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Population Dynamics of a Whip Fin Silverbiddy *Gerres filamentosus* Cuvier, 1829 from the Parangipettai Waters, Southeast Coast of India

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Abstract

The present study was undertaken to get information on the maximum size, age and growth parameters and mortality of *Gerres filamentosus*. The length frequency data were grouped sex wise into 1 cm class intervals, sequentially arranged for two years and used for estimation of growth and mortality. L_∞ and K values were obtained by electronic length frequency analysis of computer based method. Value of 't_0' (age at '0' length) was estimated by substituting the L_∞ and K in the Pauly's empirical equation. Natural mortality was estimated using Pauly's method. Fishing mortality rate (F) was calculated from the F = Z – M relationship. The asymptotic length (L_∞) and growth coefficient (K) were found to be 26.9 cm and 1.45•year^{-1}, respectively in males, and 27.11 cm and 1.50•year^{-1} in females. The 't_0' values estimated by substituting the L_∞ and K in Pauly's equation were -0.1109 in males and -0.1073 in females. Instantaneous rates of mortality (Z) estimated by length converted catch curve for male and female were 3.14 and 3.27. Natural mortality (M) estimated by Pauly's empirical equation for male and female were 2.41 and 2.47 and the estimated fishing mortality for male and female were 0.73 and 0.80, respectively. The computed current exploitation ratios (E) were 0.23 and 0.24. It is concluded that because computed current exploitation rates (E) are lower than the predicted E, the stock is not overexploited and the fishing pressure on the stock is not excessive. As the *G. filamento-*

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sus is exploited under this condition, below the optimum level indicating scope of slight increase in efforts.

Introduction

Whip fin silverbiddies are members of the Teleostean family Gerreidae of the order Perciformes. These are small to medium sized fishes valued as delicious ones. These are popularly called as ‘Mojarras’ or gerreids. These are distributed widely in the Indo-Pacific region and support fisheries significantly in many countries such as Bahrain, Fiji islands, India, Kiribati, Malaysia, Mexico, Philippines, Qatar, Saudi Arabia, Sri Lanka, United Arab Emirates and United States of America (Froese and Pauly 2000).

FAO annual catch data showed that 4370 metric tons of gerreids were captured in the Philippines during 1998, with 1730 metric tons captured in Kiribati and 1324 metric tons in the United Arab Emirates (Froese and Pauly 2000). The maximum catch of 9658 metric tons was recorded in Mexico during 1990. Silver biddies constitute an important fishery in the Pulicat Lake (Prabhakara Rao 1968), Chilka Lake, India (Patnaik 1971) and in Africa in the Kosi system (Blaber 1978; Cyrus 1980). There is no separate fishery statistics for *Gerres* species in India. In Pulicat Lake, where the silver biddies are esteemed as delicious food and a major portion of the landings consumed locally in the fresh as well as dried condition, *G. oyena* along with *G. filamentosus* and *G. limbatus* constitute an important fishery. Biology of these species was studied by Prabhakara Rao (1970). However the studies performed on *G. filamentosus* are incidental (Kurup and Samuel 1987; 1991) and no detailed study is available for this species.

In Parangipettai waters, mechanized boats, catamarans, plank-built boats and dugout canoes are mainly employed for fishing gerreids. Gill nets are the common gears used to catch gerreids. Gill nets measure about 300 m in length and 8 m in height with a mesh size of 3.5 cm. The plastic floats and the granite block sinkers are attached to the rope of the net. This type of net is operated from catamarans or from dugout canoes. Though both species are available throughout the year at Parangipettai waters, the main fishing season is from April to December. The other species are available in huge numbers only during pre-monsoon and monsoon seasons. The Parangipettai landing center (79°43’E longitude and 11°29’N latitude) is situated on the northern bank of Vellar estuary where it empties into the

Bay of Bengal at about 30 km south of Cuddalore, on the south east coast of India. Along the Parangipettai coast there are seven fishing villages from Mudasalodai to Pudukuppam extending over a distance of 30 km.

