Khulna University Studies Volume 20(2):46-57: 2023

ORIGINAL ARTICLE **LIFE SCIENCE**

SEX RATIO AND BIOMETRIC INDICES OF PAMA CROAKER, *OTOLITHOIDES PAMA* (HAMILTON, 1822) FROM THE BAY OF BENGAL, SOUTH-WEST BANGLADESH

Wasim Sabbir[a]*, Asikur Rahman[a], Md. Asadujjaman[b], Sarower Mahfuj[c], Md. Nuruzzaman Khan[a] and Md. Musfike Meraz[d]

[a]Fisheries and Marine Resource Technology Discipline, Khulna University, Khulna-9208, Bangladesh
[b]Department of Aquaculture, Faculty of Fisheries & Ocean Sciences, Khulna Agricultural University, Khulna-9202, Bangladesh
[C]Department of Fisheries and Marine Bioscience, Jashore University of Science and Technology, Jashore-7408, Bangladesh
[d]Environmental Science Discipline, Khulna University, Khulna-9208, Bangladesh

KUS: 1014: 28072023

Manuscript submitted: July 28, 2023 Accepted: September 10, 2023

Abstract

The Pama croaker, *Otolithoides pama* is a prominent marine species under Sciaenidae family. This Sciaenid fish is a popular table food and a perceptible protein source for Bangladeshi rural people. Our research highlights a comprehensive description of the biometric indices of *O. pama* sampled from the Bay of Bengal, south-west Bangladesh, together with sex ratio, length-frequency distribution, growth pattern, form factor, Fulton's condition and prey-predator status. Overall 252 specimens (male = 171 and female = 81) were sampled by gill net during 2022 on seasonal basis (summer, rainy and winter). Length and weight of the sampled fish were assessed with measuring board and digital balance. While the sex ratio (male: female = 1.00:0.47) deviated from the conventional ratio of 1:1, total length varied from 13.0 to 26.7 cm for pooled data. Both sexes revealed negative allometric growth ($b < 3.00$) pattern as a whole. Form factor ($a_{3.0}$) was found 0.0074 which stated that the fish possessed a fusiform body shape. The mean Fulton's condition factor denoted an indecorous state of health. Alternatively, prey-predator status was found quite suitable for *O. pama* population. The outcomes of our research would be highly effective for executing sound management policy in the marine water of Bangladesh.

Keywords: Sex ratio, Growth pattern, Form factor, Fulton's condition factor, *Otolithoides pama*, Bay of Bengal.

Introduction

The marine water of Bangladesh is considered one of the richest ecosystems of the world with higher yield due to the tropical warm climate and adequate supply of nutrients from the adjacent estuarine and land (Shamsuzzaman et al., 2017). The Bay of Bengal is an excellent hub of aquatic biodiversity including fish, mammals, crustaceans, mollusks and seaweeds. A total of 475 fish fauna exist in the marine water of Bangladesh (Hussain & Mazid, 2010). The coastal fisher folk typically use different traditional fishing gears to fish in the vast water of Bay of Bengal throughout the year (Sabbir et al., 2021). Therefore, overfishing is considered the main threat to the marine fish stocks in Bangladesh (Sabbir et al., 2022; Hossen et al., 2019). Information about life history traits is indispensable to ensure the sustainability of a fish species in its wild ecosystem (Foster & Vincent, 2004). Further, the growing necessity of fish protein globally results massive fishing activities in open-water habitats. Therefore, improved biological management is considered as the possible way to enhance fish production in open water ecosystems (Panhwar et al., 2013) which requires adequate information about the population parameters of a given fish stock (Allison et al., 2009).

The variation of sex ratio and length-frequency distributions (LFDs) provides fundamental information about the stock structure of a fish population in a particular habitat (Mawa et al., 2022). Further, LFD indicates the

*Corresponding author: <wasimsabbirait@gmail.com >
DOI: https://doi.org/10.53808/KUS.2023.20.02.1014-ls

specific size range of fishing mortality (Sabbir et al., 2022). Likewise, data about length-weight relationships (LWRs) of an aquatic fauna is indispensable to implement sound fisheries activities as well as environmental monitoring programs in a specific geographic arena (Froese, 2006; Hossain et al., 2012). Stock assessment activities of a fish population largely depend of LWRs data (Ahmed et al., 2012). The form factor ($a_{3.0}$) is commonly used to specify the body shape of a fish in its wild habitat (Froese, 2006). Further, the wellbeing of a fish population is denoted by the condition factor index (Mac Gregoer, 1959). On the other hand, relative weight (W_R) is a numerical index that indicates the environmental condition of a fish population in an aquatic habitat concerning prey-predator status (Froese, 2006).

