Research Article

Stock's Status of Elongate Glass-Perchlet *Chanda nama* in the Ganges River (Bangladesh): Suggestions for Future Proper Management

Md. Asadujjaman[1], Md. Yeamin Hossain[2*], Most. Farida Parvin[3], Most. Shakila Sarmin[2], Fairuz Nawer[2], Wasim Sabbir[4], Md. Ashekur Rahman[2], Nur-E-Farjana Ilah[2], Md. Joynal Abedin[5], Md. Abdus Samad[6] and Gitartha Kaushik[7]

[1]Department of Aquaculture, Khulna Agricultural University, Khulna 9100, Bangladesh; [2]Department of Fisheries, University of Rajshahi, Rajshahi 6205, Bangladesh; [3]Institute of Environmental Science (IES), University of Rajshahi, Rajshahi 6205; Bangladesh; [4]Fisheries and Marine Resource Technology Discipline, Khulna University, Khulna 9208, Bangladesh; [5]Department of Zoology, Carmichael College, National University, Bangladesh; [6]Department of Fisheries and Marine Bioscience, Jashore University of Science and Technology, Jashore 7408, Bangladesh; [7]Department of Zoology, Rangapara College, Sonitpur, Assam 784505, India.

Abstract | The Elongate glass-perchlet *Chanda nama* Hamilton, 1822 is broadly found in Bangladesh, Myanmar, India, Pakistan, and Nepal. Our study represents a detailed report on stock status such as population structure, growth parameter (asymptotic length, L_∞; growth co-efficient, K; age at zero length, t_0; growth performance index, $Ø'$), life span (t_{max}), mortality (total, Z; natural, M; fishing, F), recruitment pattern, exploitation rate (E) and maximum sustainable yield (MSY) of ray-finned *Chanda nama* for the first time from the Ganges River of north-western Bangladesh. A sum of 1260 fish was collected during January to December 2017. The total length (TL) was recorded in the range of 3.3 to 9.9 cm. The negative allometric growth pattern was assessed through the b value < 3.0. Further, the L_∞ was 10.25 cm as well as K was found 0.55 year^{-1}. The $Ø'$ was calculated as 1.762, t_0 was 0.057 years while the t_{max} was estimated as 2.49 years. In addition, the Z, M, and F were obtained as 3.11, 1.63, and 1.48 year^{-1}, respectively. The trend of recruitment was continual through one peak occurrence in May-July. Length of the first capture (L_c50) observed at TL of 3.32 cm. However, the exploitation rate (E) was assessed as 0.48 whereas the maximum allowable yield (E_{max}) was 0.46. The maximum sustainable yield was estimated as 4.51 metric tons. Consequently, the information from this study would be beneficial for the implementation of a proper management strategy in the Ganges River and the related ecosystems.

Received | December 08, 2022; **Accepted** | December 18, 2023; **Published** | March 22, 2024
***Correspondence** | Md. Yeamin Hossain, Department of Fisheries, University of Rajshahi, Rajshahi 6205, Bangladesh; **Email:** hossainyeamin@gmail.com
Citation | Asadujjaman, M., M.Y. Hossain, M.F. Parvin, M.S. Sarmin, F. Nawer, W. Sabbir, M.A. Rahman, N.F. Ilah, M.J. Abedin, M.A. Samad and G. Kaushik. 2024. Stock's status of elongate glass-perchlet *Chanda nama* in the Ganges River (Bangladesh): Suggestions for future proper management. *Sarhad Journal of Agriculture,* 40(2): 275-285.
DOI | https://dx.doi.org/10.17582/journal.sja/2024/40.2.275.285
Keywords | *Chanda nama,* Ganges River, Management, Mortality, Stock assessment

Introduction

Fish are considered the most important source of animal protein worldwide (Roy *et al*., 2020). In open-water habitats, the increasing demand for fish and fisheries products results from immense pressure on their natural stocks (Sabbir *et al*., 2021). Fish are currently known as inadequate renewable resource (Panhwar *et al*., 2013). Therefore, sustainability is obligatory to maintain the renewable capability of the wild fisheries stock by the appropriate assessment of the exploitation rate. About 2,000 species were recorded from freshwater under the order of Perciformes (Froese and Pauly, 2022). Around 8 genera and 51 species are covered by the family Ambassidae (Nelson, 1994) including *Chanda nama* Hamilton, 1822. This species is popularly known as the semi-transparent-body ray-finned fish. Further, this species has a wide range of distribution from Bangladesh, Myanmar, India, Pakistan to Nepal (Roberts, 1994). Globally *C. nama* is identified as the name of Elongate glass-perchlet whereas in Bangladesh and India, it is popular as Chanda or Nama chanda and in Nepal as Nata channa or Chanerbijuwa (Froese and Pauly, 2022). It inhabits clear streams, static and flowing waters, ponds, canals, and flooded fields (Rahman, 1989). It is a very popular ornamental cum food fish for rural people of south-east Asia and provides a source of nutrition with a low market price. Earlier, *C. nama* in Bangladesh was evaluated as vulnerable (IUCN Bangladesh, 2000) and now it is categorized as the least concern (IUCN, 2021).

Understanding the life history characteristics of a particular fish population is necessary to ensure sustainability in the wild environment (Foster and Vincent, 2004). However, the study gap of the life history traits of fish populations in the open water ecosystem is a major problem to execute proper fishing policies in the wild ecosystem and it requires immediate investigation (Sabbir *et al*., 2021). Stock assessment of fish allows us to ensure appropriate management of natural fish stock by providing baseline information. Observation of the growth pattern for a particular species is significant to analyze the seasonal variation of growth rate, and condition indices and to estimate biomass as well as production (Sabbir *et al*., 2021; Mawa *et al*., 2022; Nadia *et al*., 2022). Dynamic models (Beverton and Holt, 1957) help us in determining potential yields and stock biomass, which are helpful to define management strategies comprehensively. For deriving these models, knowledge of growth, recruitment, mortality, MSY, and exploitation rate of fish stocks is essential. However, stock assessment through length-based methodology is effective in studying fish population parameters in open-water habitats (Pauly and Morgan, 1987). Moreover, knowledge about length-frequency distribution (LFD) is crucial to detect the health of waterbody by stock assessment of existing biomass (Ranjan *et al*., 2005; Sabbir *et al*., 2022).

A few research have been carried out on different aspects of *C. nama*, particularly feeding ecology (Grubh and Winemiller, 2004), length-length and length-weight relations (Hossain *et al*., 2012, 2016; Islam *et al*., 2017), life-history considerations (Hossain *et al*., 2021a) but study on stock assessment is not available. Because of the inadequacy of biotic knowledge, the current investigation was conducted to describe the population dynamics of economically valuable *C. nama*. We analyzed the growth parameters, mortality rate, MSY, recruitment, and relative yield per-recruitment of *C. nama* with one year of sampling which covers small to large sizes in the Ganges River.

