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OBSERVATIONS ON SOME ASPECTS OF BIOLOGY AND POPULATION DYNAMICS OF THE SCAD *DECAPTERUS RUSSELLI* (RUPPELL) (CARANGIDAE) IN THE TRAWLING GROUNDS OFF KAKINADA*

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ABSTRACT

Decapterus russelli (Ruppell)[2] is abundant in relatively deeper waters and forms 80-90% of carangid catches by trawlers. The von Bertalanffy growth parameters are estimated as L_∞ = 232.3 mm, K = 1.08 per year and t_0 = —0.08 year. The length-weight relationship can be described by the equation log W (g) = —5.93433+3.40764 log L (mm). The length and age at first maturity are estimated as 150 mm and 0.88 year respectively. This species spawns off Kakinada during December-August. The different mortality rates are estimated as Z = 6.65, M = 1.90 and F = 4.75 and the length and age at first capture as 158 mm and 0.98 year respectively. The yield per recruit analysis shows that : with t_c above 0.6 the Y_w/R increases with increased F without reaching maximum. The highest Yw/R, however, is obtained with tc at 0.6 only.

INTRODUCTION

THE FISHES of the family carangidae are an important group of exploited pelagic resources of India; an estimated average annual carangid catch of 38,685 tonnes was landed during 1981 and 1982 (CMFRI, 1982 ; 1983) forming 2.8% of the total marine landings of the country. Though this family is represented by about 50 species in Indian seas, only a few contribute to the fisheries at different places and *D. russelli* is the most dominant carangid landed by trawlers at Kakinada : an estimated annual average of 1229 t were landed during July 1979-June 1983 forming 83% of all carangids landed. Excepting the work of Sreenivasan (1982, 1983, 1984) from Vizhinjam, there is no information on the biology of *D. russelli* from India. The present paper deals with some aspects of biology and population dynamics of *D. russelli* on the basis of data obtained from commercial shrimp trawlers at Kakinada during July 1979-June 1983.

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MATERIAL AND METHODS

Data on effort and catch were collected for about 18 days each month and samples for biological study were obtained at weekly intervals. The data obtained on each observation day were weighted to get the

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[2] Smith-Vaniz (1984) considered *Decapterus dayi* Wakiya as a junior synonym of *D. russelli* (Ruppell).

estimates for that day and the pooled days' estimates were weighted to get monthly estimated effort, catch and length composition of catch. The length data were grouped into 5 mm class intervals and the mid points of these groups were considered for estimation of growth. The parameters of von Bertalanffy growth equation were estimated using the monthly length frequency data obtained during March 1979-February 1983 and following the integrated method of Pauly (1980 a). The length-weight relationship was calculated following Le Cren (1951) using the formula log W = log a + b log L, where W = weight in grams, L = total length in mm, 'a' a constant and 'b' the exponent, The specimens were examined in fresh condition; each fish was measured and weighed to an accuracy of 1 mm and 0.5 g respectively. The stages of maturation were fixed following Kagwade (1971) and Sreenivasan (1981). Ova diameter measurements were taken from ovaries fixed in 4% formalin following the procedure of Clark (1934). From each ovary about 300 ova were measured using an ocular micrometer at a magnification where each micrometer division (md) was equal to 0.017 mm. The instantaneous rate of total mortality (Z) was estimated following the length-converted catch curve method of Pauly (1982). The natural mortality rate (M) was estimated assuming that 99% of fish by numbers would die if there was no exploitation by the time they attained t_{max} and by taking t_{max} as corresponding to L_{max} in the catch (Sekharan, 1975), or to $L\infty$ - 0.50 cm (Alagaraja, 1984) or to 95% of $L\infty$ (Pauly, 1983). The value of M was also obtained using the equation of Pauly (1980 b), taking the average water temperature as 27.2°C following Ganapati and Murthy (1954) and LaFond (1958). The length at first capture was estimated following Pauly (1984 a) and the yield in weight per recruit by following Beverton and Holt (1957) method.

TABLE 1. *Estimated annual effort and catches (t) of all carangids and* Decapterus russelli *by private trawlers at Kakinada (Values in parantheses show % increase or decrease over each previous year)*

Years		Effort		All carangid catch	Catch of *D. russelli*	% of *D. russelli* in all carangid catch
		Units	Tr. Hrs.			
1979-80	..	47,948	3,41,997	442	350	79.2
1980-81	..	40,294 (—16.0)	3,29,179 (—3.7)	1,003 (+126.9)	900 (+157.1)	89.7
1981-82	..	50,462 (+25.2)	4,45,794 (+35.4)	1,652 (+64.7)	1,360 (+51.1)	82.3
1982-83	..	48,550 (—3.8)	3,19,864 (—28.2)	2,823 (+70.9)	2,305 (+69.5)	81.7

CATCHES AND EFFORT

The estimated annual catches of carangids by trawlers at Kakinada varied from 442 t in 1979-80 to 2,823 t in 1982-83 (Table 1); though there were fluctuations in the effort in different years, the catches showed considerable increase in succeeding years. The seasonal variations in the catches of carangids showed (Fig. 1) that peak periods of abundance varied during different years: there were major peaks during February 1982, 1983;

April 1980 or May 1981. A minor peak in abundance was observed during September 1979 and 1980. *Decapterus russelli* was the most dominant species in the catches and formed about 80-90% of carangid catches during different years (Table 1), though it contributed to the fishery significantly only during certain months particularly during January-April (Fig. 2).

