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POPULATION DYNAMICS OF THE SQUID *LOLIGO DUVAUCELII* D'ORBIGNY (CEPHALOPODA) IN SAURASHTRA WATERS

H. MOHAMAD KASIM*

Central Marine Fisheries Research Institute, Cochin-682 031

ABSTRACT

Age and growth, gear selection, instantaneous total mortality co-efficient (Z) and instantaneous natural mortality co-efficient (M) were estimated for the squid *Loligo duvaucelii* from catch, effort and length frequency data collected from trawl net operations at Veraval from 1979 to 1983. Estimated yield per recruit at different combinations of age at first capture, fishing mortality co-efficient (F) and cod end mesh size are given in the form of yield isopleth diagrams for two different M/K ratios. Optimum effort was found to be just higher than the present average effort expended indicating that the squid fishery does not presently suffer from overfishing. For better management of this fishery, it is observed that the prevailing mesh size be increased to 35 mm so as to realise higher yield and to cope with the impending increase in effort. This observation is valid only when the fishery is aimed mainly at *L. duvaucelii* as the squid is only a by-catch in the trawl net.

INTRODUCTION

POPULATION dynamics of some of the important fisheries of the world and recommendations for the efficient management of the same have been brought out by various workers (Beverton and Holt, 1957; Gulland, 1961; Cushing and Bridger, 1966; Schaefer, 1967; Ricker, 1975). The Indian contributions have been on some of the commercially important fisheries such as oilsardine (Annigeri, 1971; Sekharan, 1974), mackerel (Banerji, 1970; Sekharan, 1974; Yohannan, 1982), 'ghol' (Rao, 1968), prawn (Ramamurthy *et al.*, 1975), catfish (Dan, 1981) and silverbelly (Venkataraman *et al.*, 1981). Interest on the population dynamics of cephalopods has been recent. An attempt is made in this paper to estimate population parameters and study the dynamics of one of the commercially important squids *Loligo duvaucelii*, based on the data collected from Veraval, one of the major fishing ports of Gujarat.

* *Present address:* Tuticorin Research Centre of CMFRI, 90 North Beach Road, Tuticorin 628 001.

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FISHERY

The cephalopods form one of the important by-catches landed by the mechanised trawlers of Veraval and contribute to an average 5% of the total trawl landings of the centre. *Loligo duvaucelii* constitutes almost 90% of the total cephalopod landings. The estimated monthwise catch and catch per unit effort of *L. duvaucelii* during 1979-83 are given in Table 1. As might be seen from the Table the abundance of the squid was low at the beginning and end of the fishing seasons. Higher abundance

TABLE 1. *Estimated monthwise catch composition (Kg) and CPUE* within brackets of* Loligo duvaucelii *during* 1979-83

Season	September	October	November	December	January	February	March	April	May	June	Total
1979—80	1,555	1,52,280	14,344	71,456	1,24,390	45,392	1,25,976	1,62,988	39,438	..	7,37,919
	(0.142)	(3.369)	(0.480)	(1.673)	(2.306)	(1.474)	(2.641)	(2.512)	(1.149)		(2.05)
1980—81	..	57,707	12,909	36,863	56,478	2,09,800	3,78,330	3,91,884	57,316	..	12,01,287
		(1.658)	(0.371)	(0.704)	(1.128)	(3.264)	(6.820)	(7.124)	(1.506)		(3.05)
1981—82	..	4,508	43,320	37,618	87,548	1,55,172	3,08,165	2,38,650	16,485	..	8,91,466
		(0.111)	(0.764)	(0.454)	(1.175)	(2.334)	(3.208)	(3.112)	(0.593)		(1.68)
1982—83	98	18,684	33,216	1,69,774	87,313	84,373	89,475	5,07,488	2,27,059	364	12,17,844
	(0.004)	(0.307)	(0.733)	(2.260)	(1.480)	(1.577)	(3.326)	(7.660)	(4.355)	(0.167)	(2.624)
Total	1,653	2,33,179	1,03,789	3,15,711	3,55,729	4,94,737	9,01,946	13,01,010	3,40,298	364	40,48,416

* Catch per unit effort=Catch per trawling hour.

was observed uniformly during January-April in all the four seasons. The cod end mesh size of the trawl nets in operation off Veraval during 1979-1983 was 20 mm.

