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Assessment of some demographic trends of Spadenose shark (*Scoliodon laticaudus*) of the Bay of Bengal, Bangladesh

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Present study featuring the assessment of demographical trends of *Scoliodon laticaudus* that were analyzed on the basis of monthly length frequency data from the Bay of Bengal, Bangladesh from July 2014 to June 2015. Total length (*TL*) range of the collected 1520 specimens were 26 to 70 cm and weight (*W*) 329 to 2758 g. The relationship of length and weight was $W= 0.3409L^{2.1137}$, $R^2= 0.9987$). The von Bertalanffy growth model parameters were $L_\infty= 73.75$ cm and $K= 0.30$ yr^{-1}, hypothetical age at zero length of $t_0= -0.3922$ years and goodness of the fit of $R_n= 0.112$. The natural mortality rate at average annual water surface temperature of 22^0C was 0.5651 yr^{-1}. The total mortality was 1.31 yr^{-1} while fishing mortality was 0.745 yr^{-1} and the current exploitation ratio 0.57. The Beverton-Holt yield per recruit model was done by *FiSAT-II* in which when t_c was 1 the F_{max} was estimated at 0.95 yr^{-1} and $F_{0.1}$ was 0.8 yr^{-1}. Current age at the first capture was approximately 1 year, $F_{current}= 0.745$ yr^{-1}which is smaller than $F_{0.1}$ indicating the current stock of *S. laticaudus* of Bangladesh is in safer state but more work is needed for the sustainable management of this fishery resource.

[Keywords: *Scoliodon laticaudus*, Bay of Bengal, growth, mortality, FiSAT-II]

Introduction

In Bangladesh, shark fishery is a non-targeted fishery; its availability is incidental as by-catch which contributes only a minor portion (0.94% of the total marine catch) to overall fish production (0.17%) in Bangladesh[1]. The total production of shark mostly depends on artisanal catch that shows the declining trend in the recent years. The highest quantity reported as 5,162 ton in 2001 and then gradually declined to 4,085 ton in 2005 and then 3,865 ton in 2011-12[2]. The number of shark species is also reported to be declined being highest number reported as 63 in 1978, followed by 56 in 2000 and finally 22 in 2007[3,4,5,6]. In the IUCN list, the Kala Hangor (Black shark, *Carcharhinus limbatus*) marked as vulnerable species and Karat Hangor (Saw shark, *Pristis microdon*) as endangered species[6]. However, in the deep-sea region, the large pelagic sharks are distinctly dominating (37%) compared to other pelagic finfishes[7]. The economic activities depending on the shark fisheries are growing remarkably day by day both in domestic and export markets[8]. Although the sharks are important groups of marine catch fishery in Bangladesh, no works have been done so far on its population dynamics and biodiversity throughout the entire coastal belt of Bangladesh. The aim of this study is to analyze population parameters of an important shark species Spade nose shark (*Scoliodon laticaudus*) of Bangladesh.

The Spadenose shark (*Scoliodon laticaudus*) is a species under the family Carcharhinidae, which is common in the tropical Indian and western Pacific Oceans forms large schools in shallow water and for its distinctively flattened, triangular snout, it is called

spadenose shark[9,10]. This shark is less harmful to human and is valued by artisanal and commercial fishers for its meat and fins in South and Southeast Asia. The International Union for Conservation of Nature (IUCN) has assessed this species as 'Near Threatened'[4]. The maximum known length of this species is 74 cm, although some unsubstantiated reports of reaching 120cm[11].

The relationships between weight and length of any fish species are important for fisheries ecology and stock assessment e.g. for converting growth-in-length to growth-in-weight,for estimating condition factor and geographic comparisons of life histories[12,13,14,15]. Apart from length-weight relationship, this study also provides the growth, mortality, biological reference points (BRP) etc of Spade nose shark (*Scoliodon laticaudus*) species which assemblages based on the artisanal catch fishery.

