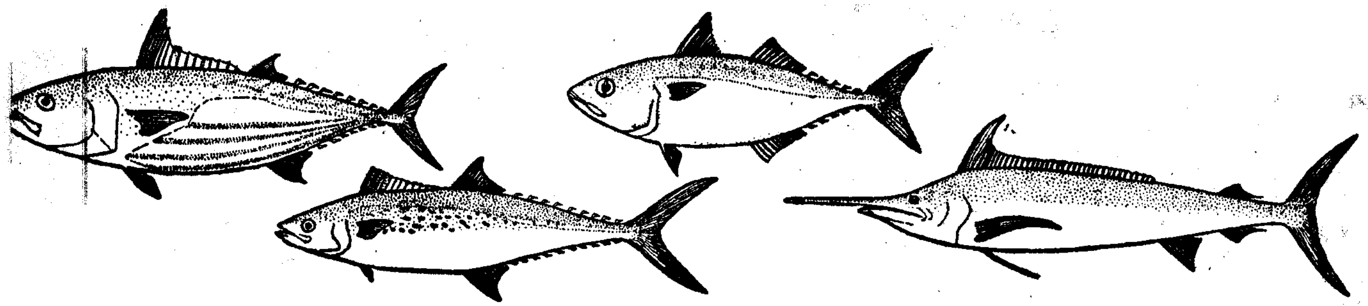


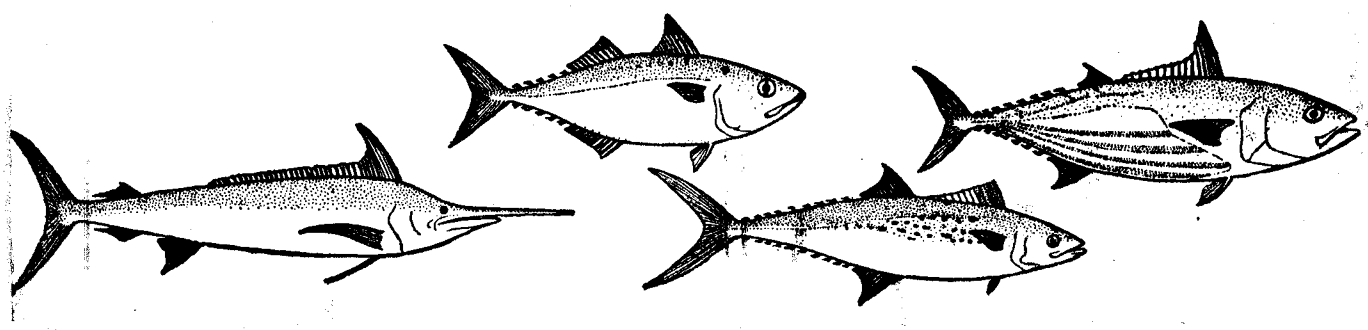
SYMPOSIUM ON SCOMBROID FISHES

PART II

MARINE BIOLOGICAL ASSOCIATION OF INDIA

MANDAPAM CAMP

S. INDIA



PROCEEDINGS OF THE

SYMPOSIUM
ON
SCOMBROID FISHES

HELD AT MANDAPAM CAMP FROM JAN. 12-15, 1962

PART II

SYMPOSIUM SERIES I

MARINE BIOLOGICAL ASSOCIATION OF INDIA

MANDAPAM CAMP

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STUDIES ON THE SPAWNING OF THE OCEANIC SKIPJACK *KATSUWONUS PELAMIS* (LINNAEUS) IN MINICOY WATERS*

By G. Raju

Central Marine Fisheries Research Institute, Mandapam Camp, India

Introduction

The oceanic skipjack *Katsuwonus pelamis* (Linn.) is the most important of the commercially exploited species of tuna at Minicoy Island (Lat. 8′ 7″ N. Long. 73′ 18″ E.). It is the species that affords the greatest promise for the expansion of the Laccadive tuna fishing industry of which extremely little is known on the feeding and spawning habits, life-history, rate of growth, racial stock, schooling behaviour and factors controlling their migration etc., essentially needed for the rational exploitation of the fishery without causing any detrimental effects on the potential resources.

Matsui (1942) from the study of the gonads of *K. pelamis* concluded that this species spawned in the vicinity of Palau. Schaefer and Marr (1948) and Schaefer (1948) have shown the spawning of skipjack in the Pacific ocean off Costa Rica and Panama from the study of skipjack in the advanced stages of sexual maturity collected in the month of February, spawned-out fish in late March and very young juveniles from the stomach of an adult of the same species. Wade (1950, 1951) by the examination of gonads and capture of larval forms was able to demonstrate the spawning of skipjack in the vicinity of Philippine islands throughout or the most of the year. Bell (1951) found juveniles of *K. pelamis* in the stomachs of large long line caught tunas near the equator between 141 and 157 E. Long. and very young juveniles were also collected near the Phoenix islands. Brock (1954) by the study of the gonads of *K. Pelamis* caught near the Hawaii islands indicated a pattern of multiple spawning from late February to first part of September. Recently Schaefer and Orange (1956) from the systematic study of the gonads of *K. pelamis*, concluded that there is though little evidence of their spawning along Baja, California, Gulf of California and off Central America there was a convincing evidence of their spawning in the vicinity of Revilla Gigedo islands during April, September and November. Jones (1959) demonstrated the spawning of this species in the Laccadive Sea during January to March through the collection of larval and juvenile forms.

The present observation on the spawning of *K. pelamis* is all the more interesting on account of the extensive work at present, carried out in different parts of the Indo-Pacific and the absence of any such observations from Indian waters. The present paper on the spawning of oceanic skipjack in Minicoy waters has the following objectives : (1) to study the reproductive process with the help of ova diameter measurements to demonstrate the developmental changes of ova that take place in the gonads from the immature to the ripe stage ; (2) to analyse the size composition of the two sexes with their seasonal distribution and the composition of different maturity stages of the populations of *K. pelamis* contributing to pole and line fishery with a view to find out whether there is any differential fishing of the sexes and differential growth of them if existent ; (3) to investigate the methods of determining rapidly and yet objectively the state of maturity of the gonads in order to provide a basis of more extensive and more efficient subsequent investigations in these and other areas, and (4) to investigate the seasonal changes of the condition factor (' k ') for finding out the seasons of this species in their best ' condition '.

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Material and Methods

The materials used in this study were obtained from skipjack landings made in waters adjacent to Minicoy Island around 4 to 6 miles by the local commercial pole and line fishery mainly operated between 7 a.m. and 2. p.m. during the period May 1958 to April 1959.

The date of collection, length, weight of the fish, gonads, sex, etc., were recorded for each. The ovaries together with the attached peritoneal and vascular tissues were carefully removed from the fish and the posterior end of each ovary was severed at its junction with the oviduct and after the superfluous tissues were removed the ovaries were weighed to the nearest 0.1 gm. and preserved in 5% formalin.

Establishment of Sampling Procedures

In order to study the distribution of the most mature group of ova within an ovary as a preliminary in establishing a procedure for sampling each ovary, the method described by Yuen (1955) and Tamio Otsu and Uchida (1959) was followed. Accordingly the cross-section from the anterior middle and posterior parts of the ovary were taken and were designated as A, B and C and three sub-sections (outer, middle and inner) were designated as 1, 2 and 3 respectively. Samples from each of these 9 sub-sections were taken and were weighed to the nearest 0.001 gm. All the ova of the most mature group were then measured.

The mean ova diameters for sections A, B and C were 0.499 mm. and 0.502 mm. and 0.499 mm. respectively. The mean ova diameters for the sub-sections ranged from 0.497 to 0.505 mm. For sections A and B the mean ova diameters were largest in the inner sub-sections being 0.504 and 0.505 mm. respectively. For section C the mean ova diameter was largest in the middle sub-section. The number of eggs in the most advanced group to be expected from 0.1 gm. of each sample was calculated. It was found to be 740, 815 and 789 respectively in sections A, B and C. Among the sub-sections they varied from 762 to 846.

Because of the close similarities in the mean ova diameter and number of ova per unit weight of the ovary these were not tested by the analysis of variance.

A comparison was made of the egg diameter frequencies of the right and left ovaries. A sample of ova was obtained from each ovary and the measurements were made of all the eggs with diameters greater than 0.13 mm. The frequency distributions for the right and left ovaries were compared by chi-square test. The results indicate the similarity in the frequency distribution of egg diameters from the right and left ovaries of the same pair $X^2=22.88$ d.f. 30 ($P=0.80$). Thus it was concluded that the ova develop uniformly throughout the ovary and in both ovaries of a fish. All further ova samples for the study were taken from the midsection of the left ovary and are considered as representative of both ovaries.

Description of the Gonads

Testes

The testes are paired, elongate organs suspended by the mesorchium in the body cavity. They are thin and ribbon-like in immature fish but with the advance in maturity they develop into somewhat flattened whitish yellow organs which are relatively solid. Their products are collected by series of small ducts vasa efferentia leading posteriorly to the large duct the vas deferens, which opens to exterior through the urinogenital orifice.

June (1955) examined both the testes and ovaries in his study of the spawning of the yellowfin tuna in Hawaii waters but found that for this study the testes were not suitable because no quantitative measure of their sexual products could be found that would provide reasonable accurate estimates of their relative stage of development. This was found to be true for the skipjack from Minicoy waters also.

Ovaries

The ovaries like the testes are paired elongate organs suspended from the dorsal wall of the body cavity by the mesovarium. In immature fish the ovaries are ribbon-like and resemble the immature testes in appearance. They become progressively enlarged in length and girth as the fish attains sexual maturity. The mature and ripe ovaries are orange yellow in colour.

Classification of Ovaries and Development of Ova

The ovaries of sexually mature fish contain several developmental groups of ova at one time or other throughout the year. On the basis of the characteristics of the largest ova present, the ovaries were designated the following stages of maturity. For studying the frequency of ova in an ovary, a random sample of ova from each ovary was measured by the methods adopted by Clark (1934) and De Jong (1934), and Prabhu (1956).

Immature.—Immature ova ranged from 0.1 mm. to 0.19 mm. in diameter with a mode at about 0.08 mm. Each ovum contains a large vesicular nucleus enclosed in a clearly defined nuclear membrane. Ova of this group are present in all the ovaries throughout the year. Preserved in formalin the ova are translucent spherical bodies and are invisible to the naked eye.

