Iranian Journal of Fisheries Sciences 19(2) 793-813 2020
DOI: 10.22092/ijfs.2018.119873.

Comparative assessment of population biology of three popular pomfret species, *Pampus argenteus, Pampus chinensis* and *Parastromateus niger* in the Bay of Bengal, Bangladesh

Karim E.[1,3]; Liu Q.[1]*; Forruq Rahman M.[1]; Khatun M.H.[1]; Protim Barman P.[1]; Shamsuzzaman M.M.[2]; Mahmud Y.[3]

Received: November 2017 Accepted: November 2018

Abstract

Pomfrets are one of the most ample high priced fisheries of the Bay of Bengal, Bangladesh. The present study featuring the comparison of the life history parameters of three Pomfrets i.e. Silver (*Pampus argenteus*), Chinese (*P. chinensis*) and Black (*Parastromateus niger*) is based on the monthly length frequency data from the commercial landings from July 2015 through June 2016. The length (*TL*) of all three Pomfrets ranged from 8 to 55cm and weight (*W*) varied from 24 to 1302g. An allometric growth pattern was found in all cases when estimating *LWR*. The VBGF parameters for silver pomfret was L_∞= 54.6cm, K= 0.39yr^{-1} while it was 54.6cm, 0.62yr^{-1}, 57.75cm, and 0.94yr^{-1} for both Chinese and black pomfrets, respectively. Based on LCCC analysis the total mortality (*Z*), natural mortality (*M*) and fishing mortality (*F*) for silver and Chinese pomfrets were found to be the lowest compared with some previous studies related to the Indian Ocean, whereas black pomfret showed higher mortality rates to some extent. The exploitation ratio ($E=F/Z$) of silver and Chinese pomfrets were lower than the Gulland (1971) criterion of demarcation point of 0.5 and was higher for black pomfret which showed over-exploited stocks. The *YPR* analysis also showed the heavily exploited state of black pomfret fishery, therefore, immediate management approach should be required to maintain sustainable stocks.

Keywords: Bay of Bengal, Pomfrets, Growth, Mortality, Exploitation

1-College of Fisheries, Ocean University of China, Qingdao 266003, China
2-School of Environmental and Natural Resources Law, Ocean University of China, Qingdao 266100, China
3-Bangladesh Fisheries Research Institute (BFRI), Mymensingh-2201, Bangladesh
*Corresponding author's Email: qunliu@ouc.edu.cn

Introduction

Pomfrets belong to the family Stromatidae (*Pampus argenteus* and *P. chinensis*) and Carangidae (*Parastromateus niger*) have been widely distributed in coastal, estuarine and marine habitats ranging from 5-105 meters in depth in the Bay of Bengal, Bangladesh coast (Shahidhullah, 1986), and are an extremely relished table fish in domestic and export markets. Pomfrets fishery of Bangladesh is mainly based on three popular species i.e. silver pomfret (*P. argenteus*), Chinese pomfret (*P. chinensis*) and black pomfret (*P. niger*) that comprises more or less 95% of the total catches among the all pomfret fisheries (DoF, 2016). Over the last 15 years, the annual average catch was about 21,890 t. Less than 4% of this came from industrial trawl landings of Bangladesh, comprising silver pomfrets (42.4%), black pomfrets (29.7%) and Chinese pomfrets (23.4%). The remaining 98% of landings was through artisanal captures which was mainly based on both mechanized and non-mechanized boats-capture fish from 10-50m depth contributing to about 35%, 29% and 27% of black, silver and Chinese promfrets, respectively (FRSS, DoF). Most of this catch came from Sundarban Mangrove Forest (SMF), adjacent coastal and marine areas in the south and the Cox's Bazar and Chittagong, southeast coast of Bangladesh.

Pomfrets are mostly inshore species that are also entitled amphidromous and benthopelagic fish (Riede, 2004). They usually form small schools or shoals associated with other fishes over the muddy bottoms with coarse sands and feed mainly on zooplankton, salps, ctenophores, jellyfish, medusa and small benthic organisms (Last, 1997). Mean annual landings of Bay of Bengal, Bangladesh indicate that pomfrets are abundant in the month of November to April (FRSS, DoF). Some previous studies of pomfrets of this region by Pati (1982, 1985), Hussain *et al.* (1977), Mustafa (1999), mainly focused on the biology, feeding habit and breeding or spawning including some demographic properties as well. Significant writings on the fishery and stock estimates especially of silver pomfrets of Bay of Bengal, Bangladesh belong to the fishery that existed over a couple of decades ago (Khan, 1982; Khan *et al*., 1992; Khan and Latif, 1997; Khan, 2000; Sivakami *et al*., 2003). Despite their commercial value, detailed research on the recent pomfret fishery with special reference to the population dynamics of these areas are scanty and scattered. This study mainly deals with the assessment of population characteristics of three commercially important pomfrets of Bay of Bengal, Bangladesh with special consideration to the comparison of their life history parameters too.

Length-structured data for assessing stock and population dynamics study were commonly used where age-structure data are limited (Sparre and Venema, 1998). Age determination of pomfrets has not been possible, so length-based methods are applied to assess stocks in these areas (Parsamanesh *et al.,* 1998; Morgan,

1985). Age data are more tough and painstaking to collect because the bends on the otolith were indistinct and not easy to interpret (Morale-Nin and Panfili, 2005). The dissimilarity in parameters evaluated for pomfrets depends on many factors such as temperature, geographical area, type of ecosystem and the approaches deployed for the assessment of parameters. Nevertheless, for the Bay of Bengal area, it seems that the approaches used for the assessments are the key factor in the detected differences in the estimated parameters, which somewhat reflects the difference of the results acquired by applying the length-based methods. This work is the first attempt to provide data on the parameters of growth and standing stocks of three pomfret species of the Bay of Bengal, Bangladesh, which will shed light on future research for fisheries scientists and researchers of various agencies for the sustainable management and production of pomfret fishery.

Materials and methods

Sampling

At present, artisanal fishery of Bangladesh contributed to more or less 91% of total marine captures, the rest coming from industrial trawls. In artisanal catches, the maximum species are caught with drift gill nets (DGN), which is basically used to catch *Hilsa* (sardine), set bag nets (SBN) and seine nets (TN) (Mustafa, 1999). For this reason, the whole study was conducted in three important marine landing spots throughout the coastal belt of Bangladesh including Cox's Bazar, Chittagong, Kuakata and Pathorghata (Figure 1). All of the biological data of silver, Chinese and black Pomfrets of both sexes were collected between July 2015 and June 2016 (12 months) from different artisanal fishing vessels that captured fishes by using several gear like SBN, gill net, seine net etc. from the above mentioned landing stations that were visited monthly. Best efforts were given to sample identification and data was recorded together with their specific catch in weight and size in length. The total length (*TL*) of fish samples was measured to the nearest 0.1 cm and body weight (*W*) to the nearest 0.1g. Fish were placed ventral side down and the upper lobe of the caudal fin depressed in line with the body axis (Compagno, 1984a). Length frequency and length-weight data of a total of 1472, 1402 and 1022 individuals of silver pomfret, Chinese pomfret and black pomfret, respectively of both sexes' were measured and data were recorded in 3cm class intervals on the excel sheet.

