Population parameters of Spadenose shark, *Scoliodon laticaudus* in the Bay of Bengal, Bangladesh

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Population parameters of Spadenose shark, *Scoliodon laticaudus* in the Bay of Bengal, Bangladesh

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DECLARATION

Population parameters of Spadenose shark, *Scoliodon laticaudus* in the Bay of Bengal, Bangladesh

The results presented in the thesis with the above mentioned title are entirely of the candidate's own investigations and no part of the results has been accepted for any degree nor is it being concurrently submitted for any degree.

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Dedicated

To

My Beloved Parents

Acknowledgement

At first, all my admiration goes to the supreme creator and Ruler of the universe, the Almighty Allah for His great mercy to keep me alive and enables me to pursue my education in Fisheries and Marine Resource Technology Discipline as well as to complete my work for the degree of Bachelor of Science in Fisheries.

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Md. Tabarok Hossain

September, 2018

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Abstract

Population parameters of Spadenose shark, *Scoliodon laticaudus* in the Bay of Bengal were estimated in the coastal waters of Bay of Bengal. Total 829 Specimen were sampled at five different landing sites from the southern part of the country between March 2017 and February 2018. The study provides information on length weight relationship, growth parameters (growth coefficient, asymptotic length), mortality and recruitment based on monthly length-frequency data using FiSAT II software. The derived length weight relationship was $W = 0.1893L^{1.4574}$ which revealed negative allometric growth. The study estimated Growth parameters: $K = 0.5$ year^{-1} and $L_\infty = 75.6$ cm, Mortality: $Z = 1.97$ year^{-1}, $M = 0.78$ year^{-1} $F = 1.18$ year^{-1}, Length at recruitment: 46.30 cm, and Exploitation ration: 0.60. The exploitation ratio indicates overfishing. Immediate action should be taken to reduce the exploitation. Recruitment pattern showed continuous recruitment with two major peaks per year; one peak in March and other in September. The results obtained from this study would be utilized to manage the unregulated and undersized (<46.30 cm) catches of Spadenose shark population in the Bay of Bangal, Bangladesh.

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List of Abbreviation

CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DoF	Department of Fisheries
E	Exploitation ratio
ELEFAN	Electronic Length Frequency Analysis
F	Fishing mortality
FAO	Food and Agriculture Organization
FiSAT	Federal Institute of Science And Technology
FL	Fork Length
IUCN	International Union for Conservation of Nature
K	Growth coefficient
L	Length
L_∞	Asymptote length
LVPA	Length-structured Von Bertalanffy Growth Function
LWR	Length Weight Relationship
M	Natural mortality
NT	Near Threatened
SL	Standard Length
TL	Total Length
VBGF	Von Bertalanffy Growth Function
VPA	Virtual population analysis
W	Weight
WCS	Wildlife Conservation Society
Z	Total mortality

CHAPTER ONE

INTRODUCTION

1. Introduction

The Spadenose shark (*Scoliodon laticaudus*) is a species under the family *Carcharhinidae*, which is common in the tropical Indian and western Pacific. As it is distinctively flattened with triangular snout, it is called Spadenose shark (Simpfendorfer 2012, FAO 1984). Not being a free swimmer, Spadenose shark are found near shore in shallow waters and being caught in trawl gear as by catch (Devadoss 1998). The Spadenose Shark is distributed with a wider geographical range of Southeast Asia and northeastern Africa. It is commonly recorded from the lower reaches of rivers in at least Malaysia, Sumatra and Borneo and native to Bangladesh, India, Indonesia, Japan, China, Brunei Darussalam, Cambodia, Macao, Malaysia, Myanmar, Oman, Pakistan, Philippines, Singapore, Somalia, Sri Lanka, Taiwan, Province of China, Thailand and Viet Nam (Compagno 1984). It feeds mostly on small benthic fish, cephalopods, crabs and stomatopods (Setna & Sarangdhar 1948, Compagno 1984).

Spadenose shark being placentally viviparous, have the most advanced reproductive system among elasmobranchs. Eggs are ovulated at only 1 mm in diameter and a few millimeters embryos can form the stalked placenta (Wourms 1993).Young are born at size ranges from 12-15 cm. Males become matured at 24-36 cm while females at 33-35 cm (Devadoss 1979, Compagno 1984). Breeding of this species is continuous (Devadoss 1979) and females probably mate at least once each year. The young are born throughout the year, after a gestation period of five or six months (Compagno 1984).

Roy *et al.* (2015) revealed 10 shark's species in Chittagong and Cox'sbazar where Spadenose shark were more abundant covering 22.09 percent of total shark catches in that two landing site. Despite Spadenose covers a huge portion of the catches in Bangladesh, there is insufficient investigation on the abundance, growth and economic turn-over of shark fishery in Bangladesh as well as in the world.

Sharks being apex predators play an important role in marine ecosystem. Sharks are in discriminately targeted for their meat, fins, liver and other products. The global sharks landing has come down since last decade. In India, shark landing increased from 1961 to 1998, but after that it starts to fall down. It has been recorded that sharks landed in 2014 is 70% of historical highest landing. The contribution to marine fisheries is decreased to 0.6% from 3.4% in 2014. Shark fishery in Bangladesh is mostly a non-targeted incidental by-catch which contributes only a small portion (0.94% of the total marine catch) to overall fish production

(0.17%) in Bangladesh (MFSMU 2012). A modified gill net named shark net has been introduced to catch valuable targeted shark species (Roy *et al.* 2007). 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 (FRSS report 2012, 2005, and 2001). 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 (Day 1978, IUCN 2000, Roy *et al.* 2007, Haldar 2010). The associate economy related to shark fishery has been increasing over the time both in domestic and foreign markets (DoF 2015). Though the sharks contribute to marine are increasing over time of marine catch fishery in Bangladesh, very little works have been done so far to explore its population dynamics and biodiversity throughout the entire coastal belt of Bangladesh

Drift gill nets accounted for the landings of large sized sharks due to larger mesh size (Devadoss 1989). The maximum known length of Spadenose shark is 74 cm, although some unsubstantiated reports of reaching 120cm (Compagno 1984). Females grow larger and live longer than males having overall sex ratio 1: 1.31 (Devadoss 1998). The International Union for Conservation of Nature (IUCN) has assessed this species as Near Threatened (IUCN 2000). There is no rules and regulation to encounter dramatic decline of Spadenose shark in the world. Depart of Forestry of Bangladesh have formulated wildlife protection and conservation act 2012 to protect wildlife to uphold the constitution of Bangladesh article no. 18A. The department of forestry also responsible to encounter wildlife trade of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). Department of forestry have enlisted 20 shark species shown in Appendix 1 and 2 of wildlife protection and conservation act 2012. Unfortunately Spadenose shark have not been included in the list.

Although Marine fisheries ordinance 1983 and marine fisheries rules empowered manger to formulate rules and regulation to protect biological species, No rules and regulation have been formulated for shark fishery by the department of fisheries in Bangladesh.

Effective management and formulation of rules and regulation on exploited shark populations requires a sound understanding of the life history of target species. For example, robust estimates of age provide a basis for determining other pertinent parameters such as longevity, growth rate, natural mortality, and hence resilience to various levels of fishing pressure (Goldman 2004).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 (Gonçalves *et al.* 1997). Catch statistics on elasmobranch species are not enough and length weight data which provide a very useful tool for estimating growth rates, length and age structures, and the improvement of the knowledge regarding fish population dynamics are still missing.

However, in the deep-sea region, the large pelagic sharks are distinctly dominating (37%) compared to other pelagic finfishes (Rahman 2007). The economic activities depending on the shark fisheries are growing remarkably day by day both in domestic and export markets (DoF 2015). Very little information is available on Spadenose shark.

As Spadenose shark is well known but very little investigation have been conducted to explore population parameters of these outstanding creature (Sen *et al.* 2017). Though it is more abundant, there are limited age and growth data available for the Spadenose Shark. Although the sharks are important groups of marine catch fishery in Bangladesh, insufficient 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 the population parameters of Spadenose shark (*Scoliodon laticaudus*) of Bangladesh to support formulation of rules and regulation specially targeted species.

Objectives of the study

- To estimate the length-weight relationship growth model of spadenose shark population.
- To estimate the growth, recruitment and mortality of spadenose shark.

