speed, it is difficult for a confined fish to give the gills enough water to supply abundant oxygen. Skipjack and frigate mackerel are said to need a strong water current, but Tester found that a great swimming speed is not necessary for the establishment of small yaito though he also pointed out the possibility of lowering mortality by supplying an adequate water current and thus causing an optimum swimming rate. These facts are considered to show the hardiness of yaito, especially of the smaller individuals .

Tester (1952 a, b) reported that these yaito reared were in good condition for a few months, but that they gradually weakened, failed to feed and eventually died. The causes of this decline were not clear but it was observed that many deaths followed a period of cold, wet weather.

3.3.5 Parasites and diseases

Little has been reported on parasites of yaito. In skipjack, closely related to yaito, gill filament, pseudo gill, first dorsal membrane and mouth cavity are the main sites of external parasitism. As internal sites the ventral muscles (Cestoda larva), digestive system (Distoma, Acanthocephala), ovary, and liver (Nematoda), can be cited (Yoshisaki, unpublished). Kishinouye (1923) found a very long Nematoda in the cutaneous artery of yaito. Kishinouye recognized Nematoda also in the dorsal aorta of yellowfin tuna and attributed to it the hardening and discoloration of blood vessels in the yellowfin tuna but for yaito little is known on this point.

3.4 Nutrition and growth

3.4.1 Feeding (time, place, manner, season)

Van Weel (1952), in his rearing experiments with yaito, observed the fishes' response to aqueous extracts of various diets. The species yaito showed little response to extracts of natural diets such as squid or ordinary baitfish, but clearly responded to extracts from tuna flesh. From this experiment Van Weel concluded:

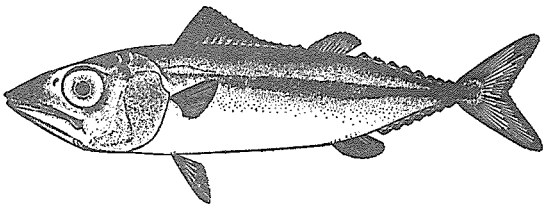
(a) the effective component of extracts which attracts the fish is not fat, but protein;

(b) yaito is more sensitive than yellowfin; and

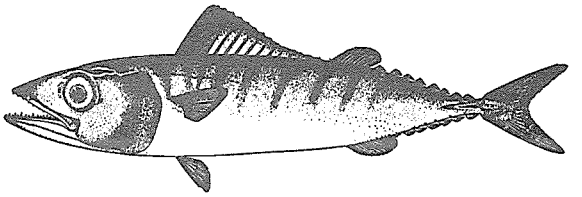
(c) in feeding, the sense of smell or taste plays a more important part than the sense of sight.

In a pond test by Tester et al (1954), yaito was shown to be attracted to some strong smelling aromatics and to avoid some highly-colored dyes. In this test, yaito were given extracts from flesh, viscera and blood of skipjack, dolphin, anchovy and other fish and from the substance of squid and shrimp, and they responded to all of these various extracts with active feeding. However, their response to extracts of the same kind as a subsistence diet was better than to other types of diet and it was suggested that the response to extracts was entirely conditioned by the nature of the food.

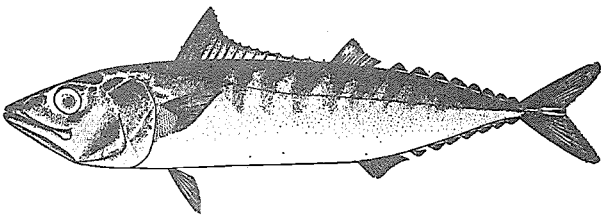
Sea tests using various kinds of extracts were made on a skipjack group, but the results were negative. From these tests it was deduced that also in feeding of yaito the sense of smell played little part under natural conditions (Tester et al 1954).



