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Impact of eco-hydrological factors on growth of Asian stinging catfish *Heteropneustes fossilis* (Bloch, 1794) in Wetland Ecosystem

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ABSTRACT

Our research demonstrates the impacts of eco-hydrological factors (Temperature, rainfall, dissolved oxygen, pH, total dissolved solids and alkalinity) on the growth of Asian stinging catfish *Heteropneustes fossilis* (Bloch, 1794) in the Ganjer *Beel* wetland ecosystem, northwestern Bangladesh. This study was conducted in the *Gajner Beel* wetland ecosystem which is located at Sujanagar under Pabna District, NW Bangladesh. Eight hundreds forty five (845) fish individuals were collected from January to December 2019. Total length (TL) and body weight (BW) were measured using measuring board and electronic balance with 0.01cm and 0.01g, precision. Length-weight relationship was calculated by this equation: $W = a \times L^b$. TL was ranged from 6.30–24.10 cm and BW was 1.20–83.94 g. Overall growth pattern (GP) was positive allometric of *H. fossilis* in this wetland. Among the eco- hydrological factors temperature, DO and pH showed significant correlation with the growth pattern of *H. fossilis*. Finally, these findings will be useful for further studies and to suggest sound policy for the sustainable management of *H. fossilis* in the wetland ecosystems.

INTRODUCTION

A wetland is an area of land contiguous to a river or stream that expanses from the banks of its channel to the base of the encircling valley walls and which flooded during periods of high discharge (Goudie, 2004). Additionally, *Beels* are made by cataclysm of low-lying lands during diluvium, where some water becomes entrapped even after flood waters get off back from the flood plains (Banglapedia, 2004). Gajner *Beel* is situated at Sujanagar, Pabna in the northwestern (NW) Bangladesh. This *Beel* used as an imperative feeding and spawning ground by many freshwater fish species. Near about 0.5 million people of surrounding villages of this *Beel* are directly or indirectly reliant on this wetland for their livelihood (Mazidet al. 2005).

Catfish are most important for relative biological studies because their phylogenetic position places them near to a common fish ancestor than most bony fish (Liu *et al*., 2016). The stinging catfish *Heteropneutes fossilis* (Bloch, 1794), is the part of Heteropneustidae family (Siluriformes) generally known as the 'Shingi or Singhee' in Bangladesh (Rahman *et al*., 2019a). It is extensively distributed in Bangladesh, India, Pakistan, Laos, Myanmar, Nepal, Sri Lanka, and Thailand (Talwar and Jhingran, 1991). Adults live in ditches, ponds, marshes, swamps, and sometimes in muddy rivers (Halwart and Gupta, 2004). This catfish is an important food fish as it contains high amounts of protein, iron (226 mg/100g) and calcium (Saha and Guha, 1939) and they also have high market price (Alok *et al*., 1993). *H. fossilis* is categorized as least concern both in Bangladesh (IUCN Bangladesh, 2015) and worldwide (IUCN, 2020).

Knowledge about the length-weight relationships (LWRs) of a fish species is essential to transformation of their length form into the weight. Although the LWRs are mostly helpful for the researcher for observing the well-being of fishes (Ecoutin *et al*., 2005; Hossain *et al*., 2009; Hassan *et al*., 2020). It is broadly used in the exploration of fishery data, typically because of the firmness and time mandatory to record weight in the field (Andrade and Camos, 2002). Estimation of stock size, production, recruitment and mortality of fish growth are used as a very important tools and it also used to manage the fisheries resources (Issac, 1990; Tracey *et al*., 2007).

Climate change is considered as an important hazard to fisheries along with other different risk such as overfishing, pollution and habitat deterioration (Rose, 2005; Sabbir *et al.*, 2020). Climatic factors mainly temperature and rainfall has constant effect on fish growth and survival (Shoji *et al*., 2011; Sabbir *et al*., 2020). Temperature is the most significant climatic factor regulating the progresses of larval accumulations of freshwater as well as marine species (Houde and Zastrow, 1993; Jakobsen *et al*., 2009). Similarly, rainfall is a basic climatic factor influencing the entire chain of hydrological events through runoff and river inflow (Patrick, 2016). To ensure comprehensive fish health, it is urgent to maintain an optimum DO (dissolved oxygen) level for physiological and metabolic activities. The DO requirement increases with increasing fish size during grow out period (Abdel-Tawwab *et al*., 2015). Alternatively, pH indicates whether the habitat is acidic or alkaline condition. Higher level of pH (9-14) not only affects fish by denaturing cell membranes but also alter other water quality parameters (Brown and Sadler, 1989).

However, a very few researches have been done on different aspects including LWRs (Alam and Ferdaushy, 2015) and length-weight relationships (LWRs) (Muhammad *et al*., 2017; Alam and Ferdaushy, 2015; Das *et al*., 2015; Hossain *et al*., 2017; Khan *et al*., 2012; Rahman *et al.*, 2019a). To the best of our knowledge, there was no works on this aspect of *H. fossilis* in the Gajner *Beel* even though whole the world. Therefore, this is the first study which gives clear explanation on the effect of eco-hydrological parameters on growth of *H. fossilis* in the Gajner *Beel* Wetland Ecosystem, northwestern Bangladesh.

MATERIALS AND METHODS

Study site and sampling

Eight hundreds forty five individuals of *H. fossilis* were collected during January to December 2019 from the Gajner *Beel*, NW Bangladesh (Fig. 1). Samples (70–90 individuals/month) were gathered from the fisher. Seine net, and gill net were used by fishers to catch the fish samples. Fishes were instantly kept in ice on the spot and on the arrival to laboratory fixed them with 10% buffered solution.

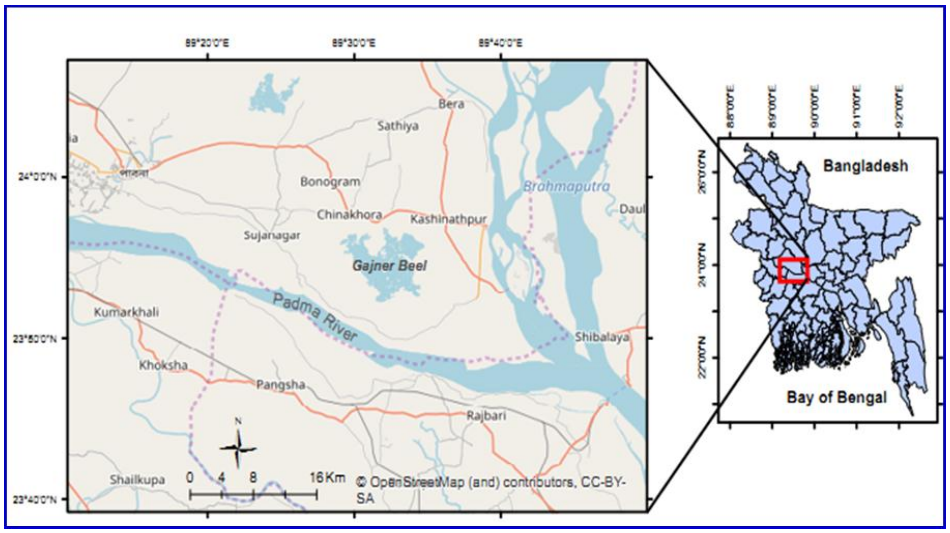

Fig. 1. Sampling sites in the Gajner *Beel* (indicated by red circle), northwestern Bangladesh.

