SPAWNING OF THE OCEANIC SKIPJACK *Katsuwonus pelamis* (Linnaeus) IN THE LACCADIVE SEA

By

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Abstract

Preliminary observations on the spawning of *K. pelamis* in the Laccadive Sea have been made and comparisons drawn with observations from different parts of the Pacific. The peak spawning of *K. pelamis* in Laccadive Sea around Minicoy island appears to be mainly February through June. Fractional or multiple spawning is indicated.

Disparity in the sex ratio of *K. pelamis* in Minicoy waters with the males predominating during most months and the occurrence of slightly higher percentages of females among the smaller size groups and males among the larger size groups are indicated. The size of the female skipjack at Minicoy at first maturity is around 400 to 450 mm in total length. The fecundity of 63 skipjack varying in length from 418 to 703 mm observed from Minicoy varied from 151.9 to 1,977.9 thousands of ova in the most mature mode of ovaries.

FRAI DE LA BONITE A VENTRE RAYE *Katsuwonus pelamis* (Linnaeus) DANS LES EAUX DES LACCADIVES

Résumé

On a effectué des observations préliminaires sur le frai de *K. pelamis* dans les eaux des Laccadives et on les a comparées avec des observations effectuées dans différentes parties du Pacifique. Le frai le plus important de *K. pelamis* dans les eaux des Laccadives aux environs de l'île Minicoy semble intervenir surtout entre février et juin. Ce serait un frai fractionné ou multiple.

On a relevé un déséquilibre dans le rapport des sexes de *K. pelamis* dans les eaux de Minicoy, avec prédominance des mâles la plupart du temps et présence de pourcentages de femelles légèrement plus élevés dans les classes des plus petites dimensions et de mâles dans les classes des plus grandes dimensions. La taille d'une bonite à ventre raye femelle à Minicoy dans sa première maturité est de l'ordre de 400 à 450 mm en longueur totale. La fécondité de 63 bonites dont la longueur allait de 418 à 703 mm et observées à Minicoy variait de 151.900 à 1.977.900 œufs dans les ovaires de l'état le plus mature.

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DESOVE DEL BARRILETE Katsuwonus pelamis (Linnaeus) EN AGUAS DE LAS LAQUEDIVAS

Extracto

Se han efectuado observaciones preliminares del desove de K. pelamis en aguas de las Laquedivas y se han comparado con otras de diversas partes del Pacífico. La máxima actividad de desove en las proximidades de la Isla Minicoy parece ser de febrero a junio principalmente. Se indica un desove fraccionado o múltiple.

Se señala una disparidad en la proporción de los sexos de K. pelamis en aguas de Minicoy, con predominio de los machos durante casi todos los meses y porcentajes ligeramente mayores de hembras en los grupos de menor talla y de machos en los de mayor talla. La hembra del barrilete en Minicoy, al alcanzar la madurez, tiene una talla total de 400 a 450 mm. La fecundidad de 63 barriletes cuya talla variaba de 418 a 703 mm. observados en Minicoy oscilaba entre 151,9 y 1.977,9 miles de huevos en los ovarios más maduros.

1 INTRODUCTION

The oceanic skipjack, Katsuwonus pelamis (Linn.) is the largest single component of world tuna production. In recent years, skipjack have accounted for as much as 35 percent of total tuna production (Chapman, 1962). A major share is harvested from the Pacific. Skipjack remain practically an untapped resource in Indian waters, though there is no reason to suspect they are not abundant. Spawning in space and time is one aspect of skipjack biology on which factual information has been continually added in recent years. This paper is a review of information on spawning of skipjack from the Laccadive Sea. Spawning has been studied in greater detail for Pacific Ocean skipjack.

Schaefer and Marr (1948) were the first to indicate skipjack spawning from January through March in the eastern Pacific and off Costa Rica and upper Panama. They based their work on collection of adults with advanced gonads and juveniles. Schaefer and Orange (1956), from the study of specimens with advanced gonads, and Schaefer (1957, 1959 and 1960), from collection of early skipjack juveniles obtained evidence of spawning around the offshore islands Revilla Gigedo, between Cocos and Clipperton Islands, and indications of probable spawning around Galapagos Islands. The spawning period was June through November.

Many have demonstrated a definite but prolonged spawning from March through September, around the Hawaiian Islands (Eckles, 1949; Brock, 1954; Tester and Nakamura, 1957; Brock and Marr,1960). According to Brock and Marr (1960), there is a seasonal variation in the spawning of Marquesan skipjack, with the principal period from November through April. Matsumoto (1958) on analysing larvae from the central Pacific, concluded that spawning occurred at all longitudes between 120°W and 180° and up to 25°N and as far as the Samoan Islands (14°30'S) in the south, with a definite peak between 4°N and 5°S from May through September.

Kishinouye (1923, 1924 and 1926) found that in Japanese waters, spawning occurred around Ryukyu Islands from May to August. Further extension of spawning areas north of Ryukyu Islands is evident from recent studies of Yokota et al., (1961). The recovery of numerous juvenile skipjack from the stomach contents of yellowfin tuna indicated that the spawning area extends from the equatorial seas to near Tokara from November to May, and also around the southern sea of Kyushu (Yao, 1955). Advanced skipjack gonads were collected from Shikoku between Iyo and Tosa (Hatai et al., 1941) and juveniles in the south sea areas (Yabe, 1953 and 1955). Year-round spawning near the Philippine Islands has been demonstrated by Wade (1950a and 1950b) and Bunag (1956). The following western Pacific areas have been indicated as probable spawning localities, principally from April through July: in Moluccas and Celebes Seas (Shapiro, 1948); around Palau (Hatai et al., 1941, Matsui, 1942); around the equator between 141° and 157°E (Inanmi, 1942, Shimada, 1951a); around northern Marshall Islands (Marr, 1948) and near Phoenix Islands (Shimada, 1951b).