Material and Methods

Before 2005, various fishing gear involves in Sharks capturing in the artisanal fishery of Bangladesh[16]. Nevertheless, maximum species are caught with drift gill nets (DGN) which is basically used for *Hilsa* (Sardine) catching, set bag nets (SBN), long lines/hook and lines (LL/HL) and trammel nets (TN)[5,14,16]. At present, the shark fishing activities are mostly performed by using newly introduced 'shark net'- a modified gill net[5]. The whole study was conducted in the important shark landing spots throughout the coastal belt of Bangladesh including Cox's Bazar, Chittagong, Kuakata and Pathorghata (Figure 1b).

Majority of biological samples (*S. laticaudus*) of both sexes were collected between July 2014 to June 2015 from above landing stations. Best efforts were given in sample identification and data recorded together with their particular catch in weight and size in length. Shark length was measured as total length (*TL*) in centimeters (cm) and weight (*W*) in grams (gm) by following the method - fish was placed ventral side down and the upper lobe of the caudal fin depressed line with the body axis[11]. A total of 1520 nos. of *S. laticaudus* of both sexes' length-weight data were measured and recorded. Then the collected data were compiled in 1cm interval in an excel sheet and average value of length-weight also calculated.

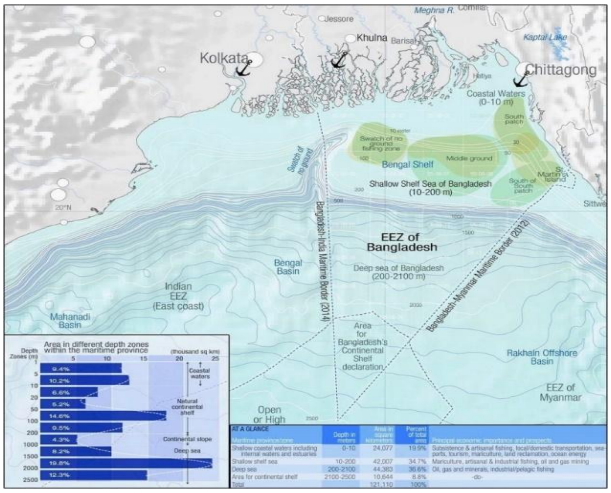

Figure 1a. Maritime area of Bangladesh (Source: Chowdhury, 2014)[21]

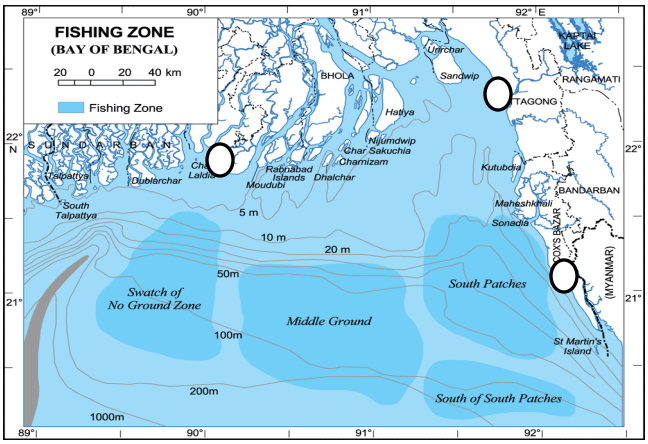

Figure 1b: Three Major data collecting areas of Bay of Bengal, Bangladesh from the period of July 2014 to June 2015

In this study, a computer software packages named FiSAT II (use either italic or normal in whole manuscript) (FAO-ICLARM stock assessment tool)[15,17] were used to analyze the length frequency data of *S. laticaudus*. Actually, FiSAT 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[15].

For the assessment of LWR, total length of all 1520 nos (*S. laticaudus*) individuals were measured which indicated as *TL* to the nearest cm and weighed which indicated as *W* to the nearest gram. Then the length-weight relationship was calculated by using the power function: $W = aL^b$ where *a* is a constant

condition factor and *b* is slope or allometric growth parameter[21]. Parameters *a* and *b* of the length-weight relationship were estimated by linear regression analysis based on logarithms $log(W) = log(a) + b\ log(L)$.