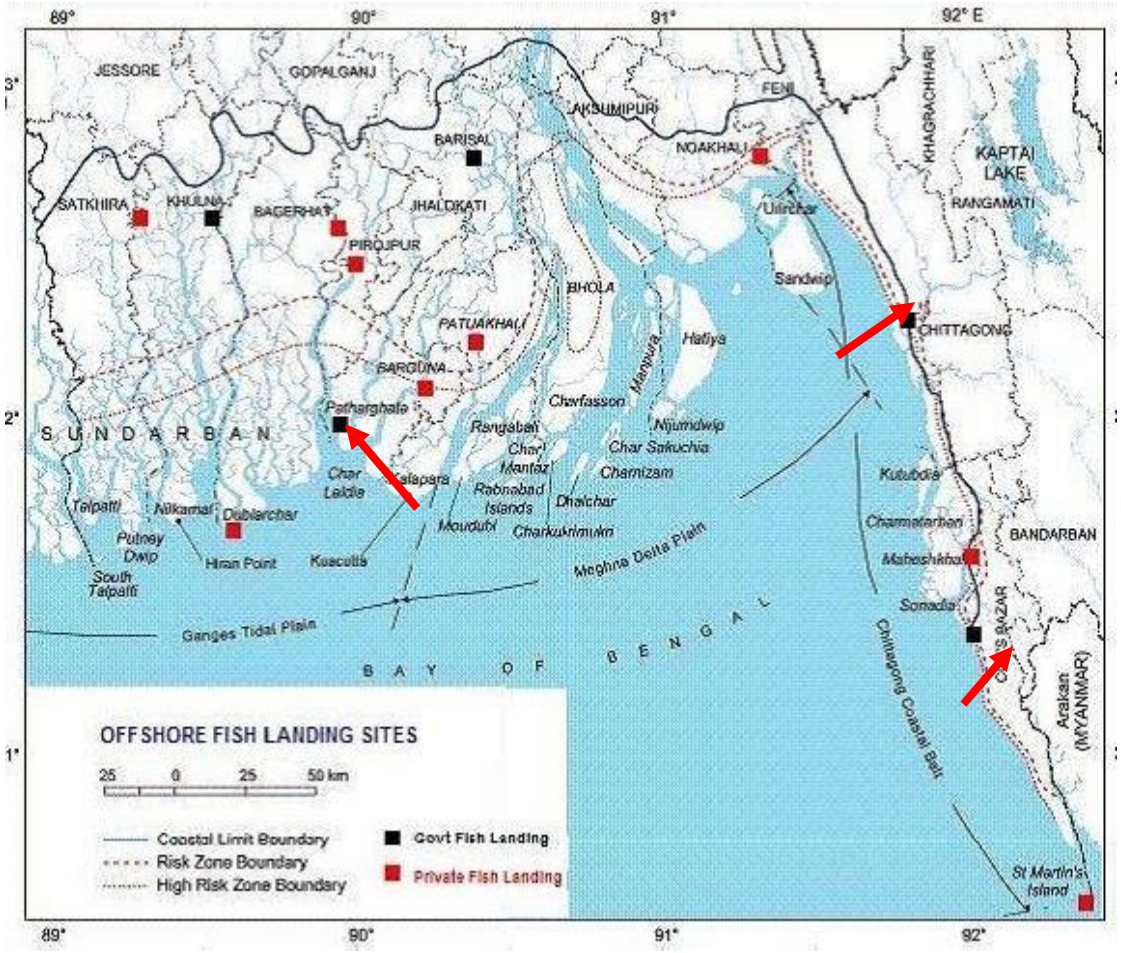


Figure 1: Visited Fish landing centers (red arrows) of Bangladesh for collecting data from July 2015 to June 2016.

Data analysis

In this study, a computer software package named FiSAT II (FAO-ICLARM stock assessment tool, Gayanilo *et al*., 2005) was used to analyze the length frequency data. Actually, this software was developed mainly for analyzing length-frequency but also enables related analyses like size at age, growth, mortality rate, biological reference points, growth performance index, virtual population analysis and so on.

Steps of the procedure

Firstly, in order to assess length-weight relationship (*LWR*), *TL* and *W* of three species were calculated separately with log10-transformed data (Le Cren, 1951) then calculated by using the power function: $W = aL^b$ where *a* is a constant condition factor and *b* is slope or allometric growth parameter. After that,

- Evaluating initial value of asymptotic length (L_∞) and growth constant (K) using the von Bertalanffy growth function (VBGF) parameters of the method ELEFAN-I (Electronic Length Frequency Analysis). The von Bertalanffy equation for growth in length according to Haddon (2011) is: $L_t = L_\infty\ (1–exp\ (-K\ (t– t_0))$, where L_t was the length at time t, L_∞ was the asymptotic length, K was the growth coefficient and t_0 was the hypothetical

age or time where length was equal to zero. Additional estimated value of t_0 was obtained by the empirical equation by Pauly (1983) as $log_{10}(-t_0) = -0.3922 - 0.275\ log_{10} L_\infty - 1.038\ log_{10} K$.

- Estimation of instantaneous total mortality (Z) through length converted catch curve method by Pauly (1983) was used. Additional parameters of M and F (natural mortality and fishing mortality) were also calculated. The regression formula for Z is $Ln(N_t) = Ln(N_0) - Zt$, where N_t is the population size at age t and N_0 is population size at zero (Pauly, 1980). The equation by Pauly (1980) was used for natural mortality (M) from $log_{10} M = 0.0066 - 0.279\ log_{10} L_\infty + 0.654\ log_{10} K + 0.4634\ log_{10} T$. Where $T = 23^oC$ was average annual surface temperature of the water in the Bay of Bengal, Bangladeshi waters in which the stock of pomfrets occurs. The F (Fishing mortality) was evaluated by using the relationship of subtracting $F=Z-M$. The exploitation ratio (E) was evaluated by using the relationship of Gulland (1971a): $E = F/Z = F/(F+M)$.
- Estimating probabilities of capture by detailed analysis of the left ascending part of the catch curve, and by constructing a selection curve by using Z (total mortality) and M (natural mortality) including asymptotic length (L_∞) and growth coefficient (K).
- Length-structured virtual population analysis (VPA) of three species were carried out with the input values of LWR parameters i.e. intercept (a), slope (b) and growth parameters values e.g. asymptotic length (L_∞), growth coefficient (K) and mortality parameters values e.g. natural mortality (M) and fishing mortality (F) to evaluate the fishing mortalities per length class by using the formula of Sparre and Venema (1998). The t_0 value was taken as zero.
- Then the optimal fishing mortality rate $F_{opt} = M$ was determined as the limit of biological reference points for pomfrets in the Bay of Bengal, Bangladesh following methods of Gulland (1969).
- Estimation of yield per recruit ($Y\ R^{-1}$) values by using the model of Beverton and Holt (1957) incorporated into the FiSAT-II program (Gayanilo *et al*., 2005) through the formula $Y_w / R = FW_\infty e^{-M(t_c - t_r)} \sum_{n=0}^{3} \frac{Q_n e^{-nK(t_c - t_0)}}{F + M + nK} (1 - e^{-(F+M+nK)(t_\lambda - t_c)})$ were done. In which $Y_w\ R^{-1}$ was yield per recruit, t_c was the average age of first capture, t_λ was the asymptotically ages, t_r was the age of recruitment, Q_n was the constant and equal to 1, -3,3 and -1 when n was 0, 1, 2 and 3 correspondingly (Pitcher and Hart, 1982).
- Lastly, estimating growth performance index (Phi prime Φ') through following equations by Pauly and Munro (1984) $\Phi' = log_{10} K + 2\ log_{10} L_\infty$ and $\Phi = log_{10} K + 2/3\ log_{10} W_\infty$.

Results

Length–weight relationship parameters (LWRPs)

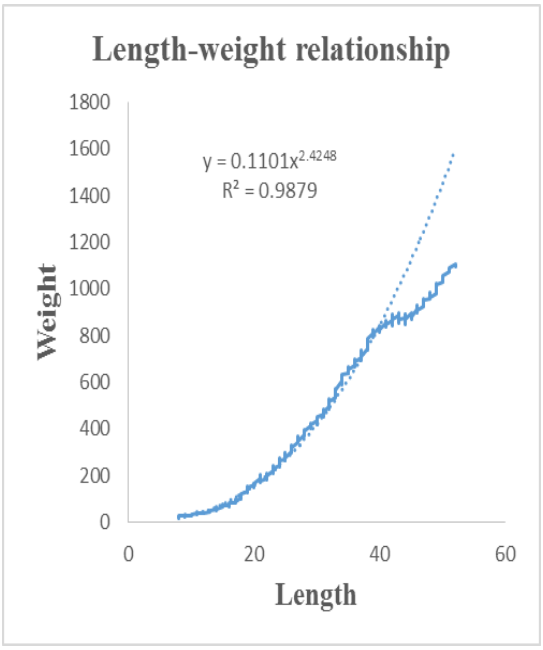
The length-weight relationships of three pomfret species silver, Chinese and black are shown in Figure 2 where length ranged between 10 and 52 cm at average length 26.7 cm with SD±5.26cm for silver pomfret, between

8 and 50 cm with SD±4.67cm for Chinese and between 11 and 54 cm with SD±5.56cm for black pomfret. The length–weight relationship parameter *a* and *b* for the three pomfret species i.e. silver, Chinese and black were described by the power equation as $W= 0.1101\ L^{2.4248}$ where R^2=0.9879 (*n*=1472), $W=0.393L^{2.07}$ where R^2= 0.9848 (*n*=1402) and $W= 0.3539L^{2.1113}$ where R^2= 0.9887 (*n*=1022). Dominant lengths were found between 20 and 31cm for *P. argenteus*, between 22 and 30 cm for *P. chinensis* and between 23 and 30 cm for *P. niger*, respectively (Table 1).

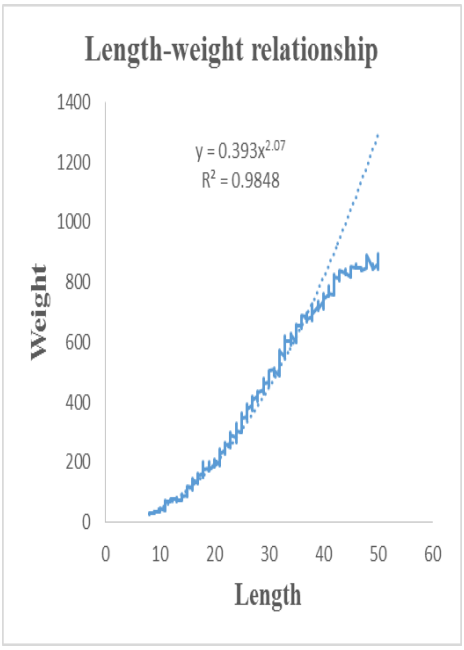
Table 1: Estimated key parameters of growth, mortality, exploitation and yield of three pomfret species of the Bay of Bengal, Bangladesh during July 2015 to June 2016.