2 SPAWNING OF SKIPJACK IN THE LACCADIVE SEA

Available information from Indian waters is from the Laccadive Sea. Two juvenile skipjack from the Arabian Sea about 350 miles west of the Laccadives were collected by the Dana Oceanographical Expedition (Ehrenbaum, 1924). The Danish Dana round-the-world expedition of 1928-30 obtained a large number of tuna larvae from the Indian Ocean. Examination of the specimens between stations 3905 and 3975 has revealed the presence of larval K. pelamis (Jones, 1959). From 38 larval specimens ranging in length from 2.63 to 7.08 mm and one juvenile measuring 27 mm collected mostly from around the Laccadive Islands and Minicoy (Jones, 1959), spawning was indicated in these regions. From the conditions of gonads of skipjack caught in Minicoy, Jones (1959) indicated the probability of an extended breeding period with January to March as peak breeding time.

2.1 Spawning season

The author has studied spawning around Minicoy Island on the basis of gonads collected from May 1958 to April 1959. A brief account is given below. Details of treatment of materials and data processing are described elsewhere (Raju, 1962a). The percentage of occurrence of fish with mature ovaries during different months; the monthly mean of the 95th centile of the total frequency distribution of the ova in the random samples of the ovaries; and the monthly mean of the "gonad indices" of the skipjack collected at random from the pole and line fishery, were utilized to delineate the spawning periods at Minicoy.

In the previous study (Raju, 1962a) three stages of ovary development (imma-

ture, maturing and mature) were based on the mode of the most mature group of ova. But in the present study, use is made of the position of the 95th centile of the total frequency distribution to characterize the size of the most advanced group of ova as selected by Schaefer and Orange (1956). The classification based on the above two methods was very nearly the same. The ovaries containing the 95th centile of the total ova frequency distribution up to 0.15 mm corresponds to immature stage; those between 0.16 and 0.5 mm to maturing stage; those between 0.51 to 0.72 mm to mature stage. The ovaries designated as mature represent the highest degree of sexual maturity of the ovaries collected from Minicoy in 1958 and 1959.

Though regular weekly collections of gonads from the random samples of skipjack landing were obtained, only alternate weekly samples were utilized for ova diameter studies, as this required a great deal of time. Fig. 1 plots the percentage of occurrence of skipjack in different maturity stages. It is seen that the occurrence of mature ovaries was first observed in November and they continued more or less in the same proportion from November through January. Relatively large percentages of these ovaries were encountered in the samples from February through June.

They occurred in the samples up to July though percentages were much reduced. The mature gonads from February through July show practically no trend in the development of the ova, but merely fluctuate in that range. Ovaries with egg remnants were observed from February, though no ripe ovary in the running condition was encountered. What was believed to be a spent ovary was obtained in April. But spent ovaries with the typical bloodshot and flabby appearance were observed in fairly good numbers during June and they were frequent during July and August. From September there was a sudden decline in the proportion of occurrence, perhaps showing that recoveries of the ovaries had started without much delay in preparing for the next spawning season. Fig. 2 gives the monthly frequency distribution of the ovaries with different 95th centile groups of ova. The monthly means of these are also shown by the thick connecting line.

The "gonad index" -- the function of fish length and gonad weight (Schaefer and Orange, 1956) to determine rapidly, but objectively, the state of maturity of gonads, was determined for each fish in the weekly random samples. The monthly frequency distribution of the skipjack with various gonad indices, with their mean for each month, is given in Fig. 3. Fig. 4 plots gonad indices and the positions of the 95th centile of the ova diameter frequency for each specimen and for three arbitrary stages of maturity.

Something more is to be added about the period August to October 1958, during which the mature gonads were absent from the samples. This is the monsoon period when the fishery becomes very poor. Fishing becomes occasional and is restricted to the eastern side of the island. There is no information on whether mature females were absent on the regular island fishing grounds or only absent in the particular area where fishing was restricted. But when fishing resumed in mid-October, mature females were not encountered and from November through January they were apparently in reduced proportions. This leads one to ask whether there is a definite spawning period or at least a peak spawning season, from February through June.

Mature ovaries first appear in November. But as they are not fully ripe, some time must elapse before they begin to spawn. Unfortunately no information is available on the rate of ova development. Jones (1959) collected three larvae during early December. The possibility that those gonads which mature during November can reach spawning condition and commence first spawning in December around this island is not ruled out. Dr. Jones made no collection of larvae during months other than December to March in 1958-59 around Minicoy.

2.2 Size of mature ova

Ova diameters of K. pelamis, observed from the advanced ovaries by many workers in different parts of the Indo-Pacific, range mostly from 0.55 to 0.80 mm. This is believed to represent a somewhat earlier stage of maturity. The largest transparent ova with a single golden yellow oil globule recorded from a hermophrodite skipjack from Minicoy was 0.809 mm in diameter (Raju, 1960). The largest ova that Brock (1954) found measured 1.125 mm in diameter and this perhaps is close to the size of the fully ripe ova in normal individuals.