Even though these silver biddies do not form a major fishery they are liked by people, as the flesh is meaty and tasty and the price is affordable. In Parangipettai markets the fish are sold at the price of 35 to 55 Indian Rupees•kg^{-1} whereas in Sri Lanka they cost about 75 to 100 Sri Lankan Rupees•kg^{-1}. These fishes are in the 3^{rd} trophic level and consumed by larger fishes. Moreover these fishes also serve as excellent baits for capturing large fishes. Even though they grow only up to 25-30 cm in total length, they have established a place for themselves among people living in the southeast and west coasts of India as the cheapest fish available throughout the year. As they provide a livelihood and income for millions of the poorest people and also contribute to the overall economic well being of the country, detailed research on gerreids can make a positive contribution to every socio-economic resource or environmental issue.

As there is no information on age and growth, natural and fishing mortality, life span, age at maturity, age of spawning and the exploitation rate of this species in Indian waters the present study was undertaken to get information on the maximum size and age of fish, growth parameters, mortality and exploitation rate of *Gerres filamentosus* from the Parangipettai waters based on length frequency data of this fish.

Materials and Methods

Random samples of *G. filamentosus* were collected from the commercial gill net and boat seine catches of Parangipettai waters (latitude 11°29' N and longitude 79°46' E) at weekly intervals during September 2001 to August 2003. Sex was determined macroscopically and the total length (TL) was measured to the nearest 1 mm from the tip of the snout to the tip of caudal fin. A total of 4135 specimens (2110 males and 2025 females) of *G. filamentosus* ranging in total length from 7.1 to 26.5 cm were analyzed for the age and growth studies. The length frequency data were grouped sex wise into 1 cm class intervals, sequentially arranged for two years and used for estimation of growth. In the present study length frequency analysis were done with FiSAT II (Gayanilo and Pauly 1997).

The length frequency data of *G. filamentosus* from the gill net and boat seine catches were analyzed using ELEFAN I routine of FiSAT II software (Gayanilo and Pauly 1997; Pauly 1987). The following stepwise procedure was adopted to estimate L_∞ and K and for correction of length frequency data for mesh selection (Amarasinghe and De Silva 1992; Sparre and Venema 1992; Amarasinghe 2002).

• Estimation of an initial value for asymptotic length (L_∞) and Z/K (Z = total mortality and K = growth coefficient) using the Powell-Wetherall method (Powell 1979; Wetherall 1986).

• Preliminary estimation of asymptotic length (L_∞) and growth coefficient (K) using the initial estimates of L_∞ estimated by Powell-Wetherall method.

• Estimation of probabilities of capture by detailed analysis of left ascending part of the catch curve using the preliminary estimation made on the asymptotic length (L_∞), growth coefficient (K) and computed t_0.

• Correction of the original length frequencies using probabilities of capture (Pauly 1986a; 1986b; 1986c) for incomplete selection for length classes smaller than the first fully selected length through appropriate routine.

• Estimation of best optimized estimates of L_∞ and K through ELEFAN I routine (Gayanilo and Pauly 1997) from the corrected length frequency data.

The ELEFAN I routine of FiSAT II software (Gayanilo and Pauly 1997) attempts to combine the logic of the Peterson method and that of modal progression analysis with a minimum of subjective inputs (Pauly 1983). The L_∞ and K values were obtained through the four options such as, curve fitting by eye, response surface analysis, scan of K – values and automatic search routine. In this method the growth parameters L_∞ and K were estimated following the von Bertalanffy growth equation (von Bertalanffy 1938). The equation for growth in length is given by,

$$L_t = L_\infty [1\text{-}\exp\{-K (t\text{-}t_0)\}] \quad (1)$$

where L_t is the length at age t, L_∞ the asymptotic length, K the growth coefficient and 't_0' theoretical age at which fish would have had zero length if they had always grown according to the above equation. The most optimized L_∞ and K values were obtained by ELEFAN I - automatic search routine and the restructured length frequency histograms were also obtained. The growth performance index (Ø) for *G. filamentosus* male and female was computed using the following equation (Pauly and Munro 1984):