Population parameters	Silver Pomfret	Chinese Pomfret	Black Pomfret
Intercept (*a*)	0.11	0.393	0.3539
Exponent (*b*)	2.4248	2.07	2.1113
Coefficient of determination (R^2)	0.9879	0.9848	0.9887
Asymptotic length (L_∞)	54.6cm	54.6cm	57.75cm
Growth coefficient (*K*)	0.39 yr^{-1}	0.62 yr^{-1}	0.94 yr^{-1}
Theoretical age (*t*) at zero length (t_0)	- 0.44545 years	-0.65443 years	-0.84873 years
Goodness of fit (R_n)	0.197	0.118	0.246
Total mortality (*Z*)	0.95yr^{-1} at $CI_{95\%}$ 0.33 – 2.12	1.53yr^{-1} at $CI_{95\%}$ 0.42 – 3.76	2.89yr^{-1} at Cl 95% at -0.31 – 7.21
Mean annual water temperature of Bay of Bengal, Bangladesh	24^0C	24^0C	24^0C
Natural mortality (*M*)	0.72895 yr^{-1}	0.98725 yr^{-1}	1.2761 yr^{-1}
Fishing mortality (*F*) *F= Z-M*	0.22105 yr^{-1}	0.54275 yr^{-1}	1.6139 yr^{-1}
Exploitation rate (*E*) *E= F/Z*	0.2327	0.355	0.55844
M/K ratio	1.87	1.59	1.36
F_{max}	1.2 yr^{-1}	2.0 yr^{-1}	2.85 yr^{-1}
$F_{0.1}$	1.0 yr^{-1}	1.5 yr^{-1}	1.6 yr^{-1}
Maximum mortality range (cm)	34-38	47-50	49-52
GPI Φ' (phi prime)	3.065	3.267	3.496
Dominant Length range (*cm*)	20-31	22-30	23-30
Dominant weight range (g)	191-478	302-423	304-545g
Sample size (*n*)	1472	1402	1022

Silver Pomfrets



Chinese Pomfrets



Black Pomfret

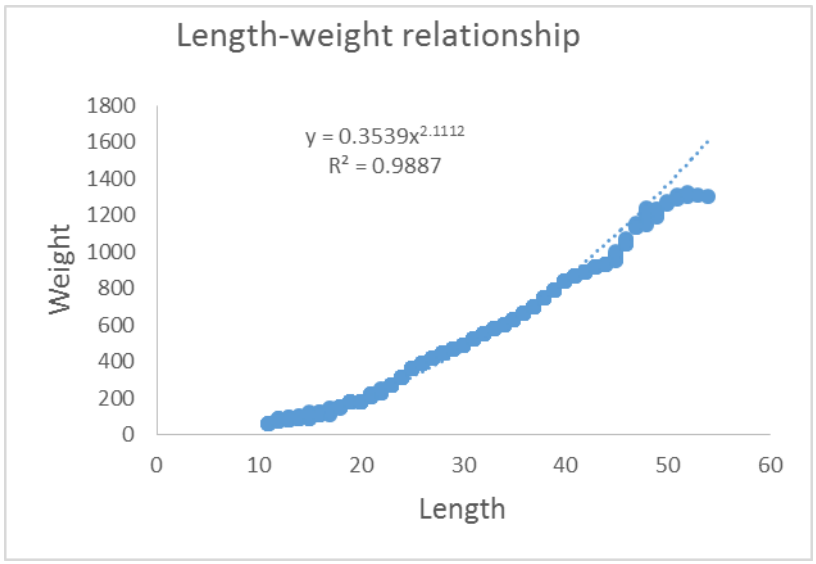


Figure 2: Length-weight relationship of three pomfret species i.e. Silver (*n*= 1472), Chinese (*n*= 1402) and Black (*n*= 1022) from the Bay of Bengal, Bangladesh.

Estimation of growth parameters (GPs)

The method of ELEFAN-I in FiSAT II packages (Pauly, 1983) was used to estimate the L_∞ (asymptotic length) and K (growth coefficient). Size distribution of length frequency data of the three pomfret species were arranged at 3 cm interval. The estimated values of L_∞ and K were obtained as L_∞= 54.6cm, 54.6cm and 57.75cm while K= 0.39yr^{-1}, 0.62yr^{-1} and 0.94 yr^{-1} for *P. argenteus*, *P. chinensis* and *P. niger*, respectively. The goodness fit index values (R_n) from the ELEFAN-I routine (0.197 for silver, 0.118 for Chinese and 0.246 for black pomfret) were constructed by the totality of observation in this function. The hypothetical age of the three species at zero length was estimated as t_0= -0.44545 years for silver, -0.65443

for Chinese and -0.84873 for black pomfret, respectively (Table 1). The graphical representations of the output VBGF curves are shown in Figure 3.

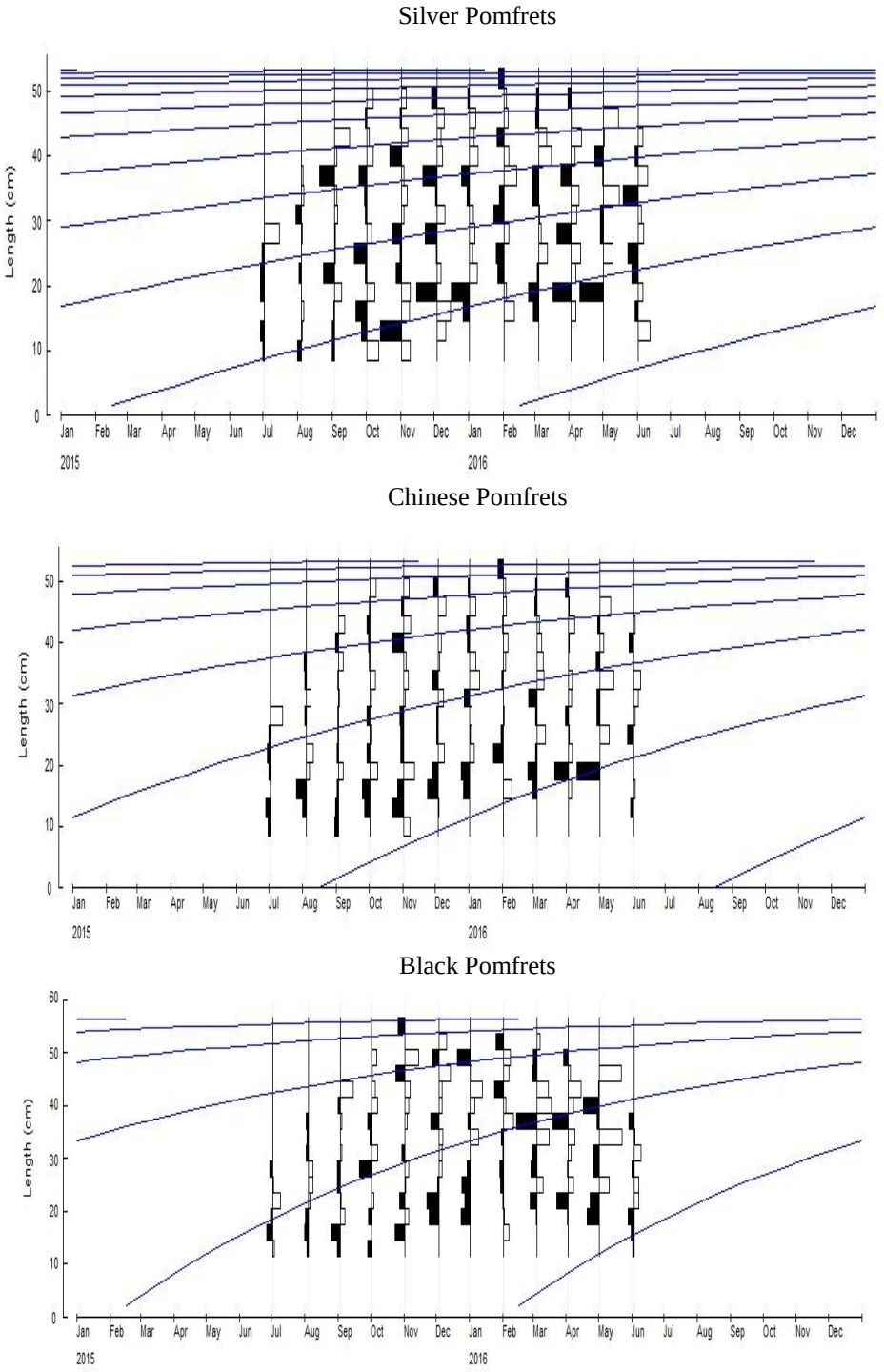


Figure 3: Comparative analysis of growth curves (restructured) for three pomfret species of the Bay of Bengal, Bangladesh with model of von Bertalanffy growth function (VBGF).