2.3 Indication of spawning

The spawning places of tunas are indicated from the evidence based on the

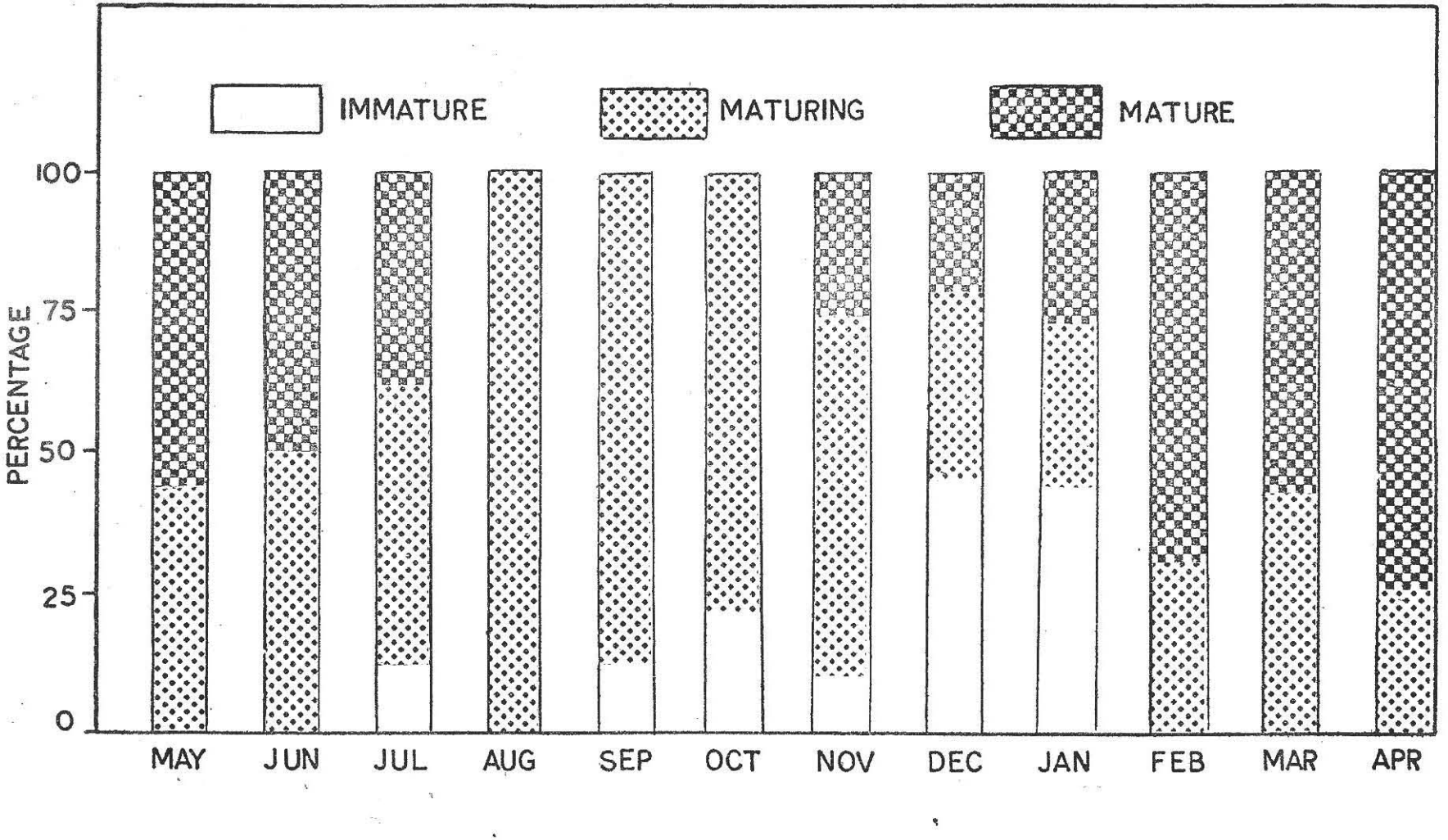

Fig. 1. Monthly percentage frequency of occurrence of the skipjack with different maturity stages among the random samples obtained from the pole and line fishery at Minicoy, 1958 to April 1959

