PATTERNS OF SEX RATIO IN THE OIL-SARDINE, *SARDINELLA LONGICEPS* VAL., AT CALICUT

B.T. ANTONY RAJA

Central Marine Fisheries Research Institute; Sub-station, Karwar, Mysore State

ABSTRACT

Categorising the fish according to maturity, month of capture and length groups, the data on the sex distribution of the Indian oil-sardine (*Sardinella longiceps*) collected at Calicut during 1959-60 to 1965-66 seasons are subjected to statistical tests to find out the nature and cause of dominance of either sex, if any.

For the immature fish the overall inference is that there may not be any significant differences in the annual recruited population. In the adult fish the possibility of more males in May is suggested as due to the fact that the males may start maturing a little earlier than the females. The dominance of males in 140-150 mm group and that of females in 170-190 mm groups is brought about by differential growth, the females growing faster during June to October period. It is recommended that the size of each sample for sex ratio studies should be at least 50. Based on the earlier and the present studies of this author, it is indicated that 375 million ova can be expected from a tonne of adult biomass of the oil-sardine population.

INTRODUCTION

In fishery biological investigations on a commercially important fish, detailed analysis of the sex composition in the catches is considered essential for determining whether fishing is more intense on one sex than on the other and, if so, whether the observed dominance of either sex is due to shoaling behaviour or due to other causes like differential accessibility, vulnerability, growth and mortality. The sex-ratio studies also contribute towards stock estimation by the selective removal method by knowing the sex ratio in each length group (Holt, 1959).

Studies on the patterns of sex composition in the Indian oil-sardine have not received due attention in the past and the available reports on the preponderance of one sex or the other (Hornell and Nayudu, 1924; Chidambaram, 1950; Nair, 1959) can be said to be largely qualitative inasmuch as they are not supported by sufficient data. Recently some attempts have been made to look into this aspect (Radhakrishnan, 1969; Balan, 1971). In the following account the data collected at Calicut for 7 seasons from 1959-60 to 1965-66 are presented and the significant differences in sex ratio commented upon.

METHODS

Routine random samples, each consisting of 25 fish, were drawn, normally twice a week from the local landing place. Although George (1959) has described a method of sex diagnosis from external secondary sexual characters in the cloacal region, in view of the practical difficulty in recognising these features resulting in high percentages of error, the method was found not adoptable and hence the fish were sexed after dissection. In this report, the record of analysis on 6,878 fish obtained from boat seine catches is presented after categorising the fish into 3 major groups, immature (stage I), maturing and mature (stages IIa, III, IV, V and VI), and spent and spent-resting (stages VIIa, VIIb and IIb). The stages of maturity are according to the criteria set out earlier by this author (Antony Raja, 1969, 1971a). The above classification in relevance to maturity groups has been designed in order to know whether there are any marked deviations in the patterns between the juvenile and the adult phases. Before combining the data relating to the entire period of observation certain preliminary tests were considered essential. Hence, under each of the above 3 major categories, the fish were first classified according to the month of capture and length groups of 10 mm class intervals to determine whether there are any distinct features of variations in respect of month or size groups in each season. The observed sex ratios were tested against an expected ratio of 1 : 1 by the method of Chi-square. Since Fisher and Mather (1936) have shown that a measure of inconsistency of the deviations of the sample ratios from the hypothetical could be derived by taking the difference between the summed and the pooled Chi-squares, a measure termed the heterogeneity Chi-square, the latter was also tested along with the pooled and sum of Chi-squares. For most of the seasons the heterogeneity χ^2 values were found not significant and even in those seasons when the heterogeneity was declared significant, it was found that it was an artefact due to small size of one of the subgroups. Hence, it was decided to combine the data of all the seasons and test the significance of the sex distribution in the constituent subgroups—on the basis of length as well as the month of caputre—of each major group mentioned earlier. The significance, if any, at 5% and 1% level are shown respectively with one and two asterisks.

OBSERVATIONS

Immature

In Table 1 are presented the data on the ratio of male to female against each 10 mm group. It is seen that only the size group of 120 mm shows a χ^2 value of high significance with the males dominating. This dominance is largely a reflection of significant differences seen in 1964-65 season only. Since differential growth rate could not be perceived during that season, it is suspected that under conditions of superabundance of the juveniles and an almost static growth from September to November at 120 mm (Antony Raja, MS1) some inadvertent error has crept in while sexing the fish with advancing age during that season, and some of the indeterminates also have been classified as males. While such an error is possible in a length range of 110 - 120 mm which is roughly the earliest stage of sex differentiation (Antony Raja, 1969), this is unlikely to happen in the still smaller size groups as no such dominance of males is seen in the lesser size groups, namely, 100 and 110 mm.