Growth Parameters

A total of 8,984 specimens of the length range 52-217 mm were measured. The monthly modal lengths and growth curves drawn through majority of them are shown in Fig. 3; it may be seen that the curves are more or less parallel. The lengths attained at intervals of six months starting from the smallest modal length in each curve were read off these curves: in each curve, only the portion between the smallest and largest modal lengths was taken; sometimes to enable reading the growth for 6 month period the portion of the curve slightly beyond the largest modal length was also taken. The values thus taken from all the curves were used to estimate the parameters of von Bertalanffy equation.

A plot of L_{t+1} against L_t (similar to that of Manzer and Taylor, 1947) shows that the observed points are well represented (Fig. 4) by the straight line ($r^2 = 0.89$). From this relation, the values of $L\infty$ and K were estimated as 232.3 mm and 1.08 per year respectively.

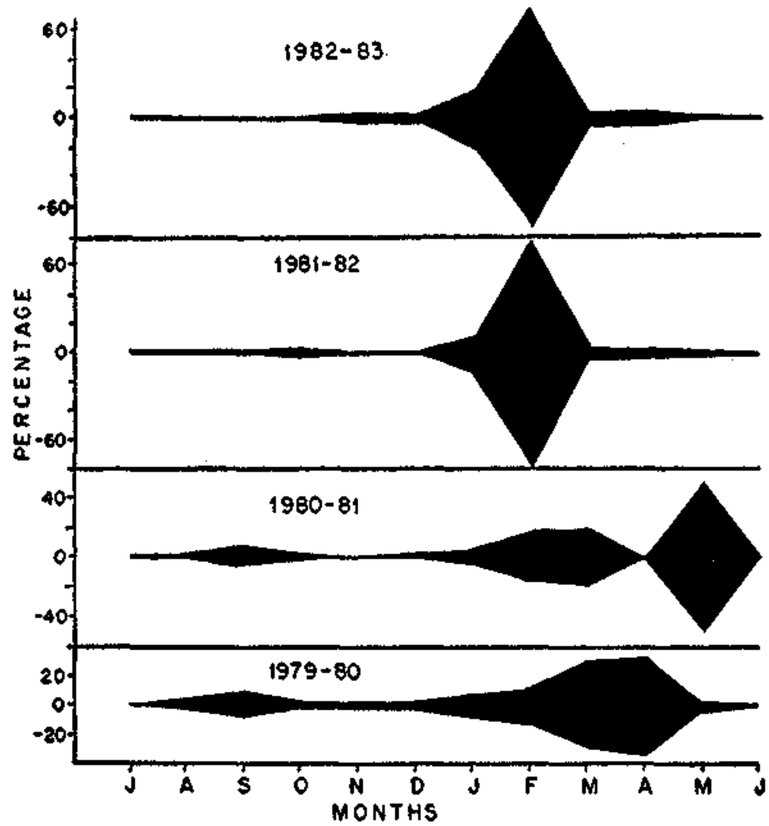

Fig. 1. Estimated monthly percentage of carangids in the total catch of each year.

From the origin of the curve D (Fig. 3), the age of the smallest modal length at 67 mm was read as three months and taking this into account, the lengths at successive half years were estimated using the constants of the above regression for estimating t_0 (Fig. 5) ; the value was estimated as —0.08 year.

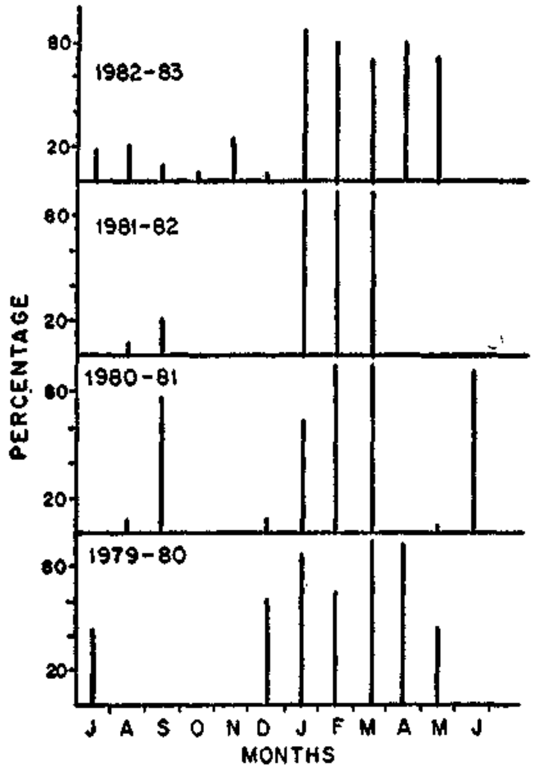

Fig. 2. Monthly percentage composition of *D. russelli* in the carangid catches of each month.