CHAPTER TWO

LITERATURE REVIEW

2. Literature Review

Sharks play a crucial functional role as the apex predators in marine ecosystem and being in the top of food chain, are usually found in lower biomass compared to those occupying lower trophic levels (Bonfil 1994, Camhi 1998). Sharks are targeted due to rising demand for their meat, fins, liver and other products that has led to indiscriminate fishing of the resource which is decimating their population. The global shark landing has come down from 893,000 tonnes in 2000 to 766,000 tonnes in 2011 registering a 15% decline in a decade (Dent 2015).

Scoliodon laticaudus, Muller & Henle (1838), one of the smallest tropical under family carcharhinid, is locally known as "*sandhi*" in coastal area of Saurashtra region, India (Fofandi *et al.* 2013). In Bangladesh it is locally familiar as "Churi hangor". Taxonomy of Spadenose shark is as follow:

Kingdom	Animalia
Phylum	Chordata
Class	Chondrichthyes
Order	Carcharhiniformes
Family	Carcharhinidae
Genus	*Scoliodon*
Species	*Scoliodon laticaudus*

Sources: Muller & Henle (1838)

In recent years, elasmobranchs have attracted the attention of the fishing industry because of their fins and flesh which have high utility value in both export market as well as with in the country. Sharks are processed for meat which is sold frozen or dried, for shark fin soup, leather, liver oil and cartilage for export to different countries namely Singapore, Thailand, Malaysia, China and others. However, shark fins are most valuable fetching $60 per 0.5 kg (Cheung 2003).

The earlier works on this species were mostly done on the aspects of taxonomy and distribution. Literature on the biology of Spadenose shark (*Scoliodon laticaudus*) is limited, Those worth mentioning are Mahadevan (1940), Setna and Sarangdhar (1948), Nair (1976), Nair *et al.* (1974), Kulkarni *et al.* (1988) and Devadoss (1979, 1989). The Spadenose Shark is a small species, growing to a maximum length of approximately 74 cm. It feeds mostly on small

benthic fish, cephalopods, crabs and stomatopods (Setna & Sarangdhar 1948, Compagno 1984).

This shark is placentally viviparous, with arguably the most advanced reproductive mode of the elasmobranchs. Eggs are ovulated at only 1 mm in diameter and the stalked placenta forms when the embryos are only a few millimeters in length (Wourms 1993). The young are born at a length of 12-15 cm. Males mature at 24-36 cm and females at 33-35 cm (Devadoss 1979, Compagno 1984). Breeding occurs throughout the year (Devadoss 1979) and females probably mate at least once each year. Litter sizes range from 6-18 cm, with a mean of 13 cm (Devadoss 1979). The young are born throughout the year, after a gestation period of five or six months (Compagno 1984).

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 (Gonçalves *et al.* 1997, Karim *et al.* 2012, Gayanilo 2005). Length- weight relationship (LWR) data can used to determine different fisheries stock assessment (Richter *et al.* 2000). Total biomass can be calculated with length- weight relation data (Petrakis & Stergiou 1995). A lot of studies were conducted on LWR of different fish's species in Turkish waters, also in the Greek Aegean coast (Bilge *et al.* 2014). Gönülal (2017) emphasized on the necessity of determining length weight relationship to do management and conservation of unexplored fishery stock. Length-weight relationship as character can be used in defining taxonomic units, developmental pattern of life like metamorphosis, growth and onset of maturity, and to convert unknown weight from known length or vice versa because weight is function of length. These data are needed to estimate growth rates, length and age structures, and other components of fish population dynamics (Kohler *et al.*, 1996). It also allows fisheries scientists to convert growth-in-length equations to growth-in-weight for stock assessment models (Froese 2015). Length and weight relationships are basic, yet represent fundamental data that are essential to understanding the biological parameters of fishes, which can then be applied to fisheries stock assessment and management (Gonzales *et al.* 2000, Muto *et al.* 2000; Morato *et al.* 2001, Can *et al.* 2002, Abdurahiman *et al.* 2004; and Frota *et al.* 2004). Length weight relationship is an important tools to produce valuable information about biological species. It helps to analysis growth stages. Studies of length-weight relationships are widely used to produce information about biology of various species, helping in the analysis of growth rates, length or weight increase, stage of development of a species (Kohler *et al.*1996). Growth and mortality population

parameters are very important as a basic estimation for stock assessment and management (Kevrekidis and Thessalou-Legaki 2011). Moreover, intense exploitation has resulted in a severe reduction in catches in most countries. While Montgomery *et al.* (2012) stated that estimates of rates of mortality (fishing and natural) are important to stock assessments and to the effective management of fish resources. The instantaneous mortality rate (M) is an important parameter in elasmobranch management and conservation, but is difficult to estimate directly. Thus, indirect estimates based on relatively easily obtained life history parameters are commonly used. Age and growth rate information are one of the most important variables for estimating the status of a population and assessing the risks associated with its exploitation as they constitute the basis for the calculations of mortality rate and productivity (Sabrah 2015).

A study on the description, bionomics and development of *S. sorrakowah*, which is now considered a synonym of *S. laticaudus* was carried out by Setna & Sarangdhar (1948). The age and growth of *S. laticaudus* were studied in Bombay waters by Nair (1976). Devadoss (1984) carried out a detailed study on the maturity, breeding and development of this shark. Devadoss (1989) also studied the growth and population parameters of *S. laticaudus* from Calicut coast, India. Kasim (1991) reported on the shark fishery of Veraval coast with special reference to population dynamics of *S. laticaudus* and *Rhizoprionodon acutus*. Unfortunately, no work has been done on the other aspects of biology like length-weight relationship, food and feeding habits and sex ratio of this shark species from the Bay of Bengal region of Bangladesh. But recently Fofandi *et al.*, (2013) studied about the biological aspects of this species from Saurashtra coast. India. Karim *et al.*, (2017) assessed assessment of demographical trends of *Scoliodon laticaudus* that were analyzed on the basis of monthly length frequency data from the Bay of Bengal, Bangladesh and measured Total length (*TL*) range of 26 to 70 cm, weight (*W*) 329 to 2758 g, relationship of length and weight was $W = 0.3409L^{2.1137}$, $R^2 = 0.9987$, 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 $R_n = 0.112$. They also measured the natural mortality rate at average annual water surface temperature of 22^{0}C was 0.5651 yr^{-1}, the total mortality was 1.31 yr^{-1} while fishing mortality was 0.745 yr^{-1} and the exploitation ratio 0.57.

In India, Mathew and Devaraj (1997) studied the biology and dynamics *of Scoliodon laticaudus* indicates a fast growth of 21.8 cm, 54.5 cm and 65.5 cm, in the first, second, and third year respectively. Growth parameters calculated (on an annual basis) were : K = 0.6812, L_∞ = 74.023 cm, T_0 = 12 years and t_0 = -0.01 year, maximum length was about 66 cm (3.1 years) and weight

growth parameters (on an annual basis) were K = 0.5823, W_∞ = 1756.93 g, t_0= 0.0032 year. The length at birth is 14 cm with a gestation period of 4 months. The study also reported that optimum exploitation level.

Spade nose shark, Scoliodon laticaudus from Calicut coast, The L_∞, K and t_0 values estimated were 715 mm, 0.3580, and 0.590 for females and 676 mm 0.4046 and 0.590 for males respectively and Females grow larger and live longer than males. The average estimated annual catch was 14.4 tonnes at the existing F value of 0.73. (Devadoss 1998).

Jayawardane *et al.* (2002) computed growth performance index (f) for *P. indicus* by using length weight data followed by Moreau and Moreau (1987). Jayawardane *et al.* (2002) used ELEFAN I program to find out L_∞ and K value. He estimated the recruitment patterns of P. indicus to both estuarine and offshore areas with pooled length frequency data from each area using the FiSAT computer programme (Gayanilo and Pauly 2005). Author opinioned the L_∞ were computed or estimated imprecisely (Knight 1968; Roff 1980; Moreau and Moreau 1987) and he performed the length-based Virtual Population Analysis (VPA) to estimate the mean number in the population and the overall fishing mortality by length group. Human and Al-Busaidi (2008) found lower allometric growth coefficient in his study in the Arabian Sea of Oman had decreased slightly during the time interval between the two studies. He mentioned the the higher allometric growth indicates growth rate may have increased at the cost of general condition and may reflect the impact of heavy fisheries pressure on this species in this area.