Maturing.—The ovaries at this stage contain ova which range from 0.23 to 0.43 mm. As the ova increases to about 0.23 mm. the nucleus enlarges and the yolk granule appears and as the ova advance towards maturity the group beyond 0.29 mm. become opaque and exhibit the

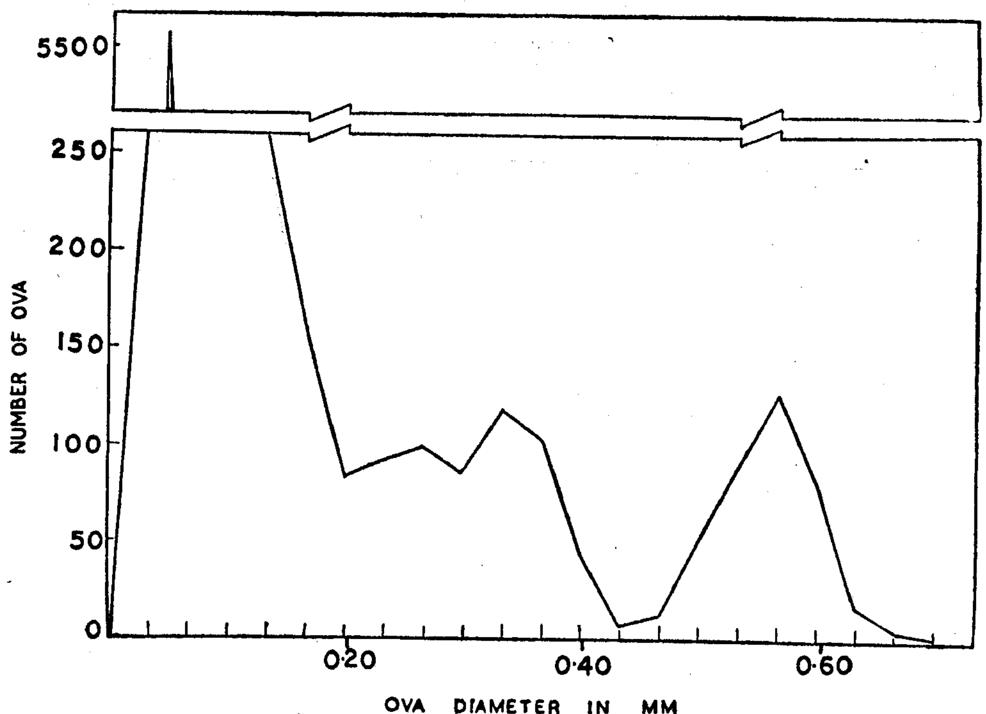


Fig. 1. Frequency polygon of ova diameters of a random sample of ova from a mature ovary of a skipjack taken in Minicoy waters.

characteristic yellowish colour in formalin. The yolk granules appear as highly refractive spherical bodies in the cytoplasm.

Mature.—On reaching the stage at which the ova are about to be spawned distinct morphological changes occur in them and they begin to lose their opacity. The ova in the mature condition measure between 0.43 to 0.83 mm. in diameter.

Ripe.—The mature ova on further losing their opacity assume a translucent greyish colour in formalin. In the present study there was no normal ovary in fully ripe stage. However, one hermaphrodite gonad described elsewhere (Raju 1960) had fully ripe ova with a single golden yellow oil globule. The frequency distribution of ova diameter of this ovary (Fig. 2) was in all essential respects similar to this stage and is taken to represent the highly developed ova of the sample studied. To show further the size distribution of the developmental groups the frequency distribution of a random sample of ova from a normal mature ovary in the ovarian region of the hermaphrodite gonad is shown in Figures 1 & 2 respectively. The presence of two prominent modes is quite clear in both cases.

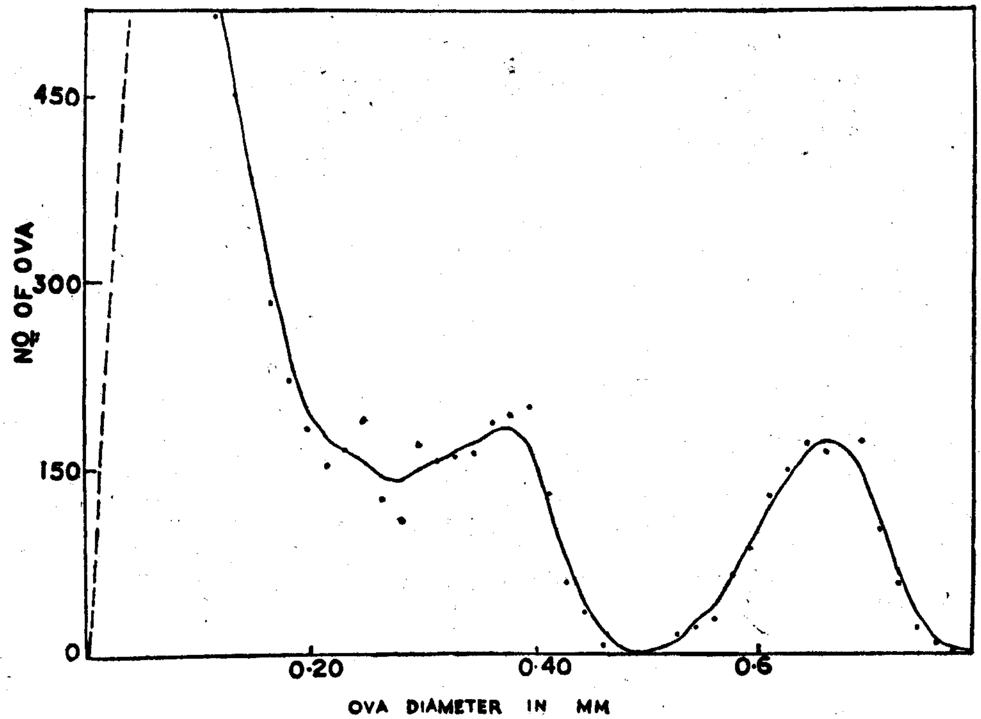


Fig. 2. Frequency curve of ova diameters measured from a random sample from the ovarian part of a hermaphrodite skipjack obtained from Minicoy waters. (The original data represented in dots are smoothed twice by a moving average of three and is represented by the line.)

Spent.—Towards the end of spawning season the ovaries decrease in size and become hollow, flaccid and bloodshot and gradually assume the immature—maturing stages. Therefore while classifying them on the basis of ova diameter frequencies these are included under the maturing stage. Following spawning, ripe ova remnants in various stages of degeneration are found in the lamina of the ovaries.

As pointed out by Bunag (1956) the available literature does not show any standardized method of classifying ovaries. Basing the classification on the external appearance alone as done by Matsui (1942) Schaefer and Marr (1948) was found to be inadequate and often misleading even for gross classification of gonads. The characters used for classifying the ovaries on the external appearances alone were size, degree of softness or turgidity and the degree of ramification of blood vessels. These were often found to be poor criteria for classifying ovaries. Therefore the ovaries are classified as immature, maturing, mature and ripe on the basis of ova frequency distribution.

According to the position of the most mature group of ova in the frequency polygon in the present study 104 ovaries were examined and classified under 8 arbitrary stages.

Immature :

Stage A : Mode at about 0.8 mm. and no ova above 0.13 mm.

Maturing :

Stage B : Mode of most mature group of ova below 0.23 and no ova above 0.29 mm.
Stage C : Mode of the most maturing ova between 0.23 and 0.33 mm.
Stage D : Mode of the most maturing ova between 0.33 and 0.43 mm.

Mature :

Stage E : Mode of the most mature ova between 0.43 and 0.53 mm.
Stage F : Mode of the most mature ova between 0.53 and 0.63 mm.
Stage G : Mode of the most mature ova between 0.63 and 0.73 mm.
Stage H : Mode of the most mature ova between 0.73 and 0.83 mm.

These stages are graphically shown in fig. 3. which has no connotation of time but simply illustrates the developmental stages from the immature to the ripe or spawning stage. These are the polygons of pooled frequencies of several fish of the same maturity stage as indicated in the right side of the figure.