Fish measurement

Lengths were measured (e.g., TL, SL) by using a measuring board and total weight (BW) were taken by an electronic balance. Sex was identified by the help of meristic and morphometric features of this fish.

Growth pattern

According to Le Cren (1951), LWRs was calculated by: $W = a \times L^b$. The parameters a and b were estimated by: $ln(W) = ln\ (a) + b\ ln(L)$. In addition, 95% CL of a and b and the r^2 were estimated. According to Froese (2006) unacceptable outliers were omitted. Student test (t-test) was used to approve b were significantly different from the isometric value (b = 3) (Sokal and Rohlf, 1987).

Eco-climatic parameters

To evaluate the effect of eco-hydrological features on growth of *H. fossilis*, monthly ecological parameters were recorded from the sampling site by using HACH (HQ 40d) digital multi-meter. The collected parameters were temperature (^oC), pH and dissolved oxygen (mg/L), TDS (mg/L) and alkalinity (mEq/L). Further, the data of monthly rainfall (mm) were collected from meteorological station of Dhaka, Bangladesh.

Statistical analyses

GraphPad Prism 6.5 software was used for the statistical analyses. Normality of the data was checked before analysis through Violin and Box plot. Moreover, the Pearson/Spearman rank test was used to correlate the growth and eco-hydrological parameters. Statistical analyses were performed at 5% ($p < 0.05$) level of significant.

RESULTS

Growth pattern

The descriptive statistics (TL, BW and estimated parameters of the LWR) of *H. fossilis* in the Gajner *Beel* were shown in Tables 1 & 2, and LWR is demonstrated in Figure 2. Data (TL, BW) normality was checked with violin and box plot (Fig. 3). Also, normality of regression parameter (*a*) and allometric coeffient (*b*) were checked with box plot (Fig. 4).

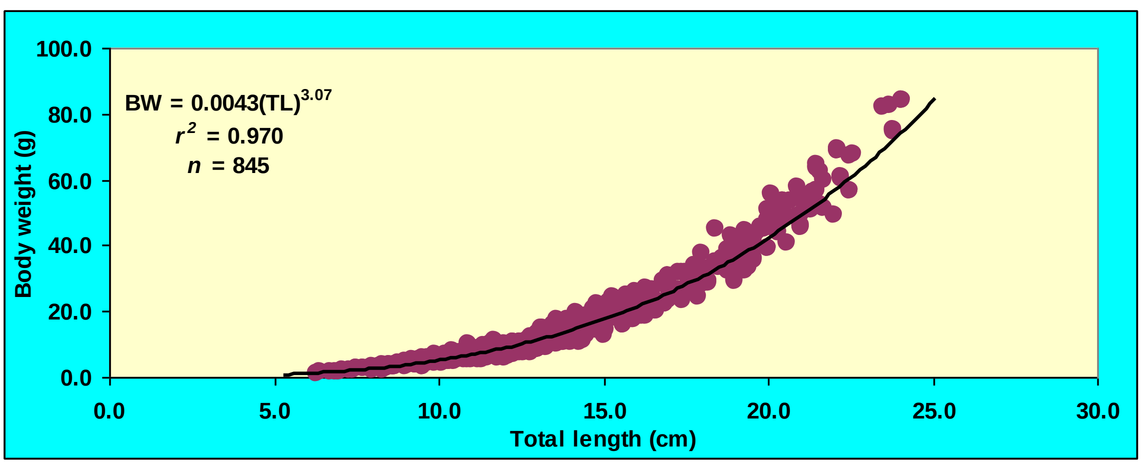

Fig. 2. Length-weight relationships of *Heteropneustes fossilis* from the Gajner *Beel*, northwestern Bangladesh.

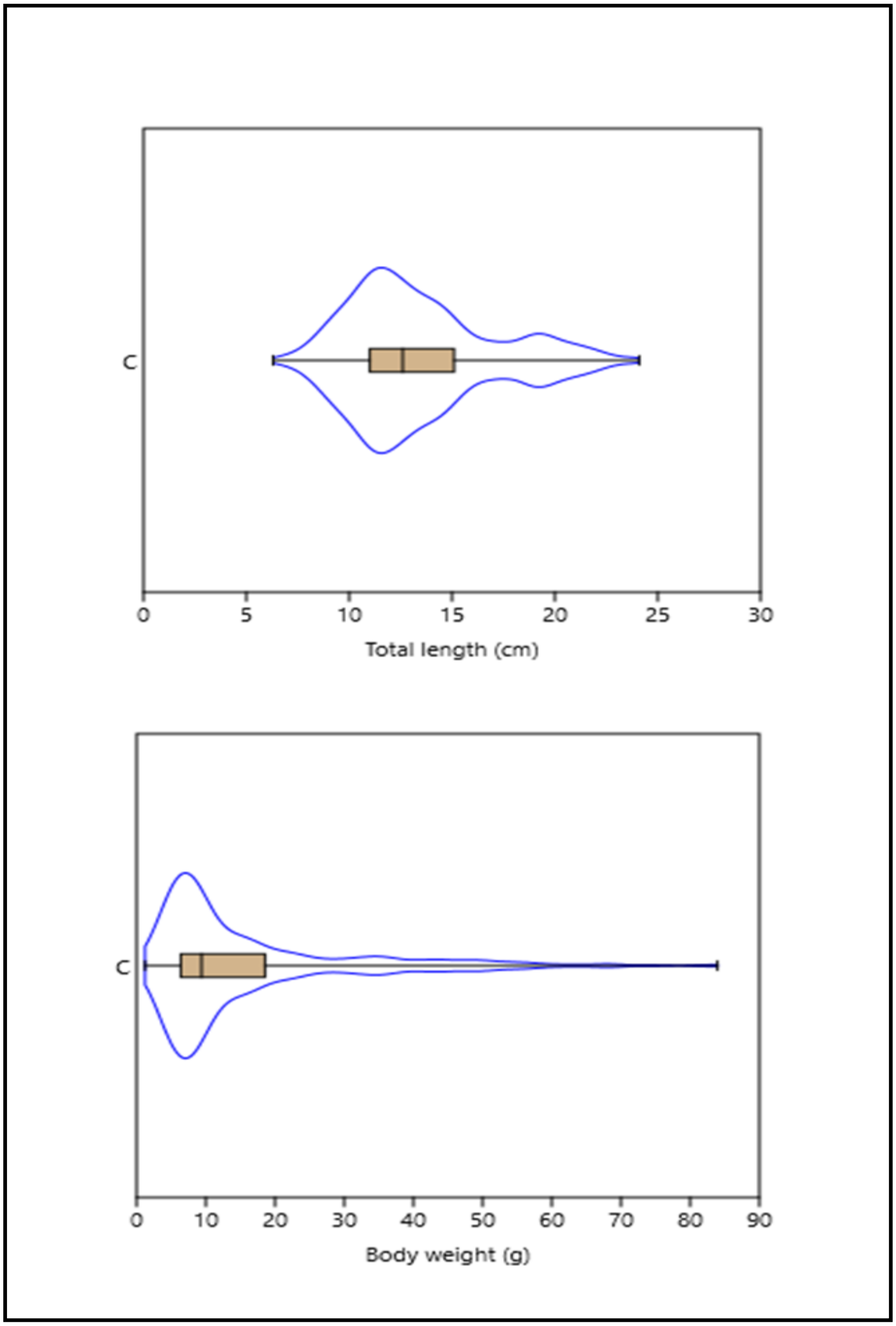

Fig. 3. Violin and box plot of total length and body weight of *Heteropneustes fossilis* from the Gajner *Beel*, northwestern Bangladesh.

