J. mar. biol. Ass. India, 1993, 35 (1 & 2) : 80-86

POPULATION DYNAMICS OF THE CUTTLEFISH *SEPIA ELLIPTICA* HOYLE IN SAURASHTRA WATERS*

H. MOHAMAD KASIM

Central Marine Fisheries Research Institute, Cochin-682 014

ABSTRACT

The cephalopod fishery in Veraval is sustained mostly by five important species which are the squid *Loligo duvaucelii*, the cuttlefishes *Sepia elliptica*, *S. pharaonis*, *S. aculeata* and *Sepiella inermis*. On an average 1582.3 t of cephalopods were landed in a year during 1979-84 which constituted 5% of total catch by trawlers in Veraval. The annual average catch composition of the cuttlefish *Sepia elliptica* was 435.3 t forming 27.5% of cephalopod landings. Age and growth, instantaneous total mortality coefficient (Z) and instantaneous natural mortality coefficient (M) were estimated for *S. elliptica*. The natural mortality coefficient is estimated to be 1.59 by regressing the Z obtained for 5 years as per the method of Alagaraja (1984) against the annual effort. The Z varied from 3.33 in 1979-80 to 5.17 in 1983-84 with an average of 3.93. Yield per recruit at constant age at first capture and varying fishing mortality coefficient for different M/K ratios are inversely proportionate. For the prevailing M/K ratio and cod end mesh size (20 mm) the F_{max} which can produce the yield max of 33 g is 2.0. This study indicates that further increase in effort may not result in proportionate increase in production. The exploitation ratio E is higher than the E_{opt} during the period of this study indicating that the stock is exposed to higher fishing pressure. An increase in the cod end mesh size from 20 mm to 30 mm may favour increased production in commensuration with the effort increase. This suggestion is valid only when the fishery is aimed at exploitation of *S. elliptica* subjected to modifications with reference to other commercially important fisheries like prawn fishery.

INTRODUCTION

TRAWLING has been developed into a viable commercial fishing industry in India mainly owing to its capacity to exploit a variety of marine fishery resources. Apart from the well known economically important resources, some of the unconventional resources have been promoted into commercially important ones due to the increasing demand in foreign trade for such resources. Presently, in addition to prawns, cephalopod is considered as one such resource, though there is no exclusive fishery for cephalopod in India and it forms only a bycatch in trawl net operations. Growing demand and better price offered in the market during nineteen seventies induced the fishermen to land more and more cephalopods in the following years. Considering the commercial and economic importance of this resource, it was felt essential to undertake a systematic study on this resource to provide required information for proper exploitation and management of this resource. Such a programme was initiated by the Central Marine Fisheries Research Institute in 1976 on all India level and this account is a part of this programme carried out at Veraval, Gujarat. This

* Presented at the 'Symposium on Tropical Marine Living Resources' held by the Marine Biological Association of India at Cochin from January 12 to 16, 1988.

study deals on the cephalopod fishery and the growth, mortality rates, yield per recruit, exploitation ratio and stock of the component species *Sepia elliptica.*

The author is immensely thankful to Dr. P. S. B. R. James, Director, C.M.F.R.I. for his encouragements; to Dr. E. G. Silas, former Director and Dr. K. Alagarswami for offering valuable guidance during the study and to Shri S. Mahadevan for his useful suggestions for the improvement of this paper.

OBSERVATIONS AND METHODS

Since none of the trawlers maintained fishing log, the data on catch, effort and species composition were collected once in a week by sampling 5-10% of the total units operated on the sampling day. The catch per trawling hour is taken as the index of abundance. The data on length frequency of *S. elliptica* were used for the estimation of growth, mortality rates, yield per recruit, optimum age of exploitation and potential yield per recruit.

FISHERY

All India cephalopod production indicates that Gujarat contributes on an average 3243 t in a year during 1981-84 ranking fourth in production and the first three in the order being Kerala, Maharashtra and Tamil Nadu (Silas *et al.*, 1986). Gearwise cephalopod production of Gujarat is 99.5% by trawl net and the rest by boat seines and hook and line. Veraval being the most important fishing port of Gujarat, as many as 666 trawlers were registered at Veraval out of 900 trawlers then operating along the coast of Junagadh District in Saurashtra (C.M.F.R.I., 1981). On an average 1582.3 t of cephalopods were landed during 1979-84 which is nearly 50% of Gujarat total cephalopod production. The catch declined from 1477 t in 1979-80 to 1127.6 t in 1981-82. This decline appears to be temporary as the catch improved considerably to 1305.2 t in 1982-83 and further to 2568.1 t in 1983-84 indicating revival in the fishery (Table 1). The effort of trawlers increased continuously except for a marginal decline in 1982-83.