According to the Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora, the shark is included in Appendix II (Dulvy *et al.* 2014; White *et al. 2008;* Sentosa *et al.* 2017; Haldar 2010, DoF 2015, Bonfil 1994). The International Union for Conservation of Nature (IUCN) has assessed Spadenose shark as Near Threatened (IUCN 2000).

CHAPTER THREE

MATERIALS & METHODS

3. Materials and Methods

3.1. Study area

The fisheries resources exploited from the Bay of Bengal are brought to different landing sites along the coastal region of Bangladesh. Five landing sites as mentioned below were selected for the study area along the coastal region of Bangladesh.

- Rupsha landing site, Khulna
- Bagerhat landing site, Bagerhat
- Parerhat landing site, Pirojpur
- Chittagong landing site, Chittagong.
- Cox's Bazar landing site, Cox's Bazar

Fig. 1. Map of Study Area.

3.2. Sample collection

Sample were collected opportunistically from five selected landing sites in a daily interval throughout the study time with the cooperation of Wildlife Conservation Society (WCS) Bangladesh Progamme. Sample were collected using commercial large and medium size gill net and set bag net. A total number of 829 individual from both sex were sampled from March 2017 to February 2018 at five different landing sites along the coastal zone of Bangladesh.

Total lengths were measured to the nearest 1.0 cm using a soft tape and body weight of each individual were weighted and recorded to nearest gram by using an electronic weighing machine.

3.3. Data processing and analysis

Daily length frequency data were summed up to calculate monthly length frequency distribution. Length measured from 829 sample were grouped in 28 length classes with a class interval 2 started from 17 cm and ended in 73 cm. Data were processed monthly basis and organized according FiSAT II software. Then frequency data were plotted against mid length of length class to obtain length frequency distribution of Spadenose Shark of the Bay of Bengal.

For determining population parameters, mid length of length classes and monthly frequency data were arranged in FiSAT II. Von Bertalanffy growth parameters; asymptotic length (L_∞) and growth coefficient were assessed by using monthly length frequency data in the ELEFAN 1 module of FiSAT II.

The VBGM is a single curve in which growth steadily slows as it approaches an upper asymptote (Von Bertalanffy 1938, Beverton and Holt 1957). This curve is typically expressed as:

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

Parameters of the VBGF;

K= growth coefficient, L_∞= Asymptote length, L_t= Length at the time of t, t_0= age at zero length.

Considering t_0= 0, Equation (1) was modified to calculate length at recruitment as fellow:

$$L_t = L_\infty[1 - e^{-Kt}] \quad \text{.....(2)}$$

Length-weight relationship of Spadenose were estimated by following $W=aL^b$ (Ricker 1975).

Where, W and L represent weight and length of a species respectively, besides, (a) and (b) are constant indicating the body form and the fish growth type. Moreover, the length weight relations were done using the linear regression between logarithm transformed length (L) and Weight (W).

To get growth the instantaneous total mortality rate were estimated by FiSAT II package using the length converted catch curve method. To estimate mortality parameters, length converted catch curve was constructed from the input of VBGF growth parameters (L_∞ and K) through K-scan. Pauly's traditional formula were used to estimate natural mortality.

$$\ln(M) = -0.0152 - 0.279 \ln(L_\infty) + 0.6543 \ln(K) + 0.463 \ln(T) \quad \ldots\ldots\ldots\ldots (2)$$

Fishing mortality were assessed by using following equation, F=Z-M (Gulland 1971) Whereas, Z= Total mortality; F= Fishing mortality; M= Natural mortality Exploitation ration (E) was calculated by equation; E= F/Z (Gulland 1971).

The modal class progression analysis were carried out to refine the growth parameters obtained from ELEFAN 1. Bhattacharya methods was used to compose the composite length frequency distribution to different cohorts for each month.

CHAPTER FOUR

RESULTS

4. Results

4.1. Length-frequency distribution

Total lengths of individual Spadenose shark measured at different landing sites ranged from 17.94 to 71.12 cm. The weights of Spadenose shark ranged from 100 to 900 gm. Length frequency data obtained from present study are represented in Fig. 2. Length frequency distribution showed maximum frequency in the modal group 49-51cm. (Fig. 2).

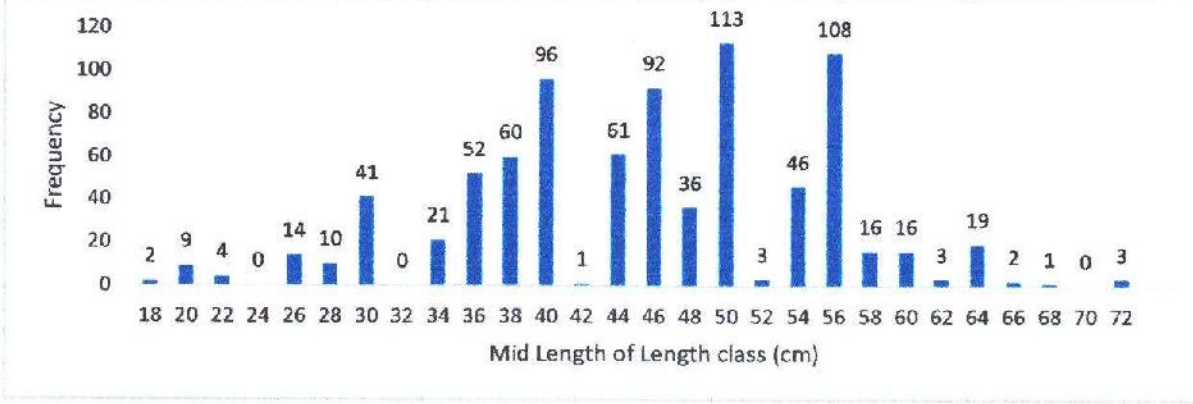

Fig. 2. Length- frequency distribution of Spadenose shark in the Bay of Bengal.

4.2. Length weight relationship

The length weight relationship based on log form of length and weight are shown in Fig. 3. (a). The exponent "b" estimated were 1.4574 with the R^2 of 0.5872.

The derived power equation of length-weight relationship for Spadenose shark was $W=0.1893L^{1.4574}$ and the curve are shown in Fig. 3. (b).

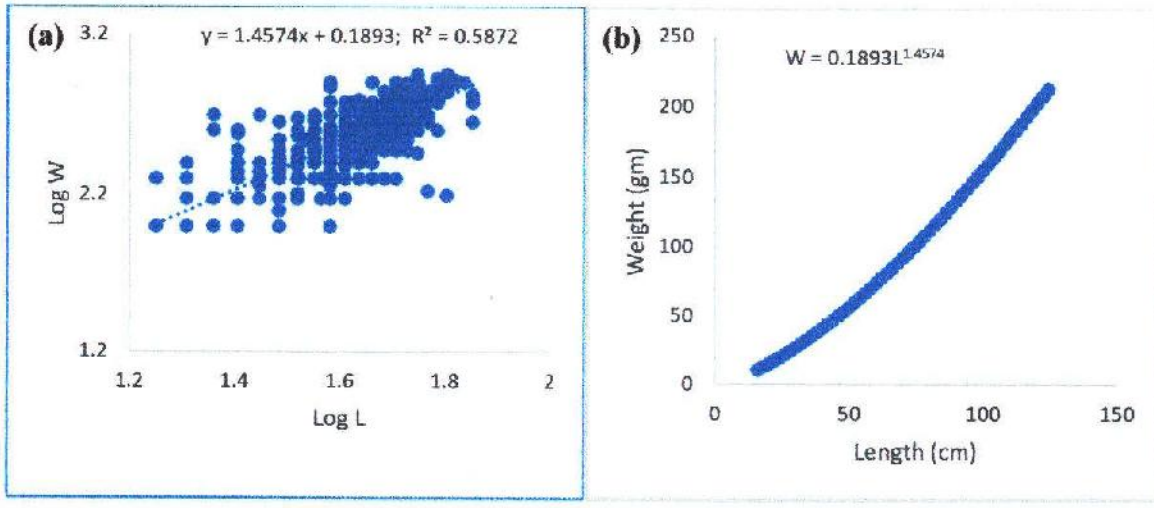

Fig. 3. Scatter plot for length weight data (a); The curve $W= 0.1839L^{1.4574}$ which relates total wet weight to length (b).