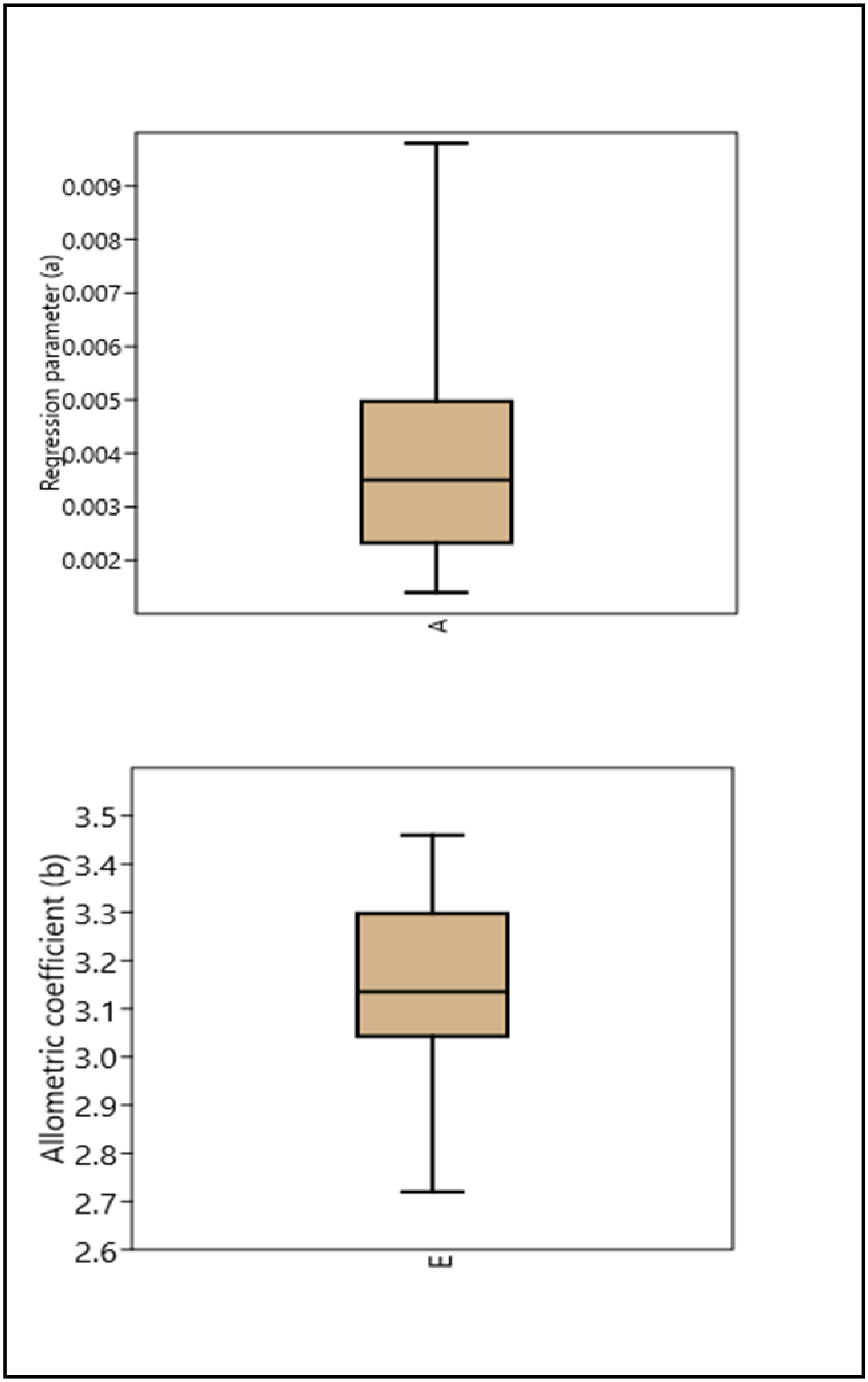

Fig. 4. Box plot of regression parameter (*a*) and allometric coefficient (*b*) of *Heteropneustes fossilis* from the Gajner *Beel*, northwestern Bangladesh.

Table 1: Descriptive statistics on the length (cm) and weight (g) measurements of *Heteropneutes fossilis* (Bloch, 1794) in the Gajner *Beel*, northwestern Bangladesh

Month	*n*	TL (cm)				BW (g)			
		Min	Max	Mean ± SD	95% CL	Min	Max	Mean ± SD	95% CI
January	97	7.7	16.6	10.43 ±1.85	9.90 –10.96	2.54	20.27	6.23 ± 3.56	5.22–7.24
February	96	9.5	22.0	14.99 ± 2.61	14.29 – 15.68	4.86	49.20	16.97 ± 10.08	14.30–19.65
March	52	15.10	23.80	20.14 ± 2.13	19.33 – 20.95	17.626	74.87	46.05 ± 15.63	40.11–52.00
April	84	9.90	16.90	13.11 ± 1.75	12.50 – 13.71	4.15	22.19	10.51 ± 5.17	8.72–12.29
May	46	10.30	21.70	18.53 ± 2.22	17.69–19.37	5.07	51.24	35.32 ± 11.15	31.07–39.55
June	57	16.30	24.10	20.59 ± 2.00	19.91–21.27	0.40	25.90	8.48 ± 6.98	6.08–10.87
July	70	11.00	21.70	14.31 ± 2.19	13.59–15.03	8.59	59.73	18.27 ± 9.96	14.99–21.54
August	79	9.20	18.90	13.68 ± 2.13	12.98–14.38	5.31	42.86	15.93 ± 7.93	13.32–18.54
September	55	10.50	20.30	13.58 ± 2.65	12.44–14.73	6.15	51.77	14.75 ± 11.16	9.92–19.58
October	90	11.00	20.90	15.81 ± 2.72	14.92–16.69	8.37	57.51	25.93 ± 13.52	21.54–30.31
November	51	9.90	14.10	11.82 ± 0.93	11.43–12.20	5.19	15.49	9.07 ± 2.18	8.17–9.96
December	68	6.70	14.20	10.02 ± 1.86	9.30–10.75	1.37	15.36	5.61 ± 3.19	4.37–6.84

Notes: *n*, sample size; M, male; F, female; TL, total length (cm) W, body weight (g); min, minimum; max, maximum, SD, standard deviation; CL, confidence limit

Maximum and minimum length was 6.30–24.10 cm TL and BW was 1.20–83.94 g. Maximum TL was found in June and minimum was in December. In the Gajner *Beel* wetland ecosystem, isometric growth (*b*=3.07) are found of *H. fossilis.* Monthly variations of TL, BW and allometric coefficient (*b*) values are shown in Figure 5. Negative growth pattern was found in January and December, Isometric in May and November as well as rest months are showed positive allometric growth. LWR was highly significant (p<0.01), with r^2 values ≥ 0.970.