TABLE 1. *Estimated specieswise catch in kg, effort and catch per trawling hour of cephalopod landings at Veraval during* 1979-84

Fishing season	*L. duvaucelli*	*S. elliptica*	*S. inermis*	*S. pharaonis*	*S. aculeata*	Total	Effort(hrs)	CPUE (kg)
1979-80	737819	513786	199051	26369	—	1477025	360392	4.2
1980-81	1201287	193162	38491	384	—	1433324	393695	3.6
1981-82	891466	225832	6337	4031	—	1127666	532090	2.1
1982-83	1217902	24137	605	7411	55178	1305233	464052	2.8
1983-84	1316599	1219416	30234	—	1849	2568098	771180	3.3
Average	1073014	435267	54944	7639	11405	1582269	504282	3.2
%	67.8	27.5	3.5	0.5	0.7			

Five important species have been observed to support the cephalopod fishery at Veraval. The species composition of cephalopod landings indicates that the squid *Loligo duvaucelli* constituted major portion of the catch (67.8%) followed by *Sepia elliptica* (27.5%), *Sepiella* *inermis* (3.5%), *Sepia aculeata* (0.7%) and *Sepia pharaonis* (0.5%) (Table 1). The landings of *S. elliptica* fluctuated from 24.1 t in 1982-83 to 1219.4 t in 1983-84. This fluctuation my be attributed to the identical variation in the abundance of the cuttlefish as indicated by its annual catch rate. The monthwise average catch rate shows that the peak period of abundance for this species is during October to January.

Population Dynamics

Review of literature reveals that earlier studies on cephalopods were mostly on various aspects of taxanomy, biology and fisheries of different species by Hornell (1917), Rao (1954, 1958, 1969, 1973), Jones (1971), Sarvesan (1974) and Silas *et al.* (1976, 1986) and the most recent being the C.M.F.R.I. Bulletin (1986) on the bionomics, fisheries and resources of cephalopods with a brief account on the stock assessment of *L. duvaucelli*, *S. aculeata* and *S. pharaonis*. Detailed study on the age and growth, mortality rates, yield per recruit, exploitation rate and stock assessment of *L. duvaucelli* (Kassim, 1985) and *Sepiella inermis* (Kasim, 1988) has been carried out and such studies on other component species are lacking. An attempt is being made hereunder to present an account on these aspects on the cuttlefish *Sepia elliptica*.

Age and growth: The estimated length frequency of *S. elliptica* obtained during 1979-82 was used to study the age and growth of this species by integrated method of Pauly (1980) wherein the series of modes available in different months were plotted as a scatter diagram against respective fishing months and the progress of the modes was traced in subsequent months by free hand curves as shown in Fig. 1. The time of origin o, some of the modes present in lower size ranges could be traced by extrapolating the curves backward to the time axis which is shown by broken lines in Fig. 1. The modes thus traced were arranged chronologically in a tabular form

