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SYNOPSIS OF BIOLOGICAL DATA ON SKIPJACK *Katsuwonus pelamis* (Linnaeus) 1758 (PACIFIC OCEAN)

Exposé synoptique sur la biologie du bonite à ventre rayé *Katsuwonus palamis* (Linnaeus) 1758 (Océan Pacifique)

Sinopsis sobre la biología del bonito de vientre rayado *Katsuwonus pelamis* (Linnaeus) 1758 (Océano Pacífico)

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1 IDENTITY

1.1 Taxonomy

1.1.1 Definition (after Schultz, et al, 1960)

Phylum CHORDATA
Subphylum Craniata
Superclass Gnathostomata
Class Osteichthys
Subclass Teleostomi
Superorder Teleosteica
Order Percomorphida
Suborder Scombrina
Family Scombridae
Genus Katsuwonus
Species pelamis

Some of the larger taxa under which skipjack have been listed are shown in Table I. The tendency over the past few decades has been to set the tuna apart from other scombroids, and further to set up monotypic genera. Within recent years this tendency appears to be changing to one of re-including tuna in the family Scombridae and doing away with some of the monotypic genera. Under this system it is likely that skipjack will be included in the genus Euthynnus.

1.1.2 Description

- Genus Katsuwonus

"Body robust, naked outside the corselet; maxillary not concealed by preorbital; teeth present in jaws only; dorsal fins with only a short space between them, the anterior spines of the first fin very high, decreasing rapidly in length; second dorsal and anal each followed by 7 or 8 finlets; pectoral not very long, placed at or near level of eye, with about 26 or 27 rays." (Hildebrand, 1946). The foregoing statement is applicable to mature adults of the genus.

- Species Katsuwonus pelamis (Linnaeus) (Fig. 1)

"Head 3.0 to 3.2; depth 3.8 to 4.1; D. XIV or XV - I, 13 or 14 - VIII; A. II, 12 or 13 - VII; P. 26 or 27; vertebrae 40 (one specimen dissected). [Note: Both Kishinouye, 1923 and Godsil and Byers, 1944 give the number of vertebrae as 41.]

"Body robust, its greatest thickness about two-thirds its depth, tapering strongly posteriorly; caudal peduncle slender, depressed, with a strong lateral keel, its depth 14 to 15.3 in head, head somewhat compressed, convex above; snout long, pointed, 3.3 to 3.7 in head; eye moderate, round, 5.7 to 6.1; interorbital 3.7 to 4.0; mouth slightly oblique, terminal; maxillary reaching nearly or quite opposite middle of eye, 2.6 to 2.8 in head; teeth in jaws in single series, short and rather stocky; gill rakers long, slender, about four-fifths length

Table I

Classification of skipjack according to different authors

Group	Authority				
	Regan 1909a, b	Kishinouye 1923	Jordan, Evermann and Clark 1930	Berg 1940	Schultz et al. 1960
PHYLUM	-	-	-	-	Chordata
SUBPHYLUM	-	-	-	-	Craniata
CLASS	Pisces	-	Pisces	Teleostomi	Osteichthys
SUBCLASS	Neopterygii	-	Actinopteri	Actinopterygii	Teleostomi
SUPERORDER	-	-	Acanthopterygii	-	Teleosteica
ORDER	Percomorphi	Plecostei	Percomorphi	Thunniformes	Percomorphida
SUBORDER	Scombroidei	-	Rhegnopteri	-	Scombrina
SERIES, SECTION DIVISION	Scombriformes	-	Scombriformes	-	
FAMILY	Scombridae	Katsuwonidae	Katsuwonidae	Thunnidae	Scombridae
SUBFAMILY	-	-	-	Auxidini	-
GENUS	-	Katsuwonus	Katsuwonus	Katsuwonus	Katsuwonus
SPECIES	-	pelamis	vagans	-	pelamis

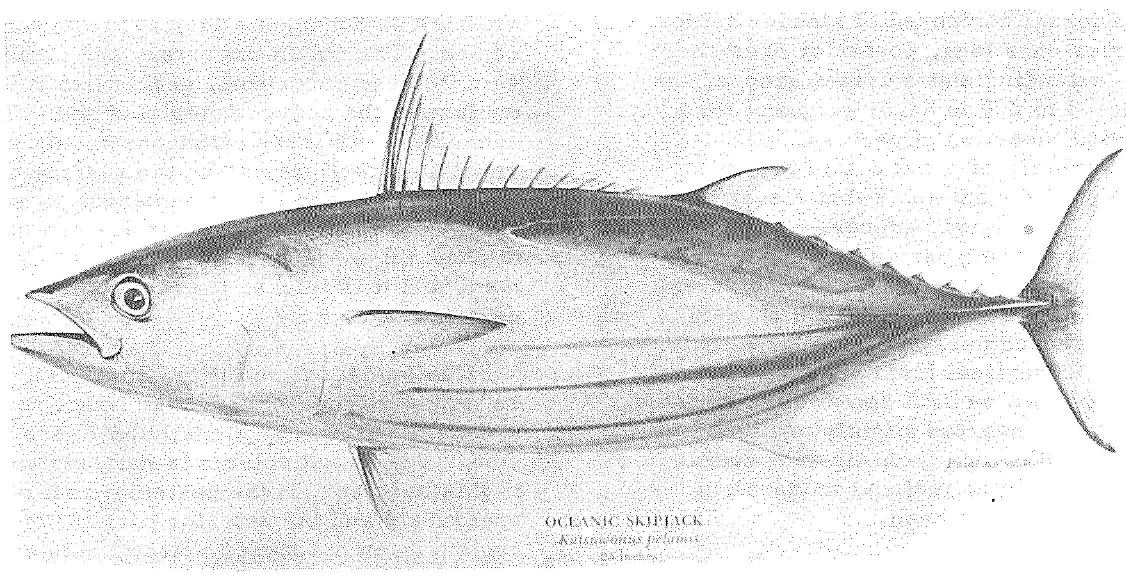

Fig. 1 Lateral view of an adult skipjack, Katsuwonus pelamis (Linnaeus) (from Walford, 1937)

of eye, 36 to 40 on lower and 15 or 16 (counted in only 3 specimens) on upper limb of first arch; lateral line missing anteriorly, curved downward at midlength, attaining a midlateral position under about the first dorsal finlet, straight from thence to caudal keel; scales present anteriorly in region of pectoral, extending on back to or beyond origin of first dorsal, reduced scales in lateral line, and a pointed area of scales extending about an eye's diameter beyond tip of pectoral fin; first dorsal composed of slender spines, the anterior ones long, posterior ones short, scarcely extending above dorsal groove, the first one 1.8 to 2.0 in head, origin of fin a little behind insertion of pectoral, its distance from tip of snout 2.6 to 2.9 in length; second dorsal somewhat elevated anteriorly, with deeply concave margin, the posterior rays being very short, its origin about equidistant from origin of first dorsal and base of next to last dorsal finlet; anal similar to second dorsal, its origin a little in advance of vertical from base of last ray of second dorsal; ventral somewhat shorter than pectoral, inserted slightly posterior to pectoral, its distance from tip of mandible 2.7 to 2.9 in length; pectoral moderately pointed, 1.9 to 2.1 in head.

"Color very dark blue above, with metallic reflections; silvery below; lower part of head, chest, and area around ventral fins dirty white; lower half of side with two to four dark longitudinal strips; spines of first dorsal dusky, anterior margin of first spine and membranes pale or white; second dorsal, dorsal and anal finlets, caudal, anal, and pectoral all more or less dusky; pectoral much darker on inner side than outside, the upper rays generally silvery; ventral fins white on outside, inner side dusky; inside of mouth largely dusky." (Hildebrand, 1946). In life, and in some preserved specimens, light vertical bars are evident along the sides.

Anatomical descriptions of the species and genus may be found in Kishinouye (1923), Godsil and Byers (1944), Schultz et al (1960).

Kishinouye (1923, p. 452) states, "The cutaneous circulatory system is unique. A pair of cutaneous arteries branch just behind the insertion of the pharyngeal muscles as in the tunnies and other bonitos; but passing through the kidneys the arteries turn outward and forward, instead of turning more or less backward as in the other plecostean fishes. Each artery reaching to the myotome of the first rib is divided into two arteries, epaxial and hypaxial. The epaxial artery runs below the first rib, while the hypaxial artery runs above the rib. These two arteries, are nearly equally developed, and are separated from each other at a distance of 6-8 times the breadth of the blood-vessels. These arteries do not form a loop at the caudal region. The cutaneous artery and cutaneous vein lie in juxtaposition, nearly flat at the surface of the body. Arterioles and venules connected with these cutaneous canals run in opposite directions, along the surface of the body and they are not so numerous as in the tunnies. The rod of the vascular plexus in the haemal canal is called kurochiai by fishermen, and it is thicker than the diameter of the vertebral column."

The spinal column (Fig. 2) differs sufficiently from that of other fishes to be worthy of comment. Godsil and Byers (1944) state "The spinal column is extremely complex in this species. In the posterior half of the precaudal, and the anterior part of the caudal region, haemopophyses arise at both ends of each vertebra, with the anterior haemopophyses of one vertebra articulating with the posterior haemopophyses of the preceding vertebra. These haemopophyses project far below the spinal column and alternate with the longer haemal spines described below. An osseous bridge roughly parallel with the spinal column unites the anterior and posterior haemopophyses of each vertebra. Viewing the spinal column laterally, the bridge and the circular opening it forms may be easily seen. A branch arises from each bridge and extends downward to unite in the median line with its fellow from the opposite side. This forms the haemal arch from the tip of which a single haemal spine continues ventralward. This complex basketwork occurs only in the skipjack."

The skipjack lacks an air bladder.

Some of the organs not mentioned by Godsil and Byers (1944) or not described in detail by Kishinouye (1923) have been described by other authors. Among these descriptions are those of Rivas (1953) and Rasquin (1958) concerning the pineal region; Uchihashi (1953) on the brain as related to ecology; Hanyu (1959) on certain structures of the eye; and Suyehiro (1941, 1942, 1950) on the pituitary body, the Islets of Langerhans, and the digestive system (it might be noted that this author erred in ascribing an air bladder to skipjack).

1.2 Nomenclature

1.2.1 Valid scientific name

Katsuwonus pelamis (Linnaeus, 1758) has been widely accepted as the scientific name of skipjack since it was first proposed in 1915 by Kishinouye, although at that time he used the spelling "*pelamys*". The present tendency appears to be towards replacing *Katsuwonus* with *Euthynnus*, retaining the specific name *pelamis*.

1.2.2 Other scientific names ascribed to this species

The following list of names, taken mainly from Rosa (1950), is arranged in alphabetical rather than chronological order. Each name is followed by one of the early authors to use the combination.

Euthynnus pelamis	Tanaka, 1912
Euthynnus (Katsuwonus) pelamis	Fraser-Brunner, 1950
Euthynnus pelamys	Jordan and Gilbert, 1882
Gymnosarda pelamis	Dresslar and Fesler, 1889
Gymnosarda pelamys	Barnard, 1925
Katsuwonis pelamis	Herre, 1933
Katsuwonus pelamis	Kishinouye, 1923
Katsuwonus pelamys	Kishinouye, 1915
Katsuwonus vagans	Jordan, Evermann, and Clark, 1930
Orcynus pelamis	Goode and Bean, 1879
Pelamys pelamys	Bleeker, 1865
Pelamys thynnus	Jenkins, 1925
Scomber pelamides	Lacépède, 1802
Scomber pelamis	Linnaeus, 1758
Scomber pelamys	Bloch and Schneider, 1801
Thynnus pelamis	Hoek, 1914
Thynnus pelamys	Cuvier and Valenciennes, 1831
Thynnus vagans	Lesson, 1830

1.2.3 Standard common names, vernacular names

The following list of common names and vernacular names, the latter in parentheses, and the countries in which they are used was taken from Rosa (1950). Other common names not included in the list, refer to skipjack of a particular size, or to aggregations of skipjack as opposed to individual fish.

1.3 General variability

1.3.1 Subspecific fragmentation (races, varieties, hybrids)

It is generally recognized that there is but one world-wide species of skipjack, which cannot be differentiated into subspecies. Working with Pacific specimens, Hennemuth (1959) stated that, "The statistical analysis indicates then, that the commercially available stocks of skipjack inhabiting the various fishing areas within the Eastern Pacific for which data are available represent semi-independent populations of fish, and the stocks of the Eastern and Central Pacific also appear to be at least semi-independent."

- Varieties

There are no records of varieties of skipjack.

- Meristic counts

Table II presents meristic counts listed in two publications.

1.3.2 Genetic data (chromosome number, protein specificity)

Little data concerning the genetics of skipjack exist in the literature, and what can be found are of recent origin. There are no data concerning the chromosome number of skipjack.

Considerable work is being done at present (1962) concerning the serological relations between skipjack from the same and from

COMMON NAMES OF SKIPJACK FOR PACIFIC COUNTRIES (FROM ROSA, 1950)

Australia	Striped tuna
Canada	Skipjack (Oceanic bonito)
Chile	Atún (Cachurreta, Cachureta, Cachorreta, Barrilete)
China	Tow chung (Chien)
Hawaiian Is.	Skipjack (Ocean bonito, Little tunny, Striped tuna, Aku, Aku kinau)
Indonesia	Bonito
Japan	Katuwo (Katsuwo, Katsuo, Magatsuwo, Mandagagatsuwo)
Mexico	Barrilete
New Guinea (Neth.)	Tjakalang
New Zealand	Bonito
Peru	Barrilete
Philippines	Skipjack (Striped tuna, Gulyasan, Pundahan, Bankulis, Oceanic bonito, Sobad, Bonito, Palawayan)
Polynesia (except Tahiti and Hawaii)	Atu
Tahiti	Auhopu
United States	Skipjack (Arctic bonito, Oceanic skipjack, Striped tuna, Watermelon, Victor fish, Striped bonito, Oceanic bonito, Skippy, Ocean bonito)

Table II

Meristic characters of skipjack from the Pacific

	Japan (Godsil and Byers, 1944)	Japan (Nakamura Res. Stf. 1949)	Hawaii (Godsil and Byers, 1944)	Eastern Pacific (Godsil and Byers, 1944)
1st Dorsal	15-16	14-17	15-16	15-16
2nd Dorsal	14-15	13-15	14-16	14-15
D. Finlets	8	8-10	7-8	7-8
Anal	14-15	13-15	15	14-16
Anal Finlets	7	6-9	7	6-8
Pectoral	-	24-32	-	-
Ventral	-	-	-	-
Gill Rakers	16-20+		19-20+	18-22+
Upper + Lower	36-41		37-42	35-43
Total		44-61		
Vertebrae	41		41	41

different locations. Most of this work is being done in the Pacific.

Cushing (1952) in one of his early studies of skipjack blood found that it contained an agglutinin specific for the human type B substance. Later he found (Cushing, 1956) that within a group of ten skipjack taken from one location near the Hawaiian Is. four different categories based on blood factors were discernible. Group one had a strong affinity for antibodies of rabbit antiserums prepared against the blood of yellowfin tuna, albacore, skipjack, and white croakers. Group two contained antigens with strong affinities for the "natural" antibodies of "normal" sera (human, bovine, sheep). Group three contained both of the above antigens, while group four contained neither.

Recently Sprague (1961) and Sprague and Nakashima (1961) reported finding differences in the agglutination by phytoagglutinins of blood of skipjack from different localities in the Pacific. They used saline extracts of the seeds from various legumes to define four blood factors which were named A-positive, D-positive, Be, and Bf, which could be detected by extracts of seeds of Glycine max, Phaseolus vulgaris, Virgilia divaricata, and Caragana arborescens respectively. Working with reagents which detect A-positive, C-positive, and Be-positive bloods it was possible to differentiate between groups of skipjack from Rangiroa, from the Marquesas Is., and from the Hawaii-Johnston-Christmas Is. area.

Schaefer (1961a) reported the discovery of possibly two blood-type systems among skipjack from the eastern Pacific through the use of a battery of phytohemagglutinins. He expressed the belief that at least one of the systems would be suitable for the study of skipjack populations within the area of the eastern Pacific fishery.

Matsumoto (1960) reported on the differentiation of tuna species by means of paper chromatography and found that skipjack could be separated from yellowfin, bigeye, albacore, and two species of frigate mackerel on the basis of two-dimensional chromatograms. Fig. 3 shows the two-dimensional chromatograms for adult and larval skipjack from central Pacific waters.

