



Research Article

Temporal Variation of Biometric Indices for *Megalaspis cordyla* (Linnaeus, 1758) from the Bay of Bengal, Bangladesh

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Abstract | This study described the population sizes structure, growth pattern, maturity size (L_m), and optimum catchable size (L_{opt}) of *Megalaspis cordyla*. Fish were sampled (male = 720, female = 793) from commercial vessels operating in the Bay of Bengal (BoB), Bangladesh between January-December 2020. All lengths (TL, total; FL, fork; SL, standard length), were taken using a fish measuring board to 0.01 cm as well as a digital balance is used to weigh body weight (BW) to 0.01 g precision. The size structure (length-frequency distributions, LFDs) indicated that the males with TL 22.0-22.9 cm and females with 29.0-29.9 cm size group were statistically more appeared. The TL and BW varied between 11.5-53.0 cm and 27.6 to 1228.0 g for males, and 18.2-45.0 cm and 57.0 to 728.0 g for females. The length-weight relations (LWRs) were significantly correlated ($p < 0.0001$), with values of $r^2 \geq 0.961$. The monthly co-efficient (b) revealed negative allometric growth (< 3.0) of all LWRs for both sexes, excluding males showed isometric growth in December (TL *vs.* BW). Additionally, length-length relationships (LLRs) indicated notable relation ($p < 0.0001$), with all $r^2 \geq 0.991$. The estimated L_m was 27.82 and 23.92 cm for male and female of *M. cordyla*, separately. The assessed L_{opt} were 24.87 cm for females and 29.13 cm for males. Accordingly, this research will be a guide to the study of stock assessment, physiology, and biology for *M. cordyla* in the BoB and the related ecosystems.

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Keywords | Bay of Bengal (BoB), Growth pattern, *Megalaspis cordyla*, Population structure, Size at sexual maturity



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Introduction

Carangid is identified as the main pelagic fisheries resource in the Bay of Bengal. *Megalaspis cordyla*

(Linnaeus, 1758) is a migratory pelagic species, found through inshore and offshore oceanic waters, with depths ranging from around 20 to 100 meters (Al-Sakaff and Esseen, 1999). Torpedo scad forms most of

the carangid catches as a dominant species. This species has a good quality of flesh and is marketed in fresh, salted, and dried conditions (FAO, 2009). *M. cordyla* is abundant in the tropical and subtropical Indian Ocean as well as the west Pacific Ocean (Smith-Vaniz, 1999). This species is found from the South-East African coastline to the Persian Gulf along with the Red Sea (Froese and Pauly, 2021). Trawls, purse seines, and drift gill nets are popular methods of catching this species (Sivakami, 1995). The maximum size was recorded as 80 cm (Smith-Vaniz, 1984) and the body weight was found 4 kg (Bykov, 1983), although it is common at lengths of 45 cm (Bouhleh, 1988).

Length-frequency distributions (LFDs) are an essential biometric criterion for detecting dynamic recruitment, growth, and mortality rates (Neuman and Allen, 2001). Also, LFD is an important indicator of stock status, and spawning period, including the ecology of fish (Ranjan *et al.*, 2005; Khatun *et al.*, 2019). Besides, LFD is useful for the comparison of morphology within species or populations of definite species from varied inhabitants (Hossain *et al.*, 2013). Furthermore, length-weight relationships (LWRs) are crucial for assessing fish well-being and identifying potential discrepancies between various unit stocks (Hossain *et al.*, 2010; Parvin *et al.*, 2021; Sarmin *et al.*, 2021a), while also essential for determining stock status, biomass, and maximum sustainable yield (Anderson and Gutreuter, 1983; Rahman *et al.*, 2020; Sarmin *et al.*, 2021b; Sabbir *et al.*, 2022). Moreover, the length-length relationships (LLRs) are significant as a number of physiological features are related to length (Sabbir *et al.*, 2020). The maturity length (L_m) is the most significant attribute to explain the reproductive biology of fish species that aid in the conservation and sustainable management of fish stock. Fish's sexual maturity length is used to determine the lowest-permeable size to catch (Parvin *et al.*, 2022) and is crucial in identifying the causes of changes in maturity size (Templeman, 1987). The L_{opt} aids in the fishing gear selection with appropriate mesh sizes and the restriction of catching fish below this permissible catch size for sustainable management (Mawa *et al.*, 2021).

Some studies with different aspects of *M. cordyla* have been carried out from worldwide waterbodies but knowledge on size structure, growth pattern, and sexual maturity for this species are very limited in the Bay of Bengal (BoB) from Bangladesh. As a consequence, this

study revealed the precise explanation of population size structure, monthly variations of length-weight and length-length relationships, and length of maturity for *M. cordyla* in the BoB exploited by seine net and drift gillnet units to provide necessary details for proper management of the species.

Materials and Methods

Sampling and data collection

The individuals of *M. cordyla* (male, 720 and female, 793) were sampled from the Bay of Bengal by commercial fishers with seine nets (mesh size of 1.5 to 3 cm) and gill nets (mesh size of 3 cm) during January to December 2020. The specimens of different size groups were collected randomly. For each sample, body weight (BW) and lengths (total, TL; fork, FL; standard, SL) were recorded with an electronic weighing balance and the standard fish measuring board to 0.01 g accuracy and 0.01 cm, respectively.