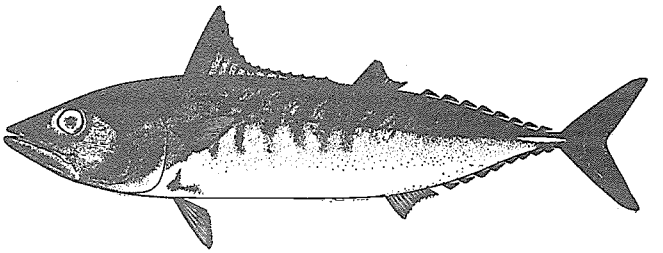
(a) E. yaito, 33.5 mm fork length



(b) E yaito, 67 mm fork length



(c) E. yaito, 110 mm fork length



(d) E. yaito, 156 mm fork length

Fig. 4 Euthynnus yaito - juvenile stages (after Wade 1950)

Tester et al describe the manner of feeding, as observed in a tank, as follows: "While feeding, they swim with great rapidity, taking food at or near the surface. They enter into active competition for food both with each other and with the yellowfin tuna which is also present in the tank."

3.4.2 Food (type, volume)

Yabe et al (1953) examined the digestive tract of yaito juveniles near Aburatsu and found that its main content was Engraulis japonicus, the remainder being larvae of various kinds of Arthropods. However, in the waters near Ryukyu where E. japonicus are not found, fishes comprise a very small portion of the digestive tract content of yaito (0.8 - 2.5 kg), which consists mainly of larvae of various Arthropoda, squids and Pteropoda (Yabe et al 1953).

Ronquillo (1953) studied the stomach content of yaito near the Philippines, and found that the main diet was Stomatopoda and Decapoda, especially their megalopa larvae, and that fishes made up only a small portion. It may be concluded that in waters where pelagic predominant species such as E. japonica are not present the food of yaito depends to a greater extent on various kinds of planktonic crustacean larvae.

3.4.3 Relative and absolute growth patterns and rates

No detailed studies have been made on the growth of yaito. Some estimations of growth rate during the larval and young periods have, however, been attempted. For example, Kishinouye (1923) supposed that a 115 mm long juvenile caught in Port Keelung in August might have been spawned in May, namely three months before. Wade (1950) also presumed a juvenile 115 mm long from the Celebes Sea to be three or four months old. Again, Wade estimates 33.5 mm and 35 mm young from Marigabato Point to be one month old and specimens 40 to 175 mm long from Batangas to be spawned about six months before. That is, fish 40 to 175 mm long are estimated to be 1.2 to 6 months old.

Yabe et al (1953) presumed yaito about 150 to 250 mm fished near Aburatsu to be in their first year of life, and showed the change in the body-length composition of these catches through the fishing season. As the appearance of young is roughly simultaneous in different parts of southern Japan and as their active appetite suggests a large growth rate per individual, the figure shown could well designate the growth pattern of yaito, though for a very short period.

3.4.4 Relation of growth to feeding, to other activities, and to environmental factors

The relation between feeding and growth has not intentionally been studied either in tank or pond tests. In a concrete tank built on the seashore, to give an example, 5 yaito weighing about 5 lb which were transferred to the tank from late August to early November 1951, increased by 1 to 2 lb until they all died in early December (Tester 1952). The relation between the amount of food eaten and body weight increase was not defined.

3.5 Behavior

3.5.1 Migration and local movement

Young yaito in the waters near Japan in different parts of the Pacific coast west of Suruga Bay appear over a comparatively short period from late summer to early autumn. Yabe et al (1953) suppose that these young are probably in the first year of life, that they migrate from the southern waters, stay near Japan for several months of higher water temperatures, grow feeding on Engraulis japonicus, and leave for the south when the water temperature becomes lower.

From collection of the larvae near the Philippines, Wade (1951) shows the diurnal vertical migration of yaito. (Table VI). Of 250 net towings during daytime, the larvae were captured in 16 towings (6.4%), with an average catch of 0.39, and a total of 97 larvae. At night, on the other hand, out of 212 towings 43 (20.2%) were successful, the catch per trial averaged 5.05 (total 1,070), being far greater than in the day. This shows that the fish migrate to deeper layers in the daytime and move upward to surface water at night.