4.3. Growth parameters

Growth parameters were computed by Von Bertalanffy Growth Frequency Function (VBGF) and the obtained values were L_{∞}= 75.6 cm and K=0.50 year^{-1}. The graphical output of VBGF is represented in Fig. 4.

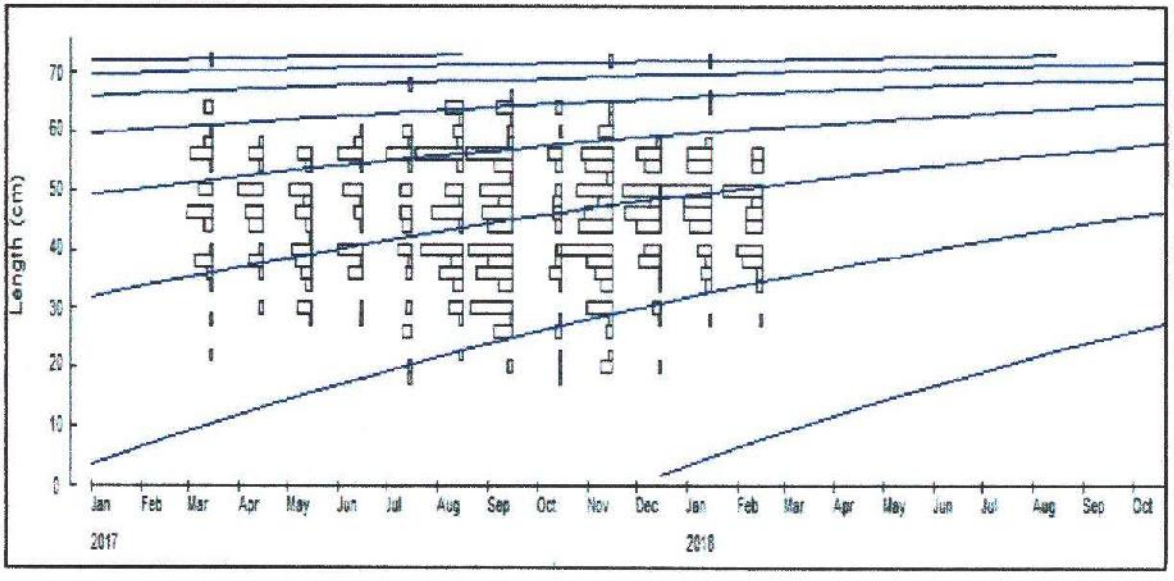

Fig. 4. Von Bertalanffy growth curve of Spadenose shark superimposed on the restructured length frequency histograms in the Bay of Bengal, Bangladesh.

4.4. Mortality estimation

Natural mortality (M) were determined through Pauly's equation and the value was 0.78 year^{-1} at 22 ^{0}C. The instantaneous total mortality for Spadenose shark in the Bay of Bengal was estimated as Z= 1.97 year^{-1} with a class interval from length-converted catch curve (Fig. 5). Fishing mortality was calculated 1.19 year^{-1} by subtracting natural mortality from instantaneous total mortality (Z). The exploitation ratio (E) of the species at study area was 0.60. All the values obtained through Length weight relationship, VBGF and mortality are presented in table 1.

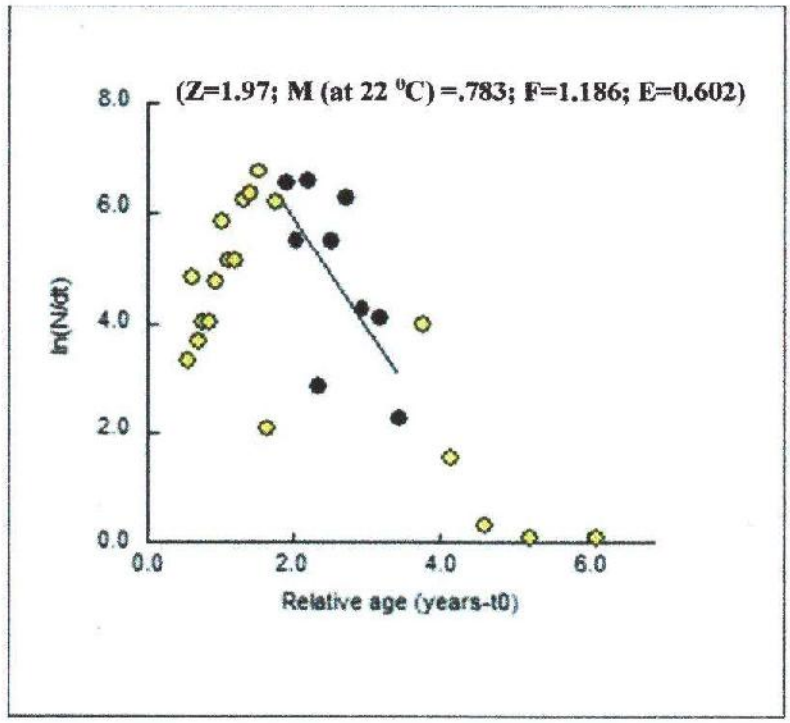

Fig. 5. Length-converted catch curve analysis of Spadenose shark in the Bay of Bengal (2017-2018).

Table 1. Population parameters of Spadenose Shark of the Bay of Bengal during 2017-2018

Population parameters	**Parameters value**
Intercept (a)	0.1893
Slope (b)	1.4574
Coefficient determination (R^2)	0.5872
Asymptotic length (L_∞)	75.6 cm
Growth coefficient (K)	0.50 $year^{-1}$
Total mortality (Z)	1.97 $year^{-1}$
Natural mortality (M)	0.783 $year^{-1}$
Fishing mortality (F)	1.186 $year^{-1}$
Exploitation ratio (E)	0.602 **(Overexploited)**

4.5. Recruitment Pattern

Recruitment pattern of Spadenose shark were analyzed and presented in graphical way in fig. 6. In the figure horizontal axis indicate months of the year and vertical axis represented the percentage of recruitment each month. The recruitment pattern of Spadenose shark showed continuous recruitment with two major picks. One pick was obtained in May and another in December (Fig. 6).

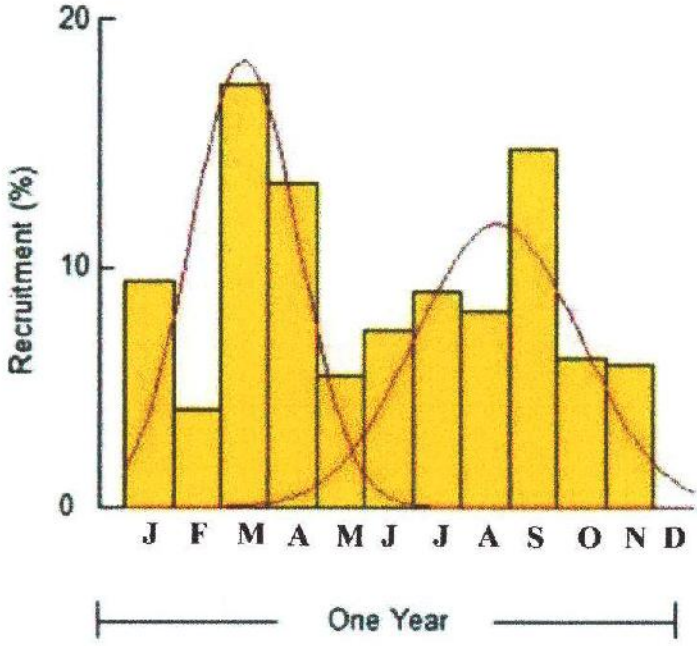

Fig. 6. Recruitment pattern of Spadenose shark of the Bay of Bengal during March 2017 to February 2018.

4.6. Length-structured virtual population

Length-structured virtual population analysis (LVPA) was determined from the input parameters of Von Bertalanffy growth function, length weight relationship and mortality equation by pauly and was shown in graphical representation in Fig. 7. Higher fishing mortality was observed from 52 cm to 58 cm range length class. Different length class showed irregular fishing mortality (Fig.7). Fish catch was found to be started from 35- 37 cm length class.