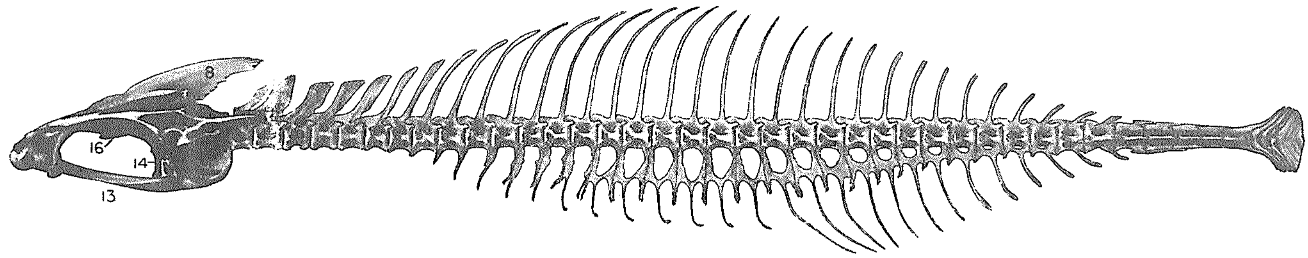

Fig. 2 Cranium and spinal column of an adult skipjack (after Godsil and Byers, 1944)

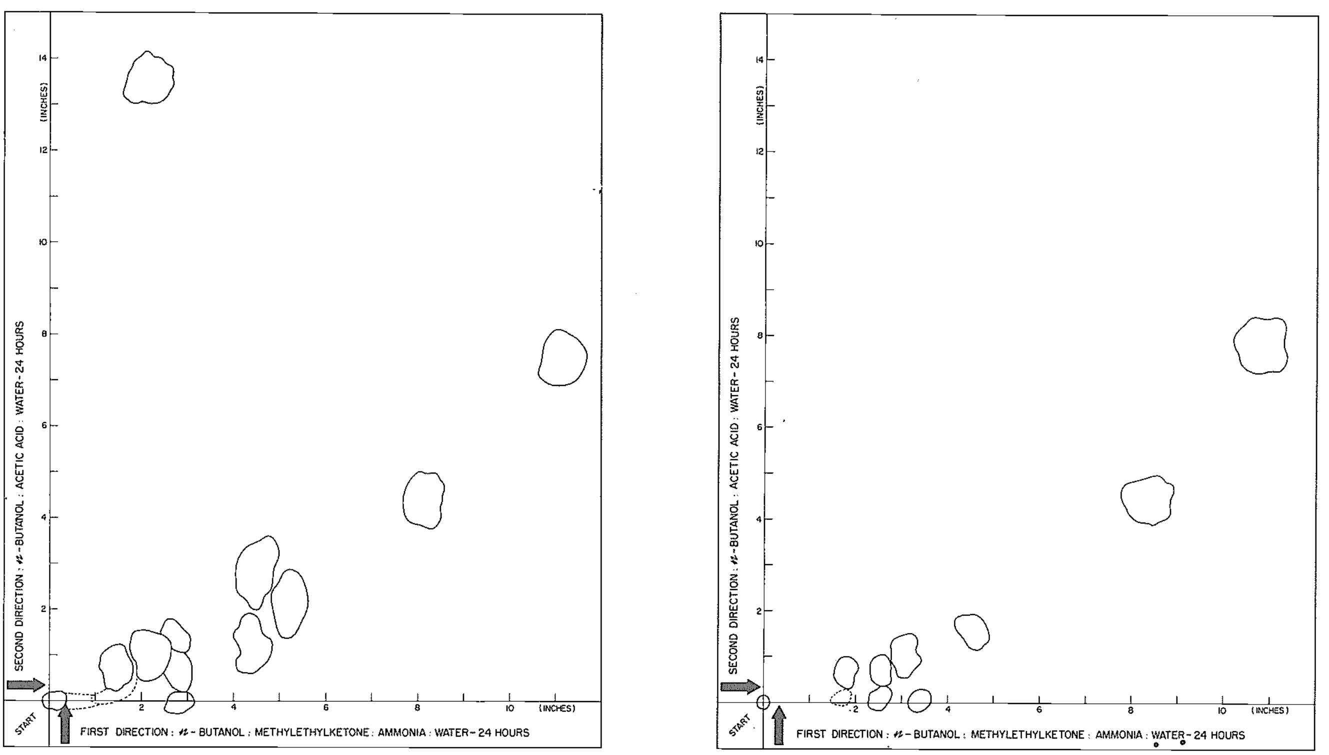

Fig. 3 Two dimensional chromatograms for adult (left panel) and larval skipjack (right panel)(from Matsumoto, 1960)

2 DISTRIBUTION

2.1 Delimitation of the total area of distribution and ecological characterization of this area (Fig. 4)

Rosa (1950) gives the following distribution for skipjack in the Pacific Ocean.

"South Pacific Ocean - Coast of Ecuador including Galapagos Is., off the coast of Peru approaching it during certain periods of the year in certain areas, coast of Chile as far south as Valparaiso, coast of Australia from New Guinea to St. Helens in northeast Tasmania, coast of New Zealand.

"North Pacific Ocean - Seldom found on the coast of Canada on Vancouver Is., and on the coast of the United States north of Point Conception in California, common from this point to Mexico, entire coast of Mexico, including the Gulf of California, entire coast of Central America; Marshall, Caroline, and Palau Is., Philippines, Formosa Is., Ryukyu Is., Pacific coast of Japan as far north as off the south coast of Hokkaido, Kurile Is., Bonin and Marianas Is., occasionally found in the Japan Sea as far as the coast of U.S.S.R. during the summer."

Skipjack are also taken throughout the general Pacific areas of Polynesia including Hawaii, Melanesia, and Micronesia. In the mid-North Pacific skipjack have been taken as far north as latitude 43° N.

The area described above and shown in Fig. 4 is characterized in general by temperatures at the surface of 15° C or greater and lies roughly between latitudes 40° N and 40° S. Where skipjack are found outside these limits may indicate the presence of a tongue of warmer water.

Blackburn (1961) has pointed out that skipjack may avoid areas with temperatures above 28° C.

- Vertical distribution

While no direct evidence is available it is generally considered that skipjack inhabit only the upper one or two hundred meters of the surface waters.

2.2 Differential distribution

2.2.1 Areas occupied by eggs, larvae, and other young 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

The distribution of skipjack eggs has not been described, because it has not been possible to differentiate skipjack eggs from those of other tunas.

- Yolk sac stage

This developmental stage is so rare in collections that it is not possible to define the distribution. With the possible exception of the vertical distribution, it is probably found in the same areas as the non-yolk sac stages.

- Larval stages

Larval skipjack have been found in all the major oceans of the world. In the Pacific, Kishinouye (1926) collected larvae from the Ryukyu Is. area, and Yabe (1955) reported on larvae collected in the waters of the Caroline and Marianas Is. as well as from the Ryukyu Is. Matsumoto (1958) and Strasburg (1960) reported on larvae collected in the central Pacific, both north and south of the Equator, Wade (1950) reported on older larvae from Philippine waters, Schaefer and Marr (1948) reported the capture of large larvae from the Marshall Is., and Schaefer (1960) reported the capture of larvae and juveniles in the eastern Pacific.

Skipjack larvae have been taken within 600 feet (= ca. 185 m) of shore in the Hawaiian Is. (Strasburg, 1960), as well as in the open ocean far from land.

The north-south distribution of larvae appears to be somewhat more restricted than does that of the adults. Matsumoto (1958) reported the capture of larvae to latitude 25° N, and Strasburg (1960) records

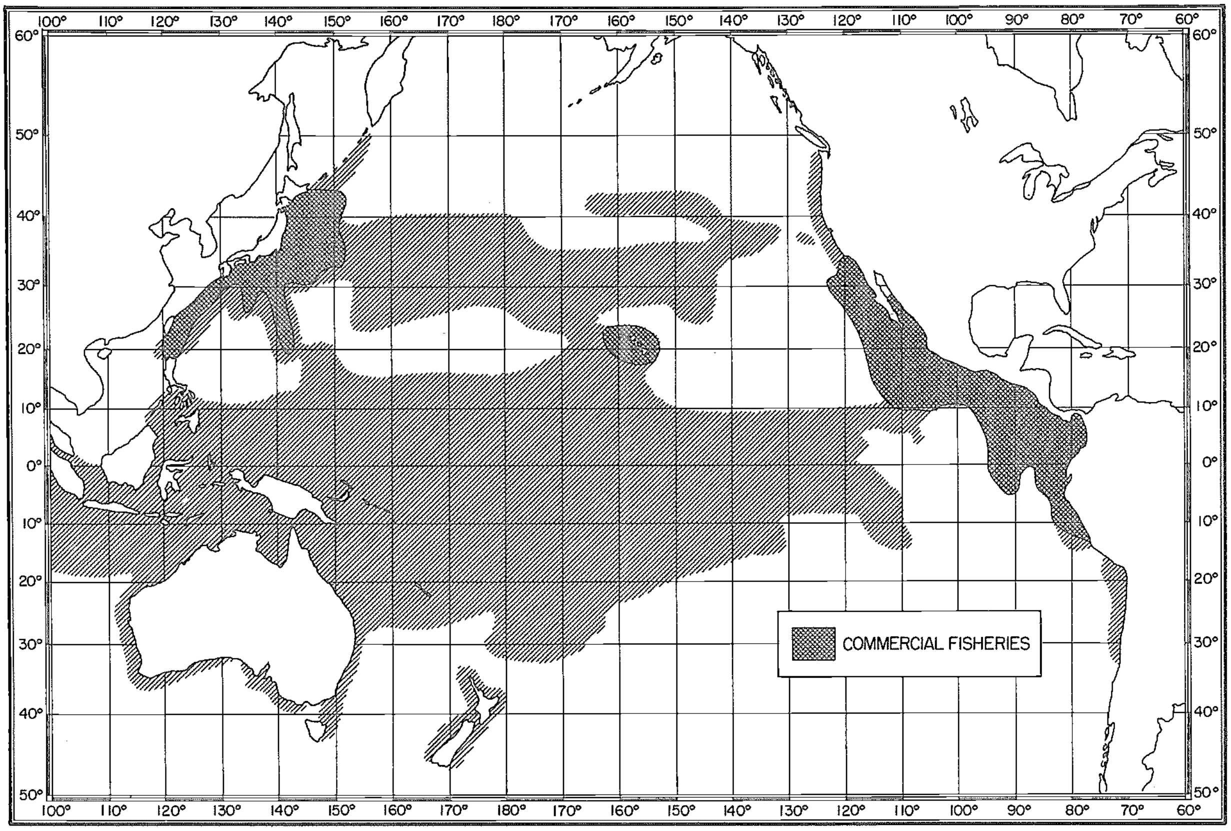

Fig. 4 Distribution of adult skipjack in the Pacific Ocean, and location of the commercial fisheries in the western, central, and eastern Pacific (Brock, 1959)

larvae to latitude 18° S in the mid-Pacific. However, this was also the limit of sampling, and so may represent an artifact of sampling rather than the limit of distribution of the larvae. In the western Pacific Yabe (1955) reported skipjack larvae from about latitude 33° N, and Brock (1959) shows larvae occurring off the Australian east coast at about latitude 33° S. Fig. 5 shows locations in the Pacific from which larvae have been collected.

With respect to vertical distribution, Strasburg (1960) has shown that in the Pacific, larval skipjack (specimens less than 15 mm length) are very rarely taken below 140 m depth. He further stated that 15° C appeared to be a limiting temperature, and in the one exception, when larvae were collected below 140 m, a tongue of warm water extended below this depth.

- Juveniles

By the time the young reach a length of about 20 mm they have acquired many of the adult characteristics, although the body form is somewhat different. They may be considered juveniles until they have acquired the coloration and body form of the adult, this occurring at a length of about 200 to 250 mm.

Juvenile skipjack have been reported from much the same locations as have the larvae and the adults. Up to a length of about 45 mm they have been collected under night lights with dip nets. Above that size most of the specimens collected have come from the stomachs of larger fish, mainly other tunas and spearfishes.

Most of the published records are from the Pacific area, and Table III lists collections of juvenile skipjack up to 1951. Chapman (1946) reported schools of "8-10 inch skipjack" in the Solomons Is. area, and skipjack of less than 250-mm size have been observed in Hawaiian waters.

Table III

Records of the capture of juvenile skipjack (Shimada, 1951)

Author and date of publication	Locality of capture or Latitude Longitude	Length of specimens in mm	Number of specimens	Date of capture
Kishinouye, 1923	Ryukyu Is. (Okinawa)	210	1	Aug. 1916
Kishinouye, 1924	do.	105, 125	2	July 1923
Do.	do.	120, 153	2	June 1924
Do.	28°10' N 129°15' E	58	1	May 1924
Do.	29°51' N 129°52' E	60, 80	2	May 1924
Do.	29°47' N 129°25' E	63, 83, 85	3	May 1924
Kishinouye, 1926	29°47' N 129°25' E	26	1	April 1924
Do.	Ryukyu Is. (Okinawa)	210	1	Aug. 1923
Do.	do.	100-140	3	June 1924
Inanami, 1942	Truk Is.	198	1	April 1939
Do.	do.	45	1	May 1940
Schaefer and Marr, 1948	9°22.5' N 85°47.5' W	21	1	Jan. 1947
Do.	9°10' N 85°20' W	44	1	Mar. 1947
Marr, 1948	Bikini Atoll	45, 50	2	July 1947
Wade, 1950	6°37.2' N 121°31' E	13-27	6	July 1948
Eckles, 1949	20°30' N 158°45' W.	113-118	6	July 1948
Do.	19°33' N 156°00' W	183	1	Sept. 1948
Shimada, 1951	3°50.5' S 171°48.5' W	35, 48	2	July 1950
Do.	4°30' S 172°11' W	20, 22, 36	3	Aug. 1950

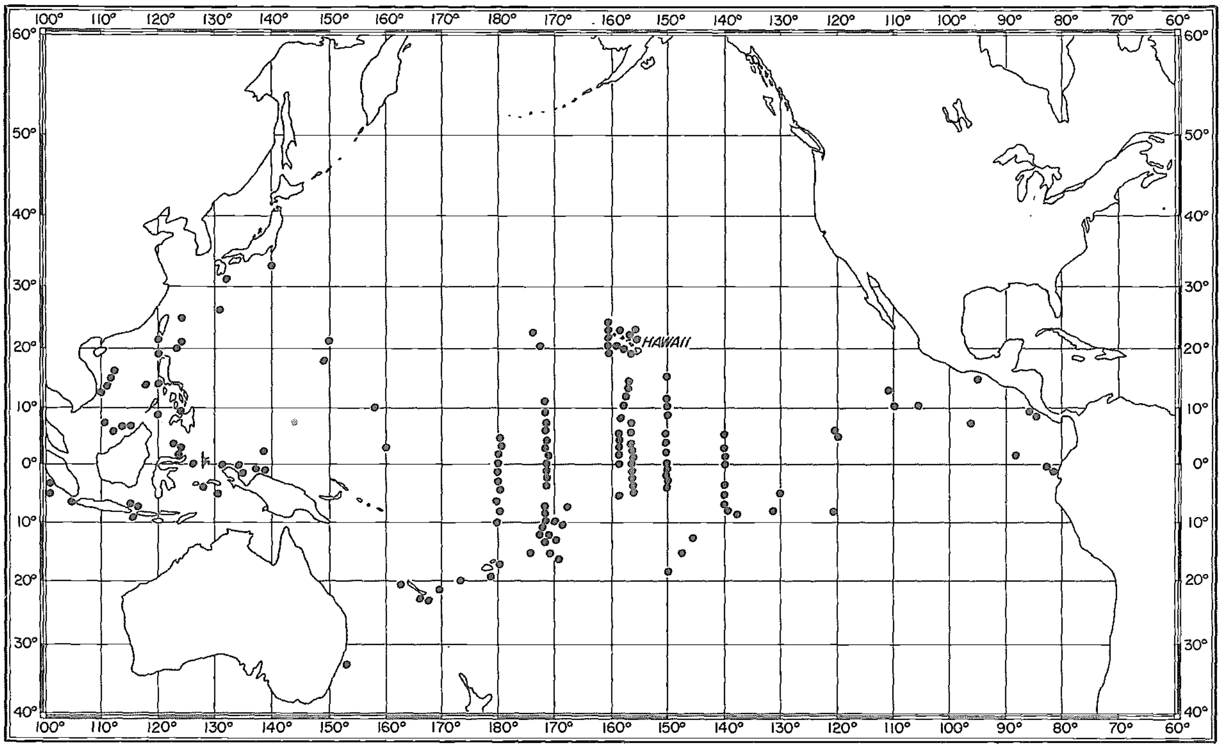

Fig. 5 Distribution of larval skipjack in the Pacific Ocean (Brock, 1959; Yabe, 1955; Schaefer, 1960)

With the exception of the eastern Pacific specimens (Schaefer and Marr, 1948) all of the juveniles were collected between April and September. The eastern Pacific specimens were collected in January and March. Suda (1953) reported young skipjack most numerous in stomachs of large predators during June and August in the Bonin-Minamitorishima area south of Japan.

- Adults

At about 220 mm skipjack begin to be taken in commercial fisheries and may be considered as sexually immature sub-adults.

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.1.1 Sexuality (hermaphroditism, heterosexuality, intersexuality)

The skipjack is normally heterosexual. There are a few recorded instances of hermaphroditism (Nakamura, 1935; Uchida, 1961). It is not known if these examples were functional hermaphrodites. In a specimen received at the Biological Laboratory, Honolulu, and described by Uchida (1961) the ovarian section contained ripe and resorbing ova, but the testicular portion showed no evidence of running milt.

3.1.2 Maturity (age and size)

There is no definite information concerning the age at which skipjack mature, and this can be attributed to differences of opinion as to the age of skipjack in general. Brock (1954) used length frequencies occurring in commercial landings to age fish and with respect to maturity stated, "It therefore appears likely, considering also the information on age and rate of growth, that aku may mature at 1 year." Yabe (1954), following the aging method developed by Aikawa and Kato (1938), stated with respect to maturity that, "Providing that these represent the smallest mature fish, both male and female were age IV fish, according to the age determination of Dr. Aikawa." Ripe males 391 mm and spawned out females 407 mm in length have been reported by Marr (1948) from the Marshall Is. area. In Hawaiian waters Brock (1954) reported a ripe female 432 mm in length, and he also stated that the smallest fish with maturing ovaries were between 40 and 45 cm in length. Yabe (1954) reported the smallest skipjack with mature eggs measured 46.8 cm. Wade (1950) reported a ripe female only 340 mm in length from Philippine waters, although most of the ripe females which he reported were above 400 mm in length.

3.1.3 Mating (monogamous, polygamous, promiscuous)

No information is available as to the mating behavior of skipjack. In view of their known schooling behavior it is reasonable to assume that mating is promiscuous.

3.1.4 Fertilization (internal, external)

There are no publications describing fertilization of skipjack eggs, but since males lack any intromittent organ fertilization is probably external.

3.1.5 Fecundity

- Relation of gonad size and egg number to body size and to age

Yabe (1954) found considerable variation in the number of eggs in skipjack of similar and different sizes. Table IV is modified from his table 6.

As can be seen from the table, skipjack differing in weight by only 0.7 kg may differ by over 700,000 in the number of ova (specimens 1 and 2). Both these fish were presumably the same age, either age group IV according to Aikawa and Kato (1938) or 1-year-olds according to Brock (1954).

Yoshida (MS) made ova counts on four skipjack from the Marquesas Is. area and found the ripening eggs numbered 0.1 million in a 43-cm and 2.0 million in a 75-cm skipjack.