The von Bertalanffy growth function (VBGF) parameters of *S. laticaudus* were determined by using the method ELEFAN-I (Electronic Length Frequency Analysis) in this study. The von Bertalanffy equation for growth in length is: $L_t = L_\infty\ (1–exp(-K\ (t– t_0)))$[19], 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[19], as: $log_{10}(-t_0) = -0.3922 – 0.275\ log_{10}L_\infty - 1.038\ log_{10}K$.

For estimating instantaneous total mortality (*Z*) the length converted catch curve method by Pauly[20]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[22,23]. The equation by Pauly[19] 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 *S. laticaudus* take place. The *F* (Fishing mortality) was evaluated by using the relationship of subtracting $F = Z-M$ and also exploitation ratio (*E*) was evaluated by using the formula[24]:$E = F/Z = F/(F+M)$.

According to Sparre and Venema[25] the Length structured virtual population analysis (VPA) of *S. laticaudus* was carried out with the input values of LWR parameters intercept (*a*), slope (*b*) and growth parameters values of asymptotic length (L_∞), growth coefficient (*K*) and mortality parameters values of natural mortality (*M*) and fishing mortality (*F*) to evaluate the fishing mortalities per length class. The t_0 value was taken as zero.

According to Gulland[23], the optimal fishing mortality rate $F_{opt} = M$ was determined as the limit of biological reference points for *S. laticaudus* in the Bay of Bengal, Bangladesh. Using the model of Beverton and Holt[26] incorporated into the FiSAT-II program[15] with the formula

$$Y_w / R = FW_\infty e^{-M(t_c - t_r)} \sum_{n=0}^{3} \frac{Q_n e^{-nK(t_c - t_0)}}{F + M + nK} (1 - e^{-(F+M+nK)(t_\lambda - t_c)})$$

relative yield per recruitment (*Y*/*R*) values of *S. laticaudus* were estimated. where Y_w/R was yield per recruit, t_c was the average age of first capture, t_r was the age of recruitment, t_λ was the asymptotically ages, Q_n was the constant and equal to 1, -3,3 and -1 when n was 0, 1, 2 and 3 correspondingly[27].

The estimated growth parameters values of L_∞ (asymptotic length) and *K* (growth constant) were used to compute the growth performance index (Phi prime Φ'). Following equations by Pauly and Munro[28] $\Phi' = log_{10}K + 2\ log_{10}L_\infty$ and $\Phi = log_{10}K + 2/3\ log_{10}W_\infty$ were used.

Results

The total length ranged between 26 and 70 cm at average length 48 cm with SD±7.33cm, while total individual weight varied between 329 to 2758 g with an average 1187 g to SD±210.17g (Fig.2). The LWR parameters *a* and *b* for *S. laticaudus* were described by the power equation as $W = 0.3409\ L^{2.1137}$ where $R^2 = 0.9987$ (n=1520). Dominant length and weight of *S. laticaudus* was between 41 to 57 cm (Table 1) and 878 to 1736 g respectively.

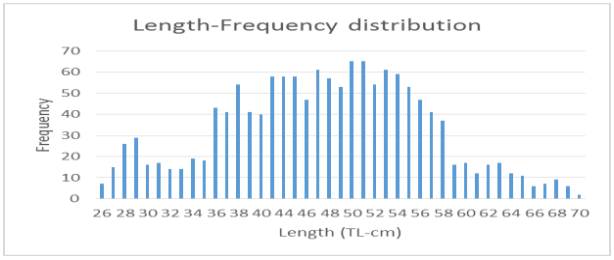

Figure 2: Length frequency distribution (n = 1520) ranging from 26 to 70 cm (*TL*) of both sexes combined of *Scoliodon laticaudus* using the landing data from the Bay of Bengal, Bangladesh during 2014 - 2015.

