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Population Dynamics of Commercial Fish, *Gerres filamentosus* Cuvier, 1829 (Family: Gerreidae) along the Coast of South West India

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Abstract

Population parameters of *Gerres filamentosus* Cuvier, 1829 (Family: Gerreidae) along the south west coast of India were assessed using FiSAT II software for samples collected from July 2009 to June 2011. The asymptotic lengths (L_∞), growth constants (K) and lengths at first maturity (Lm_{50}) for female and male were 304.5 mm, 0.40 year^{-1}, 203.0 mm and 283.5 mm, 0.45 year^{-1}, 189.0 mm, respectively. The annual instantaneous rates of total mortality (Z), fishing mortality (F), the natural mortality (M) and the lengths at first capture for female and male were estimated at 1.43 year^{-1}, 0.98 year^{-1}, 0.45 year^{-1} and 123.5 mm, and 1.49 year^{-1}, 1.08 year^{-1}, 0.41 year^{-1} and 130.9 mm, respectively. The exploitation rate was 0.31 for females and 0.28 for males. The values of exploitation rates for female and male were found to be lower than 0.50 (optimum level), which pointed toward under fishing condition in the fishery of Mangalore.

Keywords Growth parameters · Growth and age · Mortality · Exploitation · *Gerres filamentosus* · India

Introduction

Gerres filamentosus Cuvier, 1829 (Family: Gerreidae), commonly known as whipfin silver biddy or whiptail silver biddy is an important fish in the inshore waters of Karnataka, India. Members of the family Gerreidae are characterized by having a highly protrusible mouth which can be extended as a tube into the substrate during feeding, and a sheath of scales along the bases of their median fins. In some regions, they are tropical-subtropical euryhaline fishes while some species are even adapted to a total freshwater environment (Austin 1971). These species are abundant in the coastal inshore waters and estuaries with a sandy bottom. In India, the silver biddies constitute an important fishery in the Vembanad lake, Pulicat lake, Chilka lake, Gulf of Mannar and Palk Bay. In Karnataka, they are known as *Holebaige* and found in the estuaries of the Dakshina Kannada and Uttara Kannada districts of Karnataka.

The fishing for *G. filamentosus* is done in the shallow water areas, and the most important means of capture are by gill nets, cast nets, drift nets, hook and line, hand trawl and shore seine along the Mangalore coast in Dakshina Kannada district, Karnataka. This fish is commercially important in Karnataka. DoF's (2020)'s catch data showed that 0.07 lakh tonnes of gerreids were captured in Karnataka coast during 2019–2020. The nets used for catching this fish in the Chilka lake are Menjijal, Nolijal, Khadijal, Patuajal, Behidajal and Khapajal (Jhingran 1963, 1966, 1969). The chief gear used in the Pulicat lake for the fishery include drag net (Ponda Valai and Konda Vali), hook and line, shore seine (Badi Valai) and miscellaneous fishing methods like handpicking with and without scare line.

Growth characteristics of fishes are an important part of population dynamics and essential parameters to take a serious decision on the management issues of any fishery. Age refers to the quantified time of time when the fish lives. However, growth is the definite size change of fish between certain periods (DeVries and Frie 1996). The growth and age parameters of fish provide indispensable

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data to understand the dynamics of ichthyological populations. Apart from this, they can also give an important indication on the fisheries management and on the level of their exploitation (Beamish and MacFarlane 1987). With the progress of fishery research, different methods have been evolved for determining the age of the fish in an open system. These methods may be broadly classified into direct (counting of year rings on hard parts such as otoliths and scales) (Cailliet et al. 1986; Cailliet 1990; McFarlane et al. 2002) and indirect methods (conversion of length-frequency data into age composition) (Gayanilo and Pauly 1997). On the other hand, estimation of growth and age parameters in tropical fishes hopefully achieved by microcomputer program packages such as Length-based Fish Stock Assessment (LFSA) (Sparre 1987), compleat ELEFAN (Gayanilo et al. 1998), MULTIFAN (Fournier et al. 1990) and FiSAT (Gayanilo and Pauly 1997).

As there was no information on growth and age, natural and fishing mortalities, life span and exploitation rate of female and male of *G. filamentosus* in Karnataka waters, the present study was undertaken to get information on the maximum size and age of fish, growth parameters, mortality and exploitation rate of female and male *G. filamentosus* from the Mangalore coastal waters (Karnataka, India) based on length-frequency data of this fish.