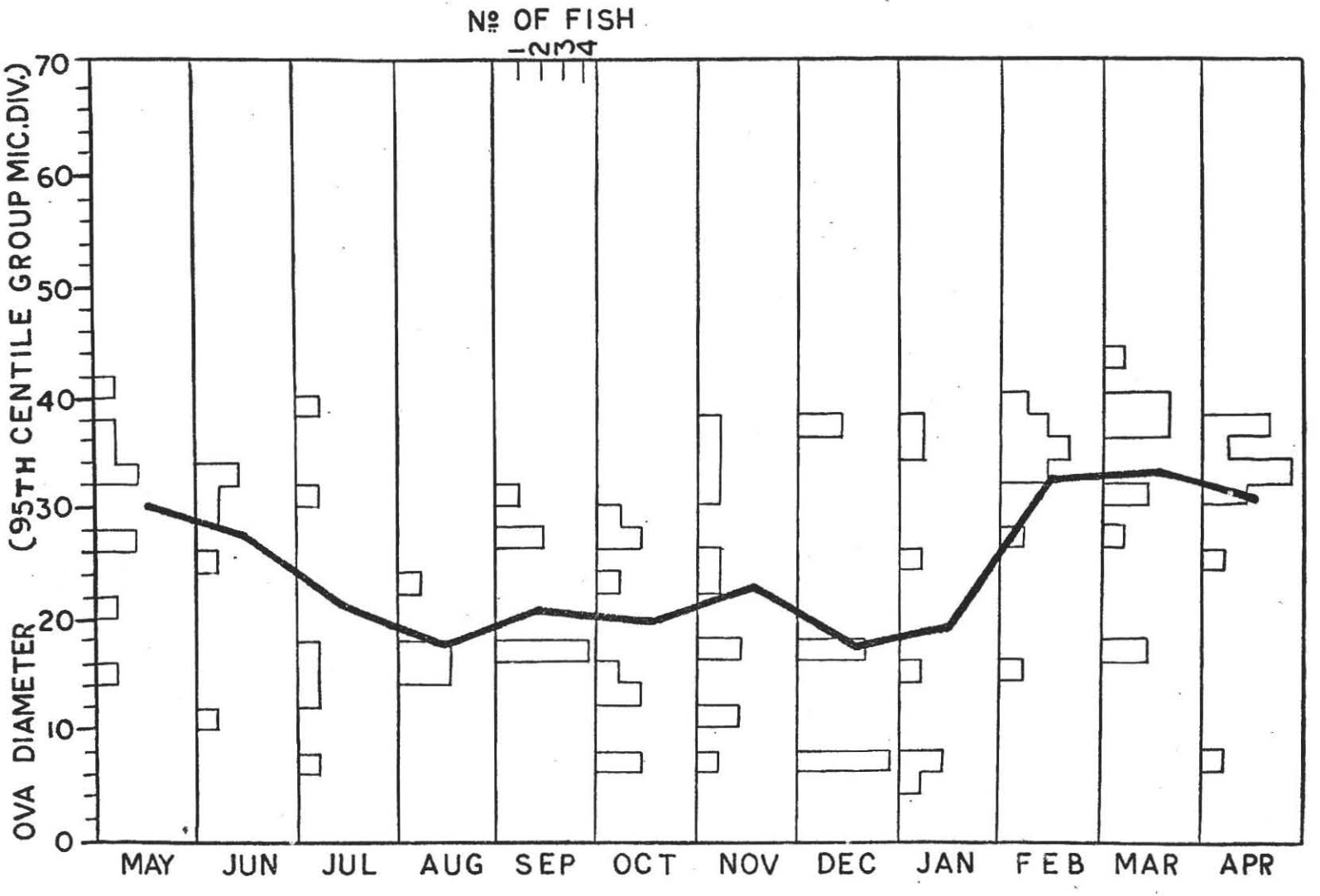

Fig. 2. Monthly frequency distribution of ovaries with 95th centile groups of ova obtained from the random samples of pole and line fishery, May 1958 to April 1959, at Minicoy (The monthly means are connected by thick lines. One micrometer division equals 0.0165 mm)