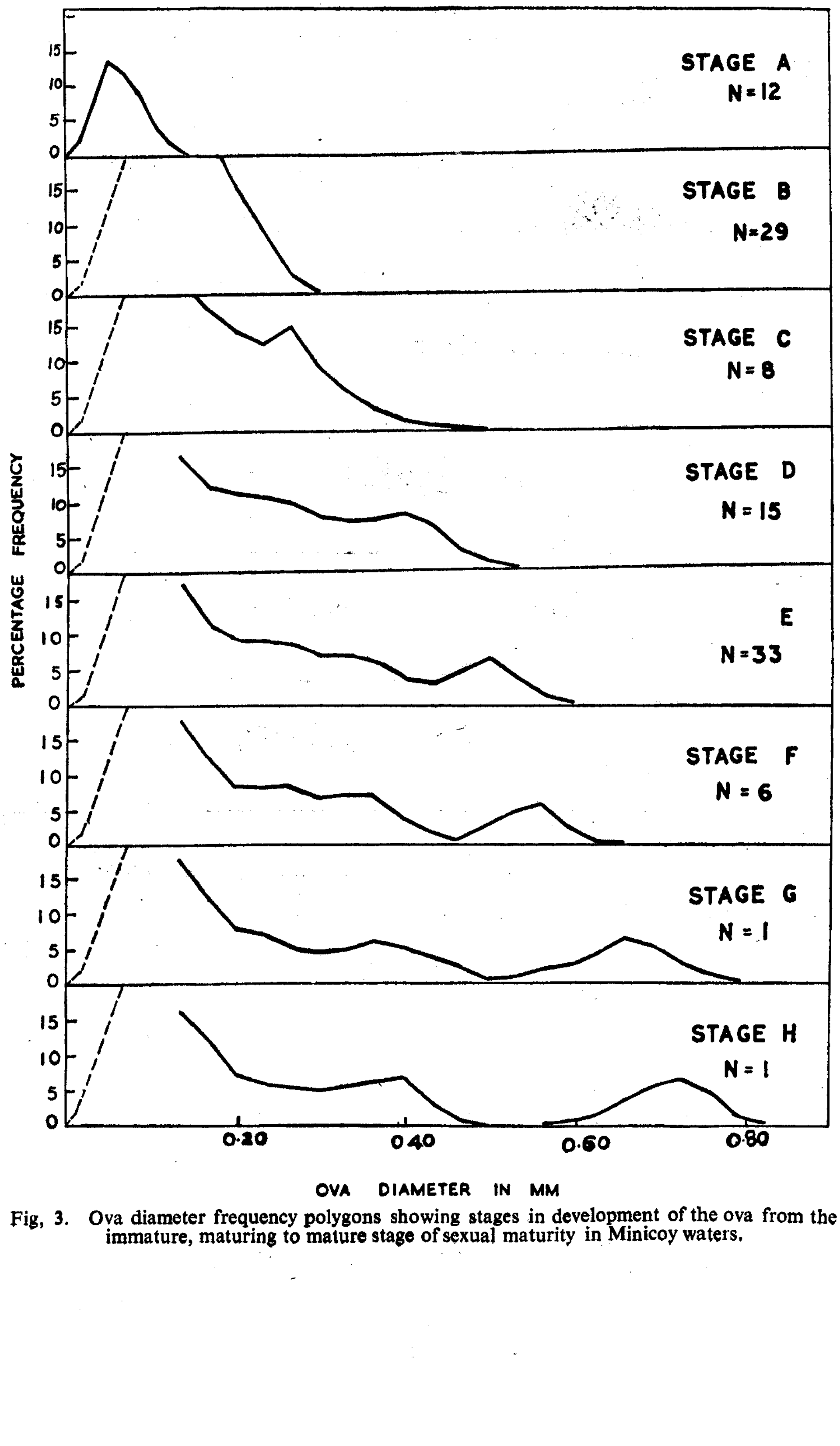
Frequency of Spawning

Clark (1934) bases the cases for multiple spawning on four lines of evidence. ' The multiplicity of modes and the diameter frequency curves, a high degree of correlation between the growth of these successive groups of eggs, the occasional presence in the ovary of a few ripe unspawned accompanied by a new ripening group and the decrease as the breeding season advances, in the numerical ratio between the successive batches of eggs and the largest size group.' June (1953) also used these evidences for the study of the spawning habits of the yellowfin tuna, *Neothunnus macropterus.*

It may be seen from Fig. 3 that as the last group of ova evident in the frequency polygon progresses towards maturity a second group becomes differentiated and also progresses towards maturity. The progression of modes of the successive groups is more evident in Fig. 4 where the frequency distribution of Fig. 3 are expressed as deviations from the average frequency polygons of stages B through G.

The progression of the two right hand modes is compared in fig. 5 by a scatter diagram wherein the position of the mode of the last group (Y) is plotted against the mode of the preceding group (X). A coefficient correlation of 0.604 emphasises the close relation between the progression of successive modes.

In addition, the presence of ova remnants in maturing ovaries, shows every indication of the past spawning and gives further evidence in favour of the hypothesis that more than one group of ova is matured and spawned by an individual fish in a single breeding season.



Fig, 3. Ova diameter frequency polygons showing stages in development of the ova from the immature, maturing to mature stage of sexual maturity in Minicoy waters.

To determine whether there is any decrease as the spawning approaches in the proportionate numbers of ova composing the maturing group, it is compared to the proportionate number of

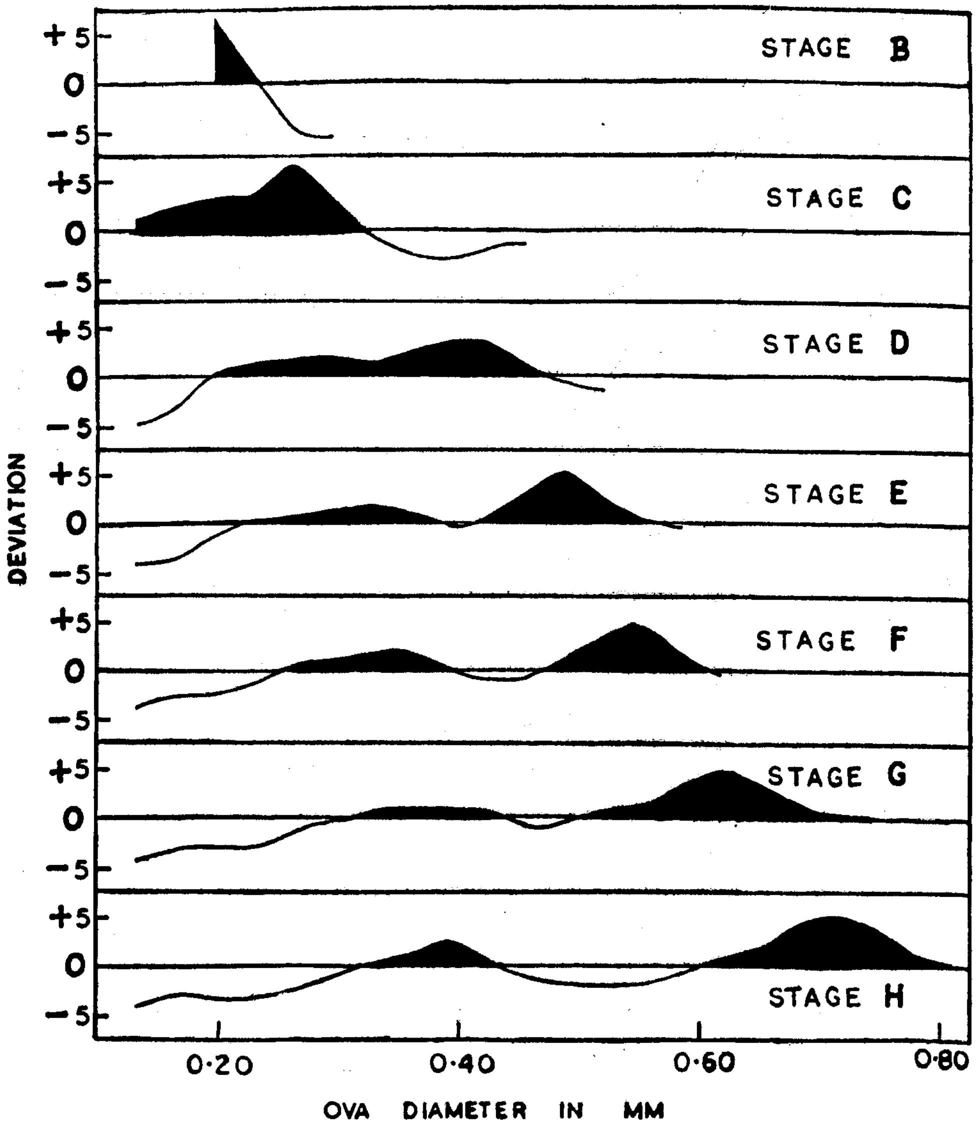


Fig. 4. Deviations from the average frequency polygon of stages B through H of Figure 3.

ova composing the mature group. Ratios of the number of the ova composing maturing and the mature groups for all fish in stage E were determined. It was found that the average in February was 4.29 : 1 ; for March it was 3.51 : 1 ; for April the average declined further to 3.27 : 1 ; in May to 3.14 : 1, and in June to 2.78 : 1.

The fact that the declining ratio is not due to the change in the size of the fish during the spawning is evident from the fact that mean weight of the skipjack with ovary in stage E did not change appreciably during the period considered. By an analysis of variance it was found that among the samples the difference between the months was not more significant than within the months (P-0.5). In other words the population did not change significantly during the season as to its weight.

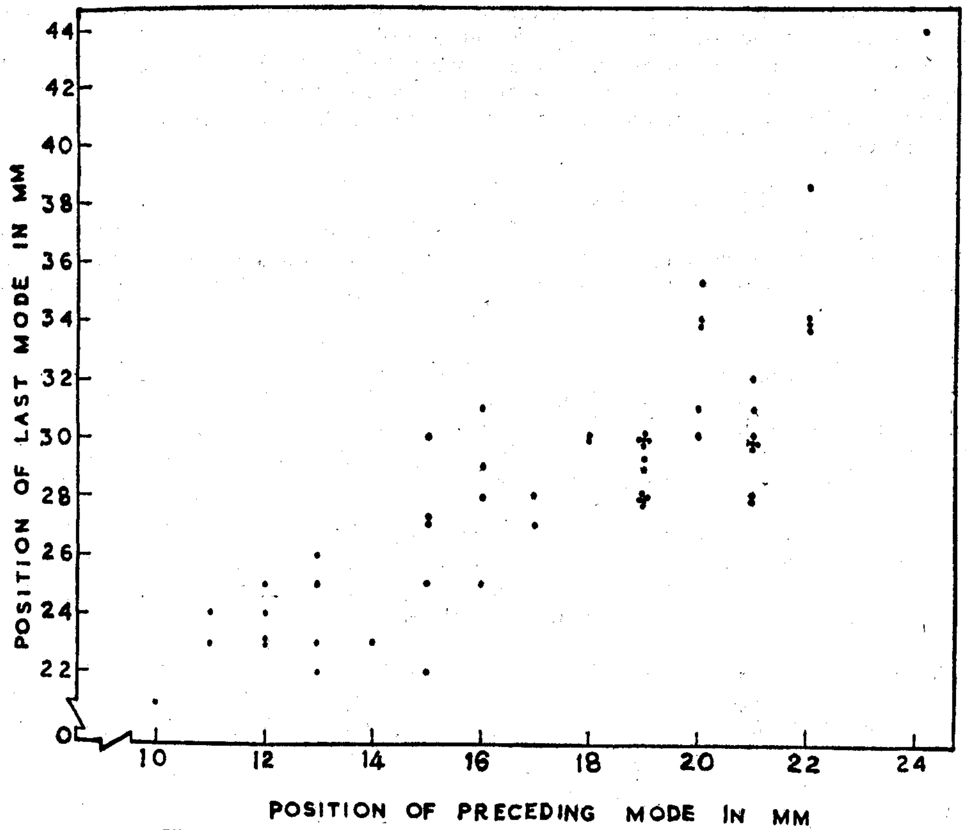


Fig. 5. Scatter diagrams showing the relationship between modal groups of ova in the ovaries, stages D through H.

Thus if the change is not connected with the size of the fish, it doubtless reflects a decline in proportionate numbers of ova composing the intermediate groups. This decline is to be expected if there is successive spawning by each fish.

Gonad Index

Though characterising the stages of maturity of tunas on the basis of the measurements of a large number of ova from the ovary of each specimen can be considered the best method in tuna biology, this involves a great deal of time and labour. Therefore a less laborious and yet an objective method of estimating the maturity is really welcome in this respect. Kikawa (1953) Yuen (1955) Schaefer and Orange (1956) Otsu and Uchida (1959) have investigated the possibility of estimating the size of the ovarian eggs and thereby the degree of maturity from the weight of the ovaries and the size of the fish. The relation between ovary weight and fish length and ova diameter may be treated as a regression problem in 3 variables. But Schaefer and Orange (*op. cit.*) with a view to employ a simpler method, combined the weight of the ovaries and the fish length and treated it as a problem in only two variables.

