Population dynamics of silver biddy *Gerres setifer* (Pisces: Perciformes) in the Parangipettai waters, southeast coast of India

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Growth parameters of *Gerres setifer* (Hamilton, 1822) in the Parangipettai waters were estimated using ELEFAN I programme. The asymptotic length \( L_\infty \) and growth coefficient \( K \) were found to be respectively 174.05 mm and 1.19 year\(^{-1} \) respectively in male and 170.5 mm and 1.26 year\(^{-1} \) in female. The ‘\( t_0 \)’ estimated by substituting the \( L_\infty \) and \( K \) in Pauly’s equation was -0.0817 in males and -0.0775 in females. Instantaneous rates of mortality (Z), natural mortality (M) and fishing mortality (F) in male were 2.53, 1.26 and 1.26 while in females the above values were 2.80, 1.32 and 1.48. The results of the present study showed that exploitation of *G. setifer* in the Parangipettai waters is below the optimum level indicating scope for slight increase in catch efforts.

**Key words:** Asymptotic length, *Gerres setifer*, growth, mortality, Parangipettai

**Introduction**

*Gerres setifer* (Hamilton, 1822) belonging to the teleostean family Gerreidae and order Perciformes is one of the economically important small silvery food fishes of Parangipettai waters. It is popularly called as ‘Mojarras’ or ‘Gerreids’ or ‘Deep body Silver biddies’. This species is distributed in tropical seas and reported from the west, south and east coasts of India, through the Indo-Malayan Archipelago, the South China Sea, Papua New Guinea to Northern Australia\(^1\). The biology of the species belonging to the family Gerreidae has been little investigated and most published information consists of incidental records or notes in general surveys. Some aspects on the biology of *G. setifer* from Chilka Lake\(^2\), India and some information on age and growth of *G. setifer* from Mangalore coastal waters\(^3\) were reported. Population dynamics of this species is not reported so far. The present study was undertaken to get information on the maximum size and age of fish, growth parameters, mortality and exploitation rate of *G. setifer* from the Parangipettai waters based on length frequency data as the knowledge of these population parameters are essential for proper management and conservation of the stock.

**Materials and Methods**

Samples were collected from the commercial catches of gill nets operating in Parangipettai waters (lat. 11°29’N and long. 79°46’E) at weekly intervals during September 2001 to August 2003. The male and female fishes were identified by examining the gonads and the total length (TL) was measured to the nearest 1 mm from tip of snout to tip of caudal fin using a measuring board. Weight (W) was recorded to the nearest 0.1 g using an electronic balance. A total of 593 males with total length ranging from 70 to 165 mm and 576 females ranging from 75 to 162 mm were considered for computing length-weight relationship. The length-weight data were analysed following the cubic relationship\(^4\). The regression lines of males and females of *G. setifer* were then analyzed further for significant differences by General Linear Model ANalysis of COVariance (GLM ANCOVA) using MINITAB (Version 13) statistical software.

For gathering length frequency data a total of 2103 males with total length ranging from 70 to 165 mm and 2393 females ranging from 72 to 163 mm were sampled. The length frequency data were grouped sex wise into 5 mm class intervals. An initial estimate of asymptotic length \( L_\infty \) and the ratio of total mortality and growth coefficient \( Z/K \) was obtained through Powell-wetherall method\(^5\). Length frequency data were then analysed by Electronic LEngth Frequency ANalysis (ELEFAN I)\(^6,7\) using the appropriate routines in FiSAT II package\(^8\). In this method the growth parameters, asymptotic length \( L_\infty \) and growth coefficient \( K \) were estimated following the von Bertalanffy growth equation (VBGE)\(^9\):

\[ L(t) = L_\infty - \frac{L_\infty - L_0}{1 + e^{-K(t-t_0)}} \]
\[ L_t = L_\infty (1-\exp^{-K(t-t_0)}) \]  \hspace{1cm} (1)

where \( L_t \) is the length at age \( t \), \( L_\infty \) the asymptotic length, \( K \) the growth coefficient and ‘\( t_0 \)’ age at which fish would have had zero length if they had always grown according to the above equation. Parameters of \( L_\infty \) and \( K \) were computed from the ELEFAN I. The growth performance index (\( \Omega \)) for \( G. \) setifer male and female was computed using the following equation\(^\text{10}\):

\[ \Omega = \log_{10}K + 2 \log_{10}L_\infty \]  \hspace{1cm} (2)