Table 2: Descriptive statistics and estimated parameters of the length-weight relationships (BW=a×TL^b) of *Heteropneutes fossilis* (Bloch, 1794) in the Gajner *Beel*, northwestern Bangladesh

Month	***n***	**Regression parameters**				r^2	**GT**
		a	***b***	**95% CL of *a***	**95% CL of *b***		
January	97	0.0098	2.72	0.0076 – 0.0126	2.61 – 2.83	0.963	-A***
February	96	0.0032	3.12	0.0023 – 0.0045	2.99 – 3.24	0.965	+A***
March	52	0.0023	3.29	0.0015 – 0.0033	3.16 – 3.43	0.980	+A***
April	84	0.0020	3.30	0.0013 – 0.0030	3.14 – 3.46	0.955	+A***
May	46	0.0050	3.05	0.0027 – 0.0077	2.87 – 3.23	0.963	I^{ns}
June	57	0.0014	3.46	0.0008 – 0.0024	3.28 – 3.64	0.969	+A***
July	70	0.0024	3.32	0.0015 – 0.0038	3.14 – 3.50	0.952	+A***
August	79	0.0038	3.15	0.0028 – 0.0051	3.03 – 3.28	0.972	+A***
September	55	0.0027	3.25	0.0017 – 0.0040	3.08 – 3.42	0.965	+A***
October	90	0.0045	3.10	0.0036 – 0.0057	3.01 – 3.19	0.981	+A***
November	51	0.0049	3.04	0.0036 – 0.0067	2.91 – 3.17	0.978	I^{ns}
December	68	0.0062	2.91	0.0045 – 0.0086	2.78 – 3.05	0.964	-A***

Notes: *n*, sample size; *a, b* are length-weight relationships parameter; CL, confidence limit; r^2, co-efficient of determination; GT, growth type; -A, negative allometric growth; I, isometric growth; +A, positive allometric growth

Maximum and minimum length was 6.30–24.10 cm TL and BW was 1.20–83.94 g. Maximum TL was found in June and minimum was in December. In the Gajner *Beel* wetland ecosystem, isometric growth (b=3.07) are found of *H. fossilis.* Monthly variations of TL, BW and allometric coefficient (b) values are shown in Figure 5. Negative growth pattern was found in January and December, Isometric in May and November as well as rest months are showed positive allometric growth. LWR was highly significant ($p<0.01$), with r^2 values ≥ 0.970.

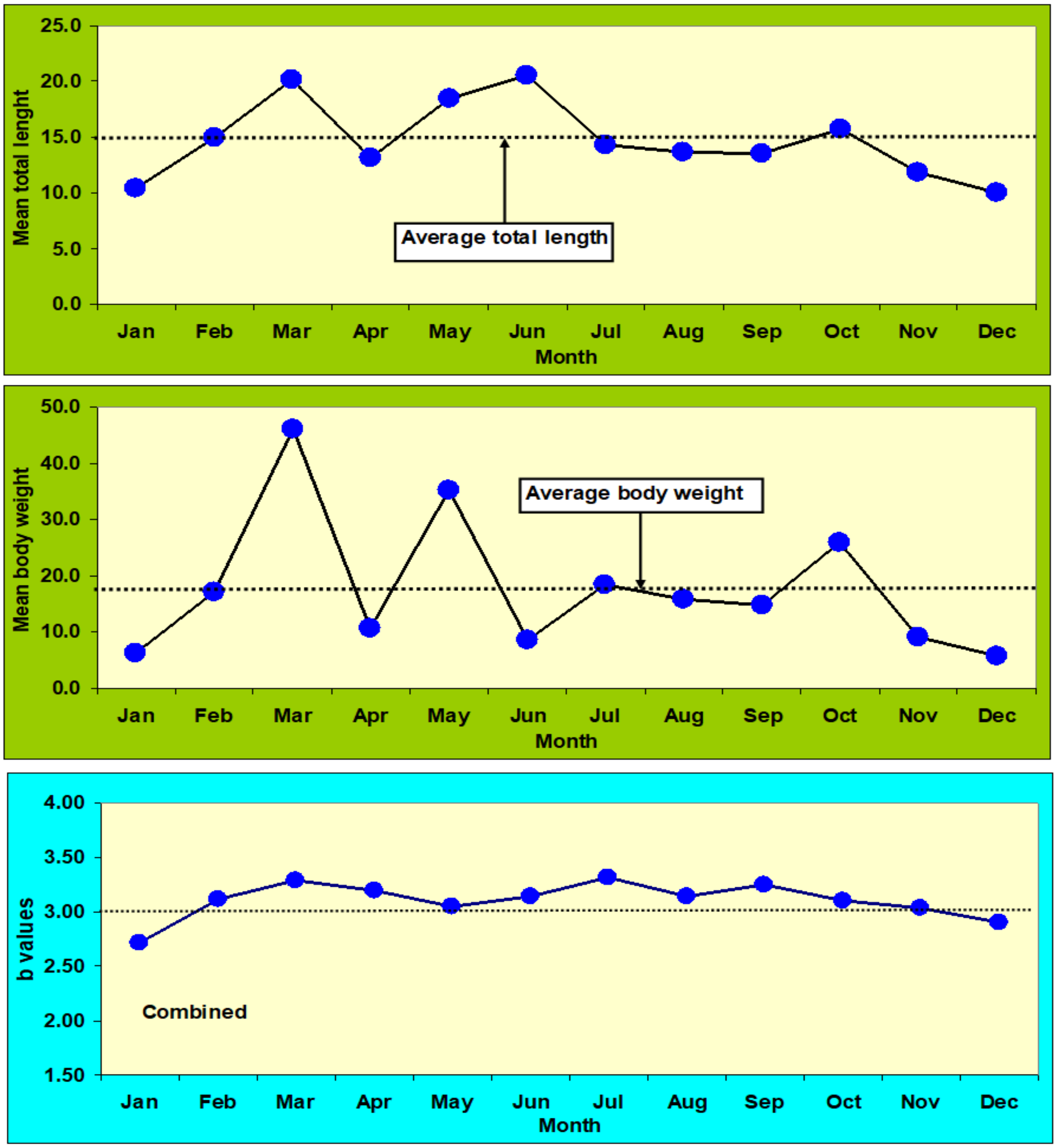

Fig. 5. Monthly variations of total length, body weight and allometric coefficient (*b*) of *Heteropneustes fossilis* in the Gajner *Beel*, northwestern Bangladesh.