Materials and Methods

Study Area

Netravati-Gurupura river mouth area (Karnataka state), a stretch along the Mangalore coast from Talapady in the south and Tannirbhavi beach in the north, along the west coast of India, is the study area (12°51′01.9"N,74°49′43.8"E) (Fig. 1). Netravati and Gurupura rivers originate in the Western Ghats flows westward, take almost 90˚ turns near the coast and then flows parallel to the coast before joining the Arabian Sea at Mangalore (Dwarakish, 2001). Bengre at north and Ullal at south are two active submerged sand spits attached to mainland developing in front of the confluence of river mouth. The landing centre, Bengre (Mangalore), was visited once a month for two years. *G. filamentosus* were collected with the help of local people using commercial cast nets, gill nets, and drift nets in Mangalore coastal waters from July 2009 to June 2011, based on their availability and condition of weather.

Laboratory Work and Data Processing

The fish samples were brought to the laboratory and cleaned using tap water. The total length (TL) was measured using a measuring board. The TL is the length of fish measured from the tip of the snout to the tip of the longer lobe of the caudal fin. Female and male individuals were identified by examining the gonads and cutting the body cavity. Length frequency data were collected from a total of 1043 females ranging in length from 70 to 300 mm and 701 males ranging from 60 to 275 mm and grouped into 2 mm class interval. These data of *G. filamentosus* collected from the cast net, gill net and drift net catches were analyzed using ELEFAN I routine of FiSAT II software (Gayanilo and Pauly 1997).

Growth Parameters

The growth parameters (L_∞ and K) for *G. filamentosus* have been calculated using the FiSAT II software in the present study. Since ELEFAN cannot estimate the t_o value from the length frequency data, a very approximate value of 't_o' was estimated by substituting the L_∞ (in cm) and K ($year^{-1}$) from the equation of Pauly (1983):

$$log\,(-t_0) = -0.3922 - 0.2752\, log\, L_\infty - 1.038\, log\, K$$

The von Bertalanffy growth function (VBGF) was used to describe the growth. The simplest version of VBGF is $L_t = L_\infty\,(1 - e^{-k\,(t-to)})$, where L_t is the length of fish at age t, L_∞ is the average maximum length, K the growth constant and t_o the time (age) at which length is zero. The growth performance index (ϕ) was calculated by employing the following equation of Pauly and Munro (Pauly and Munro 1984): $\phi = 2\log_{10}L_\infty + \log_{10}K$.

Mortality Parameters and Exploitation

The total mortality (Z) was estimated using length converted catch curve analysis (Pauly 1984a, b; Gayanilo et al. 2005) in the FiSAT II program using the input parameters L_∞, K and t_o. The theoretical equation in this analysis is Ln $(N_i/\Delta t) = a + b{*}t_i$, where Ni is the number of fish in length class i, Δt is the time needed to grow through length class i, t_i is the age (or the relative age) corresponding to the mid-length of class i, and b, with the sign changed, is an estimate of Z.

Estimation of the natural mortality rate was obtained through Pauly's empirical model (Pauly 1980) using a mean surface temperature (T) of 28.2 °C: $Log_{10}M = -0.0066 - 0.279\ log_{10}L_\infty + 0.6543\ log_{10}K + 0.4634\ log_{10}T$, where M is the natural mortality and K refers to the growth rate of the VBGF. Fishing mortality (F) was calculated using the formula: $F = Z - M$ (Gulland 1969), Z is the total mortality, and M is the natural mortality. Exploitation rate (E) was determined from the relationship, $E = F/Z$ (Gulland 1969).