As ELEFAN cannot estimate the \( t_0 \) value from the length-frequency data, a very approximate value of ‘\( t_0 \)’ was estimated by substituting the \( L_\infty \) and \( K \) in the following equation\(^\text{11}\):

\[ \log(-t_0) \approx -0.3922 - 0.2752 \log L_\infty - 1.038 \log K \]  \hspace{1cm} (3)

where \(-0.3922\), \(-0.2752\) and \(-1.038\) are constants derived from 153 triplets of \( t_0 \), \( L_\infty \) and \( K \) selected from the compilation of length growth parameters such as to cover a wide diversity of taxa and size.

Lengths at three months intervals were obtained from the von Bertalanffy growth equation (Eq. 1). Longevity was obtained from the following equation\(^\text{11}\):

\[ t_{\text{max}} = t_0 + 3/K \]  \hspace{1cm} (4)

where \( t_{\text{max}} \) is the approximate maximum age the fish of a given population would reach. The recruitment pattern of \( G. \) setifer was estimated by analysis of pooled length frequency data using FiSAT\(^8\).

The total mortality coefficient (\( Z \)) was estimated using the method of length converted catch curve analysis\(^\text{12}\) in the FiSAT II program using the input parameters \( L_\infty \), \( K \) and \( t_0 \). The theoretical equation used in this analysis is,

\[ \ln \left( \frac{N_i}{d_i} \right) = a + b.t_i \]  \hspace{1cm} (5)

where \( N_i \) is the number of fish in length class \( i \), \( dt_i \) is the time needed for the fish to grow through length class \( i \), \( t_i \) is the age (or the relative age, computed with \( t_0 = 0 \)) corresponding to the mid length of class \( i \), ‘\( a \)’ is a constant and ‘\( b \)’, with sign changed, is an estimate of total mortality (\( Z \)).

The histogram showing probability of capture for each size class was obtained by backward extrapolation of the straight portion of the right descending part of the catch curve. The length at first capture \( L_c \) (length at 50% capture) was obtained from the plot of cumulative probability of capture against mid-length of class interval.

Estimation of natural mortality rate was obtained through Pauly’s empirical model\(^\text{13}\),

\[ \ln M = -0.0152 - 0.279 \ln L_\infty + 0.06543 \ln K + 0.4634 \ln \bar{T} \]  \hspace{1cm} (6)

where \( M \) is the natural mortality, \( L_\infty \) is in cm, \( K \) is annual and \( \bar{T} \) is the mean annual temperature (in °C), which is assumed to reflect the water surface temperature and taken as 30°C. Fishing mortality (\( F \)) was calculated using the formula,

\[ F = Z - M \]  \hspace{1cm} (7)

where \( Z \) is the total mortality and \( M \) is the natural mortality. Exploitation rate (\( E \)) was determined from the relationship, \( F/Z \).

The relative yield per recruit (\( Y'/R \)) was predicted by considering \( Y'/R \) as a function of \( U \), \( E \) and \( M/K \) by employing Beverton and Holt \( Y'/R \) analysis (knife edge) in the FiSAT package. The relative yield per recruit equation which gives a quantity proportional to \( Y'/R \) was derived from the method of Beverton & Holt\(^\text{14}\) through a number of algebraic manipulations. The predicted values were obtained by substituting the input parameters of \( L_c/L_\infty \) (\( L_c \) is the minimum length captured; obtained from the extrapolation of length converted catch curve) and \( M/K \) in the FiSAT II package\(^8\), and according to the model,

\[ Y'/R = EU^{M/K} \left[ 1 - (3U/1+m) + (3U^2/1+2m) - U^3/(1+3m) \right] \]  \hspace{1cm} (8)

where,

\[ m = (1 - E) / (M/K) = K/Z \]  \hspace{1cm} (9)

\[ U = 1 - (L_c/L_\infty), \]  \hspace{1cm} (10)

(\( U \) is the fraction of growth to be completed by the fish after entry into the exploitation phase)

\[ E = F/Z \] (exploitation rate)  \hspace{1cm} (11)

The assumptions considered in this model being fishing and natural mortalities are constant from the moment of entry to the exploited phase, recruitment is
constant and the length-weight relationship has the exponent 3. The yield isopleth diagram was also derived by analysis of the length frequency data by FiSAT. Yield isopleth diagrams demonstrated the response of the yield-per-recruit of the fish to both variation in \( L_c \) and the fishing pressure as indicated by the exploitation rate \( E \) over a wide range of both parameters.

