Research Article

Growth and Conditions Appraisal of *Atropus atropos* (Carangidae) in the Bay of Bengal

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Abstract | This study aims to provide insights into the growth pattern and conditions of *Atropus atropos* in the Bay of Bengal, Bangladesh. The lack of information on this species in the region has made it crucial to carry out such research for better understanding about its growth and health in this particular habitat. A total 100 individuals were collected from fishers catch during November 2021 to October 2022 by using traditional fishing gears such as trawl and gill nets (mesh size: 2-3 cm). Data showed that TL was found to be between 15 and 21 cm and the BW remained as 46 and 136 g. All LWRs had r^2 values below 0.945 and were significant (P<0.001). The estimated allometric coefficient (b) suggested the combined sexes showed isometric growth (b~3). The statistical analysis conducted in this study revealed a highly significant LLR (p<0.001) with an r^2 value exceeding 0.944. The form factor ($a_{3.0}$) was found as 0.0155, while the size at first sexual maturity (L_m) was determined as 12.36 cm TL. The natural mortality (M_w) was calculated as 1.57 y^{-1}. A major connection between K_R and BW for this species, indicating that K_R was an exceptionally significant in revealing the health of *A. atropos*. Thereafter, a high condition rating (K_F, K_A, and K_R) indicates that the species is in short and deep shape. This study found that the habitat was in a state of equilibrium and the mean W_R indicated that there was no significant deviation from the expected value of 100 for *A. atropos*. Consequently, information gathered from the present study would be impactful for managing this fishery in the Bay of Bengal, Bangladesh, along with the surroundings.

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Introduction

The family Carangidae includes the species *Atropus atropos* which is commonly known as the Cleftbelly trevally. It is native to the tropical as well as subtropical water bodies of the Indo-West Pacific area. It is locally known as "Tak Chanda" in Bangladesh. This is a demandable fish species and is abundantly found in winter. In Bangladesh, *A. atropos* is classified as LC (Least Concern) (IUCN, 2023). Fowler and Henry (1935) and Carpenter *et al.* (2001) stated that the distribution of this species spans across South Africa to the East African coast and throughout the rest of Africa, the Middle East, Asia, Oceania, and Europe, with recent sightings in the Persian Gulf, India, Southeast Asia, the Philippines, Taiwan, and southern Japan. However, the specimens collected by Henry Fowler from South and Eastern Africa in the 1930s suggested that this claim is not entirely accurate, despite Fowler and Henry (1935) statement that the westernmost point of the species range is the Persian Gulf.

A. atropos lives in shallow coastal water and swim near to surface. Certain species may be able to survive in brackish water conditions based on the results of a study of those, found in locations near estuary that experienced a substantial amount of freshwater drift (Ansari *et al.*, 1995). This species is amphidromous and pelagic-neritic marine fish (Riede, 2004). Cleftbelly trevally are predators that dine on a variety of smaller marine organisms, including crustaceans like prawns and zooplankton even some smaller fish also (Masuda *et al.*, 1984). *A. atropos* contains a high level of Omega-3 fatty acid (0.314 g/100g) (Hicks *et al.*, 2019).

The production of marine fisheries accounts for 16.18% of overall fish production in Bangladesh (DoF, 2019). Throughout its range, the species has minor importance to fisheries, being caught primarily with methods like trawls, traps, various hooks and line also. Study species is catching widely from savage environments due to inadequacy of culture practice. Moreover, exploitation of fishing is the most serious alarm to the wild population of *A. atropos.*

Length-frequency distribution (LFDs) is considered as an important biometric statistic that should be used for calculating the growth rate, growth performance index as well as fish morbidity are accepted widely (Sabbir *et al.*, 2022). Furthermore, LFD is employed for estimation the state of a river health by conducting stock assessments of residual biomass and breeding season (Ranjan *et al.*, 2005; Ilah *et al.*, 2022). Moreover, LFD aids in comparing the physical traits of many species and the population of a single species from various aqueous ecosystem (Sabbir *et al.*, 2020a; Hasan *et al.*, 2022). Alternatively, the length-weight relationships (LWRs) and the length-length relationships (LLRs) are major biometrically indicates that may be used to compare and contrast a range of biological conditions (Sabbir *et al.*, 2020b). In addition, LWRs and LLRs both are criteria to carry out successful assessment of a natural species of lotic water territory (Muchlisin *et al.*, 2010).