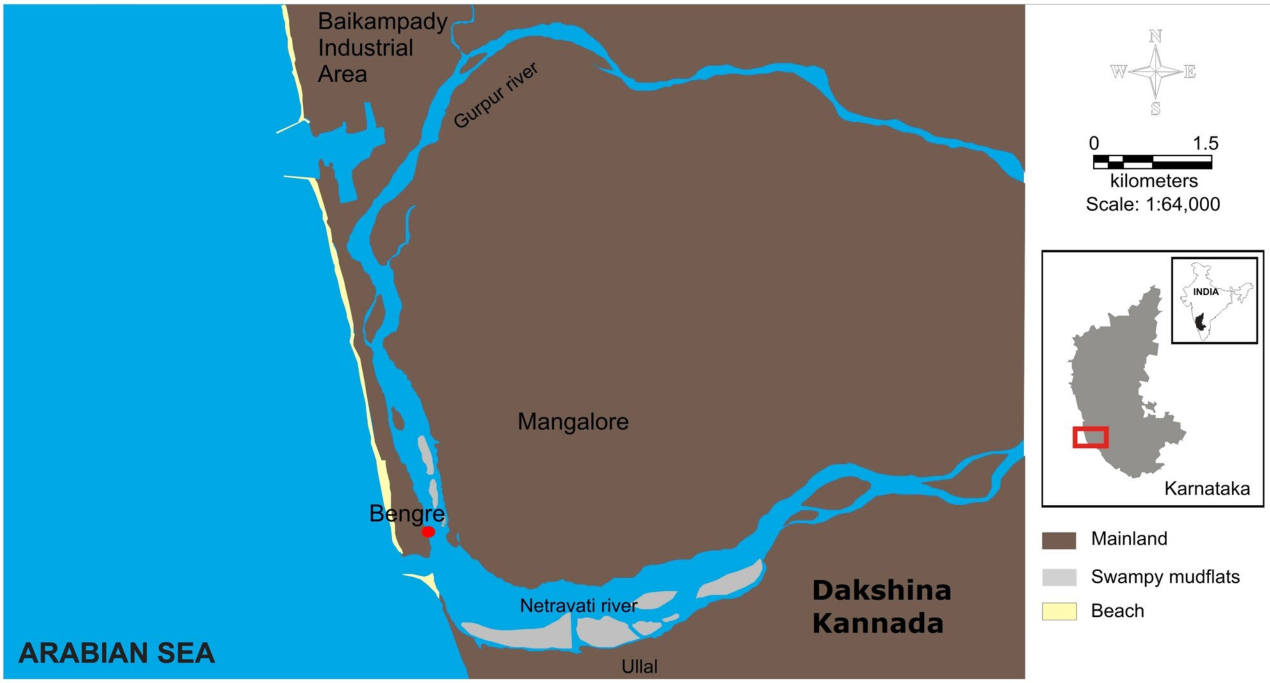

Fig. 1 Location of sampling site, Bengre, Karnataka. Red circle: study area

Length at First Capture (Lc_{50}) and Maturity (Lm_{50})

To identify the fishing regime, the length at first capture (Lc_{50}) was estimated. The ascending left arm of the length-converted catch curve incorporated in the FiSAT II tool was used to estimate the probability of length at first capture (Lc_{50}) in addition to the length at both 75 and 25 captures which corresponded to the cumulative probability at 75% and 25%, respectively. The length at first maturity was estimated using the expression: Length at first maturity (Lm_{50}) = ($2*L_\infty$)/3 (Hoggarth et al. 2006).

Virtual Population Analysis

A virtual population denotes the exploited population, and the analysis estimates the fish population that must have been present to produce the catch. From the observations on the number caught in each age/length group and from independent estimates of the natural mortality, the VPA estimates how many fish there must have been in the sea to account for that catch (Prakarn 2002). Length structured VPA using FiSAT was used to obtain the fishing mortalities per length class.

Results

Growth Parameters

The optimized values for L_∞ obtained by the ELEFAN I for female and male were 304.5 and 283.5 mm, respectively in the present study, whereas the values for K for female and male were 0.40 and 0.45 year^{-1}, respectively (Fig. 2). The estimated t_o values for females and males were -0.52 and -0.46, respectively. The von Bertalanffy's growth equations for *G. filamentosus* can be expressed as:

$$\text{Female}: L_t = 304.5[1 - e^{0.40(t+0.52)}]$$

$$\text{Male}: L_t = 283.5[1 - e^{0.45(t+0.56)}]$$

The estimated growth performance index (ϕ) for *G. filamentosus* females and males were 2.57 and 2.56, respectively (Fig. 3).

Growth and Age

Using the growth parameters, growth and age of *G. filamentosus* were calculated. The growth rate and the absolute increase in age for both female and male *G. filamentosus* are shown in Fig. 4. The sizes of female *G. filamentosus* attained 13.7, 19.1, 22.7, 25.1, 26.7, 27.8, 28.5, 29.0 and 29.3 cm at the end of first, second, third, fourth, fifth, sixth, seventh, eighth and ninth years of age, respectively. The average growth rates for female *G. filamentosus* from first to ninth years were 1.14, 0.45, 0.30, 0.20, 0.14, 0.10, 0.06, 0.04 and 0.03 mm, respectively. In the case of male *G. filamentosus*, the sizes attained were 13.7, 19.0, 22.4, 24.5, 25.9, 26.8 and 27.4 cm at the end of first, second, third, fourth, fifth, sixth and seventh years of age, respectively. The calculated average growth rate for male *G. filamentosus* first to seventh years were 1.14, 0.44, 0.28, 0.18, 0.12, 0.07 and 0.05 mm, respectively.

Longevity

In the present study, the longevities of *G. filamentosus* of females and males were calculated as 9 and 7 years, respectively.

Mortality Parameters and Exploitation

Total mortality coefficients (Z) for females and males were estimated as 1.43 and 1.49 $year^{-1}$ using the length converted catch curve (Fig. 5). Natural mortality (M) and fishing mortality (F) calculated for females and males were 0.98 and 1.08 $year^{-1}$, and 0.45 and 0.41 $year^{-1}$, respectively (Fig. 5). From these figures, exploitation levels (E) of 0.31 and 0.28 were obtained for the *G. filamentosus* females and males in the present study, which were lower than the expected optimum level of exploitation (E = 0.50).