Age and Growth

Age and growth of this species was estimated from length frequency data for four seasons. The results obtained from this study agree with earlier report on the growth of this species (Silas *et al.*, 1982). The number of squids falling in different length groups (5 mm groupings) in a particular sampling day were raised to the catch of the sampling day and the pooled length frequency of different sampling days were again raised to the monthly catch, thus arriving at weighted frequencies in number for different months of the season. Based on these data for four seasons, the length frequency polygons in percentage were plotted for different months. Each month had a series of modes indicating successive broods. The integrated method *i.e.*, the simultaneous application of Peterson's method and the Modal progression analysis was used (Pauly, 1980). The modes were plotted against their respective months and their progression was traced as shown in Fig. 1. The modes of the same age groups were pooled and the average size obtained indicate the length attained by the squid in consecutive months and the values are given in Table 2.

The values of K, L ∞ and t_o were estimated by regressing the observed values of Lt + 1 against Lt from Table 2 as per Bagenal's method (Bagenal, 1955). The von Bertalanffy growth equation for the squid is

$$Lt = 334\ [1 - e^{-0.5\ (t + 0.0146)}]$$

The length weight relationship of this species worked out from the pooled data of male, female and indeterminate was: Log W = −3.0037 + 2.3154 Log L (r + 0.9642). Based on this relationship the asymptotic weight, W ∞ was estimated as 691.5 g.

Recruitment and Selection

Gear selection is one of the important factors which affects the fishing mortality of any species. As per Beverton and Holt (1957), the age of entry to the exploited phase ('t_p') is determined by the size at which 50% of the individuals are retained by the fishing gear.

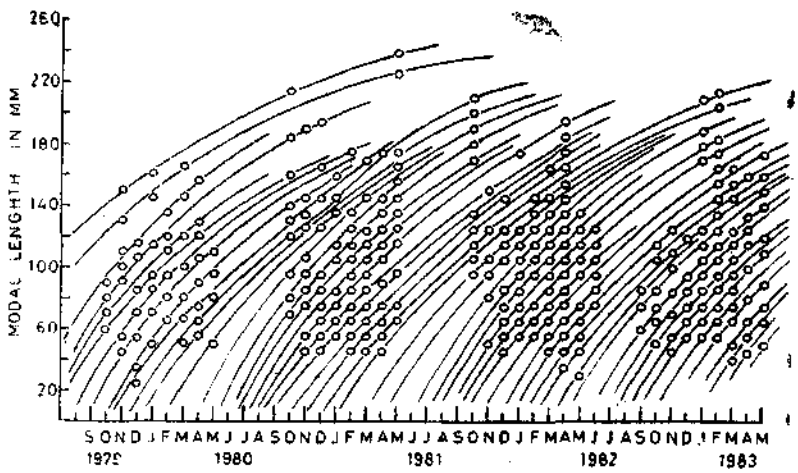

FIG. 1. Plots of modes against their respective months and tracing their progression as per 'Integrated method' of Peterson's method and Modal progression analysis (Pauly, 1980).

TABLE 2. *Observed and estimated length of squid* Loligo duvaucelii *at different ages* (Loo =334 mm, K=0.5, *to* = —0.0146)

Age in months	Observed pooled average size (mm)	Growth increment (Lt+1— Lt)	Estimated size (in mm)
1	20.0	13.3	15.8
2	33.3	12.0	28.7
3	45.3	10.2	41.1
4	55.5	9.9	52.9
5	65.4	9.8	64.3
6	75.2	9.6	75.2
7	84.8	10.0	85.7
8	94.8	10.2	95.7
9	105.0	10.0	105.4
10	115.0	10.2	114.6
11	125.2	10.1	123.5
12	135.3	10.0	132.0
13	145.3	9.0	140.2
14	154.3	8.6	148.0
15	162.9	6.1	155.5
16	169.0	6.0	162.8
17	175.0	6.7	169.7
18	181.7	5.8	176.3
19	187.5	6.3	182.7
20	193.8	6.2	118.8
21	200.0	6.3	194.7
22	206.3	5.4	200.3
23	211.7	3.3	205.8
24	215.0	2.0	210.9
25	217.0		215.9

In the absence of required data on the trawl selection, the same was estimated indirectly from the left side of a length converted catch curve (Pauly, 1984). Estimated 50% retention length (Lc) was 55 mm and thus selection factor was

$$\frac{50\%\text{ retention length}}{\text{mesh size}} = \frac{55\text{ mm}}{20\text{ mm}} = 2.75$$

as shown in Fig. 2. The size at first capture (Lc) and the size at recruitment obtained by the graphical method as described by Venkataraman (1981) was 56.3 mm and 46.3 mm respectively and the selection factor was 2.8.