**Results**

Among the fishes considered for length-weight relationship, \( TL \) varied from 70 mm \((L_c)\) to 165 mm, with a mean of \(116 \pm 25\) mm in males and from 75 mm \((L_c)\) to 162 mm, with a mean of \(117 \pm 24\) mm in females. The computed length-weight relationships of *G. setifer*, the respective correlation coefficients and probability values are as follows:

<table>
<thead>
<tr>
<th>Sex</th>
<th>Parabolic equation</th>
<th>( R^2 )</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>( W = 0.018498 TL^{2.8690} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>( W = 0.017698 TL^{2.9022} )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sex</th>
<th>Logarithmic transformation</th>
<th>( R^2 )</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>( \log W = -1.73288 + 2.8690 \log TL )</td>
<td>0.9961</td>
<td>0.00</td>
</tr>
<tr>
<td>Female</td>
<td>( \log W = -1.75208 + 2.9022 \log TL )</td>
<td>0.9856</td>
<td>0.00</td>
</tr>
</tbody>
</table>

The exponent coefficient values 2.8690 and 2.9022 obtained for *Gerres setifer*, males and females respectively indicated that the fish follows the cube law; its growth is proportionally three-dimensional. That is, with increasing age, rate of growth in terms of weight, becomes faster than that of its length. Correlation coefficients \((r)\) of 0.9980 for males and 0.9928 for females were found to be highly significant \((P<0.001)\) indicating good correlation between length and weight of *G. setifer*.

The GLM ANCOVA results for the comparison of regression coefficients \((b)\) of the length-weight relationship of males and females of *G. setifer* showed the slopes \((b)\) of males and females to exhibit significant interaction \((\text{computed } F_{1,1165}>3.84, P<0.05)\).

The Powell-Wetherall plots for males and females (Fig. 1) gave an initial estimate of \( L_\infty \) value of 168.75 mm and \(Z/K\) value of 1.984 \([r = -0.922; \text{regression equation, } Y = 56.55 + (-0.335)\times]\) for males and \( L_\infty \) value of 168.52 mm and \(Z/K\) value of 2.488 \([r = -0.946; \text{regression equation, } Y = 48.32 + (-0.287)\times]\) for females. These initial estimates were fed into ELEFAN I in order to get the optimized values for \( L_\infty \) and \( K \). The most optimized \( L_\infty \) values were obtained by ELEFAN I-automatic search routine and the restructured length frequency histograms were also obtained. The optimized values for \( K \), obtained by the ELEFAN I were 1.19 year\(^{-1}\) and 1.26 year\(^{-1}\) for males and females respectively. The goodness of fit index \((R_n)\) for the obtained \( K \) and \( L_\infty \) values of male and female were 0.241 and 0.277 respectively. Usually, the \( R_n \) value ranges between 0 and 1 in the ELEFAN-FISAT package. The oscillation parameter \((C)\) and winter point were assumed to be 0 as it is a tropical species. The non-seasonalized restructured length frequency histograms with growth curves for males and females.

**Fig. 1—Powell-Wetherall plots of *Gerres setifer* – A) Male, B) Female**
are shown in Fig. 2. The estimated growth performance index (\( \Omega \)) for \textit{G. setifer} male and female were 4.55 and 4.56. The estimated \( t_0 \) values for males and females were -0.0817 and -0.0775 respectively.

The von Bertalanffy’s growth equations for \textit{G. setifer} can be expressed as:

\[
\text{Male: } L_t = 174.05(1-\exp^{–1.19(t+0.0817)}) \\
\text{Female: } L_t = 170.5(1-\exp^{–1.26(t+0.0775)})
\]

The calculated length-at-ages at 6, 12, 18, 24, 30 and 36 months are 86.94, 126.0, 147.55, 159.43, 165.98 and 169.60 for males and 88.14, 126.64, 147.14, 158.06, 163.87 and 166.97 for females respectively. Estimated longevity for male and female \textit{G. setifer} calculated from Eq. (2) is 2.439 and 2.303 years respectively. The recruitment pattern of \textit{G. setifer} (Fig. 3) shows two major recruitment peaks in a year, (in January and May for males and December and April for females) both of which overlap in time to give one continuous recruitment pattern.

