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## Age, Growth and Stock assessment of Malabar sole, *Cynoglossus macrostomus* (Norman) off Kerala Coast

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### Abstract

The age and growth of the Malabar sole, *Cynoglossus macrostomus* (Norman) occurring along the coastal seas, off Kerala have been studied by length - frequency method and by reading the growth checks on scales. The growth rate was found to be very fast during the first six months. But with the onset of sexual maturity by the end of one year and further, the growth rate slowed down. The length frequency studies showed that the fish grows to 115.0 mm, 136.5 mm, 152.5 mm and 161.1 mm at the completion of I to IV year of life respectively. The growth rings on scales indicated that the fish attains 118.5 mm, 134.6 mm and 149.8 mm when 1 to 3 ring are formed on the scales. There was no growth difference in males and females. The growth checks have been found to be annual and are formed as a result of spawning stress. The time of formation of the rings on scales was found to be during October to December and February to April which coincided with the two spawning peaks in Malabar sole population. Von Bertalanffy growth equation was fitted to the observed values and the growth parameters were estimated as length infinite ( $L_{\infty}$ ) = 166 mm and  $K = 0.714/\text{yr}$ . The length at age, annual increment and the growth rate obtained by the different methods were almost identical.

**Keywords :** Malabar sole, age and growth, growth checks.

### Introduction

The Malabar sole *Cynoglossus macrostomus* Norman is a small flatfish that supports a single species commercial fishery along the maritime states of Kerala. The annual production of this species showed wide fluctuations and varied from 2,726 t in 1956 to a highest of 28,445 t in 1992. The resource which used to be exploited mostly by the indigenous gears indicated an upward trend ever since the mechanisation of the fishing craft and increase in fleet size of trawls. Though there is no target fishing for Malabar sole, it is essentially a by-catch in the trawls. During 1985- 96 the annual average production was 16,000 t in the state. The production

during 1998-99 was 17,000 t that formed 36% of the all India production of 48,000 t of flat fishes.

Information on the age and growth of Malabar sole is limited to a very early work by Seshappa and Bhimachar<sup>1,2</sup>. So also studies on the stock assessment of this species by Feroz Khan and Nandakumaran<sup>3</sup> relate to Calicut area. Hence a detailed study on both these aspects were undertaken during 1994 to 1997 by collecting the data from two major trawl landing centres in Kerala like Cochin and Neendakara in Quilon. The results are presented here.

## Material and methods

The monthly and annual estimated numbers of Malabar sole, *C. macrostomus* of different size groups caught in the shrimp trawls for the fishing seasons 1994-95 and 1995-96 were obtained by weekly and fortnightly samplings done at Cochin (Lat. 09° 58' N, Long. 76° 17' E) and Neendakara (Lat. 08° 54' N and Long. 76° 38' E). The size group wise data collected on each sampling day (total length in mm of 150 to 200 fishes measured at random) was raised to the day's total catch and estimates of all observation day's catch in a month were pooled and then weighted to get the monthly estimates of the species at both centres during 1994-95 and 1995-1996. Based on the scatter diagram of modes derived from the monthly frequency polygon trend lines were fitted and averages of modal values at quarterly intervals were found out. For studies on growth rings, scales from the pectoral region of 648 males and 585 females, of size range 44 - 162 mm TL were used. A monocular microscope was used to study the growth rings. Based on the above studies the growth parameters  $L_{\infty}$  and  $k$  were determined by (VBG) von Bertalanffy<sup>4</sup> growth equation and regression analysis. These values were further used in the stock assessment studies.

Instantaneous mortality rate ( $Z$ ) was estimated by the length converted catch curve method<sup>5,6</sup>

$$t(L) = t_0 - 1/K \times \ln(1-L/L_{\infty}) \quad \text{for making use of the equation}$$

$$\frac{\ln \frac{C(L_1, L_2)}{\Delta t(L_1, L_2)}}{2} = C-Z \times t \frac{(L_1+L_2)}{2}$$

where  $C$  = numbers caught in each length class,  $\Delta t$  = time taken to grow from  $L_1$  (lower) to  $L_2$  (upper) length class. Then the equation becomes linear where

$$Y = \ln \frac{C(L_1, L_2)}{\Delta t (L_1, L_2)} \text{ and } x = t(L_1 + L_2)$$

which is the form of  $Y = a + bx$  where the slope  $(b) = -Z$  and with the sign changed 'Z' is obtained.