$$\text{Ø} = \log_{10} K + 2 \log_{10} L_\infty \quad (2)$$

Since 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_∞ (in cm) and K ($year^{-1}$) in the following equation (Pauly 1983):

$$\log(-t_0) \approx -0.3922 - 0.2752 \log L_\infty - 1.038 \log K \quad (3)$$

Longevity was obtained from the following equation (Pauly 1983):

$$t_{max} = t_0 + 3/K \quad (4)$$

where t_{max} is the approximate maximum age the fish of a given population would reach.

The total mortality coefficient (Z) was estimated using length converted catch curve analysis (Gayanilo and Pauly 1997) in the FiSAT II program using the input parameters L_∞, K and t_0. The theoretical equation used in this analysis is,

$$\text{Ln}(N_i/dt_i) = a + b.t_i \quad (5)$$

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 corresponding to the mid length of class i, and where b, with sign changed, is an estimate of 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, through detailed analysis of ascending part of catch curve.

Estimation of natural mortality rate was obtained through Pauly's empirical model (Pauly 1980):

$$\ln M = -0.0152 - 0.279 \ln L_\infty + 0.06543 \ln K + 0.4634 \ln \check{T} \quad (6)$$

where M is the natural mortality, L_∞ is in cm, K is annual and $\check{T}$ is the mean annual temperature (in ˚C), which is taken as 30˚C.

Fishing mortality (F) was calculated using the formula:

$$Z = M + F \quad (7)$$

Exploitation rate (E) was determined from the relationship:

$$E = F/Z. \quad (8)$$

The relative yield per recruit (Y'/R) was predicted by considering Y'/R as a function of U and E and M/K as a constant '1' by employing Beverton and Holt Y'/R analysis (selection ogive) 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 and Holt (1966) through a number of algebraic manipulations. The predicted values were obtained by substituting the input parameters of L_c/L_∞ (L_c is the minimum length captured; obtained from the extrapolation of length converted catch curve) and M/ K in the FiSAT II package (Gayanilo and Pauly 1997) and according to the model,

$$Y'/R = EU^{M/K}[\, 1- (3U/1+m) + (3U^2/1 + 2m) - U^3 / (1+ 3m)\,] \quad (9)$$

where,

$$m = (1 - E) / (M/K) = K/Z \quad (10)$$

$$U = 1 - (L_c/ L_\infty) \quad (11)$$

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

$$E = F/Z \text{ (exploitation rate)} \quad (12)$$

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.

Results

The Powell-Wetherall plots for male and female *Gerres filamentosus* are shown in figures 1a and 1b, respectively. The analysis of length frequency data by the Powell-Wetherall method gave an initial estimate of L_∞ value of 27.05 cm [r = -0.998; regression equation, Y = 89.67 + (-0.332)*X; where Y = L_{mean} – L' and X = L'] and Z/K value of 2.017 for males and L_∞ value of 27.21 cm [r = -0.998; regression equation, Y = 8.36 + (-0.307)*X] and Z/K value of 2.253 for females. Initial estimate of K values for males and females obtained from K-scan in the ELEFAN I were 1.55 and 1.68, respectively. The optimized values for K and L_∞ obtained by the ELEFAN I were 1.45•$year^{-1}$ and 27.3 cm for males and 1.50•$year^{-1}$

and 27.11 cm for females, respectively. The non-seasonalized restructured length frequency histograms with growth curves for males and females are shown in figures 2a and 2b. The estimated growth performance index (Ø) for *G. filamentosus* males and females were 3.03 and 3.04. The estimated t_0 values for males and females were -0.11093 and -0.10731 respectively.