Population structure and growth pattern

Population structure through LFDs for *M. cordyla* was assembled with TL of 1 cm intervals. The growth pattern was obtained by the equation of LWRs: $W = a \times L^b$, where W points to body weight (g) and L denotes lengths (TL, FL, and SL) in cm. Based on natural logarithms, the parameters a and b were obtained through the linear regression analysis: $\ln(W) = \ln(a) + b \ln(L)$. A t-test was done to check how the calculated b values were significantly altered from 3.0 (Sokal and Rohlf, 1987), specifying isometric growth ($b = 3.0$), and allometric growth ($b > 3.0$, positive), or ($b < 3.0$, negative) (Tesch, 1971; Das *et al.*, 2014). The LLRs (TL *vs.* FL, SL) have also been evaluated with the analysis of linear regression.

Maturity length (L_m)

The L_m for *M. cordyla* was obtained following $\log(L_m) = -0.1189 + 0.9157 \times \log(L_{max})$, where L_{max} indicates the maximum length recorded (Binohlan and Froese, 2009). The length of optimum catchable size (L_{opt}) was calculated by $\log(L_{opt}) = 1.053 \times \log(L_m) - 0.0565$ (Froese and Binohlan, 2000). Besides, the maximum lengths of diverse populations were derived from accessible data to describe the size of sexual maturity as well as optimum catchable size in aquatic bodies all over the world.

Statistical analysis

We used Microsoft® Excel-add-in-DDXL and

GraphPad Prism 6.5 software to conduct statistical analyses in all cases with the significance level of 5%. The homogeneity and normality of the data were checked by the Shapiro-Wilk test. The test of Mann-Whitney U was followed to link the mean values of the two sexes. The Spearman rank correlation test has been considered to examine the LWRs and LLRs for male and female.

Results and Discussion

Population structure

The length frequency (LFDs) of *M. cordyla* revealed that the size range was 11.9-53.9 and 18.9-45.9 cm TL for males and females, respectively. Further, the population showed that 22.0-22.9, 28.0-28.9, 29.0-29.9 cm of TL size groups contain 51, 50, 50 individuals for male indicated dominant group and 29.0-29.9 and 30.0-30.9 cm group with 68 and 61 individuals were precisely dominant for the female population, respectively (Figure 1). Furthermore, Mann-Whitney U-test revealed significant variances between males and females for LFD ($U = 219764$, $p = 0.0001$). The TL ranged between 10.5-53.0 cm for males, while 18.2-45.0 cm for females (Figure 2). In this study, also the BW varied from 27.6 to 1228.0 g for the male population and 57.0 to 728.0 g for females (Table 1). Besides, Mann-Whitney U-test indicated that the BW of both sexes was significantly different (Mann-Whitney $U = 213311$, $p = 0.0001$).

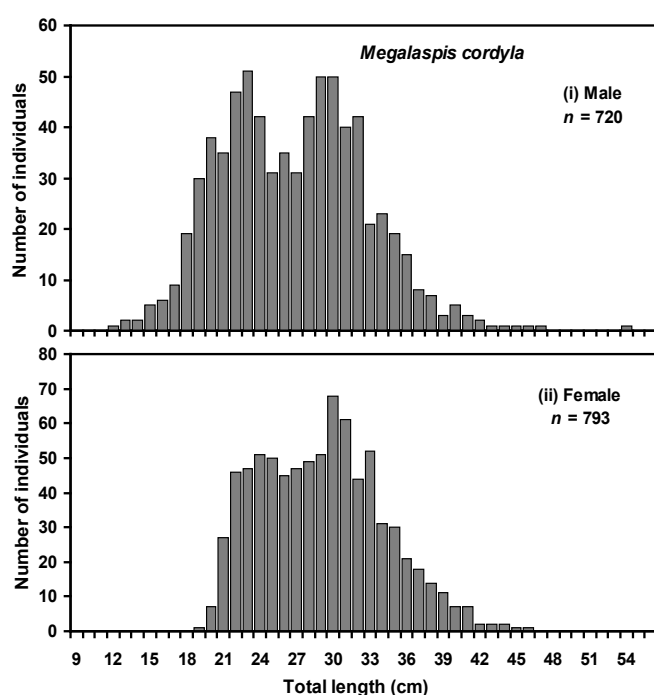


Figure 1: Length-frequency distributions for (i) male and (ii) female of *Megalaspis cordyla* (Linnaeus, 1758) in the Bay of Bengal, Bangladesh.

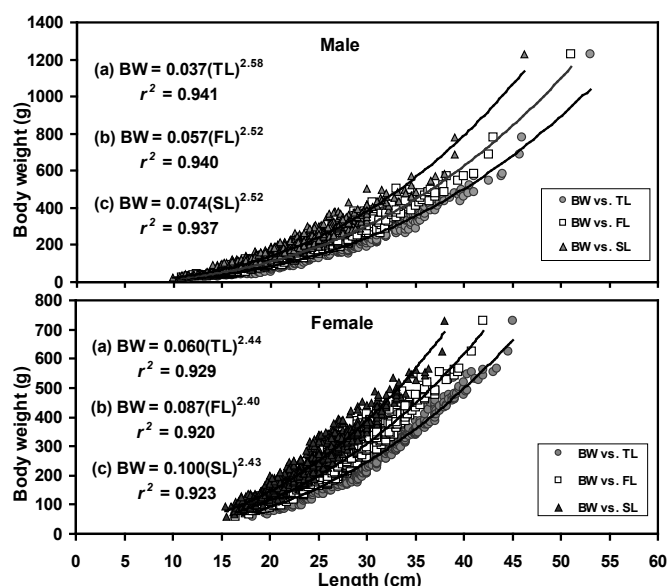


Figure 2: Length-weight relationships of *Megalaspis cordyla* (Linnaeus, 1758) in the Bay of Bengal, Bangladesh.