TOTAL MORTALITY COEFFICIENT (Z)

On the basis of the age and growth studies the squids measuring below 133 mm (size group 125-129 mm) were designated as 0 + year group, those falling above 133 mm and below 211 mm were designated as 1 + year old squids.

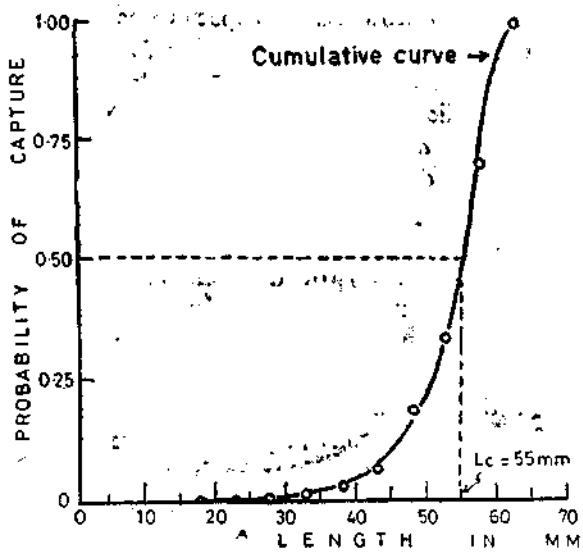

FIG. 2. The results of division of numbers caught by numbers available which corresponding to a selection curve and the estimate of Lc as per the method of Pauly (1984).

Those measuring above 211 mm and upto 259 mm were designated as 2 + year old and above 259 mm as 3 + year squids. The annual catch per hour in number of the above said year classes were used for the estimation of instantaneous total mortality coefficient (Z) (Gulland, 1969). In addition to this, the estimates of total mortality coefficients were obtained by the catch curve method described by Pauly (1980), where the value of ' b ' with sign changed provides the estimate of Z. These estimates are higher (nearly 42%) than the Z obtained by the first method.

NATURAL MORTALITY COEFFICIENT (M)

The data on the annual instantaneous total mortality coefficient were regressed against

TABLE 3. *Estimated annual instantaneous total mortality coefficient (Z) from the data on catch per unit effort in number (Gulland, 1969) and catch curve method (Pauly, 1980)*

Fishing season	CPUE × 100			Instantaneous total mortality (Z)			
	0 + Year	1 + Year	2 + Year	0 +/1 +	1 +/2 +	Mean	Catch curve method
1979-80	6700	393	23	2.24	1.97	2.11	3.25
1980-81	6591	716	55	2.48	2.53	2.51	3.28
1981-82	3369	554	57	1.70	3.43	2.57	3.74
1982-83	8083	618	18				3.33
				Mean 2.14	2.64	2.40	3.40