Materials and Methods

Sampling and measurement

The experiment has been carried out in the Ganges River (24° 65' N and 88° 06' E), north-western Bangladesh. 1260 samples of *C. nama* were taken from the fisherman's catch through January-December 2017 using the gill net (mesh size: 1.5-2.5 cm). Fish were immediately iced at the sampling sites and then kept with 10% formalin for further study. Measurements of the individual's total length (TL, cm) and body weight (BW, g) were recorded with a measuring board and digital balance, accordingly. However, only TL was utilized for the estimation of the stock through stock assessment tools FiSAT II (FAO-ICLARM) (Gayanilo and Pauly, 1997).

Growth pattern and parameters

The growth pattern was determined using the equation BW = a*(TL)^b where a and b were analyzed from ln (W) = ln (a) + b*ln (L) (Froese, 2006). To verify isometric or (±) allometric growth (Tesch, 1971), the t-test has been considered. The Powell-Wetherall method was followed to analyze the length-frequency distribution (Wetherall, 1986) through the FISAT software (Gayanilo *et al*., 1994). This assisted an adjustment of the length-based Z-equation of Beverton and Holt (1956) into a form of $\acute{L}$ - $L'a$ + Lb (L' = cut-off length, as the length for each size class of the smallest recruited fish), $\acute{L} = (L_\infty + L')/[1+(Z/K)]$ indicates the mean length of all fish ≥ L'. An initial L_∞ was obtained from s/b and Z/K as – (1+b)/b through the above equation. Depending on the size range captured for the species, the frequency of the size-class intervals was used. The length-frequency dataset was arranged to assess von Bertalanffy growth function (VBGF) such as asymptotic length (L_∞) and growth constant (K) by FiSAT software with the ELEFAN I tools (Gayanilo *et al*., 2005). The life-span (t_{max}) was evaluated with log t_{max} = 0.5496 + 0.957*log(t_m) where t_m means the age of first sexual maturity (Froese and Binohlan, 2000). Following the Log (-t_0) = -0.3922 - 0.2752 Log L_∞ - 1.038 Log K, age at zero length (t_0) was computed (Pauly, 1980). Whereas the growth performance index was evaluated via $\emptyset' = \log_{10}K + 2\log_{10}L_\infty$ (Pauly and Munro, 1984).

Mortality, exploitation and recruitment

The total mortality rate (Z) was obtained through the length converted catch curve procedures. The natural mortality (M) was computed by the empirical formula (Pauly, 1980) using growth parameters: $\log_{10}M = -0.0152 - 0.279 \log_{10}L_\infty + 0.6543 \log_{10}K + 0.4634 \log_{10}T$; where T signifies the average annual ambient temperature (°C). The mortality by fishing (F) was obtained from Z-M. Furthermore, the exploitation rate (E) was estimated by $E = F/Z = F/(F + M)$ (Gulland, 1983). The recruitment pattern was determined with growth parameters, where plots revealed the seasonal trends of fish recruitment. Recruitment patterns specified by the VBGF frequencies and reconstructed samples were used.

Relative yield-per-recruit (Y'/R) and maximum sustainable yield (MSY)

Beverton and Holt's (1979) concept has been followed to estimate Y'/R of *C. nama*. E_{max}, $E_{0.1}$ and $E_{0.5}$ were obtained from the Y'/R *vs*. E model. At the $E_{0.5}$ stage, the length of the first capture (L_c) was suggested. Using the length-structured VPA routine, the steady state biomass (SSB) was computed. As a consequence, the MSY of *C. nama* was determined through the equation of Gulland (1983) as 0.5*SSB*Z.

Results and Discussion

Growth pattern and parameters

Table 1 presented monthly descriptive information on the length and weight of *C. nama*. Additionally, variables *a* and *b* of LWR were inferred from the growth data and the correlation was defined through W = 0.0071TL$^{3.13}$ (Figure 1). The Powell-Werherall technique combined and evaluated monthly length frequency data with the expected findings: L_∞ = 7.56 along with Z/K = 2.92 (Figure 2). Further, the K-scan method generated L_∞ as TL of 10.25 cm whereas the K value was 0.55 year^{-1} (Table 2 and Figure 3). The growth curves (von Bertalanffy) were illustrated in Figures 4 and 5. The t_0 was assessed as 0.057 years, while the $\emptyset'$ was 1.762 and t_{max} was estimated as 2.49 years (Table 2).

Table 1: *Descriptive statistics on the total length (cm) and body weight (g) measurements of Chanda nama Hamilton, 1822 in the Ganges River of north-western Bangladesh during January–December 2017.*

Month	n	TL				BW			
		Min	Max	Mean ± SD	95% CL	Min	Max	Mean ± SD	95% CL
Jan	101	2.1	6.7	4.251±0.970	4.060 to 4.443	0.07	3.25	0.820±0.643	0.693 to 0.946
Feb	121	2.6	7.3	4.360±0.095	4.171 to 4.548	0.11	3.84	0.866±0.657	0.747 to 0.984
Mar	108	2.1	8	4.969±0.952	4.788 to 5.151	0.05	4.64	1.048±0.691	0.917 to 1.180
Apr	106	3	5.8	4.057±0.520	3.956 to 4.157	0.25	1.82	0.622±0.276	0.569 to 0.675
May	107	2.6	5.4	4.185±0.610	4.061 to 4.302	0.15	1.6	0.717±0.320	0.655 to 0.778
Jun	137	2.9	6.3	4.747±0.547	4.654 to 4.839	0.24	2.36	1.015±0.340	0.957 to 1.072
Jul	104	2.2	6.2	4.401±0.746	4.256 to 4.546	0.06	2.14	0.795±0.418	0.713 to 0.876
Aug	102	2.2	6.3	4.109±0.760	3.959 to 4.258	0.07	2.31	0.677±0.376	0.603 to 0.751
Sep	107	1.7	5	3.052±0.769	2.905 to 3.200	0.05	1.2	0.318±0.246	0.270 to 0.365
Oct	80	2.2	6.5	4.156±1.324	3.861 to 4.451	0.04	2.8	0.864±0.797	0.686 to 1.041
Nov	99	2.7	6.3	4.119±0.721	3.975 to 4.263	0.17	2.31	0.659±0.389	0.582 to 0.736
Dec	88	3	7.3	4.903±1.213	4.646 to 5.160	0.19	3.5	1.243±0.947	1.043 to 1.444

