JBS

Research Article

Journal of Biological Studies

eISSN: 2209-2560

V. 9, N. 2: 31-46, 2026

https://doi.org/10.62400/jbs.v9i2.18130

Population dynamics and stock assessment of the high-valued small indigenous fish mola (*Amblypharyngodon mola)* through length-based stock models in the River Chitra, Bangladesh

M. Aminur Rahman[1,4*], Shoumik Mojumdar[1,5], Sabnil Biswas[1], Sadek Ahammed Maruf[1], Selina Yeasmine[2] and Kasi Marimuthu[3]

[1]Department of Fisheries and Marine Bioscience, Faculty of Biological Science and Technology, Jashore University of Science and Technology, Jashore-7408, Bangladesh
[2]Freshwater Station, Bangladesh Fisheries Research Institute, Mymensingh 2201, Bangladesh
[3]Department of Environmental Science, Tezpur University, Tezpur -784028, Assam, India
[4]Institute for Higher Education and Research, Jashore University of Science and Technology, Jashore-7408, Bangladesh
[5]Department of Fish Health Management, Faculty of Fisheries and Ocean Sciences, Khulna Agricultural University, Khulna-9202, Bangladesh

*Correspondence author: amin2019@just.edu.bd / aminur1963@gmail.com

Received 13 July 2025 | Accepted 26 March 2026 | Published 03 June 2026

Abstract

The current study focused on the detailed data on stock assessments, including population structure, growth parameters, mortality, recruitment pattern, exploitation rate (E), maximum sustainable yield (MSY) and relative yield per-recruit of the commercially important small indigenous fish, mola (*Amblypharyngodon mola).* In total, 410 specimens of *A. mola* were collected through regular monthly intervals during January to December 2023, using the gill net from the Chitra River, located in the plain region of Narail district, Bangladesh. Total length (TL) and body weight (BW) of the collected *A. mola* specimens were measured using the digital slide callipers and electronic balance. The asymptotic length (L_∞) was estimated to be 8.9 cm, and growth coefficient (K) was 0.67 year^{-1}. The isometric value, b, was 3.133, which indicated the positive allometric growth. The growth performance index (Ø′) was estimated to be 4.02. The age at zero length (t_0) was 0.15 years and life-span (t_{max}) was found to be 4.22 years. The estimated total mortality (Z), natural mortality (M) and fishing mortality (F) were obtained to be 0.86, 1.03 and -0.19 year^{-1}, respectively. However, the negative fishing mortality indicated minimal fishing pressure on the stock of *A. mola*. The recruitment was observed throughout the year with two peak events during the months of July and October. Length at first capture (L_c) was 7.05 cm TL. The exploitation rate (E) was -0.19, where the E_{max} (exploitation rate producing maximum yield) was 0.42, suggesting under exploitation. The MSY of the *A. mola* stock was estimated at 1.01 mt. The results obtained from this study would be very useful to execute specific management for *A. mola* in the Chitra River. This study is the first investigation on population dynamics and stock status of the economically

important *A. mola* fish in the Chitra River, the plain region of Narail, Bangladesh, the findings of which would be helpful towards the fisheries management and biodiversity conservation of this important fish species substantially.
Keywords: *Amblypharyngodon mola*, Population structure, Stock status, Growth parameters, Exploitation rate, MSY, Fisheries management, Biodiversity conservation.

1. Introduction

The fisheries sector of Bangladesh contributes significantly to the national economy through nutrition, employment, income generation and foreign exchange earnings. Currently, fisheries account for approximately 3.57% of Bangladesh's GDP and contribute around 1.24% to the nation's foreign exchange income. Among the different sub-sectors, inland fisheries play a dominant role in sustaining the growth of Bangladesh's fisheries (Sunny *et al.*, 2021). The country's inland water bodies harbor a rich variety of aquatic species, with about 267 freshwater fish species reported. During 2018–2019, inland capture fish production from rivers, beels (natural depressions), floodplains, and Kaptai Lake were estimated at 3.25, 0.99, 7.81, and 0.11 lakh metric tons, respectively (Hasan *et al.*, 2021). Inland fisheries account for nearly 84% of the country's total fish production, placing Bangladesh third in global inland capture production and fifth in aquaculture output (Shamsuzzaman *et al.*, 2017). To evaluate the health and status of fish populations, length-weight relationship (LWR) studies are widely utilized (Mandal & Mandal, 2021). LWRs are fundamental tools in fishery biology, serving various purposes such as converting length-based growth models into weight-based models, assessing biomass, evaluating condition factors and conducting life-history comparisons across geographic populations (Kuriakose, 2017; Falsone *et al.*, 2022). Alongside, length-length relationships (LLRs) also provide critical insights for fish stock assessments and management strategies. These relationships are particularly valuable for understanding growth patterns and the effects of overexploitation on native fish populations, especially those with conservation concerns (Hossain *et al.*, 2012; Alam *et al.*, 2013). Understanding the growth dynamics of fish is essential for both theoretical research and practical applications, such as biomass estimation, yield prediction and determining seasonal variations in condition indices (Hossain et al., 2010). Several mathematical models (e.g., Beverton, 1966) have been developed to aid fisheries management by predicting potential yields and stock biomass at various exploitation levels (Dadzie *et al.*, 2017). These models depend on a wide range of biological parameters, including growth, recruitment, mortality rates and yield-per-recruit estimates. Stock assessment, which involves the collection, and analysis of biological and fishery data, is critical for evaluating current stock conditions and projecting future trends under different management scenarios (Cooper, 2006). Key parameters in stock assessment include age structure, fecundity, natural and fishing mortality, spawning behavior, and habitat use, all of which guide sustainable exploitation and conservation decisions.

Small Indigenous Fish Species (SIFS), defined as species with a maximum length of 25 cm, represent over 120 species in Bangladesh. These fishes contribute significantly to rural nutrition and livelihoods but face increasing threats from overfishing, habitat destruction and pollution (Alam *et al.*, 2013; Samad *et al.*, 2021). Among these, *A. mola*, a cyprinid fish widely distributed across South Asia including Bangladesh, India, Pakistan, Myanmar and Afghanistan is of particular importance (Coad, 1981; Talwar and Jhingran, 1991). This species is highly valued in artisanal fisheries due to its palatability and high nutritional content, being rich in protein, iron, zinc, calcium and essential vitamins (Zafri and Ahmed, 1981; Roos et al., 2007; Kongsbak *et al.*, 2008). It is also utilized as an ornamental fish (Gupta & Banerjee, 2015). In Bangladesh, *A. mola* serves as a vital source of micronutrients for rural communities, particularly for women and children. Although not currently listed as threatened in the

IUCN Red List (IUCN Bangladesh, 2000), its populations face risks due to environmental degradation and seed availability issues. Given these concerns, sustainable management of *A. mola* in natural habitats is crucial. This study was conducted in the Chitra River to assess the stock status of *A. mola*, aiming to inform effective conservation and management strategies.

