POPULATION DYNAMICS OF INDIAN MACKEREL BASED ON DATA FROM MANGALORE DURING 1967-1975

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ABSTRACT

The total mortality rate (Z), as on data collected at Mangalore during 1967-75, ranged between 2.54 and 6.21. Since the total mortality had no regression on fishing intensity the natural mortality rate (M) was calculated as 1.5 from the effective life span of mackerel. K, t_o and W_∞ values were estimated based on the growth in weight. The studies indicated that mackerel can withstand heavy fishing mortalities (F) and the value of F that gives the maximum yield is 6.00. The recommended age at entry into the exploited phase ($t_{p'}$) is 8 months instead of the present 6 months. Increasing the F value to 6.00 and $t_{p'}$ to 8 months it is found that the existing quantity of the average standing stock can give an average annual catch of 1,98,870 tonnes instead of the present 96,451 tonnes.

INTRODUCTION

The Indian mackerel, *Rastrelliger kanagurta*, is a very important pelagic resource along the west coast of India, showing wide fluctuations from year to year. Hence, extensive studies on the dynamics of its population are indispensable for understanding its reactions to various amounts and kinds of fishing activity to which it will be subjected to. Apart from the contributions by Banerji (1963, 1970 and 1973) and Sekharan (1974) on this aspect, no further studies have been made. An attempt is made in this paper to estimate population parameters and study the dynamics of mackerel population. The limiting factors causing the study less conclusive are also discussed.

SOURCE OF DATA

Detailed catch, effort and length-frequency data collected from one of the representative centres in the Mangalore area viz., Baikampady, on mackerel, during the seasons from 1967-75 form the basis of this study.

ESTIMATION OF PARAMETERS

1. *Total mortality* (Z): Detailed studies on the growth pattern of mackerel were made by Yohannan (1979). The average modal size of mackerel population

when they complete one year is 222 mm with minor variations from season to season. The growth equation gives a length of 250 mm and 262 mm for the fishes completing second and third year of life, respectively. When mackerel fishery commences after the southwest monsoon in the Mangalore area in August or September the main landings are by gill nets, which land mackerel with a modal size of 222 mm or more. They are the one-year-olds. Juveniles start appearing in the 'Rampani' catches generally by about October or sometimes even in September. The recruitment of this 0-year class to the fishery is normally completed by about November. After September, the one-year-old group is represented by stray catches by gill nets. Though the 0-year class will have a modal length below 222 mm, the size range may go well beyond 230 mm. So, the year classes were separated by taking into consideration of the modes as well as the size range and its progression during a season. It is seen that the size of mackerel has a normal distribution, especially during the later half of the season. The size distribution of mackerel in the commercial catches are plotted and the age groups are separated as shown in the Fig. 1. By this method it is seen that the Rampani

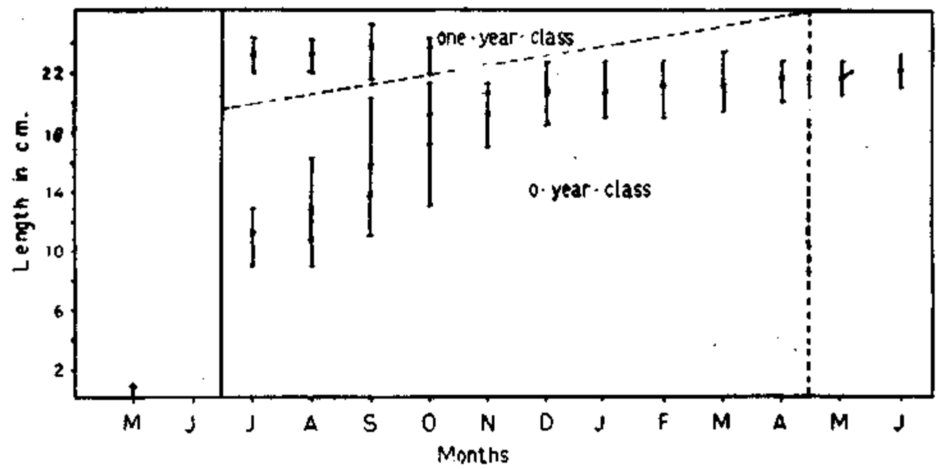

FIG. 1. Method of separation of year classes of mackerel.

landings are constituted of mainly 0-year class. Hence, to get an estimate of abundance of one year olds the gill net landings are also taken into consideration. The effort of all the gears are standardised in terms of Rampani using the formula:

$$\frac{Cb}{Ua} \quad \ldots\ldots\ldots\ldots(1)$$

Where, Cb is the catch of a particular gear and Ua, the catch per unit effort (CPUE) of Rampani.