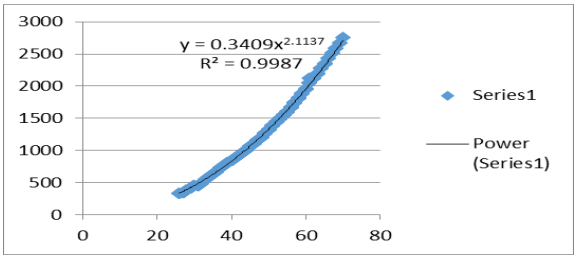

Figure 3**:** Length-weight relationships both sexes combined of *Scoliodon laticaudus* using landing data from the Bay of Bengal, Bangladeshi waters during 2014 – 2015.

The procedure of K-scan was computed to estimate the L_∞ (asymptotic length) and K (growth coefficient) through the method of ELEFAN-I and obtained as L_∞= 73.5cm and K= 0.30 yr^{-1} respectively. The score of goodness fit index of the ELEFAN-I routine (R_n= 0.112) was constructed by the total sum of observation in this function. Hypothetical age at zero length was estimated as t_0= -0.3922 years. The graphical representations of these output VBGF curves are shown in Figure 4.

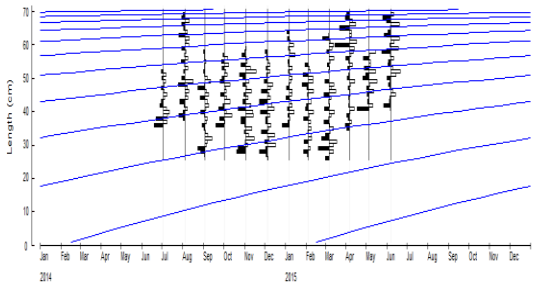

Figure 4**:** Length frequency distribution data (n = 1520) and the growth curves was estimated by using ELEFANfor *S. laticaudus*in which L_∞ =73.5 cm and K= 0.30yr^{-1}.

The value of instantaneous total mortality for *S. laticaudus* of Bay of Bengal, Bangladesh Z=1.31 yr^{-1} with $CI_{95\%}$ of 0.43–2.23 (r^2 = 0.9772) was constructed from the input values of VBGF growth parameters (L_∞ and K) in the length converted catch curve model described by Pauly[23] (Figure 5 and Table 1). Whereas the value of natural mortality was M= 0.5651 yr^{-1} using Pauly[24] equation. Fishing mortality (F= 0.745 yr^{-1}) was obtained by the subtracting Z from M and the exploitation ratio (E= 0.57) was achieved.

Input value of von Bertalanffy growth function of the 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 *S. laticaudus* in the Bay of Bengal, Bangladesh. Cohort analysis to output graphics for LVPA was done by FiSAT-II (Figure 6). The length of the higher fishing mortality was observed in 66.0 to 70.0 cm range.

The relative yield per recruitment of *S. laticaudus* was analyzed by using the model of Beverton-Holt yield per recruit with the knife-edge selection in FiSAT-II (Figure 7). When t_c was 1 the F_{max} was estimated at 0.95yr^{-1} and $F_{0.1}$ was 0.8yr^{-1}. Since the current age at the first capture was approximately 1 year and $F_{current}$ was 0.7, which was smaller than F_{max} and $F_{0.1}$ indicating the stock of *S. laticaudus* in the Bay of Bengal, Bangladesh is a little bit safe. However, the current fishing mortality rate of 0.7yr^{-1} was higher than the biological reference point (F_{opt} = 0.565) on the target scale.

The von Bertalanffy growth parameters of L_∞ and K were used for the estimation of growth performance indices (phi prime or index Φ') for *S. laticaudus* of the Bay of Bengal, Bangladesh as Φ'= 3.210.

Discussion

This study seems to be the first attempt on analyzing the demographic trends of *S. laticaudus*, the prime elasmobranch fish species of the Bay of Bengal, Bangladesh coast. Fishing consequence not only shrinks population but also make modifications in the species inter-relations[41]. According to Gayanilo and Pauly[17], length frequency distribution analysis can be used for the resource evaluation and management of the fish populations and this study was also based on length composed data.