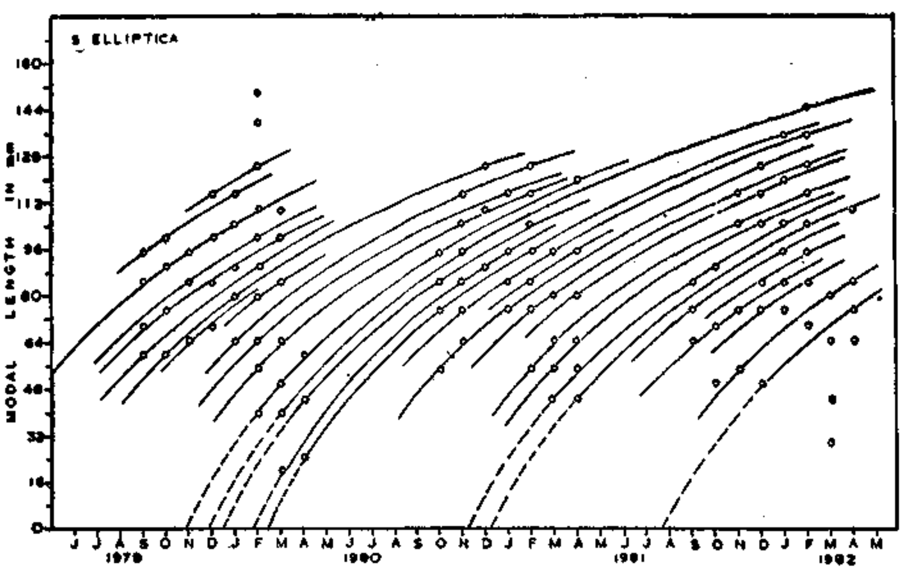

FIG. 1. Tracing of the progression of modes by scatter diagram of modal length—month for *S. elliptica* from Veraval.

and average sizes attained by this species in subsequent months were obtained as per George and Banerji (1968). These average sizes were plotted against respective months and a curve was fitted through the plots (Fig. 2). This curve may be taken as the empirical growth curve of this species and it can be read from this curve that this species attains 60.9, 95.9, 120.3, 137.8 and 148.4 mm in 0.5, 1.0, 1.5, 2.0 and 2.5 years respectively. These data were used to estimate the vital

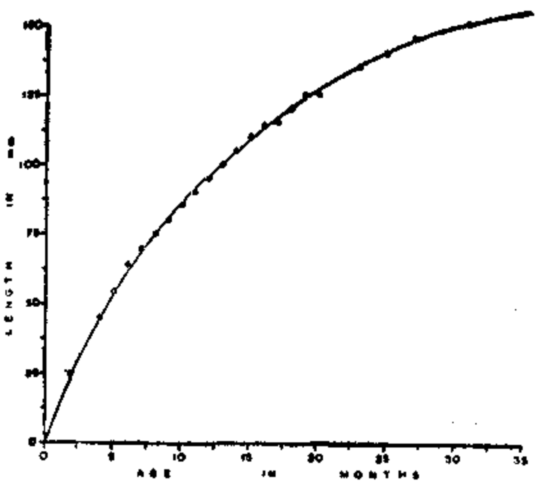

FIG. 2. Fitting a growth curve through the plots of mean lengths obtained from the scatter diagram for *S. elliptica* from Veraval.

growth parameters to L_{∞}, K and t_0 by Bagenal (1955) method. The growth in length of this species may be written as per von Bertalanffy growth equation

$$L_t = 174\ (1 - e^{-0.7478\ (t + 0.0887)}).$$

The length-weight relationship of this species is descried as per the equation

$$\text{Log } W = 3.1491 + 2.6464 \text{ Log } L.$$

Gear selection: The size at first capture (L^b) and recruitment (L_r) due to selective property of trawl net were estimated from the left side of the length converted catch curve as per Pauly (1984) and the average length at first capture and recruitment are 52.1 and 45.5 mm respectively. The corresponding age at first capture and recruitment are 0.4375 and 0.3669 year respectively.

Mortality rates: The total mortality coefficient *Z* is estimated by the method of Alagaraja (1984) and the estimates are 3.33, 3.43, 4.19, 3.55 and 5.17 during 1979-80, 1980-81, 1981-82, 1982-83 and 1983-84 respectively. The average annual total mortality coefficient is 3.93. The annual effort in trawling hours were regressed against annual Z to obtain the natural mortality coefficient M. The M is estimated to be 1.59 *i.e.* the intercept (*a*) of the regression and the slope *b*, provides the catchability coefficient '*q*'. The *q* is estimated to be 4.6362^{-6}. This regression analysis indicates that the stock of *S. elliptica* is affected by trawling. The catchability coefficient *q* is used for the conversion of the fishing mortality *F* into trawling hours.

Yield per recruit: The yield per recruit estimated by Beverton and Holt (1957) modal simplified by Ricker (1958) for M/K ratios 1.5, 1.96 and 2.5 keeping the age at first capture at prevailing level of 0.4375 yr and at varying *F* are shown in Fig. 3 for this species. The yield per recruit increases with the increase in *F* to a certain level and then it tends to decline on higher *F* in all the M/K ratios. Lower the M/K ratio and higher the yield per recruit. The optimum age of exploitation and potential yield per recruit estimated as per Krishnankutty and Qasim (1968) are 0.9991 yr and 45 g respectively for this species.