Probability of Capture (length-at-first-capture)

Probability of capture of both female and male *G. filamentosus* was estimated in the present study (Fig. 6). The values L_{25}, L_{50} and L_{75} estimated were the average total length at which 25%, 50% and 75% of animals were retained in the nets. The computed length-at-first-capture, L_{50} or L_c of female *G. filamentosus* was 123.5 mm total length (TL) using logistic transformation. The estimated values of L_{25} and L_{75} for males were 112.9 and 134.1 mm respectively in the present study. In the case of male *G. filamentosus,* the computed length-at-first-capture, L_c of was 130.9 mm total length (TL) using logistic transformation. The values of L_{25} and L_{75} for males were 116.7 and 145.0 mm, respectively. The lengths at first maturity (Lm_{50}) of females and males were estimated at 203.0 mm and 189.0 mm, respectively.

Discussion

The knowledge of the growth and age of commercially important fishes is essential for understanding the age-class structure of the stocks and the role played by various year-classes in the fisheries. Knowledge of the growth and age of fish is also essential to determine the survival and mortality rate of various year-classes and the success of the yearly broods. Hence an in-depth knowledge of the age and growth of a fish is of vital importance in the

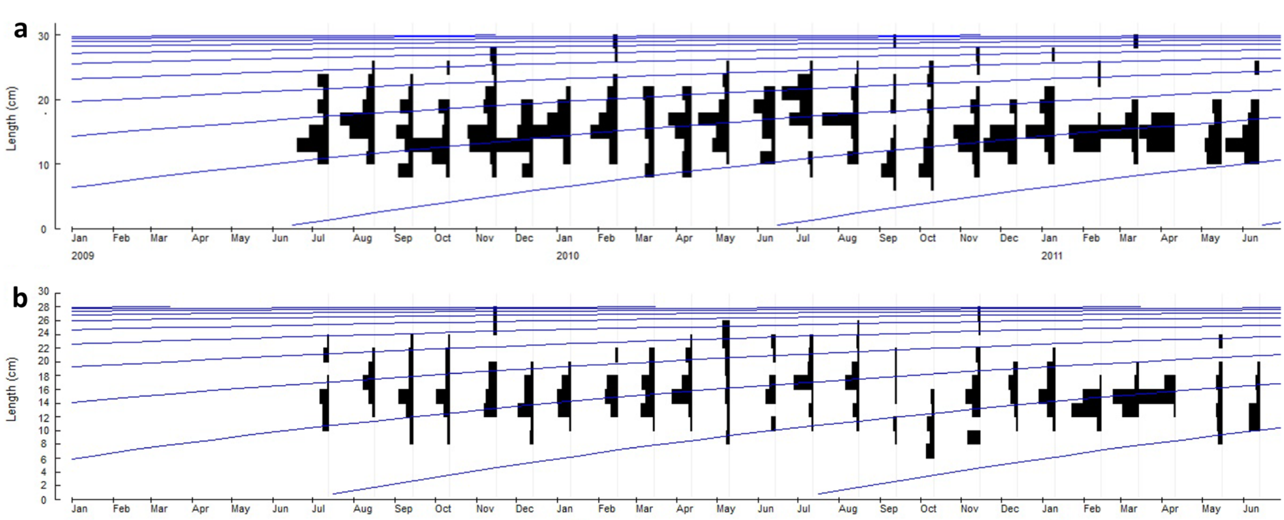

Fig. 2 Growth curves fitted by ELEFAN I to length-frequency of female (**a**) and male (**b**) *Gerres filamentosus*