The Pama croaker, *Otolithoides pama* is a marine fish species under Sciaenidae family (Riede, 2004). This species is found widely in Bangladesh, Myanmar, India, Vietnam, Indonesia, Thailand and Malaysia (Talwar & Jhingran, 1991). Typically this fish species is called *Vola* or *Poa* in Bangladesh. This fish species is a prominent carnivore and typically consume small fish and prawn (Bhakta et al., 2019). The female *O. pama* attains sexual maturity at around 19.6 cm total length and spawn throughout the year (Bhakta et al., 2021). This species is a popular food fish and serves as an important source of protein for the rural marginal population of Bangladesh. Unfortunately, the entire demand for *O. pama* is filled from marine and coastal ecosystems due to lack of captive breeding and aquaculture practice. Consequently, continuous monitoring is needed for this species to ensure sustainability in the marine water of Bangladesh. However, little information was found in literature regarding the growth pattern (Bhakta et al., 2019; Hossain et al., 2015) of *O. pama* from different water body of Bangladesh and India (Table 1). Demographic data regarding sex ratio, growth pattern, length-length relations (LLRs), form factor, condition (K_F) and prey-predator status (W_R) of *O. pama* are still inadequate from the marine water of Bangladesh. Consequently, the current research was conducted to explain the biometric indices of *O. pama* on a seasonal basis from the Bay of Bengal (BoB), south-west Bangladesh.

Table 1. Assessment of regression parameters of the LWRs of *Otolithoides pama* with previous researches.

Location	Sex	*n*	Length range (cm)	Weight range (g)	*a*	CL 95% of *a*	*b*	CL 95% of *b*	References
Hoohgly-Matlah estuarine, West Bengal, India.	Male	298	-	-	-	-	2.88	-	Bhakta et al. (2019)
	Female	320	-	-	-	-	2.84		
	Pooled	618	-	-	-	-	2.86		
Tetulia River, Bangladesh.	Pooled	135	17.4-23.5	40.3-95.6	0.0075	0.0024-0.0235	3.02	2.64-3.40	Hossain et al. (2015)
Bay of Bengal, south-west Bangladesh.	Male	171	13.0-26.7	18.52-141.33	0.0142	0.0106-0.0189	2.78	2.68-2.88	Present study
	Female	81	13.5-26.0	20.01-132.66	0.0107	0.0078-0.0147	2.90	2.79-3.01	

Note: n, sample size; a, intercept; b, slope; CL, confidence limit.

Materials and Methods

Fish sampling

A total of 252 individuals (male = 171 and female = 81) of *O. pama* were collected randomly from commercial fishermen of Dublar Char situated in the Bay of Bengal (BoB), South West Bangladesh on a seasonal basis (summer, rainy and winter) during 2022 (Figure 1). Sampling was done using mainly gill net (mesh size 3 cm). Further, males were separated from females by observing gonads under the microscope.