In the present study the gonad index (G. I.) was calculated by the same formula as used by Schaefer and Orange (1956) viz., $G.I.=W/L^3$ where W is the weight of both the lobes of the ovary in grams and L^3 the cube of the length of the fish in mm. The figure thus obtained was multiplied by 10^8 to get a 2 digit whole number. Schaefer and Orange (*op. cit.*) in their investigations on the relation between the ova diameter and the gonad index, made use of the 95th centile of the total frequency distribution to characterise the size of the most advanced ova rather than attempting to determine the modal size as done by June (1953) and Yuen (1955). In the present investigation however, the position of the most advanced mode of the ova diameter frequency polygon of each ovary, determined by smoothing the data twice by a moving average of three, was employed.

Yuen (1955) Otsu and Uchida (1959) used the relative ovary weight in their studies which is obtained by dividing the gonad weight by body weight. As the weight in tunas is nearly proportional to the cube of the length, this is very nearly proportional to the gonad index obtained by the above method. Kikawa (1953) employed the same gonad index as the present one but his unit differs from the present one by a factor of 10^2.

The gonad index employed in the present study does not appear to be completely correct for the effect of length of fish on the size of their gonads at more or less identical stages of maturity. The relationship between the total length of skipjack and gonad index is shown in figure 6. The middle line is the regression line fitted to the data of 163 female skipjack which were in the immature and maturing stages of sexual maturity. All the other specimens which were in the advanced stages of sexual maturity were however, excluded from the regression. The upper broken line drawn parallel to the regression indicates twice the standard deviation. This is used to separate the gonad indices considered to correspond to immature and maturing stages of sexual maturity of ovaries from those that are considered to be mature. The curve shows the percentage of gonad indices considered as mature in each 25 mm. length class.

It is however, evident from figure 6, that the regression line shows slightly higher average gonad indices as the fish size increases. Orange (1961) who also observed this upward slope of the regression line from his data on yellowfin tuna and skipjack from the Eastern Tropical Pacific, explained that this ' may be due to the occurrence of more immature females in the smaller size classes, the larger size classes being predominantly females in the resting stage, or because the gonads, grow proportionately faster than the rest of the fish, or because the cube of the fish length is not proportional to weight.'

The value of the gonad index as indicating the relative development of the ovary is not in any way seriously hindered, though a slight increase in its value was noted with the increase of fish length. It is evident from figure 6 that when a female is reasonably well advanced towards sexual maturity the corresponding value of gonad index is well above its value in either the immature or maturing stages.

In figure 7 are plotted the gonad index and the position of the mode of most mature group of ova in the ova diameter frequency distribution of each specimen. The regression line is described by the formal $Y=0.0990+.0.0103\ X$ where Y=mode of the most mature group of the ova diameter frequency polygon and X=the gonad index. It is seen that the 104 gonad index values of different stages of maturity are very nearly comparable to the values of ova diameter measurements. They distribute themselves in 3 groups classified on the basis of the mode of the most mature group of ova. Therefore it may be possible to determine the sexual development of the ovaries on the basis of the gonad index values, instead of resorting to the laborious and time-consuming method of measuring the ova diameter and determining its mode.

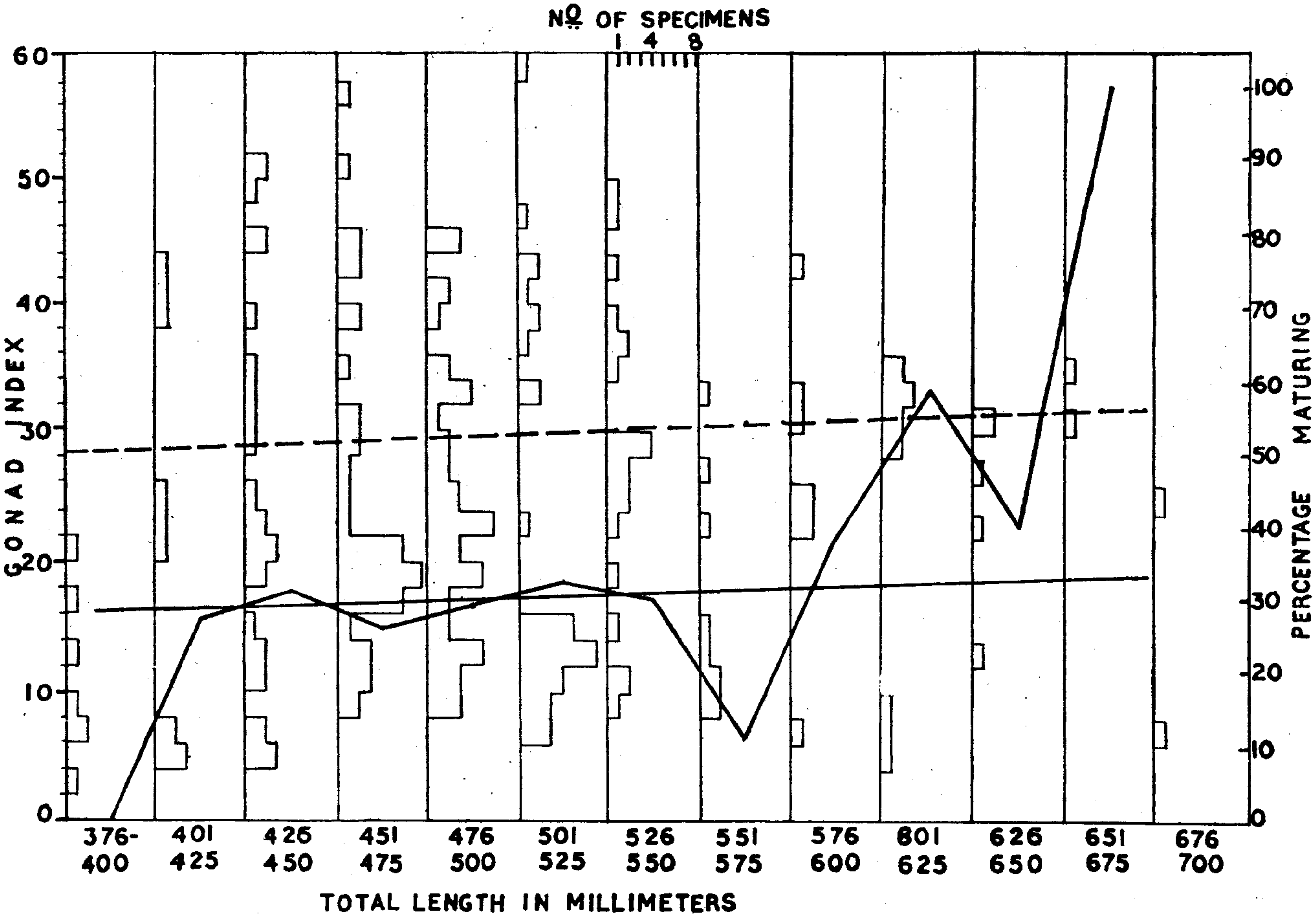


Fig. 6. Relationship between total length and gonad index and total length and percentage of mature ovaries of skipjack from Minicoy waters. The thick straight line is the best fit for the data of 163 specimens. The upper dashed line is twice the standard deviation of the regression of line and represents the minimal gonad index level at which the ovaries are considered to be mature. The curve indicates the percentage of mature females in various size groups.

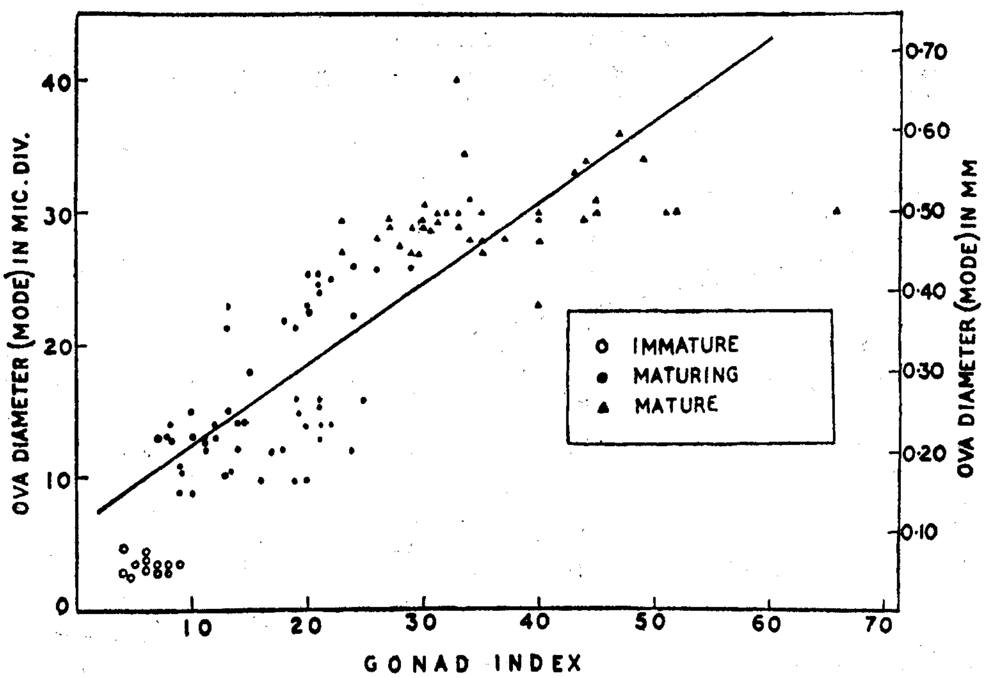


Fig. 7. Relationship between gonad index and mode of the most mature group of the ova diameter frequency distribution of 104 skipjack observed from Minicoy.

Spawning Season

Excepting for the recent observations on the spawning of the oceanic skipjack in the Laccadive Sea, based on the larval collections (Jones 1959), there are no previous reports that can give us a very comprehensive idea of the spawning of this species in Laccadive area with particular reference to Minicoy waters. Therefore in the present study the changes in the gonads that were observed were utilised to determine the period during which spawning takes place around Minicoy Island and to establish its limits in time.

The relative percentage of occurrence of fish with mature ovary during different months, the monthly mean of the gonad indices of the skipjack obtained from the random samples of the pole and line fishery at Minicoy, the monthly mean of the mode of the most mature group of ova in the random samples of ovaries were utilised to delineate the spawning period of skipjack in Minicoy waters.