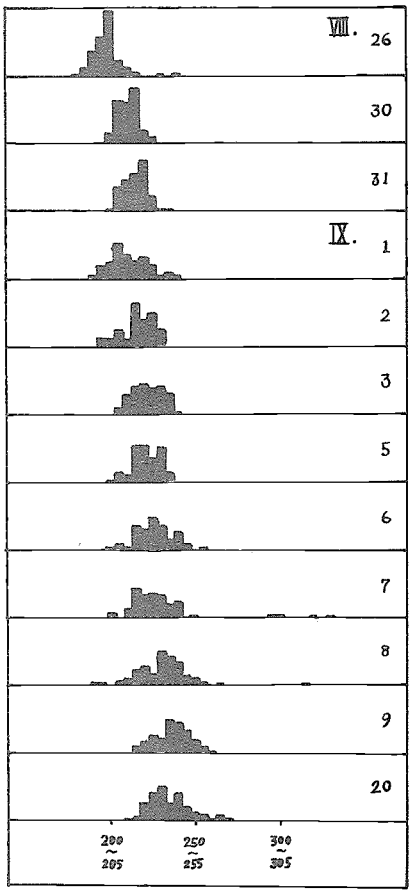


Fig. 5 Euthynnus yaito - Change of body-length composition of yaito young during the 1950 fishing season (Aburatsu Fish Market, Kyūshū; see Yabe et al 1953)

TABLE VI

Hourly summary of larval Euthynnus yaito collected in Philippine waters, 1947 to 1949

Hour	Total number of plankton tows	Tows with larvae		larvae	
		Number	Percent	Number	Average catch per tow
0600 - 0659	26	2	7.7	13	0.50
0700 - 0759	18	1	5.5	7	0.39
0800 - 0859	19	2	10.5	11	0.58
0900 - 0959	23	1	4.4	2	0.09
1000 - 1059	15	1	6.8	24	1.60
1100 - 1159	18	-	-	-	-
1200 - 1259	22	-	-	-	-
1300 - 1359	19	1	5.3	8	0.42
1400 - 1459	21	3	14.3	13	0.62
1500 - 1559	16	1	6.2	1	0.06
1600 - 1659	31	2	6.5	5	0.16
1700 - 1759	22	2	9.1	13	0.59
1800 - 1859	16	3	18.7	9	0.56
1900 - 1959	21	7	33.3	619	29.50
2000 - 2059	16	2	12.5	49	3.06
2100 - 2159	23	4	17.4	55	2.38
2200 - 2259	21	2	9.5	9	0.43
2300 - 2359	17	-	-	-	-
0000 - 0059	18	4	22.2	25	1.39
0100 - 0159	13	5	38.4	14	1.07
0200 - 0259	21	6	28.5	67	3.19
0300 - 0359	15	5	33.3	56	3.73
0400 - 0459	13	3	23.0	3	0.23
0500 - 0559	18	2	22.2	164	9.12

3.5.2 Schooling

Young fish of yaito have the habit of forming a shoal, as do many other species (Yabe et al 1953).

Tominaga (1943) describes the behavior of yaito as follows: "Though yaito live mainly in rapid tidal currents near solitary islands, they avoid the farthest flow and hold the body in a comparatively slow current. When they find a suitable place they stay there as a nest and dart at crustaceans (for the most part the megalopa larvae), squids and young fishes which happen to drift near them and capture these. They pursue the food animals obliquely anteriorly but do not follow them posteriorly for a long distance and return to the nest. So we must arrange so that the imitation bait may come within the sight field anterior to them near their nest and at the same

time to simulate the respiratory movement of squid. With a mere straight hauling we cannot get a good result. This relation between the behavior of fish and the fishing technique is very interesting. In dim light of morning and evening they leave the nest and eat plankton and small fishes, forming small schools and splashing water at the surface. Then we can angle them with scattering bait, although in this way they cannot be fished so abundantly as in the case of skipjack which leap at the surface much more wildly. In particular, as yaito feed on megalopa larvae which are carried by upwelling currents caused by the tide, they do not leave islands for a long distance, and only very rarely migrate into an open ocean, and, moreover, the schools they form are very small. So they cannot be the objective of a skipjack fishery. Their jaw teeth are small in size and their gill rakers also those of plankton-feeders. But they have vomer teeth which permit them to catch slightly larger foods and this, as described above, causes them not to form a large school but to seek for a nest in an appropriate site."