Table IV

Estimated numbers of maturing ova in skipjack of different size

Fish		Ovaries		Total number of eggs
Length (cm)	Weight (kg)	Weight (gm)	Maturity	
46.8	2.55	106.5	mature	113,364
49.5	3.2	227	mature	856,180
54.5	4.5	119	immature	565,131
56.2	5.25	250	mature	609,730
61.0	5.96	148.9	immature	859,897

3.1.6 Spawning

- Spawning seasons (beginning, end, peak)

The literature contains a number of references to spawning seasons, most of which are based on the presence of young in collections or on the stage of gonad maturity in the adult fish. Table V lists some of the more recent estimates of spawning seasons, and the basis of the estimate, in the Pacific. It appears that in equatorial waters spawning occurs throughout the year, although there may be identifiable peak periods. At increasing distances from the Equator the season becomes progressively shorter and occurs during the summer months.

The presence of larval skipjack in plankton collections probably provides a more precise estimate of spawning seasons than does the presence of mature ovaries in the adults. Brock (1954), on the basis of gonad condition, placed the spawning season in Hawaiian waters between February and September, while Sherman and Brown (MS), working with larval collections from Hawaiian waters, have hypothesized that spawning activity peaks sharply in late spring and early summer, i.e., May to July.

Yabe (1954) states that in the western Pacific skipjack above 50 cm length show the greatest gonad development between May and June, while the smaller skipjack under 45 cm length show the greatest gonad development during June to August.

- Number of spawnings per year, frequency

There is no direct evidence as to the number of spawnings per year. Brock (1954) and Yoshida (MS) have hypothesized, on the basis of multiple modes in ova diameter frequency distributions that there is multiple spawning

- Spawning time of day

No information available nor does the literature contain any hypotheses concerning this aspect of spawning.

3.1.7 Spawning grounds

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

No direct evidence exists as to the localized distribution of spawning. Larvae have been found in very close proximity to land, e.g. Strasburg (1960) reported larvae in Hawaiian waters collected within a few hundred yards of shore. However, spawning could have taken place at some distance offshore and the larvae have been carried inshore by currents.

Table V

Skipjack spawning periods in the Pacific Ocean

Area	Author	Spawning period	Evidence[1/]
Central America	Schaefer and Marr, 1948	January - March	Gonad; juveniles
Central America	Schaefer and Orange, 1956	December - March	Gonadal
Revillagigedos	Schaefer and Orange, 1956	Summer and Fall [2/]	Gonadal
Hawaiian waters	Brock, 1954	February - September	Gonadal
Hawaiian waters	Sherman and Brown (MS)	May - July	Larvae
Central Equatorial Pac.	Matsumoto, 1958	All months except April and December	Larvae
Marquesas-Society Is.	Yoshida (MS)	November to April	Gonadal and larvae
Marshall Is.	Marr, 1948	April to August	Gonadal and juveniles
Philippine waters	Wade, 1951	All year with peak September to April	Larvae
Japanese waters	Yao, 1955	June - August	Gonadal
Japanese waters	Yabe, 1954	May to August	Gonadal

1/ Evidence: Gonadal = Presence of ripe or maturing ovaries in adults observed.
Juveniles = Juveniles collected.
Larvae = Larvae collected.

2/ Near the Revillagigedos summer and fall would be from July to December approximately.

- Oceanic (surface, bottom)

Again there is no direct evidence as to the exact location of spawning, but most of the larvae collected have been taken in plankton tows made at some distance from land. Because most of the larvae have been collected from the upper 200 m of the ocean (Strasburg, 1960) it might be assumed that spawning takes place no deeper than this. Further, fishermen have reported sighting spawning fish near the surface, however, the spawning activity was deduced from the behavior of the fish rather than from an actual observation of the spawning act.

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

Yoshida (MS) gives the following description of the ovarian eggs of skipjack: "Four rather distinct developmental stages were recognized and designated as 'early developing,' 'developing,' 'advanced', and 'ripe'. The early developing category includes ova which in the most primitive stage appear as simple transparent cells. The larger ova in this stage contain a relatively large nucleus. The mean diameter ranged from 0.16 to 0.33 mm. Ova in this category are present in all ovaries. The developing ova are completely opaque owing to the deposition of yolk granules. The mean diameter of these ova ranged from 0.37 mm to 0.66 mm. The advanced stage includes ova ranging in appearance from those which were still relatively opaque and containing a cluster of small oil droplets, to those which were semi-transparent and containing a well-developed, bright yellow oil globule. The mean diameter of these ova ranged from 0.49 mm to 0.74 mm." Yoshida goes on to describe the running ripe eggs of skipjack as, "They were almost perfectly spherical and transparent, with a distinct straw-colored oil globule. Fifty were measured. They ranged in diameter from 0.85 mm to 1.12 mm with a mean diameter of 0.96 mm. The oil globule measured about 0.14 mm in diameter."

Brock (1954) described running ripe skipjack ova as averaging 1.125 mm in diameter, spherical to slightly oval, with a single oil globule which was between 0.22 and 0.45 mm in diameter. Yabe (1954) gave the size of running ripe ova as 0.80 to 1.17 mm diameter (average 1.00 mm), with a single oil globule measuring 0.22 to 0.27 mm in diameter (average 0.23 mm).

No information is available concerning the embryonic development, hatching type, parasites, or predators of the skipjack egg.

3.2 Larval history

3.2.1 Account of embryonic and juvenile life (prelarva, larva, post larva, juvenile) (Fig. 6)

Accounts of the embryonic development of skipjack are lacking from the literature. The first distinguishable skipjack are in the post-yolk-sac stage at a length of about 3 mm (Kishinouye, 1926). Considering that the ripe ovarian egg is about 1.0 mm in diameter, the skipjack larvae must approach 3.0 mm in length at hatching. As Kishinouye himself points out, these 3.00 mm larvae must have been hatched very recently. The first specimens which Kishinouye (1926) identified positively as skipjack were 4 mm in length. He described this specimen as follows: "The head is greatly developed and about 10 large sharp teeth appear on each side of both jaws. The vomerine teeth are not yet developed. There are two spines on the surface of the preopercle and five or six spines on its edge. The spines on the posterior edge are long and stout, with the one at the angle being the longest. There is only a shallow round depression at the location of the nasal cavity. The distribution of melanophores is roughly the same as in the specimens described above /Note: these refer to the 3 mm specimens/, but one notable difference is the presence of a large melanophore slightly anterior and ventral to the caudal peduncle. There are also many melanophores around the anterior end of the spinal cord, and the tip of the mandible is blackish. The posterior end of the spinal cord is perfectly straight. It is difficult to tell the number of myotomes because they are not yet fully developed at the posterior end of the body, but there appear to be forty-one of them."

Wade (1951), Yabe (1955), and Matsumoto (1958) provide descriptions of larval skipjack less than 15 mm in length collected from the Pacific area. Two characteristics which appear in all of the descriptions are the large size of the head, and the presence on the mid-ventral portion of the caudal peduncle of a melanophore or group of melanophores. These two characteristics, together with the presence of 41 myomeres, appear to distinguish skipjack larvae of about 4 to 5 mm length. Matsumoto (1958) gives the following distinguishing characteristics of skipjack larvae between 3.7 and 14.5 mm in length (Table VI).

Kishinouye (1926), Marr (1948), Schaefer and Marr (1948), Wade (1950, 1951), and Shimada (1951) describe the juvenile skipjack, generally those above 15 mm in length. The most reliable characteristic used in identifying specimens above this size appears to be the presence of 41 vertebrae and the complex trellis or basket-work formed by the haemal arches. In stained specimens these are visible in juveniles as small as 27 mm length (Wade, 1950), although the haemal arches are not completely closed.

Preopercular spines, which have been used in describing the larvae become buried in bone by the time juveniles reach 40 mm (Schaefer and Marr, 1948), while the palatine teeth do not become overgrown until about 60-75 mm length (Kishinouye, 1926). The adult fin ray-and-spine complement is attained at a length of only 15 mm, except for the pectoral in which rays continue to develop until about 30 mm length is reached. The trellis formed by the haemal arches is fully developed at about 27 mm, and the vertebrae are fully ossified at a length of 10.9 mm (Matsumoto, 1958). Certain characteristics of juvenile skipjack are listed in Table VII.

- Feeding

Little is known regarding the food of larval and juvenile skipjack. Hotta and Ogawa (1955) found that the stomachs of juveniles which had been consumed by adults contained fish and crustaceans, with a higher proportion of copepods than had been found in adult stomachs. Yuen (1959) found that among the smaller adults the diet consisted of a larger proportion of Crustacea and molluscs than that of the larger adults. Nakamura (MS) found that the stomachs of juvenile skipjack contained mysiids, euphausiids, amphipods, megalops larvae, copepods, squid and fish.

3.3. Adult history

3.3.1 Longevity

No direct evidence exists concerning the greatest age attained by skpjack. Brock (1954), on the basis of modal groups in the Hawaiian skipjackcatch, hypothesized that the largest group (fork length about 75 to 85 cm) was composed of skipjack in their 4th year. If his estimate of the age at which the fish entered the fishery was in error by 1 year, which he stated was possible, the largest group would be in their 5th year. Aikawa and Kato (1938) used the growth rings on vertebrae to estimate the age of skipjack from Japanese waters. They estimated skipjack of the 72 to 80 cm length group to be 7th-year fish, or in age group VI. Recent tagging studies indicate that the growth deduced by Brock (1954) is more nearly correct than that estimated by Aikawa and Kato (1938). Skipjack larger than those found generally in the Hawaiian fishery are known to occur, and presumably these fish have also attained a greater age.

3.3.2 Hardiness

The literature contains no references to the hardiness of skipjack living in the normal range of their environment. Under abnormal conditions such as when fish are caught, either in nets or by hook-and-line, skipjack are thought to die quicker than some of the other tunas, such as albacore and yellowfin.

3.3.3 Competitors

In the commercial and experimental fisheries of the Pacific the following fish have been observed in or taken from feeding aggregations of skipjack, and should probably be considered competitors for food:

Whale Shark (Rhineodon typus)	(Gudger, 1941)
Yellowfin Tuna (Neothunnus macropterus)	(Broadhead & Orange, 1960)
Little Tunny (Euthynnus yaito)	(Data files, BLH)
Frigate Mackerel (Auxis sp.)	(Data files, BLH)
Albacore (Thunnus germo)	(Data files, BLH)
Dolphin (Coryphaena hippurus)	(Data files, BLH)
Rainbow Runner (Elagatis bipinnulatus)	(U.S. Fish and Wildlife Service, 1961)

These are the adult fishes known to compete with skipjack. In addition sea birds may be considered competitors, for both birds and skipjack feed on the same aggregations of forage organisms at the sea surface.

The literature contains no mention of small fish which may compete with juvenile skipjack.

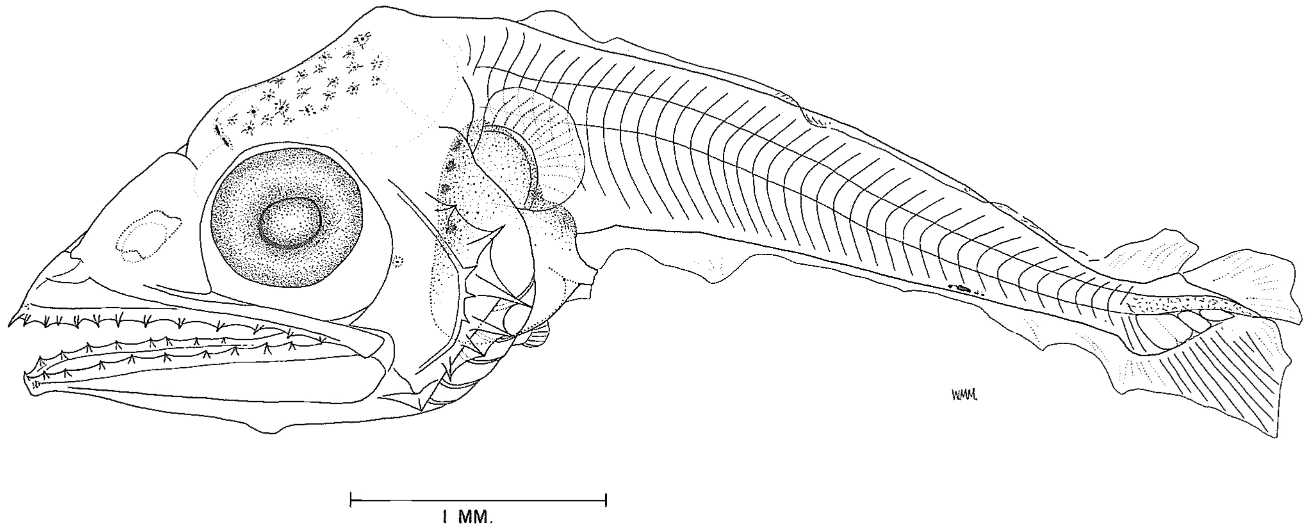

Fig. 6a Lateral view of larval skipjack, 5.35 mm length (from Matsumoto, 1958)

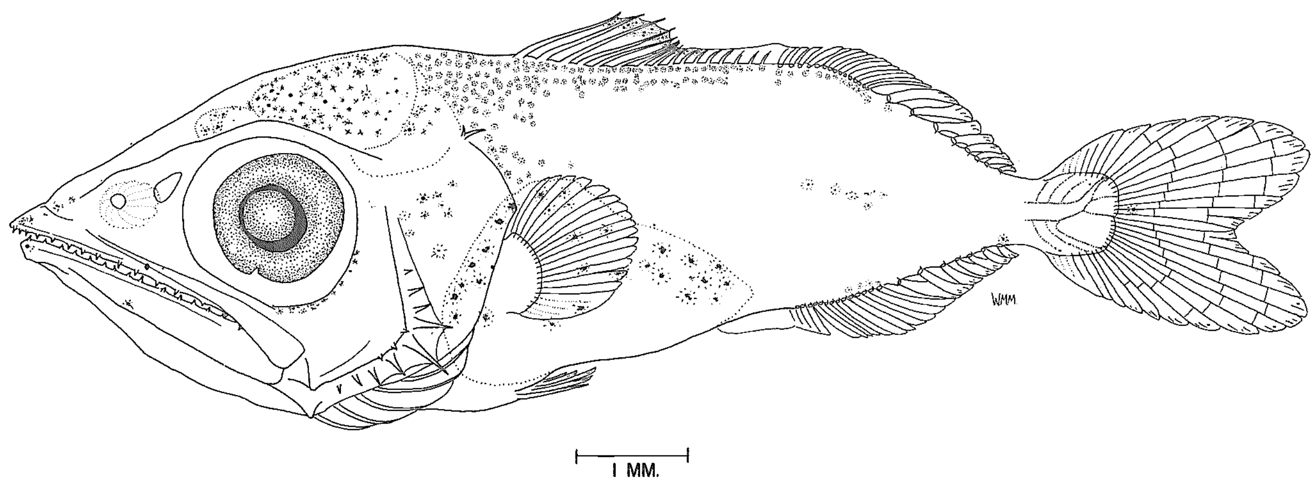

Fig. 6b Lateral view of larval skipjack, 10.9 mm length (from Matsumoto, 1958)

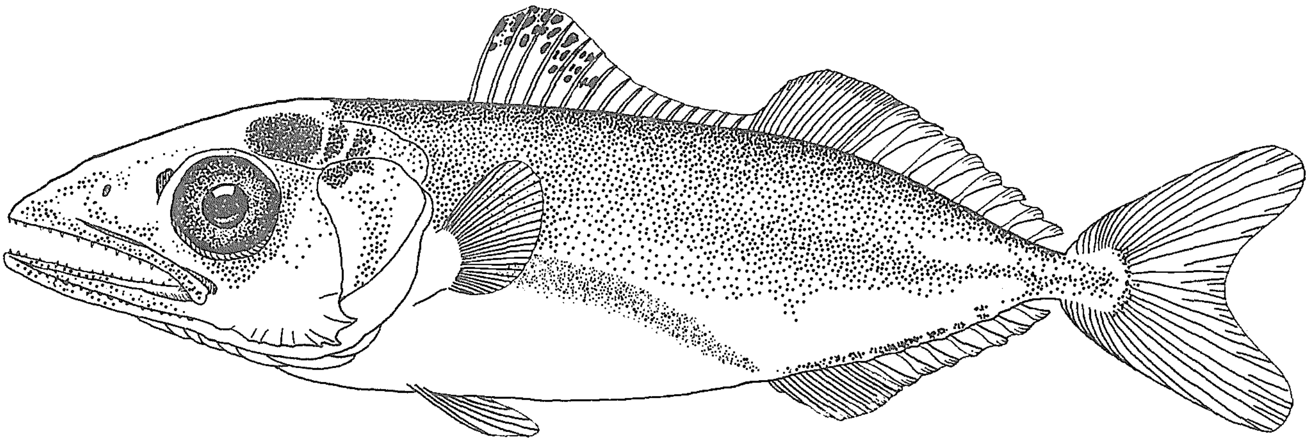

Fig. 6c Lateral view of juvenile skipjack, 21 mm length (from Schaefer and Marr, 1948)

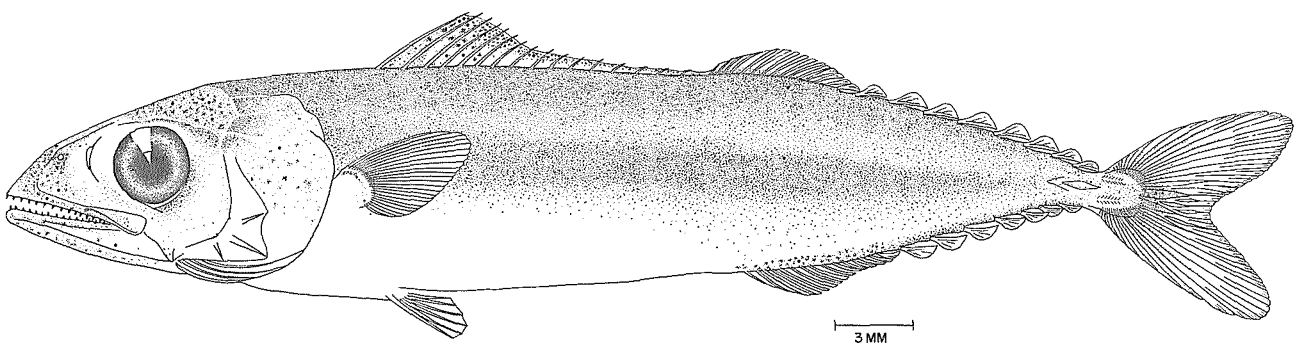

Fig. 6d Lateral view of juvenile skipjack, 47 mm length (from Matsumoto, in press)

Table VI
Summary of the more prominent diagnostic characters of skipjack larvae at various sizes (after Matsumoto, 1958, table 5)

Characters	Length (mm) 3.7	5.35	7.1	8.75	10.9	14.5
Teeth (1 side)	4 upper; 6 lower	13 upper; 11 lower	15 each jaw	16-18 each jaw	15 each jaw	15 upper; 17 lower
Preopercular spines	3	6	7	7	9	8
Myomeres	incomplete	41 or 42	41	41-42	-	-
Vertebrae	-	-	-	-	20+21 (on a 9.85 mm. specimen)	20+21
1st dorsal spines	-	-	8; longest spine < 1/3 dorsal interspace[1/]	8 or 9	13; longest spine < 1/2 dorsal interspace[1/]	16; longest spine = 1/2 dorsal interspace[1/]
1st dorsal fin outline	-	-	-	-	concave	concave
Pigmentation[2/] 1st dorsal fin	-	-	1 chrom.[2/]	6 chrom. on outer fin edge	chrom. on outer edge to 12th spine	6 or 7 chrom. on outer edge of fin
Middorsal line	no chrom.	no chrom.	no chrom.	6-8 chrom. at base of 1st dorsal; 1 at origin of 2nd dorsal	chrom. to 1st finlet	Band of chrom. to 5th finlet
Midlateral line	no chrom.	no chrom.	no chrom.	no chrom.	6 chrom. forward of caudal peduncle	Band of chrom. from 2nd to 5th finlet
Midventral line	1 chrom. on caudal peduncle	1 chrom. on caudal peduncle	1 chrom. on caudal peduncle	3 chrom. at base of anal; 1 on caudal peduncle	4 chrom. at bases of anal and finlets; 1 on caudal peduncle	Band of chrom. at bases of anal and finlets; 1 on caudal peduncle
Tip of pectoral girdle	no chrom.	no chrom.	no chrom.	no chrom.	no chrom.	no chrom.
Anal opening	no chrom.	no chrom.	no chrom.	no chrom.	no chrom.	no chrom.
Midbrain	10 chrom. over large area	24 chrom. over large area	50 chrom. over large area	45+ chrom. over wide area	80 chrom. over large area	numerous chrom. over large area
Forebrain	no chrom.	no chrom.	2 chrom.	2-3 chrom.	4 chrom.	12 chrom.