The annual catch per standard effort of different year classes were used for estimating the instantaneous total mortality coefficient (Z) using the formula:

$$Z = \text{Log e} \frac{\bar{N}_0}{\bar{N}_1}$$ (Gulland 1969)..........(2)

Where $\bar{N}_0$ and $\bar{N}_1$ denote the seasonal catch per unit effort of an year class during two consecutive seasons. The estimated values are given in Table 1.

TABLE 1. *Details of standard effort, catch per standard effort in numbers of different age groups and the annual instantaneous total mortality (Z) of mackerel.*

Seasons	Standard effort	CPSUE of 0-year class	CPSUE of one-year class	Total mortality (Z)
1967-68	102.16	5850	74	2.63
1968-69	108.95	8547	422	2.54
1969-70	119.77	20940	674	3.68
1970-71	111.50	113889	526	6.03
1971-72	91.72	37396	273	6.21
1972-73	129.10	1294	75	5.38
1973-74	77.62	10265	6	4.39
1974-75	61.44	17061	127	

2. *Quarterly instantaneous rate of decrease*: A study of catch and CPUE data (Yohannan 1977) of mackerel has revealed that generally the recruitment is completed by the last quarter of the calendar year. A good fishery continues during the first quarter of the following year and the fishery dwindles by the second quarter. The instantaneous rate of decrease from the last quarter of the calendar year to the first quarter of the following year was calculated for studying its properties using the formula (2) when N_0 and N_1 represented the CPUE during two consecutive quarters. The rates are given in the following Table.

Seasons	Quarterly Z
1967-68	6.53
1968-69	4.92
1969-70	0.015
1970-71	1.46
1971-72	−3.58
1972-73	2.61
1973-74	0.31
1974-75	−2.45

3. *Natural mortality* (M): An attempt was made to separate the instantaneous natural mortality coefficient (M) from Z by studying the regression of Z on fishing intensity. The result is given in Fig. 2. The correlation coefficient r was also calculated. The value of r was −0.016 indicating absence of linear relationship between the fishing intensity and Z and hence, separation of M from Z by this method was not found valid here. So, the value of M is calculated based on the effective life span of mackerel. The rate at which its population will be reduced to 1% in an unfished state during its effective life span can be taken as its M (Sekharan 1974). According to Yohannan (1979) the effective life span of mackerel is about 3 years. Hence, its M value will be about 1.5. Subtracting M from Z the value of F is got.