TABLE 1. *Chi-square test for the immature oil-sardine of different size groups (in mm)*

Size group	Males	Females	χ^2	D.F.
100	36	26	1.613	1
110	187	162	1.791	1
120	579	462	13.150**	1
130	488	496	0.065	1
140	516	524	0.062	1
150	202	229	1.691	1
160	37	43	0.450	1
170	1	9	6.400*	1
Pooled	2046	1951	2.258	1

In the month-wise data presented in Table 2 the sex ratios obtained for September, November and April are found to show different degrees of significance. Of these, the high significant deviation for November has resulted mainly from 1959-60 records for that month and the lesser degree of significance in September is influenced by a feature seen in 1960-61 only. Since deletion of these respective season's data reveals no significant differences, perhaps it can be concluded that the pattern was one of peculiarity of the shoals encountered during those months of the respective seasons. On the other hand, the significant χ^2 value seen for April is a cumulative effect of the data of all the seasons indicating a slight preponderance of females. It can also be seen that the records of March to May generally show the females as more numerous. While a perusal of the growth records with this author faintly indicates an increased growth rate among the females during this period, it is not emphasised here as a causal factor, for the question of differential availability also should not be ruled out.

TABLE 2. *Chi-square test for the immature oil-sardine obtained in different months*

Month	Males	Females	χ^2	D.F.
Aug.	25	25	0.000	1
Sep.	64	91	4.703*	1
Oct.	265	255	0.192	1
Nov.	478	401	6.745**	1
Dec.	265	233	2.056	1
Jan.	339	303	2.019	1
Feb.	270	233	2.722	1
Mar.	188	209	1.111	1
Apr.	91	125	5.352*	1
May	61	76	1.642	1
Pooled	2046	1951	2.258	1

Maturing and mature

The relevant data and the χ^2 values for the different size groups of maturing-mature category are shown in Table 3. The records indicate that in 140 and 150 mm length groups the males are more numerous whereas in the larger fish, from 170 mm onwards, the females preponderate. In view of the knowledge of a growth of about 150 mm at sexual maturity at the end of first year and about 170 - 180 mm at the end of second (Antony Raja, 1969, MS1), a question may arise whether it can be assumed that there is a likelihood of greater number of males among the virgin spawners but lesser in the recovering ones. But since it has been shown above that there are no significant differences between the sexes in the immature state and as it is also known that there is increased growth activity among the adult fish during the spawning season (Antony Raja, 1967, 1969, MS1), the differential growth rate as a factor responsible for these differences appears to be a possibility.

TABLE 3. *Chi-square test for the maturing-mature oil-sardine of different size groups (in mm)*

Size group	Males	Females	χ^2	D.F.
120	9	5	1.143	1
130	57	42	2.273	1
140	124	83	8.121**	1
150	195	157	4.102*	1
160	153	144	0.273	1
170	101	134	4.634*	1
180	36	75	13.703**	1
190	1	10	7.364**	1
200	1	0	1.000	1
Pooled	677	650	0.549	1

To look into this possibility, the modal sizes of the two sexes are plotted in Fig. 1 for the period from June to October of 1960 through 1965. It may be seen that while growth is generally discernible during the above period, the records of 1962, 1963 and 1965 show that among the 130 to 150 mm groups of fish, there is a difference of 10 mm in the modal sizes, the males being smaller. In other words, faster rate of growth among the females would have resulted in their modal progression to the next higher size groups. The fact that the numerical differences get reduced in 150 and 160 mm groups but widen out to show increased number of females in the 170 and 180 mm groups appears to support that the differences in the sex ratio seen in the maturing-mature group is a result of differential growth. It is also seen from Fig. 1 that, in 4 out of 6 years, at the end of the spawning season, the modal sizes of the females are larger by 10 mm. Even in the other two years where the modal sizes were found to be the same, it is observed that the length group immediately following the modal size showed greater percentage frequency in the case of the females. Thus, it appears that by October the females assume slightly greater sizes than the males and hence their dominance throughout in groups 170 mm and above. It may be mentioned here that in the case of the plaice, differential growth after sexual maturity has been suggested as the reason for the preponderance of females in the larger-sized fish (Graham, 1956). In some Indian freshwater fishes also it has been shown that differences in growth rate cause differences in sex ratio (Qasim, 1966).