Natural mortality (M) was calculated as per formula proposed by Pauly<sup>7</sup>.

$$\ln M = -0.01523 - 0.279 \ln L_{\infty} + 0.6543 \ln \bar{L} + 0.463 \ln T$$

The fishing mortality (F) was obtained by subtracting M from Z. Also, F was estimated independently using Allen's formula<sup>8</sup>.

$$F = U \times Z / 1 - e^{-Z}$$

$$U + L_c / \bar{L} = F \times A / Z = F / Z (1 - e^{-Z})$$

where  $U$  = exploitation rate,  $L_c$  = Length at first capture,  $\bar{L}$  = mean size of the fish above  $L_c$  and  $A$  = annual survival rate.

Exploitation ratio (E) was obtained from the relation  $E = F/Z$  and the exploitation rate (U) from the equation  $U = F/Z (1 - e^{-Z})$ . The total stock (P) was estimated from the relation  $P = Y/u$  where  $Y$  is the yield in tonnes and  $U$  is the exploitation rate. Standing stock was estimated from the relation  $Y/F$  where  $Y$  is the yield and  $F$  is the rate of fishing mortality.

To study the stock and yield of Malabar sole, the VPA or the Virtual Population Analysis<sup>9,10</sup> and the yield per recruit model of Beverton and Hold<sup>11</sup> were used. From the observations on the numbers caught in each age group the VPA estimates how many fish there must have been in the sea to account for that catch, under the assumption that natural mortality is known. Here, higher the fishing mortality the more dependable is the VPA. The reliability of VPA is also dependent on the size of 'M' relative to 'F'.

The whole set of VPA equations consists of pairs of Eqs.

$$\begin{aligned} \frac{C(y, t, t+1)}{N(y+1, t+1)} &= \frac{F(y, t, t+1) \times \{ \exp [F(y, t, t+1) + M - 1] \}}{M + F(y, t, t+1)} \\ N(y, t) &= N(y+1, t+1) \times \exp [F(y, t, t+1) + M] \end{aligned}$$

where  $y$  = year,  $C(y, t, t+1)$  = numbers caught during year  $y$ ;  $F(y, t, t+1)$  = fishing mortality during year  $y$ ;  $N(y, t)$  = numbers surviving at the beginning of the year. The problem with the first set of equations pertaining to the oldest age group is solved by making plausible assumptions and formulating it as an additional equation. The solution in the case of VPA is to assume a value for the  $F$  of the oldest age group, the so called "terminal  $F$ ".

Beverton and Holt yield per recruit model<sup>11</sup> written in the form suggested by Gulland<sup>12</sup> express yield on a "per recruit basis", the yields are relative, i.e., relative to the recruitment. The equation is:

$$Y/R = F \times \exp(-M \times (t_c - t_r)) \times W_{\infty} \times \frac{1}{Z} - \frac{3S}{Z+K} + \frac{3S^2}{Z+2K} - \frac{S^3}{Z+3K}$$