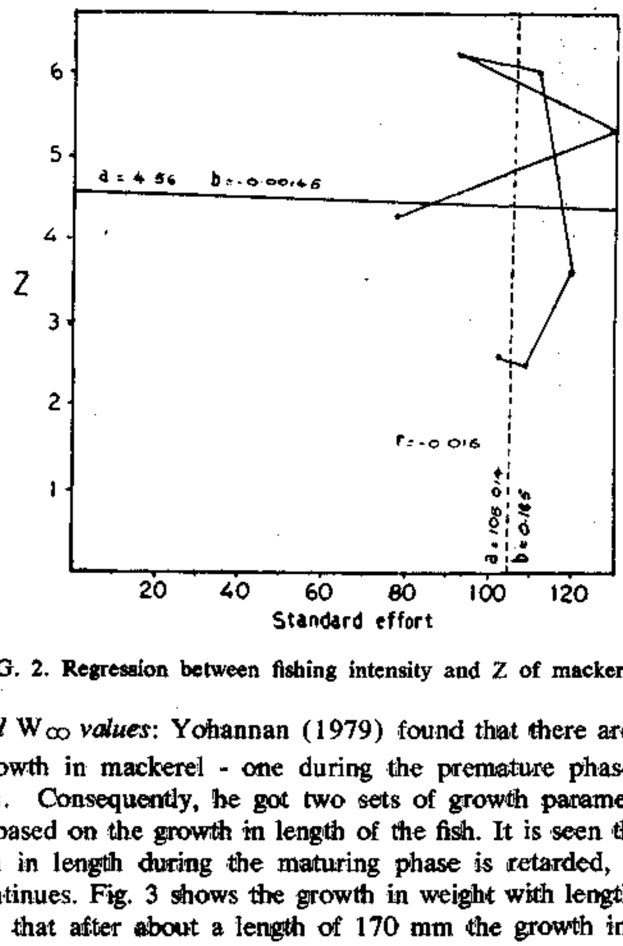

FIG. 2. Regression between fishing intensity and Z of mackerel.

4. K, t_o, *and* W_∞ *values*: Yohannan (1979) found that there are two dinstinct patterns of growth in mackerel - one during the premature phase and another one afterwards. Consequently, he got two sets of growth parameters. His conclusions were based on the growth in length of the fish. It is seen that though the rate of growth in length during the maturing phase is retarded, the growth in weight still continues. Fig. 3 shows the growth in weight with length of mackerel. It can be seen that after about a length of 170 mm the growth in weight is relatively fast. Hence, in the place of length measurements the corresponding weights to length given by Yohannan (1979) for different ages in months were taken and the growth parameters calculated. The values are:

Monthly basis			Yearly basis		
1 W_∞	=	217 g	W_∞	=	217 g
1 K	=	0.1536	K	=	1.84
1 t_o	=	−0.2857 months	t_o	=	−0.02 years

The resultant curve is given in Fig. 4. Unlike the L_∞ value estimated from 24 months data (Yohannan 1979) W_∞ gives a satisfactory value. Hence, the W_∞ value and K and t_o values calculated for growth in weight are taken for studying the population characteristics.

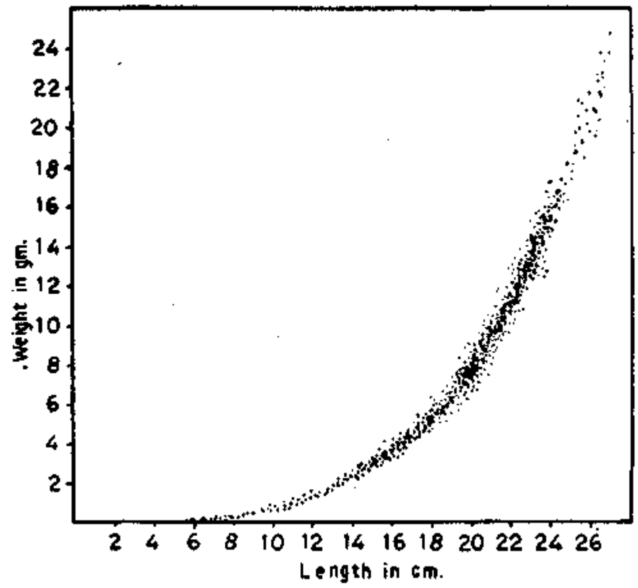

FIG. 3. Relation between length and weight of mackerel.

5. *Age at recruitment* (t_p) *and age at entry into the exploited phase* ($t_{p'}$)

Yohannan (1979) has observed that the intensive spawning of mackerel takes place during April-June. Fig. 1 also indicates such a possibility. For the purpose of calculation it is assumed that the mackerel are born in the month of May. When they start appearing in the fishery in September they are 4 months old. Hence, the age at recruitment (t_p) is taken as 0.33 years. They form sizeable shoals and are intensively exploited in the Mangalore area in the month of November. Hence, the age at entry into the exploited phase ($t_{p'}$) is about 6 months or 0.5 years.