Form factor ($a_{3.0}$) is applied all over the world for determining the anatomical structure of fish living in water bodies (Froese, 2006; Mawa *et al.*, 2022). Since, fish are the primary source of protein, producing on a worldwide scale is crucial to comprehend fish biology and health. A condition factor may be thought of as an indicator that is used to learn about fish ability to survive, mature, maintain their health and reproduction (Le Cren, 1951; Sabbir *et al.*, 2020c). It measures how fit the habitat is, as a whole along with how healthy the water is, in a given waterbody (Tsoumani *et al.*, 2006). All of these attributes, fertility, environmental factors, dietary accessibility and the time of year are taken into account when assessing fish condition (Hossain *et al.*, 2006). Having details on the circumstances of *A. atropos*, in order to calculate the lifespan of a specific group for the purpose of precise governance as well as to maintain the balance of an environment is highly required (Hossain *et al.*, 2013).

Furthermore, W_R approach is most commonly used to analyze fish population in a certain ecosystem, whereby, considering their function as either prey or predator (Froese, 2006). Moreover, the fish resources of the Bay of Bengal are in severe vulnerability due to a multitude of factors, including overfishing, destruction of habitat, degradation, fishing practices that are harmful to marine life and a great number of other problems. A few studies on the length weight relationship and conditions of *A. atropos* were carried out (Table 1). As a consequence, earlier study lacked appropriate demographic data on conditions and form factors throughout the year. During twelve-month period, we were trying to explain LFDs, growth patterns depending on LWRs, LLRs, form factor ($a_{3.0}$) and status of *A. atropos* from the studied region.

Materials and Methods

Sampling and sampling site

A. atropos (100 specimens) were collected from fishers in the Bay of Bengal, Bangladesh. By means of

Table 1: *Available literature of Atropus atropos from worldwide water bodies.*

Aspects	Water body	References
Biology	Ratnagiri coast of India	Rakhunde *et al.* (2023)
Length-weight relationship	Northern Arabian Sea coast, Pakistan	Qamar and Panhwar (2018)
Length-weight relationship and relative condition factor	Mangalore coast, India	Rajesh *et al.* (2020)
Length-weight relationship	Bay of Bengal, Bangladesh	Rahman *et al.* (2021)
Population characteristics	Mangalore coast, India	Rajesh *et al.* (2019)

traditional fishing techniques and gears such as gill nets and trawls during the months of November 2021 to October 2022 (wire spacing: 2-3 cm), these fish were captured. After the collection of specimens, they were immediately placed on ice and afterwards in the research center, in order to keep them in good condition for subsequent research and 10% buffered formalin was used for preservation. Using digital slide calipers, the essential length of each individual *A. atropos* was measured the next day in the laboratory to the closest 0.01 cm. In addition, using an electric balance, the total body weight of every specimen was determined to an accuracy of within 0.01 g.

Population structure

LFD in the species of *A. atropos* was arranged through 1.0 cm class interval of total length (TL).

Length- weight and length- length relationship

Body weight (g) and total length (cm) were entered into the equation BW = a*(TL)^b to get LWRs (cm). Using natural logarithms and linear regression analysis, we were able to get the values of a and b: ln (BW) = ln a + ln b(BW) (TL). According to Froese (2006), the regression analysis was adjusted such, that extreme outliers were not included. On the other hand, the linear regression of TL, FL and SL was respectively used to estimate the length-length associations among the three variables. The equation used to compute the length-length connection is as follows: y = a+ bx; as, y representing the different body length, x represents overall length, a represents a constant, and b represents a regression coefficient.

Condition factor

Tesch (1968) provided the equation that was used to determine the allometric condition factor (K_A), which is as follows: K_A = W/L^b; where, W represents the body weight in grams, L represents the total length in centimeters and b refers to the LWR parameter. While calculating the Fulton condition factor, the following formula from Fulton (1904) was utilized: K_F=100*(W/L^3). In this formula, W represents the body weight in grams, and L represents the total length in cm. The scaling factor of 100 was utilized to obtain the K_F value that is nearer to unit (Froese, 2006). Additionally, the relative condition factor was determined by applying the access this information by Le Cren (1951): K_R = W/(a*L^b); in which W represents the body weight in grams, L represents the total length in centimeters and a and b refer to the LWR parameters.

The equation of Froese (2006) was used to calculate the relative weight (W_R); which reads as follows: W_R = (W/W_S)*100; whereby W_S is for estimated standard weight of the specimen no different calculated as W_S = a*L^b; wherein a as well as b are regression parameters of LWR.