On the basis of stages of maturity already described the relative percentages of fish with ovary in the various stages gives a good indication of the extent of development of ovaries with respect of the time of the year. These percentages for different size groups are represented in fig. 8.

In figure 9 are plotted the relative percentages of occurrence of ovaries in 3 major stages of maturity already described viz. Immature, Maturing and Mature. It is evident from figure 9 that all the fish with ovary in the immature and maturing stages, were found in the samples during the months August through September, thereby indicating that spawning did not occur during these months. However, it should also be remembered that the period August to October corresponds to the final half of the monsoon period during which the weather conditions are

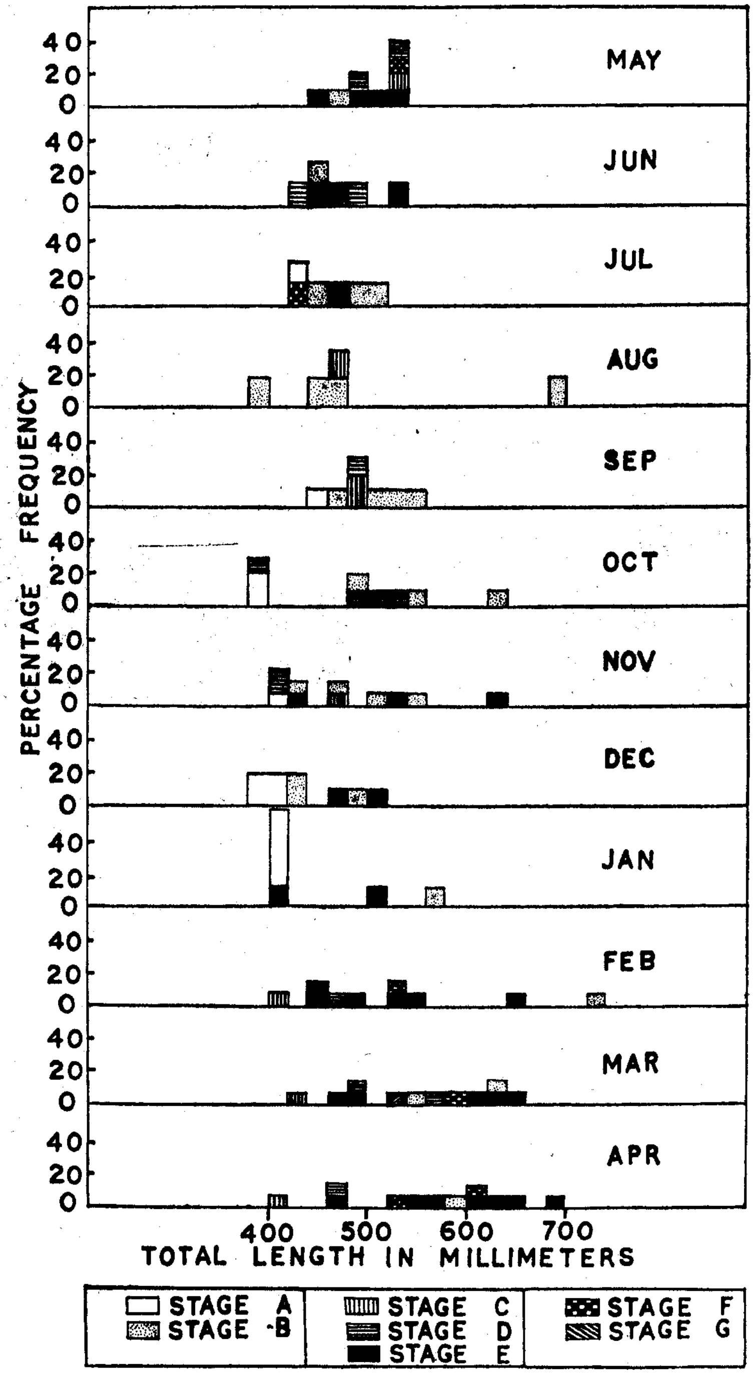


Fig. 8. Percentage frequency of skipjack of different length groups with different stages of sexual maturity among the random samples obtained from the landings of pole and line fishery with live-bait at Minicoy, during the period May 1958-April 1959.

unfavourable for regular fishing. Therefore during the period August to September, fishing is rather restricted to the eastern side of the island only and that too occasionally as and when the

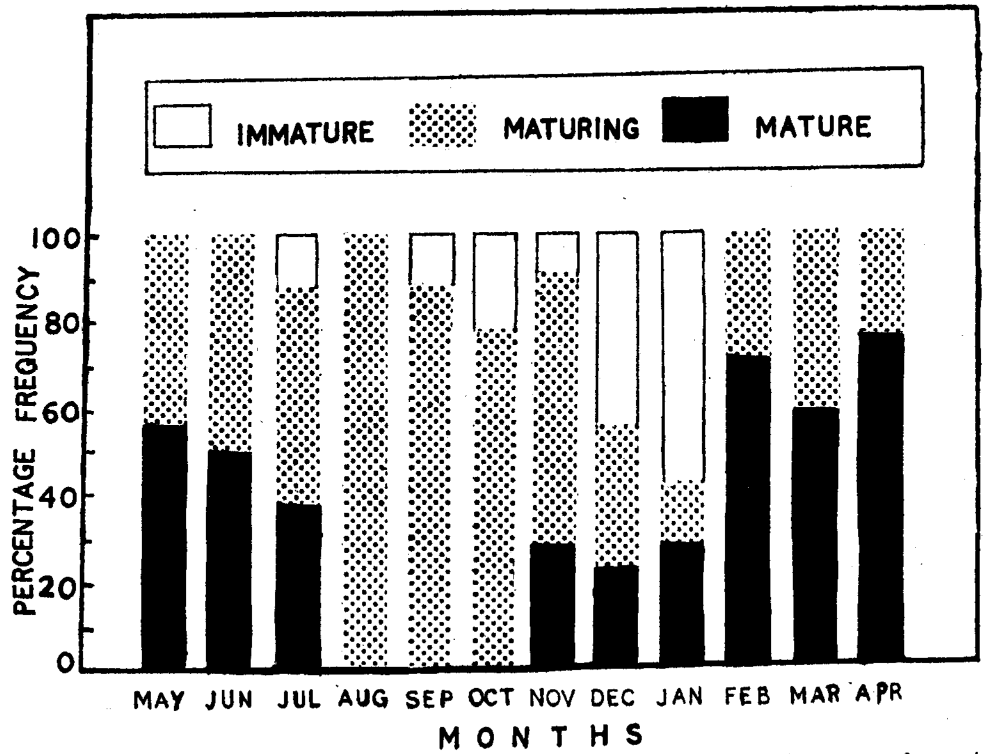


Fig. 9. The relative percentage distribution of skipjack with ovaries in 3 major stages of sexual maturity (immature, maturing and mature) during different months of the period of observation May 1958-April 1959 at Minicoy.

weather permits the fishing operations. There is no information as to whether the mature females were actually absent around the regular fishing areas of the island or these were absent in the particular area where the fishing was restricted during the monsoon season. What was believed to be a spent ovary was obtained in April. But the definite 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 however, there is a sudden decline in their proportion of occurrence perhaps showing that recovery of the ovaries has started without much delay in preparing for the next spawning season. But when the normal and regular fishery is resumed in the middle of October, those mature females continued to be absent until the middle of November. They occurred during November to January, but apparently in lesser proportions. High percentages of mature ovaries occurred during the period February to July, which can be viewed as the period of definite spawning or peak spawning.

The monthwise frequency distribution of skipjack with various gonad indices, together with their mean are plotted in figures 10 and 11 separately for males and females. Except for certain minor fluctuations, the trend of high and low values more or less correspond with the spawning or peak spawning and non-spawning periods respectively. The monthly frequency distribution of the ovaries containing different modes of the most matured group of ova together with their monthly mean values are shown in figure 12.

All the above evidences uniformly suggest that the spawning period of skipjack around Minicoy Island is principally between February and July—a quite prolonged one.

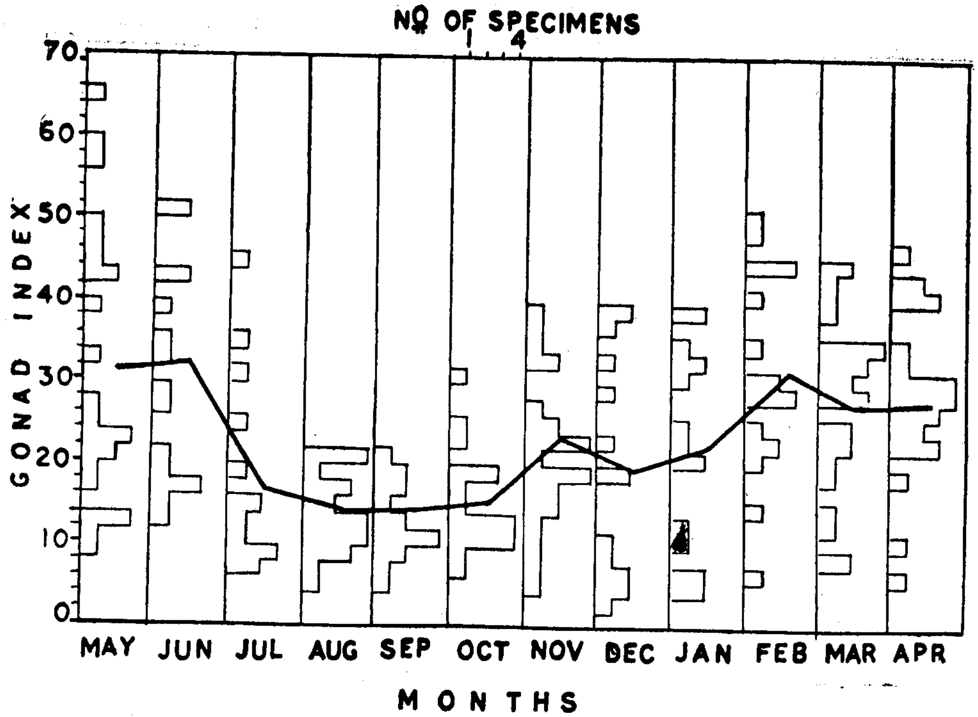


Fig. 10. The monthwise frequency distribution of gonad indices of female skipjack at Minicoy during May 1958—April 1959. The thick line connects the means of gonad index values for each month.