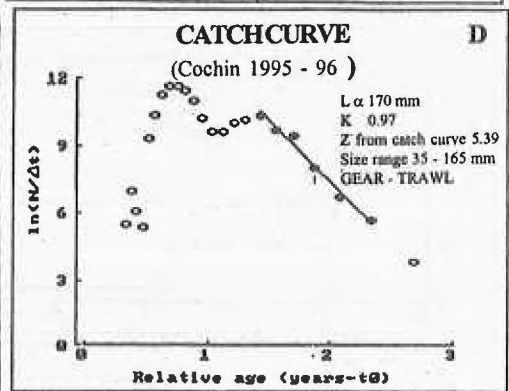
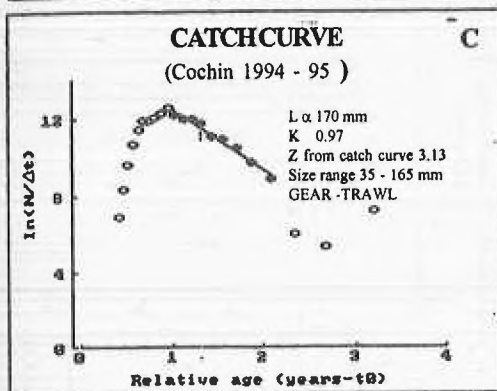
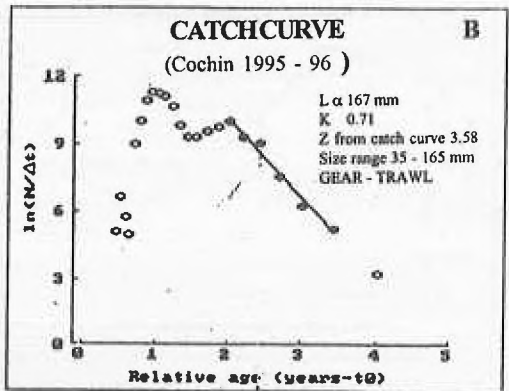
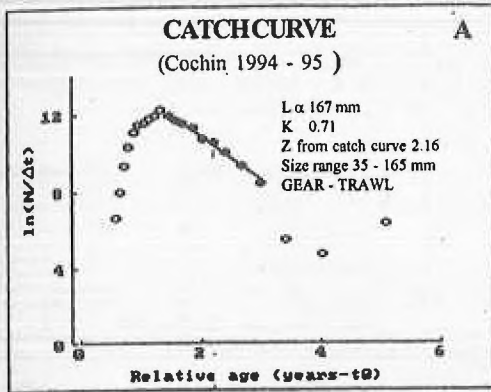
where  $S = \exp(-M \times (t_c - t_r))$ ,  $K$  and  $t_0$  VBG parameter,  $t_c$  = age at first capture,  $t_r$  = age at recruitment,  $W_{\infty}$  = asymptotic body weight,  $F$  = fishing mortality,  $M$  = natural mortality,  $Z = F + M$  total mortality.

The two parameters  $F$  and  $t_c$  are those which can be controlled by fishery managers. Therefore,  $Y/R$  is considered a function of  $F$  and  $t_c$ . The "yield per recruit curve" often has a maximum: "the maximum sustainable yield (MSY)". The portion of the maximum depends on the mesh size used in the fishery. Hence, the model is important for fishery biologist and planner.

## Results

### Length frequency studies

The mean length (TL) attained at the completion of successive quarters from 1st to 16th were found to be 72.5, 87.5, 101.5, 114, 122, 126.5, 131.5, 136.5, 141.5, 145.5, 149, 152, 154.5, 158, 159.5 and 161 mm respectively. The initial growth was high and slowed down with onset of maturity. The total length attained at the end of 1 to 4 years were 114, 136.5, 152, and 159.5 mm at Cochin and 115, 135, and 160 at Neendakara respectively.