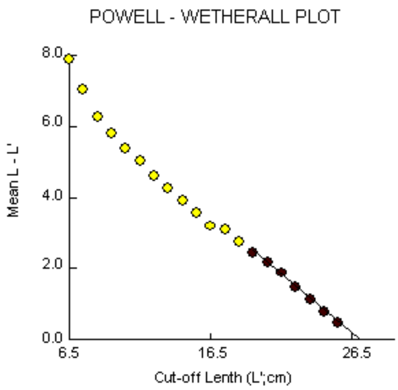

Figure 1a. Powell-Wetherall plot of male *Gerres filamentosus*

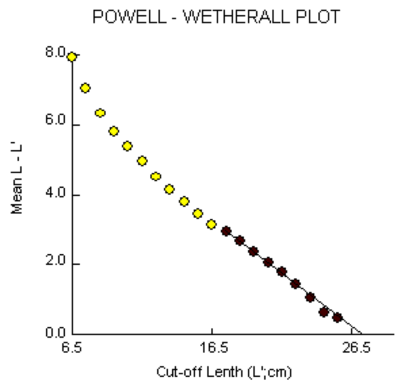

Figure 1b. Powell-Wetherall plot of female *G. filamentosus*

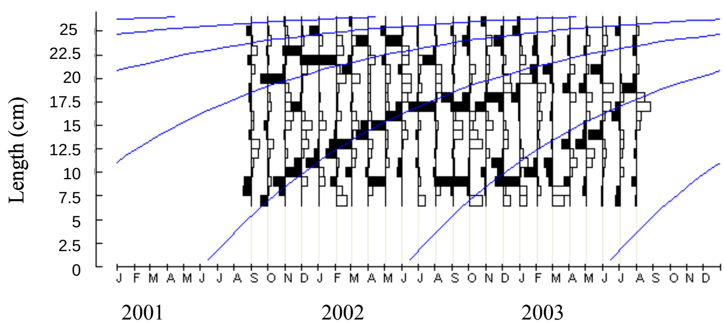

Figure 2a. Growth curve of male *G. filamentosus* drawn using ELEFAN I programme (L_∞ = 27.3 cm and K = 1.45• year^{-1})

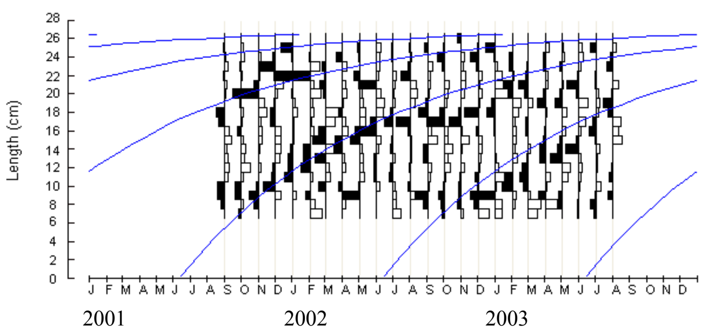

Figure 2b. Growth curve of female *G. filamentosus* drawn using ELEFAN programme (L_∞ = 27.11 cm and K = 1.50• year^{-1})

The von Bertalanffy's growth equations for *G. filamentosus* can be expressed as:

Male: L_t=27.3 [1 – exp {-1.45(t+0.1109)}] (13)

Female: L_t=27.11 [1-exp {-1.50 (t+ 0.1073)}] (14)

Estimated longevity for male and female *G. filamentosus* calculated from Pauly's equation is 1.96 and 1.89 years, respectively.

The length-converted catch curves for males and females are shown in figures 3a and 3b. The length-converted catch curve gave a Z value of 3.14•year^{-1} (confidence interval of Z = 3.32 -2.96; standard deviation of the slope = 0.081; r = -0.996) for males and 3.27•year^{-1} [95% of confidence interval (CI) of Z = 3.45 - 3.10; standard deviation of the slope = 0.079; r = -0.9968] 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 for males and females are shown in figures 4a and 4b. The lengths at first capture L_c (length at 50% capture) estimated by backward extrapolation of the straight portion of the right descending part of the catch curve were 6.74 and 6.73 cm for male and female *Gerres filamentosus*, respectively.