2. Materials and Methods

2.1. Study Area and Sample Collection

A total of 410 individuals of *A. mola* were collected monthly from January to December 2023 (Table 1) in the Chitra River, located in the Narail district of Bangladesh (Figure 1). Specimens were obtained from local fishers using standard fishing techniques, primarily with cast nets (mesh size: 1.0–2.0 cm) and gill nets (mesh size: 1.5–2.5 cm). Following collection, the fish were immediately chilled on-site and subsequently transported to the laboratory at Jashore University of Science and Technology. In the lab, the specimens were preserved in 10% ethanol for further morphometric analysis.

2.2. Morphometric Measurements

Total length (TL, cm) of each fish was measured using a digital caliper, while body weight (BW, g) was recorded with an electronic balance. The precision for TL and BW measurements was 0.01 cm and 0.01 g, respectively. These length measurements were utilized in the FAO-ICLARM Stock Assessment Tools II (FiSAT II; Gayanilo and Pauly, 1997) and TropFishR package in R (Mildenberger et al., 2017) for stock assessment. All sample collection and measurement procedures adhered to ethical guidelines approved by the Agricultural Research Institute (ARI) and were overseen by the Bangladesh Fisheries Research Institute (BFRI).

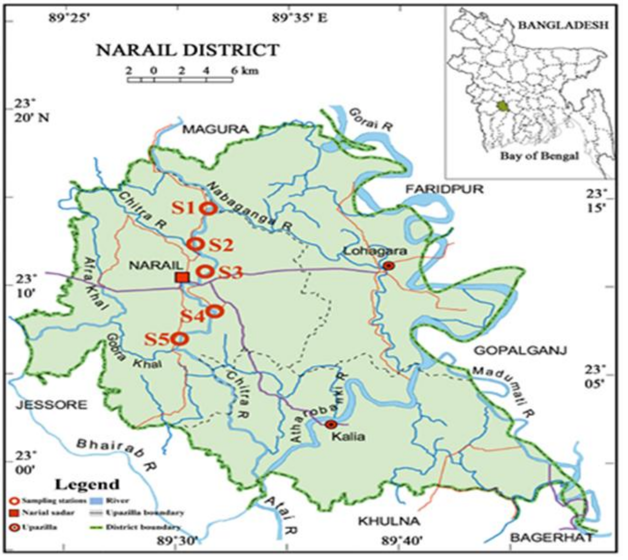

Figure 1. Map, showing the location of the study area (red- marked circle indicates sampling point) for *A. mola* in the Chitra River, Bangladesh

2.3. Analysis of Growth Patterns

Growth form was analyzed using the power function equation: BW = a × (TL)^b. Logarithmic transformation of the data yielded the linear equation ln (W) = ln (a) + b × ln (L). Linear regression analysis was applied to estimate the constants "a" and "b". Outliers were excluded following (Froese, 2006). A t-test was performed to determine whether the growth pattern was isometric (b = 3) or allometric, based on the method outlined by (Sokal and Rohlf, 1987).

2.4. Estimation of Growth Parameters

Length-frequency data (LFD) collected monthly, were analyzed using FiSAT II software (Gayanilo *et al.*, 1996). The Powell-Wetherall method (Powell, 1979; Pauly, 1984; Wetherall, 1986) was initially used to estimate the asymptotic length ($L\infty$) and the Z/K ratio, where Z is total mortality and K is the growth coefficient. These parameters were refined using the ELEFAN I algorithm and TropFishR in R (Mildenberger *et al.*, 2017). Gear selectivity was corrected using a probability capture model to improve the accuracy of growth parameter estimation.

Preliminary estimates of K and $L\infty$ were used to construct a length-converted catch curve and evaluate fishing gear selectivity. The corrected LFD was re-analyzed to obtain more precise values of K and $L\infty$ (Gayanilo *et al.*, 2002, 2005). The theoretical maximum age (t_{max}) was calculated using the equation of Froese and Binohlan (2000): $\log t_{max} = 0.5496 + 0.957 \times \log (t_m)$, and age at zero length (t_0) was estimated using Pauly's (1980) formula: $\log(-t_0) = -0.3922 - 0.2752 \log L_\infty - 1.038 \log K$. Growth performance index ($\emptyset'$) was calculated using the equation: $\emptyset' = \log_{10} K + 2 \log_{10} L_\infty$ (Pauly and Munro, 1984).

2.5. Capture Probability Estimation

Catch-curve analysis following Sparre (1987) was used to estimate capture probabilities by back-calculating fish numbers in the absence of gear selectivity.

2.6. Length at Recruitment

Seasonal recruitment patterns were assessed through back-calculation methods using the von Bertalanffy Growth Function (VBGF). The model inputs included the growth parameters L_∞, K, and amplitude of recruitment (C). Monthly sample frequency data were aligned over time as per Moreau and Cuende (1991) to generate recruitment curves.

2.7. Stock Assessment

The length-converted catch curve method (Gayanilo *et al.*, 2002, 2005) was applied to estimate total mortality (Z). Natural mortality (M) was calculated using Pauly's empirical formula (Pauly, 1980) as follows:

$$\log_{10} M = -0.0066 - 0.279 \log_{10} L\infty + 0.6543 \log_{10} K + 0.0463 \log_{10} T$$

where, T is the average water temperature, measured at 27°C, with a range from 26°C to 28°C. Fishing mortality (F) was determined by subtracting M from Z (F = Z - M), and exploitation rate (E) was calculated as E = F/Z.

The optimum exploitation levels Emax (maximum yield), $E_{0.1}$ (10% of virgin biomass), and $E_{0.5}$ (50% of virgin biomass) were derived using Beverton and Holt's (1966) yield-per-recruit model. From these values, the recommended length at first capture (L_c) was determined, and yield curves were generated to assess the effect of varying exploitation and L_c/L_∞ ratios.