Mortality (M) and exploitation ratio (ERs)

Rapid total mortality values for the three pomfret species of the Bay of Bengal, Bangladesh Z=0.95yr^{-1}, 1.53yr^{-1} and 2.89yr^{-1} for silver, Chinese and black pomfret, respectively accordingly were constructed from the input values of VBGF growth parameters (L_∞ and K) in the length converted catch curve model described by Pauly (1983) (Fig. 4). Whereas by using Pauly (1980) equation, the value of natural mortality was found (M= 0.72895yr^{-1}, 0.98725yr^{-1} and 1.2761yr^{-1}) and the fishing mortality (F= 0.22105yr^{-1}, 0.54275yr^{-1} and 1.6139yr^{-1}) was obtained by the subtracting Z from M values of three species silver, Chinese and black pomfret, respectively. The exploitation ratio (E= F/Z eg. 0.2327 for silver, 0.335 for Chinese and 0.558 for black pomfret) was also achieved (Table 1).

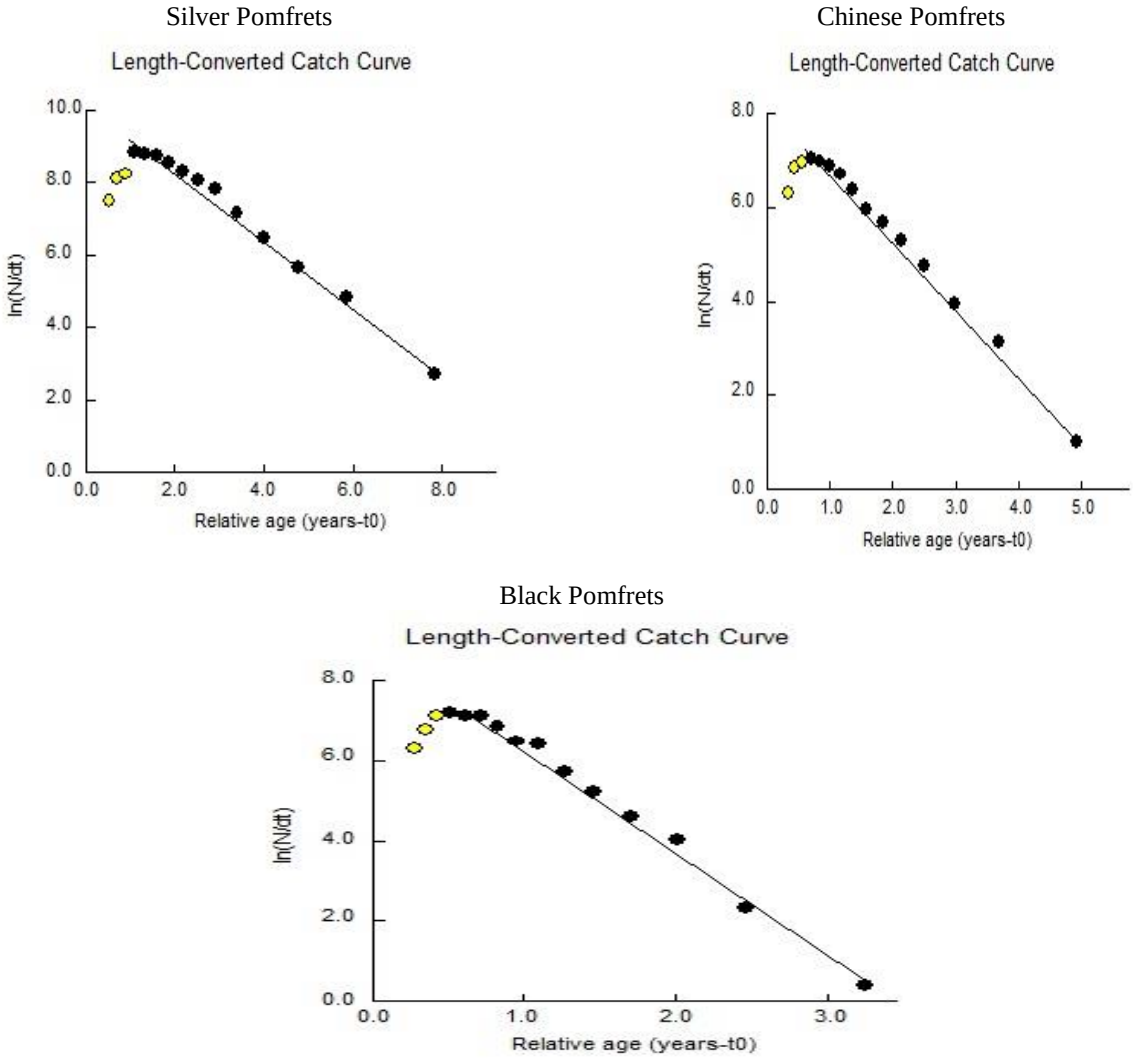


Figure 4: Length converted catch curve of the three pomfret species from Bangladeshi waters.

Virtual population analysis (VPA)

The value of growth parameters (L_∞ and K), mortality parameters (M and F) and length weight relationship parameters (a and b) were used to shape the length structured virtual population analysis

(LVPA) for the three pomfret species of Bangladesh from the output graphics of LVPA by FiSAT (Figure 5) which indicated the higher fishing mortality of the three pomfret species.

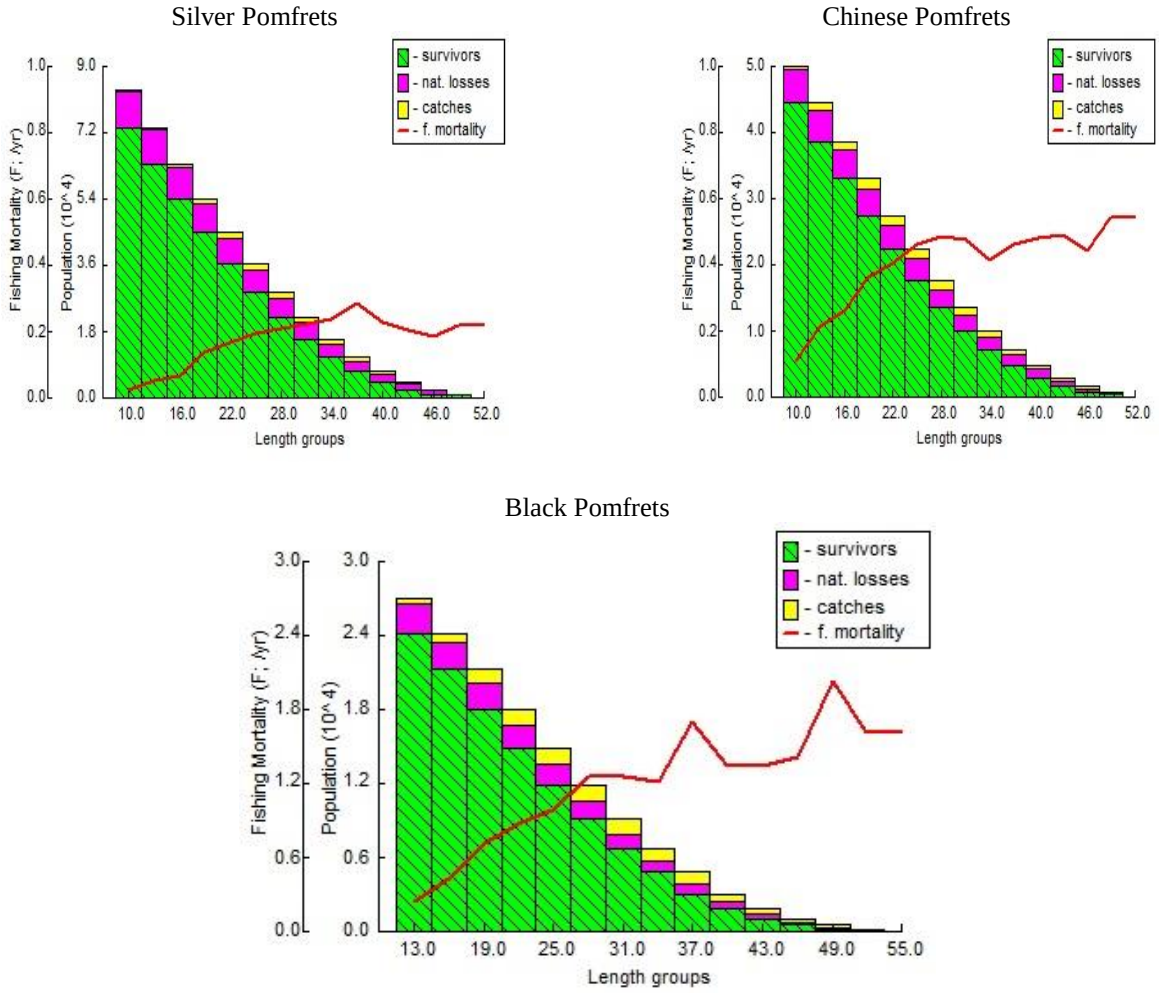


Figure 5: Comparative study of Length structured virtual population analysis cohort (LVPA) for the three pomfret species of Bay of Bengal, Bangladesh.