Yield per Recruit

For the assessment of maximum yield from the fishery the equation:

$$Y/f = a - bf \qquad \ldots\ldots\ldots\ldots\ldots (3)$$

(where Y/f = catch per unit effort and f = fishing intensity and 'a' and 'b' are constants) used by Banerji (1973) was attempted. The effort and CPUE of Rampani was used for this calculation. The result is given in Fig. 5. It can be

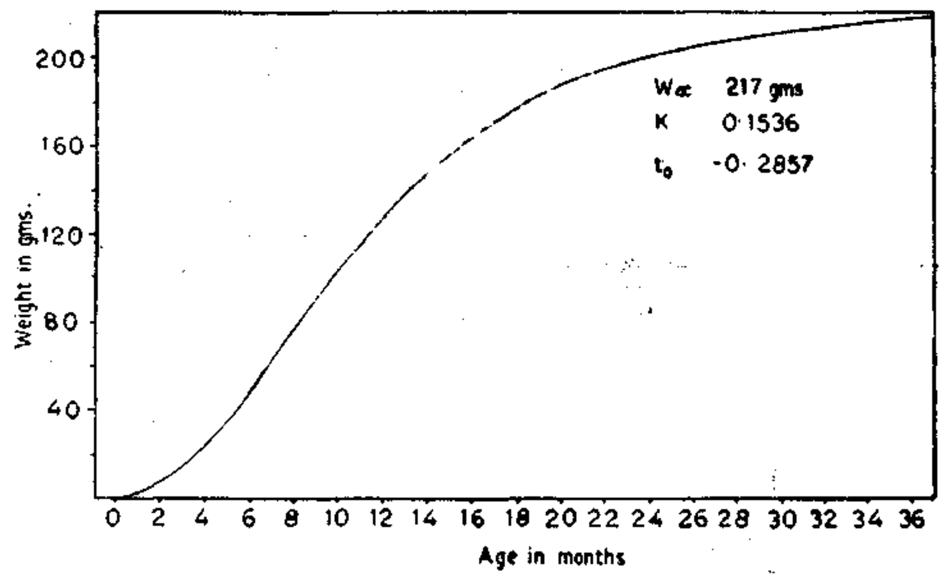

FIG. 4. Growth in weight of mackerel.

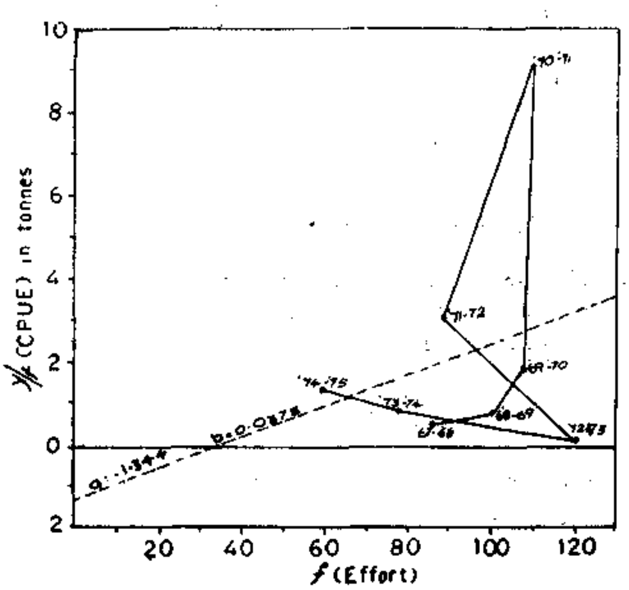

FIG. 5. Relation between effort and CPUE in mackerel fishery.

seen that 'b' has a positive value and 'a' has a negative value. This means that the fishing does not affect the stock and hence the equation can not be used here.

The estimation of the yield per recruit (Yw/R) at different levels of fishing mortality were made by using the formula of Beverton and Holt (1957) simplified by Ricker (1958):

$$Yw/R = F e^{-M(t_{p'}-t_p)}\, W_\infty \left\{ \frac{1}{F+M} - \frac{3e^{-K(t_{p'}-t_0)}}{F+M+K} + \frac{3e^{-2K(t_{p'}-t_0)}}{F+M+2K} - \frac{e^{-3K(t_{p'}-t_0)}}{F+M+3K} \right\}$$

The resultant curve is given in Fig. 6. The maximum value of yield (Y max) is reached at a fishing mortality of 6.