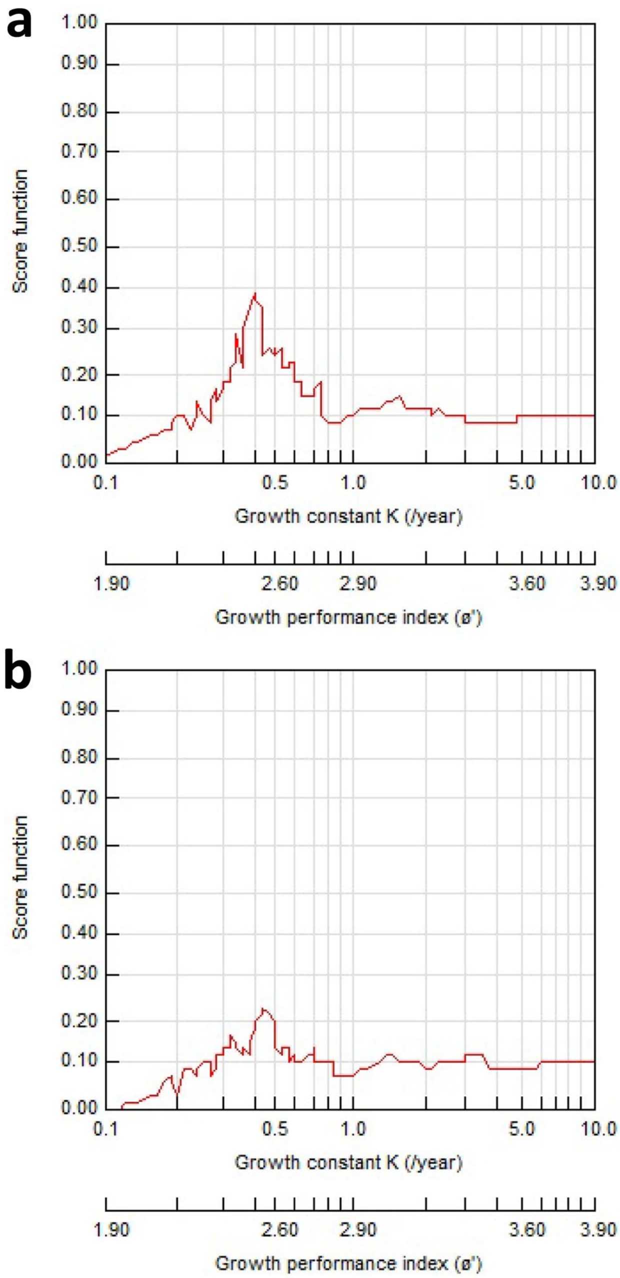

Fig. 3 Estimation of growth performance index of (GPI) of female (**a**) and male (**b**) *Gerres filamentosus*

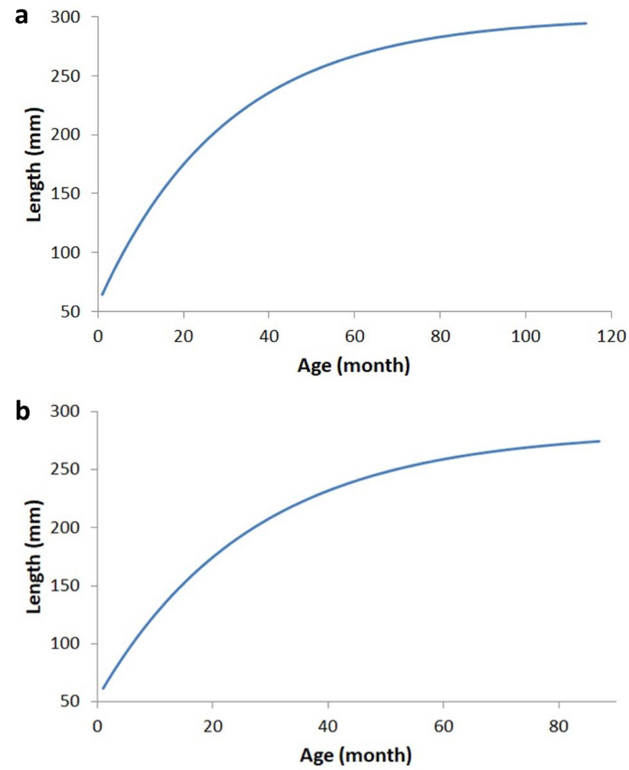

Fig. 4 Plot of growth and age of female (**a**) and male (**b**) *Gerres filamentosus* based on computed growth parameters

management of its fishery. The maximum size of organisms is a strong predictor for many life history parameters (Blueweiss et al. 1978). The L_∞, K and t_o values estimated for *G. filamentosus* from different geographical regions are given in Table 1. In Indian regions, the L_∞, K and t_o values of *G. filamentosus* were reported from Azhikode estuary, south west coast of India and Parangipettai, south east of India (Sivashanthini 2009; Aziz et al. 2013). In India, the highest values of L_∞ for both female and male were reported from the Azhikode estuary. Whereas the lowest values of L_∞ for both female and male were reported from the coastal waters of Parangipettai (Sivashanthini 2009). In contrast, the highest values of K for female (1.50) and male (1.45) were reported from Parangipettai. On the other hand, the lowest values of K for female (0.40) and male (0.25) were reported from Bengere (present study) and Parangipettai, respectively. In case of t_o, the lowest values for female and male were found to be -0.1073 and -0.1109 in Parangipettai (Sivashanthini 2009). However, the highest values for female and male were found to be -0.54 and -0.78 in the Azhikode estuary (Aziz et al. 2013). The results of L_∞ of both female and male are acceptable because L_∞ is a regression estimate, and thus an average that represents an average maximum length if fish live and grow according to the von Bertalanffy equation. Pauly (1984a, b) reported that species having shorter life have higher K value and reach their L within one or two years. On the other hand, those having low growth rates have lower K values and take many years reach their L_∞. *G. filamentosus* has high K values and a long life span which is in general agreement with the relationship between K values and L_∞ as reported by Pauly (1984a, b).