The estimated lengths at the completion of I, II and III years are 160, 208 and 224 mm respectively (Fig. 3). The maximum recorded length at Kakinada was 217 mm (age 2.4 years)

Length-Weight Relationship

Data of 267 females ranging from 132 to 201 mm in total length and from 19 to 87 g weight and 325 males ranging from 120 to 205 mm and 15 to 89 g were considered. The equations obtained for each sex were :

Females : $\log W = -5.97804 + 3.42534 \log L$ ($r^2 = 0.92$)

Males : $\log W = -5.88927 + 3.38898 \log L$ ($r^2 = 0.86$)

The analysis of covariance (Snedecor and Cochran, 1967) showed that the differences between regression coefficients and Y-intercepts of sexes were not significant at 5% level. Hence the data of sexes were pooled and the relationship for the species was calculated as :

$$\log W = -5.93433 + 3.40764 \log L \ (r^2 = 0.90)$$

The value of regression coefficient was tested against the theoretical value of 3 by the t-test ; it was significantly different from 3.

Maturation and Spawning

Length and age at first maturity : Only females were considered and individuals in stages III-VII of maturation were taken as mature. Fishes of 135 mm and above showed mature ovaries. On the basis of the percentage of mature fishes in each length group, length at first maturity could be taken as 150 mm (Fig. 6) whose age could be calculated as 0.88 year.

Spawning habits : Three specimens each of stages IV and V and one each of stages VI and VII were examined for ova diameter frequency distribution. Three types of ova were recognised in ovaries in stages IV and V, the first one representing immature ova with the diameter extending upto 4 md and the second one representing maturing ova with the diameters ranging from 5 to 18 md. The former were transparent and irregularly-shaped with the nucleus clearly visible and the latter were more or less spherical, yolked, translucent and the nucleus was not clearly visible. For the present study, ova upto 6 md were not considered as they were of no consequence in interpreting the periodicity of spawning. The third group Fig. 7) represented the mature ova with the diameters ranging from 19 to 32 md; these ova were spherical and opaque. In stage VI. in addition to the above, there was another group (Fig. 7) which represented the ripe translucent ova with a distinct oil globule; these ova were spherical and ranged from 33 to 48 md and the diameter of the oil globule ranged from 9 to 11 md.

The ova diameter frequency distribution in ovaries of different stages of maturation (Fig. 7) showed that the mode at 11-12 md in stage IV remained stationery in stage V. but in stage VI it had shifted to 17-18 md; the ova in this group were mature opaque and maturing. The mode at 23-24 md in stage IV had shifted to 27-28 md in stage V and then to 39-40 md in stage VI. In stage VII. in addition to the modes in maturing ova, there were two minor modes one each in mature opaque ova and ripe translucent ova. The situation therefore, indicates that the species probably spawns twice in a season in the sea off Kakinada.

Spawning season: Only females of and above the length at first maturity were considered. The frequency distribution of females in different stages of maturation (Table 2) suggests that *D. russelli* in the sea off Kakinada spawns during December-June the period sometimes extending upto August.

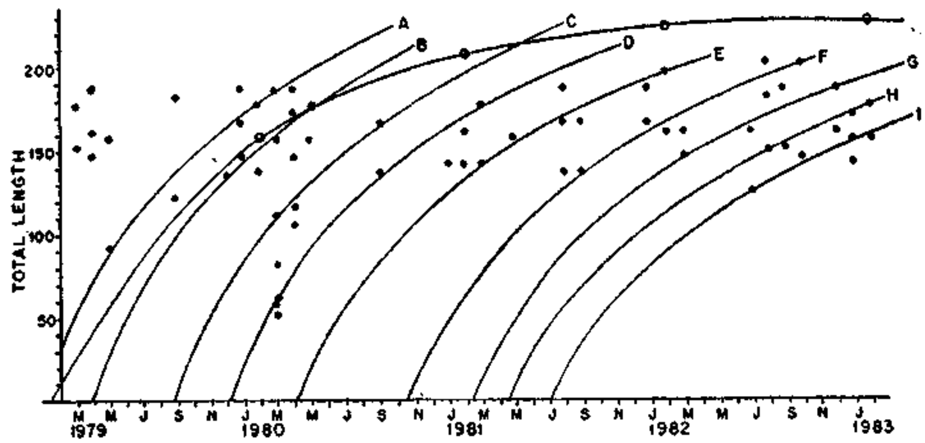

Fig. 3. Growth curves in *D. russelli* to estimate growth. The VBG curve is also shown.

Mortality Rates

Total mortality rate: During 1982-83 the data were not available for several months, hence the data of this year were not used. Through the length-converted catch curves (Fig. 8), the values of Z were estimated to range from 4.78 to 8.75 with the average at 6.65.