The coefficient of determination (R^2) of was found 0.9987 for LWR (Table 1 and Figure 2) which showed a close relationship between length and weight of *S. laticaudus*. According to Wootton[42], Pauly and Gayanilo[17], when the value of b will be 3, growth form will be isometric, which indicates that the fish embraces the same proportion of its shape throughout the life. When the value is larger or smaller than 3, it indicates that the growth rate is positive or negative allometric, and the fish will grow differently in three dimensions[18]. Hence, in this study, b value was found 2.1137 for *S. laticaudus*, which indicated the negative allometric growth pattern.

Devadoss'[29] reported the value of b for males, females, pooled and combined of the species Spadenose Shark (*S. laticaudus*)were 2.8905, 2.9575, 2.928 and 2.934 respectively from Calicut coast, India and Kasim[31] also reported (b= 2.9349 for male and 2.7837 for female) negative allometric growth from the Veraval coast, Gujrat, India.

Table 1: Estimated key parameters of growth, mortality, exploitation and yield of *S. laticaudus* of the Bay of Bengal, Bangladesh during July 2014 to June 2015

Population parameters	*S. laticaudus* of the Bay of Bengal, Bangladesh
Intercept (a) =	0.3409
Exponent (b) =	2.1137
Coefficient of determination (R^2) =	0.9987
Asymptotic length (L_∞) =	73.5cm
Growth coefficient (K) =	$0.30yr^{-1}$
Theoretical age (t) at zero length (t_0) =	- 0.4335 years
Goodness of fit (R_n) =	0.112
Total mortality (Z) =	$1.31yr^{-1}$ at $CI_{95\%}$ to $0.43 – 2.23yr^{-1}$
Mean annual water temperature of Bay of Bengal, Bangladesh	22^0C
Natural mortality (M) =	$0.5651\ yr^{-1}$
Fishing mortality (F) $F= Z-M$ =	$0.745\ yr^{-1}$
Exploitation ratio (E) $E= F/Z$ =	0.571
GPIΦ' (L_∞) =	3.210
GPIΦ (W_∞) =	1.979
Dominant Length range (cm)	41-57cm
Dominant weight range (g)	878-1736g
Sample size (n)	1520

Table 2. Comparison of the estimated LWR parameters of Carcharhinid sharks with the studies from various areas of the world

Species Name	Location	Slope "b"	Source
Spadenose Shark (*S. laticaudus*)	Bay of Bengal, Bangladesh	Combined 2.1137	Current study
Spadenose Shark (*S. laticaudus*)	Calikut, India	Male 2.8905 Female 2.9575 Pooled 2.928 Combined 2.934	[29]Devadoss (1989)
Spadenose Shark (*S. laticaudus*)	Maharastra State, India	Male 3.1914 Female 3.1799 Combined 3.1904	[30]Mathew et al.,(1997)
Spadenose Shark (*S. laticaudus*)	Verabal Coast, Gujrat India	Male 2.9349 Female 2.7837	[31]Kasim (1991)
Spadenose Shark/ Dog Shark (*S. laticaudus*)	Bay of Bengal, Bangladesh	Combined 2.710	[14]Karim et al., (2012)
Silky Shark (*C. falciformis*)	Western North Atlantic, California	Combined 2.9221	[32]Kohler et al., (1995)

Table 3. Summary of estimated growth parameters of various Carcharhinid sharks in different regions