Eco-climatic parameters

The growth pattern statistically highly correlated with temperature, DO and pH. However, Rainfall, TDS and alkalinity did not expose any significant correlation with the growth (Table 3). The relationship between *b* and eco-climatic factors are presented in Figure 6 and changes of allometric coefficient b values with the changes of hydrological parameters (Temperature, DO and pH) demonstrated in Figure 7.

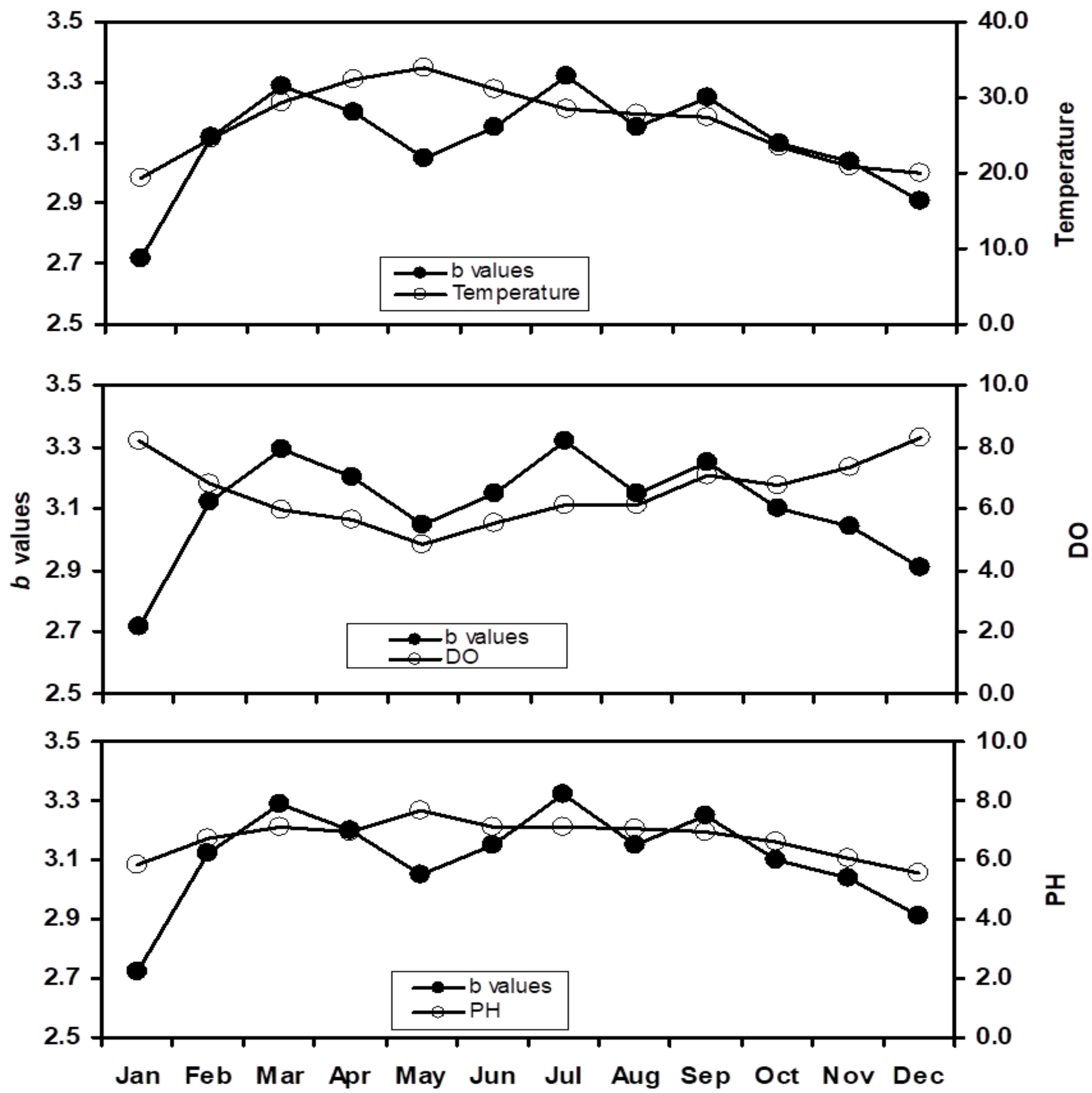

Fig. 6. Relationship between growth pattern (*b* values) and different hydrological parameters of *Heteropneutes fossilis* in the wetland ecosystem, northwestern Bangladesh.