The results obtained in the present study for *G. filamentosus* shows the values for growth performance index

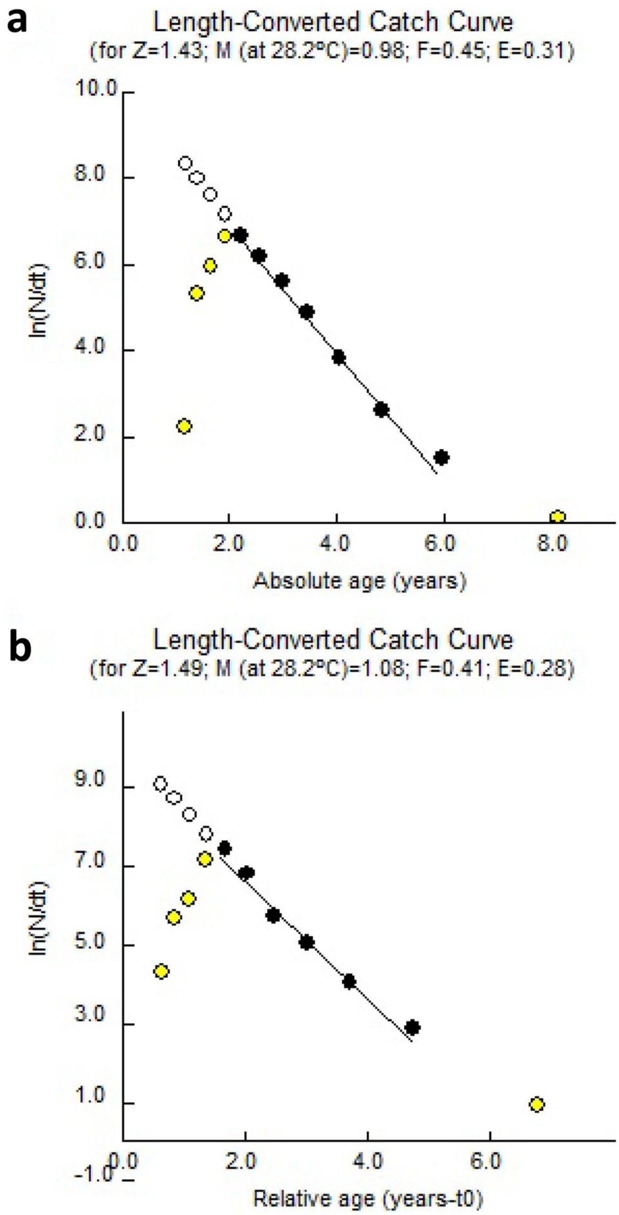

Fig. 5 Mortality estimation of female (**a**) and male (**b**) *Gerres filamentosus* using Pauly's linearized length converted catch curve method and estimation of exploitation. Solid dots indicated the points used in calculating through the least square linear regression and open dots represented the points either not fully recruited or nearing L_∞