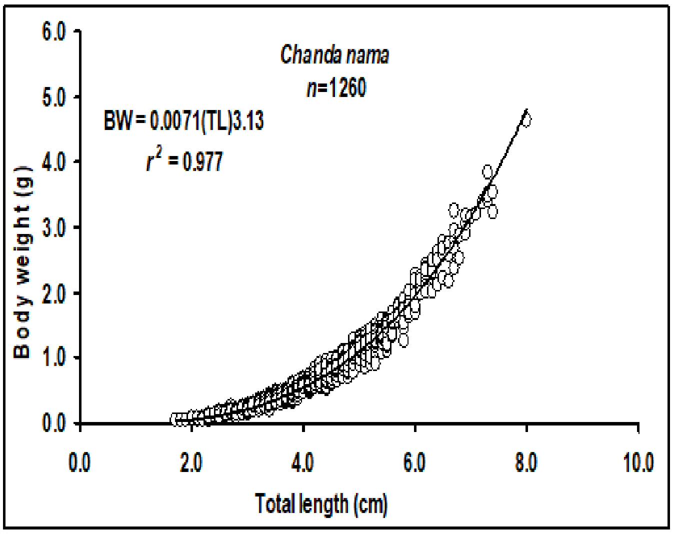

Figure 1: *Growth pattern of Chanda nama in the Ganges River, Bangladesh.*

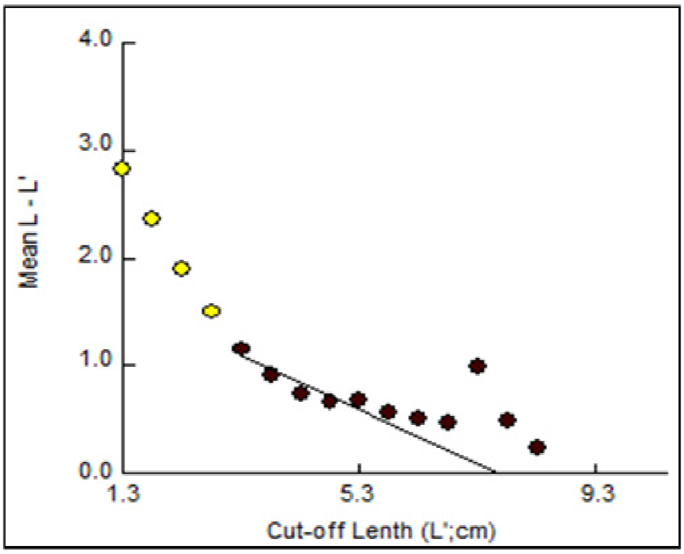

Figure 2: *Powell-Wetherall regression plot, equation is Y = 1.03–0.255X, r = 0.922 (L_{∞} = 26.39 cm and Z/K = 2.92).*

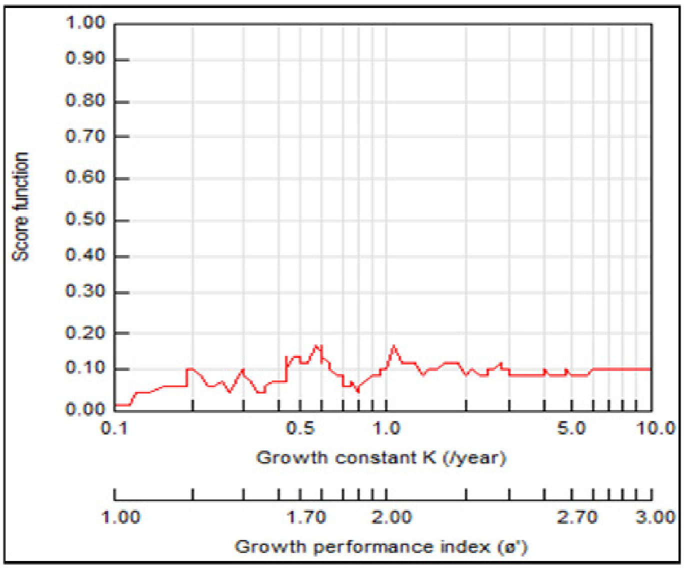

Figure 3: *K-scan routine with growth performance indices in Chanda nama from the Ganges River, Bangladesh.*

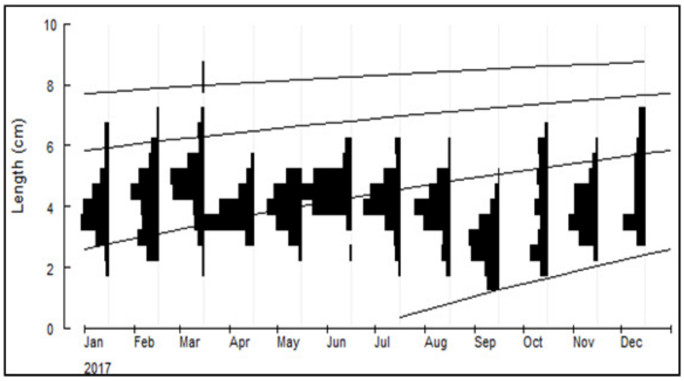

Figure 4: *von Bertalanffy growth curve for Chanda nama in the Ganges River, Bangladesh.*

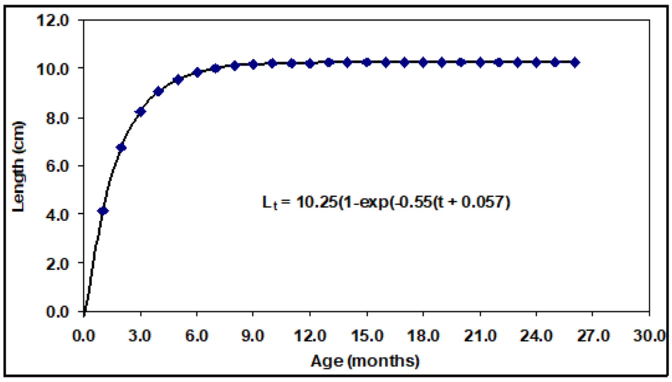

Figure 5: *Growth curve of Chanda nama based on VBGF computed growth parameters in the Ganges River, Bangladesh.*

Table 2: *Growth parameters (L_{∞} and K), mortality (Z, M, F) and Fishery parameters (E, L_c and MSY) of Chanda nama Hamilton, 1822 in the Ganges River of north-western Bangladesh.*

Description of parameters	**Values**
Growth and reproduction	
Asymptotic length (L_{∞})	10.25 cm TL
Growth coefficient (*K*)	0.55 year^{-1}
Life-span (t_{max})	2.49 years
Growth performance indexes (Ø')	1.762
Age at zero length (t_0)	0.057 years
Size at first sexual maturity (L_m)	5.11 cm TL
Age at first sexual maturity (t_m)	0.69 years
Mortality parameters	
Total mortality (*Z*)	3.11 year^{-1}
Natural mortality (*M*),	1.63 year^{-1}
Fshing mortality (*F*)	1.48 year^{-1}
Fishery parameters	
Exploitation (*E*)	0.48
E_{max}	0.46
$E_{0.1}$	0.37
$E_{0.5}$	0.27
Total length at first capture (L_c)	3.32 cm TL
Maximum sustainable yield (MSY)	4.51 metric tons