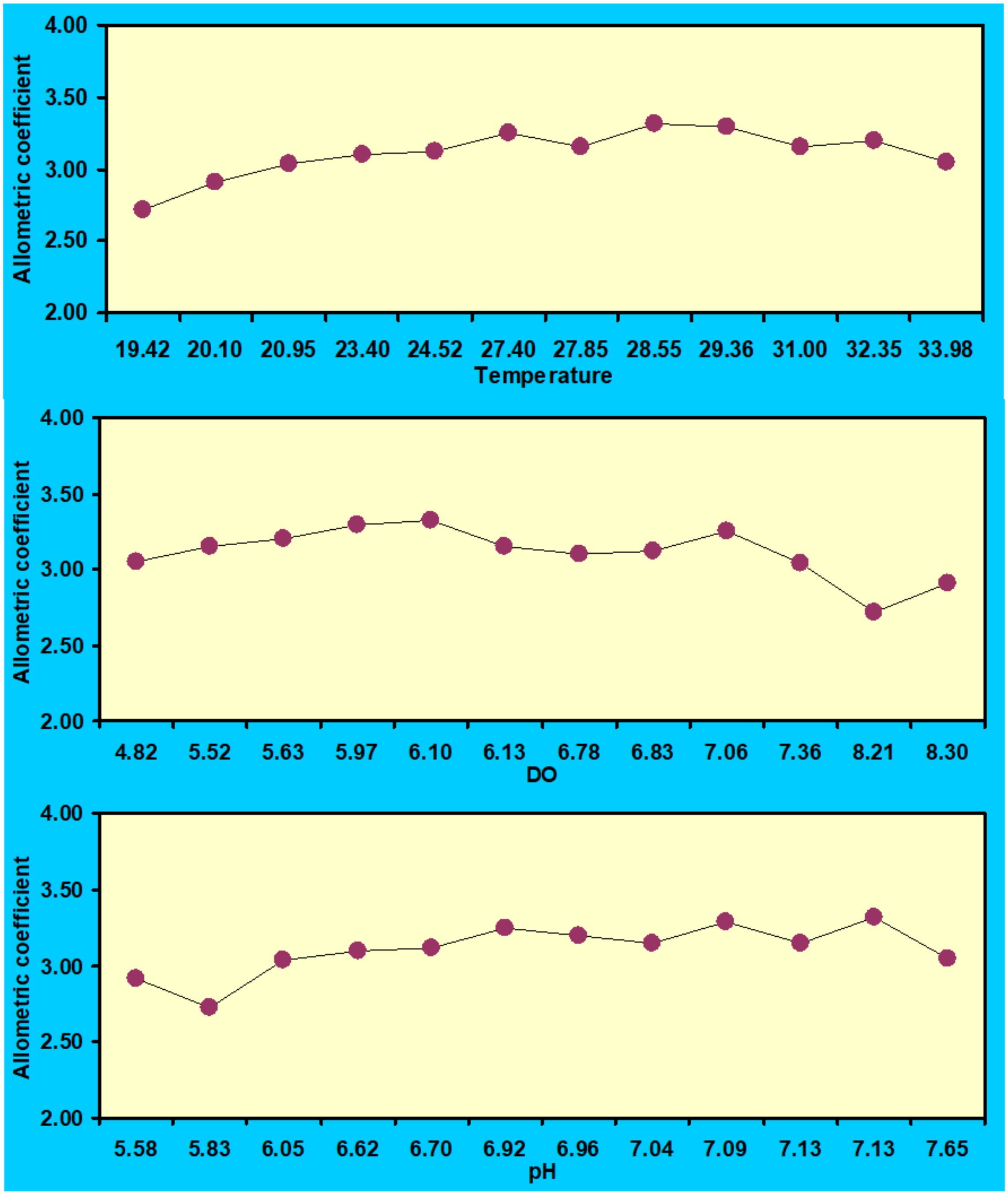

Fig. 7. Changes of allometric coefficient (*b*) with the changes of hydrological parameters (Temperature, DO and pH) of *Heteropneutes fossilis* in the wetland ecosystem, northwestern Bangladesh.

Table 3: Relationship between eco-climatic factors with growth pattern of *Heteropneutes fossilis* (Bloch, 1794) in the Gajner *Beel*, northwestern Bangladesh

Relationships	r_s / r_p values	95% CL of r_s	*P* values	Significance
Temp. *vs. b*	0.6595 r_p	0.1376 to 0.8948	0.0196	*
Rain *vs. b*	-0.5053 r_s	-0.0967 to 0.8367	0.0938	*ns*
DO *vs. b*	-0.6210 r_p	-0.8810 to -0.0731	0.0311	*
pH *vs. b*	0.7114 r_p	0.2323 to 0.9127	0.0095	**
TDS *vs. b*	0.0001 r_s	-0.5739 to 0.5741	0.9997	*ns*
Alkalinity *vs. b*	-0.5481 r_s	0.8536 to 0.0378	0.0650	*ns*

Note: Temp, temperature (^{o}C); Rain, rainfall (mm); DO, dissolved oxygen (mg/l); TDS, Total dissolve solids; *b*, growth pattern; r_s, Spearman rank correlation values; $r_{p,}$ Pearson rank correlation values; CL, confidence limit; *P*, level of significance; *ns*, not significant; *significant; **highly significant.

DISCUSSION

In our research, the maximum length of *H. fossilis* was 24.10 cm in TL which is smaller than 31.0 cm in TL in the Ganga River, India (Khan *et al*., 2012) and 26.80 cm in TL from an earlier study in the Gajner *Beel*, Bangladesh (Rahman *et al*., 2019a). Knowledge about maximum length is vital to estimate the growth parameters, which is important for development of fisheries resource and their management (Khatun *et al*., 2018, 2019; Parvin *et al*., 2018; Rahman *et al.*, 2019b, Nima *et al*., 2020).

Based on Froese (2006) *b* values should keep in the range of 2.5–3.5. In our study, all the *b* values are within the predictable range. According to Tesch (1971), *b* values near to 3.0, indicating that fish grow isometric, larger than 3.0 indicate positive allometric and smaller than 3.0 revealed negative allometric. In the current study, over all *b* value was 3.07 that indicate isometric growth of *H. fossilis* in the Gajner *Beel*, wetland ecosystem, NW Bangladesh. Positive growth pattern was observed by Khan *et al*. (2012) (*b*=3.14) from the Ganga River, India and Rahman *et al*. (2019a) (*b*=3.08) from the Gajner *Beel*, Bangladesh. However, Hossain *et al*. (2017), in an earlier study in the Gajner *Beel* during which period, reported isometric growth (*b*= 3.01), which is in similar with our study.

However, the fluctuation in growth pattern occur because of some factors such as sex, habitat availability, gonad ripeness, level of stomach fullness, seasonal effect, well-being of fish health, preservation method and deviations in the length class (Hossain *et al*., 2013, 2018), which are not accounted in this study.

Growth of *H. fossilis* was showed significant relation with temperature, DO and pH. Fish is a poikilothermic animal. Habitat temperature controls the fish body growth rate, temperature, food consumption, and various body functions because of fish is poikilothermic animal (Houlihan *et al*., 1993; Azevedo *et al*., 1998; Sigurd *et al*., 2008**)**. Throughout the study, the maximum water temperature was recorded in May (31.0^{o}C) and the minimum was in January (19.0^{o}C). Freshwater fish have an optimum growing temperature in the range of 25- 30°C (El-Shebly *et al*., 2007; Shah *et al*., 2008; Hossain *et al*., 2013). The *b* value showed a positive correlation with temperature. The highest rainfall was observed in June and no precipitation was occurred in the month of December. Rainfall doesn’t show any relation with growth. DO is considered the most vital parameter due to its necessity for aerobic metabolism **(**Timmons *et al*., 2001**)**. DO and pH also revealed correlation with growth. According to Biswas and Panigrahi (2015) desired level of DO is 5.0 to 15.0 mg/l. At least 3.0-5.0 mg/l DO is needed of for survive. Similarly, pH is also considered crucial for any aquatic ecosystem. If the pH value of any aquatic ecosystem is more acidic (pH < 4.5) or more alkaline (pH > 9.5) for long time, growth and reproduction will be diminished **(**Ndubuisi *et al*., 2015**)**. In our study, the monthly DO level ranged from 4.82 to 8.30 mg/l and pH ranged from 5.58 to 7.65 indicating a suitable habitat for fresh water fisheries resources in the Gajner *Beel*, (NW) Bangladesh.

CONCLUSION

In summary, our research describes the effect of eco-hydrological factors (Temperature, rainfall, dissolved oxygen, pH, total dissolved solids and alkalinity) on growth of *H fossilis* in a wetland ecosystem. Growth pattern was isometric and it was correlated with temperature, DO and pH. These parameters were within the suitable range for *H. fossilis* in the Gajner *Beel* wetland ecosystem. So, it would be the helpful tool for fishery scientist and researcher to prompt the management approaches for the stocks of *H. fossilis* in the Gajner *Beel* wetland ecosystem and contiguous ecosystems.

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REFERENCES

Abdel-Tawwb, M.; Hagras, A. E.; Elbaghdady, H. A. M. and Monier, M. N. (2015). Effect of dissolved oxygen and fish size on Nile tilapia *Oreochromis niloticus* (L.): growth performance, whole body composition and innate immunity. Aquaculture International, 23: 1261 – 1274.