Species Name	Location	L_∞	K	t_0	Source
Spadenose Shark (*S. laticaudus*)	Bay of Bengal, Bangladesh	73.5	0.30	-0.4335	Present Study
Spadenose Shark (*S. laticaudus*)	India (Calicut)	F 71.5 M 57.6	0.358 0.4046	0.590 0.590	[33]Devadoss (1998)
Spadenose Shark (*S. laticaudus*)	Maharastra State, India	74.023	0.6812	-0.01	[30]Mathew et al., (1997)
Spadenose Shark (*S. laticaudus*)	Bombay waters, India	75.52	0.2731	-0.5664	[34]Nair (1976)
Spadenose Shark (*S. laticaudus*)	Veraval Coast, Gujrat, India	F 74.9 M 68.0	0.8818 1.082	0.0123 - 0.0119	[31]Kasim (1991)
Spot tail Shark (*C. sorrah*)	Northern Australia	F 123.9 M 98.4	0.34 1.17	-1.9 -0.6	[35]Davenport and Stevens (1988)
Silky Shark (*C. falciformis*)	Campeche Beach, Atlantic	311	0.101	-2.718	[36]Bonfil et al., (1993)
White Shark (*C. carcharias*)	California coast, USA	763 pcl	0.058	-3.53	[37]Cailliet et al., (1985)
Blacktip Shark (*C. limbatus*)	Tampa Bay, Florida, USA	M121.3 F142.9	0.276 0.197	-0.88 -1.15	[38]Killam and Parsons (1989)
Spinner Shark (*C. brevipinnia*)	North Western Gulf of Mexico	214	0.212	-1.94	[39]Branstetter (1987a)

L_∞ = asymptotic length (cm -*TL*), *K* = growth rate/yr, t_0 = hypothetical age (yr) at which length of the fish is equal to zero, $\emptyset'$= growth performance index (- data not available in papers), pcl=pre-caudal length

Table 4. Estimated mortality rates of various Carcharhinid sharks from different regions and compared with the current study

Species Name	Area	*Z*	*M*	*F*	Source
Spadenose Shark	Bay of Bengal, Bangladesh	1.31	0.5651	0.745	Present study
Spadenose Shark	India Calicut coast (1977)				
(*S. laticaudus*)	(1978)	1.16	0.72	0.44	[33]Devadoss (1998)
	(1979)	1.24	0.72	0.54	[33]Devadoss (1998)
	(1980)	1.64	0.72	0.92	[33]Devadoss (1998)
		1.76	0.72	0.73	[33]Devadoss (1998)
Spadenose Shark	Maharastra State, India				
(*S. laticaudus*)	(1986-87)	4.38	0.969	3.41	[30]Mathew et al., (1997)
	(1987-88)	3.91	0.969	2.94	
	Average (1986-88)	4.15	0.969	3.18	
Spadenose Shark	Veraval coast, Gujrat	3.39	1.53	1.86	[31]Kasim (1991)
(*S. laticaudus*)		3.32	1.12	2.20	
Spot tail Shark (*C. sorrah*)	Queensland East Coast	0.86	0.73	0.13	[40]Tobin et al., (2014)

In another study, Mathew et al.,[30] found the *b* value of 3.1914, 3.1799 and 3.1904 for male, female and combined or both sexes respectively from Bombay waters, Maharastra State, India which indicated positive allometric growth pattern in that areas. However *b*= 2.7104 for combined was observed by Karim et al.[14] from Bay of Bengal, Bangladesh (Table 1). Pauly and Gayanilo[18] reported that the value of *b* is between 2.5 to 3.5, suggesting that the result of this study agrees with these observations.

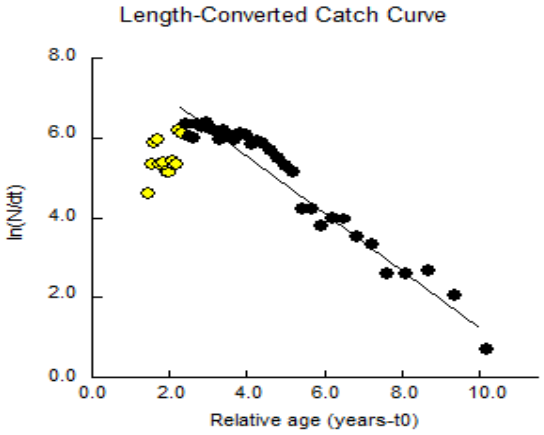

Figure 5: Length converted catch curve analysis of *S. laticaudus* applying growth parameters [L_∞ =73.5 cm and *K*=0.30 yr $^{-1}$] using landing data from the Bay of Bengal, Bangladeshi waters during 2014 – 2015.