Table VI

Summary of the more prominent diagnostic characters of skipjack larvae at various sizes (after Matsumoto, 1950, table 5) (con.)

Characters	Length (mm) 3.7	5.35	7.1	8.75	10.9	14.5
Mandible (other than at tip)	no chrom.	no chrom.	1 chrom. 1/4 distance from tip	1 chrom. 1/2 distance from tip	1 chrom.	chrom. on 2/3 of length

1/ distance between insertions of 1st and 2nd dorsal fins
2/ chrom. = chromatophores

Table VII
Some characters of larval and juvenile skipjack

Author	Specimen length mm	Preopercle edge	Spines surface	Teeth: Each jaw	Teeth: Palatine	Fin rays and spines: 1st D.	Fin rays and spines: 2nd D.	Fin rays and spines: D. finlets	Fin rays and spines: Anal	A. finlets	Caudal	Pelvic	Pectoral	Gill rakers	Haemal trellis
Kishinouye (1926)	60-75	-	-	-	⩾ 10	-	-	-	-	-	-	-	-	-	-
Schaefer and Marr (1948)	21	2 or 3	-	-	Pres.	-	-	-	-	-	-	-	-	-	-
	44	0	-	-	-	XVI	15	8	15	7	-	-	26	8 + 33	-
Marr (1948)	45	-	-	-	Pres.									6 + 32	-
	50	-	-	-	Pres.									6 + 32	-
Wade (1950)	13-27	9	-	upper - 21 lower - 26	8	XVI	15	7 or 8	14 or 15	7	-	-	-	-	-
Wade (1951)	5	6	3	8	-	-	-	-	-	-	-	-	-	-	-
	7	6	3	10-12		9	11	5	10	5	-	-	-	-	-
	9	8	3	16-18	Pres.	14	15	8	13	7	-	-	-	-	-
Shimada (1951)	35	1	-	-	-	XVI	14	8	15	7	-	6	27	-	-
Matsumoto (1958)	3.7	3	2	upper - 4 lower - 6	-	no fin rays			-	-	-	-	-	-	-
	5.35	6	3	upper - 13 lower - 11	-	-	-	-	-	-	-	-	-	-	-
	6.7	6	3	-	-	IV	-	-	-	-	18	-	-	-	-
	7.1	7	3	-	-	VIII	Pres.	Pres.	-		12 + 11	-	-	-	-
	8.75	7	3	16-18	5	VIII-IX	10	6-7	10	6-7	-	I + 5	striations	-	-
	10.9	9	3	-	-	XIII	15	8	14	7	16 + 16	I + 5	-	-	-
	14.5	-	-	upper - 15 lower - 17	6	XVI	15	8	-		22 + 22	-	20	-	not developed
	20	-	-	-	-	XVI	15	8	15	7	22 + 22	-	20-21	-	13th-22nd vert. partially closed
	27	-	-	-	-	-	-	-	-	-	-	-	-	-	14th-33rd closed
Comments		Disappear at about 40 mm			Not present in specimens > 50 mm	All spines and rays present at 15 mm.						All spines and rays present at 9 mm	All rays present at about 40 mm		Trellis well-formed at 27 mm

3.3.4 Predators

The literature contains references to the following animals as predators on either juvenile or adult skipjack:

Katsuwonus pelamis	Eckles 1949, Marr 1948
Neothunnus macropterus	Kishinouye 1924, Reintjes and King 1953, Koga 1958
Thunnus germo	Koga 1958
Parathunnus sibi	Koga 1958
Istiompax marlina	Royce 1957
Makaira ampla	Royce 1957, Koga 1958
Makaira audax	Royce 1957
Makaira mazara	Shimada 1951
Istiophorus orientalis	Shimada 1951
Cybium chinense	Imamura 1949
Alopias (sp.)	Strasburg 1958
Acanthocybium solandri	Iversen and Yoshida 1957
Gempylidae	Nakamura (MS)

3.3.5 Parasites

The skipjack is listed by various authors as host for the following parasites:

Cestoda

Tentacularia coryphaenae (Bosc 1802)	Yamaguti 1934
Callotetrarhynchus speciosus (Linton 1897)	Yamaguti 1952
Pelichnibothrium (larva)	Yamaguti 1934
Rhyncobothrium	Kishinouye 1923

Trematoda

Dinurus thynni Yamaguti 1934	Yamaguti 1953
Syncoelium katuwo Yamaguti 1938	Yamaguti 1953
Didymozoon filicolle Ishii 1935	Yamaguti 1953
Didymozoon longicolle Ishii 1935	Yamaguti 1953
Didymozoon minor Yamaguti 1934	Yamaguti 1953
Didymozoon auxis Taschenberg 1879	Dawes 1947
Didymocystis abdominalis Yamaguti 1938	Yamaguti 1953
Didymocystis bilobata Ishii 1935	Yamaguti 1953
Didymocystis dissimilis Yamaguti 1938	Yamaguti 1953
Didymocystis ovata Ishii 1935	Yamaguti 1953
Didymocystis simplex Ishii 1935	Yamaguti 1953
Didymocystis soleiformes Ishii 1935	Yamaguti 1953
Didymocystis submentalis Yamaguti 1938	Yamaguti 1953
Didymocystis wedli Ariola 1902	Yamaguti 1953
Didymocylindrus filiformis Ishii 1935	Yamaguti 1953
Didymoproblema fusiforme Ishii 1935	Yamaguti 1953
Neodiplotrema pelamydis Yamaguti 1938	Yamaguti 1953
Lobatozoum multisacculatum Ishii 1935	Yamaguti 1953
Kollikeria globosa Ishii 1935	Yamaguti 1953
Kollikeria orientalis (Yamaguti 1934)	Yamaguti 1953

Kollikeria reniformis Ishii 1935	Yamaguti 1953
Tergestia laticollis	Manter 1940
Hirudinella clavata	Manter 1940
Hirudinella marina Garcin 1730	Nigrelli and Stunkard 1947
Hirudinella ventricosa (Pallas 1774)	Nigrelli and Stunkard 1947
Tristomum laeve Verrill	Linton 1901

Nematodes

Anisakis (larva)	Yamaguti 1941
Philometroides sp.	Personal comm. J. Harada

Acanthocephala

Nipporhynchus ornatus (Van Cleave 1918)	Van Cleave 1940
Acanthocephala (as a group)	Van Cleave 1940

Crustacea: Copepoda

Caligus aliuncus Wilson	Wilson 1937
Caligus bonito Wilson	Wilson 1905
Caligus katuwo	Yamaguti 1936
Caligus pelamydis Kroyer	Wilson 1905
Caligus productus Dana 1854	Wilson 1905
Caligus tessifera Shiino	Shiino 1952
Caligus thymni Dana 1852	Wilson 1905
Homoiotes bermudensis	Heegaard 1943
Lepeophtheirus dissimulatus	Heegaard 1943
Lepeophtheirus salmonis	Heegaard 1943

3.3.6 Greatest size

In the literature the greatest size mentioned is a length of about 1 m and a weight of 25 kg; Kishinouye (1923) states that this size is rarely attained.

3.3.7 Body temperature

Tuna as a group appear to have a body temperature higher than that of the surrounding waters, and in this respect differ from many other fish. Because of the problems of obtaining accurate measurements of body temperature of living skipjack, the only measurements have been of recently killed or dying fish. Uda (1941) reported the body temperature of skipjack to be 1° C to 3° C higher than the water from which they were taken, while Watanabe (1941) found the body temperature exceeded the water temperature by 2.1° C to 3.4° C. More recently Fukushima (1953) found that the temperature of the body cavity of skipjack was 1.4° C higher and the so-called "red muscle" was 5.9° C higher than the surrounding water temperature.

3.3.8 Biochemistry (chemical composition, amino-acids, seasonal variations)

This section is not intended to cover exhaustively the field of biochemistry of skipjack but only to give a brief review of the chemical composition of the fish and some of its organs.

Dill (1921) analyzed 10 skipjack from southern California waters and gave the following composition of the edible portion, i.e., the lateral musculature:

Moisture [1]	65.94%
Solids	34.06%
Ether Extracts	7.37%
Ash	1.30%
Total Nitrogen	4.07%

Suzuki, et al (1909) found that the soft tissues of skipjack contain 1.469% phosphorus on a dry weight basis. More recently Imanishi in a series of papers (Imanishi 1960a, 1960b, 1960d, 1960e, 1961a, 1961b, 1961c) has described in some detail the inorganic chemical constituents of the various organs and regions of the skipjack body. He lists (1960a) the following elements as occurring in the ash of skipjack, determination being by spectrographic analysis:

Aluminum	Manganese
Calcium	Phosphorus
Carbon	Potassium
Chlorine	Silicon
Copper	Sodium
Iron	Sulphur
Lead	Tin
Magnesium	Zinc

Horiguchi, Kashiwada, and Kakimoto (1953) found that the pyloric coeca contained the cations Al, Zn, Fe, Ca, Mg, Na, K, and traces of Ni, and Co, the anions S, P, Cl, and traces of Si. This differs from the list of elements shown by Imanishi (1960a) in containing nickel and cobalt and lacking copper, lead, manganese, and tin.

In additional studies of the pyloric coeca Kashiwada, Kakimoto and Horiguchi (1952) found a seasonal variation in the crude fat content of this organ, with the content highest in the spring, decreasing during the summer, increasing in early autumn, and decreasing slightly during late autumn.

Within the past two decades considerable work has been done in describing the protein structure of skipjack, a major portion of this work being done by Japanese scientists. Lukton and Olcott (1958) described the occurrence of free imidazole compounds in the muscle tissue of skipjack, including the amino acid histidine and the polypeptides carnosine and anserine.

Table VIII lists the amino-acids found in skipjack by Sugimura, et al (1954). Matsuura,

Table VIII
Amino-acids found in skipjack (Sugimura, et al., 1954) [1]

Amino-acid	Percent of total N in muscle	Amino-acid	Percent of total N in muscle
Arginine	8.7	Methionine	1.0
Aspartic acid	6.3	Phenyl-alanine	2.0
Glutamic acid	5.9	Proline	4.3
Glycine	5.3	Serine	2.6
Histidine	5.7	Threonine	2.2
Isoleucine	3.1	Tryptophane	0.6
Leucine	4.2	Tyrosine	1.5
Lysine	9.1	Valine	7.2

1/ In addition to the above, Kakimoto, Kanazawa and Kashiwada (1953) reported the presence of Alanine, Cystine, and Ornithine.

1/ Dill does not list moisture, but Vinogradov (1953) attributes this figure to Dill (1921).

et al. (1954) listed most of these same amino-acids, and also noted slight differences in the composition of certain muscle layers.

In other studies Kashiwada (1952) found a seasonal change in the proteolytic enzyme activity in the pyloric coeca, with the highest activity during the spring, a decrease in the summer, and a fluctuating degree of activity during the fall. He noted that the enzyme activity appeared to follow the skipjack catch in the southern sea of Kyushu.

Other articles concerned with the biochemistry may be found in such journals as the Bulletin of the Japanese Society of Scientific Fisheries.

3.4 Nutrition and growth

3.4.1 Feeding (time, place, manner, season)

- Time

Very little is known concerning the feeding habits of skipjack, and most existing knowledge has been deduced from variations in the catch rates of commercial fishing, or from variations in the volume of the stomach contents rather than from direct observation.

Uda (1940) stated that skipjack feed most actively in the early morning and somewhat less actively around noon and just before dusk. Nakamura (MS) hypothesized a midmorning period of active feeding, followed by a midday minimum and another period of active feeding just before sunset. Data from Yuen (1959) indicate minimum feeding activity in early afternoon with higher degrees of feeding activity in the morning and later afternoon, although the differences are not statistically significant.

- Place

Feeding skipjack are found in oceanic waters, both near to and far from land, over shallow or very deep water. Aside from these rather general statements which may be found in Kishinouye (1923), Suyehiro (1938), Nakamura (MS), and others, little is known regarding the place in which skipjack feed.

The vertical range over which skipjack feed is not known. However, it is known that they feed at and just below the surface, for it is at this time that it is possible to observe them. To a surface observer it appears that skipjack drive their prey to the surface, where both the fish and any nearby birds feed on the forage organisms. Fishermen utilize this behavior to locate fish schools, i.e., a flock of birds seen feeding at the surface may be taken to indicate a fish school in the same location.

- Manner

The exact manner in which skipjack feed is not well known. Kishinouye (1923) and Imamura (1949) state that skipjack may surround and concentrate schools of small fish and feed on the periphery, rather than make dashes into the center of this mass.

Recently, during the course of experimental fishing in Hawaiian waters, it has been possible to observe, through subsurface viewing ports, the actions of feeding skipjack. Certain of these observations, not yet published, will be reported here as personal communications from members of the Behavior Program at the Bureau of Commercial Fisheries Biological Laboratory at Honolulu. Skipjack swim in a horizontal attitude with their mouths slightly agape while searching for food. When taking prey of a size visible to an observer, the mouth is opened and then closed. Food organisms may be taken while the fish is moving in any direction from vertically upward to vertically downward.

- Season

Hotta and Ogawa (1955) found seasonal differences in the types of food consumed by skipjack in some areas and no differences in that consumed in other areas. In general the greatest differences were in the non-fish portion of the diet (excluding larval fish). It was felt that the diet was determined largely by the availability of particular items, e.g., when larval forms were abundant, large quantities of larvae would occur in the stomach contents.

Nakamura (MS) found little seasonal variation in the amount of fish consumed, but the amount of Crustacea consumed was lowest in the winter and highest in summer, while the greatest amount of Mollusca was consumed in the winter and the least in the spring.

3.4.2 Food (type, volume)

The major food items have been described as fish, crustaceans, and molluscs by various authors (Kishinouye, 1923; Suyehiro, 1938; Welch, 1949; Ronquillo, 1953; Tester and Nakamura, 1957; Nakamura, MS; Waldron and King, 1962). In addition there are numerous other reports with brief mention of food as fish, crustaceans, and molluscs or squids. The most comprehensive studies to date are those by Hotta and Ogawa (1955), and unpublished manuscript by Nakamura (MS), and Waldron and King (1962). Table IX compiled from the above sources, lists the food organisms consumed by skipjack.

Hotta and Ogawa (1955) give the amount of food consumed in terms of grams of food per kilogram of body weight. The greatest weight of any one organism is 81.5 gm /kg body weight, with other values ranging down to a few tenths of a gram or to zero. Nakamura (MS) lists the average volume of stomach contents for skipjack under 60 cm length as between 4 and 24 cc, with considerable variation with time of day at which the fish were captured. Yuen (1959) lists values of up to 214 cc for large skipjack, i.e., above 60 cm, and gives values of 9.1 ml, 20.4 ml, and 35.6 ml as the mean volume of stomach contents for fish of less than 50 cm, 50 to 60 cm, and greater than 60 cm. fork length respectively.

With respect to size of organisms consumed, Waldron and King (1962) found that the average volume for individual Crustacea was 0.2 cc, for Mollusca 3.9 cc, and for fish 3.7 cc. The greatest average size of organisms consumed was 34.8 cc (a squid, *Sepioteuthis* sp.) and 34.3 cc (a fish, *Decapterus pinnulatus*).

Rather striking differences are observed in the food of skipjack from different areas. Waldron and King (1962) reported that fish, molluscs, and crustaceans make up respectively 75, 20, and 4 percent of the diet of central Pacific skipjack, while Schaefer (1960) reports these same groups contribute about 33, 4, and 62 percent of the diet of eastern Pacific skipjack.

3.4.3 Growth

Hayashi (1958) reviewed the age determinations of Pacific tunas, including skipjack. He noted considerable disagreement between the only works describing growth and age of skipjack, those by Aikawa (1937) and Aikawa and Kato (1938) working with skipjack from Japanese waters, and that by Brock (1954) working with skipjack from Hawaiian waters. Hayashi attributed part of the difficulty in aging skipjack by means of rings on hard parts, the method followed by Aikawa, to the slight seasonal change of the environment in which skipjack live.