**Fig. 1 Length converted catch curve for the estimaiton of Z of Malabar sole at Cochin (1994 - 95 & 1995 - 96)**

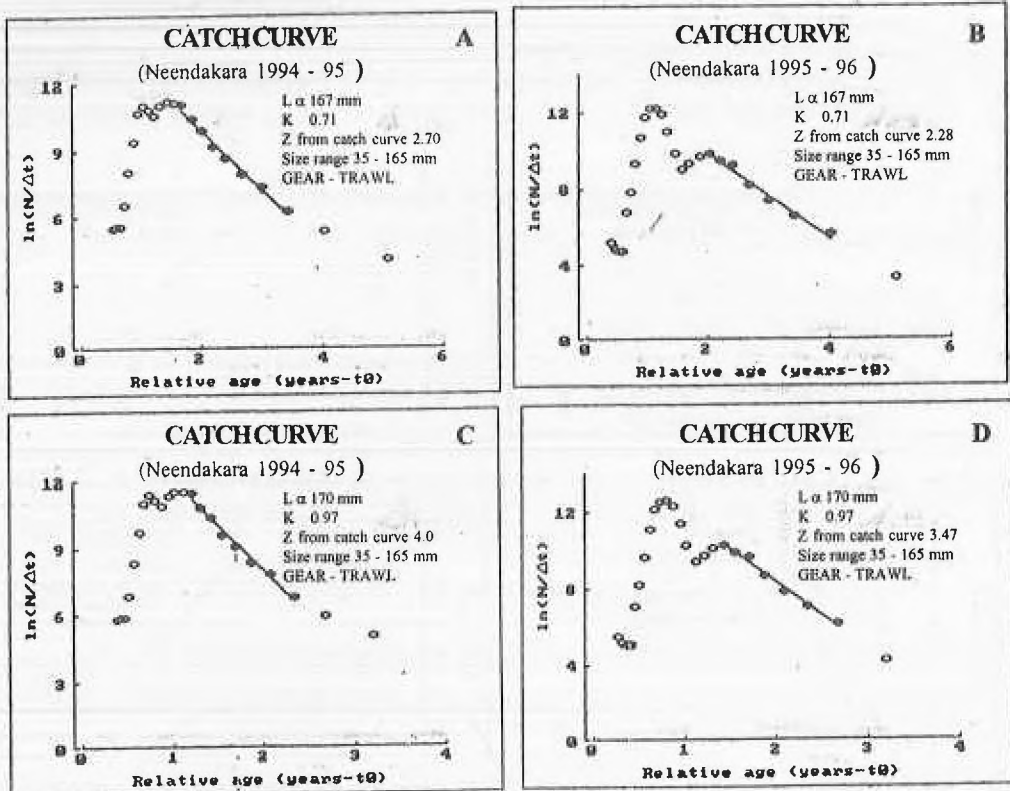


Fig. 2 Length converted catch curve for the estimaiton of Z of Malabar sole at Neendakara (1994 - 95 & 1995 - 96)

Fig. 3 Length Structured virtual population analysis

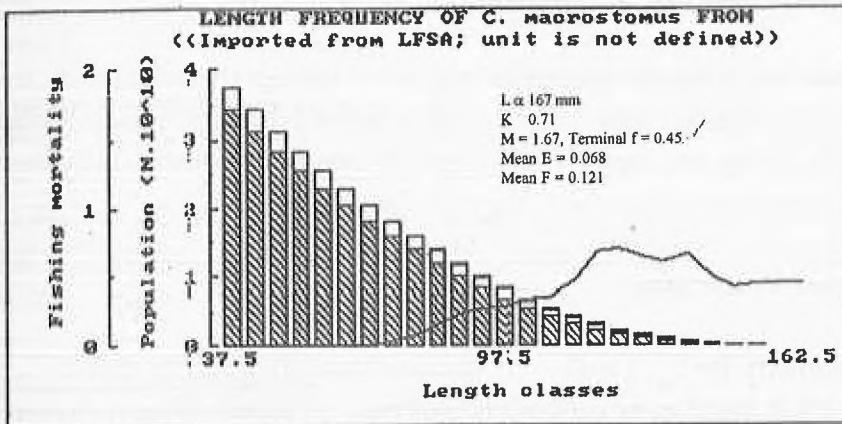
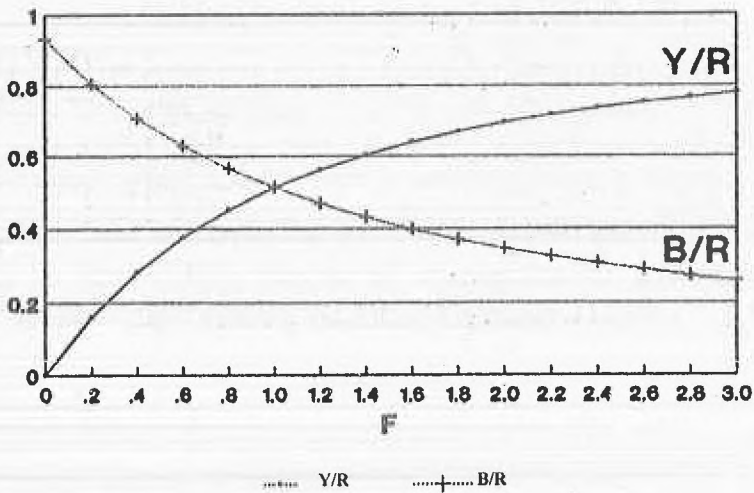