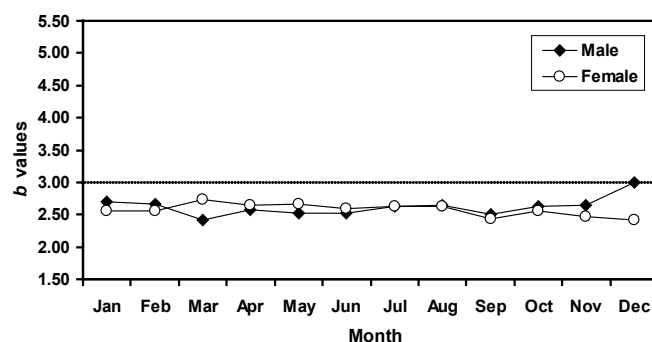


Figure 3: Monthly changes of growth coefficient (b) for *Megalaspis cordyla* (Linnaeus, 1758) in the Bay of Bengal, Bangladesh.

Growth pattern

The study further stated that the overall, as well as monthly b values for both males and females specified negative allometric growth ($b < 3.0$) (Figure 3). However, males exhibited isometric growth ($b = 3.0$) in December. The variances in the " b " value were observed from 2.35 to 3.0 with the correlation coefficient (r^2) of 0.927 to 0.987 for all LWRs. The monthly sample size (n), regression parameters with 95 percent confidence limit of the LWRs, and r^2 values of *M. cordyla* were presented in Tables 2, 3, 4. Followed by the Spearman rank correlation test, BW and TL, FL, SL had identical significant relationships. Moreover, ANCOVA revealed statistical differences in LWRs between the male and female populations ($p < 0.0001$). The LLRs (TL vs. FL, SL) showed prominent relation ($p < 0.0001$), with $r^2 \geq 0.960$ (Tables 5, 6 and Figure 4). The LWRs were extremely significant ($p < 0.0001$), with the values of $r^2 \geq 0.961$ (Table 7). Also, the Spearman rank correlation test presented substantial relationships among TL and FL, SL (Table 7).

Table 1: Descriptive statistics on the length (cm) and weight (g) measurements of male and female *Megalaspis cordyla* (Linnaeus, 1758) in the Bay of Bengal, Bangladesh during January–December, 2020.

Months	Sex	n	TL (cm)				BW (g)			
			Min	Max	Mean ± SD	95% CL	Min	Max	Mean ± SD	95% CL
January	M	25	17.0	29.5	22.46±2.97	21.23-23.68	57.21	302.0	133.81±52.07	112.32-155.31
	F	40	20.0	29.4	24.16±2.70	23.30-25.03	98.94	293.0	165.24±50.33	149.15-181.34
February	M	52	17.0	33.8	23.93±3.85	22.86-25.00	50.00	353.0	157.23±69.26	137.95-176.51
	F	48	20.0	34.0	25.13±3.70	24.06-26.21	92.00	358.0	182.03±70.64	161.52-202.54
March	M	59	17.0	33.0	24.03±3.74	23.06-25.01	77.00	432.0	178.31±73.62	159.12-197.49
	F	86	19.0	34.5	24.92±3.73	24.13-25.72	85.00	437.0	192.09±84.92	173.89-210.30
April	M	50	18.0	35.0	24.46±4.60	23.15-25.77	57.00	319.0	139.10±70.92	118.94-159.26
	F	56	21.0	35.0	26.79±4.21	25.66-27.91	83.00	360.0	174.84±73.07	155.27-194.41
May	M	57	18.5	36.0	26.89±5.02	25.56-28.22	65.00	351.0	172.53±79.92	151.32-193.73
	F	61	18.2	37.0	26.36±5.26	25.01-27.70	57.00	388.0	172.89±94.38	148.71-197.06
June	M	70	20.0	38	28.68±4.00	27.72-29.63	85.00	458.0	210.2±77.12	119.81-228.59
	F	81	22.0	38.8	30.76±3.91	29.89-31.62	112.0	470.0	256.40±85.21	237.55-275.24
July	M	73	21.0	42.5	30.89±5.02	29.32-31.66	84.00	546.0	254.74±107.5	229.65-279.83
	F	79	23.0	42.0	31.53±4.85	30.44-32.62	96.00	544.0	275.81±113.0	252.50-301.13
August	M	75	19.8	53.0	28.76±6.45	27.28-30.24	73.04	1228	226.22±177.9	185.28-267.17
	F	63	22.0	45.0	30.42±5.93	28.93-31.91	98.50	728.0	261.71±145.2	225.15-298.27
September	M	66	11.5	37.4	24.88±6.96	23.17-26.59	27.60	455.0	171.29±109.2	144.44-198.14
	F	57	20.2	37.0	28.11±4.31	26.96-29.25	93.00	440.0	217.81±86.56	194.84-240.77
October	M	51	14.0	36.0	22.56±5.52	21.01-24.11	36.08	406.0	122.15±83.87	98.56-145.74
	F	60	20.5	37.0	28.53±4.13	27.46-29.59	90.00	445.0	210.07±82.15	188.85-231.30
November	M	81	16.8	37.5	26.02±5.67	24.77-27.28	45.19	504.0	211.21±111.3	186.60-235.82
	F	92	20.8	38.9	28.90±4.15	28.04-29.76	120.0	535.0	265.31±95.38	245.56-285.06
December	M	61	16.0	41.0	24.29±7.50	22.37-26.21	38.0	568.0	163.00±148.3	125.02-200.98
	F	70	20.0	40.8	30.49±5.56	29.16-31.82	78.35	554.0	276.92±119.3	248.49-305.36

n, sample size; M, male; F, female; TL, total length; BW, body weight; Min, minimum; Max, maximum; SD, standard deviation; CL, confidence limit for mean values.