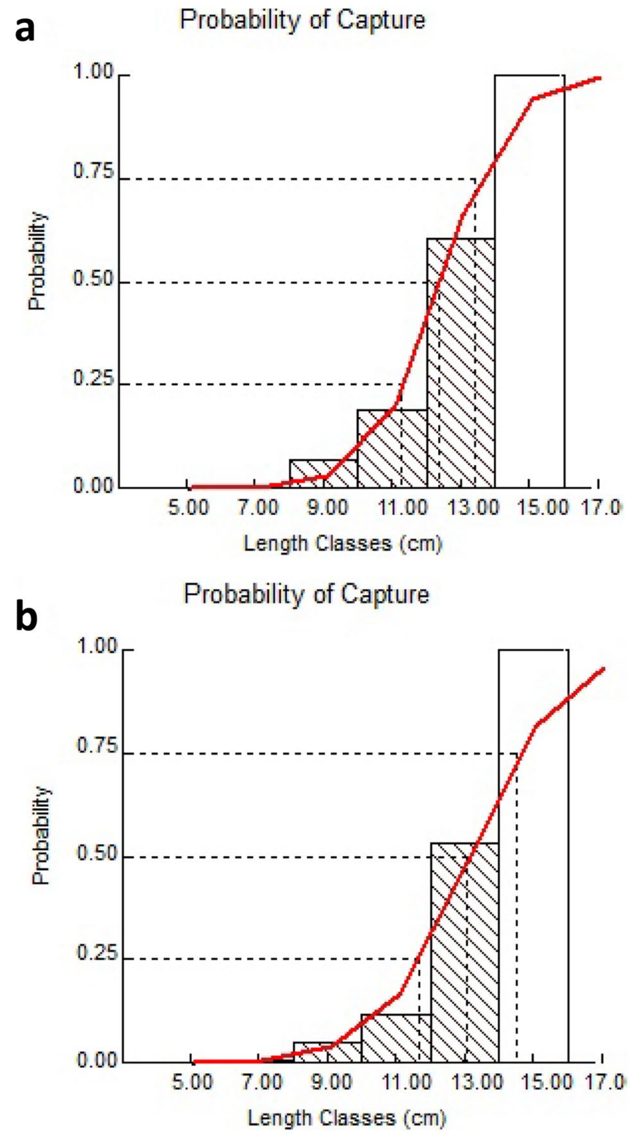

Fig. 6 Logistic selection curve for probability of capture, showing 25%, 50% and 75% selection length of female (**a**) and male (**b**) *Gerres filamentosus* in study area

for female and male are 2.569 and 2.558, respectively. These values are lower than the growth performance indices estimated for the same species from the Azhikode and Parangipettai waters, south India. Even it shows comparatively low growth performance index, this species could also be considered as a fast-growing species based on the value obtained.

According to Pitcher and Hart (1982), quantifying growth rate in fishes by fitting the von Bertallanfy asymptotic growth model to mean lengths at the age from the otolith is also an efficient method in fishery biology. But this method is expensive and will not be effective for tropical fishes, for which the growth rings overlap. So, length-frequency analysis becomes the effective techniques to quantify growth for tropical fishes. The growth parameters ($L_{\infty,}$ K and $t_{o)}$ obtained in the present study are useful and fundamental indicators for the population dynamics studies of the *G. filamentosus.*

Table 1 The growth parameters estimated for gerreids from different geographical regions; (TL: Total length, FL: Fork length, BL: Body length, SL: Standard length); ϕ: growth performance index

	Sex	L_∞ (mm)	K ($year^{-1}$)	t_o	ϕ	Region	Source
Gerres abbreviatus	Male	278.0 TL	1.30	-0.1236	3.002	India, Bay of Bengal	Kuganathan (2006)
	Female	282.0 TL	1.36	-0.1175	3.034		
G. filamentosus	Unsexed	219.0 TL	2.616	–	3.099	Madagascar, Ambaro Bay	Pauly (1978)
	Unsexed	269.0 TL	1.788	–	3.112		
	Unsexed	329.0 TL	0.756	–	2.913		
G. longirostris	Male	188.0 FL	1.3	- 0.02	2.662	United Arab Emirates, Arabian Gulf	Grandcourt et al. (2006)
	Female	212.0 FL	1.0	- 0.1	2.653		
	Unsexed	208.0 FL	1.1	- 0.1	2.678		
G. filamentosus	Male	269.0 TL	1.45	-0.1109	3.021	India, Bay of Bengal	Sivashanthini (2009)
	Female	271.1 TL	1.50	-0.1073	3.042		
G. filamentosus	Male	693.66	0.25	-0.78	3.080	India, Arabian Sea	Aziz et al. (2013)
	Female	391.35	0.86	-0.54	3.120		
	Unsexed	299.33	1.0	-0.58	2.952		
G. filamentosus	Male	283.5 TL	0.45	-0.46	2.558	India, Arabian Sea	Present study
	Female	304.5 TL	0.40	-0.52	2.569		
G. filamentosus	Unsexed	234.4 BL	0.35	-0.996	2.284	Vietnam, Quang Binh Province	Thiep et al. (2014)
G. filamentosus	Male	407.3 TL	0.3049	0.1855	2.704	Egypt, Red Sea	Abu El-Nasr (2017)
	Male	408.2 TL	0.2987	0.1772	2.697		
	Male	407.3 TL	0.3026	0.2178	2.701		
	Female	419.2 TL	0.2968	0.0447	2.717		
	Female	419.5 TL	0.2954	-0.1564	2.716		
	Female	419.2 TL	0.2981	-0.1069	2.719		
	Unsexed	421.2 TL	0.2946	0.0347	2.718		
	Unsexed	421.7 TL	0.2937	-0.0283	2.718		
	Unsexed	421.2 TL	0.2969	0.0197	2.722		
G. oblongus	Unsexed	294.0 TL	1.0	-0.151	2.937	Sri Lanka, Palk Bay	Shutharshan and Sivashanthin (2011)
G. oyena	Unsexed	182.0*	1.1	–	2.562	Tanzania, Indian ocean	Benno (1992)
G. setifer	Male	174.0 TL	1.19	-0.0817	2.557	India, Bay of Bengal	Sivashanthini and Ajmal Khan (2004)
G. setifer	Female	170.5 TL	1.26	-0.0775	2.564		
G. cinerus	Unsexed	280.0 FL	0.62	–	2.687	Cuba, Caribbean Sea	Baez and Alvarez-Lajonchere (1983)
G. cinerus	Unsexed	360.0 TL	0.341	-1.03	2.645	Mexico, Caribbean Sea	Alvarez-Hernandez (1999)
G. cinerus	Unsexed	280.0*	0.650	–	2.707	Cuba, Caribbean Sea	Claro and Garcia-Arteaga (2001)
G. cinerus	Unsexed	511.5 TL	0.270	-0.534	2.849	Mexico, Caribbean Sea	Espino-Barr et al. (2014)
	Unsexed	564.3 TL	0.203	-0.669	2.811		
	Unsexed	564.3 TL	0.208	-0.669	2.821		
G. punctatus	Unsexed	270.0 TL	1.8	–	3.118	Madagascar, Ambaro Bay	Pauly (1983)