Alam, M. M. and Ferdaushy, M. H. (2015). Length-length and length-weight relationships and condition factor of nine freshwater fish species of Nageshwari, Bangladesh. International Journal of Aquatic Biolology, 3: 149 – 154.

Alok, D.; Krishnan, T.; Talwar, G. P. and Garg, L. C. (1993). Induced spawning of catfish, *Heteropneustes fossilis* (Bloch), using D-Lys6 salmon gonadotropin-releasing hormone analog. Aquaculture, 115: 159 – 167.

Andrade, H. A. and Camos, R. O. (2002). Allometry coefficient variations of the length–weight relationship skipjack tuna (Katsuwonus pelamis) caught in the southwest South Atlantic. Fisheries Research, 55: 307 – 312.

Azevedo, P. A.; Cho, C. Y.; Leeson, S. and Bureau, D. P. (1998). Effects of feeding level and water temperature on growth, nutrient and energy utilization and waste outputs of rainbow trout (*Oncorhynchus mykiss*). Aquatic Living Resource, 11: 227 – 238.

Banglapedia (2004). National Encyclopedia of Bangladesh, Asiatic Society of Bangladesh, 1st edn. February 2004. Dhaka, Bangladesh.

Biswas, B. C. and Panigrahi, A. K. (2015). Ecology and zooplankton diversity of a wetland at Jhenidah district Bangladesh. International Journal for Innovative Research in Science and Technology, 1: 246 – 269.

Brown, D. J. A. and Sadler, K. (1989). Fish survival in acid waters, In: Morris R. (ed.) Society for Experimental Biology Seminar Series, University Press, London, pp. 31 – 44.

Das, P.; Rahman, W.; Talukdar, K. and Deka, P. (2015). Length-weight relationship and relative condition factor of *Heteropneustes fossilis* (Bloch) of Deepar *Beel*, a Ramsar site of Assam, India. International Journal of Applied Research, 12: 1024 – 1027.

Ecoutin, J. M.; Albaret, J. J. and Trape, S. (2005). Length–weight relationships for fish populations of a relatively undisturbed tropical estuary: The Gambia. Fisheries Research, 72: 347 – 351.

El-Shebly, A. A.; El-Kady, M. A. and Hossian, M. Y. (2007). A preliminary observation of the pond culture of European eel, *Anguilla anguilla* (Linnaeus, 1758) in Egypt: recommendations for future studies. Pakistan Journal of Biological Sciences, 10: 1050 – 1055.

Froese, R. (2006). Cube law, Condition Factor and Weight Length Relationship. History Meta-Analysis and Recommendations. Journal of Applied Ichthyology, 22: 241 – 253.

Goudie, A. S. (2004). Encyclopedia of geomorphology Vol. 1. New York, NY: Routledge. ISBN 0-415: 32737 – 7.

Halwart, M. and Gupta, M. V. (2004). Culture of fish in rice fields. FAO and the WorldFish Center, 83 p.

Hassan, H. U.; Ali, Q. M.; Rahman, M. A.; Kamal, M.; Tanjin, S.; Farooq, U.; Mawa, Z.; Badshah, N.; Mahmood, K.; Hasan, M. R.; Gabool, K.; Rima, F. A.; Islam, M. A.; Rahman, O. and Hossain, M. Y. (2020). Growth pattern, condition and prey-predator status of 9 fish species from the Arabian Sea (Baluchistan and Sindh), Pakistan. Egyptian Journal of Aquatic Biology & Fisheries, 24: 281 – 292.

Hossain, M. I.; Alam, M. M.; Alam, M.; Kamal, B. M. M. and Galib, S. M. (2013). Investigation of phytoplankton and physico-chemical parameters in nursery, grow out and brood stock ponds. Journal Scientific Research, 5: 553 – 569.

Hossain, M. Y.; Hossen, M. A.; Islam, M. S.; Jasmine, S.; Nawer, F. and Rahman, M. M. (2017). Reproductive biology of *Pethia ticto* (Cyprinidae) from the Gorai River (SW Bangladesh). Journal of Applied Ichthyology, 33: 1007–1014.

Hossain, M. Y.; Ohtomi, J.; Ahmed, Z. F.; Ibrahim, A. H. M. and 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 Sciencce, 22: 961 – 969.

Hossain, M. Y.; Pramanik, M. N. U.; Hossen, M. A.; Nawer, F.; Khatun, D.; Parvin, M. F.; Rahman, O.; Ahmed, Z. F. and Ahamed, F. (2018). Life History Traits of the Pool Barb *Puntius sophore* (Cyprinidae) in different ecosystem of, Bangladesh. Indian Journal of Geo Marine Science, 47: 1446 – 1454.

Hossain, M. Y.; Rahman, M. M.; Jewel, M. A. S.; Hossain, M. A.; Ahamed, F.; Tumpa, A. S.; Abdallah, E. M. and Ohtomi, J. (2013). Life History Traits of the Critically Endangered Catfish *Eutropiichthys vacha* (Hamilton 1822) in the Jamuna (Brahmaputra River Distributary) River, Northern Bangladesh. Sains Malaysiana, 42: 265 – 277.

Houde, E. D. and Zastrow, C. E. (1993). Ecosystem and Taxon-specific dynamic and energetics properties of larval fish assemblages. Bulletin of Marine Science, 53: 290 – 335.

Houlihan, D. F.; Mathers, E. M. and Foster, A. (1993). Biochemical correlates of growth rate in fish, In: *Fish Ecophysiology*. J.C. Rankin and F.B. Jensen (Eds.). Chapman and Hall. London. UK.

Issac, V. J. (1990). The accuracy of some length-based methods for fish population studies. ICLARM, Manila, Philippines. pp 81.

IUCN, Bangladesh. (2015). Red List of Bangladesh. *Volume 5: Freshwater Fishes.* IUCN, International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh, xvi+360 pp.

IUCN. (2018). IUCN Red List of Threatened Species, Version 2020-2. Downloaded on 19 April 2020.

Jakobsen, T.; Fogarty, M. J.; Mergrey, B. A. and Moksness, E. (2009). Fish reproductive biology, John Wiley & Sons, Chichester, United Kingdom.

Khan, M. A.; Khan, S. and Miyan, K. (2012). Length–weight relationship of giant snakehead, *Channa marulius* and stinging catfish, *Heteropneustes fossilis* from the River Ganga, India. Journal of Applied Ichthyology, 28: 154 – 155.

Khatun, D.; Hossain, M. Y.; Nawer, F.; Mostafa, A. A. and Al-Askar, A. A. (2019). Reproduction of *Eutropiichthys vacha* (Schilbeidae) in the Ganges River (NW Bangladesh) with special reference to potential influence of climate variability. *Environmental Science and Pollution Research,* 26**:** 10800-10815.

Khatun, D.; Hossain, M. Y.; Parvin, M. F. and Ohtomi, J. (2018) Temporal variation of sex ratio, growth pattern and physiological status of *Eutropiichthys vacha* (Schilbeidae) in the Ganges River, NW Bangladesh. Zoology and Ecology, 28: 343 – 354.