Natural and fishing mortality rates: The values of M estimated by following different approaches are shown in Table 3. In the present study, however, the M value obtained by Sekharan's (1975) method at 1.90 was considered. Since the average total mortality during the period was estimated as 6.65, the present F value became 4.75.

Estimation of Length at First Capture

Since the gear operated was the same with the same cod end mesh size in all the three years, the data of these three years were pooled and a length converted catch curve was obtained to estimate the number of fish in the first length class that was fully selected (*i.e.*) the estimated number of fish corresponding to the first point in the straight descending portion of the length-converted catch curve. Taking this value, and the M value at 1.90, the length at first capture (L_c) was estimated as 158 mm (Fig. 9); the t_c could therefore be calculated as 0.98 year.

Yield per Recruit

The smallest length in the catch (52 mm) was taken as the length at recruitment (L_r) and its age at 0.15 year as t_r. The value of W_∞ was calculated as 134.4 g taking the value of L_∞ and the length-weight relationship.

The yield in weight per recruit (Y_w/R), at $M=1.9$ and five values of t_c corresponding to L_c values of 108, 118, 128, 148 and 158 mm (Fig. 10) against F showed that, within the range of F values considered :

1. With t_c ranging from 0.50 to 0.66, the Y_w/R was greater if t_c was greater and attained maximum at greater values of F if t_c was greater ; there was however no maximum if t_c was 0.66.
2. With t_c above 0.66, the Y_w/R increased with increased F without attaining a maximum.

The Y_w/R as a function of t_c with the present F (Fig. 11) showed that maximum Y_w/R was obtained with t_c at only 0.6, whereas the present t_c was 0.98.

It is thus clear that highest yield of *D. russelli*, with the present F or by increasing the same, can be obtained only if the t_c is 0.6. It is also clear, however, that yield can still be increased from the present level, without decreasing t_c, but by increasing the effort, though the yield will be less than when t_c is 0.6.

TABLE 2. *Gonadal condition of adult females of* D. russelli *in different months (data of all years pooled)*

Months	Females examined (No)	% of maturation stages II	III+IV	V+VI	VII
July ..	—	—	—	—	—
August ..	22	86.4	4.5	4.5	4.5
September ..	6	100.0	—	—	—
October ..	13	100.0	—	—	—
November ..	—	—	—	—	—
December ..	41	80.5	14.6	4.9	—
January ..	157	44.6	32.5	20.3	2.5
February ..	198	1.0	40.9	54.5	3.5
March ..	46	15.2	69.6	13.0	2.2
April ..	9	55.5	45.5	—	—
May ..	19	63.1	36.9	—	—
June ..	—	—	—	—	—

Discussion

The trawling experiments in the sea off Kakinada in the depth range 5-100 m by Narayanappa *et al.* (1968), Satyanarayana *et al.* (1972) and Satyanarayana and Narayanappa (1972) have shown that *Decapterus* spp. are abundant beyond 50 m depth. According to Muthu *et al.* (1977), the abundance of these fishes during February-April off Kakinada may be due to possible upwelling in the region. On the basis of data of 10 year period (1969-'79) it was shown (CMFRI, 1981) that *Decapterus* spp. are abundant in the catches during January-March at Kakinada. The greater returns of *D. russelli* during January-April, as observed in the present study, may be because the boats conduct fishing in the relatively deeper waters during this period.

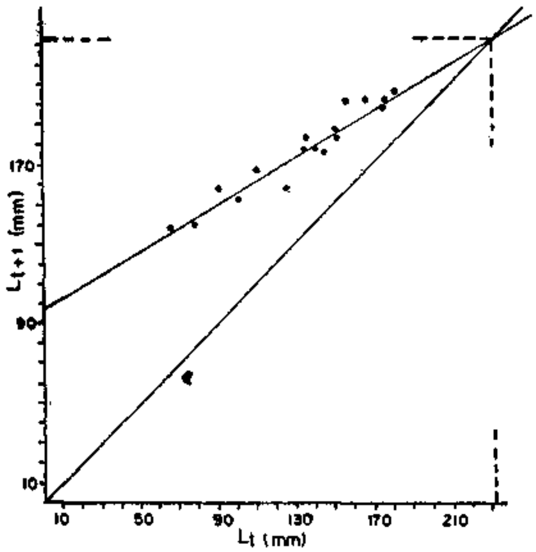

Fig. 4. Plot of L_{t+1} against L_t in *D. russelli* a intervals of 6 months.

It is known (Qasim, 1973) that spawning in majority of Indian marine fishes is prolonged lasting 7-9 months in a year and the present observation on *D. russelli* are in agreement with this. The conclusion on spawning period as December-August is in conformity with the observations of Rao *et al.* (1977) along the Indian west coast: they observed scads with ripe and running ovaries during October-August. The ova diameter frequency distribution in mature and ripe ovaries (Fig. 7) indicates that spawning takes place in two batches during a season. The growth curves (Fig. 3) show that 2-3 broods are recruited to the fishery in different years indicating tha. ova are also released in 2-3 spawnings a yeart Though the data on hand do not give evidence of spawning in three batches in a year, the observations of Rao *et al.* (1977) show that the scad spawns over an 'extended period with two or three peaks in an year'.