DISCUSSION

Population dynamics of short lived species with emphasis on squids and cuttlefish have been dealt in detail by Pauly (1985), Silas *et al.* (1986) and Kasim (1985). Estimation of growth and natural mortality coefficient for tropical species is affected to a great extent by interference of different factors such as short life span, more than one breeding season and variation in growth within a year (Sparre, 1985; Pauly, 1980). The largest sizes recorded for males and females of *S. elliptica* caught in trawl net in Cochin area by Silas *et al.* (1986) are 129 mm and 119 mm respectively. The

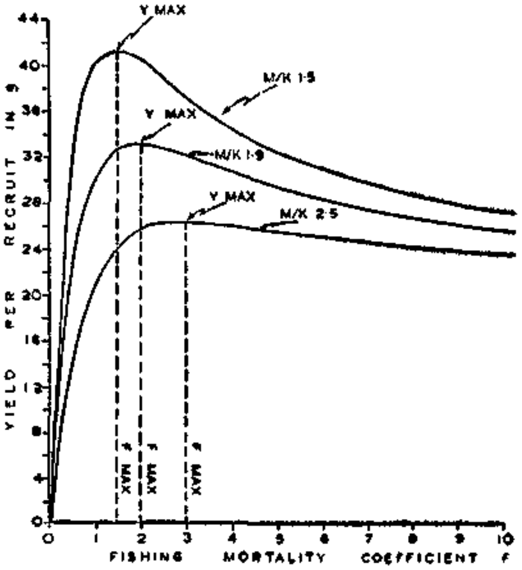

FIG. 3. Yield per recruitment of *S. elliptica* at different M/K ratios and various fishing mortality coefficients for the prevailing age at first capture. The corresponding Y_{max} and F_{max} are indicated for each curve.

maximum size observed in the fishery during 1979-84 in Veraval is 149 mm. The study of the progression of modal sizes of males and females of this species by Silas *et al.* (1986) showed a growth of 75 mm in six months and 117 mm in one year and this is little lower than the growth observed in this study. Naturally the oldest individuals in a stock grow to reach nearly 95 per cent of their asymptotic length (Taylor, 1962; Beverton, 1963). Considering the oldest cuttlefish observed in the fishery, *i.e.* 149 mm the L_∞ may be 157 mm. Present estimate of L_∞ is 174 mm which is marginally higher than the estimate from L_{max}.

In nature, there are necessarily minimal and maximal natural mortality rates which vary according to the stage of life of the individual specimen. Maximum rates occur at the larval and juvenile stages and in latter life, particularly after spawning. However, in general the natural mortality rate remains constant when the longevity of the species in natural conditions remains relatively constant (Caddy, 1983). Further, shorter is the longevity and higher the natural mortality rate specially so among tropical species (Pauly, 1985). The longevity of *S. elliptica* is determined as 4.0 years from the relation $T_{max.} = 3 / K$ (Pauly, 1980) and the M is 1.59. The natural mortality rate of *S. elliptica* is barely higher than the squid *Loligo duvaucelli* (Kasim, 1985) and lower than the cuttlefish *Sepiella inermis* (Kasim, 1988) from Veraval.

The average effort expended during the period of this study was 504282 trawling hrs which generated a fishing mortality rate of 2.4 and yield per recruit of 30.5 g for the prevailing age at first capture 0.4375 yr with 20 mm cod end mesh size. Whereas for the above-said conditions the effort should have been only 430459 hrs with F 2.0 and yield 33 g. The annual effort expended in all the three years during 1981-84 were higher than the effort which can produce the highest yield. The exploitation rate U calculated from the relation $U = F \div Z\ (1-e^{-z})$ and the exploitation ratio $E = F \div Z$ also indicate that the stock of *S. elliptica* was under higher fishing pressure during the period of this study as the E was higher than the E_{opt} *i.e* $E_{opt} = 0.50$ (Pauly, 1980). The annual average stock of *S. elliptica* is estimated to be 725.5 t from the relation $P = Y/U$ where P is the stock, Y is the annual catch and U the exploitation rate.