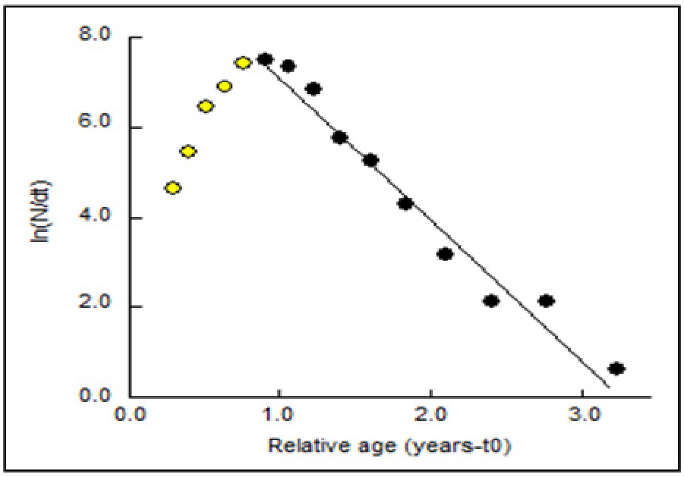

Figure 6: *Length-converted catch curve for Chanda nama in the Ganges River, Bangladesh.*

Mortality and recruitment

The assessed *Z*, *F*, and *M* were 3.11, 1.48, and 1.63 year^{-1}, respectively (Figure 6 and Table 2). The pattern of recruitment for *C. nama* population was mostly continual. The spawning activity was expected to begin in February and continue within September, while its main recruitment season coincided with the major spawning period between the month of May and July with only a peak during July (15.28 percent), suggesting a strong seasonal recruitment pattern (Figure 7).

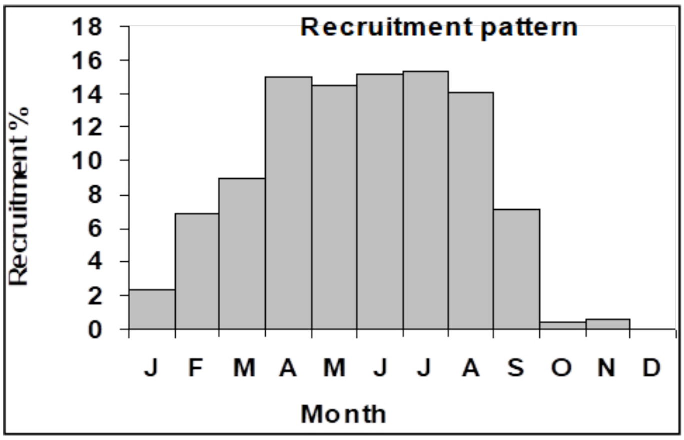

Figure 7: *Recruitment pattern of Chanda nama in Ganges River estimated from field data.*

Relative yield-per recruits (Y'/R) and maximum sustainable yield (MSY)

The calculated E_{max} was 0.46, while the $E_{0.1}$ and $E_{0.5}$ were 0.37 and 0.27, according to the *Y'/R* analysis (Figure 8 and Table 2). The recommended exploitation rate (*E*) was found 0.48 (Figure 9). Further, the optimum TL at the first capture ($L_c = L_c50$) was determined as 3.32 cm for *C. nama* (Figure 10). From the VPA analysis (Figure 11), the approximate SSB was 2.90 metric tons. Therefore, the MSY was calculated as 4.51 metric tons, when the required length (L_c = 3.32 cm TL) is sustained at first capture.

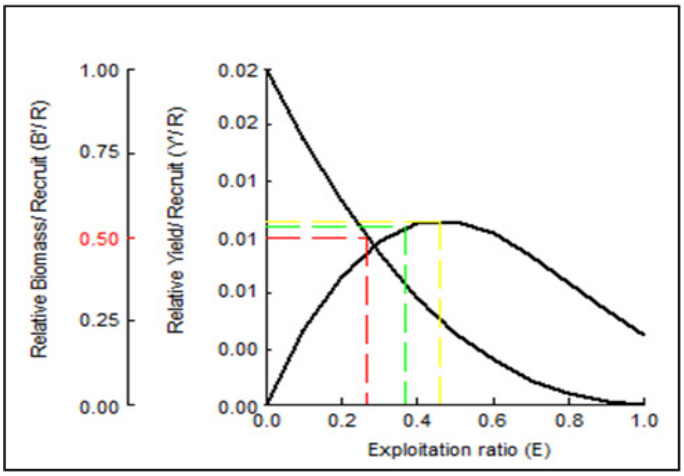

Figure 8: *Yield-per-recruit and average biomass per recruit models for Chanda nama.*

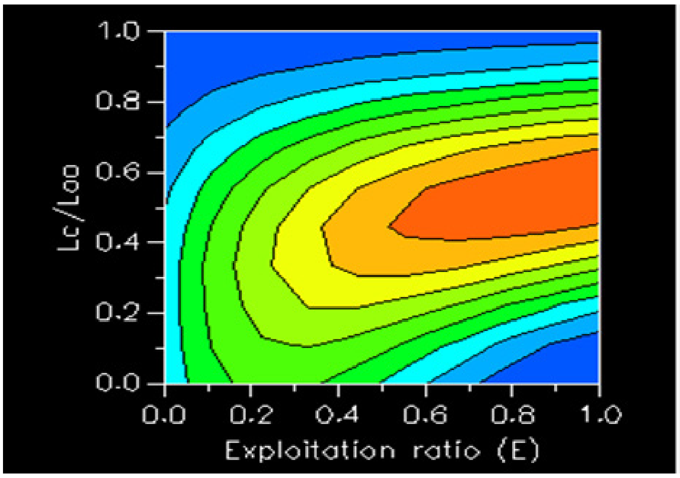

Figure 9: *Isopleths, showing optimum fishing activity both in terms of fishing effort and size of first capture.*