TABLE 3. *Estimated values of M obtained by different methods along with the values of L_{max} and t_{max} in* D. russelli *at Kakinada*

Method adopted		L_{max} (mm)	t_{max} (years)	M
Sekharan (1975)	In the catch:	217	2.4	1.9
Alagaraja (1984)	$L\infty$ -5 mm:	227.3	3.5	1.3
Pauly (1983)	95% $L\infty$:	220.7	2.7	1.7
Pauly (1980 b)	—		—	2.0

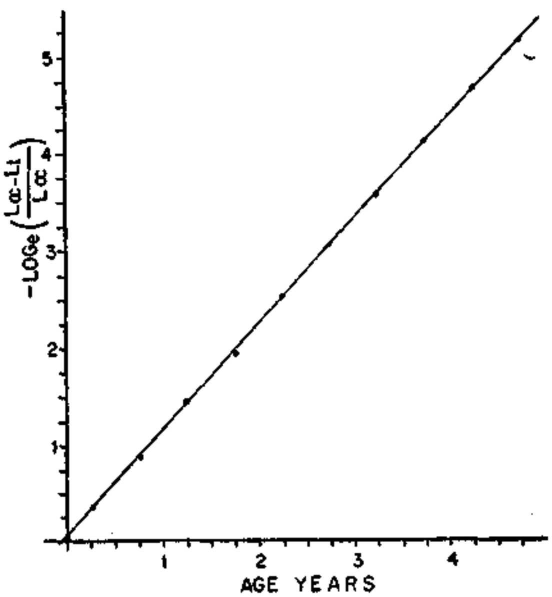

Fig. 5. Estimation of t_0 in *D. russelli.*

From Vizhinjam along the southwest coast, Sreenivasan (1983) estimated the growth parameters of *D. dayi* (=*D. russelli*) as $L\infty=260$ mm fork length (288 mm TL*), $K=0.74$ per year and $t_0=-0.13$ year whereas the same

* Sreenivasan (1983) considered fork length only; the total length was calculated from TL-FL relationship given by him.

from Kakinada were estimated as 232.3 mm TL, 1.08 per year and -0.08 year respectively. The length range and maximum length at Vizhinjam (20-219 mm FL or 21-243 mm TL and 271 mm FL or 300 mm TL) are greater than those at Kakinada (52-217 mm TL and 217 mm TL); these differences appear to be responsible for the differences in the estimated values of growth parameters though such

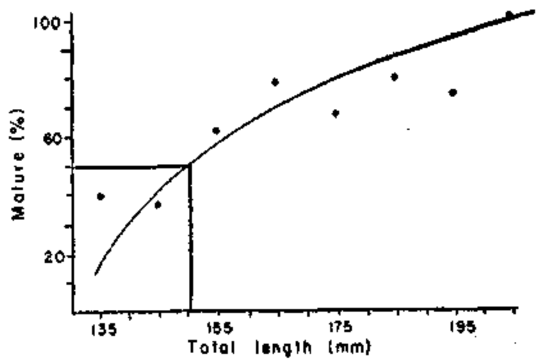

Fig. 6. Percentage of matured individuals of *D. russelli* in each length group.

differences in growth parameter estimates can also occur (for various reasons) in different stocks of the same species and during different periods in the same stock. Further, the non availability of data in some months (Fig. 2, 3) and the narrow length range in the catch in most months (probably because of size specific shoaling behaviour) which resulted in the data having over 90% of the modal values between 100 and 200 mm (Fig. 3) only, could also possibly have lead to the differences in the growth parameter values.

According to Munro and Pauly (1983) the frequency distribution of the values of ϕ ($\phi = \log K + 0.67 \log W_{\infty}$) of a particular species from different areas produces normal distribution and that the growth parameter estimates pertaining to a species of a particular area have to be checked, if the ϕ value from that region does not fit into the already known range of normal distribution (obviously assuming that the ϕ values producing the normal distribution have *indeed* resulted from reliable growth estimates). In the case of *D. dayi* (=*D. russelli*) from Vizhinjam, the ϕ value can be calculated as 1.6 (taking different parameter values from Sreenivasan 1982, 1983) and the one from Kakinada as 1.5 which are close to each other.