It can be seen from the yield isopleth diagram (Fig. 4) that further increase in effort keeping the age at first capture at present level may not be desirable as the yield per recruit is not commensurate with the increase in effort. However, if the age at first capture is increased from the present level by enlarging the cod end mesh size there is scope for increase in effort and yield. Further increase in effort is inevitable as the expansion of the fisheries end mesh size is maintained even at 30 mm the age at first capture increases to 0.7592 yr, the yield increases to 38 g and the effort to 860919 hrs. Similar studies on other component species, the squid *Loligo duvaucelii* (Kasim, 1985) and *Sepiella inermis* (Kasim, 1988) from Veraval indicate that an increase in the

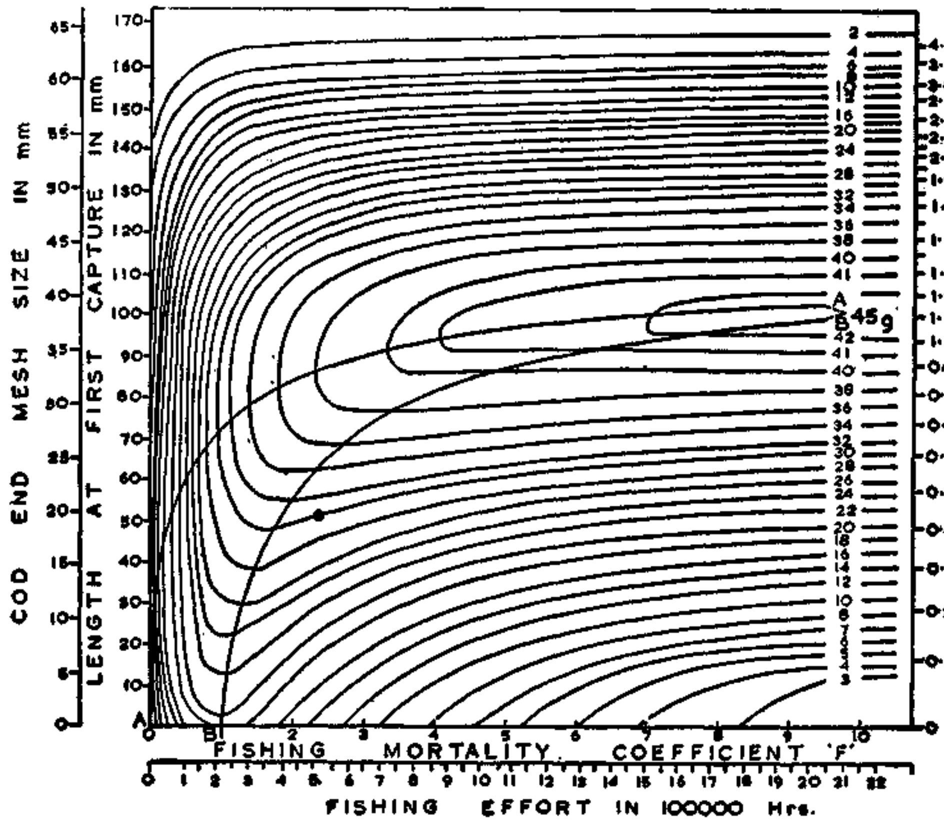

FIG. 4. Isopleth diagram for yield per recruit in gram of *S. elliptica* population from Veraval waters. The line A—A indicate the eumetric fishing curve and the line B—B the maximum sustainable yield curve. The potential yield per recruit of 45 g is also shown.

harbour at Veraval would have already been completed which would have increased the berthing facilities of fishing vessels and handling of the landings. To regulate the fishery of *S. elliptica* at the optimum age of exploitation, the mesh size should be 36 mm and the effort can also be increased manyfold which will result in enhanced production. When the cod age at first capture by way of increasing the cod end mesh size to be favourable for higher yield and increased effort input. However, considering the trawl fishery, increasing the cod end mesh size may not be possible practically as main aim of the gear is to exploit the prawn resource and the cephalopod are only by-catch. Therefore, if the prawn resource also exhibits similar condition explained in this study, then the above observations may hold good and implementation of mesh size regulation may be considered for better management of these resources.

REFERENCES

ALAGARAJA, K. 1984. Simple methods for estimation of parameters for assessing exploited stocks. *Indian J. Fish.*, **31** : 177-208.

BAGENAL, T. B. 1955. The growth rate of the long rough dab *Hippoglossoides platessoides* (Fabr.). *J. Mar. Biol. Ass. U.K.*, **43** : 297-311.

BEVERTON, R. J. H. 1963. Maturation, growth and mortality of clupeoid and engraulid stocks in relation to fishing. *Rapp. Cons. Perm. Int. Explor. Mer.*, **154** : 44-67.