In their study of the age of skipjack, using vertebral rings, Aikawa and Kato (1938) gave the following lengths, weights, and growth rates for skipjack from Japanese waters.

Age group	Length range cm	Weight range kg	Growth rate
0	< 27	< 0.4	-
I	27 - 37	0.4 - 1.3	0.90
II	37 - 46	1.3 - 2.5	0.69
III	46 - 55	2.5 - 4.1	0.53
IV	55 - 64	4.1 - 6.5	0.46
V	64 - 72	6.5 - 9.5	0.37
VI	72 - 80	9.5 -13.0	0.31
VII	> 80	> 13.0	?

This growth is considerably different from the growth as determined by Brock (1954) based on the presence of modes in the size distribution of Hawaiian skipjack. Brock's growth curve shows that at the end of periods of 1, 2, 3, and 4 years skipjack may attain lengths of 41 cm, 69 cm, 79 cm, and 82 cm. respectively. His estimates are thus greater than those of Aikawa and Kato by a factor approaching two. Kawasaki (1955b, his figure 8) shows that Japanese skipjack of the "Archipelago group" grow about 18 cm during the third year and 12 cm during the fourth year. This is much more rapid growth than that estimated by Aikawa and Kato and more nearly approaches the growth hypothesized by Brock (1954) for Hawaiian skipjack.

On the basis of growth of tagged skipjack, released at a size of about 2.5 kg, Yamashita and Waldron (1959) estimated an increase in weight of about 0.36 kg per month, or about

Table IX
A list of food organisms consumed by *Katsuwonus pelamis*

	Hotta and Ogawa (1955) Japanese waters	Waldron and King (1962)	Welch (1949) Hawaiian waters	Ronquillo (1953) Philippine waters	Nakamura (MS) South Pacific - Marquesas
Arthropoda	X	X	X	X	X
Crustacea	X	X	X	X	X
Copepoda		X			
Malacostraca	X	X		X	X
Mysidacea		X			
Mysiidae		X			
Isopoda		X			
Amphipoda		X		X	X
Hyperiidae		X			
Phronimidae		X			
Phronima sp.		X			
Phrosinidae		X			
Pronoidae		X			
Oxycephalidae		X			
Oxycephalus sp.		X			
Euphausiacea	X	X			X
Euphausiidae		X			
Thysanopoda tricuspidata		X			
Euphausia sp.		X			
Decapoda	X	X	X	X	X
Natantia	X	X		X	X
Pandalidae		X			
Heterocarpus ensifer		X			
Reptantia		X		X	
Scyllaridae		X			
Palinuridae				X	
Phyllosoma larvae					X
Nephropsidae		X			
Enoplometra occidentalis					
Brachyuran zoea larvae				X	
Brachyuran megalops larvae		X		X	X
Crab larvae			X		
Stomatopoda		X	X	X	X
Squillidae		X	X		
Squilla sp.		X			
Pseudosquilla sp.		X			
Pseudosquilla ciliata		X			
Pseudosquilla occulata		X			
Lysiosquilla sp.		X			
Lysiosquilla maculata			X		
Odontodactylus sp.		X	X		

Table IX
A list of food organisms consumed by *Katsuwonus pelamis* (con.)

	Hotta and Ogawa (1955) Japanese waters	Waldron and King (1962)	Welch (1949) Hawaiian waters	Ronquillo (1953) Philippine waters	Nakamura (MS) South Pacific - Marquesas
Odontodactylus hanseni		X			
Gonodactylus sp.		X			
Coronida sp.		X			
Mollusca	X	X	X	X	X
Gastropoda		X			X
Heteropoda		X			X
Atlantidae		X			
Atlanta sp.		X			
Pteropoda		X			X
Carolinidae		X			
Carolinia sp.		X			
Cephalopoda	X	X	X	X	X
Octopoda	X	X	X	X	X
Argonautidae	X	X		X	X
Argonauta sp.	X				
Decapoda	X	X	X	X	X
Loliginidae	X	X			
Sepioteuthis sp.		X			
Loligo bleederi	X				
Ommastrephidae		X			
Ommastrephes hawaiiensis		X			
Symplectoteuthis sp.		X			
Sepiolidae	X				
Euprymna marsei	X				
Chordata	X	X	X	X	X
Tunicata		X			X
Salpidae		X			
Vertebrata	X	X	X	X	X
Pisces	X	X	X	X	X
Albulidae		X			
Dussumieriidae	X		X		
Spratelloides japonicus	X				
Spratelloides delicatulus			X		
Clupeidae	X	X		X	
Sardinella sp.				X	
Etrumeus micropus		X			
Gonostomidae	X				
Sternoptychidae	X	X		X	
Sternoptyx diaphana	X	X		X	
Stomiatidae		X		X	
Idiacanthidae					X

Table IX
A list of food organisms consumed by Katsuwonus pelamis (con.)

	Hotta and Ogawa (1955) Japanese waters	Waldron and King (1962)	Welch (1949) Hawaiian waters	Ronquillo (1953) Philippine waters	Nakamura (MS) South Pacific - Marquesas
Synodontidae		X	X	X	X
Paralepidae (= Sudidae)	X	X		X	
Lestidium prolixom	X				
Lestidium philippina				X	
Alepisauridae	X	X			
Alepisaurus borealis		X			
Myctophidae	X	X		X	X
Diaphus sp.		X			
Diaphus caeruleus	X				
Belonidae					X
Scomberesocidae	X	X			
Cololabis sp.		X			
Cololabis saira	X				
Hemirhamphidae		X		X	
Exocoetidae	X	X	X	X	X
Parexocoetus brachypterus		X			
Exocoetus obtusirostris	X				
Exocoetus volitans	X				
Cypselurus poecilopterus	X				
Oxyporhamphidae	X				
Aulostomidae			X		
Aulostomus chinensis			X		
Fistulariidae		X		X	X
Macrorhamphosidae	X				
Macrorhamphosus japonicus	X				
Syngnathidae		X	X	X	
Hippocampus sp.		X			
Hippocampus kuda			X		
Holocentridae	X	X	X	X	X
Holocentrus sp.		X			
Holocentrus spinosissimus	X				
Holocentrus diadema	X				
Myripristis murdjan	X				
Grammicolepidae	X				
Xenolepidichthys dalgleishi	X				
Antigonidae				X	
Sphyraenidae	X	X			X
Atherinidae		X			
Polynemidae	X				
Polydactylus plebius	X				
Serranidae	X				X

Table IX
A list of food organisms consumed by Katsuwonus pelamis (con.)

	Hotta and Ogawa (1955) Japanese waters	Waldron and King (1962)	Welch (1949) Hawaiian waters	Ronquillo (1953) Philippine waters	Nakamura (MS) South Pacific - Marquesas
Epinephelidae	X				
Kuhliidae		X			
Priacanthidae	X	X	X	X	X
Priacanthus cruentatus		X	X		
Priacanthus boops	X				
Priacanthus macracanthus	X				
Labracoglossidae	X				
Labracoglossa argentiventris	X				
Carangidae	X	X	X	X	X
Caranx uraspis	X				
Decapterus sp.				X	
Decapterus muroadsii	X				
Decapterus russellii	X				
Decapterus pinnulatus		X	X		
Trachurus japonicus	X				
Trachurops crumenophthalus		X	X		
Megalaspis cordyla				X	
Scomberoides sanctipetri		X			
Menidae	X				
Mene maculata	X				
Bramidae		X	X	X	X
Collybus drachme		X			
Coryphaenidae	X	X		X	X
Coryphaena hippurus	X	X		X	
Emmelichthyidae	X				X
Erythrocles schlegeli	X				
Lutianidae	X				X
Etelis sp.	X				
Denticidae	X				
Gymnocranius griseus	X				
Caesionidae	X				
Caesio chrysozonus	X				
Caesio tile	X				
Caesio sp.				X	
Mullidae	X	X	X	X	X
Mulloidichthys auriflamma		X			
Pempheridae	X				
Parapriacanthus bryceformes	X				
Kyphosidae					X
Chaetodontidae	X	X	X	X	X
Pomacentridae				X	X

Table IX
A list of food organisms consumed by *Katsuwonus pelamis* (con.)

	Hotta and Ogawa (1955) Japanese waters	Waldron and King (1962)	Welch (1949) Hawaiian waters	Ronquillo (1953) Philippine waters	Nakamura (MS) South Pacific - Marquesas
Pomacanthidae		X			
Chiasmodontidae				X	
Blennidae		X			X
Brotulidae		X			
Ammodytidae	X	X			X
Bleekeria sp.		X			
Embolichthys mitsukuri	X				
Siganidae	X			X	
Teuthidae				X	
Acronurus larvae				X	
Zanclidae	X				
Zanclus cornutus	X				
Acanthuridae	X	X	X		X
Acanthurus sp.			X		
Gempylidae (= Acinaceidae)	X	X	X	X	X
Gempylus serpens		X		X	
Rexia solandri				X	
Neolatus tripes	X				
Mimasea taeniosoma	X				
Acinacea notha	X				
Dicrotus sp.	X				
Trichiuridae	X			X	
Lepidopus tenuis	X				
Scombridae (including Thunnidae)	X	X	X	X	X
Neothunnus macropterus		X			X
Euthynnus sp.					X
Euthynnus yaito		X		X	
Auxis sp.				X	X
Auxis thazard	X				
Auxis tapeinosoma	X				
Katsuwonus pelamis	X	X			X
Scomber sp.		X			
Scomberomoridae	X	X			
Scomberomorus sp.	X				
Histiophoridae	X				
Tetragonuridae		X			
Nomeidae	X	X			X
Cubiceps sp.		X			
Nomeus albula	X				
Centrolophidae			X		
Scorpaenidae		X			X

Table IX
A list of food organisms consumed by *Katsuwonus pelamis* (con.)

	Hotta and Ogawa (1955) Japanese waters	Waldron and King (1962)	Welch (1949) Hawaiian waters	Ronquillo (1953) Philippine waters	Nakamura (MS) South Pacific - Marquesas
Pontinus sp.		X			
Scorpaena sp.		X			
Setarchus sp.		X			
Triglidae			X		
Peristedidae	X				
Satyrichthys amiscus	X				
Platycephalidae					X
Dactylopteridae				X	X
Echeneidae	X				
Remora remora	X				
Triacanthidae				X	
Balistidae	X	X	X	X	X
Balistes ringens		X			
Monacanthidae	X	X	X		X
Ostraciidae	X	X	X	X	X
Lactoria diaphanus	X	X			
Lactoria fornasina			X		
Tetraodontidae	X	X		X	
Sphaeroides exilis	X				
Canthigasteridae	X	X			
Canthigaster rivulatus	X				
Diodontidae	X	X		X	X
Diodon holacanthus		X			
Molidae	X	X			
Ranzania truncata		X			
Masturus lanceolatus	X				
Pegasidae					X

Additional food organisms not listed by the above authors:

Chaetodon corallicola: Chaetodontidae	- Strasburg (1961)
Holocentrus lacteoguttatus: Holocentridae	- do.
Parupeneus sp.: Mullidae	- do.
Synodus variegatus: Synodontidae	- do.
Symplectoteuthis oualaniensis: Decapod Mollusca	- do.
Vinciguerria lucetia	- Schaefer (1960)
Pleuroncodes planipes: Decapoda: Crustacea	- Schaefer (1959)

4.36 kg per year. This growth is more similar to that estimated by Brock than to the estimates of Aikawa and Kato (1938). In the eastern Pacific, Schaefer, Chatwin, and Broadhead (1961) reported a growth of 12.1 cm and 2.7 kg per year for skipjack tagged at a length of between 40.0 and 55.0 cm. These same authors also stated that the growth of tagged skipjack was substantially slower than that of untagged skipjack. However, Schaefer (1961a), using length frequency data, indicates a growth of only 12 to 15 cm per year for skipjack of about 45 cm length.

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

Kawasaki (1955a, 1955b) studying changes in the size composition of skipjack catches from certain areas near Japan, found that growth of the "sedentary" and "migratory" groups differed. He concluded that the sedentary groups had a low rate of growth during the summer because they were maturing sexually. In contrast, the migratory groups had a high rate of growth during the summer because they were on a feeding migration. During the winter the growth of these two groups reversed as did their habits. The summer sedentary-sexually maturing group became a feeding-migratory group, while the summer migratory-feeding group became a sedentary-sexually maturing group.

3.5 Behavior

3.5.1 Migrations and local movements

Descriptions of the migrations of skipjack exist only for areas with commercial fisheries, but not for all such areas. In the western Pacific the migrations into and through the Japanese fishery have been described by Uda and Tsukushi (1934), Sasaki (1939), Imamura (1949), Tauchi (1943), Shapiro (1948), Kawasaki (1955a, 1955b), and others. Imamura (1949) classified the skipjack of the western Pacific according to their migratory behavior as follows: (1) Skipjack which spend their whole lives in the tropical seas south of latitude 23° N., (2) skipjack which make a great circular migration in the North Equatorial Current in the spring and summer, and (3) skipjack which move north and south in the Kuroshio current system. The migratory skipjack are thought to follow three routes (Fig. 7): (1) Along the North Equatorial Current past the Philippines, Taiwan, and Okinawa to the Satsunan area and thence gradually northward. (2) Another group is thought to move from the South Seas Area to the Zunan area along the northerly warm current of the Kuroshio which originates in the waters near the Bonins in the spring. (3) The third route is northward between the North Equatorial Current and the northerly warm current of the Ogasawara region to the vicinity of the Kinan reefs in the Kinan area (30°10' N, 136°45' E). These routes have been deduced from studies of changes in the concentrations of schools during the fishing season, studies of the current systems, and studies of the size and condition of the fish.

Tauchi (1943) divided the skipjack contributing to the Japanese fishery into (1) migratory and (2) resident types. He described the migratory types as originating in the "South Seas Area" where they spend their larval and juvenile existence. The majority of the migratory fish which move into the Japanese fishery are in age-group III, with smaller numbers of age-groups II and IV (age determined from Aikawa's tables). After they have migrated into Japanese waters Tauchi (1943) concludes that these skipjack return to the South Seas Area and do not undertake a second migration. Kawasaki (1955a, 1955b) describes in considerable detail the movements of skipjack within certain areas to the southwest and southeast of Japan. He portrays a migration up and down the Ryukyu Is. archipelago, and a similar migration along the Bonin Is. and the Northeastern Sea Area.

In the central Pacific there is evidence, from changes in the composition and amount of the catch, that skipjack, possibly both large and small, but especially those above 15 pounds in weight (about 7 kg.), migrate into the Hawaiian fishery during the spring (April to June). The location of these fish prior to their entry into the Hawaiian fishery is not known. In late summer or fall (August to October) this group of large fish disappears from the Hawaiian fishery, but their destination is not known.

Within the Hawaiian fishery skipjack appear to follow a rather random pattern of movement in both easterly and westerly directions along

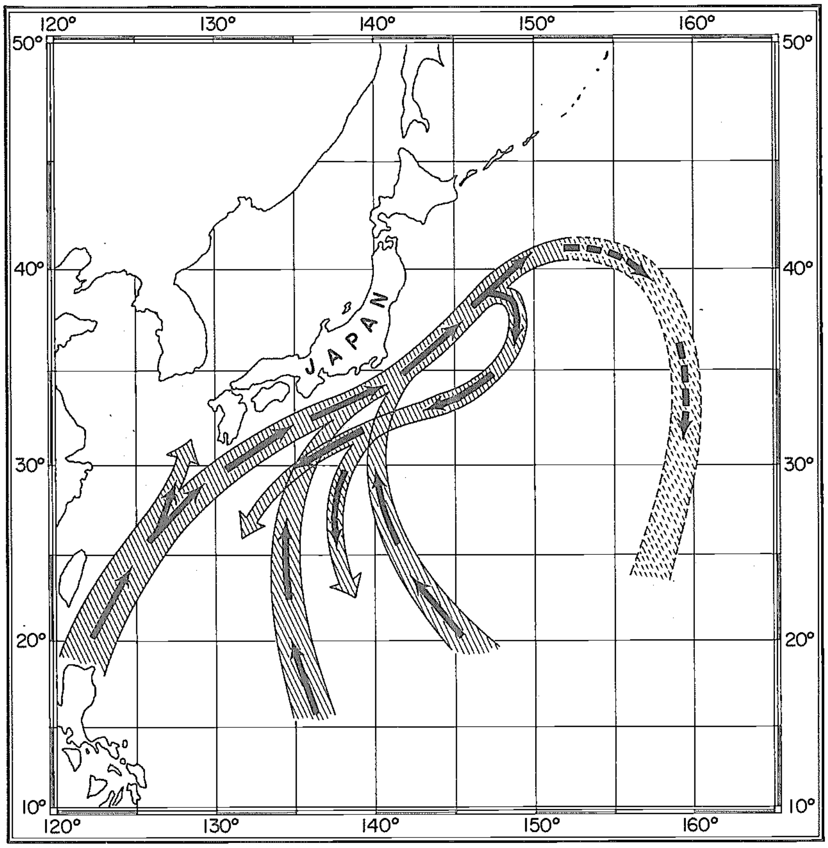

Fig. 7 Migrations of skipjack in the western Pacific Ocean (according to Imamura, 1949; Kawasaki, 1955a, 1955b)

the archipelago, as shown by the recovery of tagged fish.

On the basis of movements of tagged skipjack, Blunt and Messersmith (1960) and Schaefer, Chatwin, and Broadhead (1961) described the movements of skipjack in the eastern Pacific.

None of the skipjack tagged and released in the eastern Pacific fishery have been recovered in other fisheries of the Pacific, e.g., the Hawaiian or Japanese. On this basis it is concluded that there is little if any interchange of fish on an oceanwide scale such as has been observed for albacore.

Taken by quarters of the year, the within-fishery migration of skipjack according to Blunt and Messersmith (1960) and Schaefer, Chatwin, and Broadhead (1961) appears to be as described below, and shown in Fig. 8. In this description the term "northern area" refers to all of the eastern Pacific fishery north of latitude 10° N, while the term "southern area" includes all south of this latitude. The term "region" will be used to indicate subdivisions of these areas.