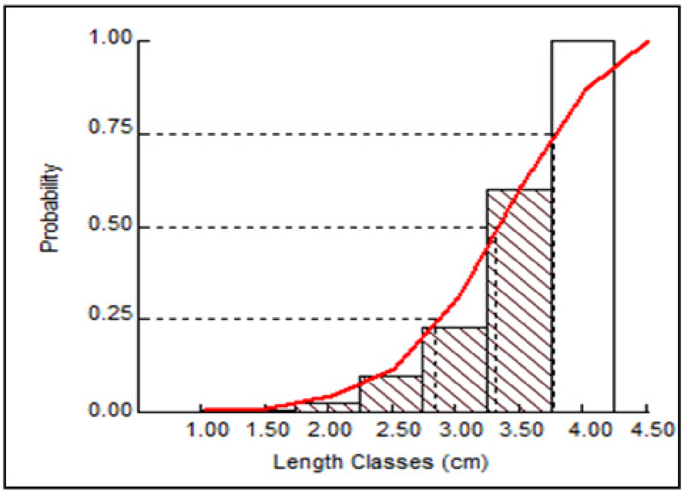

Figure 10: *Probability of capture, showing 25%, 50% and 75% selection length of Chanda nama.*

Stock assessments are considered to understand the growth, birth, and mortality of a fish, which is helpful for fish stock predictions to select the management approach (Hilborn and Walters, 1992). There is no information in the literature on the stock status of *C. nama*. Individuals of different sizes were captured throughout the year from the Ganges River using regular fishing gears. In this research, it was not possible to collect samples larger than 8 cm sized and 4.64 g weighed, which can be accounted for the selection of fishing tools instead of their disappearance from fishing areas or fishers did not catch where larger sizes reside (Hossain *et al*., 2017; Nawer *et al*., 2017; Parvin *et al*., 2021; Sarmin *et al*., 2021a).

Table 3: *Population number (N× 10^4) by size (TL) and steady state biomass (SSB) of Chanda nama at different levels of fishing mortality (F) in the Ganges River of north-western Bangladesh.*

Mid-length	Population (N× 10^4)	Fishing mortality (F)	Steady state biomass (SSB) metric tons
1.5	48347300	0.0238	0.05
2	40712576	0.0635	0.12
2.5	33779904	0.2075	0.21
3	27227948	0.4149	0.31
3.5	21067352	0.9509	0.39
4	14879196	1.5007	0.44
4.5	9434261	2.1656	0.40
5	5175191	2.5363	0.32
5.5	2514054	1.7155	0.24
6	1324466	2.0986	0.17
6.5	596018	1.8408	0.11
7	256625.6	1.9921	0.06
7.5	92984.63	0	0.05
8	54168.49	0.704	0.03
8.5	21013.51	1.48	0.02
Total SSB			2.90

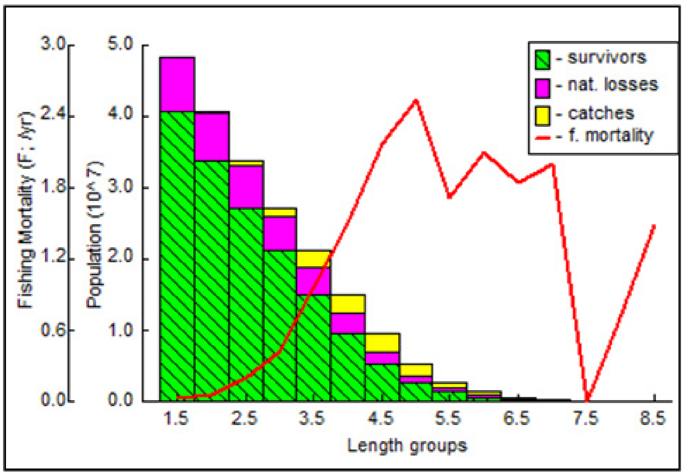

Figure 11: *Length-Structured Virtual Population Analysis of Chanda nama in the Ganges River, Bangladesh.*

The highest length of *C. nama* was recorded at 8 cm in the present study which exceeded previous records of 7.0 cm from Deepor beel Assam, India (Borah *et al*., 2017), 7.4 cm from the Brahmaputra River (Islam *et al*., 2017), and 7.5 cm from the Mathabhanga River in Bangladesh (Hossain *et al*., 2021a). But our observed TL was smaller than 11.0 cm found by Menon (1999). Each of those values varied from our observed values, which could be due to natural causes such as water temperature, food sources, and differences in geographic location (Hossain and Ohtomi, 2010). The allometric factor *b* can vary from 2 to 4, but values range from 2.5 to 3.5, which are more standard (Froese, 2006). The *b* value of LWR was 3.13 in this study, indicating positive allometric growth. However, a negative allometric growth was found (*b* = 2.79) by Hossain *et al*. (2012) from the Jamuna River, *b* = 2.87 was observed from the Brahmaputra River (Islam *et al*., 2017), and *b* = 2.80 from Deepor beel, Assam, India (Borah *et al*., 2017) for *C. nama*. Hossain *et al*. (2016) verified the isometric growth (*b* = 3.0) in the Ganges River, Bangladesh. The variation of growth pattern related to gonad ripeness, fish health, seasonal stomach contentment, sex, preservation process, and difference in size group (Hossain *et al*., 2018; Rahman *et al*., 2020; Tanjin *et al*., 2020; Hossain *et al*., 2021b; Sarmin *et al*., 2021b, 2022).

The growth parameters were analyzed to predict the stock biomass and future yields at multiple stages of fishing tactics, which are widely helpful to define different management practices. The calculated L_∞ was 10.25 cm when the *K* was 0.55 year^{-1}. We noted L_∞ was greater than our biggest fish found. A number of researchers (Gordoa and Moli, 1997; Macpherson, 1998; Vigliola *et al*., 1998) explained the reverse state where the model of von Bertalanffy is not enough to describe the growth of the Sparidae family due to the fast growth during the first year of life and noticeably decelerating thereafter. It is important to approach growth assessment from a multivariate perception, where both L_∞ and *K* need to be observed. The growth performance index (Ø') was also used to measure and display the least variation related to other available indices (Pauly and Munro, 1984). For *C. nama*, Ø' was recorded as 1.762 in this study. We have found the longevity or life span (t_{max}) for the species which was 2.49 years and t_0 was found to be 0.057 year. In the old technique, a variety of specimen characteristics (sample sizes and variation of sizes) and regional variations are likely to be due to the divergence in

Links Researchers

growth parameters (Monteiro *et al*., 2006). The previous study was unavailable in the literature, so it was not possible to compare these parameters.

The natural mortality was assessed as 1.63 $years^{-1}$ while the fishing mortality was 1.48 $years^{-1}$. Natural fish mortality is due to non-fishing causes like diseases, predation, cannibalism, competition, lack of food, stress of spawning and impact of pollution (Yongo and Outa, 2016). When observing the biological characteristics (fast-growing, small), it may be considered rational (Dulcic´ *et al*., 2007). In our study, we have found the main cause of higher natural mortality is predation. To signify the influence on yield of variations in exploitation (*E*) with the critical-length ratio (Lc/L_∞), we have been using yield isopleths (Figure 9). As far as the fishing regime is concerned, it implies fish are exploited at a low level of effort in regard to their relative yield per recruit (King and Etim, 2004). We assessed a lower maximum acceptable exploitation rate (E_{max} = 0.46) from the current exploitation level *E* = 0.48. Thus, in the Ganges River, this species is starting to face overexploitation. Further, the *Z*/*K* ratio was recorded as 2.92 (Figure 2), which indicated a slightly greater degree of exploitation.