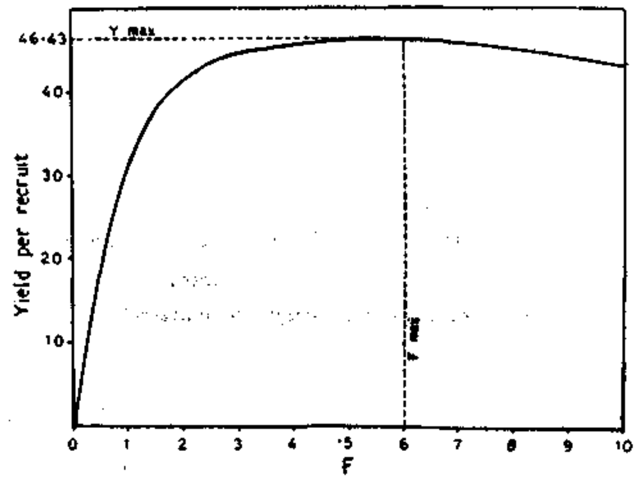

FIG. 6. Yield per recruit in mackerel fishery.

EUMETRIC FISHING AND YIELD CURVES

To study the maximum possible yield that can be obtained at each level of fishing intensity by changing the age at exploitation of mackerel when M is 1.5, the yield per recruit was calculated as a function of age at entry into the exploited phase for various values of F using the formula (4) and the resultant curves are given in Fig. 7. An eumetric yield curve (Fig. 8) is drawn by plotting the maximum values of Yw/R from each of a number of $t_{p'}$ values against the corresponding fishing mortality. An eumetric fishing curve is also drawn in the same figure by plotting $t_{p'}$ years needed to produce the maximum Yw/R for various values of F. It can be seen that the maximum Yw/R is obtained at fishing mortalities of 4 to 6 and $t_{p'}$ values of 8 months.

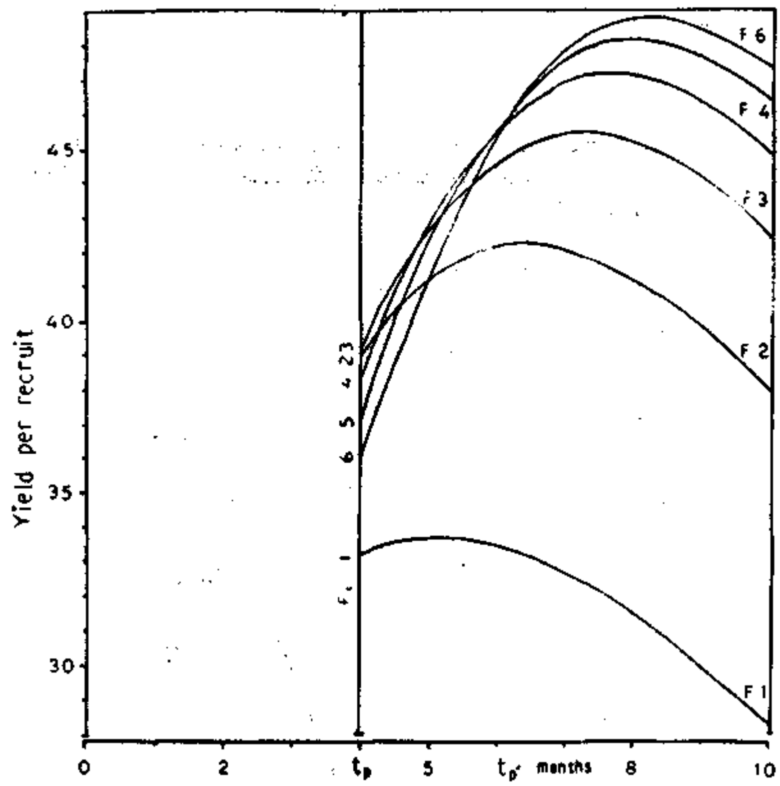

FIG. 7. Yield per recruit in the mackerel fishery for different values of t_p, months with varying F.