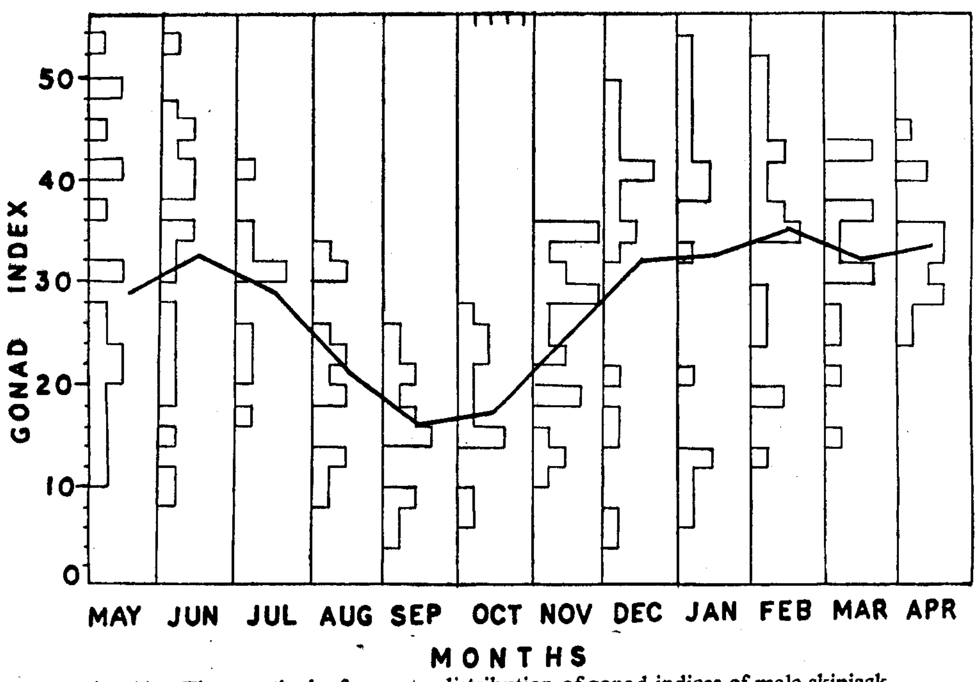


Fig. 11. The monthwise frequency distribution of gonad indices of male skipjack at Minicoy waters during May 1958—April 1959. The thick line connects the means of gonad index values for each month.

Jones (1959) succeeded in collecting the larvae and juveniles of *K. pelamis* during the period from December to April. He remarks that ' From the condition of the gonads of the skipjack caught in the Minicoy area it appears that January to March is the peak breeding period there

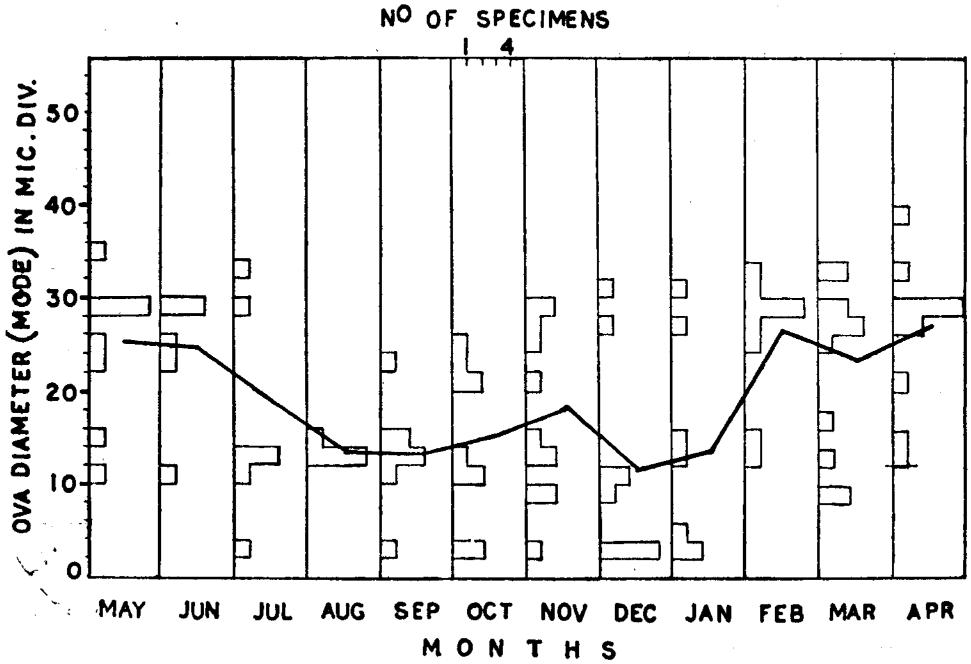


Fig. 12. Frequency distribution of the ovaries of skipjack at Minicoy containing different mode values of the most mature group of ova during different months of the period May 1958—April 1959. The curve shows the monthly mean values

but it is likely that the breeding period is rather a quite extended one.' Apart from the prolonged nature of the spawning period there are other characteristics which may lead to some guesses regarding its important features. These are: (1) the great rarity of fish containing ripe translucent ova in the fishery, (2) the lack of fish with ovaries sampled within the spawning season which present the spawned out appearance to be observed in those ovaries sampled after June.

It is now widely acknowledged that the ripe running stages of gonads of the various species of tunas of the Indo-Pacific are very rarely encountered in the commercial catches. In Philippine waters Wade (1950) found ripe yellowfin tuna in the course of his investigations but no spawning or spent individuals. Apparently this phenomenon is not limited to the yellowfin tuna only, for it has been observed in big-eyed tuna (*Parathunnus sibi*) Hatai *et al.* (1941) and Bell (1951); for oceanic skipjack (*K. pelamis*) Hatai *et al.* (1941) and Bell (1951) and for *Euthynnus yaito* Wade (1950). Schaefer and Marr (1958) who observed no running ripe females of tunas hypothesised that as the spawning approaches the fish either migrate beyond the range of fishery or stop feeding. The present observation is substantially in agreement with the findings of others in other regions of the Indo-Pacific.

Sex Ratio

The occurrence of wide disparity in the proportions of sexes among the tunas during the spawning season in different regions of the Indo-Pacific, is of interest. Bell (1951) found the sex ratio of yellowfin tuna rising as high as 80 males : 20 females in the Equatorial Pacific. Wade

(1950) noticed the majority of the spawning skipjack were males and the largest percentage of spent fish were females. Brock (1954) found a significant reduction in the proportion of female fish during the period from September to December corresponding to the non-spawning period of this species. Tester (1957) observed a percentage of 61 males and 39 females among 344 specimens of skipjack taken by the troll and pole and line fishing off Oahu, Hawaii.

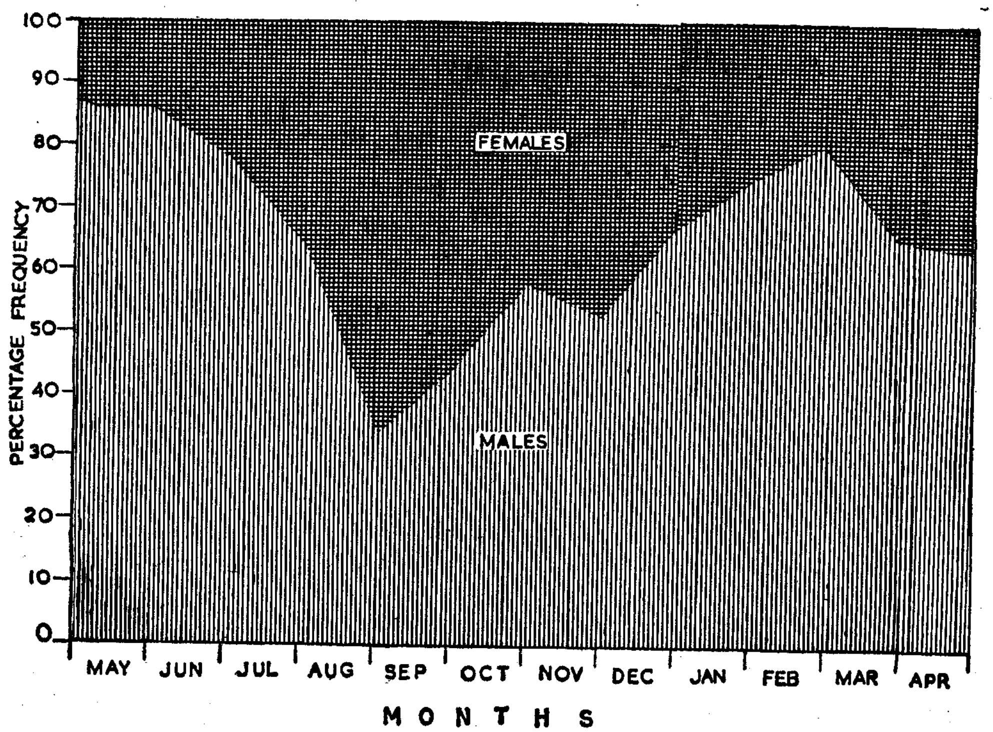


Fig. 13. The monthwise frequency of occurrence of the male and female skipjack at Minicoy during the period May 1958—April 1959.

In the present study the data were analysed to find whether any differential fishing of the sexes existed at Minicoy island and if so its extent. As the sex of skipjack could not be determined from the external characters, the body cavity of the specimens were opened to determine the sex. However Hatai *et al.* (1941) who could successfully sex the skipjack from the external characters state that those with the sharply pointed lips are males and those with somewhat rounded lips are females. A random sample was taken from the landings of skipjack from the pole and line fishery at Minicoy island and the sex ratio determined. From each random sample a small subsample was taken and the length frequency distribution of the two sexes was recorded. The live bait fishery of Minicoy was found to be very selective comprising high percentage of adults with maturing or mature gonads and a small percentage of juveniles with indeterminate gonads. Whenever such indeterminate gonads were encountered in the random samples a small portion of the gonads was examined under microscope and the sex determined. The monthwise percentages of occurrences of the two sexes of skipjack at Minicoy are shown in figure 13. Schaefer and Orange (1956) record a high percentage of occurrence of the virgin skipjack with indeterminate gonads from Eastern Pacific Ocean. The results of the present observation show great variation in the sex ratio of the individual samples. As we are more interested in the gross ratio of the whole stock, the data were arranged separately for different months of the period of observation and presented in Table I.

The monthly ratio also shows departure from the expected 1 : 1 ratio during most of the months. A chi-square test applied to find out how far these monthly ratios depart from the expected ratio of 1 : 1 shows highly significant differences (P=<.001).