It is well-known that estimation of natural mortality rate in exploited fish populations is difficult (Cushing, 1981; Alagaraja, 1984). In the absence of knowledge of effective effort pertaining to a particular species in a multispecies fishery, it is not possible to estimate M with the help of the regression of Z against effort. It is also clear (Fig. 8) that Z showed an increasing trend over different years though such a trend is not present in the effort (Table 1) which is due to the fact that the effort is not effective effort for the species. In the present study, the M value was estimated following different approaches (Table 3). In the Sekharan's (1975) method, the value of t_{max} in a virgin stock is required (Sekharan, 1975; however, considered t_{max} in the catch) and this value is not available for the stock of *D. russelli* at Kakinada. Though Alagaraja (1984) suggested that maximum length in a population (to calculate t_{max} value in a 'virgin stock, and to estimate M) could be taken as L_{∞} —0.50 cm, the reasons for doing so were not mentioned; it is also not known whether this can be done uniformly for all species having widely varying L_{∞} values. Pauly (1983) suggested that L_{max} could be taken as 95% of L_{∞} following Taylor (1962). It is, therefore, clear that all these approaches are subjective. Recently Alagaraja *et al.* (1986) estimated M in shrimps 'Assuming that when X% of L_{∞} is reached by fish X% of mortality takes place, one gets M/K=1 for all X'. Though these authors have not stated, it is also necessary to assume $t_0=0$, as otherwise M/K is not always equal to 1. This approach however, presupposes M/K=1 (which means M=K) whereas the M/K in fishes is known to range from 1 to 2.5 (Beverton and Holt, 1959). The equation of Pauly (1980 b) does not require assumptions or adjustments as above, but according to Pauly (1984 b), the value obtained by this equation 'may be biassed upward in the case of strongly schooling fishes' and therefore this approach cannot be followed in *D. russelli* which is known to form schools. Under the circumstances it is not possible to state which of the methods considered here gives the most satisfactory estimate of M for the species under consideration. The M value obtained by Sekharan's method (Table 3) was taken into account in this study, because the maximum length in the catch was considered as L_{max} without any adjustment; the value obtained this way is only slightly less than that obtained by Pauly's (1980 b) equation and slightly more than that obtained by Pauly's (1983) method (Table 3). The value obtained by Alagaraja's method is, however much smaller than those obtained by other methods.

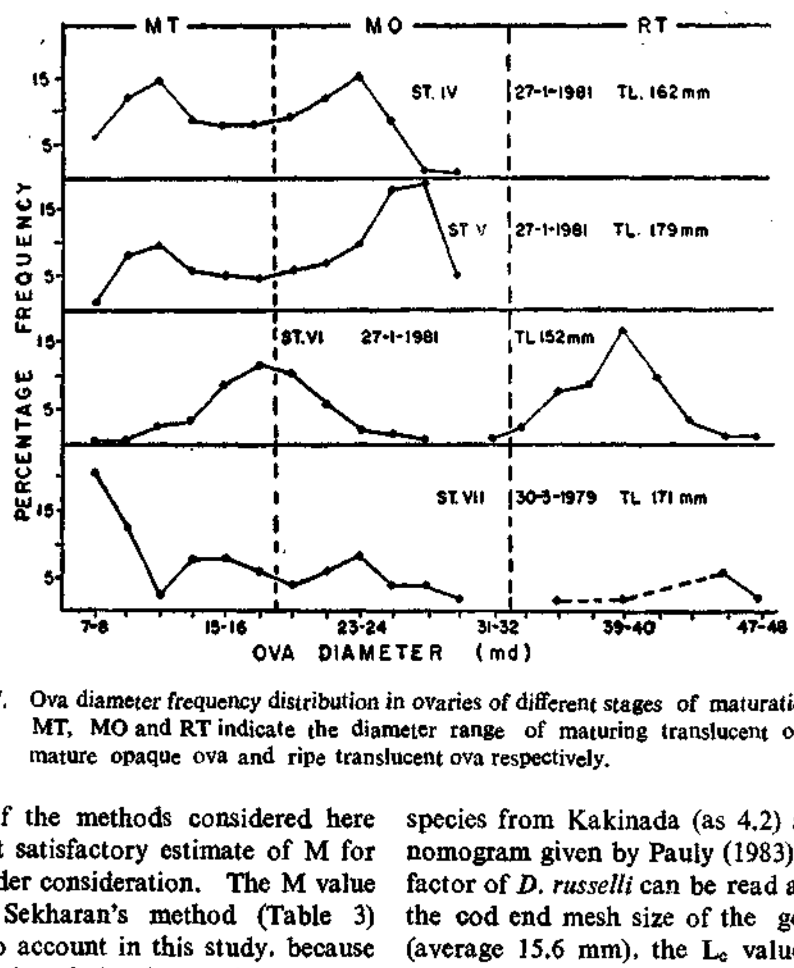

Fig. 7. Ova diameter frequency distribution in ovaries of different stages of maturation. MT, MO and RT indicate the diameter range of maturing translucent ova, mature opaque ova and ripe translucent ova respectively.