The length at first capture (L_c50), asymptotic length (L_∞), and optimum length (L_{opt}) values will be utilized to identify the extent of the exploited population for proper assessment of the valuable fishery (Akélé *et al*., 2015). If the juveniles are mostly caught then the L_c/L_∞ values are less than 0.5 (Pauly and Moreau, 1997). This also implied that the first capture size (L_c) was smaller than the optimum size (L_{opt}). A 50 percent probability of capture was 3.32 cm (L_c50) and we found L_∞ as 10.25 cm in the present investigation. As a result, the L_c/L_∞ ratio was 0.32 which is less than 0.5 and signifies the dominancy of the very small individuals in the Ganges River.

Recruitment patterns can be illustrated with a graph showing variations in recruitment frequency over time (King and Etim, 2004). As a result, the supply of food and environmental conditions may have an impact on recruitment. There was a main recruitment peak in this population in one year, primarily from May to July, and it intersected in time to provide a constant year-round trend (Figure 7). Moreover, the calculated MSY of *C. nama* from the Ganges River was 4.51 metric tons, when the required size of 3.32 cm (L_c) is managed at first capture.

Conclusions and Recommendations

Our study highlighted the stock information comprising growth, mortality, recruitment, and exploitation rate of *C. nama*. Overfishing might be a notable threat to the wild population as E_{max} = 0.46 is very close to *E* = 0.48. To ensure justifiable management of *C. nama* population in the Ganges River, illegal gear must be excluded. Besides, the mesh size needs to be increased to stop the harvesting of the small mature fish. However, to ensure a proper strategy for the management purpose, these findings might be operative in Bangladesh or elsewhere.

Acknowledgements

We wish to expand our heartfelt gratitude to (i) TWAS for research grants (Ref: RGA No. 14-028 RG/BIO/AS_1; UNESCO FR: 324028574) (ii) BARC, PIU, NATP-2, Sub-project ID: 484 for technical and financial assistance.

Novelty Statement

This study is the first record on stock assessment of *Chanda nama* from the Ganges River, Bangladesh as well as from worldwide. The information of this research would be effective for regulating early management policies to ensure the sustainable production of this species.

Author's Contribution

Md. Asadujjaman: Instructed to write the manuscript.
Md. Yeamin Hossain: Developed the idea and methodology.
Most. Farida Parvin: Wrote the manuscript.
Most. Shakila Sarmin: Edited and formatted the manuscript.
Fairuz Nawer: Carried out data analyses.
Wasim Sabbir: Helped in revision and edition of the manuscript.
Md. Ashekur Rahman: Executed sampling and data collection and laboratory work.
Nur-E-Farjana Ilah and Md. Joynal Abedin: Assisted in laboratory work.
Md. Abdus Samad: Reviewed the manuscript.
Gitartha Kaushik: Given constructive comment on our manuscript.

Conflict of interests

The authors have declared no conflict of interest.

References

Akélé, G.D., H. Agadjihouèdé, G.A. Mensah and P.A. Lalèyè. 2015. Population dynamics of freshwater oyster *Etheria elliptica* (Bivalvia: Etheriidae) in the Pendjari River (Benin-Western Africa). Knowl. Manage. Aquat. Ecosyst., 416(6): 15. https://doi.org/10.1051/kmae/2015002

Beverton, R.J.H. and S.J. Holt. 1956. A review of methods for estimating mortality rates in fish populations with special references to sources of bias in catch sampling. Rapp. P-V. Renn. Cons. Int. Explor. Mer., 140: 67-83.

Beverton, R.J.H. and S.J. Holt. 1957. On the dynamics of exploited fish populations. Gt Britain Fish Invest. Ser., 19(2): 1-553.

Beverton, R.J.H. and S.J. Holt. 1979. Manual of methods for fish stock assessment (Part II). Tables of yield functions. FAO Fisheries Technical Paper No. 38.

Borah, S., B.K. Bhattacharjya, B.J. Saud, A.K. Yadav, D. Debnath, S. Yengkokpam, P. Das, N. Sharma, N.S. Singh and K.K. Sarma. 2017. Length-weight relationship of six indigenous fish species from Deepor beel, a ramsar site in Assam, India. J. Appl. Ichthyol., 33: 655-657. https://doi.org/10.1111/jai.13348

Dulcˇicˊ, J., S. Matic-Skoko, A. Paladin and M. Kraljevic. 2007. Age, growth and mortality of brown comber, *Serranus hepatus* (Linnaeus, 1758) (Pisces: Serranidae), in the eastern Adriatic (*Croatian coast*). J. Appl. Ichthyol., 23: 195-197. https://doi.org/10.1111/j.1439-0426.2006.00840.x

Foster, S.J. and A.C.J. Vincent. 2004. Life history and ecology of seahorses: Implications for conservation and management. J. Fish. Biol., 65: 1-61. https://doi.org/10.1111/j.0022-1112.2004.00429.x

Froese, R. and C. Binohlan. 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. J. Fish. Biol., 56: 758-773. https://doi.org/10.1111/j.1095-8649.2000.tb00870.x

Froese, R. and D. Pauly. 2022. FishBase. World wide web electronic publication. (https://www.fishbase.se/summary/10132). Retrieved on Dec 15, 2022.

Froese, R., 2006. Cube law, condition factor and weight length relationship. History meta-analysis and recommendations. J. Appl. Ichthyol., 22: 241-253. https://doi.org/10.1111/j.1439-0426.2006.00805.x

Gayanilo Jr, F.C. and D. Pauly. 1997. The FAO-ICLARM stock assessment tools (FiSAT). Reference manual. FAO Computer Information Service (Fisheries), no. 8, pp. 262.

Gayanilo Jr, F.C., P. Sparre and D. Pauly. 1994. The FAO-ICLARM stock assessment tools *(*FiSAT) User's guide. FAO Computer Information Service (Fisheries), no. 8, pp. 168.

Gayanilo Jr, F.C., P. Sparre and D. Pauly. 2005. FAO-ICLARM stock assessment tools II (FiSAT II) Revised version user's guide. FAO Computerized Information Series (Fisheries) No 8, Revised version Rome, FAO.