2.8. Estimation of Maximum Sustainable Yield (MSY)

Relative yield per recruit (Y′/R) and biomass per recruit (B′/R) were calculated in FiSAT II, using the updated model of Pauly and Soriano (1986). Steady-state biomass (SSB) was estimated through Virtual Population Analysis (VPA) using TropFishR (Mildenberger *et al.*, 2017). This approach translated fish numbers to biomass based on LWR parameters for each length class. The MSY was calculated using the formula:

MSY = 0.5 × SSB × Z (Gulland, 1983; revised by Garcia, 1985).

2.9. Statistical Analysis

All statistical analyses were performed using the TropFishR package in R, FiSAT II software, and Microsoft Excel (DDXL add-in). Natural mortality (M) estimates were cross-validated using various models available in the Natural Mortality Estimator (NME) tool.

3. Results

3.1. Growth types

The length–weight relationship of *A. mola* in the Chitra River was determined as $W = 0.006TL^{3.0125}$ (Figure 2), based on monthly measurements (Table 1). This equation was used to convert length data into weight, resulting in an estimated spawning stock biomass (SSB) of 1.23 metric tonnes.

Table 1. Descriptive statistics on the total length (cm) and body weight (g) measurements of *A. mola*, collected monthly from January to December 2023 in the Chitra River, Narail, Bangladesh.

Month	n	Total length (cm)			Body Weight (g)		
		Min	Max	Mean ± SD	Min	Max	Mean ± SD
January	30	5.2	7.6	6.40 ± 1.96	4.52	5.12	4.12 ± 1.13
February	25	4.5	6.7	5.60 ± 1.56	3.09	5.54	4.43 ± 1.56
March	26	5.8	7.9	6.85 ± 1.48	4.88	6.86	5.87 ± 1.40
April	50	6.3	8.2	7.25 ± 1.34	4.43	7.21	6.32 ± 1.26
May	29	5.6	7.1	6.85 ± 1.67	4.57	6.34	5.95 ± 1.95
June	31	5.3	8.1	7.70 ± 1.97	4.23	7.05	6.64 ± 2.82
July	45	6.9	8.8	7.45 ± 2.91	4.56	8.87	7.29 ± 7.10
August	42	6.8	7.7	6.75 ± 2.75	5.76	7.09	6.42 ± 1.76
September	38	5.5	7.3	6.30 ± 2.54	4.45	7.56	5.90 ± 1.19
October	34	5.3	8.2	7.10 ± 1.13	5.37	7.89	6.13 ± 1.07
November	31	6.5	7.8	6.65 ± 1.62	5.93	8.52	7.22 ± 1.83
December	29	7.4	7.8	7.60 ± 1.13	4.72	7.38	6.05 ± 1.88

3.2. Growth parameters

Using the Powell-Wetherall method, initial estimates of *A. mola* growth parameters were L_∞ = 12.3 cm and Z/K = 1.66 (Figure 3). The K-scan method refined these estimates, yielding L_∞ = 8.92 cm and K = 0.67 $year^{-1}$ (Figure 4, Table 2). The von Bertalanffy Growth Curve (VBGC) was fitted to the length–frequency data, as shown in Figure 4. The growth performance index (Ø′), maximum lifespan (t_{max}) and age at zero length (t_0) were estimated at 4.02, 4.22 years and 0.15 years, respectively (Table 2).

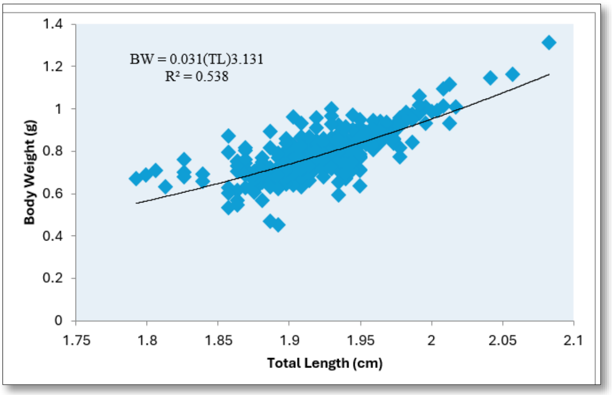

Figure 2. Length-weight relationship and growth pattern of mola fish (*A. mola*) in the Chitra River, Narail, Bangladesh.

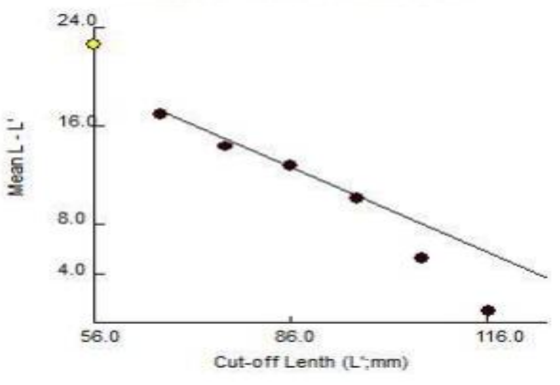

Figure 3. Powel-Wetherall plot for the length frequency data of *A. mola* in the Chitra River. Black dots are exploited samples. Solid black symbols are exploited samples that are used in the regression which provides asymptotic TL of 12.3 cm and Z/K of 1.66.

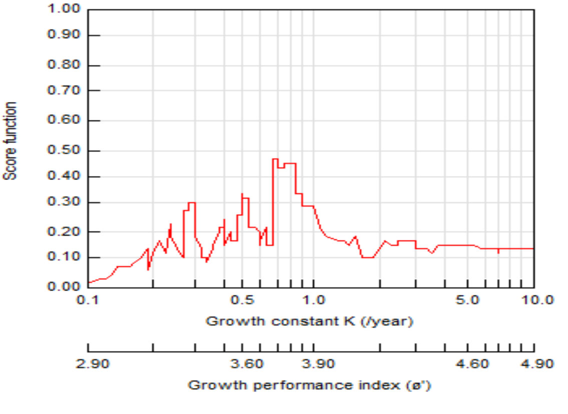

Figure 4. The growth performance index (Ø'-phi prime) of mola fish (*A. mola).*

Table 2. Growth and reproduction parameters (L_∞, K, t_{max}, Ø and t_0), mortality (Z, M and F) and fishery parameters (E, L_c and MSY) of *A. mola* (Hamilton, 1822) in the Chitra River, Bangladesh.