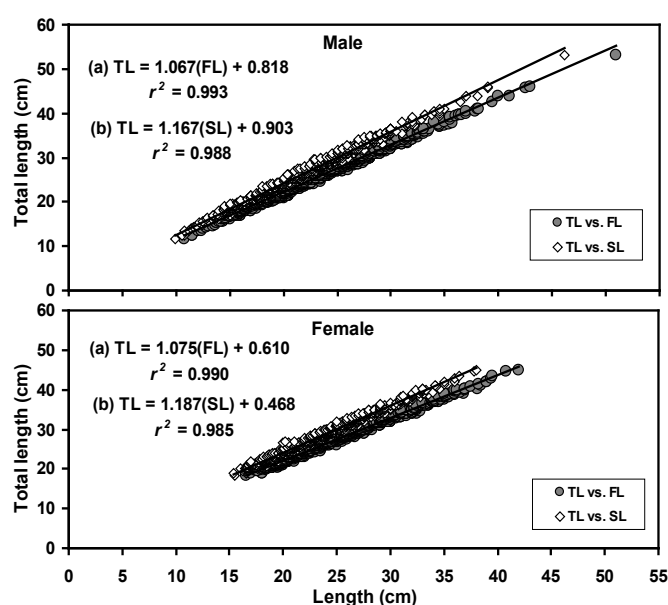


Figure 4: Length-length relationships of *Megalaspis cordyla* (Linnaeus, 1758) in the Bay of Bengal, Bangladesh.

Maturity length (L_m)

Based on maximum TL, the L_m of *M. cordyla* was evaluated as 27.82 cm with 95% CL = 18.86–41.05 cm for males and 23.92 cm with 95% CL = 16.35–35.01 cm for females (Figure 5). The calculated L_{opt} were 24.87 cm for males and 29.13 cm for the female population in the Bay of Bengal. Also, estimated L_m and L_{opt} from worldwide different populations are shown in Table 8 and Figure 6.

The current research describes the size-frequency distributions and growth pattern of *M. cordyla* from the Bay of Bengal, Bangladesh with year-round data. A total of 1513 samples of various body sizes were sampled for twelve months. However, smaller than 11.5 cm TL could not be caught, which may be related to inappropriate fishing equipment or a shortage of smaller size of *M. cordyla* (Hossain et al., 2016, 2021;

Table 2: Estimated parameters of the length-weight relationship ($BW = a \times TL^b$) of *Megalaspis cordyla* (Linnaeus, 1758) in the Bay of Bengal, Bangladesh.

Mon- ths	Sex	n	Regression parameters		95% CL of a	95% CL of b	r ²	GT
			a	b				
January	M	25	0.0289	2.70	0.0153-0.0544	2.50-2.90	0.970	A-
	F	40	0.0469	2.56	0.0262-0.0837	2.37-2.74	0.955	A-
February	M	52	0.0314	2.66	0.0195-0.0506	2.51-2.82	0.962	A-
	F	48	0.0468	2.55	0.0290-0.0758	2.40-2.70	0.962	A-
March	M	59	0.0798	2.41	0.0485-0.1313	2.25-2.57	0.943	A-
	F	86	0.0278	2.73	0.0192-0.0403	2.62-2.85	0.964	A-
April	M	50	0.0352	2.57	0.0256-0.0485	2.47-2.67	0.982	A-
	F	56	0.0275	2.65	0.0193-0.0391	2.54-2.75	0.978	A-
May	M	57	0.0406	2.52	0.0309-0.0534	2.44-2.60	0.985	A-
	F	61	0.0255	2.67	0.0196-0.0333	2.59-2.75	0.987	A-
June	M	70	0.0414	2.53	0.0282-0.0608	2.42-2.65	0.966	A-
	F	81	0.0348	2.59	0.0254-0.0477	2.50-2.68	0.975	A-
July	M	73	0.0299	2.63	0.0204-0.0438	2.52-2.74	0.969	A-
	F	79	0.0298	2.63	0.0222-0.0399	2.55-2.72	0.980	A-
August	M	75	0.0284	2.64	0.0215-0.0376	2.56-2.72	0.982	A-
	F	63	0.0306	2.63	0.0225-0.0416	2.54-2.72	0.982	A-
September	M	66	0.0460	2.51	0.0340-0.0624	2.42-2.61	0.977	A-
	F	57	0.0603	2.44	0.0379-0.0961	2.30-2.58	0.957	A-
October	M	51	0.0303	2.62	0.0217-0.0423	2.52-2.73	0.978	A-
	F	60	0.0389	2.55	0.0271-0.0560	2.44-2.66	0.974	A-
November	M	81	0.0354	2.64	0.0232-0.0538	2.51-2.77	0.954	A-
	F	92	0.0620	2.47	0.0388-0.0991	2.33-2.61	0.932	A-
December	M	61	0.0088	3.00	0.0058-0.0131	2.87-3.13	0.974	I
	F	70	0.0665	2.42	0.0493-0.0898	2.33-2.51	0.978	A-

a, intercept; b, slope; r^2 , coefficient of determination; GT, growth type; A-, negative allometric; I, isometric growth.