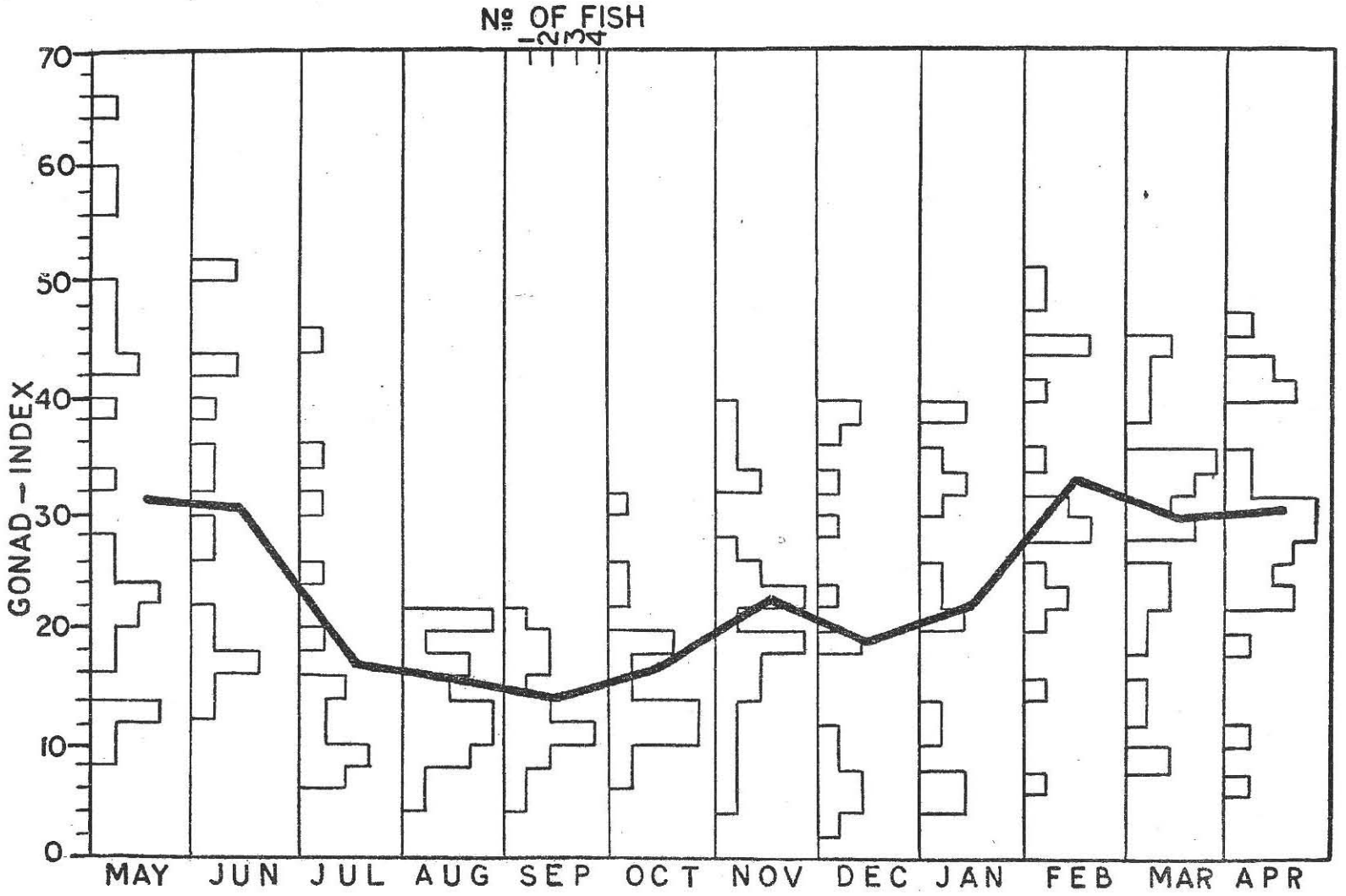

Fig. 3. The monthly frequency distribution of the female skipjack with different gonad indices observed from the random samples obtained from the pole and line fishery at Minicoy, May 1958 to April 1959 (The monthly means are connected by the thick line)

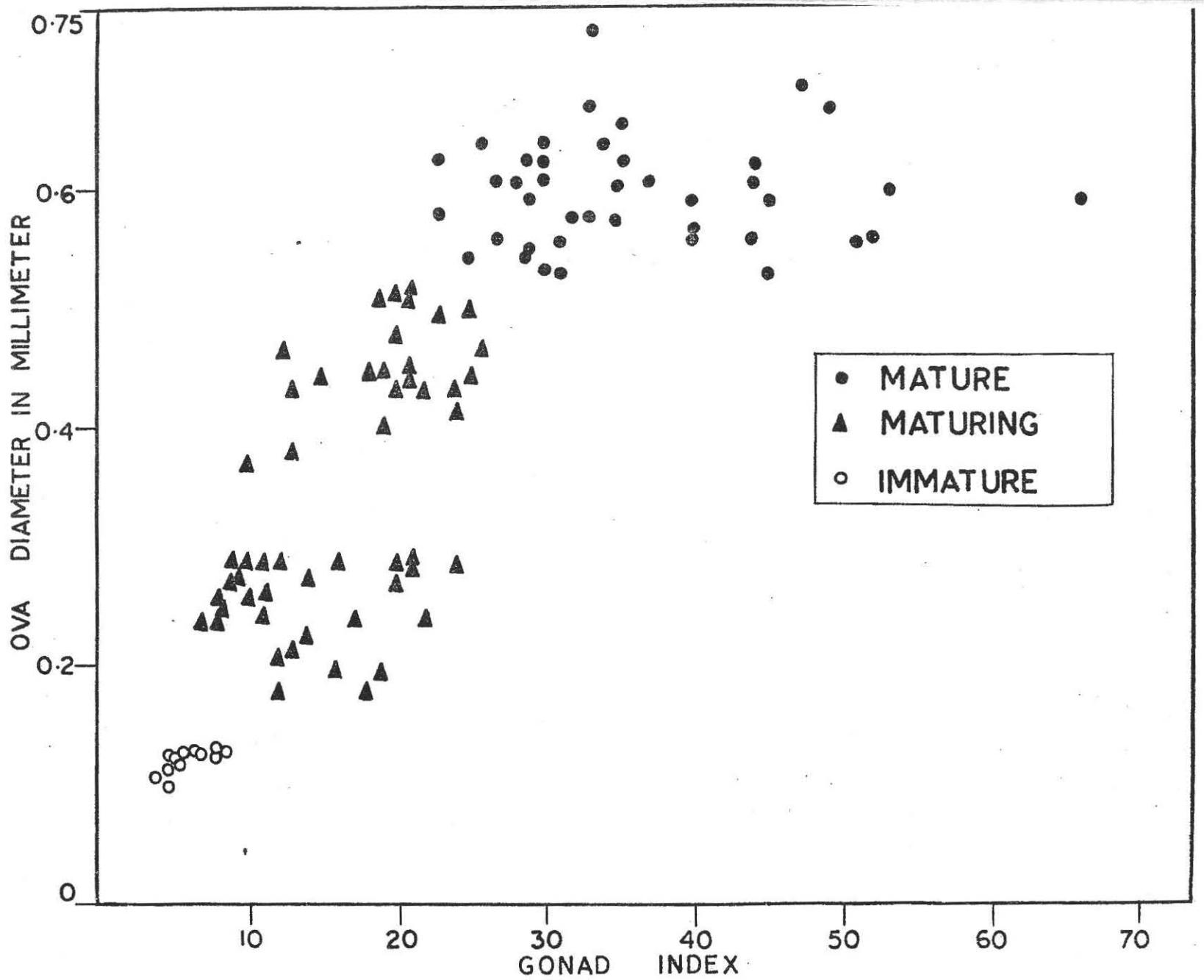

Fig. 4. Scatter diagram showing the relation between the gonad index and the position of the 95th centile of the ova diameter frequency of 103 skipjack observed from the random samples obtained from the pole and line fishery at Minicoy, May 1958to April 1959

examination of advanced gonads, collection of larvae and juveniles in plankton hauls or recovery of them from the stomach contents of pelagic fishes. Inferences on spawning around Minicoy and the probable season are made on the assumption that the occurrence of the ovaries in advanced stages of sexual maturity, or recently spent, are indicative of spawning near the place and time of capture.