(1) January, February, March: Skipjack tagged in the northern area tended to be recovered in the region in which they were released. Some skipjack moved south from the Gulf of California region into the region off southern Mexico.

In the southern area there was considerable interchange of skipjack between regions. Some fish moved in towards a location known as the "14-fathom spot" (about latitude 9° S, longitude 79°-80° W.) from the Galapagos Is. There was also some interchange between the "14-fathom spot" and the Gulf of Guayaquil, in both a north and south direction.

(2) April, May, June: Skipjack in the northern area appear to be restricted to within-region migrations, except for a movement from the Revillagigedo Is. north to the Pacific coast of Baja California. Within the region off Baja California, there is a pronounced northerly migration.

Within the southern area there is evidence of both northerly and southerly migrations at this time of year. The predominant movement appears to be north from the "14-fathom spot" to about latitude 0° off the Colombian coast, and south from the Gulf of Panama to the same region. However, there is still some southerly migration from near the Gulf of Guayaquil to the "14-fathom spot."

(3) July, August, September: As during the previous quarters there is no evidence of inter-regional migration in the northern area. Within the Baja California region the movement has become predominantly southerly, although there is still some northerly movement.

In the southern area there was a predominantly southern movement from the Gulf of Panama to the Colombian and Ecuadorian coasts as well as rather short-distance northerly and southerly movement along the coasts of Peru and Ecuador. A few skipjack moved from the "14-fathom spot" to off the Gulf of Guayaquil.

(4) October, November, December: In the northern area there was evidence of only within-region movement.

In the southern area the predominant movement was from the Gulf of Panama south to the coasts of Colombia, Ecuador, and northern Peru. From the "14-fathom spot" there was considerable movement north to the Gulf of Guayaquil and some movement offshore to north of the Galapagos Is. Skipjack also moved south from the "14-fathom spot" to off the northern portion of Chile (about latitude 19°-20° S).

3.5.2 Schooling

Skipjack are known to be a schooling fish during their adult life, and probably during their juvenile life (Kishinouye, 1923; Brock, 1954). Brock (1954) in studying samples from commercial landings noted that skipjack school by size, i.e., there was less variation in length within samples from single schools than within the total landings from which the samples were drawn. He attributed this size segregation to a dependence of maximum swimming speed upon length of the fish. Among 120 samples of about 34 fish each from pure schools he found a mean range in length of 11.3 cm, while for the landings of the period the range was 47 cm. Broadhead and Orange

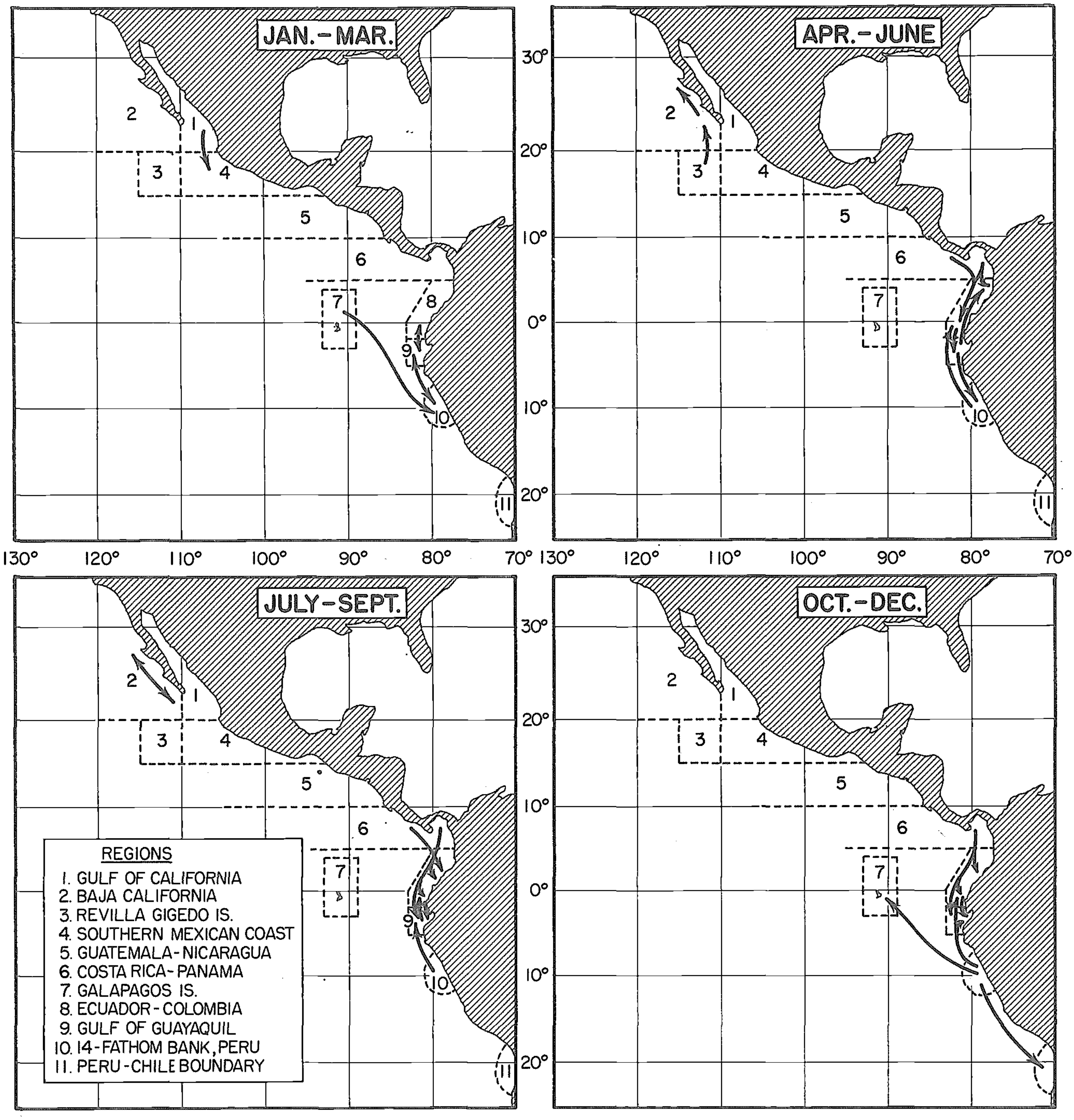

Fig. 8 Migrations of skipjack in the eastern Pacific Ocean (according to Blunt and Messersmith, 1960; Schaefer, Chatwin and Broadhead, 1961)

(1960) noted that in the eastern Pacific "individuals composing single schools are more nearly like each other than would be expected if they were drawn at random from the whole population." Among 64 samples of about 25 fish each from single schools the average range was about 9.6 cm, while the range for all samples was 30.6 cm.

Skipjack frequently form feeding aggregations with other tuna, especially yellowfin (Neothunnus macropterus), and these aggregations are usually referred to as "mixed schools." Skipjack in these mixed schools, which might more correctly be called mixed feeding aggregations, may associate with yellowfin considerably larger than themselves (Broadhead and Orange, 1960). Underwater observations show that in mixed feeding aggregations of skipjack and yellowfin, each species moves and responds to chum independently of the other species (U.S.F.W.S., 1961).

Skipjack schools may occasionally be very large, but at least to an observer on the surface the majority are of moderate size. Orange, Schaefer, and Larmie (1957) state that the average catch of skipjack per school by purse seiners is 13.8 tons, while the greatest catch which they list is between 130.0 and 134.9 tons; very few catches are above 75 tons. When it is considered that skipjack catches in the eastern Pacific fishery are composed predominantly of fish between 4 and 10 pounds, (Shimada and Schaefer, 1956) then 100 tons would represent between 20 and 50 thousand fish. Since it is unlikely that all fish in a school are captured, these figures then represent the minimum number of skipjack in a large school.

In the Japanese fishery the behavior of schools, as shown by the catch from different schools, has been shown to be related in different ways to objects with which the schools are associated, to oceanographic and sea conditions, and to certain aspects of feeding (Uda, 1933; Suyehiro, 1938; Sasaki, 1939; Kimura, 1954; Hotta, Kariya, and Ogawa, 1959; and Inoue, 1959).

Strasburg (1961) studied the diving behavior of skipjack schools during fishing operations in Hawaiian waters as related to items of diet. He found that skipjack feeding on juvenile Holocentrus lacteoguttatus and post-larval Synodus variegatus were more prone to leave the surface during fishing operations than were skipjack feeding on other animals. Yuen (1959) found that distance from land, stomach content and stage of digestion, and swimming characteristics of food fish consumed affected the response of skipjack to chum.

3.5.3 Reproductive behavior

Little is known concerning the reproductive behavior of skipjack. Brock (1954) noted that skipjack with fully ripe ova are seldom taken in the Hawaiian fishery, and Kishinouye (1923) stated that skipjack with ripe reproductive elements seemed to fast.

It appears that in ova diameter distributions the mean diameter of advanced ova is about 0.7 mm and of ripe ova about 1.0 mm, and no group of ova have been observed with a mean between these values. As Brock (1954) points out, this implies that during the period in which the ova are increasing from about 0.7 to 1.0 mm female skipjack are unavailable to a commercial fishery, especially a pole-and-line fishery. Further, if this increase required a significant period of time, say one month, and spawning of large numbers of fish occurred at the same time, then it should be possible to detect the spawning period through changes in the sex ratio of the catch. This does not appear to be the situation, so it might be inferred from Brock's statements that (1) skipjack spawn in small groups, say as individual schools, over a protracted period, (2) the time required for ova to increase from 0.7 to 1.0 mm is relatively short, or (3) male skipjack become unavailable in the same proportion and at the same time as the females.

4 POPULATION (STOCK)

For the population as a whole there is no information on structure, size and density, natality and recruitment, mortality and morbidity, dynamics, and other relations involving the population. Concerning a portion of the population, that part susceptible to capture by commercial fishing methods, there is a rather sparse literature on a few aspects of the population. Therefore, comments in the following sections are applicable only to the commercially caught segment of the population, in general those fish above 30 cm in fork length.

4.1 Structure

4.1.1 Sex ratio

The sex ratio for that portion of the population caught in commercial and exploratory fishing may depart significantly from 1:1 at certain times of the year (Brock, 1954). Table X summarizes the sex ratios observed in different areas. Perhaps the most striking departures from the 1:1 ratio are those observed by Schaefer and Orange (1956) in the eastern Pacific and by Marr (1948) in the Marshall Is. area.

4.1.2 Age and size composition

Since no commercial fishery captures skipjack over the entire age range, it is clear that samples drawn from a commercial fishery are not representative of the population.

The different methods of determining the age of skipjack of different sizes has been reviewed by Hayashi (1958), who pointed out the considerable difference in age as estimated by Aikawa (1937) and Aikawa and Kato (1938) compared to the age estimated by Brock (1954). Because of these differences it is difficult to make valid comparisons of age composition of the catch as reported by various authors. In this section reference to age will be followed, when such information is available, by a weight or length designation.

The bulk of the commercial catch from Japanese waters is, according to various authors (Aikawa, 1937; Imamura, 1949; Tauchi, 1943; Kawasaki, 1955a and 1955b), composed of skipjack in their 3rd and 4th years. Smaller quantities of fish in their 2nd and 5th years appear regularly in the landings, and occasionally fish of an older age (6th-and 7th-year fish) are caught. All of the Japanese workers refer to the age as determined by Aikawa and Kato

Table X
Sex ratios among populations of commercially caught skipjack

Area and period	Author	% Male	% Female	Number in sample
Western Pacific	Kuronuma, Kafuku,			
Japanese Fishery	and Kikawa (1949)			
	and Yabe (1954)	52.1	47.9	853
Northern Marshall Is.	Marr (1948)	61.5	38.5	179
Central N. Pacific	Brock (1954)			
Hawaiian Fishery				
March to August		50.8	49.2	2,452
September to December		59.2	40.8	1,299
Eastern Pacific	Schaefer and Orange			
January - December	(1956)	39.1	60.9	1,815
Central S. Pacific	Wilson and Rinkel (1957)			
	Wilson, Nakamura, and Yoshida (1958)			
	Yoshida (1960)	51.2	48.7	2,272
Philippines	Wade (1950)	46.2	53.8	331

(1938), and their age groups with corresponding sizes are shown in Section 3.4.3, p. 3:15 of this synopsis. Briefly, fish in their 2nd, 3rd, 4th, 5th, and 6th years are believed to be about 32 cm, 43 cm, 50 cm, 60 cm, and 68 cm respectively. Fig. 9 shows the size composition of a sample of the landings in Japan with age according to Aikawa and Kato (1938).

In the Hawaiian fishery Brock (1954) has hypothesized the presence of three age groups. These groups are usually centered around lengths of 45 cm, 79 cm, and 80 cm. The greatest amount of the landings, by weight, is from the 70-cm group, followed in importance by the 45-cm and then the 80-cm groups. There is considerable monthly and annual variation in the importance of these different groups, although the 80 cm group is seldom of great importance. Brock (1954) tentatively assigned an age of 1 year to the 45-cm fish, 2 years to the 70 cm group, and 3 years to the 80 cm group, and on this basis the most important group in the Hawaiian area would be the 2-year-old skipjack. Fig. 10 shows a composite size composition for the commercial landings.

For the eastern Pacific fisheries, only size data are available. The bulk of the catch consists of skipjack less than 65 cm long, with a small percentage of the catch being fish larger than this size. Hennemuth (1957) states, "In general, however, the catch is composed primarily of one or two age groups of fish, the numbers of larger sized (and older) fish caught being very limited." Hennemuth (1959), in a study of morphometrics of skipjack, lists a range of size from 39.6 to 75.1 cm, however, Hennemuth (1957) and Broadhead and Orange (1960) show that the bulk of the catch is composed of skipjack between 45 and 65 cm in length. It should be noted that the lower limit of the range is biased to an unknown extent by the existence of a minimum legal size limit which is usually set at 4 pounds or about 45 cm length (Schaefer, 1961a). Fig. 11 shows the size composition in a relatively small sample of skipjack from the eastern Pacific.

On the basis of the work in the central and western Pacific, it appears that skipjack up to a size of about 90 cm are present in the population, and that either four or eight age groups are included depending upon the method used to determine age. The true age and size composition of the population is not known.

4.2 Size and density of population

4.2.2 Changes in size

The size of the commercially fished population apparently fluctuates from year to year in each of the different fisheries. This is indicated by variations in the landings from year to year, although factors other than population size contribute to variations in the amount of skipjack landed. Examples of these variations in population size are to be found in the western, eastern, and central Pacific fisheries. The range in catch over a number of recent years is shown below.

Fishery	Years	Minimum (in metric tons)	Maximum (in metric tons)
Western Pacific 1/	1948-1958	51,680	147,433
Central Pacific 2/	1948-1959	2,767	6,348
Eastern Pacific 3/	1948-1960	27,900	80,550

On the basis of these figures, the population may vary three-hold, however, this may be used only as a very gross estimate, for changes in fishing effort and in the environment are known to be factors affecting the annual catch.

1/ Japan, Agriculture, Forestry, and Fishery Statistics Bulletins, No. 28, No. 30, and No. 33.

2/ Seckel and Waldon, 1960.

3/ Schaefer, Milner B., 1961.

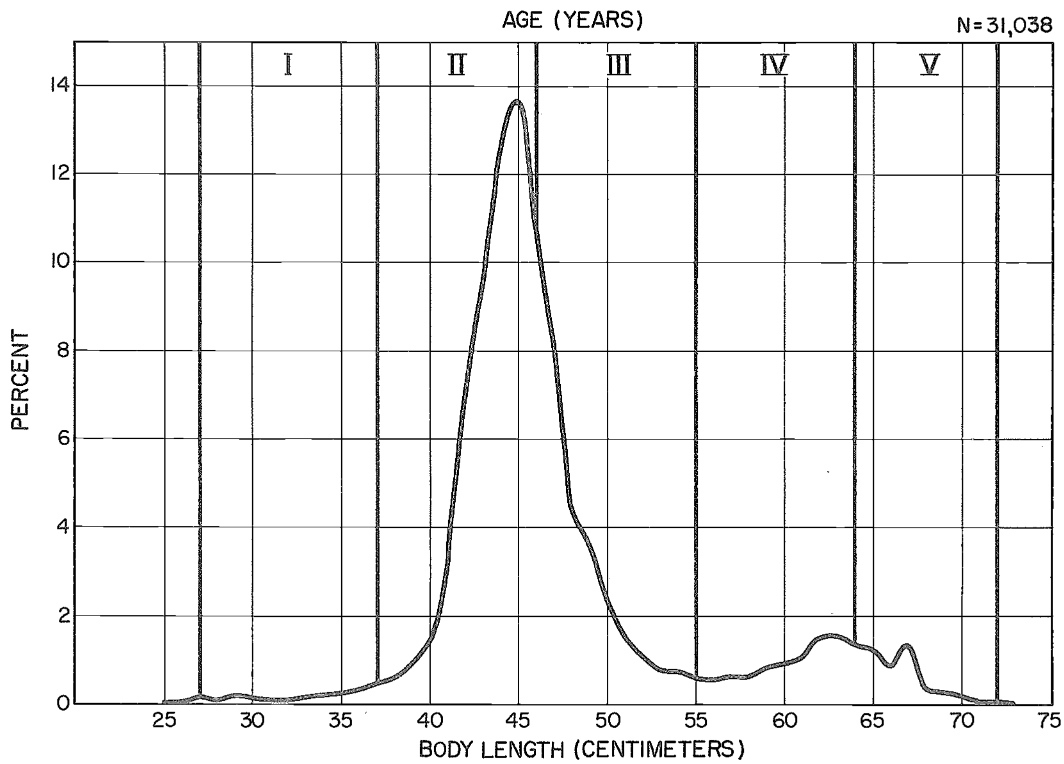

Fig. 9 Size composition of the commercial landings of skipjack in the Japanese fishery (from Kawasaki, 1955a, 1955b)