Form factor

In order to determine the form factor for *A. atropos*, the formula given by Froese (2006) was employed: $a_{3.0}$ = 10log$^{a-s(b-3)}$, where a and b denote the LWR parameters and S represents the slope of the regression line that compares ln*a to b. However, due to insufficient data on LWRs for this species, a mean slope of -1.358 was used as a substitute during this study to estimate the form factor.

Size at first sexual maturity (L_m) and natural mortality (M_w)

Log (L_m) = -0.1189 + 0.9157 *(L_{max}); where L_{max} is the longest length recorded, was used to calculate L_m (Binohlan and Froese, 2009). Peterson and Wroblewski (1984) developed a model to calculate the M_w as follows: M_w = 1.92 year^{-1*} (W)-0.25; where, M_w=Natural morbidity at mass W; and W= a*L^b, where a and b are the LWR parameters.

Statistical analysis

The statistical analysis was delegated to the use of the software packages Microsoft Excel (version 2010) and Graph Pad Prism 6.0. The Spearman rank correlation test was carried out with the purpose that determined whether or not there was a link between the condition factors and either TL or BW. For the purpose of distinguishing the mean relative weight (W_R) from 100, a Wilcoxon sign-ranked test was carried out (Anderson and Neumann, 1996). Statistical analysis was performed using a significance threshold of 5% (p<.05).

Results and Discussion

Population structure

A number of 100 individuals were collected from fishermen of the Bay of Bengal. Table 2 contains the descriptive data for length and weight and their respective 95% confidence limit (CL). LFD revealed that the lowest along with biggest values (15 cm and 21 cm)in total length respectively and that the body mass ranged from 46 to 136 g. According to LFD, the size range of 17.99 to 18.99 cm TL was numerically predominant (Figure 1).

Table 2: *Explanatory statistics on length (cm) and weight (g) measurements with their 95% confidence interval of Atropus atropos in the Bay of Bengal (Bangladesh).*

Measurement	n	Min.	Max.	Mean±SD	$CI_{95\%}$
Total length (cm)	100	15	21	17.92± 1.617	17.599-18.241
Fork length (cm)		13	18.5	15.66± 1.562	15.35-15.97
Standard length (cm)		11.5	16.5	13.82± 1.41	13.541-14.099
Body depth (cm)		6	9	7.76± 0.94	7.573-7.947
Body weight (g)		46	136	90.69± 24.15	85.896-95.48

n, sample size; CI, confidence interval for mean values.

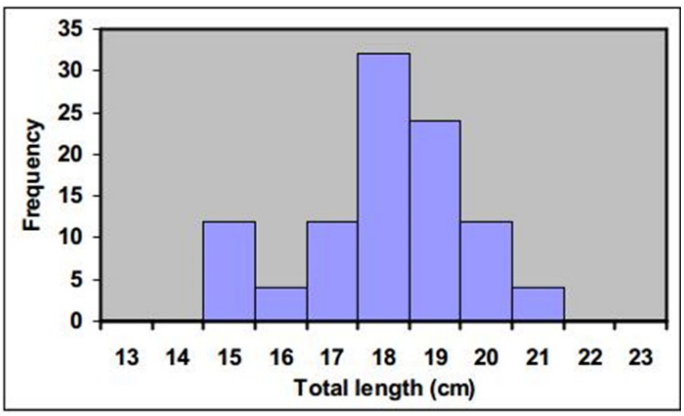

Figure 1: *Total length-frequency distribution of Atropus atropos in the Bay of Bengal (Bangladesh).*

Length-length and length-weight relationships (LWR and LLR)

Table 3 and Figure 2 show the growth pattern of *A. atropos* and provides information on the sample size (n), regression parameters of LWRs with 95% CL and the estimation coefficient (r^2). This species exhibited an isometric growth pattern, as shown by the estimated b value of LWRs. In addition, b value of LLRs showed the similar growth pattern (b<1) in Figures 3 and 4.