Gordoa, A. and B. Moliˊ. 1997. Age and growth of the sparids Diplodus vulgaris, D. sargus and D. annularis in adult populations and the differences in their juvenile growth patterns in the north-western Mediterranean Sea. Fish. Res., 33: 123-129. https://doi.org/10.1016/S0165-7836(97)00074-X

Grubh, A.R. and K.O. Winemiller. 2004. Ontogeny of scale feeding in the Asian glassfish, *Chanda nama* (Ambassidae). Copeia, pp. 903-907. https://doi.org/10.1643/CE-02-095R1

Gulland, J.A., 1983. Fish stock assessment: A manual of basic methods. Wiley Series on Food Agriculture (Book 1).

Hilborn, R. and C.J. Walters. 1992. Quantitative fisheries stock assessment, choices, dynamics and uncertainty. Chapman and Hall, New York, London.

Hossain, M.Y. and J. Ohtomi. 2010. Growth of the southern rough shrimp *Trachysalambria curvirostris* (Penaeidae) in Kagoshima Bay, southern Japan. J. Crust. Biol., 30: 75-82. https://doi.org/10.1651/08-3133.1

Hossain, M.Y., M.A. Hossen, Z. Mawa, M.A. Rahman, M.R. Hasan, M.A. Islam, D. Khatun, M.A. Rahman, S. Tanjin, M.S. Sarmin, M.A. Bashar and J. Ohtomi. 2021a. Life-history traits of three Ambassid fishes (*Chanda nama*, *Parambassis lala* and *Parambassis ranga*) from the Mathabhanga River, southwestern Bangladesh.

Lakes Reservoirs Sci. Policy Manage. Sustain. Use, 26(1): 59-69. https://doi.org/10.1111/lre.12354

Hossain, M.Y., A.A. Chowdhry, Z. Mawa, M.R. Hasan, M.A. Islam, M.A. Rahman, O. Rahman, D. Khatun, M.S. Sarmin, S. Nasrin, M.A. Rahman, A. Nima and F. Parvin. 2021b. Life-history traits of Indian River Shad *Gudusia chapra* (Hamilton, 1822) in the Mahananda River (tributary of the Ganges River) of northwestern Bangladesh. Songklanakarin J. Sci. Technol., 43(5): 1466-1472.

Hossain, M.Y., M.A. Hossen, M.M. Ali, M.N.U. Pramanik, F. Nawer, M.M. Rahman and S. Sharmin. 2017. Life history traits of the endangered carp *Botia dario* (Cyprinidae) from the Ganges River in northwestern Bangladesh. Pak. J. Zool., 49: 801-809. https://doi.org/10.17582/journal.pjz/2017.49.3.801.809

Hossain, M.Y., M.A. Hossen, M.N.U. Pramanik, Z.F. Ahmed, M.A. Hossain and M.M. Islam. 2016. Length-weight and length-length relationships of three Ambassid fishes from the Ganges River (NW Bangladesh). J. Appl. Ichthyol., 32: 1279-1281. https://doi.org/10.1111/jai.13170

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

Hossain, M.Y., M.N.U. Pramanik, M.A. Hossen, F. Nawer, D. Khatun, M.F. Parvin, O. Rahman, Z.F. Ahmed and F. Ahamed. 2018. Life history traits of the Pool barb *Puntius sophore* (Cyprinidae) in different ecosystem of Bangladesh. Indian J. Geo-Mar. Sci., 47: 1446-1454.

Islam, M.R., M.G. Azom, M. Faridullah and M. Mamun. 2017. Length-weight relationship and condition factor of 13 fish species collected from the Atrai and Brahmaputra rivers, Bangladesh. J. Biol. Environ. Sci., 10: 123-133.

IUCN Bangladesh, 2000. Red List of Bangladesh Volume 5: Freshwater Fishes. IUCN, International Union for Conservation of Nature, Bangladesh Country Offie, Dhaka, Bangladesh, pp. xvi+360.

IUCN, 2021. The IUCN red list of threatened species. Version 2021-3. Downloaded 14 Jan 2022.

King, R.P. and L. Etim. 2004. Reproduction, growth, mortality and yield of *Tilapia mariae* Boulenger 1899 (Cichlidae) in a Nigerian rainforest wetland stream. J. Appl. Ichthyol., 20: 502-510. https://doi.org/10.1111/j.1439-0426.2004.00545.x

Macpherson, E., 1998. Ontogenic shifts in habitat use and aggregation in juvenile sparid fishes. J. Exp. Mar. Biol. Ecol., 220: 127-150. https://doi.org/10.1016/S0022-0981(97)00086-5

Mawa, Z., M.Y. Hossain, M.R. Hasan, M.A. Rahman, S. Tanjin and J. Ohtomi. 2022. Life history traits of *Mystus vittatus* in the Ganges River, Bangladesh: Recommendation for its sustainable management considering climate change. Int. J. Biometeorol., 66: 927-943. https://doi.org/10.1007/s00484-022-02249-7

Menon, A.G.K., 1999. Check list fresh water fishes of India. Record of Zoological Survey of India, Miscellaneous Publication, Occasion Paper no. 175: 366.

Monteiro, P., L. Bentes, R. Coelho, C. Correia, J.M.S. Gonalves, P.G. Lino, J. Ribeiro and K. Erzini. 2006. Age and growth, mortality, reproduction and relative yield per recruit of the bogue, *Boops boops* Linne, 1758 (Sparidae), from the Algarve (south of Portugal) longline fishery. J. Appl. Ichthyol., 22: 345-352. https://doi.org/10.1111/j.1439-0426.2006.00756.x

Nadia, Z.M., N. Saha, P. Roy, M.A. Iqbal, M.S. Sarmin and M.Y. Hossain. 2022. Evaluating biometric indices for Indian Gagata, *Gagata cenia* (Hamilton, 1822) through multi-model inferences. Heliyon, 9(1): e12739. https://doi.org/10.1016/j.heliyon.2022.e12739

Nawer, F., M.Y. Hossain, M.A. Hossen, D. Khatun, M.F. Parvin, J. Ohtomi and M.A. Islam. 2017. Morphometric Relationships of the Endangered ticto barb *Pethia ticto* (Hamilton, 1822) in the Ganges River (NW Bangladesh) through multi-linear dimensions. Jordan J. Biol. Sci., 10: 199-203.

Nelson, J.S., 1994. Fishes of the world. 3rd ed. John Wiley and Sons, Inc., New York. pp. 600.