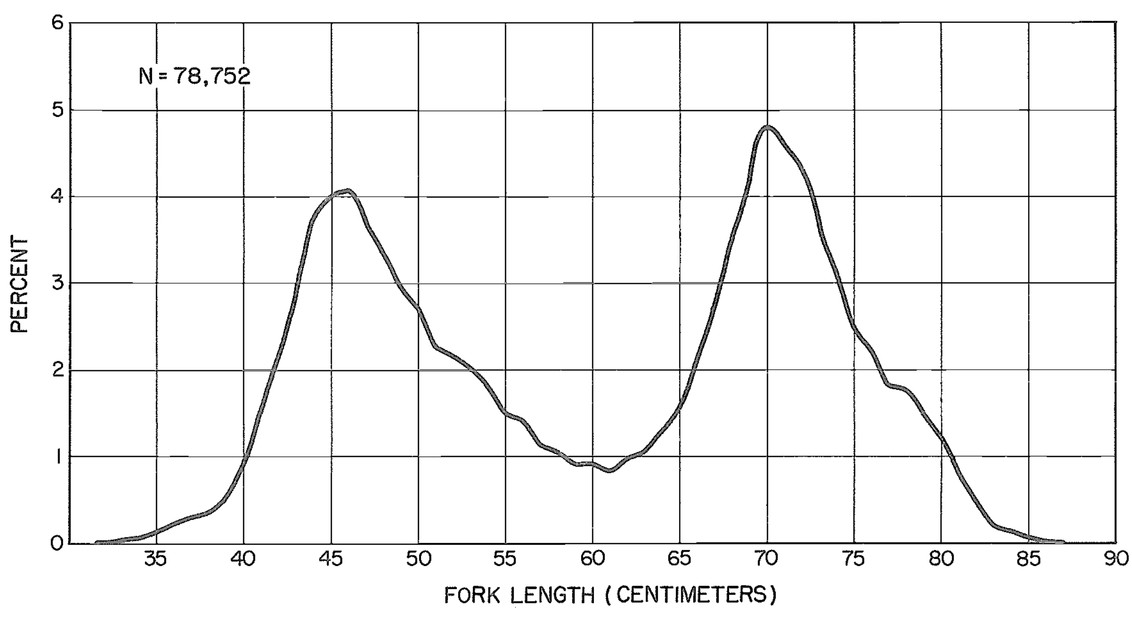

Fig. 10 Size composition of the commercial landings of skipjack in the Hawaiian fishery (from data files, Bureau of Commercial Fisheries, Biological Laboratory, Honolulu)

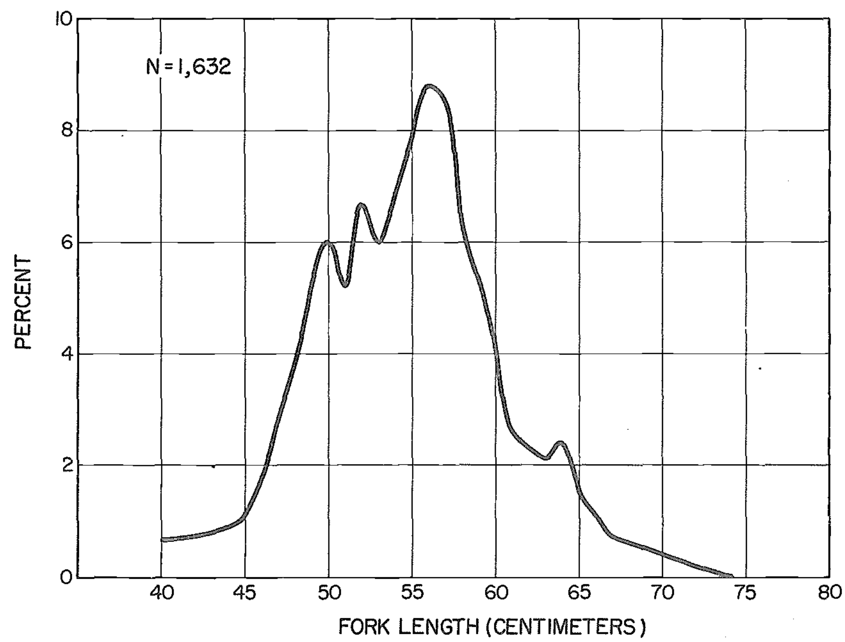

Fig. 11 Size composition of the commercial landings of skipjack in the eastern Pacific fisheries (from Broadhead and Orange, 1960)

4.4 Mortality, morbidity

4.4.1 Rates of mortality

Schaefer (1960), on the basis of the decline in rate of recovery of tagged skipjack in the eastern Pacific, states that the "annual attrition" rate for skipjack is 98.2 percent during a period of a year and a half after tagging. Schaefer, Chatwin, and Broadhead (1961) computed survival, on the basis of tag recovery data, and in their table 17 show annual survival rates of from 0.056 to 0.349. However, they point out that these rates are only for "survival of skipjack while in the area of the fishery," and that the survival in the whole population will be higher.

4.6 Relation of population to community and ecosystem, biological production, etc.

Within the marine community the skipjack may be listed both as prey and predator, although as a large adult it may be only one step removed from a climax predator. In its larval and juvenile stages it serves as food for larger fish, including adult skipjack. As an adult it serves as food for larger tunas and spearfishes, and at the same time preys upon small to moderate-sized pelagic crustaceans, molluscs, and fish. Skipjack compete for food with tunas and other fish of similar size and habits. They might even be considered as competing with sea birds, for the food organisms are often apparently driven to the surface of the water, where they are preyed upon by both skipjack and various sea birds.

Lacking estimates of the population size it is not possible to estimate the biological production of skipjack of the Pacific.

5 EXPLOITATION

5.1 Fishing equipment

5.1.1 Fishing gear

The greatest portion of the skipjack catch of the world is taken by two methods, (1) pole-and-line angling or live-bait fishing, and (2) purse seining.

In the largest fishery, that in Japanese waters, pole-and-line catches accounted for 90-95 percent of the landings and purse-seine catches for less than 10 percent during 1954-58. Set nets and various other types of angling accounted for 1 or 2 percent of the landings. Types of gear which contributed less than 1 percent to the landings included trawls, surround nets (other than purse seines), lift nets, gill nets, longlines, beach seines, and boat seines (Jap. Min. Agricul. For.,1955-1960).

During the past 2 or 3 years there has been an increase in the use of purse seines to take skipjack in the Japanese fishery. Prior to 1958 about 5 percent of the skipjack landed were caught by this method, but in 1958 and 1959, 7 and 10 percent of the skipjack landed were caught by purse seines.

In the American fishery of the eastern Pacific all skipjack landed are taken either by pole-and-line or by purse seines. Over the period 1948 to 1959 between 87 and 96 percent of skipjack in the American fishery were caught by pole-and-line angling and the remainder by purse seines. Beginning in 1959 a much greater use was made of purse seines in the tuna fishery, and by 1960 only 75 percent of the skipjack catch was taken by pole-and-line angling, with 25 percent being taken by purse-seine fishing (Schaefer, 1961).

In the central Pacific Hawaiian fishery practically all skipjack are caught by pole-and-line fishing. A very small amount is caught by trolling and by longline gear.

5.1.2 Fishing boats

Boats utilized in fishing for skipjack fall into three types according to the method used to capture the fish, i.e., (1) live-bait boats used in the pole-and-line fishery, (2) purse-seine boats, and (3) miscellaneous boats. This last group consists of boats employed mainly in fisheries catching species other than skipjack but which occasionally capture skipjack, e.g., longline vessels used in the fishery for large tunas.

Live-bait, pole-and-line vessels vary in size and design, but have a common feature, viz., wells or tanks in which live-bait fishes are carried. Those used in the American fishery of the eastern Pacific, commonly called "tuna clippers," have been described by Godsil (1938). Descriptions of newer boats can be found in trade journals and other fishery publications (Anon., 1955a; Anon., 1955b; Hanson, 1955; McNeely, 1961; Petrich, 1955). As described by Godsil (1938), tuna clippers ranged in length from 90 to 180 feet in length, had a carrying capacity of 150 to 350 short tons of frozen tuna, an operating range of 6,000 to 8,000 miles, and carried a crew of 12 to 20 fishermen.

Boats used in the Japanese pole-and-line fishery for skipjack have been described by Takagi (1955), Muramatsu (1960), and Cleaver and Shimada (1950). The deck design of Japanese vessels engaged in this fishery is different from that found in the American fleet, the most noticeable difference being that fishing racks may extend completely around the Japanese boats while in the American boats these racks are confined to the stern and the port quarter. Another difference is that with vessels of comparable length, the Japanese carry a much larger crew, up to 60 men on a 90-foot vessel.

Live-bait boats used in Hawaiian waters are generally smaller than those found in the other fisheries, and have been described by June (1951) and Yamashita (1958). While the hull design resembles the sampans of Japan, the fishing takes place only at the stern as in the American vessels.

Purse-seine vessels engaged in skipjack fishing are found mainly in the American fishery, although they are also used in the Japanese fishery. Scofield (1951) and McNeely (1961) have described the vessels and nets used in the American fishery. The latter author gives an especially detailed description of the conversion of the tuna clippers or live-bait boats to purse seiners, a movement which began in 1957 and progressed rapidly from that time to the present (1962).

Description of purse seiners used in the Japanese fishery may be found in a publication entitled "Illustrations of Japanese Fishery Boat and Fishing Gear" (Anon., 1958).

An adequate knowledge of the types of vessels and gear used in different fisheries is necessary in understanding fluctuations in catches, which in turn may be used to deduce certain characteristics of the populations. For example, Schaefer (1961) points out that increased use of purse seining in the American fishery has resulted in a decrease in the landings of skipjack, probably not because of a decrease in abundance of skipjack, but because skipjack are not as readily taken by seining as by pole-and-line angling. Shimada and Schaefer (1956) in their study of the American bait-boat fleet found that fishermen using smaller vessels were not selective between skipjack and yellowfin, but that fishermen using larger vessels were selecting yellowfin tuna when this species was readily available. They also showed that it was necessary to adjust catches to a standard size boat in studies of catch and effort. Other considerations, especially when comparing landings by bait boats and purse seiners are:

(1) Because the range is not restricted by need for bait, purse seiners may fish more intensively in areas distant from baiting grounds than could bait boats; (2) however, as inferred by Schaefer (1961), because of environmental conditions and behavioral characteristics of skipjack, purse seiners may not be able to fish in areas fished successfully by bait boats.

5.2 Fishing areas

5.2.1 General geographic distribution

Fig. 4 shows areas of the Pacific in which skipjack are caught in commercial fisheries, while Table XI lists certain of these fisheries.

Skipjack are also taken incidentally by Japanese longline vessels fishing in large areas of the North and South Pacific, by Australian fishermen, and in various subsistence fisheries of Micronesia, Melanesia, and Polynesia.

Prior to World War II considerable quantities of skipjack, as much as 33,000 tons in 1937, (Shapiro, 1948) were landed in the Marshall, Caroline, and Marianas Is.

Table XI
Major commercial skipjack fisheries of the world

Location	General limits Lat. and Long.	Approximate area in sq. naut. mi.	Number of vessels
Western Pacific (Japanese)	Lat. 18° N - 45° N Long. 120° E - 153° E	800,000	4490 (2927 < 3 tons) Jap. Min. Agric. For. 1959)
Central Pacific (Hawaiian)	Lat. 18° N - 23° N Long. 154° W - 161° W	80,000	21 (BLH files 1961)
Eastern Pacific (mostly U.S. and Peru)	Lat. 12° S - 34° N Long. 77° W - 128° W	1-1/2 mil. sq. mi.	153 (1961, Pac. Fish.)

5.2.2 Geographical ranges (latitudes, distance from the coast, etc.)

The latitudinal limits of the major fisheries are given in Table XI above, as well as the area covered by the fishery. As can be seen from Fig. 4, most of the fisheries operate within a few hundred miles of land. Even the large Japanese and American fisheries in the Pacific, although they cover over 1,500 and 2,500 miles respectively in a north-south direction, extend only 200-300 miles offshore. This situation may be a reflection of the method of capture more than the distribution of skipjack, i.e., live bait, obtainable only at inshore localities, is used in the capture of most of the skipjack, the major exception being the purse-seine methods used in the American and Japanese fisheries.

5.2.3 Depth ranges

All live-bait fisheries for skipjack are prosecuted at the immediate surface of the sea. Purse seines are essentially surface gear although the fish may be captured at a deeper level than in the live-bait fishery. Skipjack are also taken on longlines fishing at depths up to a few hundred feet, but this gear is used primarily for larger tunas and the skipjack catch is incidental to that of other tunas such as yellowfin and bigeye. Further, it has not been shown whether skipjack taken on longlines are actually caught at a depth, or at the surface while the longline gear is being set or retrieved.

5.3 Fishing seasons

5.3.1 General pattern of fishing seasons

Perhaps because of the relatively slight seasonal change in their environment, skipjack tend to be fished throughout the year. The period during which the majority of the catch is landed is seasonal in most fisheries, however, and usually occurs during the summer. Thus in the Northern Hemisphere the season usually includes the months of June, July, and August, while in the Southern Hemisphere the season includes January, February, and March. At the northern and southern limits of the fisheries the seasons tend to occur more nearly in mid-summer, while near the center of the range, i.e., in the equatorial areas, the season may include a longer time period.

5.3.2 Duration of fishing season

In any one locality the season may last for only a few months, and in fisheries which have wide latitudinal ranges it is necessary to examine the catch by area or region to determine the duration of the season. Table XII shows certain data concerning fishing seasons for the Japanese, American, and Hawaiian fisheries.

In the Hawaiian fishery, which covers only a small area (see Section 5.2.2, Fig. 4), catch statistics show a season of only about 5 months, during which time 75 percent of the annual catch is landed.

In the American fishery, extending from latitude 34° N to 12° S, it is difficult to define seasons. Alverson (1959) shows catch by quarter for the years 1952-1955 for nine regions of the fishery. An examination of his table 4 indicates that the season at the extremes of the fishery, i.e., off Baja California and the regions off South America, lasts about 3 months, while in the Central American region the season is less marked but may persist over a 6-month period (Table XII).

In the Japanese fishery, Imamura (1949) states that the duration of the season may vary from throughout the year in the South Seas Area and off Taiwan to only 6 months in the Kinan area near Japan. An examination of the monthly landings (Jap. Min. Agricul. For., 1955-1960) shows that the months of above-average landings are from April to October, or 7 months.

5.3.3 Date of beginning, peak, and end of season

Table XII lists these data for the Japanese, Hawaiian, and American fisheries.

5.3.4 Variation in time or duration of fishing season

In the Hawaiian fishery the season may begin as early as March or as late as May, and may end from September to November inclusive. The peak month is usually July, sometimes June, and rarely August.

Table XII
Time and duration of the skipjack fishing seasons in the Pacific

Area and region	Start of season	End of season	Peak of season
Eastern Pacific 1/			
Baja California			July to September
Revillagigedos			April to June
Gulf of California			October to December
Gulf of Tehuantepec			April to June
Central America			April to September
Gulf of Panama			April to June
Malpelo Is.			April to September
Northern South America			October to December
Galapagos Is.			October to March
Central Pacific 2/	May	September	July
Western Pacific 3/			
Taiwan	Throughout the year		
South Seas Area	Throughout the year		
Satsunan Area	February	November	June-July
Kinan Area	March	August	April-June
Zunan Area	March	October	June-July
Northeastern Sea Area	April	October	July-August

1/ After Alverson (1959). The season for this area can be defined only by quarters of the year.
2/ Yamashita (1958)
3/ Imamura (1949)

In the Japanese fishery the greatest variation in the season occurs in the portion of the fishery north of about latitude 35° N, known as the Northeastern Sea Area. Here the fishery may begin as early as April or as late as July, and may terminate between late August and early October (Kimura, 1949).

In the eastern Pacific fishery enough variation in catch occurs so that landings summarized by quarters of the year are sufficient to show gross seasonal changes. As shown by Alverson (1959, his table 4) the peak catches may occur in the Revillagigedos, the Gulf of Tehuantepec, and the Gulf of California regions during the second or fourth quarters. The regions off Central America, the Gulf of Panama, and Malpelo Is. may have peak catches in either the second or third quarters. In the Galapagos Is. region peak catches occur in either the first or fourth quarters. Only off Baja California and the coasts of northern South America do peak catches consistently occur during the same quarter from year to year (at least in the available data), the third quarter for the former and the fourth quarter for the latter.

5.3.5 Factors affecting fishing season

In the eastern Pacific fishery economic factors influence the landings of skipjack to a certain extent. Yellowfin tuna command a higher price generally, and when this species is readily available less effort may be expended by fishermen, especially by those with larger boats, on skipjack than when yellowfin are less available (Shimada and Schaefer, 1956). Further, when the price received by the fishermen drops below a certain point the total fishing effort decreases. Thus, decreases in skipjack landings may reflect a decrease in total fishing effort, a decrease in the effort expended on skipjack, a decrease in availability of skipjack, or a combination of two or more of these factors.

Ecological factors also affect the onset, success, and termination of the skipjack fishing season in certain areas of the eastern Pacific, particularly in the northern and southern limits of the fishery. Blackburn (1961) indicates that skipjack are sufficiently plentiful to support a fishery off northern Baja California and northern Chile and southern Peru during years when seas surface temperatures approach 21° C or greater. In addition to changes in the fishery induced by what might be termed normal movements of certain isotherms, there is the "El Niño" phenomenon occurring off the coasts of Chile and Peru, and when this phenomenon is quite marked, skipjack are more widely scattered and may be found further south than in the so-called normal years (Schaefer, 1961b). Blackburn (1960) also points out that in certain localities off southern Mexico and Central America a season for skipjack may fail to develop in years when sea surface temperatures reach 28° C or greater.

In the Japanese fishery both economic and environmental factors may contribute to variation in the onset, success, and termination of the season. Kimura (1949) has described the acceleration or delay in the onset of the season, especially in the Northeastern Sea Area, in response to changes in the flow of the Kuroshio and Oyashio current systems. A strong, northward flowing Kuroshio (warm water) early in the season will in general accelerate the onset of the fishing season. Conversely a weak Kuroshio or the late development of a strong Kuroshio, or a strong Oyashio (cold water) will delay the onset of the season. An early termination of the season occurs when there is an early weakening of the Kuroshio or strengthening of the Oyashio. Conversely a late weakening of the Kuroshio or strengthening of the Oyashio will result in a prolonged season. Imamura (1949), Sasaki (1939), Shapiro (1948), Cleaver and Shimada (1950), and Kawasaki (1955a, 1955b) also mention the dependence of the season development on the flow of the Kuroshio and Oyashio.