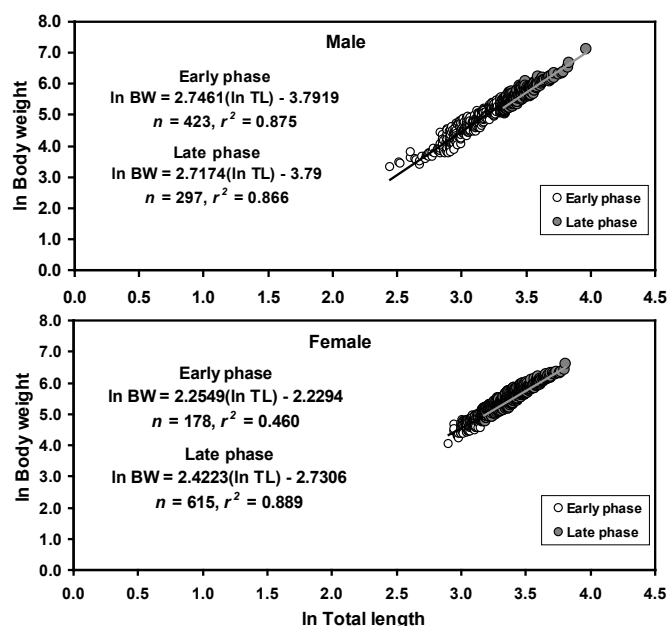


Figure 5: Size at sexual maturity of *Megalaspis cordyla* (Linnaeus, 1758) in the Bay of Bengal, Bangladesh.

Islam *et al.*, 2021). The maximum TL was found 53.0 cm in males and 45.0 cm in the female population, which is smaller than 80.0 cm reported by Smith-Vaniz (1984) and higher than 43.1 cm from the North-west coast of India (Jaiswar and Acharya, 1991); 40.2 cm from Ratnagiri coast, Maharashtra, India (Jadhav and Mohite, 2013); 40.1 cm from Mumbai coast, India (Saker *et al.*, 2004); 34.4 cm FL from the Java Sea, Indonesia (Oktaviani *et al.*, 2020); and Zafar *et al.* (2000) found 35.0 cm in the Bay of Bengal, Bangladesh. However, maximum length data is necessary for defining asymptotic length and growth co-efficient of fish to develop appropriate fisheries management policies (Ahmed *et al.*, 2012; Khatun *et al.*, 2019).

Table 3: Estimated parameters of the length-weight relationship ($BW = a \times FL^b$) of *Megalaspis cordyla* (Linnaeus, 1758) in the Bay of Bengal, Bangladesh.

Mon- ths	Sex	n	Regression parameters		95% CL of a	95% CL of b	r ²	GT
			a	b				
Janu- ary	M	25	0.0366	2.71	0.0163-0.0822	2.44-2.98	0.950	A-
	F	40	0.0478	2.63	0.0245-0.0933	2.41-2.85	0.941	A-
Febru- ary	M	52	0.0485	2.62	0.0286-0.0824	2.44-2.79	0.948	A-
	F	48	0.0647	2.53	0.0353-0.1186	2.34-2.73	0.937	A-
March	M	59	0.0983	2.42	0.0592-0.1634	2.25-2.58	0.938	A-
	F	86	0.0303	2.79	0.0199-0.0462	2.65-2.92	0.952	A-
April	M	50	0.0513	2.52	0.0359-0.0734	2.40-2.63	0.976	A-
	F	56	0.0452	2.57	0.0316-0.0647	2.45-2.68	0.975	A-
May	M	57	0.0536	2.51	0.0393-0.0732	2.41-2.60	0.980	A-
	F	61	0.0384	2.62	0.0293-0.0503	2.53-2.71	0.985	A-
June	M	70	0.0436	2.59	0.0293-0.0649	2.47-2.71	0.963	A-
	F	81	0.0525	2.54	0.0355-0.0778	2.42-2.66	0.959	A-
July	M	73	0.0464	2.57	0.0322-0.0669	2.46-2.68	0.968	A-
	F	79	0.0443	2.58	0.0320-0.0612	2.49-2.68	0.974	A-
August	M	75	0.0439	2.59	0.0335-0.0574	2.50-2.67	0.981	A-
	F	63	0.0449	2.59	0.0323-0.0626	2.49-2.69	0.978	A-
Sep- tember	M	66	0.0585	2.51	0.0452-0.0759	2.43-2.60	0.982	A-
	F	57	0.0859	2.41	0.0545-0.1354	2.27-2.55	0.955	A-
Octo- ber	M	51	0.0490	2.55	0.0343-0.0701	2.43-2.67	0.974	A-
	F	60	0.0649	2.47	0.0434-0.0971	2.34-2.59	0.965	A-
No- vember	M	81	0.0615	2.55	0.0408-0.0926	2.42-2.68	0.950	A-
	F	92	0.0695	2.51	0.0452-0.1068	2.38-2.65	0.941	A-
De- cember	M	61	0.0183	2.87	0.0130-0.0257	2.76-2.98	0.978	A-
	F	70	0.1049	2.36	0.0776-0.141	2.26-2.45	0.975	A-

For abbreviations see Table 2.

Table 4: Estimated parameters of the length-weight relationship ($BW = a \times SL^b$) of *Megalaspis cordyla* (Linnaeus, 1758) in the Bay of Bengal, Bangladesh.