The presence of egg remnants in certain of the ovaries collected from Minicoy is also a proof of spawning having taken place there. But the application of the above evidence to the spawning of skipjack (and other tunas as well) has always the limitation that skipjack is a pelagic fish capable of migrating great distances in a few days. On the other hand, the presence of young larval stages around Minicoy (Jones, 1959) provides direct evidence of recent spawning in the vicinity of the island, provided the transport of larvae by current is not considerable. Ther is no information on the direction and the velocity of the currents around Minicoy, the duration of the incubation period of skipjack eggs, the size of the larvae at hatching and the migration of adult skipjack.

2.4 Frequency of spawning

A study of the size distribution of ova in mature skipjack ovaries from Minicoy waters reveal two prominent batches of developing ova in addition to the stock of ova. The growths of the two batches could be traced from the maturing up to the mature stages of the ovaries described. These have been described in detail elsewhere (Raju, 1962a). But the absolute time interval of the growth of the batches of ova is unknown. In the fully-spent gonads, the two modes or batches of mature ova completely disappear, leaving a single mode of immature stock of ova. It was also found that in the ovaries in which the egg remnants occurred there were again two modes, except in three ovaries taken in April and July in which there was only a single mode. This clearly indicates that ova are spawned in batches, but how many times the ova are released is not known. Bunag (1956) is of the opinion that several batches of eggs are released before it becomes completely spent. Brock (1954) bases the possibility of skipjack from Hawaii spawning several times, on three lines of evidence, viz., the multi-modal distribution of ova diameters during spawning season and its absence at other times; the absence of an overall trend in ova diameter during spawning season and the absence of fish that are obviously spawned out until after the end of the spawning season. Thus, though fractional spawning has been indicated for skipjack and various other species of tuna, the exact number of batches released is still a riddle to fishery biologists.

3 GENERAL OBSERVATIONS

During observations from Minicoy Island, a very high percentage of males was found, particularly during the supposed active spawning period. This agrees with Brock (1954), Tester and Nakamura (1957) and Wade (1950a). Schaefer and Orange (1956) found a greater proportion of females during most of the periods in which they examined eastern Pacific skipjack. During the monsoon period, the percentage of females was greater. Table I shows the numbers of the males and females encountered in the random samples, and their percentages for each month. In Tables II and III are tabulated the percentage frequency of the two sexes among various groups during different months of observations, and Fig. 5 depicts the percentages of fish of the two sexes in all samples taken together within each size group. It appears there is a slightly greater percentage of females among smaller size categories and among larger size categories, a greater percentage of males. The relative percentages of the two sexes are cleary seen in Table IV where they are grouped into four broad size groups.

The smallest two skipjack that had mature ovaries were 390 mm and 396 mm in standard length. The largest with immature gonad was 481 mm. But ordinarily, fish over 450 mm with immature gonads were very rare at Minicoy. Spent ovaries were encountered in the size group 400 to 450 mm. Therefore this appears to be the size of first maturity. This agrees with the observations of Brock (1954), Wade (1950a) and Marr (1948). But Schaefer and Orange (1956) found that in the eastern tropical Pacific, the size at first maturity is near 550 mm and that a large share of individuals do not mature below 600 mm in certain areas. According to Brock (1954), skipjack reach 400 to 450 mm in one year. He concluded they first mature when about one year old.

There is not much information on fecundity. The available fecundity estimates are made from the total number of ova in the most mature mode of the ovaries in which there was no indication of

Table I

Monthly sex ratios of skipjack observed from the random samples of pole and line fishery at Minicoy Island during the period May 1958 to April 1959

No.	Months	Total number of specimens examined	Number of Males	Number of Females	Percentage of Males	Percentage of Females
1	May	274	234	40	85.4	14.6
2	June	102	79	23	77.5	22.5
3	July	55	20	35	36.4	63.6
4	Aug.	118	40	78	33.8	66.2
5	Sept.	132	58	74	43.1	56.9
6	Oct.	175	101	74	57.8	42.2
7	Nov.	233	99	134	42.5	57.5
8	Dec.	261	173	88	66.3	33.7
9	Jan.	254	189	65	74.4	25.6
10	Feb.	245	197	48	80.5	19.5
11	Mar.	167	109	58	63.5	34.7
12	Apr.	213	156	57	73.2	26.8
	T O T A L	2,229	1,455	774	65.3	34.7

Table II

Percentage frequency of female skipjack of different size groups observed from the random samples obtained from the pole and line fishery at Minicoy Island during different months of the period May 1958 to April 1959