The length-converted catch curve (Fig. 4) gave a \( Z \) value of 2.53 year\(^{-1} \) (confidence interval of \( Z = 1.90 - 3.16; \) standard deviation of the slope = 0.284; \( r = -0.9422 \) for males and 2.80 year\(^{-1} \) [95\% of confidence interval (CI) of \( Z = 2.25 - 3.35; \) standard deviation of the slope = 0.252; \( r = -0.9546 \)] for females. The histogram showing probability of capture for each size class obtained by backward extrapolation of the straight portion of the right descending part of the catch curve is shown in Fig. 5. The length at first capture \( L_c \) (length at 50\% capture) estimated from the plot of cumulative probability of capture against mid-length of class interval for males and females are 68.97 mm and 69.25 mm respectively.

**Fig. 2**—Growth curves of \textit{Gerres setifer} drawn using ELEFAN I programme

A) Male (\( L_\infty = 174.05 \text{ mm and } K = 1.19 \text{ year}^{-1} \))

B) Female (\( L_\infty = 170.5 \text{ mm and } K = 1.26 \text{ year}^{-1} \))
Fig. 3—Recruitment patterns of *Gerres setifer* – A) Male, B) Female

Fig. 4—Length-converted catch curves of *Gerres setifer*
A) Male ($L_\infty = 174.05$ mm, $K = 1.19$ year$^{-1}$)
B) Female ($L_\infty = 170.5$ mm, $K = 1.26$ year$^{-1}$)

Fig. 5—Histograms showing probability of capture for *Gerres setifer* – A) Male, B) Female
The Jones & van Zalinge plots for males and females of *G. setifer* are illustrated in Fig. 6. The estimated values of total mortality (Z) of males and females by Jones and van Zalinge method are 2.396 (95% of CI of Z = 2.1 - 2.692; standard deviation of the slope = 0.133; r = -0.9850) and 2.740 (95% of CI of Z = 2.417 – 3.063; standard deviation of the slope = 0.132; r = -0.9931) respectively.

The natural mortality coefficient (M) obtained through Pauly’s empirical model at 30°C surface temperature was 1.26 year⁻¹ for males and 1.32 year⁻¹ for females. Therefore, the computed instantaneous fishing mortality coefficient (F) for males and females are 1.26 and 1.32 respectively (total mortality estimates of length converted catch curve was considered here onwards). The respective current exploitation ratio (E) for males and females are 0.50 and 0.53. The fraction of growth to be completed by the fish after entry into the exploitation phase (U) for males and females are 0.60 and 0.59.

Two dimensional relative yield per recruit prediction models for males and females are given in Fig. 7. The knife edge procedure for the analysis of relative yield-per-recruit gave predicted values of 0.577, 0.503 and 0.338 for \( E_{\text{max}} \), \( E_{10} \) and \( E_{50} \) respectively for male *G. setifer*. These predicted values of \( E_{\text{max}}, E_{10} \) and \( E_{50} \) for females were 0.591, 0.511 and 0.343. The computed current exploitation rates (E) of 0.50 for males and 0.53 for females are lower than the predicted \( E_{\text{max}} \) of 0.577 and 0.591 for males and females respectively. The implication is that the stock is not overexploited. The relative biomass per recruit is also shown in Fig. 7.
Fig. 8—Yield isopleth diagrams for *Gerres setifer* (arrow indicates the optimum value) – A) Male, B) Female

The yield isopleth diagrams (Fig. 8) show that the maximum yield per recruit can be achieved at the exploitation ratio of 0.577 and $L_o/L_\infty$ value of 0.7 for males and the exploitation ratio of 0.591 and $L_o/L_\infty$ value of 0.7 for females.

**Discussion**

The present values of exponent coefficient of length weight relationship for male and female *G. setifer* are 2.869 and 2.902. These values are much lower as compared to the earlier report (exponent coefficient = 3.087) from Chilka lake.

In the course of progress in fishery research, different methods have been evolved for determining the age of the fish in an open system. This involves conventional methods such as integrated method, month mode curve, probability plot method and Ford-Walford method. The development of computer knowledge during the past decades led to application of microcomputer program packages in the estimation of growth parameters of fishes. There are several microcomputer program packages to determine the age and growth of fishes and shellfishes, of which FiSAT is the most widely used package all over the world especially in tropical countries by fishery scientists, nowadays.