The LWR parameter a, may vary daily, seasonally, and/or between habitats, unlike the parameters *b*, which does not vary significantly all through the year[18,19]. However, the analyzed parameters in this study should be considered composites across the whole year rather than representing a particular season as the analysis is based on all data covered whole year during July 2014 to June 2015. Differences in LWR parameters may represent spatial variation[43] due to influence of water quality or food availability on fish growth as clean water is the most favorable condition for sharks species[44]. The analyzed LWR from this work should be used with some caution due to the selective characteristics of fishing gears and most of the samples might not have included all ranges of length distribution. As suggested by Petrakis and Stergiou[45] the use of these LWR should be strictly restricted to the observed length ranges used in the estimation of the linear regression.

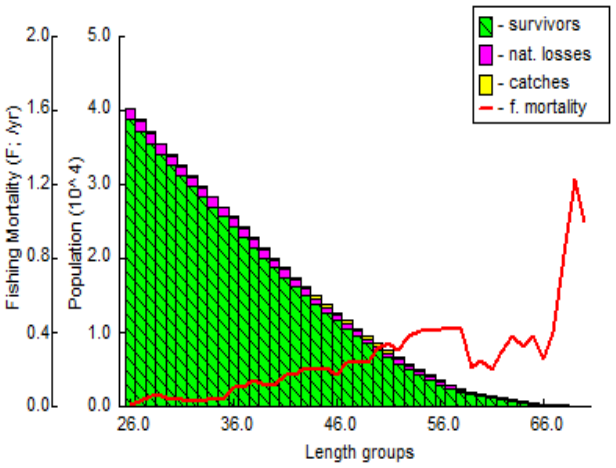

Figure 6**:** Length-Structured Virtual Population Analysis (VPA) of *S. laticaudus by* using landing data of the Bay of Bengal, Bangladesh during 2014 – 2015

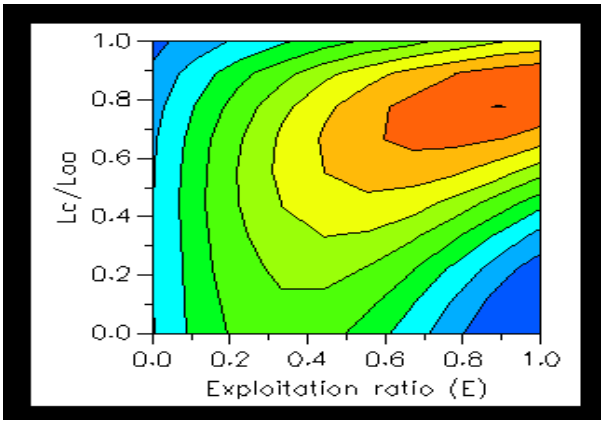

Figure 7**:** Yield per recruit contour map of *S. laticaudus* using landing data from the Bay of Bengal, Bangladesh during 2014 – 2015. Where *E* = Exploitation ratio (*E=F/Z*=natural mortality/fishing mortality), *Lc* was the length at first capture.

The estimated asymptotic length L_∞= 73.5cm of the *S. laticaudus* was found in the existing study which is the acceptable range comparing with the maximum length 70.0 cm. According to Moreau et al.[46] the estimated L_∞ parameter of the von Bertalanffy growth function 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. The analyzed L_∞, *K* and t_0 values for *S. laticaudus* of this study are presented in Table 1. The calculated t_0 value was found -0.3922 year in this study whereas analyzing the similar species t_0 = -0.590 year was found from the Calicut, India by Devadoss[33] and -0.5664year by Nair[34] from the

Bombay waters, India (Table 3). 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 that these have slower growth[47].