The value of L_c at 158 mm as obtained by following Pauly's (1984) method was used in the present study. Taking the depth ratio (standard length/maximum body depth) of this species from Kakinada (as 4.2) and using the nomogram given by Pauly (1983), the selection factor of *D. russelli* can be read as 2.5. Using the cod end mesh size of the gear under use (average 15.6 mm), the L_c value can be calculated as 39 mm which is less than even the length of the smallest fish caught (52 mm). The L_c obtained by the Pauly's (1984) method is therefore much greater than the theoretically possible value. It may be mentioned in this connection, that fishing being prawn-biassed, the effort is not uniformly distributed in the fishing grounds and this can result in the non-representativeness in the catches, of the lengths in the populations of finfishes *i.e.* fishes of certain smaller lengths are not available in areas where fishing activity is concentrated, as otherwise one would expect smaller fishes (smaller than the smallest fish caught) to be retained in the gear in large numbers since the cod end mesh size is very small. This could probably be the reason for the wide difference in the L_c values shown above. It may be argued that since *Decapterus* spp. are pelagic, catches by bottom trawl are not representative of the population. It may not hold good, because the resources surveys conducted by Rao *et al.* (1977) clearly show that the scads are distributed in dense vertically extended schools at or near the bottom during day and ascend to surface layers at night ; according to Lowe-McConnel (1977) also, the neritic pelagic fishes like the scad, have the habit of forming demersal shoals congregating near bottom

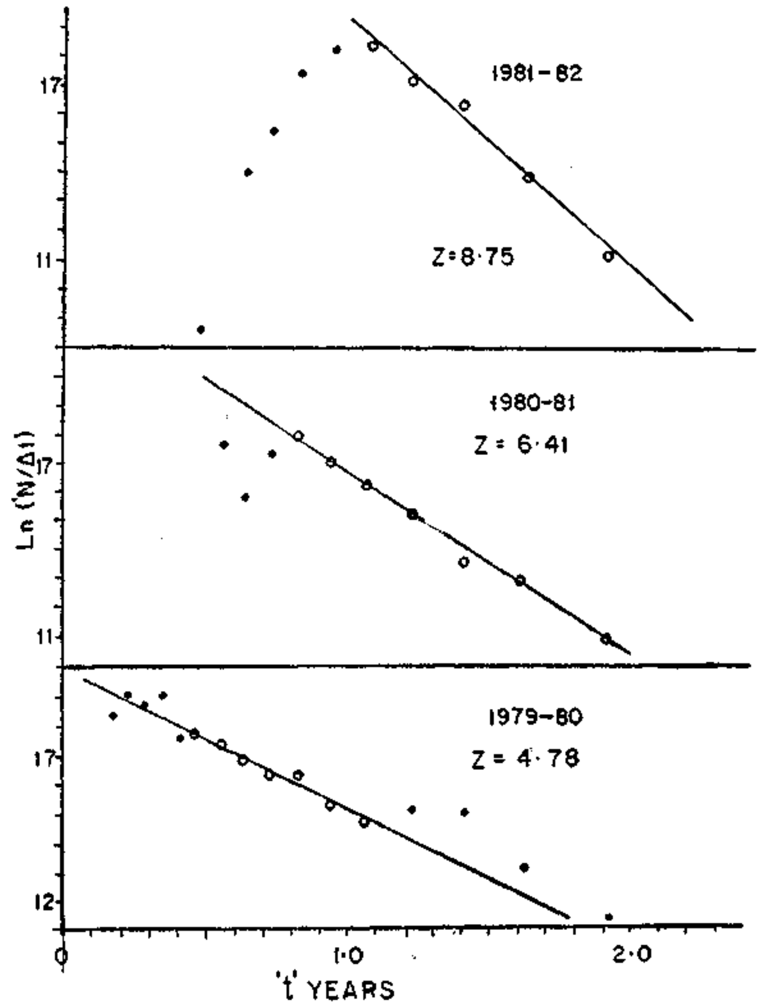

Fig. 8. Length-converted catch curves in *D. russelli* during different years.

depressions by day and moving up to feed at night. It may noted that the trawlers at Kakinada conduct fishing during day time.

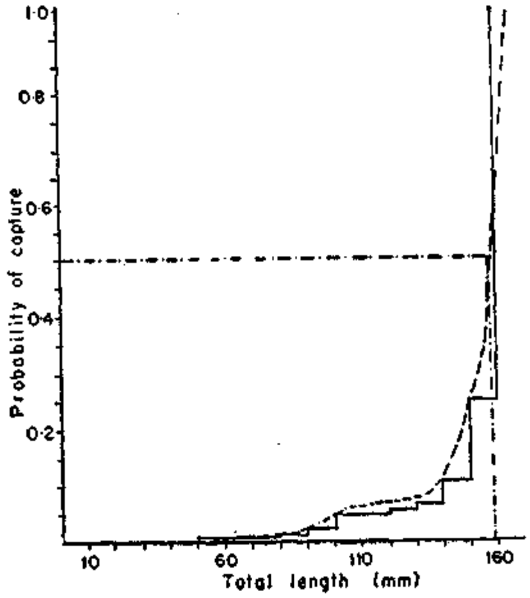

Fig. 9. Estimation of length at first capture (L_c) in *D. russelli* by trawlers at Kakinada.