Months	Sex	n	Regression parameters		95% CL of a	95% CL of b	r^2	GT
			a	b				
January	M	25	0.0651	2.59	0.0297-0.1427	2.32-2.86	0.945	A-
	F	40	0.0444	2.73	0.0208-0.0946	2.48-2.98	0.927	A-
February	M	52	0.0519	2.68	0.0292-0.0922	2.49-2.88	0.939	A-
	F	48	0.0819	2.54	0.0461-0.1455	2.35-2.73	0.940	A-
March	M	59	0.1351	2.38	0.0819-0.2228	2.22-2.55	0.934	A-
	F	86	0.0428	2.75	0.0287-0.0639	2.62-2.88	0.953	A-
April	M	50	0.0601	2.55	0.0435-0.0830	2.44-2.66	0.979	A-
	F	56	0.0623	2.55	0.0440-0.0882	2.43-2.66	0.974	A-
May	M	57	0.0675	2.51	0.0517-0.0883	2.42-2.59	0.984	A-
	F	61	0.0437	2.66	0.0333-0.0575	2.57-2.75	0.984	A-
June	M	70	0.0612	2.56	0.0375-0.0998	2.40-2.71	0.941	A-
	F	81	0.0646	2.55	0.0412-0.1013	2.41-2.69	0.944	A-
July	M	73	0.0522	2.60	0.0357-0.0763	2.48-2.72	0.965	A-
	F	79	0.0446	2.65	0.0316-0.0630	2.55-2.76	0.970	A-
August	M	75	0.0589	2.57	0.0423-0.0821	2.46-2.68	0.970	A-
	F	63	0.0625	2.56	0.0434-0.0900	2.45-2.68	0.971	A-
September	M	66	0.0763	2.51	0.0597-0.0974	2.42-2.59	0.983	A-
	F	57	0.1052	2.41	0.0682-0.1623	2.28-2.55	0.957	A-
October	M	51	0.0719	2.51	0.0501-0.1033	2.38-2.63	0.971	A-
	F	60	0.0801	2.48	0.0526-0.1221	2.35-2.61	0.960	A-
November	M	81	0.0764	2.55	0.0504-0.1158	2.42-2.69	0.946	A-
	F	92	0.0788	2.55	0.0498-0.1246	2.40-2.69	0.931	A-
December	M	61	0.0200	2.92	0.0137-0.0292	2.80-3.05	0.973	A-
	F	70	0.1325	2.35	0.0962-0.1826	2.25-2.45	0.970	A-

For abbreviations see Table 2.

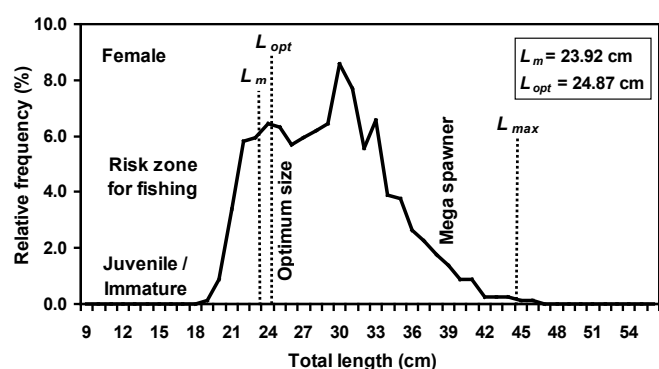


Figure 6: Optimum catchable size of *Megalaspis cordyla* (Linnaeus, 1758) stock in the Bay of Bengal, Bangladesh.

In our analysis, we found that the 22.0-22.9 cm of the TL size group contains the higher number of individuals (51) along with 28.0-28.9 and 29.0-29.9 cm size groups containing 50 individuals for male indicated dominant group. For the female population, the 29.0-29.9 cm group with 68 and 30.0-30.9 cm

class with 61 individuals were precisely dominant, and then gradually lowering the number of individuals in the size group which related to the mortality (natural or fishing). Qamar *et al.* (2016) reported the maximum 91 individuals in the 22.0-25.9 cm length class which is relatively similar to our observation.

Table 5: Estimated parameters of total and fork length relationship ($TL = a + b \times FL$) of *Megalaspis cordyla* (Linnaeus, 1758) in the Bay of Bengal, Bangladesh.

Months	Sex	n	Regression parameters		95% CL of a	95% CL of b	r^2
			a	b			
January	M	25	0.024	1.10	-1.907 to 1.954	1.01 to 1.19	0.962
	F	40	-0.517	1.13	-1.779 to 0.746	1.07 to 1.18	0.977
February	M	52	0.657	1.08	-0.165 to 1.480	1.05 to 1.12	0.985
	F	48	0.179	1.10	-0.962 to 1.320	1.05 to 1.15	0.977
March	M	59	0.299	1.09	-0.460 to 1.058	1.05 to 1.12	0.986
	F	86	-0.231	1.11	-0.946 to 0.483	1.08 to 1.14	0.983
April	M	50	0.661	1.06	-0.006 to 1.328	1.03 to 1.09	0.991
	F	56	1.033	1.05	0.241 to 1.825	1.02 to 1.08	0.988
May	M	57	0.228	1.09	-0.482 to 0.938	1.06 to 1.12	0.991
	F	61	0.724	1.07	0.078 to 1.370	1.04 to 1.09	0.991
June	M	70	0.009	1.10	-0.932 to 0.950	1.06 to 1.14	0.982
	F	81	0.875	1.07	-0.071 to 1.820	1.03 to 1.10	0.981
July	M	73	0.884	1.06	0.155 to 1.612	1.03 to 1.08	0.990
	F	79	0.761	1.06	0.107 to 1.415	1.04 to 1.09	0.992
August	M	75	1.423	1.05	0.810 to 2.035	1.03 to 1.07	0.991
	F	63	0.585	1.08	-0.086 to 1.255	1.06 to 1.10	0.993
September	M	66	0.239	1.09	-0.128 to 0.606	1.07 to 1.10	0.997
	F	57	0.540	1.08	-0.100 to 1.180	1.06 to 1.11	0.993
October	M	51	0.649	1.07	0.158 to 1.139	1.05 to 1.10	0.994
	F	60	1.058	1.06	0.258 to 1.858	1.03 to 1.09	0.988
November	M	81	0.827	1.07	0.364 to 1.291	1.05 to 1.09	0.994
	F	92	-0.133	1.11	-0.768 to 0.502	1.09 to 1.13	0.989
December	M	61	1.396	1.05	1.001 to 1.792	1.03 to 1.06	0.996
	F	70	1.200	1.06	0.412 to 1.990	1.03 to 1.09	0.988