Fig. 4 Yield per recruit and biomass per recruit - *C. macrostomus*



## Annuli on scales

Growth checks on scales of Malabar sole are characterised by narrowing of the sclerites and closing up of the intervals between successive sclerites. For the males, the mean total length for one to three rings were 118.4, 134.4, 149.4, mm and for females 118.7, 134.8, and 150.3 mm respectively which indicated no differential growth between sexes.

The time of formation of growth checks was worked out based on the width of the scales in the terminal zone. The growth rings are invariably formed during October-November and February-March. These correspond to the respective spawning season of two broods in the population.

## Estimation of growth parameters

The growth parameters like  $L_{\infty}$ ,  $k$  and  $t_0$  were estimated using the quarterly growth increments in total length of the fish, based on the Gulland and Rolt plot, von Bertalanffy growth formula and its regression analysis. Accordingly the values obtained were:  $L_{\infty} = 170$  mm,  $K = 0.9$  and  $t_0 = -0.46968$ .

## Total mortality

The total mortality rate ( $Z$ ) estimated by taking  $L_{\infty}$  as 167 mm and  $K$  as 0.71 at Cochin was 2.6 during 1994-95 and 3.8 during 1995-96. At Neendakara the value of  $Z$  obtained using the same growth parameters was 2.7 and 2.28 during 1994-95 and 1995-96 respectively. The total mortality rate was also calculated taking  $L_{\infty}$  as 170 mm and  $K$  as 0.97. This gave an  $Z$  value of 3.13 and 5.39 during 1994-96 at Lcochin compared to 4.0 and 3.47 at Neendakara respectively. A plot of  $\log_e (N/\Delta t)$  against 't' for the years 1994-95 and 1995-96 for different values of  $L_{\infty}$  167,  $L_{\infty}$  170 and  $K$  (year) at Lcochin are given in Figure 1 and at Neendakara in Figure 2.

## Natural mortality

The natural mortality ( $M$ ) estimated by Pauly's empirical formula based on  $L_{\infty}$  as 170 mm and  $K$  as 0.97 gave a value 1.67. The estimated value of  $M$  was 1.37

### Fishing mortality

The fishing mortality 'F' was obtained as 1 by subtracting the value of 'M' from the average Z value 2.67. The value of 'F' independently estimated using Allen's<sup>13</sup> formula was 0.936 which compared well with the value derived by the other method.

### Exploitation rate and exploitation ratio

The exploitation rate (U) and exploitation ratio (E) were found to be 0.35 and 0.37 respectively. Since the annual yield of the Malabar sole is showing an increasing trend the 'F' value obtained by the first method appeared to be reasonable as the 'E' value works out to 0.37 when compared to 0.35 obtained for a F value of 0.936. Hence, F value was taken as 1 for further application in the studies.

### Annual survival rate and mortality

The annual survival and mortality was found to be 0.0692 and 0.0698 respectively.

### Virtual population analysis

The raised annual length frequencies for the two years 1994-95 and 1995-96 were pooled and the annual average frequencies were obtained as input for cohort analysis. The input parameters used were  $L_{\infty} = 166$  mm,  $K = 0.71$ , natural mortality 1.67, terminal F as 0.45 and mean F = 0.121. The results indicated that the F value showed an increase to a maximum of 0.7 at 115 mm which is followed by a decline as may be seen from Figure 3. The average F for fully recruited fishes ( $L \geq 115$ ) was 0.658.