*type of length is not confirmed

The present study showed the sizes of female *G. filamentosus* attained 13.7, 19.1, 22.7, 25.1, 26.7, 27.8, 28.5, 29.0 and 29.3 cm at the end of first, second, third, fourth, fifth, sixth, seventh, eighth and ninth years of age, respectively. Whereas the size of male *G. filamentosus* attained 13.7, 19.0, 22.4, 24.5, 25.9, 26.8 and 27.4 cm at the end of first, second, third, fourth, fifth, sixth and seventh years of age, respectively. According to Sivashanthini and Khan (2004), male gerreid like *G. setifer* in Indian coastal waters attained 12.60, 15.94 and 16.96 cm at the end of first, second and third years, whereas female *G. setifer* attained 12.76, 15.81 and 16.70 cm at the end of the first, second, third years, respectively.

The life span reported for *G. filamentosus* in the coastal waters of Quang Binh Province was 3 years (Thiep et al. 2014). But, along the coastal waters of the Egyptian Hurghada Red Sea, the spans of both females and males reached 8 years (Abu El-Nasr 2017). Estimated life spans for females and males *G. filamentosus* calculated in the present study are 9 and 7 years, respectively. Life spans of this species collected from the Egyptian Hurghada Red Sea and the present study area are extremely higher than that of the Quang Binh Privince. Perhaps it is due to the low growth rate recorded for *G. filamentosus* in the present study.

Length-based models for Z-estimation (e.g. Powell-Wetherall plot, length-converted catch curve, Jones and van Zalinge method) are presented 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 and natural mortality, the highest values of 1.49 and 1.08 year^{-1} were found in males. The fishing mortality of female (0.45 year^{-1}) is almost same as that of male (0.41 year^{-1}). The exploitation rate of females (0.31) shows a higher compared to males (0.28) in the present study. The higher natural mortality in fishes is attributed to factors like diseases, old age, predation, spawning stress and starvation. Most of these causes are linked to the ecosystem where it lives. In the present investigation, *G. filamentosus* showed a comparatively low K value and also natural mortality (M). Rikhter and Efanov (1976) opined that fishes with high natural mortality mature early in life, compensating for the high M by starting to reproduce earlier. Further, Pauly's empirical formula describes M as a function of K, L_∞ and temperature. The natural mortality of fish is closely related to age and size as the larger fishes are less prone to predation.

The lengths at first capture (123.5 mm: female and 130.9 mm: male) were found to be lower than the lengths at first maturity (203.0 mm: female and 189.0 mm), indicating that growth overfishing exists within the fishery of *G. filamentosus*. Therefore, as a management intervention, mesh sizes should be increased along with decreasing fishing efforts. Gulland (1965) stated that suitable yield is optimized when F = M and when E is more than 0.5, the stock is generally supposed to be overfishing. The values of exploitation rates for female and male were found to be lower than 0.50, which clearly pointed toward under fishing condition for *G. filamentosus* in the fishery of Mangalore. Thus, the fishing pressure on the stock is not over-exploited. More yields could be obtained by a reasonable decrease in size at first capture without necessarily leading to overexploitation. However, reducing the stretched mesh size according to the minimum Lc is not a good recommendation to increase the yield (Sivashanthini 2009). As this may perhaps result in the unsustainable fishery at one instance, the suggested recommendation is increasing fishing efforts mainly by raising the number of boats to get optimum fishery in Mangalore coastal waters.

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Declarations

Conflict of Interest There is no conflict of interest.

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