According to Carlander (1969), b values may vary from 2.0 to 4.0 for fishes. Instead, Froese (2006) stated that the b values extended from 2.5 to 3.5 of LWRs. We found b values from 2.4 to 3.0 ($b = 2.41$ to 3.0 for males and $b = 2.42$ to 2.73 for females), which is similar to the range observed in teleost fishes and that indicated the large specimens' body form has changed to become more elongated (Froese, 2006; Hossain *et al.*, 2015). Furthermore, b values revealed the growth of negative allometric for both sexes in our research. The b value for combined sex was also negative allometric reported by Jaiswar and Acharya (1991) from the North-west coast of India ($b = 2.98$); Reuben *et al.* (1992) from the east, north-west

and south-west coast of India ($b = 2.94, 2.52, 2.72$); Sivakami (1995) from Cochin, India ($b = 2.69$); Saker *et al.* (2004) from Mumbai coast, India ($b = 2.88$); Das *et al.* (2014) from Tanjung Sepat, Selangor, Malaysia ($b = 2.64$); Qamar *et al.* (2016) from Northern Arabian Sea coast of Pakistan ($b = 2.82$ for male and 2.45 for female) and Zafar *et al.* (2000) from Bay of Bengal ($b = 2.82$) for *M. cordyla*. But dissimilar results found by Panda *et al.* (2011) from Mumbai, India ($b = 3.02$) signified isometric growth and Oktaviani *et al.* (2020) reported positive allometric growth from the Java Sea, Indonesia ($b = 3.15$). Though in the same species, b values may differ for various factors such as sex, gonadal development, growth variances in parts of the body, physiology and food accessibility, and preservation techniques (Le Cren, 1951; Tesch, 1968; Hossain *et al.*, 2015), those were not taken into account in our study. Moreover, the LLRs were highly related, but owing to inadequate information on *M. cordyla*, it was hard to ascertain any comparisons.

Table 6: Estimated parameters of total and standard length relationship ($TL = a + b \times SL$) of *Megalaspis cordyla* (Linnaeus, 1758) in the Bay of Bengal, Bangladesh.

Months	Sex	n	Regression parameters		95% CL of a	95% CL of b	r^2
			a	b			
January	M	25	0.595	1.17	-1.199 to 2.389	1.07 to 1.26	0.966
	F	40	-1.288	1.26	-2.996 to 0.420	1.18 to 1.35	0.960
February	M	52	0.077	1.23	-0.875 to 1.029	1.18 to 1.28	0.981
	F	48	0.349	1.21	-0.823 to 1.521	1.15 to 1.27	0.976
March	M	59	0.579	1.17	-0.400 to 1.52	1.13 to 1.22	0.976
	F	86	0.098	1.19	-0.653 to 0.849	1.15 to 1.22	0.981
April	M	50	0.340	1.19	-0.440 to 1.121	1.15 to 1.23	0.988
	F	56	1.225	1.15	0.371 to 2.079	1.11 to 1.19	0.986
May	M	57	0.416	1.19	-0.422 to 1.255	1.15 to 1.22	0.987
	F	61	0.395	1.19	-0.301 to 1.090	1.16 to 1.22	0.990
June	M	70	0.426	1.19	-0.983 to 1.834	1.13 to 1.25	0.960
	F	81	1.009	1.17	-0.269 to 2.287	1.12 to 1.22	0.965
July	M	73	0.885	1.15	-0.038 to 1.808	1.12 to 1.19	0.983
	F	79	0.132	1.19	-0.846 to 1.11	1.05 to 1.22	0.982
August	M	75	1.629	1.14	0.854 to 2.404	1.11 to 1.18	0.986
	F	63	0.857	1.18	0.017 to 1.698	1.14 to 1.21	0.988
September	M	66	0.377	1.19	-0.155 to 0.909	1.17 to 1.22	0.993
	F	57	0.673	1.18	-0.275 to 1.620	1.14 to 1.22	0.984
October	M	51	1.181	1.15	0.556 to 1.806	1.12 to 1.19	0.990
	F	60	0.953	1.17	-0.032 to 1.937	1.13 to 1.21	0.982
November	M	81	0.700	1.18	0.174 to 1.226	1.16 to 1.21	0.992
	F	92	-0.480	1.23	-1.439 to 0.478	1.19 to 1.27	0.977
December	M	61	0.959	1.17	0.460 to 1.459	1.15 to 1.19	0.994
	F	70	1.293	1.16	0.434 to 2.153	1.13 to 1.19	0.986

Table 7: Spearman rank correlations of body weight with lengths and length with lengths for *Megalaspis cordyla* (Linnaeus, 1758) in the Bay of Bengal, Bangladesh.

Relation-ships	Sex	r_s values	95% CL of r_s	p values	Significance
BW vs. TL	M	0.971	0.967 to 0.975	< 0.0001	***
	F	0.966	0.960 to 0.970	< 0.0001	***
BW vs. FL	M	0.970	0.965 to 0.974	< 0.0001	***
	F	0.961	0.955 to 0.966	< 0.0001	***
BW vs. SL	M	0.968	0.963 to 0.972	< 0.0001	***
	F	0.962	0.956 to 0.967	< 0.0001	***
TL vs. FL	M	0.993	0.992 to 0.994	< 0.0001	***
	F	0.991	0.990 to 0.993	< 0.0001	***
TL vs. SL	M	0.996	0.995 to 0.996	< 0.0001	***
	F	0.995	0.994 to 0.995	< 0.0001	***

r_s , Spearman rank correlation values; CL, confidence limit; p, shows the level of significance; ***, highly significance relationship.