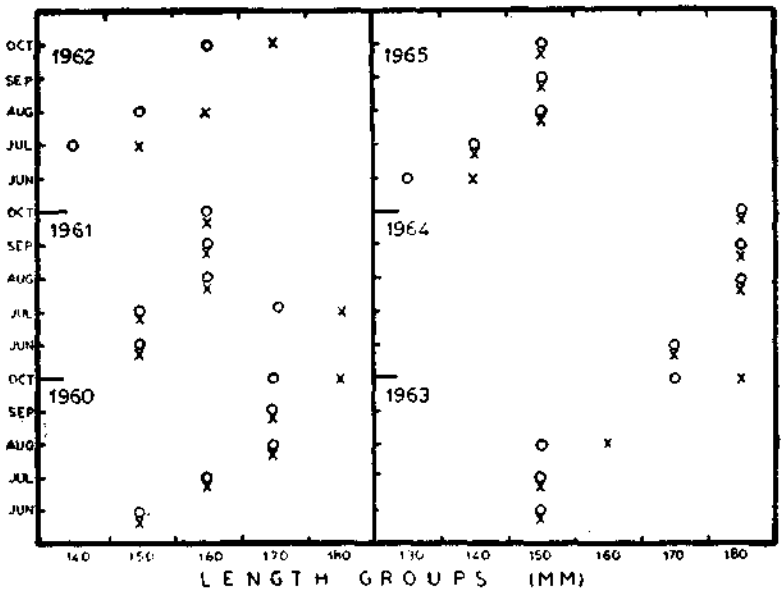

FIG. 1. Modal length groups of adult male (circles) and female (crosses) during June to October of 1960 to 1965 seasons.

In the data tabulated according to the months (Table 4), there appears to be a slight dominance of males only in May. This month represents the transitional period for the immature fish to enter the maturing stage IIa. Since, amongst the data of May, more instances of stage IIa males are encountered as compared to the corresponding stage of females, it is presumed that the males start maturing slightly in advance and thus its dominance is cast in May.

TABLE 4. *Chi-square test for the maturing-mature oil-sardine obtained in different months*

Month	Males	Females	χ^2	D.F.
May	73	50	4.301*	1
June	113	98	1.066	1
July	228	194	2.739	1
Aug.	263	308	3.546	1
Pooled	677	650	0.549	1

Spent and spent-resting

Table 5 shows the distribution of males and females in different size groups. It is seen that all the size groups appear to exhibit equal distribution of the sexes in this category. This feature requires some explanation because in the earlier phase

TABLE 5. *Chi-square test for the spent and spent-resting oil-sardine of different size groups (in mm)*

Size group	Males	Females	χ^2	D.F.
130	5	3	0.500	1
140	72	74	0.027	1
150	192	197	0.064	1
160	222	231	0.179	1
170	138	152	0.676	1
180	101	126	2.753	1
190	16	22	0.947	1
200	0	3	3.000	1
Pooled	746	808	2.474	1

there was a distinct dominance of females in the larger size groups. There are two possibilities, differential availability and differential mortality. That the latter may not be operative can be demonstrated by dissecting the entire data on the adults. If a provisional classification is made to separate all those up to 160 mm as virgin spawners and those above as recovering spawners, it is seen from Table 6 that the dominance of males is significant at 5% level for virgin spawners in the maturing-mature state whereas the same group in the spent condition exhibits no marked difference. This, as shown earlier, is due to differential growth rate during the spawning season. On the other hand, the same group, when they become mature for the second time in the subsequent season as recovering spawners, shows a high preponderance of females. If there is greater mortality among the females after the first spawning season, then there cannot be a dominance of females in the second spawning season. Since growth during the latter period is negligible (Antony Raja, 1969 MS1), it could not have also contributed for the difference in the sex ratio. Hence,

TABLE 6. *The sex ratio (male : female) among the adult oil-sardine with percentages in parentheses and statistical significance shown with asterisks*

Category	Virgin spawners	Recovering spawners	Total
Maturing-mature	538: 431*	139: 219**	677: 650
	(55.5:44.5)	(38.8:61.2)	(51.0:49.0)
Spent and resting	491: 505	255: 303*	746: 808
	(49.3:50.7)	(45.7:54.3)	(48.0:52.0)
Total	1029: 936*	394: 522**	1423:1458
	(52.4:47.6)	(43.0:57.0)	(49.4:50.6)

it is presumed that the absence of significant differences in the sex ratio of the larger-sized spent fish is due to differential availability. Perhaps, comparatively greater number of females emigrate from the fishing area after the spawning season. However, for the relatively lesser dominance of the females after their second spawning, it cannot be said whether the reason is reduced availability or greater mortality after the final spawning, as the fishable life span is believed to extend up to this period only.