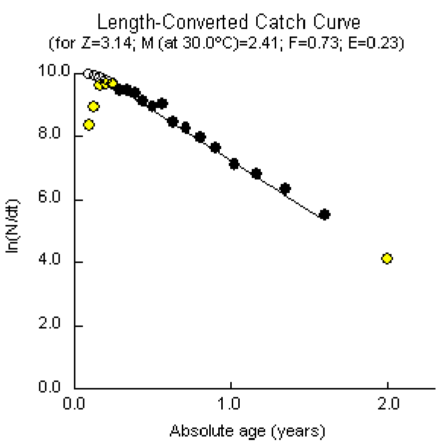

Figure 3a. Length-converted catch curve of male *G. filamentosus* (L_∞ = 27.3 cm, K = 1.45•year^{-1})

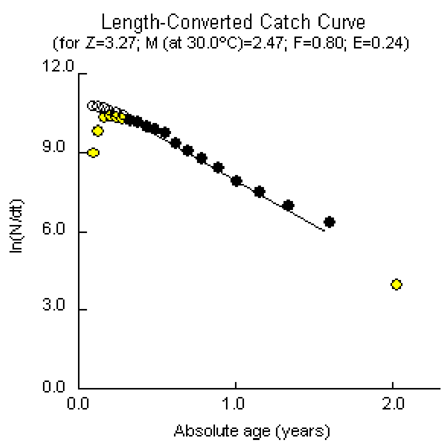

Figure 3b. Length-converted catch curve of female *G. filamentosus* (L_∞ = 27.11 cm, K = 1.50•year^{-1})

The natural mortality coefficient (M) obtained through Pauly's empirical model at 30˚C surface temperature was 2.41•year^{-1} for males and 2.47•year^{-1} for females. Therefore, the computed instantaneous fishing mortality coefficient (F) for males and females are 0.73 and 0.80•year^{-1}, respectively.

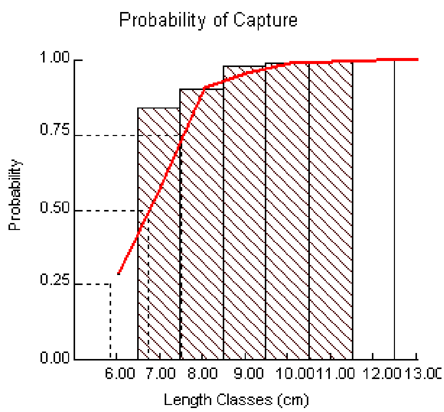

Figure 4a. Histogram showing probability of capture for male *G. filamentosus*

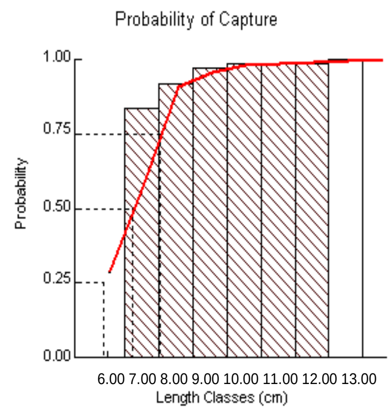

Figure 4b. Histogram showing probability of capture for female *G. filamentosus*

The respective current exploitation ratio (E) for males and females are 0.23 and 0.24, respectively. The fraction of growth to be completed by the fish after entry into the exploitation phase (U) for males and females are 0.48 in both instances. Two dimensional relative yield per recruit prediction models incorporating probabilities of capture for males and females are given in figures 5a and 5b. The analysis of relative yield-per-recruit gave a predicted value of 0.48 (E_{max}) for male and female *G. filamentosus*. The computed current exploitation rates (E) of 0.23 for males and 0.24 for females are well below the predicted E_{max} of 0.48 for males and females. Relative yield per recruit analysis incorporating probabilities of capture indicates that more yields could be obtained by a reasonable increase in the effort without necessarily leading to over exploitation. Also decrease in size at first capture of *G. filamentosus* to optimize yield would allow the stock optimally exploited, theoretically.