Description of parameters	Values
Growth parameters	
Asymptotic length (L_∞)	8.92 cm TL
Growth coefficient (K)	0.67 year^{-1}
Lifespan (t_{max})	4.22 year
Growth performance indexes (Ø)	4.02
Age at zero length (t_0)	0.15 year
Mortality parameters	
Total mortality (Z)	0.86 year^{-1}
Natural mortality (M)	1.03 year^{-1}
Fishing mortality (F)	-0.17 year^{-1}
Fishery parameters	
Exploitation rate (E)	-0.19
Exploitation rate producing maximum yield (E_{max})	0.421
Exploitation rate upon which the secondary rise of Y'/R is 10 percent of its virgin biomass ($E_{0.1}$)	0.355
Total length at first capture (L_c)	7.05 cm TL
Steady state biomass (SSB)	1.23 metric ton
Maximum sustainable yield (MSY)	1.01 metric ton

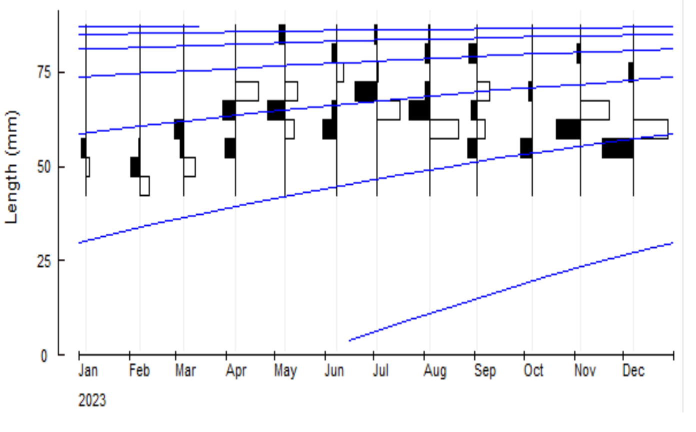

Figure 5. Von Bertalanffy growth curve of *A. mola* (TL_∞ = 8.92 cm, K = 0.67 year^{-1}) as super-imposed on the restructured total length-frequency histogram.

3.3 Length at recruitment of *A. mola*

The recruitment pattern of *A. mola* in the Chitra River was constant over the year and the major two peaks were identified during July and October (Figure 6).

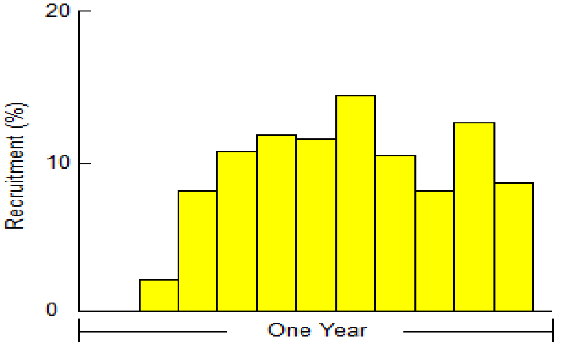

Figure 6. Recruitment pattern of *A. mola* in the Chitra River, Bangladesh from January to December 2023.

3.4. Stock assessments of *A. mola*

The total instantaneous mortality (Z) of *A. mola* in the Chitra River was estimated at 0.86 year^{-1} based on the length-converted catch curve analysis (Figure 7). At an average water temperature of 24°C, the natural mortality (M) was calculated as 1.03 year^{-1}. Consequently, the fishing mortality (F) was negative (-0.17 year^{-1}), indicating very low or negligible fishing pressure on the stock (Table 2, Figure 7).

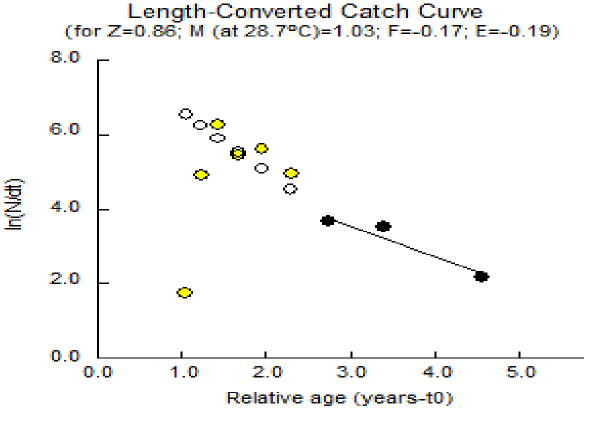

Figure 7. Length-converted catch curve of *A. mola* in the Chitra River.

3.5. Maximum sustainable yield (MSY) of *A. mola*

The maximum relative yield-per-recruit (Y'/R) for *A. mola* in the Chitra River was observed at an exploitation rate (E_{max}) of 0.421 (Figures 7 and 8), with corresponding $E_{0.1}$ and $E_{0.5}$

values of 0.355 and 0.278, respectively. The knife-edge selection model assumed individuals below the length at first capture (L_c) avoid the net, with a L_c/L_∞ ratio of 0.080, used for constructing the yield isopleths. The isopleths plot suggested optimal fishing at E ≈ 0.19 and L_c/L_∞ ≈ 0.050 (Figure 9). The current exploitation rate (~0.20) indicates that *A. mola* is not overexploited in the river. The optimal length at first capture (Lc_{50}) was estimated at 7.05 cm (Figure 8). This estimation is based on a length-structured virtual population analysis (VPA) that was conducted using the FiSAT software, with the results presented in Figure 10. **II**, the total spawning stock biomass (SSB) was approximately 1.23 metric tons, with the maximum sustainable yield (MSY) estimated at 1.01 metric tonnes if Lc = 7.05 cm is maintained.

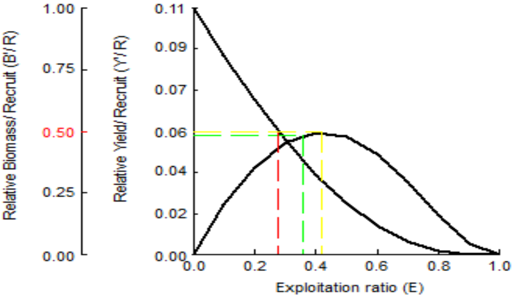

Figure 8. Yield-per-recruit and average biomass per recruit models, showing levels of yield index in *A. mola* in the Chitra River, Bangladesh.