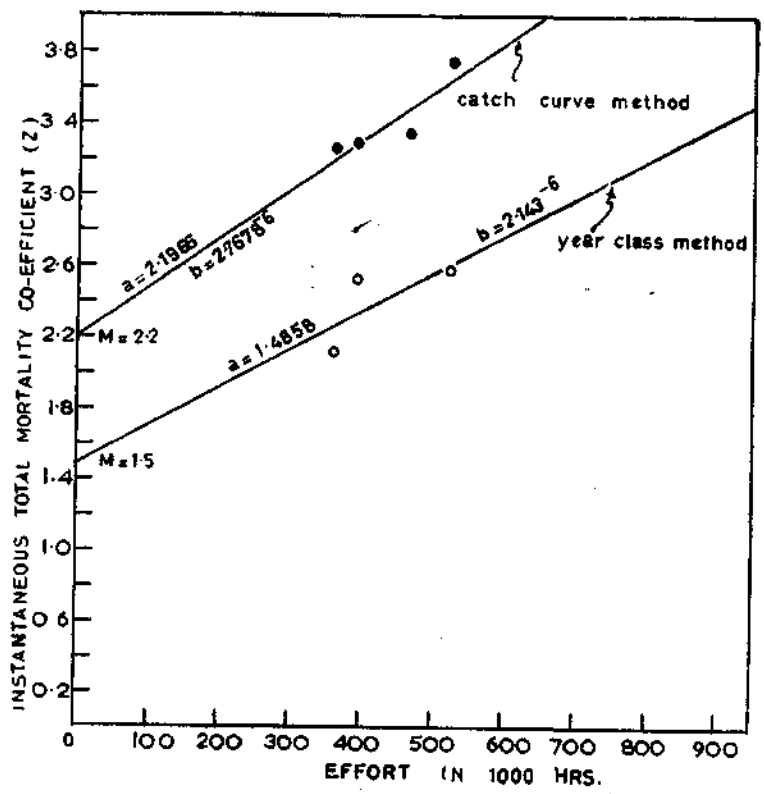

FIG. 3. Estimates of natural mortality coefficient (M) by regressing the annual instantaneous total mortality coefficient (Z) against their respective efforts.

their respective efforts by least squares method to obtain the natural mortality coefficient (M), as shown in Fig. 3. The intercept of these lines with 'Y' axis indicate the 'M' value. The estimated M was 1.5 from the data of Z by year class method and it was 2.2 from Z obtained by catch curve method. The higher value of M by the latter method was due to the high values of Z.

Yield per Recruit

The vital parameters obtained as per above descriptions were used for the estimation of yield per recruit using Beverton and Holt (1957) modal simplified by Ricker (1958). As the difference in size at first capture and size at recruitment was negligible, it was assumed that the age at first capture (t_p) and at recruitment (t_r) as same *i.e.*, 0.3 years.

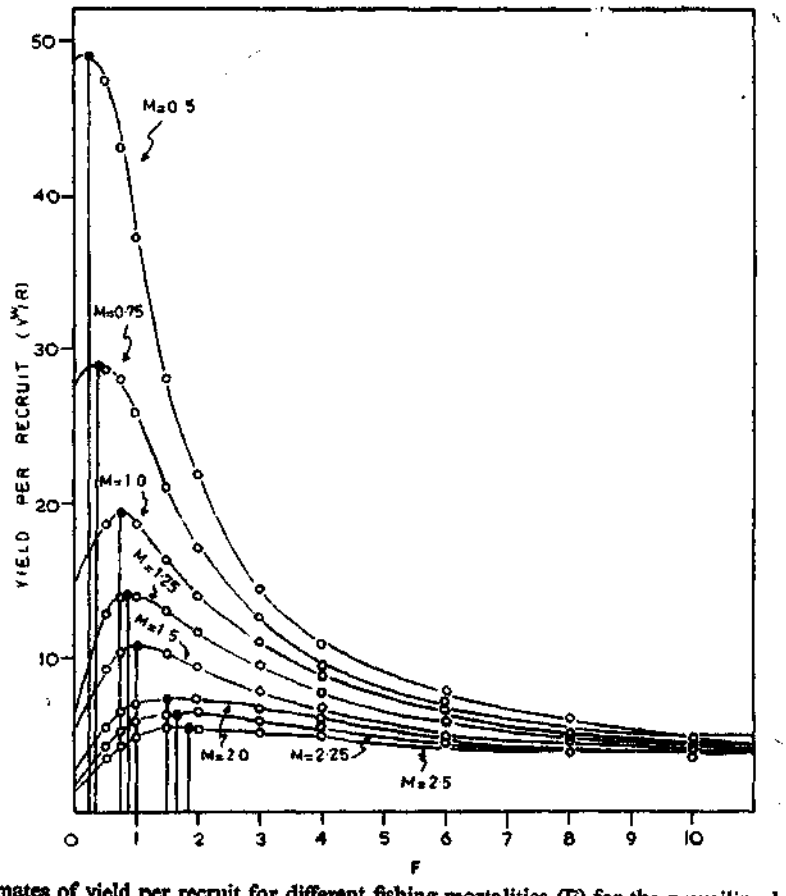

Fig. 4. Estimates of yield per recruit for different fishing mortalities (F) for the prevailing length at first capture (Lc). The yield max are shown by closed circles indicating the respective F max.