Le Cren, E. D. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in the Perch (*Perca fluviatilis*). Journal of Animal Ecology, 20: 201 – 219.

Liu, Z.; Liu, S.; Yao, J.; Bao, L.; Zhang, J.; Li, Y.; Jiang, C.; Sun, L.; Wang, R.; Zhang, Y.; Zhou, T.; Zeng, Q.; Fu, Q.; Gao, S.; Li, N.; Koren, S.; Jiang, Y.; Zimin, A.; Xu, P.; Phillippy, A. M.; Geng, W. X.; Song, L.; Sun, F.; Li, C.; Wang, X.; Chen, A.; Jin, Y.; Yuan, Z.; Yang, Y.; Tan, S.; Peatman, E.; Lu, J.; Qin, Z.; Dunham, R.; Li, Z.; Sonstegard, T.; Feng, W. J.; Danzmann, R. G.; Schroeder, S.; Scheffler, B.; Duke, M. V.; Ballard, L.; Kucuktas, H.; Kaltenboeck, L.; Liu, H.; Armbruster, J.; Xie, Y.; Kirby, M. L.; Tian, Y.; Flanagan, M. E.; Mu, W. and Waldbieser, G. C. (2016). The channel catfish genome sequence provides insights into the evolution of scale formation in teleosts, Nature communication, 11: 757

Mazid, M. A.; Rahman, M. J. and Mustafa, M. G. (2005). Abundance, migration and management of Jatka (juvenile hilsa, *Tenualosa ilisha)* in the Gajner *Beel*, Pabna, Bangladesh. Bangladesh Journal of Fisheries Research, 9: 191 – 202.

Muhammad, H.; Iqbal, Z.; Bashir, Q. and Hanif, M. A. (2017). Length-weight relationship and condition factor of cat fish species from Indus River, Pakistan. Punjab University Journal of Zoology, 32: 35 – 38.

Ndubuisi, U. C.; Chimezie, A. J.; Chinedu, U. C.; Chikwem, I. C. and Alexander, U. (2015). Effect of pH on the growth performance and survival rate of *Clarias gariepinus* fry. International Journal of Research and Biosciences, 4: 14 – 20.

Nima, A.; Hossain, M. Y.; Rahman, M. A.; Mawa, Z.; Hasan, M. R.; Islam, M. A.; Rahman, M. A.; Tanjin, S.; Sabbir, W.; Bashar, M. A. and Mahmud, Y. (2020). Temporal variations of length, weight and condition of Hilsa shad, *Tenualosa ilisha* (Hamilton, 1822) in the Meghna River, Southeastern Bangladesh. Egyptian Journal of Aquatic Biology and Fisheries, 24: 381 – 394.

Parvin, M. F.; Hossain, M. Y.; Sarmin, M. S.; Khatun, D.; Rahman, M. A.; Rahman, O.; Islam, M. A. and Sabbir, W. (2018). Morphometric and meristic characteristics of *Salmostoma bacaila* (Hamilton, 1822) (Cyprinidae) from the Ganges River in northwestern Bangladesh. Jordan Journal of Biological Sciences, 11**:** 533 – 536.

Patrick, A. E. S. (2016). Influence of rainfall and water level on inland fisheries production: A review. Archieves of Applied Science and Research 8: 44 – 51.

Rahman, M. A.; Hasan, M. R.; Hossain, M.Y.; Islam, M. A.; Khatun, D.; Rahman, O.; Mawa, Z.; Islam, M. S.; Chowdhury, A. A.; Parvin, M. F. and Khatun, H. (2019a). Morphometric and Meristic Characteristics of the Asian Stinging Catfish *Heteropneustes fossilis* (Bloch, 1794): A Key for Identification. Jordan Journal of Biological Science, 12: 467 – 470

Rahman, M. A.; Islam, M. S.; Hossain, M. Y.; Hasan, M. R.; Islam, M. A.; Khatun, D.; Rahman, O.; Parvin, M. F.; Mawa, Z. and Chowdhury, A. A. (2019b). Morphometric and meristic characteristics of the Banded Gourami, *Trichogaster fasciata* (Bloch & Schneider, 1801) in a wetland ecosystem from northwestern Bangladesh. Jordan Journal of Biological Science, 11**:** 561 – 566.

Rose, G. A. (2005). On distributional responses of North Atlantic fish to climate changes. ICES Journal of Marine Science, 62: 1360 – 1374.

Sabbir, W.; Md. Hossain, M. Y.; Rahman, M. A.; Hasan, M. R.; Mawa, Z.; Tanjin, S.; Habib- Ul, H. and Ohtomi, J. (2020). First report on condition factor of *Panna heterolepis* (Trewavas, 1977) in the Bay of Bengal (southwestern Bangladesh) in relation to eco-climatic factors. Egyptian Journal of Aquatic Biology and Fisheries, 24: 591– 608.

Saha, K. C. and Guha, B. C. (1939) Nutritional investigation of Bengal fish. Indian Journal of Medical Research, 26: 921– 927.

Shah, M. M. R.; Hossain, M. Y.; Begum, M.; Ahmed, Z. F.; Ohtomi, J.; Rahman, M. M.; Alam, M. J.; Islam, M. A. and Fulanda, B. (2008). Seasonal variations of phytoplankton community structure and production in related to environmental factors of the southwest coastal waters of Bangladesh. Journal of Fisheries and Aquatic Science, 3: 102 – 113.

Shoji, J.; Toshito, S.; Mizuno, K.; Kamimura, Y. and Hori, H. K. (2011). Possible effects of global warming on fish recruitment: shifts in spawning season and latitudinal distribution can alter growth of fish early life stages through changes in day length. ICES Journal of Marine Science, 68: 1165 – 1169.

Sigurd, O.; Handeland, a.; Albert, K.; Imsland, a. b. and Sigurd, O. S. (2008). The effect of temperature and fish size on growth, feed intake, food conversion efficiency and stomach evacuation rate of Atlantic salmon post-smolts. Aquaculture, 283: 36 – 42.

Sokal, R. R. and Rohlf, F. J. (1987) "Introduction to Biostatistics." 2nd ed. New York: Freeman Publication.

Talwar, P. K and Jhingran, A. G. (1991) "Inland Fishes of India and Adjacent Countries". vol. 2. A. A. Balkema, Rotterdam 541 pp.

Tesch, F. W. (1971) Age and growth, *In:* Ricker, W.E. (Ed.). Methods for assessment of fish production in fresh waters. Blackwell Scientific Publications, Oxford. 98–130pp.

Timmons, M.B.; James, M.E.; Fred, W.W.; Sreven, T.S. and Brian, J.V. (2001). Recirculating aquaculture systems, NRAC publication No.01- 002.

Tracey, S. R.; Lyle, J. and Haddon, M. (2007). Reproductive biology and per-recruit analyses of striped trumpeter (*Latris lineata*) from Tasmania, Australia: Implications for management. Fisheries Researce, 84: 358 – 368.