Kimura (1949) described years in which skipjack fishing began late in the season because of the availability to the fishery of large quantities of albacore.

In the Hawaiian fishery variations in the season appear to be almost entirely attributable to changes in the environment (Seckel and Waldron, 1960). The advent of the season in this area appears to depend upon the movement into the Hawaiian area of waters of the California Current extension having a salinity somewhat lower than that of the waters of the Kuroshio Current extension which generally cover the area during the off season period. The success of the season also appears to depend upon an early northward movement of the California Current extension waters. The beginning of this northward movement is reflected in a change from cooling to warming of the surface waters in the vicinity of the Hawaiian Is. early in the year. When this warming occurs before the first of March a better than average season ensues, and when the warming is delayed until after the first of March a poorer than average season can be expected. The basic reasons for this association are not known.

5.4 Fishing operations and results

5.4.1 Effort and intensity

For the eastern Pacific fishery Shimada and Schaefer (1956) have computed the relative fishing intensity in terms of fishing days for a standard size bait boat (i.e., pole-and-line fishing vessel) over the period 1934-1954, and Schaefer (1961) has extended this to include 1960. During that period there was a gradual, though fluctuating, increase in intensity from 5,939 days in 1934 to about 39,000 days in 1958 followed by a decrease to about 29,000 days in 1960. The catch per standard day's fishing (for class 3 boats, which have a fish-carrying capacity of 101 to 200 short tons, about 97 to 182 metric tons) varied between about 1.0 and 3.1 metric tons over the period 1934 to 1954.

During this period the number of vessels engaged in the fishery increased from 61 bait boats in 1934 to 225 in 1951 followed by a decrease to 182 in 1954. The number of purse seiners increased from 9 in 1934 to 89 in 1948 followed by a decrease to 69 in 1954. Since 1954 the number of bait boats has decreased sharply to only 48 in 1961, while the number of purse seiners has increased to 98 (McNeely, 1961). This is largely due to the conversion of bait boats to large purse seiners during 1958 to 1961.

Alverson (1960) summarized the fishing effort and catch in the eastern Pacific by quarters of the year and by one-degree squares for 1952-1958 but did not compute the relative intensity as did Shimada and Schaefer (1956).

It is difficult to assess the fishing effort and intensity in the Japanese fishery. The annual catch statistics for 1959 (Jap. Min. Agricul. For., 1960) give some idea of the effort and how it differs from the present American fishery. The Japanese skipjack pole-and-line fishery in 1959 was made up of about 4,490 vessels, of which 76 percent were vessels classed as less than 5 metric tons, 12.5 percent as 5 to 50 tons, and 11.5 percent as 50 to 500 tons. In 1959 these groups of vessels landed 5, 25, and 75 percent respectively of the total catch by the skipjack pole-and-line fishery during a total of 235,000 vessel-days of fishing. Catch per unit per day was 0.096, 0.675, and 1.775 metric tons for the < 5, 5 to 50, and 50 to 500 ton vessels respectively.

Relative intensity and effort in terms of days for a standard size vessel have not been computed for the Japanese fishery.

Yamashita (1958) described the Hawaiian skipjack fishery for the period 1944 to 1953; during that period there was a maximum of 28 full-time skipjack vessels. At present (1962) the Hawaiian fishery is prosecuted by 21 full-time pole-and-line vessels of about 15 to 50 net tons capacity. During 1,646 days of fishing per year this fleet landed about 4,500 metric tons of skipjack, or about 2.7 metric tons per vessel per successful day of fishing (unpublished data in BLH files) for the period 1952-60.

5.4.2 Selectivity

Two types of selectivity affect the sizes of skipjack taken in the different fisheries, (1) gear selectivity and (2) economic selectivity. Because of variations in types of gear, construction of gear, and the economy associated with different fisheries, the effect of these two types of selectivity is not always the same in different areas.

The pole-and-line fishery in Japanese waters takes skipjack from 22 cm fork length up to the maximum sizes available (Kuronuma, Kafuku, and Kikawa, 1949). Skipjack below 30 cm do not appear to be abundant in the catches as a whole, but considerable numbers may be taken on occasions. In the eastern Pacific skipjack less than 40 cm fork length are uncommon in the catch, and in the central Pacific those below 35 cm are seldom caught.

On the basis of the above information it appears that commercial pole-and-line gear selects only fish above 22 cm, and in fact rarely captures skipjack below 30 cm in length. Variations in gear characteristics, e.g., small vs. large hooks, light vs. heavy poles, etc., may account for the difference in minimum size of skipjack caught in the western, central, and eastern Pacific.

No information is available concerning the degree of selectivity for fish above the minimum size captured, although it is likely that such a selectivity does exist. However, it seems unlikely that gear selectivity is a factor for skipjack above about 45 cm length (1.9 kg wt) in any of the fisheries.

Economic selectivity is a factor restricting the capture of certain sizes of skipjack in the central Pacific, and probably in the eastern Pacific fisheries. Economic selectivity becomes effective when buyers refuse to accept skipjack below certain sizes, and when this occurs fishermen usually refrain from catching fish of or below this size. In the Hawaiian fishery, for example, skipjack below about 4 pounds are often not acceptable to the cannery, the major market during the season. In the eastern Pacific fishery the smaller skipjack often can be sold only at a price lower than that obtainable for the more desirable sizes. In addition to a price differential, a minimum legal size limit of 4 pounds (= 1.8 kg) or about 45 cm may control the minimum size of fish landed in the eastern Pacific fisheries (Schaefer, 1961). It is not known whether economic selectivity affects the catch or skipjack in the Japanese fishery, which has a much more varied market for its catch than do the central and eastern Pacific fisheries. It is quite likely that when albacore are available in large numbers, fishermen may select albacore in preference to skipjack.

5.4.3 Catches

Annual catches for the 25-year period 1935 to 1959 are listed in Table XIII and shown in Fig. 12 for the Japanese, Hawaiian, and eastern Pacific fisheries. It should be noted that the low landings for the period 1941 to about 1950 reflect changes in fishing effort due to wartime restrictions rather than changes in abundance of skipjack. This is true for all three areas of the Pacific.

It is difficult to apportion the eastern Pacific catch among the fisheries of the different countries. The FAO catch statistics for 1959 (FAO, 1960) lists skipjack landings for Mexico between 1955 and 1957, and for Peru between 1954 and 1958. However, the FAO total for the U.S., Peru, and Mexico is between 1 percent and 12 percent less than the total for the eastern Pacific listed by Schaefer (1961) for that period. It is probable that this difference is due to landings in other Central and South American countries which are not reported in the FAO summary.

The figures in Table XIII for the western Pacific are only for the Japanese skipjack landings. Other countries, including the Philippines, Australia, Korea, and Taiwan land skipjack but figures for these landings are not easily accessible because they are included in total tuna landings.

In the central Pacific, in addition to the Hawaiian fishery, there are smaller subsistence fisheries throughout the general area of Polynesia, Micronesia, and Melanesia. Skipjack are occasionally caught in the longline fishery for albacore and yellowfin in the South Pacific, but the amount of these catches is usually not included in the landings. Such catches could be considered as part of the subsistence catches, and do not reflect in any way the abundance of skipjack.

Average monthly catches for the Japanese, Hawaiian, and part of the eastern Pacific fisheries are given in Table XIV and shown in Fig. 13. The eastern Pacific landings include only those landed in or shipped into the State of California, and therefore do not equal the total eastern Pacific landings, although they include the major portion. The distinct seasonal nature of the western and central Pacific fisheries is quite apparent from this table, and it is equally apparent that the eastern Pacific landings are less seasonal.

5.5 Fisheries management and regulations

Very few regulations or management procedures affect the skipjack fisheries of the Pacific. Only in the eastern Pacific is there a legal minimum size, which as mentioned earlier is 4 pounds (= 1.8 kg or about 45 cm length). The only other limitation as to minimum size is either the refusal of processors to accept skipjack below certain sizes or to accept them at a lower price.

5.6 Fish farming, transplanting, and other intervention

Operations of this nature are not carried out with skipjack.

Table XIV
Average monthly landings of skipjack in metric tons

	Japan 1955-59	California 1955-59	Hawaii 1948-60
January	421	5,329	123
February	1,006	4,458	81
March	3,206	3,869	121
April	8,718	4,559	245
May	19,133	4,106	485
June	19,463	5,283	743
July	27,138	5,506	878
August	16,712	6,139	773
September	13,222	5,548	455
October	9,339	5,035	301
November	2,386	5,376	152
December	1,051	4,776	103

Table XIII
Landings of skipjack in the Pacific area 1935 to 1959, in metric tons
(one metric ton = 2,205 pounds or one metric ton = 266.7 kan)

	Japan 1/	Eastern Pacific 2, 3/	Hawaii 4/	Total Pacific	Mexico 5/	Peru 5/	Ryukyus 5/
1935	72,881	7,799	2,210	82,890			
1936	101,032	12,247	3,507	116,786			
1937	105,907	21,362	5,799	133,068			
1938	120,813	10,274	4,409	135,496			
1939	100,518	13,660	3,902	118,080			
1940	116,346	26,113	6,086	148,545			
1941	91,627	11,690	1,656	104,973			
1942	79,713	17,681	5	97,399			
1943	51,690	13,347	-	65,037			
1944	48,400	14,124	333	62,857			
1945	17,800	15,435	1,772	35,007			
1946	41,450	19,252	2,553	63,255			
1947	48,700	24,255	2,536	75,491			
1948	40,700	27,880	3,802	72,382			
1949	46,450	36,742	4,487	87,679			
1950	84,550	58,623	4,313	147,486			
1951	104,300	54,937	5,862	165,099	These are included in the eastern Pacific totals.		
1952	85,951	41,171	3,307	130,429			
1953	72,701	60,614	5,469	138,784			
1954	99,829	78,790	6,359	184,978		7,700	6,100
1955	99,654	58,049	4,397	162,100	300	7,600	3,900
1956	97,990	68,163	5,048	171,201	500	9,600	5,000
1957	97,463	58,185	2,780	158,428	100	10,300	4,900
1958	147,433	74,784	3,099	225,316		13,200	7,100
1959	166,707	80,543	5,629	252,879			10,800

1/ Japanese fishery statistics: 1335-1945 Espenshade, 1948
1946-1959 Japanese Ministry of Agriculture and Forestry for the years 1951, 1954-1959

2/ Eastern Pacific fishery statistics: 1935-1954 Shimada and Schaefer, 1956
1955-1959 Schaefer, 1961

3/ The eastern Pacific landings include those of Peru.

4/ Hawaiian fishery statistics: 1935-1953 Yamashita, 1958
1954-1959 Files of the Bureau of Commercial Fisheries Biological Laboratory, Honolulu

5/ FAO (1960) Yearbook of Fishery Statistics for 1959, vol. 11

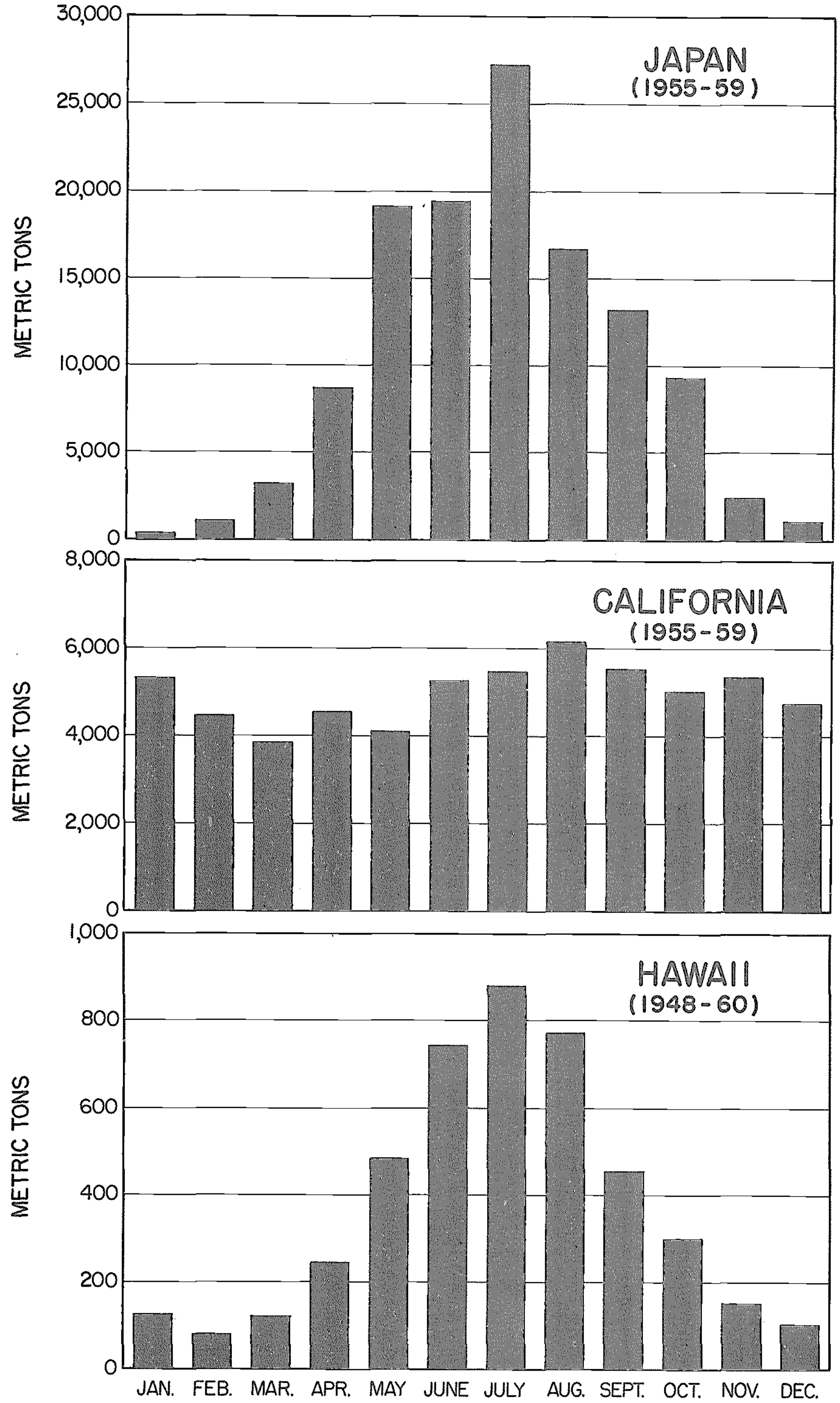

Fig. 13 Mean monthly landings of skipjack in Japan, Hawaii, and California for the period 1955 to 1959

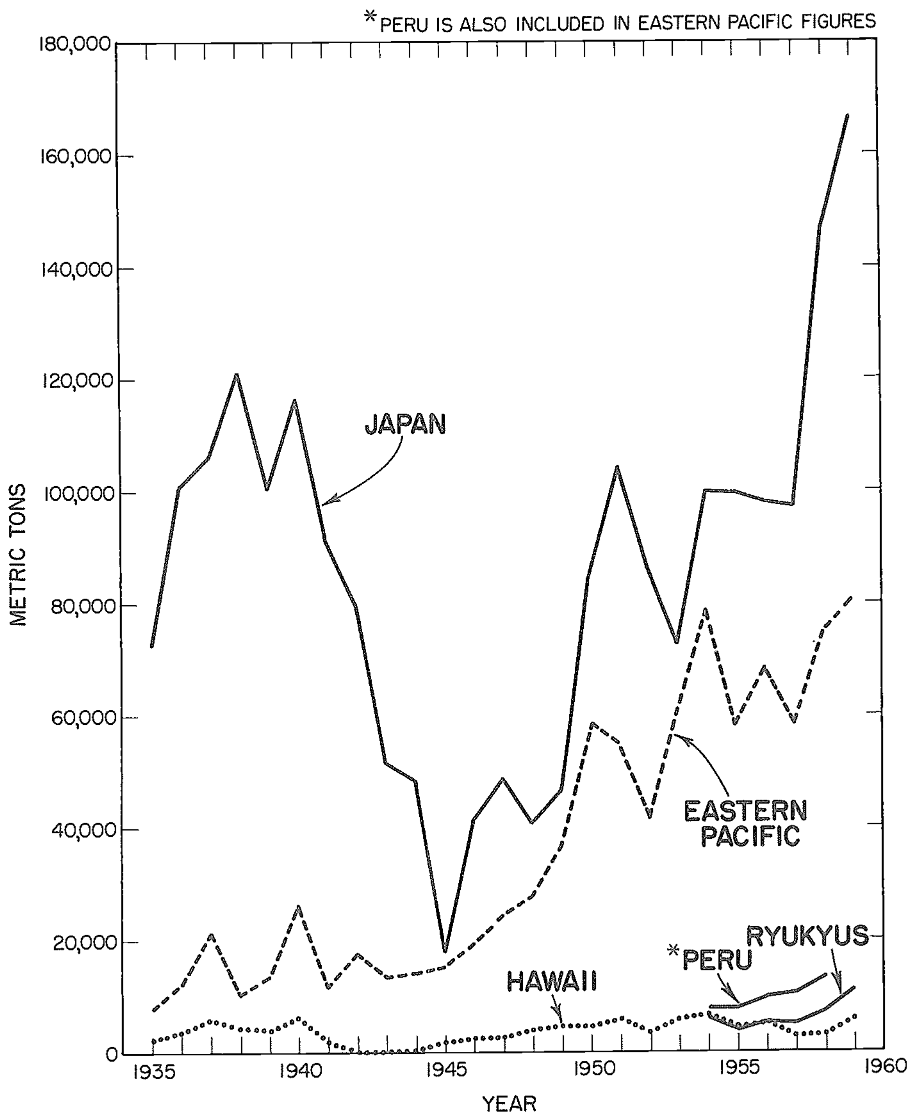

Fig. 12 Annual skipjack landings during the period 1935 to 1959 for the Japanese, Hawaiian, and eastern Pacific fisheries