Months	Total length in millimeters															
	381 to 400	401 to 420	421 to 440	441 to 460	461 to 480	481 to 500	501 to 520	521 to 540	541 to 560	561 to 580	581 to 600	601 to 620	621 to 640	641 to 660	661 to 680	681 to 700
May	..	4.1	4.1	8.3	12.5	20.9	12.5	29.3	8.3	..	..	..	..	..	..	..
June	..	..	6.2	18.8	31.3	18.8	6.2	12.5	6.2	..	..	..	..	..	..	..
July	..	..	7.7	15.4	30.7	23.1	23.1	..	..	..	..	..	..	..	..	..
Aug.	5.3	..	5.3	10.5	36.8	21.0	10.5	..	..	..	..	5.3	..	..	..	5.3
Sept.	..	..	6.7	13.3	13.3	26.7	13.3	6.7	13.3	..	..	6.7	..	..	..	..
Oct.	..	5.6	5.6	27.7	22.1	11.1	5.6	5.6	11.1	..	..	..	..	5.6	..	..
Nov.	..	8.0	8.0	8.0	24.0	8.0	8.0	16.0	8.1	4.0	4.0	..	..	4.0	..	..
Dec.	6.7	20.0	33.2	6.7	13.3	6.7	6.7	6.7	..	..	..	..	..	..	..	..
Jan.	5.9	23.5	17.6	5.9	5.9	11.8	17.6	5.9	..	5.9	..	..	..	..	..	..
Feb.	..	5.6	11.1	16.6	11.1	16.6	5.6	16.6	5.6	..	..	..	..	..	..	..
Mar.	..	..	3.7	3.7	11.1	22.3	3.7	3.7	3.7	3.7	14.8	14.8	7.4	3.7	..	..
Apr.	..	4.0	4.0	4.0	8.0	8.0	4.0	8.0	8.0	8.0	8.0	12.0	12.0	8.0	..	4.0

Table III

Percentage frequency of male skipjack of different size groups observed from the random samples obtained from the pole and the line fishery at Minicoy Island during different months of the period May 1958 to April 1959

Months	Total length in millimeters															
	381 to 400	401 to 420	421 to 440	441 to 460	461 to 480	481 to 500	501 to 520	521 to 540	541 to 560	561 to 580	581 to 600	601 to 620	621 to 640	641 to 661	661 to 680	681 to 700
May	3.4	1.7	11.9	8.4	11.9	13.6	8.4	13.6	10.2	8.4	5.1	1.7	1.7	..	..	..
June	..	..	..	..	37.9	21.6	13.5	10.8	5.4	5.4	2.7	2.7	..	..	..	..
July	..	..	..	..	55.6	11.1	..	11.1	11.1	..	11.1	..	..	..	..	..
Aug.	..	..	..	..	45.4	36.4	..	9.1	9.1	..	..	..	..	..	..	..
Sept.	..	5.3	..	..	10.5	15.8	21.0	10.5	..	10.5	10.5	5.3	5.3	5.3	..	..
Oct.	..	..	..	8.4	4.0	28.0	20.0	12.0	4.0	4.0	4.0	8.0	8.0	..	..	..
Nov.	..	..	..	..	6.4	22.5	16.1	19.4	13.0	9.7	6.4	3.2	3.2	..	..	..
Dec.	..	..	3.2	3.2	38.7	29.1	13.0	3.2	3.2	3.2	3.2	..	..	..	..	..
Jan.	..	..	2.1	14.5	18.7	20.8	12.5	6.2	6.3	..	4.2	6.3	4.2	2.1	2.1	..
Feb.	..	..	13.9	19.4	11.1	8.3	5.6	5.6	2.8	13.9	8.3	8.3	2.8	..	..	..
Mar.	..	..	5.6	11.1	16.6	11.1	16.6	..	5.6	5.6	11.1	11.1	..	..	5.6	..
Apr.	..	..	..	..	..	7.7	11.5	15.5	3.8	3.8	7.8	15.5	19.1	11.5	3.8	..

Table IV

Percentage frequency of the two sexes of skipjack observed among the random samples obtained from the pole and line fishery at Minicoy Island during the period May 1958 to April 1959

Sex	Total length in millimeters			
	381 to 460	461 to 540	541 to 560	621 to 700
Female	27.7	54.5	13.1	4.7
Male	12.5	58.6	22.6	6.2