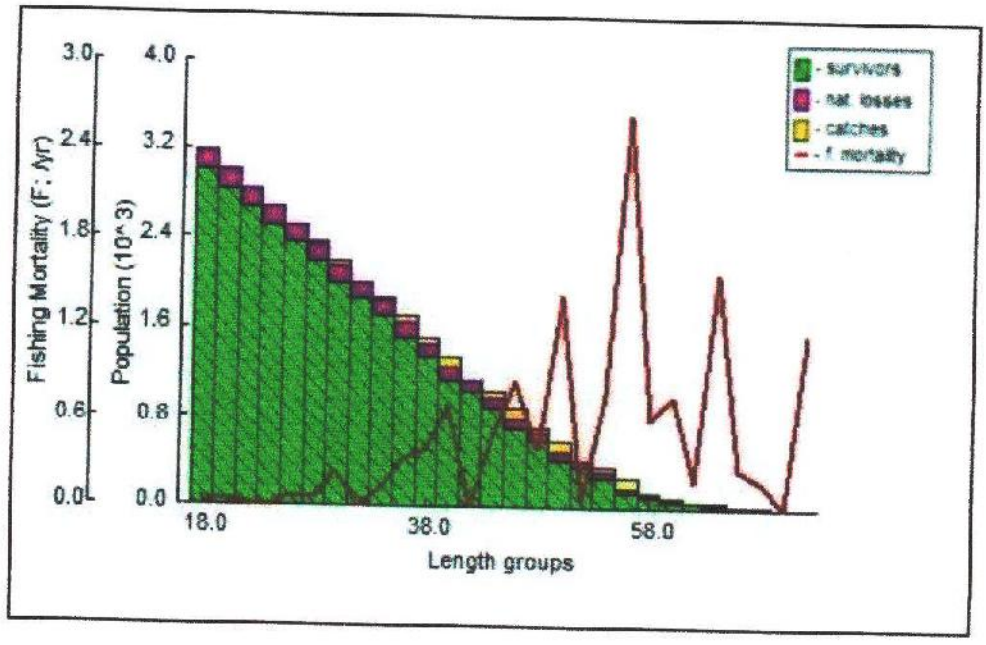

Fig. 7. Length-structured virtual population analysis of Spadenose shark in the Bay of Bengal.

CHAPTER FIVE

DISCUSSION

5. Discussion

The present study estimated the length weight relationship as $W= 0.1893L^{1.4574}$. It is clearly indicated that length weight relationship of Spadenose shark is shaped by negative allometric growth. The result of present study were compared with the results reported by different authors in various geographical region over different time. Karim *et al.*, (2017), Devadoss (1989) and Kasim (1991) observed the increase in weight with respect to length followed by negative allometric While Mathew *et al.*, (1997) recorded positive allometric growth from Maharastra state, India. Karim *et al.*, (2017) and Filiz (2002) explained the reason of difference in investigator as due to sampling time differences of the study time reflecting interpopulation variation.

Avsar (1996) suggested that the functional regression b-values smaller than 3 indicate native allometric while more than 3 indicated positive allometric growth. However, Kutaygil and Bilecik (1998) reported the "b" values for males and females and indicated male were grown faster than female based on "b" value. Mustafa (2008) observed both positive and negative allometric in same geographical location in various species group and mentioned inconsistent results may be come out because of difficulties to obtain sufficient specimen in all size classes.

Length weight relationship can serve as a good tool to induce laws to limit the overexploitation of elasmobranch fishes through direct fishing and bycatch by establishing a minimum catch weight limit with the use of lengths measured at sea (Lteif *et al.* 2016). Mustafa (2008) found the length-weight relationship constants for South Africa (a= 0.0251, b=3.11) are higher than those obtained in the present study. Authors remarked that differences in sampling times of the studies reflecting variation in food availability or differences in water temperatures for both regions. He opinioned that more extensive sampling sizes over a wider geographical range, almost equal representation of sexes, and more detailed demographic analyses including age, growth, and reproduction, is a must to be taken into consideration before certain definities of the life history of these seven species.

K value indicate the time required to achieve $L\infty$. The higher the K value, the faster growth of Spadenose shark.

Table 2. Growth parameters of Spadenose shark in different geographical areas.

Location	Sex	B	Growth	L_∞	K	t_o	Z	M	F	E	Source
Bay of Bengal, Bangladesh	Combined	1.4574	Allometric (-)	75.6	0.5	-	1.97	0.78	1.18	0.60	Current study
Bay of Bengal, Bangladesh	Combined	2.1137	Allometric (-)	73.5	0.3	-0.43	1.3*	0.56	0.75	0.60	Karim *et al.*, (2017)
Calikut, India	Male	2.8905	Allometric (-)	67.6	0.41	0.59	-	-	-	-	Devadoss (1989)
Calikut, India	Female	2.9575	Allometric (-)	71.5	0.35	0.59	-	-	-	-	Devadoss (1989)
Maharastra State, India	Male	3.1914	Allometric (+)	74.02	0.68	-0.01	4.4	0.96	3.41	0.78[c]	Mathew *et al.*,(1997)
Maharastra State, India	Female	3.1799	Allometric (+)	74.02	0.68	-0.01	-	-	-	-	Mathew *et al.*,(1997)
Maharastra State, India	Combined	3.1904	Allometric (+)	74.02	0.68	-0.01	-	-	-	-	Mathew *et al.*, (1997)
Verabal Coast, Gujrat India	Male	2.9349	Allometric (-)	68	1.08	-0.01	3.4	1.53	1.86	0.54[c]	Kasim (1991)
Verabal Coast, Gujrat India	Female	2.7837	Allometric (-)	74.9	0.88	0.88	3.3	1.12	2.2	0.67[c]	Kasim (1991)
India (Calicut)	Female	-	-	71.5	0.36	0.59	1.8	0.72	0.73	0.61[c]	Devadoss (1998)
India (Calicut)	Male	-	-	57.6	0.41	0.59	1.8	0.72	0.73	0.61[c]	Devadoss (1998)
Bombay waters, India	Combined	-	-	75.52	0.27	-0.57	-	-	-	-	Nair *et al.*, (1976)

[Superscript c= calculated Exploitation ratio from Natural and Total mortality where authors did not calculate]

The growth parameter; asymmetric length (L_∞) of Spadenose Shark (SS) was 75.6 cm and growth rate (K) was 0.5 $year^{-1}$ from the combined data (both sexes). The past studies from various geographical locations showed variation in L_∞ and K's values (Table 2). K value ranged from .27 $year^{-1}$ to 1.082 $year^{-1}$. In compere with very recent study conducted in the Bay of Bengal geographical location showed increasing trends in both L_∞ and K values. Karim *et al.*, (2017) determined K= 0.3 $year^{-1}$ and L_∞=73.5 cm respectively which were smaller than present study's outcome. Present study revealed both K and L_∞ had raised in the Bay of Bengal over time.

Devadoss (1998) revealed lowest L_∞ (57.6 cm) from Calicut coast of India compering all other studies (Table 2); in the same study he found L_∞ (71.5 cm) for male. Nair el al. found L_∞ = 75.52 cm from Bombay waters, India which was the closest match with present study but in case of K value he found lowest compering to all other studies which exhibit far difference from present study. The estimates for L_∞ (7.0 – 24.0 cm) and K (1.077±0.328 year-1) obtained were consistent with those available in literature. Relatively high K (and low L_∞) values, typical of short-lived tropical fishes, were obtained for nine species. The growth rate (K) estimates are consistent with for a similar ecosystem like Bangladesh.

The exploitation rate obtained for the 12 species out of the five water bodies are relatively lower compared to other available studies of same species. The estimated instantaneous mortality, natural mortality and fishing mortality of the present study were 1.97 $year^{-1}$, 0.783 $year^{-1}$, 1.186 $year^{-1}$ respectively. Natural mortality estimated by Karim *et al.* (2017) was 0.565 $year^{-1}$ less than that of present study. Kasim (1991) reported natural mortality in in Verabal coast, Gujrat, India for male and female were 1.53 $year^{-1}$ and 1.12 $year^{-1}$ respectively. Maharastra state, india showed greater mortality than present study (Mathew *et al.* 1997). Natural mortality depended on some factors like environmental and parasite and diseases (Gatabu *et al.* 2012). All the studies conduction on Spadenose mortality estimation indicate that fishing mortality is more than that of natural mortality regardless of sex (Table 2).