Biological reference points (Yield per recruit and probability of capture)

The relative yield per recruit (*Y'/R*) and biomass-per-recruit (*B'/R*) were determined as a function of Lc/L_∞ and *M/K* of the three pomfret species by using the model of Beverton-Holt yield per recruit with the knife-edge selection in FiSAT-II (Figure 6). When t_c was 1 the F_{max} was estimated at 1.2yr^{-1} and $F_{0.1}$ was 1.0yr^{-1} for silver pomfret. On the other hand, when t_c was 1 F_{max} was estimated at 2.0yr^{-1} and $F_{0.1}$ was 1.5yr^{-1} for Chinese pomfret and F_{max} was 2.85yr^{-1} and $F_{0.1}$ was 1.6yr^{-1} for black pomfret. Since the current age at the first capture in case of silver pomfret was approximately 1 year and $F_{current}$ was 0.221, which was smaller than F_{max} and $F_{0.1}$ represented the stock was in safe condition while safer stock result were also found from the analysis of the values of $F_{current}$ 0.543 for Chinese pomfret, which was less than F_{max} and $F_{0.1}$. In the case of black pomfret, $F_{current}$ was 1.614, which was less than

F_{max} but greater than $F_{0.1}$ indicating over exploited stocks. When using biological reference point, $F_{opt} = M$ (Patterson, 1992), it was $0.73yr^{-1}$ for silver pomfret, $0.987yr^{-1}$ for Chinese and $1.28yr^{-1}$ for black pomfret and the current fishing mortality rates were low for silver and Chinese pomfret but high for black pomfret.

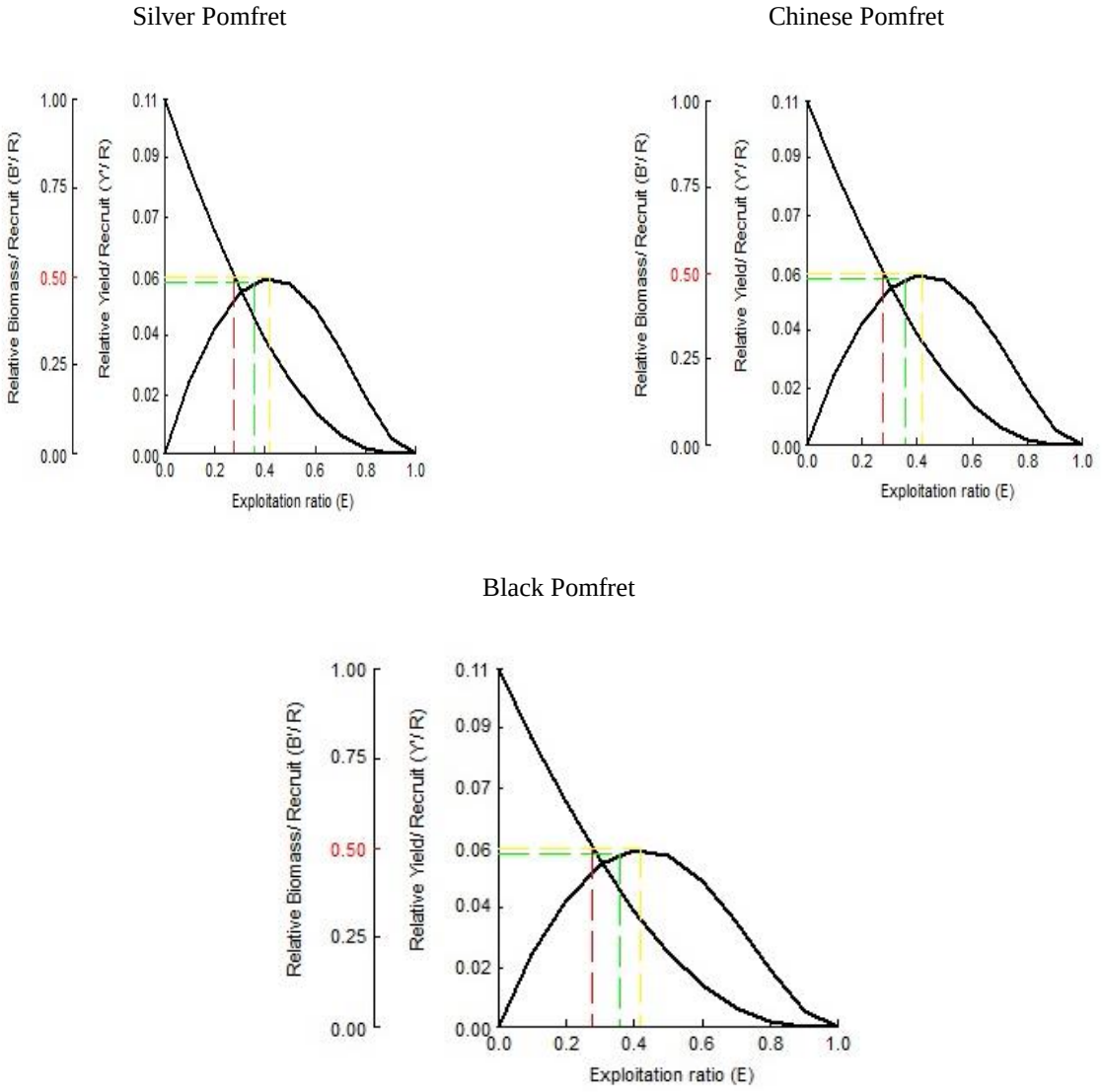


Figure 6: Relative yield per recruitment model with the knife edge selection option for three pomfret species of the Bay of Bengal, Bangladesh (yellow line: E_{max}, Red line: E_{50}).

Probabilities of capture (Figure 7) of the three pomfret species were also figured by projecting the down part of the catch curve backward and the length at 50% catch was calculated from a plot of probabilities of capture which was integrated in calculating yield per recruit. The highest captured length class values ranged from 46 cm and above for black pomfret whereas it was 37cm and lower for silver and 43cm and above for Chinese pomfret.

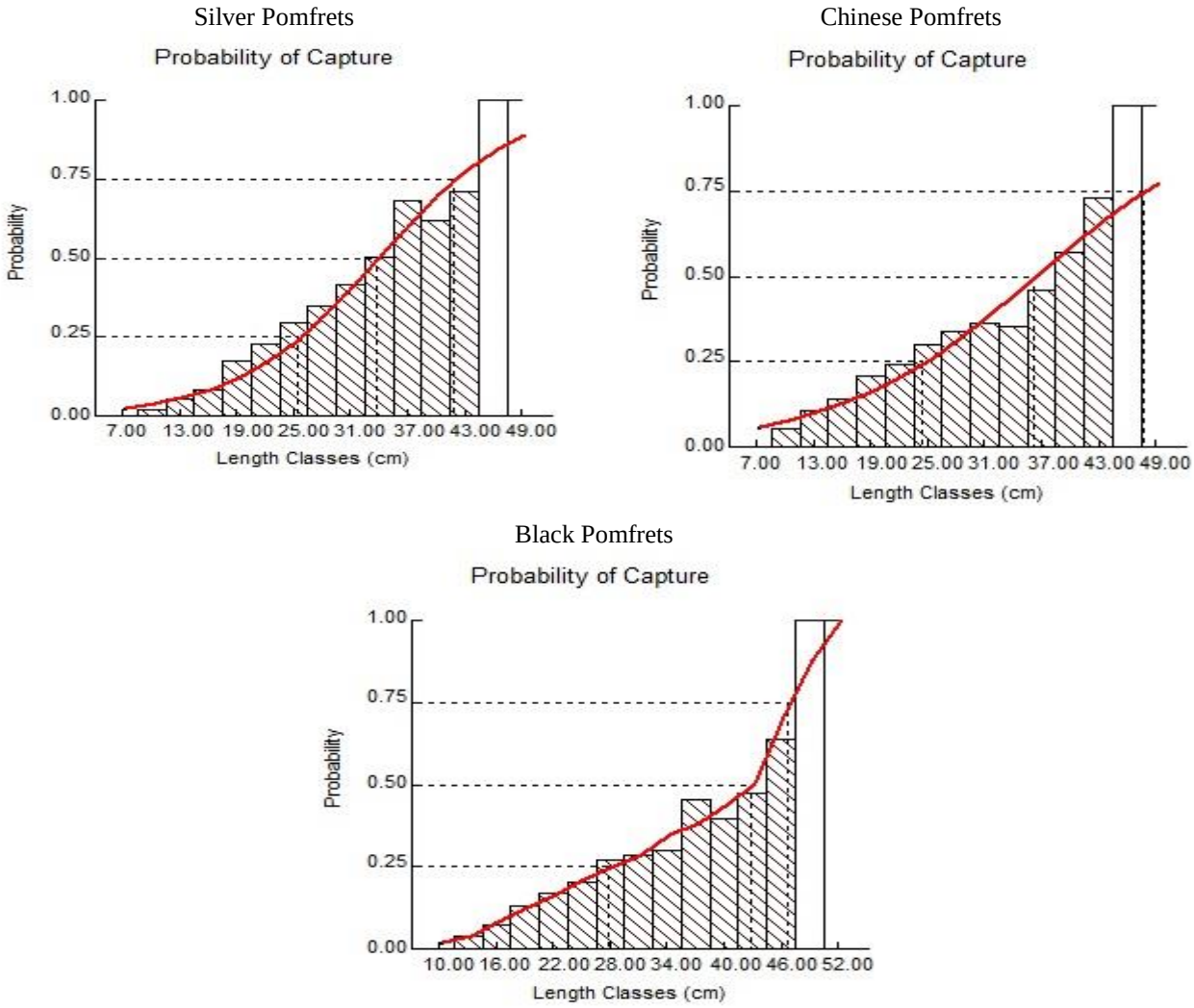


Figure 7: Comparative study of probability of capture of Silver Pomfret, Chinese Pomfret and Black Pomfret of the Bay of Bengal, Bangladesh.