The yield per recruit accordingly was estimated for different M/K ratios from 2 to 5 at an interval of 0.5. The estimates of yield per recruit obtained for different 'F' values for the prevailing length at first capture (55 mm) are given in Fig. 4. It can be seen from this figure that lower the M/K ratios and higher the yield per recruit. Further, the increase in the yield per recruit in accordance to the increase in 'F' value reaches the maximum at a particular 'F' and then tends to decline. The intercepts of this point with Y and X axes indicate the 'yield max' and 'F max' as shown in Fig. 4. The 'F max' tends to increase with the higher M/K ratio. The yield per recruit of the squid at various age at first capture and at different 'F' values are given in Fig. 5 for different M/K ratios. As seen from this figure, the yield per recruit increases with the age at first capture upto a certain level and then declines. This age at first capture

which can produce the yield max is inversely proportionate to the M/K ratio. Further below this age, the yield per recruit is inversely proportionate to the 'F' and above this age directly proportionate. Yield isopleth diagrams were drawn with the estimates of yield per recruit at different age at first capture and F values combinations for M/K ratios 3.0 and 4.5 and given in Fig 6 and 7 respectively. The equivalent scale of fishing effort (in thousand hours) for the instantaneous fishing mortality rate was calculated on the basis of catchability coefficient 'q' and shown in these figures.

For the M/K ratio 3.0, the yield max and F max for the prevailing cod end mesh size

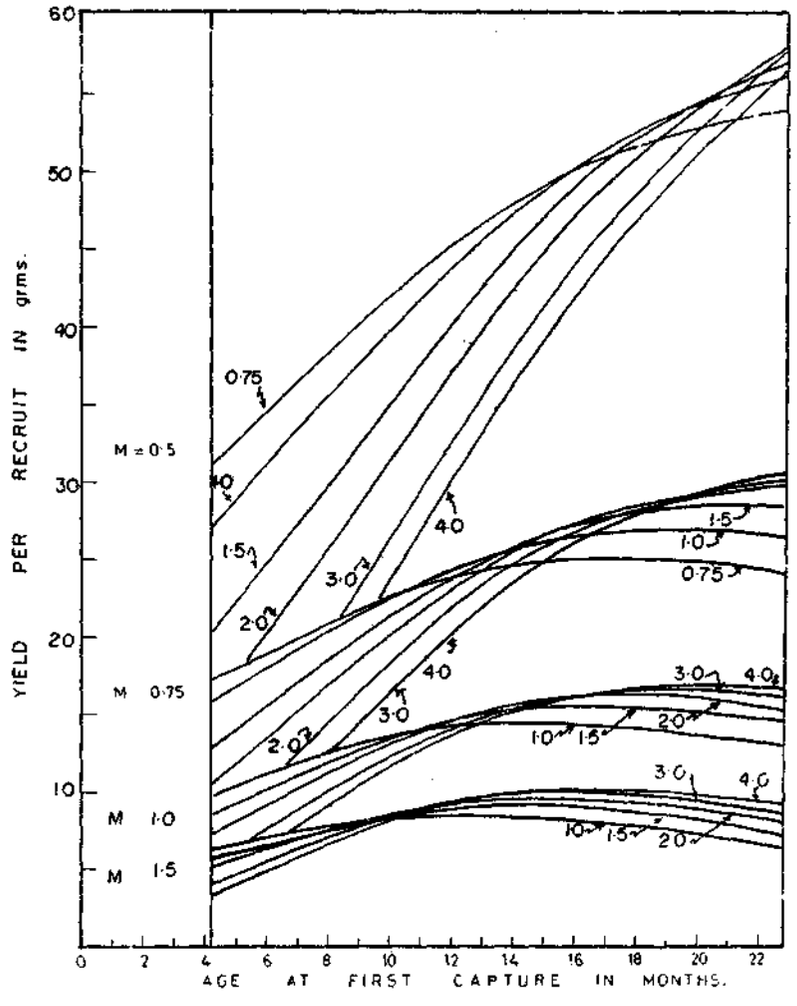

FIG. 5. The yield per recruit at different age at first capture and at different fishing mortalities 'F' (the values with arrows) for different natural mortalities (M).