### Biomass estimation

The estimated biomass from the fully exploited phase ( $L \geq 110$  mm) worked out to 17,745 tonnes. This closely agreed with an estimate of 16,384 tonnes derived by Baranov's (1918) method. The present average yield (1985-96) of Malabar sole in Kerala is 16,000 tonnes. The biomass estimated is 49,859 to or 50,000 tonnes.

## Yield per recruit

For the yield per recruit of Malabar sole stock, the parameters used were  $W_{\infty} = 23.2$  g,  $K = 0.71$ ,  $t_0 = 0$ ,  $M = 1.67$ ,  $t_c = 1.53$  years,  $t_r = 0.39$  and  $L_{\infty} = 166$  mm.

$W_{\infty}$  was computed using  $L_{\infty}$  value as

$$\text{Log } W_{\infty} = -12.86942 + 3.13309 \text{ Log } L_{\infty}$$

The yield per recruit was derived for different values of  $F$  ranging from 0 to 3.0 keeping the age at first capture ( $t_c$ ) constant. The Y/R curve has no maximum (Fig. 4). This is commonly observed in tropical fisheries. Hence the B/R values are also plotted as in Figure 4. The values decrease with increase in effort.

## Discussion

One of the most serious limitations in the stock assessment of tropical fishes is the inadequacy of methods for determining the age of the fish unlike in the temperate waters. In tropical fishes the age determination is cumbersome as most of the fishes are multiple spawners or have protracted spawning which make it difficult to trace the various broods in the fishery. There is no clear cut seasons as in temperate waters, hence interpretation of growth checks on hard parts are difficult. But it has to be admitted that there do occur changes in wind (monsoons) shifts and oceanographic conditions (upwelling) in many tropical areas, and a certain level of seasonality can still be expected. Seasonality may also be reflected in the spawning patterns and in the growth of tropical fish species, albeit less pronounced and more difficult to detect than in temperate waters. The seasonal differences make it possible to detect at least in some tropical species like the Malabar sole the existence of different cohorts. The success of the present study is that fairly concordant values of growth parameters ( $L_{\infty}$  and  $K$ ) of Malabar sole could be estimated by different methods based on the results of length frequency analyses and growth checks on scales. These parameters were helpful in stock assessment studies of the species.

Malabar sole is landed as a by-catch in shrimp trawls in Kerala. Specialised fishery targeted for this species does not exist along Kerala coast or anywhere in India. The mortality estimates indicated that the effect of fishing on the stock is negligible. Feroz Khan and Nandakumaran reported an  $M$  value of 1.52. Their studies on Malabar sole at Calicut indicated an economic yield at an  $E$  value of 0.87 compared to an observed value of  $E$  as 0.4. The  $E$  value obtained

during the present study was 0.35 for Kerala as a whole. Ferozhkhan and Nandakumaran<sup>3</sup> opined that maximum yield would be obtained at an E value of 0.96. Based on their study they recommended that the fishing effort can be increased two-fold to give a catch from the present 959.08 t to 1646 tonnes considered as economic yield at Calicut. The present study showed that the biomass from fully exploited phase ;in Kerala was 17,745 t obtained from VPA and 16,384 tonnes by Baranov's<sup>14</sup>. The mean biomass is 49,859 or 50,000 tonnes. The yield per recruit curve indicated no maximum . On the other hand the B/R curve decreased with increase in effort. The F value as 1 appeared reasonable taking into consideration Malabar sole as a by-catch in a target fishing for shrimp.

In a targeted fishery for shrimps the by-catches are not of negligible interest. The value of minor fishes can make all the difference between a profitable and non-profitable trip<sup>15</sup>. The present effort input by trawls at most of the centres in Kerala as well as along the entire coast of India has almost reached saturation, optimum or ecological limits with respect to many target resources in the 50 m depth zone<sup>16</sup>. Though effort level can be increased with respect to Malabar sole for further exploitation as revealed by the present analysis, such an enhancement in the effort has to be considered keeping in view the multispecies nature of the fishery.

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