Panhwar, S.K., Q. Liu and G. Siddiqui. 2013. Growth, mortality and stock assessment of kelee shad, *Hilsa kelle* (Fam: Clupeidae) in the coastal waters of Pakistan. J. Ichthyol., 53: 365-371. https://doi.org/10.1134/S0032945213030168

Parvin, M.F., M.Y. Hossain, M.A. Rahman, D. Khatun, M.S. Sarmin, O. Rahman, M.A. Islam, M.A.K. Azad, M.A. Samad, W. Sabbir, Sk. Kamruzzanan, U. Hosneara and H.U. Hassan. 2021. Growth, maturity, condition, size at sexual maturity and mortality of the Banded gourami *Trichogaster fasciata* from the Ganges River, Northwestern Bangladesh. Egypt. J. Aquat. Biol. Fish., 25(4): 285-299. https://doi.org/10.21608/ejabf.2021.189004

Pauly, D. and G.R. Morgan. 1987. Length-based methods in fisheries research. ICLARM Conf. Proc. no. 13, International Centre for Living Aquatic Resources Management, Manila, Philippines.

Pauly, D. and J. Moreau. 1997. Méthodes pour l'évaluation des ressources halieutiques. Cépaduès Editions: Toulouse. pp. 288.

Pauly, D. and J.L. Munro. 1984. Once more on the comparison of growth in fish and invertebrate. Int. Centre Living Aquat. Resour. Manage. Fish. Byotechnol., 2: 21.

Pauly, D., 1980. On the interrelationship between natural mortality, growth parameters and the mean environmental temperature in 175 fish stocks. ICES J. Mar. Sci., 39: 175-192. https://doi.org/10.1093/icesjms/39.2.175

Rahman, A.K.A., 1989. Freshwater Fishes of Bangladesh. Zoological Society of Bangladesh. Department of Zoology, University of Dhaka, Dhaka. pp. 364.

Rahman, O., M.Y. Hossain, M.A. Islam, M.A. Rahman, D. Khatun, M.F. Parvin, M.S. Sarmin, S. Tanjin, M.A. Rahman, Z. Mawa, M.R. Hasan, K. Zannat, W. Sabbir and M.A. Samad. 2020. Life-history traits of long whisker catfish *Mystus gulio* (siluriformes: bagridae) in the coastal water (Maloncho River) of southern Bangladesh. Pak. J. Mar. Sci., 29(2): 99-114.

Ranjan, J.B., W. Herwig, S. Subodh and S. Michael. 2005. Study of the length frequency distribution of Sucker head, *Garra gotyla gotyla* (Gray, 1830) in different rivers and seasons in Nepal and its application. Kathmandu Univ. J. Sci. Eng. Technol., 1: 1-14.

Roberts, T.R., 1994. Systematic revision of tropical Asian freshwater glass perches (Ambassidae), with descriptions of three new species. Nat. Hist. Bull. Siam Soc., 42: 263-290.

Roy, A., S. Dutta, A. Podder and S. Homechaudhuri. 2020. Variation in population characteristics and harvesting pressure influencing recruitment pattern of an economically important fish, *Osteomugil cunnesius* of Indian Sundarbans. Proc. Zool. Soc., 73: 5-15. https://doi.org/10.1007/s12595-019-00291-9

Sabbir, W., M.A. Rahman, M.Y. Hossain, M.R. Hasan, Z. Mawa, O. Rahman, S. Tanjin and M.S. Sarmin. 2021. Stock assessment of Hooghly Croaker *Panna heterolepis* in the Bay of Bengal (Southern Bangladesh): implication for sustainable management. Heliyon, 7(8): e07711. https://doi.org/10.1016/j.heliyon.2021.e07711

Sabbir, W., M.Y. Hossain, M.N. Khan, F.A. Rima, M.S. Sarmin and M.A. Rahman. 2022. Biometric Indices of Flathead Sillago, *Sillaginopsis panijus* (Hamilton, 1822) from the Bay of Bengal (Southern Bangladesh). Thalassas: Int. J. Mar. Sci., 38: 811-820. https://doi.org/10.1007/s41208-022-00421-9

Sarmin, M.S., M.A. Rahman, M.F. Parvin, M.S. Khatun, K.A. Habib, W. Sabbir, J. Ohtomi and M.Y. Hossain. 2022. Temporal variation of biometric indices for *Megalaspis cordyla* (Linnaeus, 1758) from the Bay of Bengal, Bangladesh. Sarhad J. Agric., 38(5): 300-310. https://doi.org/10.17582/journal.sja/2022/38.5.300.310

Sarmin, M.S., M.Y. Hossain, M.A. Islam, M.A. Rahman, D. Khatun, Z. Mawa, A.A. Chowdhury and J. Ohtomi. 2021a. Estimation of population parameters for a data deficient *Salmostoma bacaila* (Hamilton 1822) stock from the Mahananda river (tributary of the Ganges) in NW Bangladesh. Indian J. Geo-Mar. Sci., 50(5): 403-409. https://doi.org/10.56042/ijms.v50i05.66244

Sarmin, M.S., S. Tanjin, M.A. Rahman, M.R. Hasan, W. Sabbir, M. Asadujjaman, M.R.K. Mondol, K.A. Habib and M.Y. Hossain. 2021b. Estimation of growth pattern and form factor of Torpedo scad *Megalaspis cordyla* (Linnaeus, 1758) in the Bay of Bengal, Bangladesh. Pak. J. Mar. Sci., 30(2): 109-117. https://www.pakjmsuok.com/index.php/pjms/article/view/103

Tanjin, S., W. Sabbir, M.Y. Hossain, M.A. Rahman, Z. Mawa, M.R. Hasan, F.A. Rima, O. Rahman, M.S. Sarmin, B.K. Sarker and K.A. Habib. 2020. Morphometric and Meristic Features of Gangetic hairfin anchovy, *Setipinna phasa* (Hamilton, 1822) in the Bay of Bengal

(Bangladesh). J. King Abdulaziz Univ. Mar. Sci., 30(2): 71-83. https://doi.org/10.4197/Mar.30-2.5

Tesch, F.W., 1971. Age and Growth. In: Methods for assessment of fish production in fresh waters, edited by Ricker, W.E. Oxford: Blackwell Scientific Publications.

Vigliola, L., M. Harmelin-Vivien, F. Biagi, R. Galzin, A. Garcia-Rubies, J.G. Harmelin, J.Y. Jouvenel, L. Le Direach-Boursier, E. Macpherson and L. Tunesi. 1998. Spatial and temporal patterns of settlement among sparid fishes of the genus Diplodus in the northwestern Mediterranean. Mar. Ecol. Prog. Ser., 168: 45-56. https://www.jstor.org/stable/24828359, https://doi.org/10.3354/meps168045

Wetherall, J.A., 1986. A new method for estimating growth and mortality parameters from length frequency data. Fishbyte, 4: 12-15.

Yongo, E. and N. Outa. 2016. Growth and population parameters of Nile tilapia, *Oreochromis niloticus* (L.) in the open waters of Lake Victoria, Kenya. Lakes Reservours, 21: 375-379. https://doi.org/10.1111/lre.12154