——— AND S. J. HOLT 1957. On the dynamics of exploited fish populations. *Fishery Invest., Lond., Series* 2, **19** : 533 pp.

CADDY, J. F. 1983. Advances in assessment of world cephalopod resources. *FAO. Fish. Tech. Pap.* **231** : 452 pp.

CMFRI. 1981. All India census of marine fisheries craft and gear. 1980. *Mar. Fish. Infor. Serv., T & E Ser.*, **30** : 2-32.

——— 1986. Cephalopod bionomics, fisheries and resources of the exclusive economic zone of India. *Bull. Cent. Mar. Fish. Res. Inst.*, **37** : 195 pp.

GEORGE, K. C. AND S. K. BANERJI 1968. Age and growth studies on the Indian mackerel *Rastrelliger kanagurta* (Cuvier) with special reference to length frequency data collected at Cochin. *Indian J. Fish.*, **11** : 621-638.

HORNELL, J. 1917. The edible molluscs of Madras Presidency. *Madras Fish. Bull.*, **11** : 1-51.

JONES, S. 1971. The molluscan fishery resources of India. *Proc. Symp. Mollusca, Mar. Biol. Assn. India*, **3** : 906-918.

KASIM, H. M. 1985. Population dynamics of the squid *Loligo duvauceli* d'Orbigny (Cephalopoda) in Saurashtra waters. *J. mar. biol. Assn. India*, **27** (1 & 2) : 103-112.

——— 1988. Growth, mortality rates and stock assessment of the cuttlefish *Sepiella inermis* (Ferussac and d'Orbigny) in Saurashtra waters. *Ibid.*, **30** (1 & 2) : 99-108.

KRISHNANKUTTY, M. AND S. Z. QASIM 1968. The estimation of optimum age of exploitation and potential yield in fish population. *J. Cons. Perm. Int. Explor. Mer.*, 32 (2) : 249-255.

PAULY, D. 1980. A selection of simple methods for the assessment of tropical fish stocks. *FAO Fish. Circ.*, **729** : 54 pp.

——— 1984. Length converted catch curves : A powerful tool for fisheries research in the tropics (Part II). *Fishbyte*, **2** (1) : 17-19.

——— 1985. Population dynamics of short lived species with emphasis on squids. *Scientific council studies* No. 9. *Special session on squids, September,* 1984. *North west Atlantic Fisheries Organisation*, pp. 1-177.

RAO, K. VIRABHADRA 1954. Biology and fishery of the Palk Bay squid *Sepioteuthis arctipinnis* Gould. *Indian J. Fish.*, **1** : 37-66.

——— 1958. Molluscan fisheries. *In* : S. Jones (Ed.) *Fisheries of the west coast of India*, pp. 55-59.

——— 1969. Molluscan have many uses. *Indian Farming*, **19** (9) : 41-46.

——— 1973. Distribution pattern of the major exploited fishery resources of India. *Proc. Symp Living Resources of the Seas around India*, C.M.F.R.I. pp. 18-101.

RICKER, W. E. 1958. Handbook of computations for biological statistics of fish populations. *Bull. Fish. Res. Bd. Canada*, **119** : 300 pp.

SARVESAN, R. 1974. V. Cephalopods. *In : The commercial molluscs of India. Bull. Centr. Mar. Fish. Res. Inst.*, **25** : 63-83.

SILAS, E. G., S. K. DHARMARAJA AND K. RENGARAJAN 1976. Exploited marine fisheries resources of India — A synoptic survey with comments on potential resources. *Bull. Cent. Mar. Fish. Res. Inst.*, **27** : 1-25.

———, R. SARVESAN, K. PRABHAKARAN NAIR, Y. APPANNA SASTRI, P. V. SREENIVASAN, M. M. MEIYAPPAN, KUBER VIDYASAGAR, K. SATYANARAYANA RAO AND B. NARAYANA RAO 1986. Some aspects of the biology of cuttlefishes. *In* : E. G. Silas (Ed.) *Cephalopod bionomics, fisheries and resources of the Exclusive Economic Zone of India. Bull. Centr. Mar. Fish. Res. Inst.*, **37** : 49-70.

SPARRE, P. 1985. Introduction to tropical fish stock assessment. *FAO/DANIDA Project Training in Fish Stock Assessment GCP/INT/392/DEN* : 31 pp.

TAYLOR, C. C. 1962. Growth equation with metabolic parameters. *J. Cons. CIEM*, **27** : 270-286.