20 mm was 4 g and 1.0 respectively. The equivalent effort input for the F 1 was 4,73,000 hours which is little higher than the average effort expended during 1979-83 (*i.e.* 4,34,800 hr). However, the effort input in 1981-82

was higher (5,22,622 hrs.). The favourable mesh size for the M/K ratio 3.0 was 50 mm and the yield max was 6.0 g. The F was 2.4 and the equivalent effort was 11,26,000 hrs which is 100% more than that obtained for 20 mm mesh size and the yield also has increased by 50%. For the M/K ratio 4.5 (M 2.2 by catch curve method), the yield max is 1.44 g and this can be attained with F 1.5, the equivalent effort is 5,61,000 hrs for 20 mm mesh size. The favourable mesh size for this M/K ratio is 35 mm and the yield max is 1.85 g which is 32% higher than that of 20 mm mesh size. The F has also increased to 2.85 and the equivalent effort is 10,49,000 hr which is 87% higher than that obtained for 20 mm mesh size. As seen above the effort input under prevailing condition is very close to F max obtained for the existing mesh size of 20 mm and further increase in effort will bring the catch enhancement only to a limited extent as yield per recruit declines subsequently at higher F. However, an increase in the cod end mesh size at both the M/K ratios permits not only the enhancement in effort input, as well there is increase in the yield per recruit also. The favourable mesh size for M/K ratio 3.0 is 50 mm and for 4.5 is 35 mm. Therefore, an increase in the mesh size to 35 mm from 20 mm is suggested for a higher yield with higher effort input with due consideration to other fisheries such as prawn and finfishes.

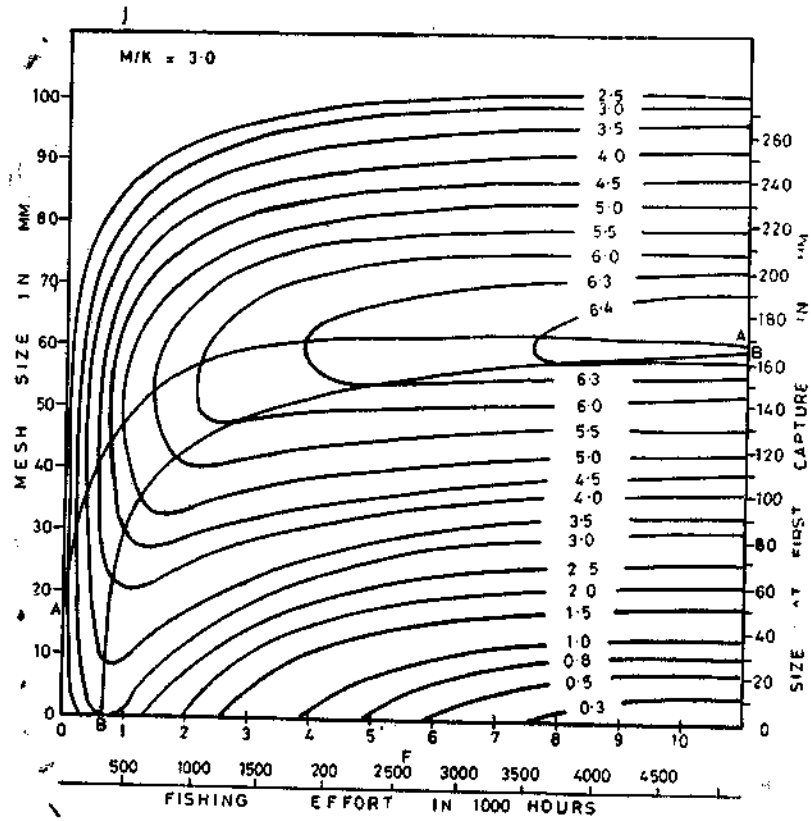

FIG. 6. Isopleth diagram for yield per recruit of *Loligo duvaucelii* in relation to size at first capture, cod end mesh size and fishing mortalities 'F' for M/K ratio 3.0. AA line indicates eumetric fishing curve and BB line MSY curve.