Table 3: *Descriptive statistics of length-weight and length-length relationships (LWR and LLR) of Atropus atropos in the Bay of Bengal (Bangladesh).*

Formula	n	Regression variables		a (±95% CI)	b (±95% CI)	r^2
		a	*b*			
BW = $a \times TL^b$	100	0.013	3.051	0.009 to 0.02	2.903 to 3.199	0.945
FL = $a + b \times TL$		-0.996	0.930	-1.810 to -0.181	0.885 to 0.975	0.944

n, sample size; TL, total length; BW, body weight; SL, standard length; a, intercept; b, slope; CI, confidence interval for mean values; r^2, coefficient of determination

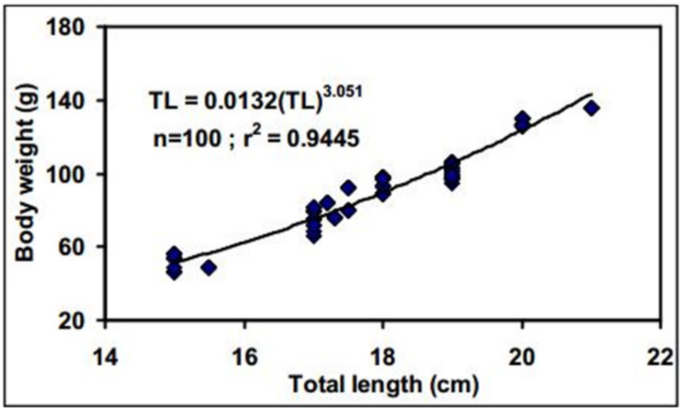

Figure 2: *Relationship (BW = a×TL^b) between total length (cm) and body weight (g) of Atropus. atropos in the Bay of Bengal (Bangladesh).*

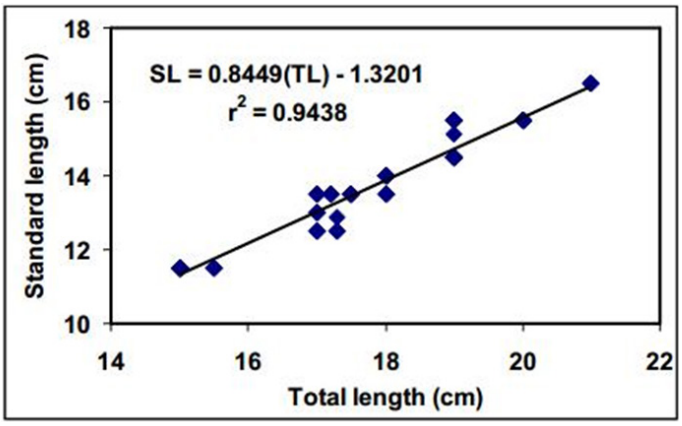

Figure 3: *Relationship (SL = a+b×TL) between standard length (cm) and total length (cm) of Atropus atropos in the Bay of Bengal (Bangladesh).*

Condition factor

Table 4 reveals the frequencies of four condition factors, namely K_A, K_F, K_R and W_R. Spearman rank correlation test showed that condition of this fish had no relationship with TL and BW except BW *vs.*K_R (Table 5). Further, W_R has no significant difference from 100 ($P < .0001$) for *A. atropos* in the Bay of Bengal. The form factor ($a_{3\cdot0}$) was calculated as 0.0155 in the Bay of Bengal, Bangladesh (Table 6).

Table 4: *Descriptive statistics on condition factors measurements and with their 95% CI of Atropus atropos in the Bay of Bengal (Bangladesh).*

Conditions	Minimum	Maximum	Mean±SD	$CI_{95\%}$
K_A	0.0114	0.0148	0.0133 ± 0.0009	0.0131-0.0135
K_F	1.3158	1.7166	1.5383± 0.1036	1.518-1.559
K_R	0.867	1.124	1.006 ± 0.068	0.993-1.02
W_R	86.68	112.384	100.612 ± 6.786	99.265-101.958

Condition factors (K_A, Allometric; K_F, Fulton's; K_R, Relative; W_R, Relative weight); and CI, confidence interval .

Table 5: *Relationships of condition factor with total length (TL) and body weight (BW) of Atropus atropos.*

Relationships	r_s values	95% CL of r_s	p values	significance
TL *vs.* K_A	-0.08567	-0.2828 to 0.1184	0.3967	NS
TL *vs.* K_F	-0.02693	-0.2278 to 0.1764	0.7902	NS
TL *vs.* K_R	-0.08031	-0.2779 to 0.1238	0.4270	NS
BW *vs.* K_A	0.1099	-0.09426 to 0.3052	0.2764	NS
BW *vs.* K_F	0.1735	-0.02963 to 0.3628	0.0843	NS
BW *vs.* K_R	0.9960	0.9939 to 0.9973	<0.0001	****