The comparative study of currently estimated growth parameters of *S. laticaudus* and other carcharhinid sharks of the different areas are shown in Table 3. The asymptotic length value for *S. laticaudus* was observed as L_∞= 73.5 cm in this study which was more or less equal to the previous estimations, while the growth coefficient value found as K= 0.3 yr^{-1} was slightly less than the outcomes of other studies from the various parts of the world as compared with this study. So existing analysis of the species *S. laticaudus* of the Bay of Bengal, Bangladeshi waters may indicate that it might have got less growth as compared to the others findings especially Devadoss[33], Mathew et al.[30], Nair[34] and Kasim[31].

The computed total mortality rate of *S. latcaudus* of the present study was higher and lower to some extent with the others which are shown in Table 4. Comparatively, the estimated natural mortality was the lowest among the other reported values from the world except the report of Calicut coast, India in the year 1989 and 1998 by Devadoss[33] in case of *S. laticaudus*. The analyzed fishing mortality rate was also found lower to some extent study compare to other's studies. Similarly, the exploitation value (F/Z) was also recorded as the lowest in the current findings as the observed values of exploitation from the other studies. It has been reported by Beverton and Holt[26] that the M/K ratio ranged from 1.12 to 2.50 has been observed in most the fish species. In the present study, M/K ratio 1.884 which has fallen within the above range. Natural mortality rate is mostly depends on some factors, i.e. predation, old age, environmental stress and parasitic affects or diseases[48]. Exploitation ratio is a measure to estimate the level of utilization of the fishery. The optimum value of utilization is that fishing mortality rate is equivalent to the natural mortality rate[23]. The estimated instantaneous fishing mortality of F= 0.745 yr^{-1} and the natural mortality rate of M= 0.5651 yr^{-1} showed a lower natural mortality rate than the present fishing mortality. According to Gulland[22] criteria, when the exploitation ratio is above 0.5 then the stock is considered as overfished or over-exploited. In this study, the exploitation ratio of E= 0.57 indicates that the stock of *S. laticaudus* is now a little bit over-exploited which may be threatened in future. Therefore, effective management plan should urgently needed to maintain the stock of this fish in the Bay of Bengal, Bangladesh.

GPI is a function of the VBGF parameters of K and L_∞[17]. The comparison of the growth rates is a matter of multiple factors of the growth rate (K) and the asymptotic length (L_∞). As the Phi prime (Φ') response to these criteria, it is easy to express the slight difference when compared to other alternatives indicators[49,50]. There is no previous record on the VBGF parameters of *S. laticaudus* of the Bay of Bengal, Bangladesh and the other adjacent coasts, so it is very hard to compare the existing values with others. Some of the earlier studies of estimating this category may be based on some other methods. According to the Pauly and Munro[28], 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. 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[50]. This index is also endorsed by the von Bertalanffy growth parameters (L_∞ and K) because it facilitates the program between the species and growth[29]. In this study, the estimated value of GPI of the species *S. laticaudus* of both sexes was 3.210 considered to specify slow growth. Apart from the genetic structure, determining growth potential of a species, overfishing, dietary patterns and their utilization may affect in terms of growth performance of a specific species[51].

It is defined as the level of fishing mortality that are now widely used for the conservation and management of fisheries resources[48]. The most familiar points are $F_{0.1}$ and F_{max}, which are frequently used in fisheries management[47]. 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 which is the point at which the marginal gain in YPR decreased to an arbitrary 10% from that at F=0 (Zero).[24,25,50]

The yield per recruit analysis for *S. laticaudus*

was done by using the Beverton and Holt model with knife-edge selection in the FiSAT-II. Biological reference point (BRP) from the procedures F_{opt} as by Patterson[52] which are F_{opt} = 0.565. The isopleth (Figure 7) indicated that when t_c was 1, the F_{max} and $F_{0.1}$ were estimated at 0.95 yr^{-1} and 0.8 yr^{-1} respectively. Since the age of first capture during the current study was approximately one year, the current fishing mortality rate ($F_{current}$) of 0.745 yr^{-1} was higher than F_{opt} but smaller than F_{max} and $F_{0.1}$. Hence the status of *S. laticaudus* stock is now a little bit safe but over-exploited that indicates not so sustainable state, more work is needed in future.

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