In this study exploitation ratio (E) was estimated 0.60 while Pauly (1984) suggested optimum E=0.5. E value exceeding 0.5 indicates the stock as overfishing or overexploited. In this study E was 0.60 that more than 0.5 which indicate that the stock was overexploited. Continuous overexploitation at this scale may pose significant decline of the stock. Karim *et al.* (2017) also determined E= 0.60 from the Bay of Bengal which almost similar to present study. Exploitation ratio were calculated from fishing and natural mortality estimation from historical studies and

presented in Table 2. All the E values presented in table 2 are greater than 0.5 which revealed that all stock have been encounter with overfishing historically. Immediate measure should be taken or needed to be concerned with this unregulated catches of Spadenose shark from different geographical region. It is essence to reassess the population parameters of those stock (table 2) to check the condition now a days. There is insufficient investigation to explore Spadenose shark recruitment pattern in the study area as well as in the world. There is no study found to compare recruitment pattern of Spadenose Shark. Pauly (1982) mentioned the importance of recruitment pattern for evaluating stock-recruitment relationship. The recruitment was continuous throughout the year and two major recruitment peaks on March and September. Continuous recruitment throughout the year is a well-known feature for this shark population but major recruitment peak varies in different geographical locations. Pauly (1982) augured that year round recruitment would produce less peaks and troughs.

Fish was found to be started from 35 to 37 cm length class with highest fishing mortality from 52 to 58 cm length classes. Zacharia *et al.* (2016) mentioned that maturity of Spadenose shark obtained at 38 cm.

Considering gestation period (six months) and obtained VBGF [t were calculated from equation (2); $38= 75.6[1 - e^{-0.5 \times t}$, Then t were added up with gestation period (first recruitment age, 1.40+.5=1.9 year), after that, t=1.90 year were used in equation (2) and calculated recruitment length was 46.30 cm)] model 46.30 cm length represent the length starting for the recruitment of Spadenose shark. Therefore, catches of Spadenose shark should be restricted below the 46.30 cm length.

CHAPTER SIX

CONCLUSION

6. Conclusion

Although Spadenose shark is more abundant than any other sharks in Bangladesh, it has given less priority for research. Present study revealed negative allometric growth, more fishing mortality than natural mortality, continuous recruitment with two major peaks in March and September, and overexploitation of Spadenose shark in the study area. In this perspectives, fishing pressure need to be controlled to minimize the overexploitation and to achieve the isometric growth. Recruitment pattern can be used to take initiative to ban undersized (< 46.30 cm) individual during two major recruitment peaks during March and September. The study will give guide lines to make policy and management plan to conserve and protect Spadenose shark from overfishing. It is also necessary to enact rules and regulations to save this most common shark species in the Bay of Bengal.

CHAPTER SEVEN

REFERENCES

7. References

Abdurahiman, K. P., Nayak, T. H., Zacharia, P. U., & Mohamed, K. S. (2004). Length-weight relationship of commercially important marine fishes and shellfishes of the southern coast of Karnataka, India. *NAGA, World Fish Centre Quarterly*, 27(1 & 2), 9-14.

Avsar, D. (1996). Sex, age and growth of the spurdog (*Squalus acanthias Linnaeus*, 1758) in the southeastern Black Sea. *Yugoslav journal of operations research*, 6(2), 295-304.

Beverton, R. J. H. (1957). On the dynamics of exploited fish populations, ministry of agriculture, fisheries and food (London). *Fishery investigations* (2), 19, 553.

Bilge, G., Yapici, S., Filiz, H., & Cerim, H. (2014). Weight-length relations for 103 fish species from the southern aegean sea, turkey. *Acta ichthyologica et piscatoria*, 44(3).

Bonfil, R. (1994). Overview of world elasmobranch fisheries (No. 341). *Food & Agriculture* Organisation, *Rome, Italy*

Camhi, M. (1998). Sharks and their relatives: ecology and conservation (No. 20). *International Union for Conservation of Nature.*

Can, M. F., Başusta, N., & Cekiç, M. (2002). Weight-length relationships for selected fish species of the small-scale fisheries off the south coast of Iskenderun Bay. *Turkish Journal of Veterinary and Animal Sciences*, 26(5), 1181-1183.

Cheung, G. C., & Chang, C. Y. (2003). Sustainable business versus sustainable environment: A case study of the Hong Kong shark fin business. *Sustainable Development*, 11(4), 223-235.

Compagno, L.J.V. (1984). 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*, 251–655.

Day, F. (1978). The Fishes of India, being a natural history of the fishes known to inhabit the seas and freshwater of India, *Burma and Ceylon* (Vol-1, New Delhi), p. 730-745.

Dent, F., & Clarke, S. (2015). State of the global market for shark products. *FAO Fisheries and Aquaculture technical paper*, (590), I.

Devadoss, P. (1979). Observations on the maturity, breeding and development of *Scoliodon laticaudus* Muller and Henle off Calicut coast. *Journal of the Marine Biological Association of India*, 21(1 & 2), 103-110.

Devadoss, P. (1984). Observations on the maturity, breeding and development of *Scoliodon laticaudus* off Calicut coast. *Journal of the Marine Biological Association of India*, 2, 103-110.

Devadoss, P. (1989). Observations on the length-weight relationship and food and feeding habits of spade nose shark, *Scoliodon laticaudus* Muller and Henle. *Indian Journal of Fisheries*, 36(2), 169-174.

Devadoss, P. (1998). Growth and population parameters of the spade nose shark, *Scoliodon laticaudus* from Calicut coast. *Indian Journal of Fisheries*, 45(1), 29-34.

DoF. (2015). National Fish Week, Compendium (In Bengali). *Department of Fisheries, Ministry of Fisheries and Livestock*, Bangladesh.

Dulvy, N. K., Fowler, S. L., Musick, J. A., Cavanagh, R. D., Kyne, P. M., Harrison, L. R., & Pollock, C. M. (2014). Extinction risk and conservation of the world's sharks and rays. *eLife*, 3, 590.

FAO. (1984). FAO Species Identification Sheets, Fishing Area 51. *FAO Rome, Italy* 13p.

Filiz, H., & Mater, S. (2002). A preliminary study on length-weight relationships for seven elasmobranch species from North Aegean Sea, Turkey. *EÜ Su Ürünleri Dergisi*, *19*(3-4), 401-409.

Fofandi, M., Zala, M.S. and Koya, M. (2013). Observations on selected biological aspects of the spadenose shark (*Scoliodon laticaudus* Müller & Henle, 1838), landed along Saurashtra coast. *Indian Journal of Fisheries*, *60*(1), 51-54.

Froese, R., Walters, C., Pauly, D., Winker, H., Weyl, O. L., Demirel, N., & Holt, S. J. (2015). A critique of the balanced harvesting approach to fishing. *ICES Journal of Marine Science*, 73(6), 1640-1650.

Frota, L. O., Costa, P. A. S., & Braga, A. C. (2004). Length-weight relationships of marine fishes from the central Brazilian coast. *NAGA, WorldFish Center Quarterly*, 27(1-2), 20-26.

FRSS. (2001). Fisheries Statistical Report of Bangladesh, Fisheries Resources Survey System (FRSS), *Department of Fisheries*, Bangladesh.

FRSS. (2007). Fisheries Statistical Report of Bangladesh, Fisheries Resources Survey System (FRSS), *Department of Fisheries*, Bangladesh.

FRSS. (2012). Fisheries Statistical Report of Bangladesh, Fisheries Resources Survey System (FRSS), *Department of Fisheries*, Bangladesh.

Gayanilo, F. C., Sparre, P., & Pauly, D. (2005). FAO-ICLARM stock assessment tools II: User's guide (No. 8). *Food and Agriculture Organization.* Rome, Italy.

Getabu, A. (1992). Growth parameters and total mortality in *Oreochromis niloticus* (Linnaeus) from Nyanza Gulf, Lake Victoria. *Hydrobiologia*, 232(1), 91-97.