Hiatt and Brock (1948) in the northern Marshall Islands observed three medium-sized yaito herding a closely packed school of several hundred scad (Decapterus sanctaehelenae (Cuvier)) over a large coral head in Rongerik lagoon. The authors reported that: "The three tuna 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 would move forward swiftly and herd them back into line. It became obvious that the school of scads was prevented from leaving the area over the top of the coral head, being herded back whenever it moved over deep water. On one occasion a laggard scad was swiftly picked off by the rearmost black skipjack; however, except for this incident, the tuna made no attempt to prey upon the scads during our period of observation. Scads are uncommon in the lagoons in the northern Marshalls and probably do not constitute a large proportion of the diet of this species of tuna."

Based on his rearing test in a tank, Van Weel (1952) reports as follows: "When two yellowfin and five tunny (yaito) were present, the two species tended to school separately and to exhibit different reaction patterns. After one yellowfin died, the other joined the tunny, and although a slower swimmer, it attempted to keep up with the school." Tester (1952) observed that: "Occasionally, the large fish would bump the sides of the wall; the small ones seemed able to keep clear. When both large and small fish were present, they tended to swim as a school, the large one keeping to the outside and the small ones to the inside of the circular course."

4 POPULATION (STOCK)

4.1 Structure

4.1.1 Sex ratio

Wade (1950) gives data on the body length and sex composition of yaito caught by trolling in Philippine waters during November 1947 to November 1948. Table VII was extracted from Wade's data to indicate the sex ratio of the catch for every month. This Table shows that the sex ratio for the whole sample is nearly 1:1, and that in autumn and winter the proportion of males is greater while in spring and summer the ratio is 1:1 or rather that the number of females is larger.

4.2 Size and density

4.2.1 Average size

Yabe et al (1953) showed the average size of yaito in the waters near Aburatsu as given in Table VIII.

4.4 Mortality, morbidity

4.4.1 Rates of mortality

No information is available on natural mortality.

The mortality rate in live wells according to Tester (1952), is 7.5 % for larger fish and 17.9 % for smaller ones. It was also suggested that the mortality during transportation depends largely on the design of the live well, namely, its capacity, pumping ability to renew the water, establishment of corner baffles, and so on. Smaller yaito are comparatively easily established in tanks or ponds, and Tester (1952) reported a case where 18 out of 23 were established, with a mortality of 21.7 %.

4.4.2 Factors or conditions affecting mortality

No information is available on factors affecting mortality under natural conditions.

TABLE VII

Sex ratio of E. yaito caught by trolling in Philippine waters

Month	No. of fish	Male	Female	$\frac{F}{M+F} \times 100$
1947				
November	1	0	1	100
December	26	19	7	26.9
1948				
January	42	22	20	47.6
February	108	58	50	46.3
March	13 + 1	4	9	69.2
April	38 + 1	12	26	68.4
May	86 + 2	48	38	44.2
June	23	12	11	47.8
July	18	9	9	50.0
August	1	1	0	0
September	-	-	-	-
October	14	9	5	35.7
November	86 + 1	49	37	43.0
TOTAL:	456 + 5	243	213	46.7

TABLE VIII

Average size of E. yaito landed at Aburatsu Fish Market (1950)

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

Deaths under rearing experiments can be said to occur in the following three periods:

(a) Deaths in live wells during transportation;

(b) Deaths during pre-feeding period in tank or pond; and

(c) Deaths occurring after establishment in tank or pond.