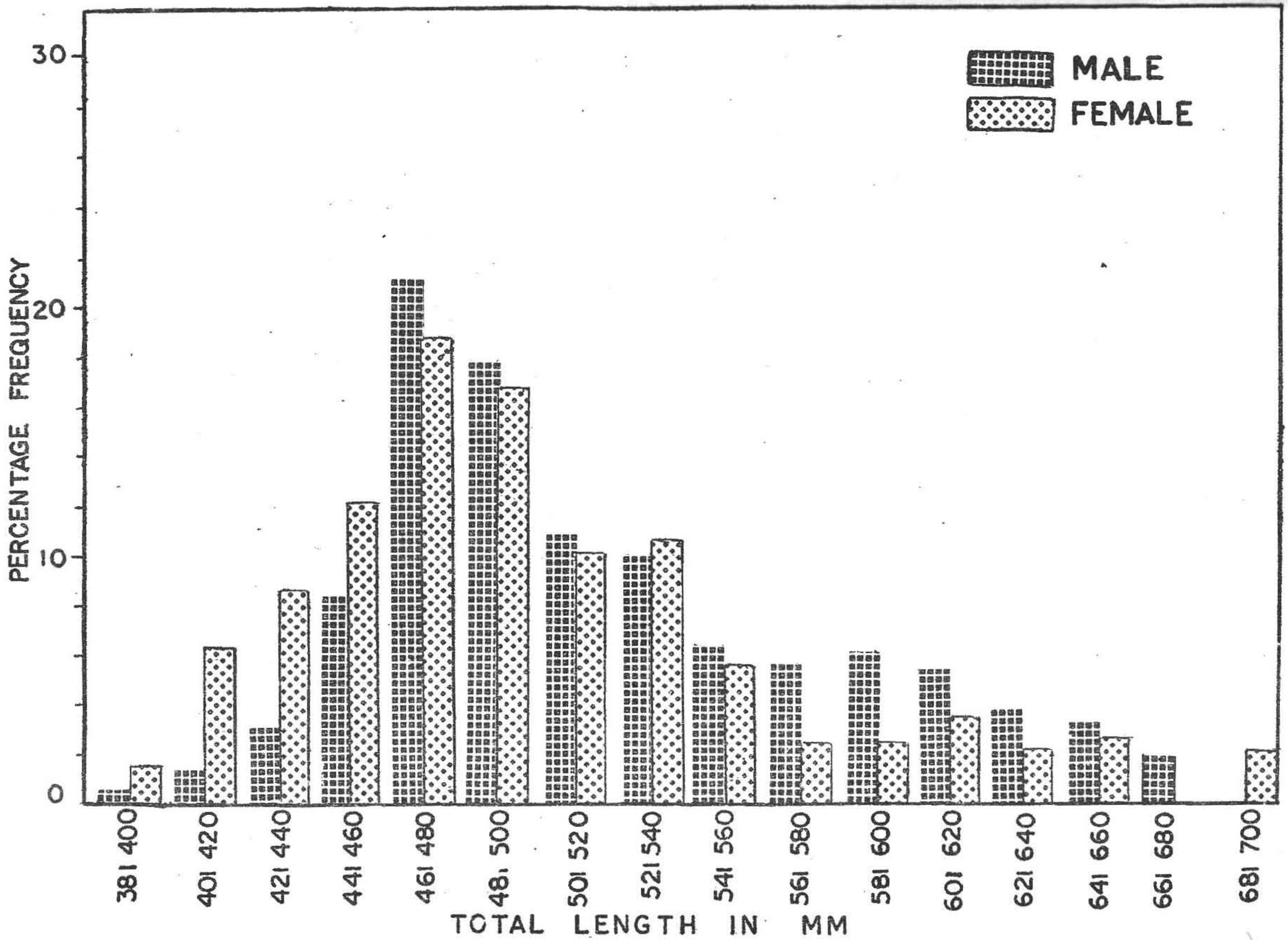

Fig. 5. The percentage of length frequency of the skipjack of the two sexes at Minicoy observed among the random samples obtained from the pole and line fishery during the period May 1958--April 1959

previous spawning in the immediate past. Schaefer(1961) found, from fourteen sets of ovaries collected near the mouth of the Gulf of California, 407 to 1327 thousands of ova in the most advanced mode from skipjack ranging in total length from 659 to 699 mm. Raju (1962b) observed that in 63 Minicoy skipjack ranging from 418 to 703 mm ova numbered from 151.9 to 1,977.9 thousands in the most advanced mode with a wide range of variations among individuals of the same size group.

4 DISCUSSION

Regarding the Pacific spawning season, we find a variety of opinions. In the final analysis it appears mainly to oscillate between two opinions: (i) that they spawn year round with perhaps some peak periods and (ii) that there is a definite spawning season. Many appear to favor the former. One handicap in the study of spawning of skipjack from the Laccadive Sea has been the lack of specimens in ripe running condition and the gonads indicating almost the same level of maturity. It may not be that the gonads remain in a single developmental stage, but it may be that schools of fish that have gonads at more or less the same stage of maturity are continually coming to the waters and become available to the fishery. The lack of ripe specimens in the catches may be due to the fish moving offshore or to deeper waters to spawn or it may be due to the schools breaking up and ceasing to feed (Schaefer and Orange, 1956). A thorough study of the differences in the individual gonads within the schools, or variations between schools, is necessary to ascertain the annual changes in the degree of ripeness of gonads.

The waters around many oceanic islands are known to be definite spawning grounds of this species.

The preponderance of males during the spawning season has also been reported by a number of workers in the Pacific. The cessation of female feeding activity during spawning or their migrations have been offered as explanations.

Within this widely-distributed species we find wide variations in spawning season, spawning intensities, size at first maturity and fecundity in different areas. Whether these variations are results of race-connected characteristics of the different "races" or "stocks" occupying different regions, is an important problem awaiting solution.

5 SUMMARY

1. Preliminary observations on the spawning of K. pelamis in the Laccadive Sea have been made and comparisons drawn with observations from different parts of the Pacific.

2. The peak spawning of K. pelamis in the Laccadive Sea around Minicoy Island appears to be mainly February through June.

3. Fractional or multiple spawning is indicated.

4. Disparity in the sex ratio of K. pelamis in Minicoy waters with the males predominating during most months and the occurrence of slightly higher percentages of females among the smaller size groups and males among the larger size groups are indicated.

5. The size of the female skipjack at Minicoy at first maturity is around 400 to 450 mm in total length.

6. The fecundity of 63 skipjack varying in length from 418 to 703 mm observed from Minicoy varied from 151.9 to 1,977.9 thousands of ova in the most mature mode of ovaries.

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