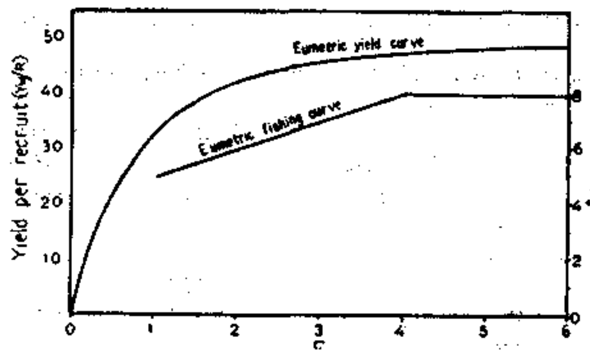

FIG. 8. Eumetric yield and fishing curves of mackerel.

Estimates of Stock

During the period under consideration the mackerel fishery in India experienced wide annual fluctuations, the catch ranging from 21,703 tonnes to 2,04,575 tonnes. Based on the present mortality rates the exploitation rate (U) during different years were calculated by using the formula:

$$U = \frac{F}{F+M}\left(1 - e^{-(F+M)}\right) \qquad \text{(Ricker, 1958)} \ldots\ldots\ldots\ldots(5)$$

The total stock was estimated by dividing th annual total catch by U and the annual average standing stock by dividing the total catch by F. The estimated values are given in Table 2.

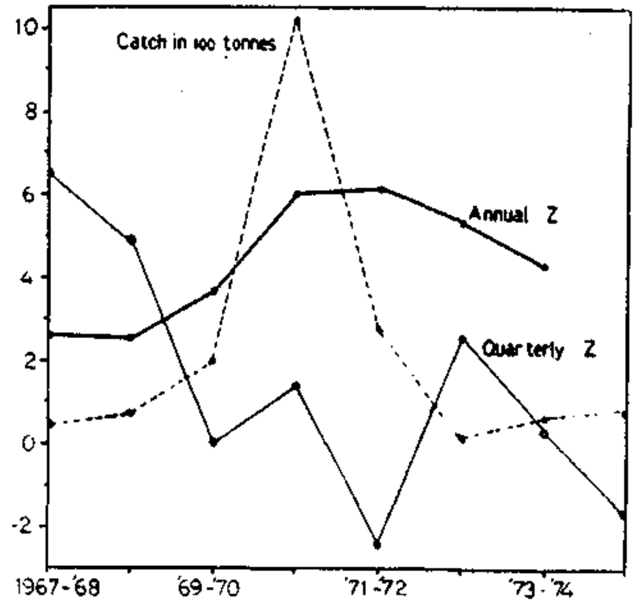

FIG. 9. Relation between total catch, annual Z and quarterly Z of mackerel at Mangalore.

TABLE 2. *Estimation of the stock of mackerel when* M = 1.5.

	Z	F	Exploitation rate (U)	Total annual stock (Y/U)	Average standing stock (Y/F)	Total mackerel catch in India (Y)
1967	2.63	1.13	0.399	73,797	26,058	29,445
1968	2.54	1.04	0.377	57,568	20,868	21,703
1969	3.68	2.18	0.578	158,888	42,127	91,837
1970	6.03	4.53	0.749	185,856	30,730	139,206
1971	6.21	4.71	0.757	270,244	43,434	204,575
1972	5.38	3.88	0.718	151,770	28,085	108,971
1973	4.39	2.89	0.650	122,189	27,482	79,423
Mean	4.41	2.91	0.650	148,386	33,145	96,451

POTENTIAL YIELD

From table 2 it can be seen that the average annual standing stock of mackerel in the presently exploited area in India during the years 1967-73 was 33,145 tonnes. The estimated F max is 6.00 (Fig. 6). From a relation:

Y/F. F max = max

it can be estimated that the Y max in mackerel fishery in India is 1,98,870 tonnes which is probably the potential average annual yield of mackerel in India from the present area of exploitation.