Discussion

The L_∞, K and t_0 values estimated for congeners of *G. filamentosus* are given in table 1. The maximum size of an organism is a strong predictor for many life history parameters (Blueweiss et al. 1978). The goodness of fit index (R_n) for the obtained K and L_∞ values of male and female were 0.179 and 0.189, 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 growth parameter estimates obtained as L_∞ and K for male and female *Gerres*

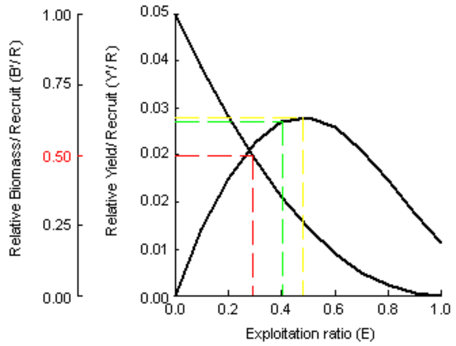

Figure 5a. Relative Y'/R and B'/R analysis of male *G. filamentosus*

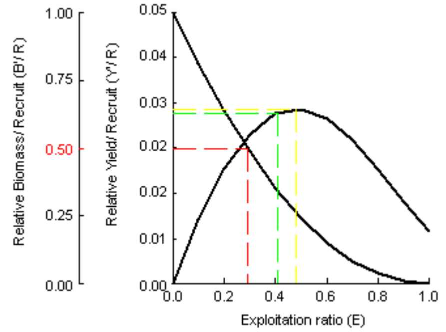

Figure 5b. Relative Y'/R and B'/R analysis of female *G. filamentosus*

Table 1. The growth parameters estimated for gerreids from different regions of the world (TL = Total length, FL = Fork length and SL = Standard length)

Species	Sex	L_∞ (mm)	K ($year^{-1}$)	t_0 ($year^{-1}$)	Region	Source
Gerres filamentosus	Unsexed	219 TL	2.616	-	Madagascar, Ambaro bay	Pauly (1978)
Gerres. filamentosus	Unsexed	269 TL	1.788	-	Madagascar, Ambaro bay	Pauly (1978)
Gerres filamentosus	Unsexed	329 TL	0.756	-	Madagascar, Ambaro bay	Pauly (1978)
Gerres oyena	Unsexed	182	1.1	-	Tanzania	Benno (1992)
Gerres setifer	Male	174 TL	1.19	-0.0817	South India	Sivashanthini and Ajmal Khan (2004)
	Female	170.5 TL	1.26	-0.0775		
Pentaprion longimanus	Unsexed	155	0.94		Australia	Cabanban (1991)
Pentaprion longimanus	Unsexed	137	1.12		Indonesia	Sadhotomo (1983)
Pentaprion longimanus	Unsexed	156	0.80		Indonesia	Sadhotomo (1983)
Pentaprion longimanus	Unsexed	134	1.77		Indonesia	Sadhotomo (1983)
Pentaprion longimanus	Unsexed	142	1.8		Indonesia	Sadhotomo (1983)
Pentaprion longimanus	Unsexed	160 TL	1.1		Malaysia	Chan and Liew (1986)
Pentaprion longimanus	Unsexed	158 FL	1.00		Philippines	Corpuz et al. (1985)
Pentaprion longimanus	Unsexed	172 FL	1.03		Philippines	Corpuz et al. (1985)
Pentaprion longimanus	Unsexed	170 FL	1.59		Philippines	Ingles & Pauly 1984

filamentosus were plotted on an 'auximetric' plot of *G. filamentosus* available in FishBase (Froese and Pauly 2000) representing the log K versus log L_∞ values of 1300 species for which the above values are known. This was done to determine the agreement of the estimated values (Figures 6a and b) with the known values. From the figures it can be observed that the estimated values of the present study show consistency with the previously recorded values for this species and others.