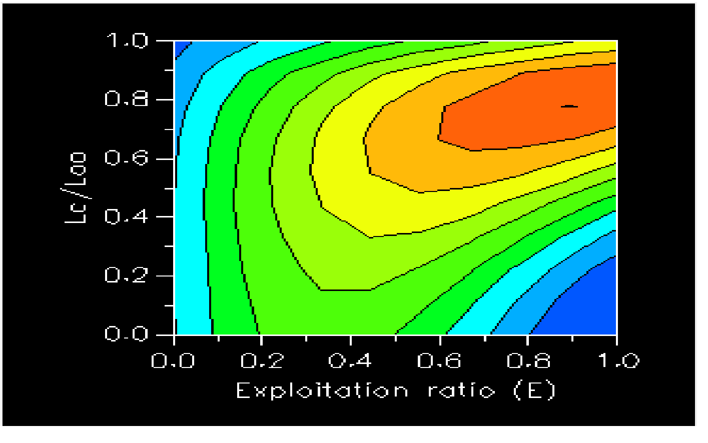

Figure 9. Yield Isopleths, showing optimum fishing activity both in terms of fishing effort and size of first capture of *A. mola* in the Chitra River, Bangladesh.

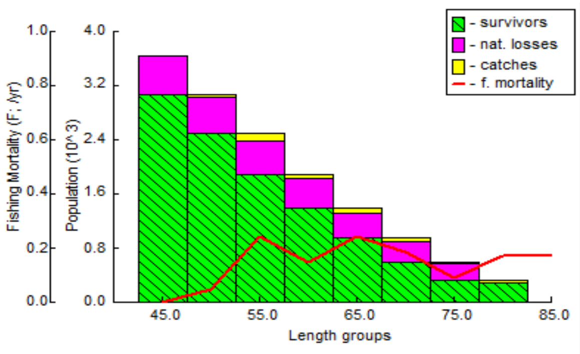

Figure 10. Length-structured virtual population analysis of *A. mola* in the Chitra River, Bangladesh.

4. Discussion

Stock assessment is a core component of fisheries science, used to evaluate the status of fish populations and predict the outcomes of various management strategies. It helps estimate key biological parameters such as growth, recruitment, mortality, exploitation rates and maximum sustainable yield (MSY), thereby supporting effective fisheries management decisions (Hilborn and Walters, 1992; Jennings *et al.*, 2001).

In this study, a significant number of *A. mola* specimens were sampled year-round using conventional fishing gears from the Chitra River. The total length (TL) of sampled individuals ranged from 4.5 to 8.8 cm, with 8.8 cm being the maximum length observed— exceedingly previously reported maximum lengths for this species in various rivers of Bangladesh and the Indian subcontinent (Hossain *et al.*, 2010; Sarker *et al.*, 2013; Islam *et al.*, 2017; Nawer *et al.*, 2018). This suggested that the Chitra River population may reach larger sizes under prevailing environmental and ecological conditions.

The length-weight relationship (LWR) for *A. mola* followed the equation W = a·L^b, with a coefficient a of 0.006 and allometric exponent b of 3.133. The b value, falling within the expected biological range (Carlander, 1969; Froese, 2006), indicates positive allometric growth, i.e., weight increases at a faster rate than length. This finding aligns with some previous studies (Das *et al.*, 2024), particularly for females and combined sexes, but contrasts with other studies reporting isometric or negative allometric growth (Sani *et al.*, 2010; Devi *et al.*, 2016; Ahmed *et al.*, 2017; Hasan *et al.*, 2020). Such discrepancies can result from differences in habitat, seasonal variations, maturity stages, food availability and sampling methods (Hossain, 2016). On the other hand, the estimated r^2 value in our study was 0.538, which is low compared to similar studies, indicating sample bias, seasonal variation, or gear selectivity issues (Mackinson, 2000; Hiddink and Jennings, 2005; Brouwer and De Roos, 2009; Kraak and Deriso, 2014; Shakya and Chhetri, 2021).

The coefficient of determination (r^2) for the LWR was 0.538, suggesting a moderate correlation between length and weight. This value is lower than those reported in several other studies (Hossain *et al.*, 2009; Islam *et al.*, 2017; Nawer *et al.*, 2018), possibly due to variability in environmental conditions or limitations in sampling smaller and larger individuals during the study.

Growth parameters estimated using the von Bertalanffy Growth Function (VBGF) showed an asymptotic length (L_∞) of 8.92 cm and a growth coefficient (K) of 0.67 $year^{-1}$. These estimates were derived from Powell-Wetherall and K-scan methods. The model fitted well to the length-frequency data without seasonal oscillation, as was also noted by Ahamed *et al.* (2012). The estimated age at zero length (t_0) was 0.15 years, and maximum life span (t_{max}) was calculated as 4.22 years, indicating a relatively short-lived species. Growth performance index (Ø′) was 4.02, consistent with findings by Azadi and Mamun (2009) and supports the suitability of the Chitra River environment for *A. mola* growth. Similar results were also obtained by Memon *et al.* (2017) in siluroid catfish (*Eutropiichthys vacha*) from Indus River, Pakistan.

Recruitment analysis revealed bimodal peaks in July and October, suggesting year-round spawning activity with distinct recruitment pulses. Although there is limited literature available for comparison, similar patterns are likely influenced by temperature, food availability and habitat quality (Choi *et al.*, 2005; Sarmin *et al.*, 2022).

Mortality analysis showed total mortality (Z) at 0.86 $year^{-1}$ and natural mortality (M) at 1.03 $year^{-1}$, resulting in a negative fishing mortality ($F = -0.17$ $year^{-1}$), indicating minimal fishing pressure on the stock. Similar to our results, several studies addressed that when a fish population is under a very low level of fishing effort (i.e., fishing pressure is negligible), it might be theoretically represented as showing negative fishing mortality in models. However, this is typically interpreted as an indication that fishing has negligible impact rather than an accurate representation of mortality (Punt and Hilborn, 1997; Restrepo and McAllister, 2001; Sainsbury and Campbell, 2001; Maunder and Deriso, 2003; Froese and Pauly, 2022). This contrasts with studies from other inland water bodies (Mustafa *et al.*, 2008), where higher fishing mortalities were observed. The exploitation rate (E) in the Chitra River was calculated at approximately 0.20, well below the estimated E_{max} of 0.42, indicating that the stock is currently underexploited. Relative yield-per-recruit analysis further revealed that maximum yield occurred at $E \approx 0.42$. Azadi and Mamun (2009) also found similar results in their investigation of *A. mola* from Kaptai Lake, Bangladesh.