Deaths in live wells and during pre-feeding, according to Tester et al (1954), can be attributed to the restricted space, but the physiological incompleteness due to unsuitability of oxygen or temperature is, probably, of secondary importance. White corner baffles, ceiling cover wire netting and illumination by night have proved considerably effective in lowering mortality. Deaths after establishment are supposed to result mainly from the physiological incompleteness, but the cause is not yet clear although lowering of temperature is recognized to have some effect (See section 3.3.2).

5 EXPLOITATION

5.1 Fishing equipment

5.1.1 Fishing gear

Fishing of yaito in the neighboring waters of Japan is effected mainly with trolling from small-sized sailing boats and, on some occasions, with trolling from small motorized vessels or angling with Engraulis japonicus as bait. The species yaito which are caught in skipjack and tuna fishery (pole and line) are mostly about 800 gr or more in body weight.

Traditional Japanese fishing gear for yaito and young of bigeye and bluefin is described below. Bamboo poles 1 to 2 m in length, and three-yarned hemp twine, are used. The total length of line, with a gut about 50 cm long joined to the end, is equal to that of the pole. A small-sized hook is used for skipjack angling. At first the Engraulis juvenile is hooked and used as bait while little shrimp are continuously scattered; the fish then become active in taking bait, and imitation bait can be used. For skipjack angling small-sized imitation bait, or sometimes also a hook with a tin lever and a plume, is used. With imitation bait, the length of pole is about 5 to 7 m, the line being as long as the pole.

In Taiwan, the Philippines and also Hawaii, yaito are fished mainly by surface trolling, and also with corrals in the Philippines (Herre 1940). Concerning trolling in Hawaii, Tester (1952) reported: "In trolling, six lines were used, two (90 feet long) from each of two outrigger poles; and one (30 feet long) from each side of the stern. A variety of relatively small lures was used as follows: usually greenish or brownish, pliable-rubber imitation squid on the outside outrigger lines; gray or red, metal-headed imitation squid with white rubber arms on the inside outrigger lines; and red or white metal-headed, feathered jigs on stern lines. For the most part, small (No. 3 or 5, Japanese) double, barbed hooks were used with the lures. Both lures and hooks were small because small fish, not over about 8 pounds in weight, were desired."

5.1.2 Fishing boats

In Japan small-sized sailing boats or small motorized vessels are used, but there are no fishing boats specialized for yaito fishing.

5.2 Fishing areas

See sections 2.1 and 2.2.

5.2.1 General geographical distribution

See section 2.2.

5.2.2 Geographical ranges (latitudes, distances from coast, etc.)

See section 2.2.

5.2.3 Depth ranges

The adults and juveniles are caught at the water surface, while the larvae make the diurnal vertical migration (See section 3.5.1). The range of vertical distribution is not known.

5.3 Fishing seasons

5.3.1 General pattern of fishing season

See sections 2.2.1 and 2.3.

5.3.2 Duration of fishing season

See sections 2.2.1 and 2.3.

5.3.3 Dates of beginning, peak and end of season

See sections 2.2.1 and 2.3.

5.4 Fishing operations and results

5.4.1 Effort and intensity

The species is caught together with frigate mackerel and juvenile, immature skipjack, yellowfin and bluefin which migrate to the coast, but there is no specialized fishery. Consumer demand for this species is not very great. In Japan it comprises only a very small part of the catches of the coastal fisheries, although a remarkable catch is obtained in southern Kyushu in some seasons. As yaito very often is bulked together with frigate mackerel and other fish, statistics on yaito itself are very uncertain.

5.4.2 Selectivity

Comparatively larger individuals are caught with pole and lines, but there seems little

difference in selectivity between pole and lines, and trolling.

5.4.3 Catches

Owing to incomplete fishery statistics, the annual catches in different parts are uncertain.

5.5 Fisheries management and regulations

Neither management nor regulation is practised.

5.6 Fish farming, transplanting and other intervention

Except for rearing experiments for ecological studies, nothing has been undertaken.