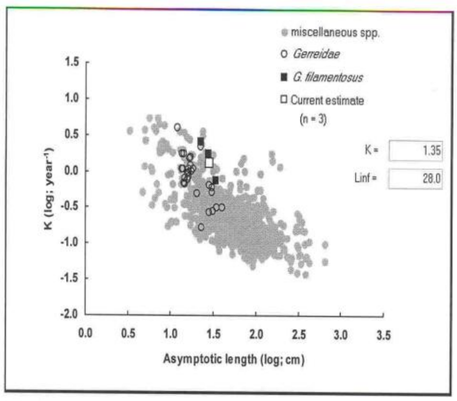

Figure 6a. Auximetric plot for male *G. filamentosus*

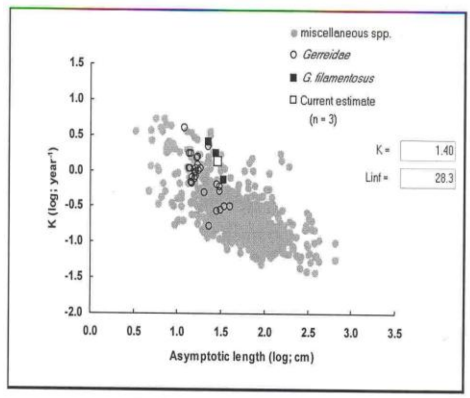

Figure 6b. Auximetric plot for female *G. filamentosus*

The estimated growth performance (Ø) index for males and females of this species is comparable with the Ø value of 3.11 obtained for *G. filamentosus* from Madagascar waters (Pauly 1978). But the estimated values are slightly higher than the value of 2.56 obtained for *G. oyena* from Tanzania waters and that of 2.55 for *G. longirostris* from Saudi Arabia waters (Pauly 1978). This clearly shows the reliability of the estimates of K and L_∞ in the present study. High annual growth rate of a fish can lead to high turnover rates or production per biomass (P:B) ratios (Gunderson 1997). Fast growth rate and small asymptotic length indicate that the fish species in these waters mature early in life and has a short life span (Sparre and Venema 1992). The life span reported for *G. filamentosus* in Madagascar waters was 1.6 years (Pauly 1978). The results obtained in the present study for male and female *G. filamentosus* (1.96 and 1.89) are a little higher than the earlier reported values for the congeners of the species (Sivashanthini and Ajmal Khan 2004).

Among fish, natural mortality is found to be positively correlated with reproductive success (Gunderson 1997). Generally M/K is used as an index for checking the validity of M and K values estimated by different methods and it is known to range from 1 to 2.5 (Beverton and Holt 1959).

The M/K ratios obtained in the present study for males and females (1.66 and 1.64) were well within this range. Instantaneous total mortality computed length converted catch curve for *Gerres setifer* in the previous studies was 2.53 and 2.80 for males and females, respectively (Sivashanthini and Ajmal Khan 2004) and the values obtained in the present study is lower than that. Only two earlier reports are available for gerreids on mortality estimates. Those are, for *Pentaprion longimanus* from the Philippine waters (Tandog-Edralin et al. 1988) where natural mortality was found as 2.41 and for *G. setifer* from the Parangipettai waters (Sivashanthini and Ajmal Khan 2004) where natural mortality was 1.26 and 1.32 for males and females.

In the relative yield per recruit and biomass per recruit prediction models the descending curves showed a decrease in biomass/recruits (B'/R) as exploitation ratio increased for both males and females. The other curve showed increase in yield/recruit (Y'/R) with increase in exploitation ratio (E) up to E_{max}. The E_{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_{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. The 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 analysis showed exploitation rates (E) of 0.23 for males and 0.24 for females which are well below the predicted maximum value of 0.55 for both males and females. The implication is that the stock is not overexploited. Thus, the fishing pressure on the stock is not excessive. More yields could be obtained by a reasonable decrease in size at first capture without necessarily leading to over exploitation. However, reducing the stretched mesh size according to the minimum L_c is not a good recommendation to increase the yield. As this may perhaps result in unsustainable fishery at one instance, the suggested recommendation is increasing fishing efforts mainly by raising the number of boats to get optimum fishery in Parangipettai waters.

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