The tabulated data on the monthly distribution (Table 7) show that but for August, the sex ratios obtained during the other months appear to satisfy the null hypothesis. As this dominance of females in August is a reflection of a feature obtained in 1965-66 season only, it can perhaps be ignored and a general conclusion drawn that there are no differences in the monthly picture.

TABLE 7. *Chi-square test for the spent and spent-resting oil-sardine obtained in different months*

Month	Males	Females	χ^2	D.F.
Jul.	14	25	3.103	1
Aug.	46	100	19.973**	1
Sep.	110	117	0.216	1
Oct.	120	127	0.198	1
Nov.	13	14	0.037	1
Dec.	97	107	0.490	1
Jan.	141	131	0.368	1
Feb.	110	92	1.604	1
Mar.	34	36	0.057	1
Apr.	35	24	2.051	1
May	26	35	1.328	1
Pooled	746	808	2.474	1

GENERAL CONSIDERATIONS

During the present study, except on rare occasions, the individual samples did not show any significant dominance of either sex. This may be due to the smallness of sample size because in a small sample the deviation from the expected mean has to be considerable in order to show a significant Chi-square value, whereas larger the sample more latitude there is for sample variation (Snedecor, 1955). Thus, in the present sampling method with 25 fish, unless the sex ratio is at least of the order of 18 : 7, the distribution cannot be considered as showing statistical evidence at 5% level against 1 : 1 ratio but when the sample size is quadrupled, it would be sufficient if the ratio stands at 60 : 40 to reject the null hypothesis at the same probability level. This brings the question as to what should be the ideal sample size for correctly evaluating the differences in the sex ratio. Since during the sampling days, among the cases of numerical dominance of either sex in a sample of 25, more instances of a ratio of 15 : 10 were seen, it is considered that a 10% deviation may perhaps constitute dominance of one sex over the other. On the basis of the equation given by Snedecor (1955, p. 26), the required sample size should be at least 96 in order to rely on the significance at 0.05 probability level. Thus, although an individual sample of 100 fish would be ideal to evaluate the real nature of sex distribution, in view of practical difficulties of examining such a large sample on each day of observation, at least 50 should form the sample size for sex-ratio studies.

It is observed that, on the whole, out of 222 tests of Chi-square on the raw data, only 7 instances of significant values are obtained if a minimum of at least 100 numbers in each sub-group is kept as a criterion to take cognizance of the significance. Among these, only 3 cases are highly significant at 1% probability level. In view of such limited differences the entire data of the observation period are combined and the percentage distribution of the sexes in each length group as well as for every month is illustrated in Fig. 2. It may be seen that almost equal distribution of sexes is obtained in the size groups 130 to 160 mm. Among the fish smaller than 130 mm, the significant excess of males in the 120 mm group is attributed, as stated earlier, to inadvertent recording of sex. Among the rest, all the size groups, 170 mm and above, can be taken to exhibit a female dominance because the observed

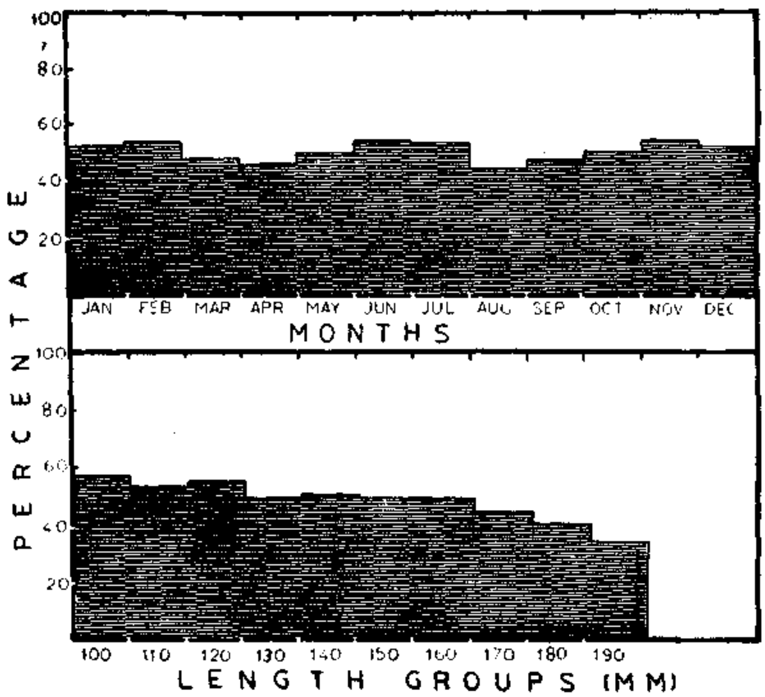

FIG. 2. Percentage of males in each length group and month of capture for all categories of oil sardine combined.