*Condition factors (K_A, Allometric; K_F, Fulton's; K_R, Relative); r_s, coefficient of spearman rank correlation test values; CL, confidence limit; NS, not significant; ****extremely significant; and P, exhibitions the intensity of significance.*

Table 6: *The calculated form factor ($a_{3.0}$), size at sexual maturity (L_m), and natural mortality of Atropus atropos (sample size, n=100).*

Sex	Total length (cm) Min	Total length (cm) Max	a	b	$a_{3.0}$	L_m	M_w	95% CL of L_m
Combined	15	21	0.013	3.051	0.0155	12.36	1.57	9.74-15.66

Min, minimum; Max, maximum

Size at first sexual maturity (L_m) and natural mortality (M_w)

The L_m of *A. atropos* in the Bay of Bengal was estimated as 12.36 cm in TL with 95% CL of 9.74-15.66 cm (Table 6). During this study, the M_w of *A. atropos* was determined as 1.57 year^{-1} in the Bay of Bengal (Table 6 and Figure 5).

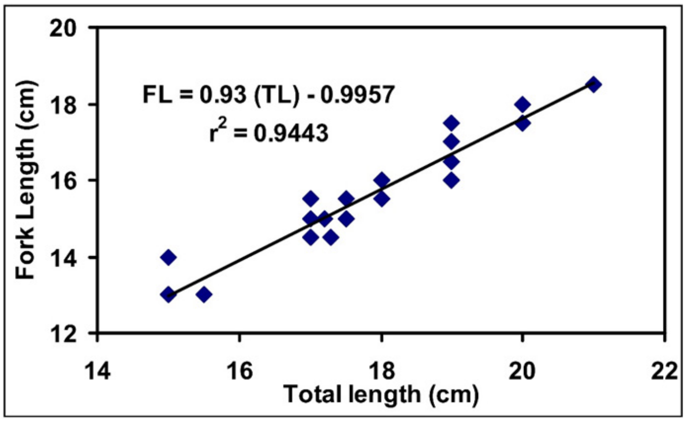

Figure 4: *Relationship (FL= a+b×TL) between Fork length (cm) and total length (cm) of Atropus atropos in the Bay of Bengal (Bangladesh).*

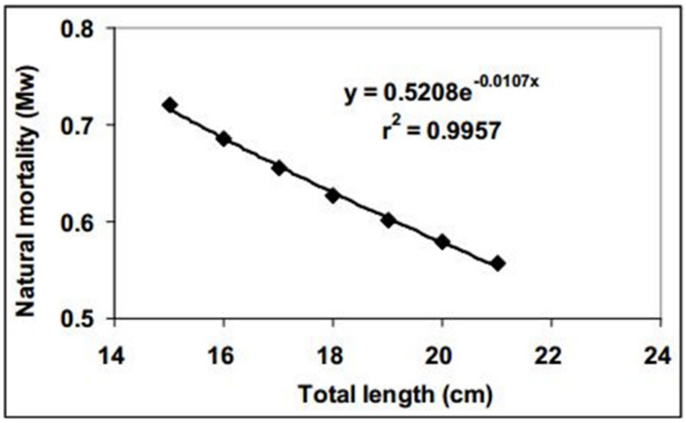

Figure 5: *Natural mortality of Atropus atropos in the Bay of Bengal (Bangladesh).*

There is a scarcity of information on *A. atropos* in published literature. As a result, the current study was concentrated on providing an accurate description of *A. atropos*, including population structure, LWR, LLR, multi-approach condition factors (K_A, K_F, K_R and W_R), form factor ($a_{3.0}$), size at first sexual maturity (L_m), and natural mortality (M_w), using numerous specimens of varying sizes collected a year-round from the Bay of Bengal, Bangladesh. During the sampling time, it was difficult to catch any *A. atropos* with a (TL) length of less than 15 centimeters in population or selection of fishing gear (Hossain *et al.*, 2012b). In this research, *A. atropos* was measured 21.0 centimeters in maximum total length, which is shorter than the highest recorded values of 40.3 centimeters in TL (Pradhan *et al.*, 2020) and 44.0 centimeters in TL (for combined data) according to Talwar and Jhingran (1991). This variance could have happened as a result of the geographic location and the availability of food

(Hossain and Ohtomi, 2010). For effective fisheries management and planning, comprehensive data is essential, addition of asymptotic length along with fish growth coefficient (Hossain *et al*., 2012a; Khatun *et al*., 2018, 2019; Parvin *et al*., 2018).