The non availability of smaller fishes in the presently fished areas could probably be due to the fact that *Decapterus* spp. are more abundant beyond 50 m depth (*Vide* supra) or, as already observed by Rao *et al.* (1977), the current system is such that young scad probably cannot enter the fishing grounds to be captured. The data of different years also show that fishes of the length range 52-89 mm were caught only during 1979-80 and not in other years. Since it is known (Fig. 10) that t_c determines the shape of the yield curve, there is need to determine L_c of *D. russelli* by experimental fishing using commercial gear in areas where it occurs in abundance for any realistic advice on optimum mesh size.

The yield per recruit analysis shows that there is need to decrease the present cod end mesh size and then to increase effort to get increased Yw/R (Fig. 10, 11). In view of the uncertainty, as shown above in the estimated

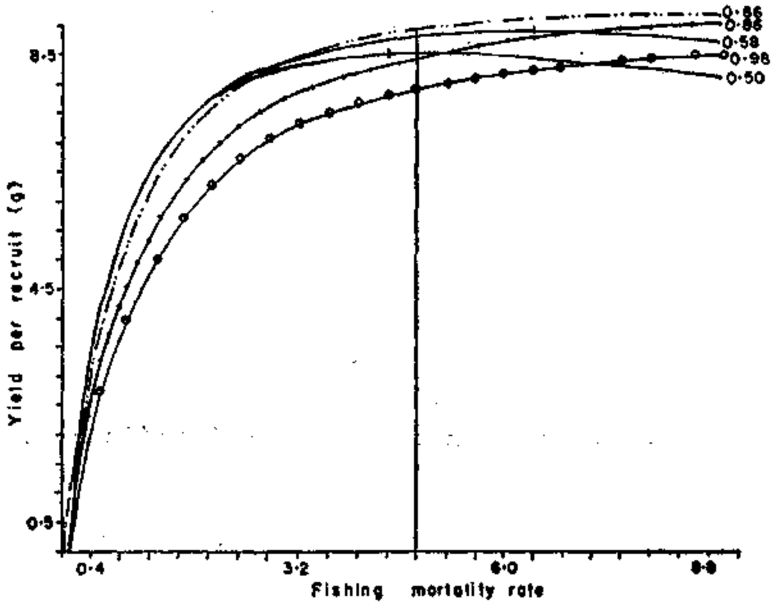

Fig. 10. Yield in weight per recruit as a function of fishing mortality rate in *D. russelli*. The numerals pertain to ages at first capture and the vertical line the present F.

value of Lc in the present study, this regulation should not be implemented. The data of different years show that the smallest modal lengths (excluding the fishes of the length range 52-89 mm caught only during 1979-80) are at 102 and 107 mm. If the average of these two values at 105 mm is taken as the present Lc the present tc works out to 0.48 year which is almost the same as one of the tc values (=0.50) considered (Fig. 10). In this case the Yw/R reaches the maximum at F=4.4 and then declines slowly with increased F, thus indicating that the effort has to be decreased (present F=4.75). The Yw/R as a function of tc (Fig. 11) shows that maximum Yw/R is obtained at tc=0.6. If the present tc is indeed 0.5 (as mentioned above) there is scope to increase the cod end mesh size to get increased and sustained yield. Further, (1) since the length at first maturity and Lc are at 150 mm and 158 mm respectively, reduction in mesh size will affect the recruitment adversely and should not be recommended; (2) since the Yw/R does not attain maximum with increased F at higher levels of tc (Fig. 10), there is no harm to the stock even if the mesh size is increased. Finally it may be pointed out that whichever may be the optimum mesh size for *D. russelli*, any regulation of mesh size or effort has to take into consideration the possible effect of such regulation on other species since the trawl fishery is a multispecies one.

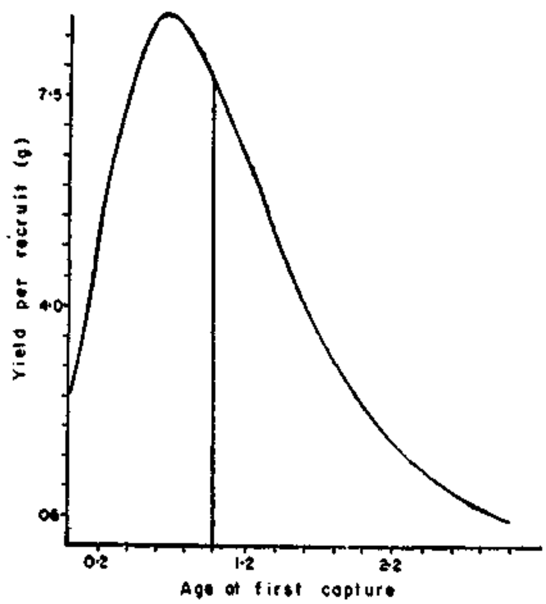

Fig. 11. Yield in weight per recruit as a function of age at first capture. The vertical line indicates the present age at first capture.

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