TABLE I

Chi-square test of Sex Ratio of the skipjack examined during the period May 1958—April 1959 at Minicoy from the Pole and Line Fishery

Months	Number Examined N	Number of males X	Probability of males p	Chi-square X^2
May	274	234	0.8540	
June	102	79	0.7745	
July	55	20	0.3636	
August	118	40	0.3389	
September	132	58	0.4394	p = 0.6528
October	175	101	0.5771	q = 0.3472
November	233	99	0.4241	
December	261	173	0.6628	X^2 = 255.3
January	254	189	0.7441	d.f. = 11
February	245	197	0.8041	p = (<0.001)
March	167	109	0.6527	Highly significant
April	213	156	0.7324	
	ΣN=2229	ΣX=1455		

The percentage of males is found to vary from 33.89 to 85.4 over the months. The average percentage for the whole year was 73.24. To test if these differences among the months are due to sampling fluctuations, i.e., to test the homogeneity of the ratios, chi-square test was applied. The test (Table I) shows highly significant difference (x^2=255.3 d.f.=11, P=.001) thereby indicating that observed ratios among the various months of the period of observation are not homogeneous.

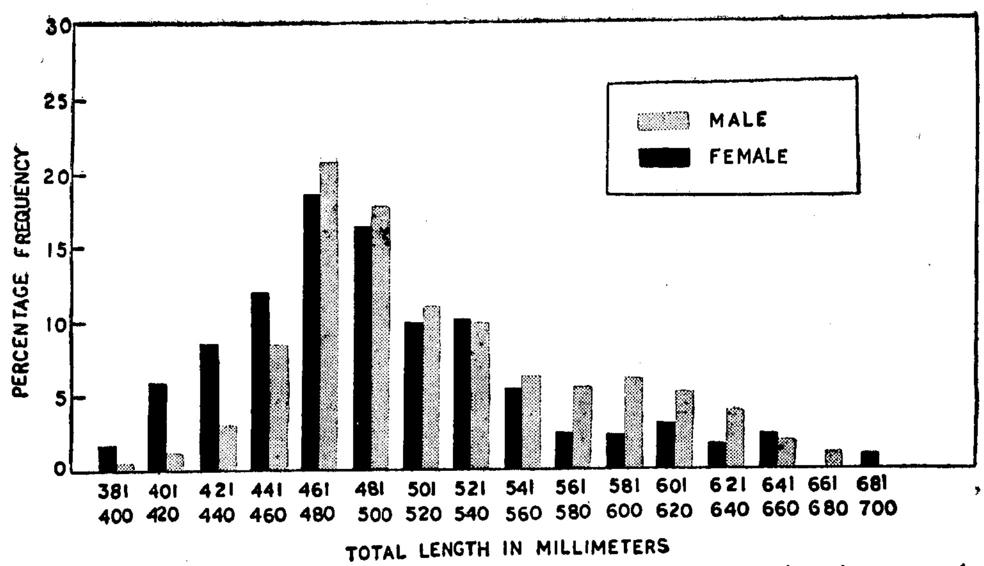


Fig. 14. The percentage frequency of the male and female skipjack among the various size groups observed from the landings of the pole and line fishery with live-bait at Minicoy during the period May 1958—April 1959.

The significant change in the sex ratio with males predominating was found during the period February through May corresponding to the active spawning period of the fish. During the spent-resting or spent-recovering period, viz., July-September the females predominate in percentages of occurrence. To find out whether observed changes in the sex ratio are linked with any changes in the size of fish available to the fishery, the fish sampled at random were arranged in 4 groups. From 381 to 460 mm. in total length, the percentage of females is higher than that of the males. Between 461 and 540 mm. total length the percentage of males and females remains more or less identical with the males showing a slightly greater percentage. Between 541 and 620 mm. total length there is higher percentage of males over females. In Tables II and III are tabulated the percentage frequency of the two sexes among various size groups during different months of the period of observation. In Figure 14 is shown the percentage of skipjack of the two sexes in all samples from Minicoy Island taken together, within each size group. The size group between 700 and 880 mm. total length was very rarely available in Minicoy fishery during the period considered. Therefore the skipjack falling under this group had to be selected and studied. The size distribution of this group is depicted in Fig. 15 for the two sexes. Here again there is a high percentage of males with the increase of size over females.

Such sex-linked differences in abundance and availability and growth are not however rare in other species of tunas. The preponderance of males among large sized tunas according to Schaefer and Orange (1956) may be due to differential growth rate, differential mortality rate or simply some sex-connected differential behaviour making larger males more amenable to be captured than the larger females. The possible explanation that was offered to the rarity of the females with the advanced gonads is that females with the approach of the spawning season either move away from the area of fishing and thereby become unavailable to the fishery or do not take the bait can also be offered to the greater preponderance of males. Wade (1950) explained that the preponderance of males may be due to the aggressiveness of the males during the spawning which makes him more prompt to strike at a lure. The skipjack fishing season lasts from November to April in Minicoy. It has been observed that this is the period of greater preponderance of males. Therefore the tuna fishery of Minicoy harvests a very high percentage or proportion of males. With the onset of Monsoon during June to August the fishery becomes very irregular and poor. This was however the period during which the sexes were harvested either in equal proportions or with females slightly predominantly.

Compared to the magnitude of the landings of male skipjack during the period of regular fishery at Minicoy, the landings of slightly greater proportions of females during the poor monsoon fishery, cannot in any way compensate the inequality in the sex ratio.

Size at First Maturity

The smallest skipjack that possessed maturing ova during the spawning season was around 400 to 450 mm. in total length. Fish measuring 35 to 45 cms. in length had ovaries that mostly appear to be immature. Although egg remnants were present in ovaries at various stages of maturity excepting in the immature—indeterminate gonads, none were found in groups less than 400 to 450 mm. Therefore the present data suggest that skipjack attains sexual maturity at a size of about 400 to 450 mm. total length. Brock (1954) inferred from his studies that the skipjack of Hawaii waters attains sexual maturity and may spawn at about 40 to 45 cms. in length. He also concluded from the study of age and rate of growth that it may mature in a year.

The percentage of females considered as mature gives a fairly reliable estimation of the minimum size at first maturity or spawning. The regression line in Figure 6 was based on the gonad indices of 163 female skipjack from Minicoy, that were not sexually mature at the time of examination. The upper dashed line is twice plus standard deviation is used to define the females, considered mature above the line and immature, maturing, spent-recovering or resting below the

TABLE II

Percentage of Males of skipjack in different size groups (Total length) during different months of the period May 1958—April 1959 with averages for each 4-month period and 3-class intervals at Minicoy.

Months	38 40	40 42	42 44	44 46	46 48	48 50	50 52	52 54	54 56	56 58	58 60	60 62	62 64	64 66	66 68	68 70
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					
August					54.4	36.4		9.1	9.1							
September		5.3			10.5	15.8	21.0	10.5		10.5	10.5	5.3	5.3	5.3		
Average % for 4 months		1.3%				77.6%				18.5%				26%		
October				8.0	4.0	28.0	20.0	12.0	4.0	4.0	4.0	8.0	8.0			
November					6.4	22.5	16.1	19.4	13.0	9.7	6.4	3.2	3.2			
December		3.2	3.2	38.7	29.1	13.0	3.2	3.2	3.2	3.2						
January			2.1	14.5	18.7	20.8	12.5	6.2	6.3		4.2	6.3	4.2	2.1	2.1	
Average % for 4 months		17.4%				58.8%				18.9%				4.9%		
February			13.9	19.4	11.1	8.3	5.6	5.6	2.8	13.9	8.3	8.3	2.8			
March			5.6	11.1	16.6	11.1	16.6	..	5.6	5.6	11.1	11.1			5.6	
April						7.7	11.5	15.5	3.8	3.8	7.8	15.5	19.1	11.5	3.8	
May	3.4	1.7	11.9	8.3	11.9	13.6	18.3	13.6	10.2	8.3	5.1	1.7	1.7			
Average % for 4 months		18.8%				39.3%				30.8%				11.1%		

line. It is seen in Figure 6 that the percentage of females in the mature class rises sharply from the size group 401-425 mm. total length. Between the size groups 401-550 about 30% of the females were found to be mature. The percentage of females in the mature class shows another

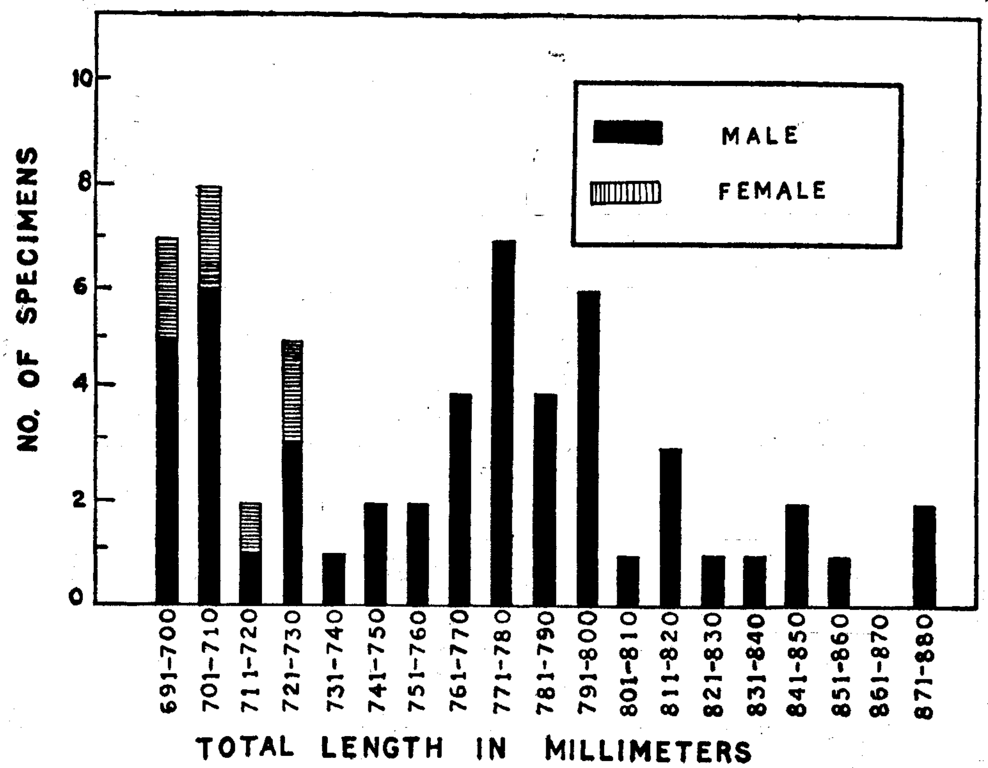


Fig. 15. The size frequency distribution and sex of skipjack of the length group 700-800 mm. landed by the pole and line fishery at Minicoy during the period May 1958—April 1959.

rise above the size group 575 mm. total length. However, above this size group not many specimens were available for observation during the period of study at Minicoy.