Growth Performance index (GPI)

The von Bertalanffy growth parameters of L_∞ and K were used for the estimation of growth performance indices (phi prime or index Φ') of silver, Chinese and black pomfret of the Bay of Bengal, Bangladesh as 3.065, 3.267 and 3.496, respectively.

Discussion

In Bangladesh, banning of industrial trawl fishing activities started from the middle of May to middle of July by the Department of Fisheries (DoF) when fishing was postponed coinciding with the monsoon as it was proved as the peak of the breeding season (Pati, 1982). Nevertheless artisanal fishers roam for fishing to nearby littoral waters of 10–40 m depth and pomfret are the major targeted fish in that period, when they start their spawning migration to their suitable spawning grounds with muddy-sandy bed rock (Pati, 1982). Hence this time is called lean period which is reflected in this study too. Fishing not only shrinks populations but also creates variations in the species inter-relations (Nikolskiii, 1980).

LWR

According to Gayanilo and Pauly (1997), length frequency distribution analysis can be used for the resource evaluation and management of the fish populations and this study was completely based on length composed data. Length-weight relationship is the basic parameter in fishery biology and stock assessment of fish (Abdurahiman *et al.*, 2004) which is also helpful to estimate gonad maturity, metamorphosis and feeding rate of fish (Le Cren, 1951). The value of *a* and *b* from the LWR study, according to Ricker (1973) may be dissimilar between the calculations done using the grouped and individual data. The slope value *b* from the *LWR* study of the three pomfret species were estimated at 2.425 for silver pomfret, 2.07 for Chinese pomfret and 2.113 for black pomfret. All of these values show negative allometric growth because *b* value equal to 3 indicates isometric growth (that the fish holds the same proportion of its shape throughout the life). Larger or smaller than 3 indicates positive or negative allometric growth as it will grow differently in three dimensions (Ricker, 1973; Wootton, 1998; Gayanilo *et al*., 2003). Comparative studies of slope values (*b*) acquired from various areas of these species are presented in Table 2. Apart from the studies of Gujrat, Maharastra and Veraval of the Indian waters by Khan, 2000, most of the studies agree with the above observations. As the fish grows, changes in weight are relatively greater than changes in length, due to approximately cubic relationships between weight and length. The *LWR* parameter *a*, may vary daily, seasonally, and/or between habitats, unlike the parameter *b*, which does not vary significantly all through the year (Bagenal and Tesch, 1978). Differences in *LWR* parameters may represent spatial variation (Sparre *et al*., 1989) due to the influence of water quality or food availability on fish growth as sandy-muddy shallow waters are the most favorable conditions for pomfrets (Pati, 1982).

Table 2: Comparative study of estimated *LWR* parameters of Pomfret from studies in various areas of the world.

Species Name	Location	Slop "*b*"	Source
Silver Pomfret (*P. argenteus*)	Bay of Bengal, Bangladesh	Combined 2.4248	Current study
Chinese Pomfret (*P. chinensis*)		Combined 2.07	Do
Black Pomfret (*P. niger*)		Combined 2.113	Do
Chinese Pomfret (*P. argenteus*)	Bay of Bengal, Bangladesh	Combined 2.983	Mustafa, 1999
Silver Pomfret (*P. argenteus*)	Bay of Bengal, Bangladesh	Combined 2.929	Mustafa, 1999
Chinese Pomfret (*P. chinensis*)	Karachi, Pakistan	Combined 1.438*	Quratulan, 2015
Silver Pomfret (*P. argenteus*)	Maharastra State, India	Combined 3.0058	Khan, 2000
Silver Pomfret (*P. argenteus*)	Gujrat, India	Combined 3.0789	Khan, 2000
Silver Pomfret (*P. argenteus*)	Karnataka, India	Combined 3.0848	Khan, 2000

Table 2 continued:			
Black Pomfret (*P. niger*)	Kerala, India	Combined 2.792	Khan, , 2000
Black Pomfret (*P. niger*)	Taiwan Strait	Combined 2.9811*	Tao *et al*., 2012
Silver Pomfret (*P. argenteus)*	Verabal, India	Combined 3.0504	Ghosh *et al*., 1995*

b = slope, * using fork length (FL)

Growth parameters

Von Bertalanffy growth function (VBGF) parameters were evaluated by ELEFAN-I method using FiSAT II (Gayanilo *et al*., 2005) software package, which is fundamentally unintended and does not rely on assessing the parameters of cohort distribution directly. Therefore, it provides a merely weak assumption about the distribution of sizes within the cohorts. The length models of each cohort are permanent to lie upon a curve labelled by growth models i.e. von Bertalanffy growth model results in the provision of a strong assumption about growth (Pitcher & Hart, 1982).

The estimated asymptotic length of the three pomfret species, L_∞= 54.6cm for silver, 54.6cm Chinese and 57.75cm for black pomfret were found in the present study which are within the acceptable range compared with the maximum length of 52cm for both silver and Chinese pomfret and 55 cm for black pomfret (Table 1). The estimated L_∞ parameter of the VBGF should be quite close to the maximum length of the fish, while t_0 should be less than zero so that the fish may have a positive length at zero age (Moreau *et al*., 1986). The t_0 value quantifies the growth rate in adults and adolescents, negative values of t_0 mean higher percentage of juveniles than the expected growth curve for adults while positive values of t_0 indicates slower growth (King, 1997). The coefficient of natural mortality *M* is proportional with the growth coefficient *K* of a fish and inversely proportional to the asymptotic length (L_∞) and longevity (Beverton and Holt, 1956). In this study, asymptotic length (L_∞) was slightly higher compared with the estimated values by Khan (2000) from the Indian waters, as well as by Haque (1998) and Mustafa (1999) from the Bay of Bengal (Table 3) which may be due to the use of total length of the species. However, the calculated growth coefficient (*K*) value for silver pomfret in this study were lower as compared to the values from different areas whereas the *K* value of black pomfret was higher. Conversely, the goodness of fit (R_n) of the model estimated in this study was between 0 and 1 and when it is close to 1, it shows a better fit (Gayanilo *et al*., 2003). The score of R_n can be used for the seasonally oscillating growth curves that fits best in the length frequency data to find the *K* values for the growth analysis through the ELEFAN-I method. However slight differences found in asymptotic length from different areas maybe because of the effect of physico-chemical and biological factors on fishing practice.

Table 3: Summary of estimated growth parameters of Pomfret in different regions.

Species Name	Location	L_∞ (cm)	K	t_0	Source
Silver Pomfret (*P. argenteus*)	Bay of Bengal, Bangladesh	54.6	0.39	-0.44455	Present Study
Chinese Pomfret (*P. chinensis*)		54.6	0.62	-0.6544	Do
Black Pomfret (*P. niger*)		57.75	0.94	-0.8487	Do
Black Pomfret (*P. niger*)	Bay of Bengal, Bangladesh	41.0	0.59	-	Mustafa, 1999*
Silver Pomfret (*P. argenteus*)	North-eastern Bay of Bengal	29.8	0.53	-	Haque, 1998*
Chinese Pomfret (*P. chinensis*)	North-eastern Bay of Bengal	38.1	0.67	-	Haque, 1998*
Silver Pomfret (*P. argenteus*)	Maharastra, India	39	0.7	-	Khan, 2000
Silver Pomfret (*P. argenteus*)	Gujrat, India	39.5	0.75	-	Khan, 2000
Silver Pomfret (*P. argenteus*)	Karnataka, India	36	0.69	-	Khan, 2000
Black Pomfret (*P. niger*)	Kerala, India	56	0.73	-	Khan, 2000
Silver Pomfret (*P. argenteus*)	Veraval	41.57	0.64	-0.0315	Ghosh *et al*., 2009
Silver Pomfret (*P. argenteus*)	Persian Gulf	40	1.1	-0.45	Parsamanesh *et al*., 1998
Chinese Pomfret (*P. chinensis*)	Persian Gulf	36.8	0.8	-0.52	Parsamanesh *et al*., 1998
Black Pomfret (*P. niger*)	Taiwan Strait	34.11	0.3157	-1.7045	Tao *et al*., 2012
Silver Pomfret (*P. argenteus*)	East China Sea & Korean Waters	38.44 (F) 33.57 (M)	0.26 0.24	-0.96 -1.10	Lee *et al*., 1992