Discussion

One of the hurdles in the study of population dynamics is the estimation of natural mortality coefficient (M) for the tropical species in view of the difficulties in determining the correct age due to interference of various factors such as short life span, seasonal variation in growth within a year etc., as in the case of mackerel (Yohannan, 1982). For mackerel the M value ranged from 0.65 to 1.5 (Banerji, 1973 ; Sekharan, 1974 ; Yohannan, 1982). In the case of oilsardine the estimate of M varied from 0.67 to 1.45 (Banerji, 1973 ; Annigeri 1971 ; Sekharan, 1974). As the ghol fishery was in an almost virgin state the estimate of Z, 0.87 was considered as equivalent to M (Rao, 1968). Venkataraman *et al.* (1981) have estimated the M as 2.28 for *Leiognathus jonesi* and have attributed the high value of M to the short life span of the species. In the present study the M was estimated to be 1.5 - 2.2 for *Loligo duvaucelii* which is lower than the silverbelly, comparable to mackerel and oilsardine and higher than the ghol. The life span of the squid may be 6 years (*i.e.* 3/K, 3/0.5 = 6., Pauly, 1980). Shorter the life span and higher the M value as in the case of pelagic shoaling fish like anchoveta *Centengraulis mysticetus* in the Panama and Eastern Pacific Ocean (Baylife, 1966, 1967).

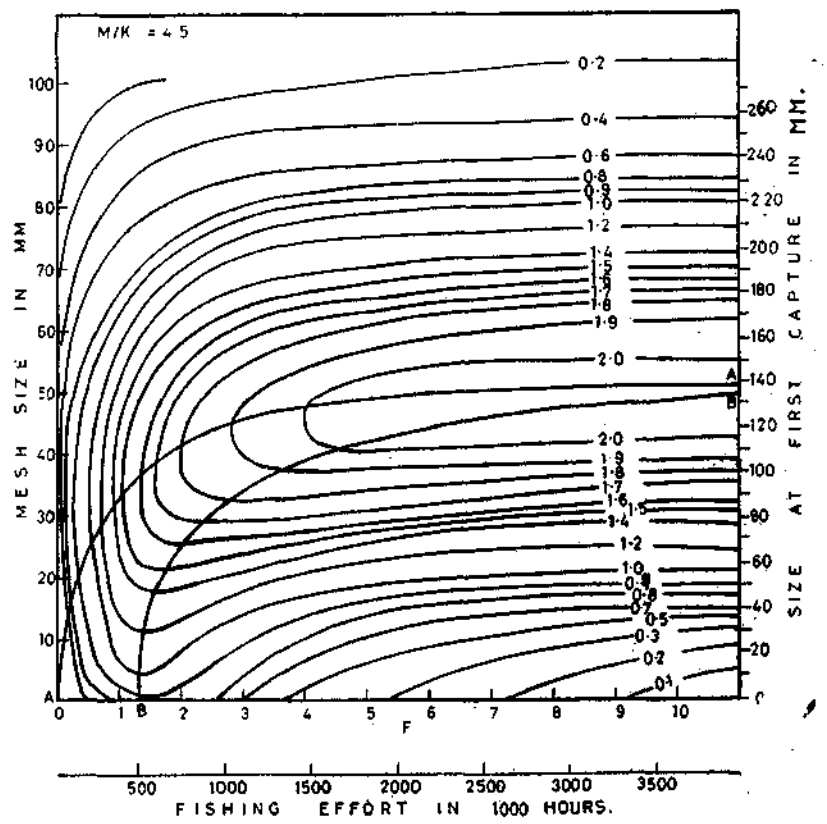

Fig. 7. Isopleth diagram for yield per recruit of *Loligo duvaucelii* in relation to size at first capture, cod end mesh size and fishing mortalities ' F ' for M/K ratio 4.5. AA line indicates eumetric fishing curve and BB line MSY curve.

The yield per recruit was estimated on the assumption that the M is constant throughout the exploited phase. All these estimates favour an increase in the age at first capture indicating that the present age at first capture is not favourable. From Fig. 7 it can be seen that further increase in the effort may not produce a better yield commensurate with the increase in effort due to the decline in the yield per recruit as pointed out earlier. Therefore, as indicated already an increase in the mesh size to 35 mm against the present 20 mm will be favourable for a better exploitation of this species.

Further, as indicated by the exploitation ratio $E = \frac{F}{Z}$ which allows a rough assessment of the stock, the squid stock is not subjected to overfishing presently as the ratio is only 0.36 and less than the 'E opt' *i.e.* 0.5. Completion of the expansion work of the Fisheries Harbour in Veraval may enhance the fishing fleet to two fold in the nearest future. The reduction in the effort in future is unlikely as the trawlers operate mainly for prawns. Therefore, the present findings are applicable only when the fishery is aimed, for squids. However, in view of the prevailing condition, the management of this resource may be taken up along with the requirements of other resources with special reference to prawns.

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