Goldman, K., & Cailliet, G. (2004). Age determination and validation in chondrichthyan fishes. *Biology of sharks and their relatives, CRC Press*, 399-447.

Gonçalves, J. M. S., Bentes, L., Lino, P. G., Ribeiro, J., Canario, A. V., & Erzini, K. (1997). Weight-length relationships for selected fish species of the small-scale demersal fisheries of the south and south-west coast of Portugal. *Fisheries Research*, 30(3), 253-256.

Gönülal, O. (2017). Length-Weight Relationships of 16 Fish Species from Deep Water of Northern Aegean Sea (500-900 m). *Turkish Journal of Fisheries and Aquatic Sciences*, 17(5), 995-1002.

Gonzales, B. J., Palla, H. P., & Mishina, H. (2000). Length-weight relationship of five serranids from Palawan Island, Philippines. *Naga, the ICLARM Quarterly*, 23(3), 26-28.

Gulland, J.A. (1971). The Fish Resources of the Ocean. *Fishing News Books Ltd, for FAO, West By fleet, Surrey*, p. 255 55–67.

Haldar, G. C. (2010). National plan of action for shark fisheries in Bangladesh. Sustainable Management of Fisheries Resources of the Bay of Bengal. *Bangladesh Fisheries Research Institute*, Bangladesh, 75-89.

Human, B. A., & Al-Busaidi, H. (2008). Length and Weight Relationships for 31 Species of Fishes Caught by Trawl Off the Arabian Sea Coast of Oman. *Journal of Agricultural and Marine Sciences (JAMS)*, *13*, 43-52.

IUCN (International Union for the Conservation of Nature), The Threatened Fishes of Bangladesh. IUCN-The World Conservation Union, Bangladesh Country Office, Dhaka Bangladesh, (2000).

Jayawardane, P. A. A. T., McLusky, D. S., & Tytler, P. (2002). Estimation of population parameters and stock assessment of Penaeus indicus (H. Milne Edwards) in the western coastal waters of Sri Lanka. *Asian Fisheries Science*, *15*(2), 155-166.

Karim, E., Qun, L. I. U., Mahmood, M. A., Baset, A., Hoq, M. E., Shamsuzzaman, M. M., & Das, A. (2017). Assessment of some demographic trends of Spadenose shark (*Scoliodon laticaudus*) of the Bay of Bengal, Bangladesh. *Indian Journal of Geo-Marine Sciences*, 46(10), 1986-1995

Karim, E., Zaher, M., Barua, S., Rahman, M. J., & Hoq, E. (2012). Catch composition, seasonal abundance and length-weight relationship of elasmobranch species of the Bay of Bengal, Bangladesh. *Bangladesh Journal of Fisheries Research*, 15-16.

Kasim, H. M. (1991). Shark fishery of Veraval coast with special reference to population dynamics of *Scoliodon laticaudus* (Muller Andhenle) and *Rhizoprionodon acutus* (Ruppell). *Journal of the Marine Biological Association of India. Cochin*, 33(1), 213-228.

Kevrekidis, K., Thessalou-Legaki, M. (2011). Population dynamics of Melicertus kerathurus (Decapoda: Penaeidae) in Thermaikos Gulf (N. Aegean Sea). *Fisheries Research*.107 (1–3), 46–58.

Knight, W. (1968). Asymptotic growth: an example of nonsense disguised as mathematics. *Journal of the Fisheries Board of Canada*, 25(6), 1303-1307.

Kohler, N. E., Casey, J. G., & Turner, P. A. (1996). Length-length and length-weight relationships for 13 shark species from the Western North Atlantic. *US Dep Commer. NOAA Tech Memo NMFS NE*, 110, 22.

Kulkarni, G. N., Shanbhogue, S. L., & Udupa, K. S. (1988). Length-weight relationship of *Scoliodon laticaudus* muller and henle and *Carcharhinus limbatus* (muller and henle), from dakshina kannada coast. *Indian Journal of Fisheries*, 35(4), 300-301.

Kutaygil, N., & Bilecik, N. (1998). Studies on a shark species, picked dogfish (*Squalus acanthias* L.) distributed along the Anatolian littoral zones in the Black Sea. *Ministry of Agriculture and Rural Affairs, Fisheries Enst. Publ*, (2), 71.

Lteif, M., Mouawad, R., Jemaa, S., Khalaf, G., Lenfant, P., & Verdoit-Jarraya, M. (2016). The length-weight relationships of three sharks and five batoids in the Lebanese marine waters, eastern Mediterranean. *The Egyptian Journal of Aquatic Research*, 42(4), 475-477.

Mahadevan, G. (1940). Preliminary observations on the structure of the uterus and the placenta of a few Indian elasmobranchs. In Proceedings of the Indian Academy of Sciences-Section B *Springer India*, 11(1), 1-44.

Mathew, C. J., & Devaraj, M. (1997). The biology and population dynamics of the spadenose shark *Scoliodon laticaudus* in the coastal waters of Maharashtra State, India. *Indian Journal of Fisheries*, 44(1), 11-27.

MFSMU (Marine Fisheries Survey and Management Unit). (2012). Marine fisheries resources and its management practices in Bangladesh. *Annual Report. MFSMU, CGO Building-1*. Chittagong, Bangladesh 13.

Montgomery, S.S., Barchia, I.M., Walsh, C.T. (2012). Estimating rates of mortality in stocks of Metapenaeus macleayi in estuaries of eastern Australia. *Fisheries Research*, 113(1).

Morato, T., Afonso, P., Lourinho, P., Barreiros, J. P., Santos, R. S., & Nash, R. D. M. (2001). Length–weight relationships for 21 coastal fish species of the Azores, north-eastern Atlantic. *Fisheries Research*, 50(3), 297-302.

Moreau, J., & Moreau, I. (1987). Fitting of von Bertalanffy growth function (VBGF) with two growth checks per year. *Journal of applied ichthyology*, 3(2), 56-60.

Mustafa, M. G., & de Graaf, G. (2008). Population parameters of important species in inland fisheries of Bangladesh. *Asian Fisheries Science, 21*(2).

Muto, E. Y., Soares, L. S. H., & Wongtschowski, B. R. (2000). Length-weight relationship of marine fish species off São Sebastião system, São Paulo, Southeastern Brazil. *Naga, the ICLARM quarterly*, 23(4), 27-29.

Nair, K. P. (1976). Age and growth of the yellow dog shark *Scoliodon laticaudus* Muller and Henle from Bombay waters. *Journal of the Marine Biological Association of India*, 18(3), 531-539.

Nair, R. V., Appukuttan, K. K., & Rajapandian, M. E. (1974). On the systematics and identity of four pelagic sharks of the family Carcharhinidae from Indian Region. *Indian Journal of Fisheries*, 21(1), 220-232.

Pauly, D. (1982). Studying single-species dynamics in a tropical multispecies context. In Theory and management of tropical fisheries. *ICLARM Conference Proceedings* (Vol. 9, No. 360, pp. 33-70). Manila, Philippines: International Centre for Living Aquatic Resources.

Pauly, D. (1984). Fish population dynamics in tropical waters: a manual for use with programmable calculators (Vol. 8). *WorldFish*.

Petrakis, G., & Stergiou, K. I. (1995). Weight-length relationships for 33 fish species in Greek waters. *Fisheries research*, 21(3-4), 465-469.

Rahman, M. J. (2007). Ecosystem-Based Fishery Management in the Bay of Bengal (A deep-sea resource survey Project Implemented by BIMSTEC). A brief national report, Bangladesh.

Richter, H., Luckstadt, C., Focken, U., & Becker, K. (2000). An improved procedure to assess fish condition on the basis of length-weight relationships. *Archive of Fishery and Marine Research*, 48(3), 255-264.

Ricker, W.E. (1975). Computation and interpretations of biological statistics of fish populations. Bull. *Fisheries Res*earch.191, p. 382.

Roff, D. A. (1980). A motion for the retirement of the von Bertalanffy function. *Canadian Journal of Fisheries and Aquatic Sciences*, 37(1), 127-129.