* Fork length, L_∞= asymptotic length (cm -TL), K = growth rate/yr, t_0 = hypothetical age (yr) at which length of the fish is equal to zero

Mortality rate

Mortality parameters are natural mortality, total mortality and fishing mortality ratio which may not stop at a constant level, but may change from time to time (Sparre and Venema, 1989). The estimated total mortality rate of the three pomfret species of the present study was lower in the case of silver and Chinese pomfret compared with some previous studies and higher for Black pomfret except in the study in Kerala, India by Khan (2000) that are shown in Table 4. Those plotted values (Table 4, Fig. 4) were overall higher than that in the current study for silver and Chinese pomfret, which may be due to the high market demand, therefore, resulting in the higher fishing mortality and some other environmental issues that may effect on natural mortality. Comparatively, the estimated natural mortality was the lowest among the other reported values of different areas in case of silver pomfret and also lower to some extent for Chinese pomfret. The analyzed fishing mortality rate of silver and Chinese pomfret were also smaller to some extent in the present study compares to that in other studies. Nevertheless, for black pomfret, except in the study in

Karnataka, Indian waters by Khan (2000), both the values were found to be slightly higher because of its higher market demand and moderately less cost compared with other pomfret species that are suitable for mass consumption in Bangladesh. The lower values of natural mortality of silver and Chinese pomfret may be different due to the water temperature (24^{0}C in the Bay of Bengal, Bangladesh) and higher fishing mortality rate is only influenced by increasing fishing efforts in the case of black pomfret. Natural mortality mostly depends on some factors, i.e. predation, old age, environmental stress and parasitic effects or diseases (King, 1997). According to Beverton and Holt (1957), in most of the fish species the *M*/*K* ratio ranging from 1.12 to 2.50 were observed. *M*/*K* ratio of the current study (1.87 for silver pomfret, 1.59 for Chinese pomfret, and 1.36 for black pomfret) were within the above range (Table 1). Similarly, except for black pomfret, the exploitation value (*F/Z*) of silver and Chinese pomfret were also recorded as the lowest in the current findings as the observed values of exploitation from the other studies. Exploitation ratio is a measure to estimate the level of utilization of the fishery. According to Gulland (1971) criteria, when the exploitation ratio is above 0.5 then the stock is considered as overfished or over-exploited. In this study, only black pomfrets showed the exploitation ratio of *E*= 0.558 indicating that the stock is over-exploited. Increased fishing pressure persisted on the black pomfret population in the Bay of Bengal, Bangladesh, and it can thus be asserted that the population in this area has not been managed properly. Therefore, effective management plans are urgently needed to maintain the stocks of this fish in the Bay of Bengal, Bangladesh.

Table 4: Estimated mortality rates of Pomfrets from different regions and comparisons with the current study.

Species Name	Area	*Z*	*M*	*F*	Source
Silver Pomfret (*P. argenteus*)	Bay of Bengal, Bangladesh	0.95	0.729	0.221	Current study
Chinese Pomftret (*P. chinensis*)		1.53	0.987	0.543	Do
Black Pomfret (*P. niger*)		2.89	1.276	1.614	Do
Black Pomfret (*P. niger*)	Bay of Bengal, Bangladesh	2.42	1.16	1.26	Mustafa, 1999
Silver Pomfret (*P. argenteus*)	North-eastern Bay of Bengal	1.97	1.18	0.79	Haque, 1998
Chinese Pomfret (*P. chinensis*)	North-eastern Bay of Bengal	2.12	1.29	0.83	Haque, 1998
Silver Pomfret (*P. argenteus*)	Maharastra, India	4.033	1.49	2.984	Khan, 2000
Silver Pomfret (*P. argenteus*)	Gujrat, India	3.165	1.05	2.114	Khan, 2000
Silver Pomfret (*P. argenteus*)	Karnataka, India	5.054	2.52	2.527	Khan, 2000

Table 4 continued:

Black Pomfret (*P. niger*)	Kerala, India	4.4	0.88	3.52	Khan, 2000
Silver Pomfret (*P. argenteus*)	Veraval, India	3.31	1.2	2.11	Ghosh *et al*., 2009
Black pomfret (*P. niger*)	Taiwan Strait	1.82	0.74	1.09	Tao *et al*., 2012
Silver Pomfret (*P. argenteus*)	East China Sea & Korean Waters	1.5	0.76	0.74	Lee *et al*., 1992

Z = total mortality, *M* = natural mortality, *F* = fishing mortality

Growth performance index (Phi prime Φ')

GPI compare the growth performance of the fish species with different populations of the same or different environmental fish populations and higher values indicate higher growth (Pauly and Munro, 1984). The comparison of the growth rates is a matter of multiple factors of the growth rate (K) and the asymptotic length (L_∞). According to the Pauly and Munro (1984), parameter Phi prime (Φ') acts as an indicator of the inconsistency on the accuracy of the estimated growth parameters of the same or related species of stocks. This index is also endorsed by the von Bertalanffy growth parameters (L_∞ and K) because it facilitates the program between the species and growth (Pauly and Munro, 1984). In this study, the estimated value of GPI of the three pomfret species were 3.065 for silver, 3.267 for Chinese and 3.496 for black pomfret which are considered to specify slow growth. Apart from the genetic structure, determining the growth potential of a species, overfishing, dietary patterns and their utilization may affect the growth performance of a specific species.

Biological reference points (BRPs)

BRPs are now widely used for the conservation and management of fisheries resources as the level of fishing mortality (Haddon, 2011). $F_{0.1}$ and F_{max} are the most familiar points which are frequently used in fisheries management (Hilborn and Walters, 1992). The target biological reference point F_{max} is the F, which produces the maximum value of yield-per-recruit (YPR). $F_{0.1}$ is another target reference point at which the marginal gain in YPR decreased to an arbitrary 10% from that at F=0. (Hilborn and Walters, 1992).

Biological reference points (*BRPs*) from the procedures $F_{opt} = M$, by Patterson (1992) which are F_{opt}= 0.73 for silver pomfret, 0.987 for Chinese pomfret, and 1.28 for black pomfret. The YPR (Figure 6 and Table 1) indicated the values of F_{max} and $F_{0.1}$ of the three pomfret species when t_c was assumed to be 1. Since the age of first capture during the current study was approximately one year, the current fishing mortality rate ($F_{current}$) of 0.221yr^{-1} for silver pomfret and 0.543 yr^{-1} for Chinese pomfret were lower than F_{opt}, F_{max} and $F_{0.1}$. Hence, the status of silver pomfret and Chinese pomfret stocks are now in safer

conditions and it is recommended to strictly maintain the current fishing efforts of the Bay of Bengal, Bangladesh. Because of limited information and available data, it is very hard to compare the life history parameters with the others i.e. that what biological and ecological differences contribute to this process. In case of black pomfret, current fishing mortality ($F_{current}$) was 1.61yr^{-1} which was higher than F_{opt} and $F_{0.1}$ indicating that the stocks of this fish are now over-exploited, therefore, immediate steps should be taken for its sustainable management. In comparison with some other studies on silver and Chinese pomfret from the Arabian and Indian waters, overfishing was found in every area, which may be due to high value and delicious characteristics of those species that result in them being the major targeted species for fishing.

The current study indicates that the stocks of silver and Chinese pomfret are now in safer conditions but the Black Pomfret fishery status is in heavily overfished state in the Bay of Bengal, Bangladesh contexts. However, in order to achieve a sustainable exploitation of the pomfret fishery, further studies on age-structure analysis through otolith observation, mortality, growth and yield-per-recruit analysis are needed through different methods or modelling to understand the population characteristics of this fishery better.

Acknowledgement

The first author would like to express appreciation to the Chinese Scholarship Council (CSC) and SOA (State Oceanic Administration) for sponsorship during his doctoral degree because this work is supported by the special research fund of Ocean University of China (201022001).

References

Abdurahiman, K.P., Harishnayak, T., Zacharia, P.U. and Mohamed, K.S., 2004. Length-weight relationship of commercially important marine fishes and shellfishes of the Southern Coast of Karnataka, *Indian Journal of Fisheries*, 27, 9-14.

Bagenal, T.B. and Tesch, P.W., 1978. Age and growth. *In*: Bagenal, T. (ed.). Methods for assessment of fish production in fresh waters. IBP Handbook No.3, 3rd edn. Blackwell Scientific Publications (Chapter 5), Oxford. pp. 101-136

Beverton, R.J. and Holt, S.J., 1956. A review of method for estimating mortality rates in exploited fish population, with special reference to source of bias in catch sampling. *Rapp. P. V. Reun. CIEM*, 140, 67-83.

Beverton, R.J.H. and Holt, S.J., 1957. On the dynamics of exploited fish populations. Fishery Investigation Series II. Ministry of Agriculture, Fisheries and Food, London. 553 P.