DISCUSSION

The estimation of different population parameters, yield per recruit, and stock position of mackerel made in this paper has its own limitations. Parrish (1956) has observed that '. .the basic figures required for the calculation of the rate of 'total' mortality are the average numbrs of each age groups per unit of fishing effort from year to year over the whole area occupied by the stock.' This condiion is not satisfied while calculating the mortality rates presented in this paper. The figures are based on the data collected from a single centre in the Mangalore area. When dealing with a pelagic fish like mackerel, with very wide distribution, exploited intensely all along the west coast employing gears of wide-ranging efficiencies, the mortality rates estimated from the data collected from a single centre will surely have its limitations. Though we are not still sure whether the mackerel population along the west coast of India belongs to a single unit stock or unit fishery because, according to Gulland (1969), different stocks of a species inhabiting a large area with no obvious dividing features so that they can mix freely together and are fished in that condition can not be treated separately because, 'even if the separation of the fish between the stocks at the end of the mixing period is perfect, the fishing mortality of the two stocks has an element in common, and neither can be treated as a unit unless the mixed catch can be separated into the elements from the stock.' Probably, this may be the situation along the west coast of India and even if there are distinct stocks of mackerel it may be permissible to treat the whole population as a single unit stock. Hence, for correct estimation of mortality rates the relative abundance of different year classes all along the west coast should be estimated after standardising the various types of gears operated in the area.

Second major problem is the limitation of the fishing area. The mackerel fishery is almost exclusively confined to a narrow coastal belt and their availability beyond the present fishing limits is not known. Possibly in mackerel population either there is heavy spawning mortality or they do not form dense shoals after spawning and migrate towards the inshore area. There are some of the factors which influence the CPUE of different year classes and hence, the mortality calculations. Moreover, if the shoreward migration of mackerel shoals are controlled by certain environmental parameters, as Ketchen (1961) has observed while discussing the Pacific cod, 'their appearances in the inshore area and sudden disappearances for a long time will obviously affect the fishing success and the CPUE would be inaccurate reflections of abundance.'

In spite of these limitations, it is believed that computations such as those presented in this report can be useful for evaluating the status in regard to fishing of species for which relatively little data are available. In addition, the results of these studies will be of value in planning further research on these species.

The rates of quarterly decrease calculated shows that during 1971-72 and 1974-75 seasons the rates have a negative value. This shows that during those seasons the recruitment was not completed in the last quarter of the calender year. The reason may be either biological or environmental. It can be seen from Fig. 9 that the annual Z and quartely Z are not proportional. But, the total catch has some kind of proportionality with annual Z. This gives further support to the assumption that there may be a heavy spawning mortality or it may be an indication of some behavioural or ecological changes after spawning.

The present value of M is higher than those calculated by Banerji (1973) and Sekharan (1974). Banerji's method was not found suitable here and Sekharan seems to have overestimated the effective life span of mackerel. Anyhow, such high values of M are found in shortlived pelagic shoaling fish like anchoveta, *Cetengraulis mysticetus* in the eastern Pacific ocean (Bayliff 1967) and in the Gulf of Panama (Bayliff 1966).

From the positive value of 'b' of the equation (3) one is tempted to conclude that an increase in effort will increase the catch. Probably it may be because the effort increases as the availability of the fish increases. Since 'Rampani' is operated for both mackerel and sardine the availability of either fish will influence the effort.

The yield per recruit indicates that mackerel population can withstand heavy fishing mortalities. But fishing at very high intensities must be taken up with caution, especially because the age of mackerel at first spawning is higher than the age at entry into the exploited phase. It may affect the recruitment. Moreover, the formula used for estimation of yield per recruit is based on the assumption that M is constant throughout the exploited phase. The validity of this assumption has to be further tested, because of the possibility of an increased natural mortality during the spawning which takes place after the peak period of exploitation.

The estimation of yield per recruit for different values of F with varying age at exploitation shows that high yield can be obtained at an F value of 4 to 6 when age at exploitation is 8 months. The present age at exploitation is 6 months in the Mangalore area. In the mackerel fishery along the west coast the age at entry into the exploited is low in the southern centres and it increases as the fishery extends towards north. Increasing the age at entry into the exploited phase will result in limiting the mackerel fishery to the northern centres only, and restricting the non-selective gears to certain periods. Determination of the best point in the eumetric yield curve should take into consideration these problems as well as the running costs and rate of profit in the industry.

It may not be possible to give the effort required to produce the F max since the effort and catch has no relation. This is so because of the wide fluctuations in the availability of the fish from time to time and their habit of moving in and out of the exploited area. A comprehensive study of the nature of these fluctuations and the factors controlling it is urgently needed.

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