While *A. mola* is listed as a species of least concern, our findings suggest it is not abundant in the Chitra River and may face ecological threats that could contribute to population decline. Therefore, conservation and management efforts are necessary to sustain this population. Recommended measures include enforcing minimum mesh size regulations, ensuring gear selectivity, restricting harvest during peak spawning periods and protecting spawning grounds.

Although this study focuses primarily on the biological aspects of stock assessment, future research should incorporate environmental and socio-economic factors. Effective fisheries management should consider fishers' livelihoods, economic efficiency and ecosystem sustainability (Hilborn & Walters, 1992). Integrated management policies targeting both ecological and human dimensions are essential for the long-term conservation of *A. mola* in the Chitra River and similar inland aquatic systems across Bangladesh.

5. Conclusion

This study evaluated the growth dynamics, mortality, recruitment, exploitation and stock status of *A. mola* in the Chitra River, Bangladesh. Our findings underscore the significance of sustaining lower exploitation rates to ensure the long-term viability of the *A. mola* population. Increasing fishing effort could pose significant risks to this species, given its ecological vulnerabilities and the potential for overfishing. Therefore, our recommendations focus on promoting sustainable fishing practices, continuous monitoring of stock health, that prioritize conservation and sustainable management of *A. mola* in natural habitats. Given the added pressure of climate change, the adoption of adaptive, science-based management strategies is also crucial.

Acknowledgments

This research work was supported by the Department of Fisheries and Marine Bioscience (FMB) at Jashore University of Science and Technology, Jashore, Bangladesh. We would like to thank all the teachers and staff of our FMB department for their full assistance and cooperation during the study. We appreciate the anonymous reviewers' insightful comments and suggestions for improving the quality of the paper.

Conflict of interests

The authors declare that they have no conflicts of interest that could have influenced the conduct, analysis or presentation of the research.

References

Ahamed, F., & Ohtomi, J. (2012). Growth patterns and longevity of the pandalid shrimp *Plesionika izumiae* (Decapoda: Caridea). Journal of Crustacean Biology, *32*(5), 733-740. https://doi.org/10.1163/193724012X645853

Ahmed, E. O., Ali, M. E., Aziz, A. A., & Rafi, E. M. (2017). Length-weight relationships and condition factors of five freshwater fish species in Roseries Reservoir. Journal of Fisheries Sciences, 11(2), 45-52.

Alam, M. M., Jahan, S. N., Hussain, M. A., De, M., Goutham-Bharathi, M.P., Magalhães, A.B., Mazlan, A. G., & Simon, K. D. (2013). Length-length relationship, length-weight relationship and condition factor of freshwater fish species of Bangladesh. AACL Bioflux, *6*(5), 498-509.

Azadi, M. A., & Mamun, A. (2009). Population dynamics of the cyprinid fish, *Amblypharyngodon mola* (Hamilton) from the Kaptai Lake, Bangladesh. Chittagong University Journal of Biological Sciences, *4*(1-2), 141-151.

Brouwer, S. L., & De Roos, A. M. (2009). The influence of fish size, season, and body condition on aquatic predation. Oecologia, *161*(4), 599-607.

Carlander, K. D. (1969). An operational-functional classification of fishery management techniques: With 1 table in the text. Internationale Vereinigung für theoretische und angewandte Limnologie: Verhandlungen, *17*(2), 636-640.

Choi, P., Jalani, N. H., & Datta, R. (2005). Thermodynamics and proton transport in nafion: II. Proton diffusion mechanisms and conductivity. Journal of the Electrochemical Society, *152*(3), E123. https://doi.org/10.1149/1.1859814

Coad B. W. (1981). Fishes of Afghanistan, anannotated check-list. National Museum of Natural Sciences Publications in Zoology, *14*, 1-26.

Cooper, A. B., & Weir, K. (2006). Cooper, A. B., & Weir, K. (2006). A guide to fisheries stock assessment: From data to recommendations (NHU-H-06-001). Durham, NH: University of New Hampshire Sea Grant College Program. https://repository.library.noaa.gov/view/noaa/38414

Dadzie, K. Q., Amponsah, D. K., Dadzie, C. A., & Winston, E. M. (2017). How firms implement marketing strategies in emerging markets: An empirical assessment of the 4A marketing mix framework. Journal of Marketing Theory and Practice, *25*(3), 234-256. https://doi.org/10.1080/10696679.2017.1311220

Das, J. N., & Saikia, S. (2024). Length-weight relationship and condition factor of *Pachypterus atherinoides* (Bloch, 1794) from upper Brahmaputra basin, Assam, NE India. Advances in Bioresearch, 15(6): 261-270. http://dx.doi.org/10.24327/ijrsr.2018.0901.1446

Falsone, F., Geraci, M. L., Scannella, D., Gancitano, V., Di Maio, F., Sardo, G., Quattrocchi, F., & Vitale, S. (2022). Length-weight relationships of 52 species from the south of Sicily (Central Mediterranean Sea). Fishes, *7*(2), 92. https://doi.org/10.3390/fishes 7020092

Froese, R. (2006). Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. Journal of Applied Ichthyology, *22*(4), 241-253. https://doi.org/10.1111/j.1439-0426.2006.00805.x

Froese, R., & Binohlan, C. (2000). Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishes, with a simple method to evaluate length frequency data. Journal of Fish Biology, *56*(4), 758-773. https://doi.org/10.1111/j.1095-8649.2000.tb00870.x

Froese, R., & Pauly, D. (Eds.). (2022). FishBase. World Wide Web electronic publication. https://www.fishbase.org.

Garcia, S., Sparre, P., & Csirke, J. (1989). Estimating surplus production and maximum sustainable yield from biomass data when catch and effort time series are not available. Fisheries Research, *8*(1), 13-23. https://doi.org/10.1016/0165-7836(89)90037-4

Gayanilo, F. C. Jr., Sparre, P., & Pauly, D. (1996). The FAO-ICLARM Stock Assessment Tools (FiSAT) User's Guide. FAO computerized information series (Fisheries), *8*, 126 p.

Gayanilo, F. C. Jr., Sparre, P., & Pauly, D. (1997). FAO-ICLARM Stock Assessment Tools (FiSAT). Reference manual. FAO computerized information series (Fisheries), FAO, Rome, Italy, 8, 262 p.