Asymptotic length is the largest theoretical size a species could attain in its habitat given the ecological peculiarities of that environment. The $L_\infty$ values recorded for male and female *G. setifer* in the present study are obviously above the $L_{max}$. The maximum size of an organism is a strong predictor for many life history parameters. The computed $L_\infty$ values for males (174.05) and females (170.5) in the present study are higher than the recorded value (152.14) for unsexed *G. setifer* for Mangalore waters. The $K$ values obtained for males (1.19) and females (1.26) in the present study are also quite high from the recorded values (0.1). The $t_0$ recorded previously for this species was -0.6139 whereas the $t_0$ values computed for males and females in the present study are -0.0817 and -0.0775.

The present study showed *G. setifer* males to attain 126.0 mm, 159.43 mm and 169.6 mm total length at the end of first, second and third year whereas *G. setifer* females attained 126.64 mm, 158.06 mm and 166.97 mm total length at the end of first, second and third year. According to Anantha & Santha-Joseph *G. setifer* attained 117.10 mm, 148.48 mm, 150.0 mm and 151.61 mm total length at the end of zero, first, second and third year, respectively.

The growth parameters estimated mostly in the incidental studies for congeners of this species from different regions (Table 1) show the agreement of the estimated K values of the present study in most instances. The recruitment patterns (Fig. 3) of male and female *G. setifer* showed two overlapping peak recruitment seasons thereby indicating that *G. setifer* is a continuous breeder with two peak breeding seasons.

Length-based models for Z-estimation (e.g. length-converted catch curve, Powell-Wetherall plot, Jones and van Zalinge method, etc.) are premised on the assumption of equilibrium (steady-state) age composition which implies constant recruitment, constant mortality with age and time. Among the
estimates of total mortality, natural mortality and fishing mortality, the highest values of 2.80, 1.32 and 1.48 were observed for females. Higher exploitation rate (0.53) was also observed for females than males (0.50). This may be due to high growth rates of females than males.

Among fish, natural mortality was found to be positively correlated with reproductive success\(^6\). High growth rates, small asymptotic lengths and high mortality indicate that the fish species in these waters mature early in life and have a small life span\(^5\). More or less similar natural and fishing mortality rates in males and females illustrate that this species is not overexploited.

Generally \(M/K\) (natural mortality/growth coefficient) is used as an index for checking the validity of \(M\) and \(K\) values estimated by different methods and it is known to range\(^9\) from 1 to 2.5. The \(M/K\) ratios obtained in the present study for males and females (1.0588 and 1.0476) were found to lie within this range.

In the relative yield per recruit and biomass per recruit prediction models (Fig. 7) the descending curves showed decrease in biomass/recruits \((B/R)\) as exploitation ratio increased for both male and female. The other curve showed increase in yield/recruit \((Y/R)\) with increase in exploitation ratio \((E)\) up to \(E_{\text{max}}\). The \(B/R\) line cut the \(Y/R\) curve at the point called Maximum Economic Yield (MEY). In the present study, this point was obtained at a lower level of exploitation rate.

The \(E_{\text{max}}\) is the value of \(E\) with the highest \(Y/R\) value that is possible with a given value of \(L_c\) i.e. exploitation rate which produces maximum sustainable yield \((E_{\text{MSY}})\) which represents the mean maximum catch that can be taken from the fishery without affecting the biology of the stock or the balance of the system. \(E_{10}\) is the exploitation rate at which the slope of the \(Y/R\) is 1/10 of its value at the origin and \(E_{50}\) is the value of \(E\) associated with a 50% reduction of the biomass (per recruit) in the unexploited stock. When harvesting at the MSY level, fishing mortality \((F)\) is roughly equal to the natural mortality \((M)\) and harvesting above MSY denotes over fishing. The present computed yield per recruit (knife edge procedure) analysis showed exploitation rates \((E)\) of 0.50, for males and 0.53 for females which are below the predicted maximum values of 0.577 for males and 0.591 for females respectively. Thus, the fishing pressure on the stock is not excessive. More yields could be obtained by a reasonable increase in the effort (Fig. 8) without necessarily leading to over exploitation.
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