Value of the regression parameter *b* for the LWR of *A. atropos* is within the recommended range (2.5–3.5) for aquatic animals Froese (2006). Our findings show that the *b* value of *A. atropos* obtained in subsequent investigations from India (2.86) and Pakistan (2.87) is less than what was found in those countries and current investigation is (3.05) similar with China (3.02) (Reuben *et al*., 1992; Xu *et al*., 1994; Qamar and Panhwar, 2018) and this number is substantially comparable (3.098) to the findings of Rahman *et al*. (2021). In the present study, *b* value was 3.05, i.e., isometric growth. This means that, fish gain weight as their length growing proportionally (Tesch, 1971), which states that, fish should have an isometric growth rate (Hossain *et al*., 2016; Hasan *et al*., 2020). The reasons for differences in *b* values have been identified as a lack of standardized sampling procedure, particularly with regard to the selection of fishing equipment, conservation efforts, environment, food, sexual orientation, health and seasonal influences and other factors that are not taken into consideration in our study. These reasons are not taken into account (Hasan *et al*., 2020).

In addition to losing weight, fish that are preserved in formalin may also endure variable degrees of length decreases. On the other hand, the rate of declination might change depending on the species and can be observed over a significant amount of time. In our investigation, the time frame between catching the fish and measuring them was just 36 hours; as a result, any shrinkage that occurred may have been little thus far. Advised that, future research quantify the influence of stabilization on LWR using fresh and stored specimens for a period ranging from a few weeks to several months.

Enough information is not available about the condition factor of *A. atropos*. This research is the attempt to explain the condition component, to attempting to explain the relative weight of *A. atropos*. We incorporated a number of different condition components in order to come up with the most accurate condition index to evaluate *A. atropos* overall health (K_F, K_A, and K_R). The Spearman rank correlation test manifested a substantial link into K_R and BW for this species, indicating that, K_R was an exceptionally significant factor in describing the health of *A.atropos* (Table 5). Furthermore, W_R values that are lower than 100 indicate an environment with a limited quantity of prey, whereas W_R values that are higher than 100 indicate an environment with an abundance of prey (Froese, 2006). In the course of our research, we determined that the ecosystem was in a condition of stability when the average W_R revealed that, neither *A. atropos* had a statistically significant deviation from the value of 100.

In current study, form factor ($a_{3.0}$) value was 0.0155 which indicates the population of *A. atropos* had a body form that was short and deep in the Bay of Bengal, Bangladesh, (Froese, 2006). In spite of the fact, a few research were carried out, that the relevant published material makes no mention of the form factor of this individual. When the length of the *A. atropos* had reached its first sexual maturity was 12.36 cm in TL. There has not been available research carried out on L_m for this fish from the seas around Bangladesh (Hossain *et al*., 2012c). When it attained at initial sexual maturity, the TL was 21.0 cm, which is comparable to the length that we determined. A few research has been conducted on L_m and contrasting it with other fields of study is challenging for obvious reasons.

According to the findings of the current study, the average yearly growth rate (M_w) of *A. atropos* in the Bay of Bengal is 1.57 year^{-1}. However, the comparison with other species of *A. atropos* is restricted due to the lack of sufficient information on M_w. Despite of this, the current study was successful in collecting baseline data that will be beneficial for future exploration and managing strategies of Bay of Bengal.

Conclusions and Recommendations

The current research highlighted that fish grew isometrically in the Bay of Bengal, Bangladesh. Through our findings, it could also be recommended from population structure that the fish might be caught above 18 cm for maximum sustainable yield. In essence, the present study contains fundamental information for further research.

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Novelty Statement

We provided critical insights into the growth patterns, condition, and habitat equilibrium of Atropus atropos in the Bay of Bengal, Bangladesh, addressing a significant knowledge gap and offering valuable data for the sustainable management of this fishery.

Author's Contribution

Md. Yeamin Hossain, Nur-E-Farjana Ilah, Md. Joynal Abedin, Esmout Jahan Alice and Taiba Akter Laboni: Conceive the concept of the review.
Mst. Shahinur Khatun, Most. Shakila Sarmin, Md. Ashekur Rahman, Obaidur Rahman, Md. Akhtarul Islam and Muhammad Ali Fardoush Siddquy: Analyzed the data.
Md. Yeamin Hossain, Nur-E-Farjana Ilah and Md. Joynal Abedin: Wrote and edit the manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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