Gayanilo, F.C. Jr., Sparre, P. and Pauly, D., 2002. The FAO-ICLARM Stock Assessment Tools II (FiSAT II Ver. 1.0). FAO, Rome, 81 p. http://www.fao.org/fi/statist/fisoft/fisat/index

Gayanilo, F. C. Jr., Sparre, P., & Pauly, D. (2005). FAO-ICLARM Stock Assessment Tools II (FiSAT II). User's Guide. FAO Computerized Information Series (Fisheries). No. 8, Revised version, FAO, Rome, 168 p. https://openknowledge.fao.org/handle/20.500.14283/y5997e

Gulland, J.A. (1983) Fish Stock Assessment. A Manual of Basic Method. FAO/Wiley Series on Food and Agriculture, Rome, 241 p.

Gupta, S., & Banerjee, S. (2015). Length–weight relationship of *Amblypharyngodon mola* (Ham. -Buch., 1822), a freshwater cyprinid fish from West Bengal, India. Zoology and Ecology, *25*(1), 54-58.

Hasan, M. R., Al Mamun, A., & Hossain, M. Y. (2020). Length-weight relationships of 12 indigenous fishes and 3 shellfishes from mangrove and floodplain ecosystems in Southwestern Bangladesh. Egyptian Journal of Aquatic Biology and Fisheries, *24*(5), 69-76. https://doi.org/10.21608/ejabf.2020.103532

Hiddink, J. G., & Jennings, S. (2005). Indicators of the impact of fishing on the biodiversity of ecosystems. Environmental Conservation, *32*(2), 145-153.

Hilborn, R., & Walters, C. J. (1992). Stock and recruitment. In: Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty, Springer, Boston, MA, USA, pp. 241-296. http://dx.doi.org/10.1007/978-1-4615-3598-0

Hossain, M. Y., Ohtomi, J., Ahmed, Z. F., Ibrahim, A. H. M., & Jasmine, S. (2009). Length-weight and morphometric relationships of the tank goby *Glossogobius giuris* (Hamilton, 1822) (Perciformes: Gobiidae) in the Ganges of Northwestern Bangladesh. Asian Fisheries Science, 22, 961-969. http://dx.doi.org/10.33997/j.afs.2009.22.3.008

Hossain, M. S., Sharifuzzaman, S. M., Chowdhury, S. R., & Sarker, S. (2016). Habitats across the life cycle of hilsa shad (*Tenualosa ilisha*) in aquatic ecosystem of Bangladesh. Fisheries Management and Ecology, 23(6), 450-462. https://doi.org/10.1111/fme.12185

Hossain, M. Y. (2010). Length-weight, length-length relationships and condition factor of three Schibid catfishes from the Padma River, Northwestern Bangladesh. *Asian Fisheries Science*, *23*(1), 329-339. https://doi.org/10.33997/j.afs.2010.23.3.005

Hossain, M. Y., Rahman, M. M., Fulanda, B., Jewel, M. A. S., Ahamed, F., & Ohtomi, J. (2012). Length–weight and length–length relationships of five threatened fish species from the Jamuna (Brahmaputra River tributary) river, northern Bangladesh. *Journal of Applied Ichthyology*, *28*(2), 275-277. https://doi.org/10.1111/j.1439-0426.2011.01900.x

Islam, M. R., Azom, M. G., Faridullah, M., & Mamun, M. (2017). Length-weight relationship and condition factor of 13 fish species collected from the Atrai and Brahmaputra rivers, Bangladesh. Journal of Biodiversity and Environmental Sciences, *10*(3), 123-133.

IUCN, Bangladesh. (2000). Red Book of Threatened Animals of Bangladesh. IUCN – The World Conservation Union, 54 p.

Jennings, S., Dinmore, T. A., Duplisea, D. E., Warr, K. J., & Lancaster, J. E. (2001). Trawling disturbance can modify benthic production processes. Journal of Animal Ecology, *70*(3), 459-475. https://doi.org/10.1046/j.1365-2656.2001.00504.x

Hilborn, R., & Walters, C. J. (1992). Stock and recruitment. In: Quantitative Fisheries Stock Assessment. Springer, Boston, MA, USA, pp. 241-296. http://dx.doi.org/10.1007/978-1-4615-3598-0

Kraak, S. B. M., & Deriso, R. B. (2014). How to manage the fishery from the first steps: The importance of stock-recruitment relationships. Fisheries Research, *153*, 1-12.

Khan, M. A., Khan, S., & Miyan, K. (2012). Studies on length-weight and length-length relationships of four freshwater fishes collected from River Ganga. Journal of Fisheries and Aquatic Science, *7*(6), 481-484. https://doi.org/10.3923/jfas.2012.481.484

Kongsbak, K., Thilsted, S. H., & Wahed, M.A. (2008). Effect of consumption of the nutrient-dense, freshwater small fish *Amblypharyngodon mola* on biochemical indicators of vitamin A status in Bangladeshi children: A randomized, controlled study of efficacy. The British Journal of Nutrition, 99 (3): 581-597. https://doi.org/10.1017/ S000711450781912 X.

Kuriakose, S. (2017) Estimation of length weight relationship in fishes. In: Course Manual Summer School on Advanced Methods for Fish Stock Assessment and Fisheries Management. Lecture Note Series No. 2/2017. CMFRI, Kochi, Japan, pp. 215-220.

Mandal, S., & Mandal, B. (2021). Study of Length-weight relationship and the condition factors of *Lepidocephalichthys guntea* (Hamilton, 1822) from Kangsabati river of district West Midnapore, West Bengal, India. Journal of University of Shanghai for Science and Technology, *23*(8), 602-615. http://dx.doi.org/10.51201/JUSST/21/08433

Mackinson, S. (2000). A comparison of models of fish growth and their impact on fisheries management. ICES Journal of Marine Science, *57*(3), 622-630.

Maunder, M. N., & Deriso, R. B. (2003). An evaluation of the relationship between fishing mortality and effort. Fishery Bulletin, *101*(3), 572-580.

Mazumder, M. S. A., Rahman, M. M., Ahmed, A. T. A., Begum, M., & Hossain, M. A. (2008). Proximate composition of some small indigenous fish species (SIS) in Bangladesh. International Journal of Sustainable Crop Production, *3*(4), 18-23.