Additionally, the study provides information on the sexual maturity length of *M. cordyla*, which could be useful in calculating the mesh size to avoid catching mature smaller individuals and allowing them to spawn. Our estimated maturity size (L_m) of *M. cordyla* was 27.82 cm in total length for males and 23.92 cm in females. Information on L_m for the fishes in Bangladesh is scarce but Qamar and Panhwar (2018) reported the L_m was 27.0 cm for male and 26.5 cm for female from the Northern Arabian Sea coast, Pakistan, Reuben *et al.* (1992) found 25.0 cm from the east, north-west and south-west coast of India, and Jadhav and Mohite (2013) observed L_m at 21.0 cm from Ratnagiri coast of Maharashtra, India. Based on the maximum total length we tried to assess L_m from different available worldwide literature. The estimated results are slightly diverse from our study which may be due to the seasonal variation in the water depth that also impacts on nutrient cycling, and energy cycling of aquatic habitat that influences the reproductive ability of fish (Lowerre-Barbieri, 2011; Rahman *et al.*, 2020).

According to our findings, approximately half of the fish spawned when their length was 23.92 cm for females and 27.82 cm for males; fish smaller than those sizes are strictly avoided to catch. The values of L_{opt} were estimated as 24.87 and 29.13 cm for females and males, respectively, suggesting the size range where optimum yield might be reached; therefore, fish larger than 24.87 cm (TL) are encouraged for exploitation. As a consequence, we aim to protect maximum brood females for their future sustainable yield.

Table 8: Estimated length at sexual maturity (L_m) and L_{opt} of *Megalaspis cordyla* (Linnaeus, 1758) from different worldwide water bodies.

Authors	Study Area	Sex	TL _{max} (cm)	Regression parameter		L _m (cm)	L _{opt} (cm)
				a	b		
Jaiswar and Aciarya, (1991)	North-west coast of India	C	43.1	0.00910	2.98	23.00	23.85
Reuben <i>et al.</i> (1992)	East coast of India	C	-	0.000012	2.94	25.00	26.03
	North-west coast of India	-	-	0.000127	2.52	-	-
	South-west coast of India	-	-	0.00005	2.72	-	-
Sivakami, (1995)	Cochin, India	M	-	0.01740	2.58	-	-
		F	-	0.00870	2.86	-	-
		C	-	0.01340	2.69	-	-
Saker <i>et al.</i> (2004)	Mumbai coast, India	M	-	0.00007	2.64	-	-
		F	-	0.00020	2.46	-	-
		C	40.1	0.00001	2.88	21.50	22.21
Panda <i>et al.</i> (2011)	Mumbai, India	M	-	0.01120	2.92	-	-
		F	-	0.02100	3.08	-	-
		C	36.4	0.00860	3.02	19.67	20.22
Jadhav and Mohite (2013)	Ratnagiri coast of Maharashtra, India	C	40.2	-	-	21.00	21.67
Oktaviani <i>et al.</i> (2020)	Java Sea, Indonesia	C	35.4(FL)	0.00700	3.15	19.17	19.68
Das <i>et al.</i> (2014)	Tanjung Sepat, Selangor, Malaysia	M	35.5	0.03400	2.65	19.22	19.74
		F	37.5	0.02100	2.77	20.21	20.81
Qamar <i>et al.</i> (2018)	Northern Arabian Sea coast of Pakistan.	M	-	-	-	27.00	28.23
		F	-	-	-	26.50	27.86
Zafar <i>et al.</i> (2000)	Bay of Bengal, Bangladesh	C	35.0	0.01790	2.82	18.97	19.47
Present study	Bay of Bengal, Bangladesh	M	53.0	0.03720	2.58	27.82	29.13
		F	45.0	0.06000	2.44	23.92	24.87
		C	53.0	0.04210	2.55	27.82	29.13

It is our first attempt at this aspect, so evaluation is difficult. But we determined the L_{opt} for this species following the L_{max} values from worldwide literature where we estimated that the smallest L_{opt} was 19.47 cm for combined sex in the BoB, Bangladesh, and we observed the largest L_{opt} was 29.13 cm for male from our study.

Conclusions and Recommendations

Our research described the population size structure, growth pattern, and maturity of *M. cordyla* from the BoB, Bangladesh. These findings could be used by fishery biologists to assess the standing stock and biomass of this species in the marine waters of Bangladesh. The optimum catchable-size was strongly recommended to avoid catching fish below that size for conserving the presence of fish from year to year by safeguarding the largest number of brood fish. Moreover, the results will be useful in future research for determining the permitted mesh size of gears, which will aid in the development of justifiable management techniques for *M. cordyla* in the coastal and marine water.

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Novelty Statement

The present study revealed the optimum catchable size of *M. cordyla*. The findings would not only serve as a baseline for further studies, especially in the area of coastal and marine water in Bangladesh as well as where outputs are needed, but also would support sustainable management and policy regulations for this species.

Author's Contribution

Most. Shakila Sarmin: Wrote the manuscript and carried out data analyses.

Md. Ashekur Rahman: Assisted with sampling and data collection.

Most. Farida Parvin: Assisted with data analyses.

Mst. Shefaly Khatun: Helped in laboratory work.

Kazi Ahsan Habib and Wasim Sabbir: Reviewed the manuscript.

Wasim Sabbir: Revised the manuscript.

Md. Yeamin Hossain: Conceptualized this study and developed the method

Conflict of interest

The authors have declared no conflict of interest.

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