The size at first maturity for skipjack from the Pacific does not appear to be well-defined. From the data collected by Wade (1950) from Philippines it appears that the smallest female that possessed ripe gonad was between 400-450 mm. in length. Bunag (1956) obtained several specimens of skipjack from 450-630 mm. with ovaries in the advanced stages of sexual maturity, from Philippine Islands. But Schaefer and Orange (1956) found that in the Eastern Pacific the minimum size at first maturity was near 550 mm. and a large share of individuals was not mature below 600 mm. in certain areas. It was observed by Orange (1961), that the minimum size at first maturity differs in different areas of the Eastern Tropical Pacific.

Condition Factor

The condition factor in fishery biology signifies heaviness relative to expected average weight at any given length of fish. The condition factor values in the present studies were obtained by dividing the weight of the fish in ounces by the cube of the length of the fish in mm. and multiplying the value by a factor of 10^9 to get a 3-digit whole number. The calculations of the con-

TABLE III

Percentage of Females in different size groups (Total length) during different months of the period May 1958—April 1959 with averages for each 4-month period and 4-class intervals at Minicoy

Months	Size Groups														
	381 400	401 420	421 440	441 460	461 480	481 500	501 520	521 540	541 560	561 580	581 600	601 620	621 640	641 660	661 680	681 700
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									
August	5.3		5.3	10.5	36.8	21.0	10.5					5.3				5.3
September			6.7	13.3	13.3	26.7	13.3	6.7				6.7				
Average % for 4 months		22.3%				68.5%				7.9%				1.3%		
October		5.6	5.6	27.7	22.1	11.1	5.6	5.6	11.1					5.6		
November		8.0	8.0	8.0	24.0	8.0	8.0	16.0	8.0	4.0	4.0			4.0		
December	6.7	20.0	33.2	6.7	13.3	6.7	6.7	6.7								
January	5.9	23.5	17.6	5.9	5.9	11.8	17.6	5.9		5.9						
Average % for 4 months		45.6%				43.8%				8.2%				2.4%		
February		5.6	11.1	16.6	11.1	16.6	5.6	16.6	5.6	5.6				5.6		
March			3.7	7.4	11.1	22.3	3.7	3.7	3.7	3.7	14.8	14.8	7.4	3.7		
April		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
May		4.1	4.1	8.3	12.5	20.9	12.5	29.3	8.3							
Average % for 4 months		18.2%				48.5%				23.1%				10.2%		

dition factor based on the empirical calculated length-weight relationship $W = CL^a$ was suggested by Le Cren (1951) to eliminate the effect of length and other correlated factors on K and this was termed relative condition factor (Kn) to be distinguished from condition factor (K) based on cube law. The method evolved by Le Cren (*op. cit.*) in studying the condition cycle of the perch, *Perca fluviatilis* was successfully employed by Sarojini (1957, 58) and Pillay (1958) in their studies on the condition cycle and size at first maturity of grey mullets of Bengal and hilsa respectively.

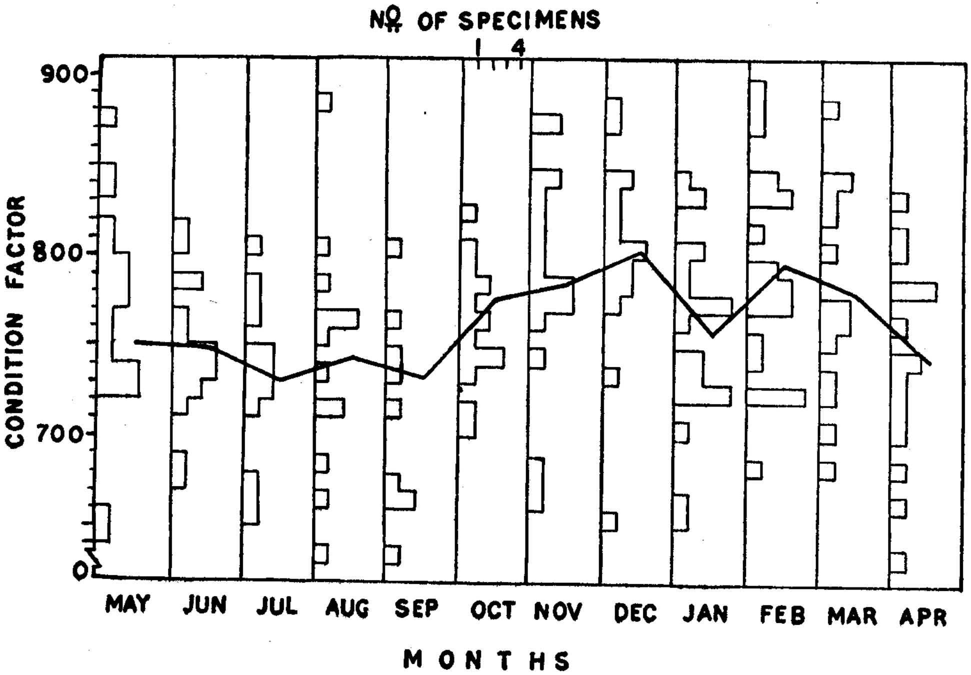


Fig. 16. Monthwise frequency of occurrence of female skipjack at Minicoy with different condition factor values during the period May 1958—April 1959. The monthly means are connected by the thick line.

The condition factor was calculated in the present study for skipjack obtained at random from the pole and line fishery at Minicoy with a view to find out the seasonal fluctuations in the condition factor value of the population in relation to their spawning cycle. The values are plotted separately for females and males in Figures 16 and 17 respectively. The curve of monthly mean values of condition factor for the females shows a steady increase from September. A sudden fall was observed in December which cannot be explained from the present data. From February there is a gradual fall ending in its lowest mean value during July. Though the gonad weights are at a maximum during February-May, the gradual fall in the mean value of K is during this period. Whether the changes in the visceral weight influence the condition factor greater than the gonad weight needs investigation. The role of gonad weight in condition factor value cannot altogether be overlooked, because when the gonad weight percentages are low, the condition factor values are also comparatively low. Only when the gonad weight percentages are high during the spawning season, the mean condition factor value shows a downward trend. It might be due to the intermittent spawning habit of this fish resulting in greater metabolic strain. Temporary cessation of feeding actively during spawning might also be responsible for lowering the condition factor values. In the absence of any data on the seasonal cycle of visceral weight, no conclusions can be drawn on this aspect at present. There is a general trend of high mean K value during the spent-recovering and spawning periods and low mean K value during the resting period.

The highest value of mean K for the male skipjack was observed during October (Figure 17) after which it merely shows fluctuations without any marked rise or fall. Here also during the resting period they are comparatively lower.

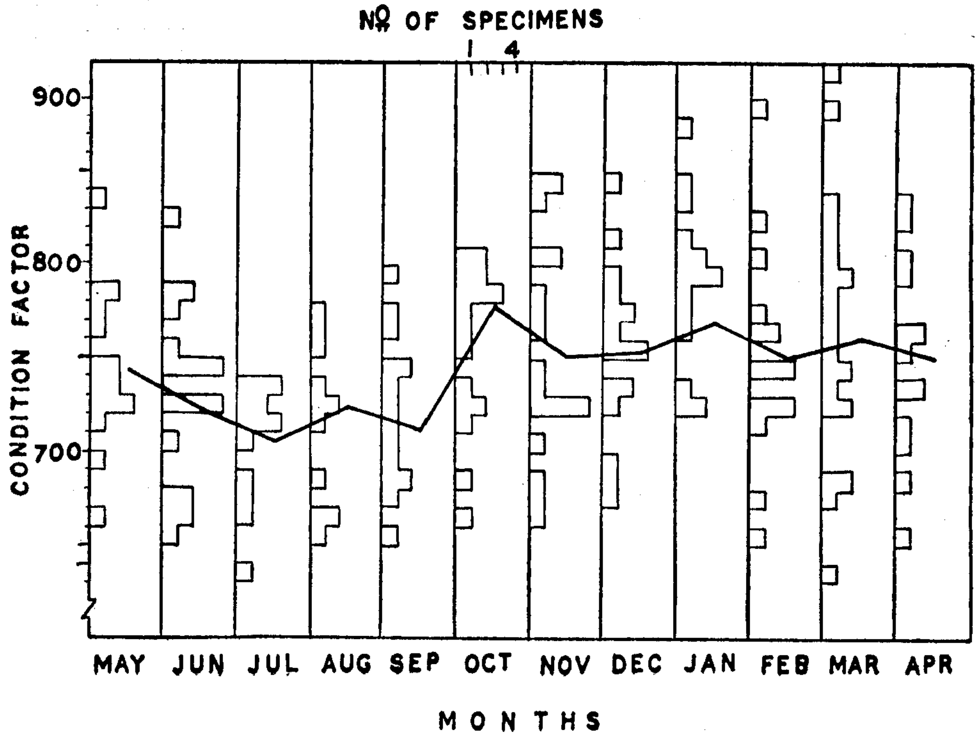


Fig. 17. Monthwise frequency of occurrence of male skipjack at Minicoy with different condition factor values during the period May 1958—April 1959. The monthly means are connected by the thick line.

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SUMMARY

Gonads of skipjack *K. pelamis* sampled from the catches of pole and line fishery of Minicoy with live-bait, were utilized for studying the nature of the spawning of this species in Minicoy waters.

Two prominent developmental groups of ova are present in the ovary of individual fish with the approach of spawning season.

Based on diameter measurements of the most mature mode of ova, 8 arbitrary stages of maturity were established that trace the development of ova from immature to the spawning stage.

Fractional multiple spawning is indicated based on several lines of evidence.

Gonad index—a numerical relationship between the cube of the total length, and weight of the ovaries, was found to be a reliable guide for distinguishing mature from immature and maturing fish without the measurement of ova.

The peak spawning of *K. pelamis* in Laccadive Sea around Minicoy Island appears to be during February-June.

Disparity in the sex ratio with males predominating during most of the months, particularly during the spawning season observed. Occurrence of slightly higher percentages of females among the smaller size groups and males among larger size groups indicated.

The minimum size at first maturity for skipjack at Minicoy appears to be around 400-450 mm. total length.

The monthly mean values of condition factor show low values during the resting period and high values during the spent recovering period with a downward trend during the actual spawning period among the females.

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