Memon, A. M., Liu Qun, L. Q., Baloch, W. A., Soomro, A. N., Mohsin, M., Noman, M., & Karim, E. (2017). Population parameters of siluroid catfish (*Eutropiichthys vacha*) from Indus River, Pakistan. International Journal of Agriculture and Biology, 19(4):751-760. https://doi.org/10.17957/IJAB/15.0352

Mildenberger, T. K., Taylor, M. H., & Wolff, M. (2017). TropFishR: an R package for fisheries analysis with length-frequency data. Methods in Ecology and Evolution, *8*(11), 1520-1527. https://doi.org/10.1111/2041-210X.12791

Moreau, J., & Cuende, F. (1991). On improving the resolution of the recruitment patterns of fishes. Fishbyte, *9*(1), 45-46. https://hdl.handle.net/20.500.12348/3109

Mustafa, M. G., & De Graaf, G. (2008). Population parameters of important species in inland fisheries of Bangladesh. Asian Fisheries Science, *21*(2), 147-158. http://dx.doi.org/10.33997/j.afs.2008.21.2.002

Nawer, F., Hossain, M. Y., Hossen, M. A., Khatun, D., Parvin, M. F., Ohtomi, J., & Islam, M. A. (2017). Morphometric relationships of the endangered Ticto barb *Pethia ticto* (Hamilton, 1822) in the Ganges River (NW Bangladesh) through multi-linear dimensions. Jordan Journal of Biological Sciences, *10*, 199-203.

Pauly, D. (1980). Length-converted catch curves and the seasonal growth of fishes. Fishbyte, *8*(3), 33-38.

Pauly, D. (1983). Length-converted catch curves: a powerful tool for fisheries research in the tropics (part 2). Fishbyte, *2*(1), 17-19.

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

Powell, D. G. (1979). Estimation of mortality and growth parameters from the length frequency in the catch. Rapports et Proces-Verbaux des Reunions (Denmark), *175*, 167-169.

Punt, A. E., & Hilborn, R. (1997). Biological assessment of the fishery for orange roughy (*Hoplostethus atlanticus*) in New Zealand. Fisheries Research, *32*(1-2), 151-167.

Restrepo, V. R., & McAllister, M. K. (2001). The role of fishing mortality in stock assessment. North American Journal of Fisheries Management, *21*(1), 285-293.

Roos, N., Wahab, M. A., Chamnan, C., & Thilsted H. (2007). The role of fish in food-based strategies to combat vitamin A and mineral deficiencies in developing countries. The Journal of Nutrition, *137*(4), 1106-1109. https://doi.org/10.1093/jn/137.4.1106

Saha, B. K., Islam, M. R., Saha, A., & Hossain, M. A. (2009). Reproductive biology of the mola carplet *Amblypharyngodon mola* (Hamilton) (Cypriniformes: Cyprinidae) from Netrakona water. Bangladesh Journal of Scientific and Industrial Research, *44*(3), 377-379. https://doi.org/10.3329/bjsir.v44i3.4414

Samad, M. A., Rahman, M. A., Mahfuj, M. S. E., Yeasmin, S. M., Sultana, M. F., Rahman, M. H., Ahmed, F. F., & Hossain, M. Y. (2022). Life-history traits of ten commercially important small indigenous fish species (SIFS) in the Oxbow lake (Southwestern Bangladesh): key for sound management. Environmental Science and Pollution Research, *29*, 23650-23664. https://doi.org/10.1007/s11356-021-17492-5

Sainsbury, K. J., & Campbell, R. A. (2001). The role of ecology in the fisheries assessment process. Australian Journal of Marine and Freshwater Research, *52*(2), 149-155.

Sani, R., Gupta, B. K., Sarkar, U. K., Pandey, A., Dubey, V. K., & Singh Lakra, W. (2010). Length–weight relationships of 14 Indian freshwater fish species from the Betwa (Yamuna River tributary) and Gomti (Ganga River tributary) rivers. Journal of Applied Ichthyology, *26*(3), 456-459. https://doi.org/10.1111/j.1439-0426.2009.01388.x

Sarkar, U. K., Khan, G. E., Dabas, A., Pathak, A. K., Mir, J. I., Rebello, S. C., Pal, A., & Singh, S.P. (2013). Length weight relationship and condition factor of selected freshwater fish species found in River Ganga, Gomti and Rapti, India. Journal of Environmental Biology, *34*(5), 951-956.

Shakya, B., & Chhetri, R. B. (2021). Effect of sampling bias and seasonal variation on the estimation of fish population parameters. International Journal of Fisheries and Aquatic Studies, *9*(3), 14-22.

Shamsuzzaman, M. M., Islam, M. M., Tania, N. J., Al-Mamun, M. A., Barman, P. P., & Xu, X. (2017). Fisheries resources of Bangladesh: Present status and future direction. Aquaculture and Fisheries, *2*(4), 145-156. https://doi.org/10.1016/j.aaf. 2017.03.006

Sharmin, S.A. (2022). Effect of acidification on the abundance of fish larvae in Rezu khal estuary, Cox's Bazar Coasts, Bangladesh, MS Thesis, Department of Fisheries Resource Management, Faculty of Fisheries, Chattogram Veterinary and Animal Sciences University, Chattogram, 44 p. Bangladesh. http://dspace.cvasu.ac.bd/jspui/ handle/123456789/1016

Sokal, R. R., & Rohlf, F. J. (1987). Biostatistics. Francise & Co, New York, 10, 2088-2092.

Sparre P. (1987). Computer programs for fish stock assessment: Length-based fish stock assessment for Apple II computers. FAO Fisheries Technical Paper (101) Supplement, *2*, 218 p.

Sunny, A. R., Mithun, M. H., Prodhan, S. H., Ashrafuzzaman, M., Rahman, S. M. A., Billah, M. M., Hussain, M., Ahmed, K. J., Sazzad, S. A., Alam, M. T., & Rashid, A. (2021). Fisheries in the context of attaining sustainable development goals (SDGs) in Bangladesh:

COVID-19 impacts and future prospects. Sustainability, *13*(17), 9912. https://doi.org/10.3390/su13179912

Talwar, P. K., & Jhingran, A. G. (1991). Inland Fishes of India and Adjacent Countries. Oxford-IBH Publishing Co. Pvt. Ltd., New Delhi, India, 1158 p.

Wetherall, J.A. (1986). A new method for estimating growth and mortality parameters from length frequency data. Fishbyte, 4(1), 12-14.

Zafri, A., & Ahmed, K. (1981). Studies on the vitamin A content of fresh water fishes. Content and distribution of vitamin A in mola (*A. mola*) and dhela (*Rohtee cotio*). Bangladesh Journal of Biological Sciences, 10, 47-53.