Roy, B. J., Singha, N. K., Rhaman, M. G., & Ali, A. H. M. H. (2015). Status and recorded of sharks and rays in the Bay of Bengal of Bangladesh Region. Brazilian Journal of Biological Sciences, 2(4), 343-367.

Roy, B.J., Dey, M.P., Alam, M.F. and Singha, N.K. (2007), Status of shark fishing in the marine water of Bangladesh. *UNEP/CMS/MS/Inf/10.* 17.

Sabrah, M. M., El-Sayed, A. Y., & El-Ganiny, A. A. (2015). Fishery and population characteristics of the Indian squids Loligo duvauceli Orbigny, 1848 from trawl survey along the north-west Red Sea. *The Egyptian Journal of Aquatic Research*, 41(3), 279-285.

Sen, S., Chakraborty, S. K., Vivekanandan, E., Zacharia, P. U., Kizhakudan, S. J., Jaiswar, A. K., & Jayshree, G. (2017). Population dynamics and stock assessment of milk shark, *Rhizoprionodon acutus* (Ruppell, 1837) along Gujarat coast of India. *NISCAIR-CSIR*, India.

Sentosa, A. A., Dharmadi, D., & Tjahjo, D. W. H. (2017). Parameter populasi hiu martil (*Sphyrna lewini* griffith & smith, 1834) di perairan selatan nusa tenggara. *Jurnal Penelitian Perikanan Indonesia*, 22(4), 253-262.

Setna, S. B., & Sarangdhar, P. N. (1948). Description, bionomics and development of *Scoliodon sorrakowah* (Cuvier). *Records of the Indian Museum*, 46(1), 25-53.

Simpfendorfer, C., (2012). "*Scoliodon laticaudus*". IUCN Red List of Threatened Species. Version- 2. *International Union for Conservation of Nature.*

Von Bertalanffy, L. (1938). A quantitative theory of organic growth (inquiries on growth laws. II). *Human biology*, 10(2), 181-213.

White, W. T., Bartron, C., & Potter, I. C. (2008). Catch composition and reproductive biology of *Sphyrna lewini* (Griffith & Smith) (Carcharhiniformes, Sphyrnidae) in Indonesian waters. *Journal of Fish Biology*, 72(7), 1675-1689.

Wourms, J.P. (1993). Maximization of evolutionary trends for placental viviparity in the spadenose shark, *Scoliodon laticaudus. Environmental Biology of Fishes* 38: 269–294.

Zacharia, P.U., Dineshbabu, A.P.,Thomas, S.,Kizhakudan, S. J.,Vivekanandan, E.,Pillai, S. L., Sivadas, M.,Ghosh, S., Ganga, U.,Rajesh, K.M., Rekha J. N.,Rajesh, K. M., Najmudeen, M. K., Anulekshmi Chellappan, Dash, G., Divipala, I., Akhilesh, I., Muktha, M., Dash, S. S. (2016). Relative vulnerability assessment of Indian marine fishes to climate change using impact and adaptation attributes. *CMFRI Special Publication No. 125, (CMFRI-NICRA Publication no. 5), Central Marine Fisheries Research Institute*, Kochi, India pp. 192.

CHAPTER EIGHT

PHOTO GALLERY

8. Photo gallery

Fig. 8. Photo of Spadenose shark's length measuring from landing site

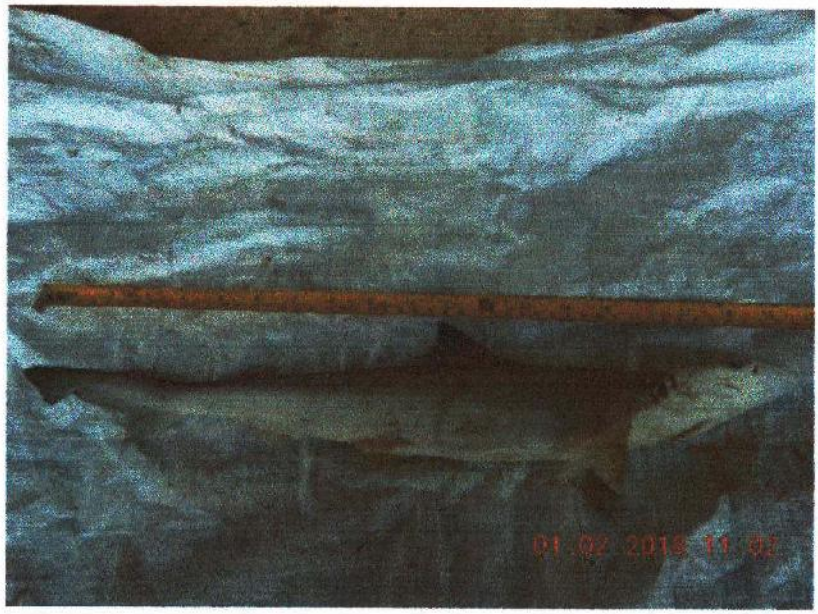

Fig. 9. Photo of Spadenose shark's length measuring from landing site

Fig. 10. Photo of Spadenose shark's length measuring from landing site

Fig. 11. Photo of Spadenose shark's length measuring from Cox's bazar's landing site

Fig. 12. Photo of Spadenose shark's length measuring from Cox'sbazar landing site

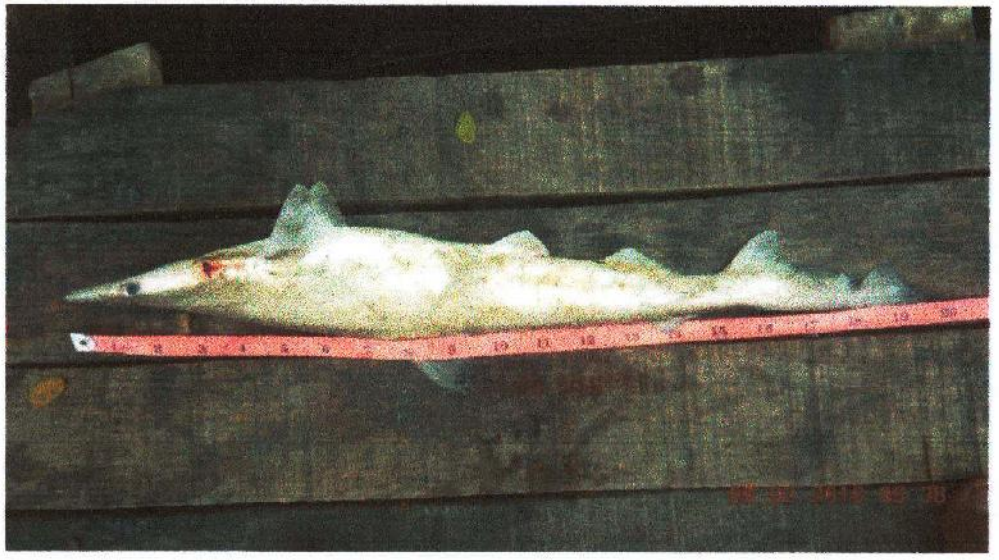

Fig. 13. Photo of Spadenose shark's length measuring from Bagerhat's landing site

WCS Bangladesh
A Wildlife Conservation Society Program

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04 November 2018

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Subject: Authorization of using data for scientific research and publication

TO WHOM IT MAY CONCERN

This letter certifies that Md. Tabarok Hossain, WCS Bangladesh Marine Megafauna Program Data Manager is authorized to use Spadenose shark length-weight data collected by WCS from different fish landing sites between March 2017 and February 2018. The data will be used for his M.Sc research title "Population parameters of Spadenose shark, *Scoliodon laticaudus* in the Bay of Bengal, Bangladesh".

WCS will not be liable for data processing and outcome of the research work. However, I have advised Mr. Hossain that, due to problems with non-random sampling, he should present the results as preliminary and discuss potential biases in how the data was collected and how these potential biases may have affected the results. This should be explicitly addressed in the thesis (preferably in its own section or chapter) to strengthen its scientific rigor and to avoid confusion about how the results should be applied to fisheries management. WCS also requests an opportunity to review any publications/articles that are prepared using these data before submission for publication.

We wish the outcome of the research will contribute WCS conservation efforts in the Bay of Bengal. It is expected that all necessary support and cooperation may be extended to him.

Yours Sincerely,

/Brian Smith

Brian D. Smith