Compagno, L.J.V., 1984a. FAO species catalogue. Vol. 4. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 2-Carcharhiniformes. *FAO Fisheries Synopsis,* 125, 251–655.

DoF (Department of Fisheries, 2016). National fish week, compendium (In

Bengali). Department of Fisheries, Ministry of Fisheries and Livestock, Bangladesh, at http://www.fisheries.gov.bd

FRSS, (Fisheries Resources Survey System), 2016. Fisheries statistical report of Bangladesh, Department of Fisheries, Bangladesh.

Gayanilo, F.C. and Pauly, D., 1997. FAO ICLARM stock assessment tools (FISAT), References Manual, FAO Computerized Information Series (Fisheries). 8, 262.

Gayanilo, F.C., Sparre, P. and Pauly, D., 2003. FAO-ICLARM stock assessment tool (FiSAT II) user's guide, FAO Computerized Information Series (Fisheries). No. 8, Rome, FAO, 266 P.

Gayanilo, F.C., Sparre, P. and Pauly, D., 2005. The FAO-ICLARM stock assessment tool (FiSAT) user's guide., FAO Computerized Information Series (Fisheries), FAO, Rome: Worldfish Center. 7, 168.

Ghosh, S., Mohanraj, G., Asokan, P.K., Dhokia, H.K., Zala, M.S. and Bhint, H.M., 2009. Fisheries and stock estimates of the silver pomfret *Pampus argenteus* (Euphrasen), landed by gill-netters of Veraval. *Indian Journal of Fisheries*, 56(**3**), 177-182.

Gulland, J.A., 1969. Manual of methods for fish stock assessment. Part 1. Fish population analysis. Fishery Resources and Exploitation Division, FAO, Rome. 154 P.

Gulland, J.A., 1971a. Estimation of mortality rates. Annex to Artic fisheries working group report. International Council for the Exploration of the Sea (ICES), M. Doc. 3 (mimeo).

Haddon, M., 2011. Modelling and quantitative methods in fisheries. Chapman and Hall / CRC Press, London. 449 P.

Haque, M.A., 1998. Population dynamics of five commercially important marine fishes in north-eastern part of the Bay of Bengal. Institute of Marine Sciences, University of Chittagong, Chittagong, Bangladesh, MSc Thesis.

Hilborn, R. and Walters, C.J., 1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Chapman and Hall, New York, London.

Hussain, N.A. and Abdullah, M.A.S., 1977. The length-weight relationship, spawning season and food habits of six commercial fishes in Kuwaiti waters. *Indian Journal of Fisheries*, 24(**1, 2**), 181-194.

Khan, M.Z., 1982. A probable nursery ground of silver pomfret *Pampus argenteus* (Euphrasen) off Nawabunder (Gujarat). *Indian Journal of Fisheries*, 29(**1,2**), 257-261.

Khan, M.G., White, T.F., Humayun, M. and Mustafa, M.G., 1986. Growth and mortality rates of the white pomfret *Pampus argenteus* in the Bay of Bengal based on the analysis of length frequency. *In*: Proceedings of Fifth National Zoology Conference, Dhaka, Bangladesh. pp. 37-44.

Khan, M.Z., Kumaran, M., Jayaprakash, A.A., Scariah, K.S.,

Desmukh, V.M. and Dhulkhed, M.H., 1992. Stock assessment of pomfrets off west coast of India. *Indian Journal of Fisheries*, 39(**3, 4**), 249-259.

Khan, M.G. and Latif, M.A., 1997. Potentials, constraints and strategies for conservation and management of open brackish water and marine fishery resources, BOBP Report of the National Workshop on Fisheries Resources Development and Management in Bangladesh. The Bay of Bengal Program, India.

Khan, M.Z., 2000. The fishery and resource characteristics of pomfrets. In: Pillai, V.N. and Menon, N.G. (Eds.), Marine fisheries research and management. Central Marine Fisheries Research Institute, Cochin, pp. 364-373.

King, R.P., 1997. Growth performance of Nigerian fish Stocks. *NAGA, the ICLARM Quarterly*, 20(**2**), 31-35.

Last, P.R., 1997. Stromateidae. butterfishes, silver pomfrets. In Carpenter, K.E., & Niem, V., (eds.) FAO identification guide for fishery purposes. The Western Central Pacific.

Le Cren, E.D., 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *Journal of Animal Ecology*, 20, 201-219.

Lee, D.W., Kim, Y.M. and Hong, B.Q., 1992. Age and growth of silver pomfret (*Pampus argenteus*) in Korean waters. *Bulletin National Fisheries Research and Development Agency, Korea,* 46, 31-40.

Moreau, J., Bambino, C. and Pauly, D., 1986. A comparison of four indices of overall growth performance based on 100 tilapia populations (Fam. Cichlidae). In: Maclean, J., Dizon, L.B. & Hosillo, L.V. (Ed.) The first Asian fisheries forum, Asian Fisheries Society, Manila, pp. 201-206.

Morgan, G.R., 1985. Stock assessment of the pomfret *(Pampas argenteus)* in Kuwaiti waters. *J. Cons. Int. Explor. Mer.*, 42, 3-10.

Mustafa, M.G., 1999. Population dynamics of penaeid shrimps and demersal finfishes from trawl fishery in the Bay of Bengal and implication for the management. PhD. Thesis, University of Dhaka, Bangladesh, 223 P.

Nikolskiii, G.V., 1980. Theory of fish population dynamics as the biological background for rational exploitation and management of fishery resources, Bishen Singh Mahendra Pal Singh Dehra Dun (India) and Otto Koeltz Science Publishers Konenigstein, W. Germany. pp.1-323.

Parsamanesh, A., Shalbaf, M. and Najafpour, N., 1998. Status of *Pampas argenteus* fisheries in Khoozestan waters (North-west Persian Gulf), I.R. Iran. *Indian Journal of Animal Sciences,* 68(**4**), 407-409.

Patterson, K., 1992. Fisheries for small pelagic species: An empirical approach to management targets.

Reviews in Fish Biology and Fisheries, 2(**4**), 321-338.

Pati, S., 1982. Studies on the maturation, spawning and migration of silver pomfret, *Pampus argenteus* (Euphrasen) from Bay of Bengal. *MATSYA*, 8, 12-22.

Pati, S., 1985. Possibilities of aquaculture of silver pomfret *Pampus argenteus* (Euphrasen) along the Balasore coast. Proceedings of the symposium on coastal aquaculture held at Cochin Jan. 12- 18, 1980, *Finfish culture*, 3(**6**), 782-786. Marine Biological Association of India, Cochin, India.

Pauly, D., 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *Journal du Conseil/Conseil permanent International Pour'l Exploration de la Mer*, 39(**2**), 175-192.

Pauly, D., 1983. Length converted catch curves. A powerful tool for fisheries research in tropics (Part-1). *ICLARM Fishbyte*, 1(**2**), 9-13.

Pauly, D., 1984. Length converted catch curves. A powerful tool for fisheries research in tropics (Part-II). *ICLARM Fishbyte*, 2(**1**), 13-14.

Pauly, D. and Munro, J.L., 1984. Once more, on the composition of growth in fish and invertebrates. *Fishbyte*, 2(**1**), 21.

Pitcher, T.J. and Hart, P.J., 1982. Fisheries ecology. Chapman and Hall, London. 414 P.

Riede, K., 2004. Global register of migratory species from global to regional scales. Final report of the R&D-Projekt 808 05 081. Federal Agency for Nature Conservation, Bonn, Germany. 329 P.

Ricker, W.E., 1973. Linear regressions in fishery research. *Journal of Fisheries Research*, Board of Canada. 30, 309-434.

Shahidhullah, M., 1986. Marine fisheries resources management in Bangladesh and current status of exploitation. *Marine Fisheries Bulletin*, 3, 22.

Sivakami, S., Vivekanandan, E., Raje, S.G., Shoba, J.K. and Rajkumar, U., 2003. Lizardfishes, pomfrets and bullseye. In: Mohan Joseph, M. and Jayaprakash, A.A (Eds.), Status of exploited marine fishery resources of India, CMFRI, Kochi, India. pp. 141-157.

Sparre, P., Ursin, E. and Venema, S.C., 1989. Introduction to tropical fish stock assessment. Part I. Manual. In: FAO Fisheries Technical Paper No. 306 P.

Sparre, P. and Venema, S.C., 1998. Introduction to tropical fish stock assessment - Part 1: Manual, FAO Fisheries Technical Paper, 306/1 Rev. 2. pp. 185-214.

Tao, Y., Mingru, C., Jianguo, D., Zhenbin, L. and Shengyun, Y., 2012. Age and growth changes and population dynamics of the black pomfret (*Parastromateus niger)* and the frigate tuna (*Auxis thazard thazard),* in the Taiwan Strait. *Latin American Journal of Aquatic Research*, 40(**3**), 649-650.

Wootton, R.J., 1998. Ecology of teleost fishes. 2nd (ed.), Kluwer, Dordrecht.