pooled ratio for all these size groups is 355 : 531 (40% : 60%) with a highly significant dominance of females. This, as shown already, is caused by differential growth during and after the first spawning season when the fish grows from 150 to 170 mm. In the monthly distribution, all the months appear to satisfy the null hypothesis except August which indicates a preponderance of females. However, since the data for this month largely relate to the spent fish of one season (1965-66), without which the differences are not significant, it can be ignored with the conclusion that no seasonal disparities are seen between the sexes. Summing up, it can be stated that among the juvenile community, although the individual samples on the observation days may show dominance of either sex or their equal representation, there appears to be no significant differences in the yearly juvenile recruitment. The records on the adult stock permit us to presume that due to differential growth, faster among the females during June to October period, the females are more numerous in the size groups 170 mm and above.

Given the fecundity estimate, the amount of ova produced by an unit quantity of adult biomass can be calculated from a knowledge of the sex ratio in the stock of potential spawners. Since in an earlier study on the length-weight relationship it was seen that there were no significant differences in the adjusted mean weights between the mature males and females (Antony Raja, 1971*b*), it can be assumed that the differences in the weight of mature fish with respect to sex are negligible. In a subsequent study, it was estimated that 750 million ova are likely to be released for every tonne of mature females (Antony Raja, MS 2). Inasmuch as the maturing-mature fish in the present study have shown no significant departures from unity during the spawning months, it may be said that half of the above estimate, 375 million ova, may be expected from a tonne of adult biomass of the oil-sardine population.

As for the past studies on the sex ratio in the oil-sardine, Hornell and Nayudu (1924) reported that up to first maturity (150 mm) the females preponderated with the disparity getting reduced to a minimum among the spawners. From the greater incidences of males among the spent survivors they inferred that there was considerably greater mortality among the females after spawning. Nair (1959) was of the opinion that there were no differences in the proportion of sexes in the different size categories and, based on the rarity of spent and recovering fish in the fishery, he presumed high mortality among both the sexes after spawning. However, as no data were advanced in support of their remarks, the observations of the above workers can only be taken as largely qualitative presumptions. Chidambaram (1950), while describing the fishery of 1936-37 season, mentioned that the samples showed equal proportion of sexes for fish up to 200 mm but thereafter the females were found to be more; but his records indicate that even in the size groups below 200 mm significant dominance of males is noticed in certain months. It is, however, generally observed from his data of 7 seasons that in the larger size groups above 150 mm there is likelihood of more females, while in the immature category the ratio would not have deviated markedly, thus conforming to the general feature seen during the present study also. Off Karwar, males appeared to be relatively more numerous among the immature group but, in the spent category, the females outnumbered the males (Radhakrishnan, 1969). Off Cochin coast, Balan (1971) noticed a preponderance of females which he related to gear selectivity. He observed that during fishing operations with the surface boat-seine, 'thangu vala', a vertical separation of sexes takes place resulting in the passive capture of females. It should be, however, remarked that to prove a natural vertical segregation of sexes, the lower section of the vertical shoals should bring out the dominance of the males, which appears to have been not examined. Since the above gear is a non-selective one capable of covering a depth up to 30 - 40 m, whereas the fishing is generally conducted at depths less than this, it is doubtful whether gear selectivity can be adduced as the reason for the dominance of females.

It would be worthwhile to subject the area differences in sex ratios, if any, to closer scrutiny. There may be instances of strong variations between localities in sex ratio. While it may throw some light on the behaviour during shoaling, it is reported that sometimes such differences may be of genetic origin also, in the sense that they can reflect true differences of abundance between the sexes, apart from the usual causes through differential accessibility, vulnerability, growth and mortality between the sexes (*vide FAO Fish. Rep.*, (6), Vol. 1, p. 41). Since all these may mean differential incidences of fishing mortality which could have a large bearing on any yield equation, it is necessary to continue the studies with this specific purpose in view.

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