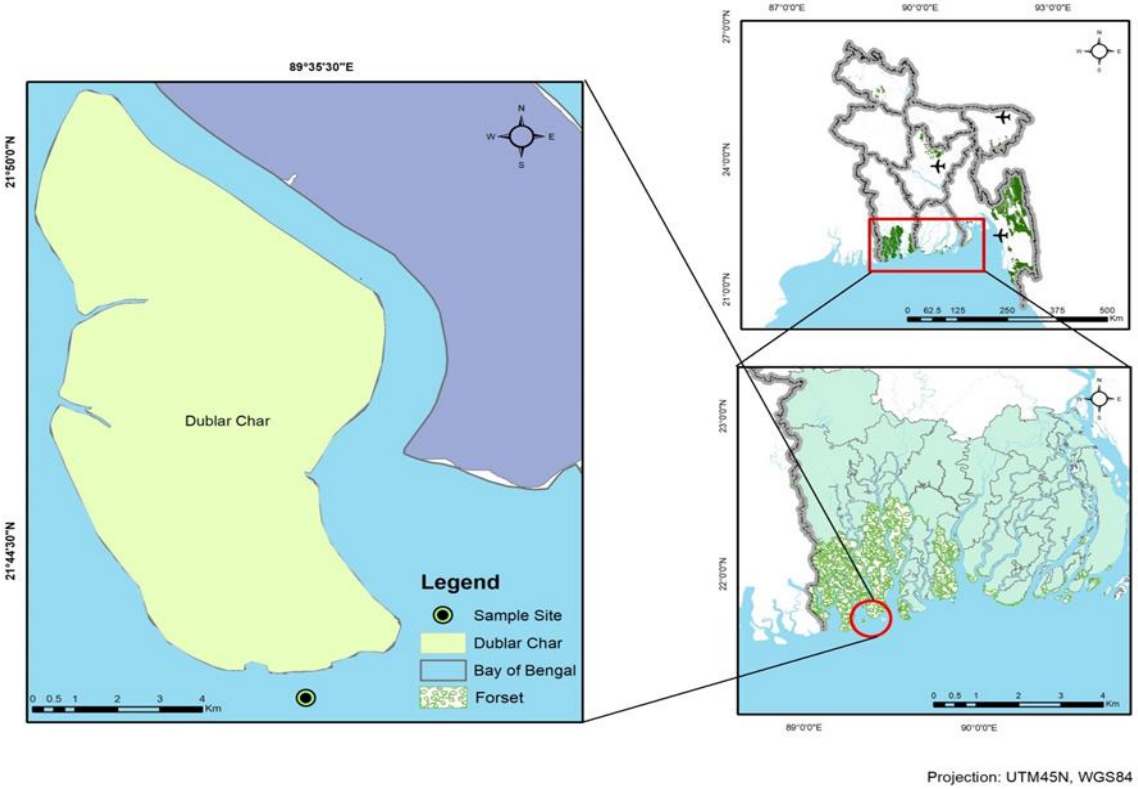

Figure 1. Location of the study area in the Bay of Bengal (BoB), South West Bangladesh.

Population structure

Body lengths (Total length, TL and Standard length, SL) along with body weight (BW) were recorded with the help of a measuring board and electric balance. LFDs for *O. pama* population were established by arranging 1 cm intervals of TL. The value of slope *b* was determined following the equation $W = a \times L^b$, here W is the body weight (g), L represents the total length (cm) and *a* along with *b* is the regression parameters. Further, linear regression analysis was conducted to ascertain the length-length relationship.

Form factor

Form factor ($a_{3.0}$) of *O. pama* population was studied following the equation $a_{3.0} = 10^{\log a - s(b-3)}$, where *S* is the slope of *ln a vs. b* (Froese, 2006).

Fulton's condition factor (K_F) and relative weight (W_R)

K_F was analyzed following the equation of Fulton (1904) as $K_F = 100 \times (W/L^3)$, where *W* is the BW in g and *L* is the TL in cm. Further, W_R was calculated following the equation of Froese (2006) as $W_R = (W/W_S) \times 100$, where W_S indicates the standard weight for a particular individual calculated as $W_S = a \times L^b$.

Statistical analysis

Data were analyzed considering 5% significance level with Microsoft® Excel-add-in-DDXL software. The sex ratio was calculated with chi-square test. Further, the relationship between W_R and 100 was detected by applying Wilcoxon signed rank test (Anderson & Neumann, 1966) with GraphPad Prism 6.5 software.

Results

Sex ratio

Altogether 252 (male = 171, Female = 81) specimens were collected during the study period. Comprehensively sex ratio differed statistically (male: female = 1:0.47) from the predicted 1:1 ratio. Further, the seasonal sex ratio indicated that males dominated during the three seasons (Table 2).

Table 2. Seasonal variation of sex ratio of the *Otolithoides pama* from the BoB, SW Bangladesh.

Season	Number of specimens			Sex ratio (Male : Female)	χ^2 (df=1)	Significance
	Male	Female	Total			
Summer	59	13	72	1:0.22	29.39	*
Rainy	56	24	80	1:0.43	12.80	*
Winter	56	44	100	1:0.79	1.44	NS
Overall	171	81	252	1:0.47	32.14	*

Note: *df*, degree of freedom; NS, not significant; * significant at 5% level ($\chi^2 > \chi^2_{t\ 1,\ 0.05} = 3.84$)

Length-frequency distribution (LFD)

The LFD of *O. pama* displayed that the TL ranged from 13.0 to 26.7 cm for pooled data. Besides, 17.00 – 17.99 and 20.00 – 20.99 cm TL groups were arithmetically dominant for male. Further, for female population 17.00 – 17.99 cm TL group was found numerically dominant (Figure 2). In addition, BW was recorded 18.52 to 141.33 g and 20.01 to 132.66 g for male and female populations, respectively (Table 3).

Table 3. TL and BW measurements of *Otolithoides pama* from the BoB, SW Bangladesh.

Month	Sex	*n*	TL (cm)				BW (g)			
			Min	Max	Mean ± SD	95% CL	Min	Max	Mean ± SD	95% CI
Summer	M	59	13.0	23.4	19.31±2.66	18.66-20.04	18.67	86.37	51.72±18.60	46.87-56.57
	F	13	14.0	23.0	17.55±2.80	15.86-19.25	20.01	93.31	42.75±20.63	30.29-55.22
Rainy	M	56	18.0	26.7	21.58±1.83	21.09-22.07	39.49	141.33	76.68±20.95	71.07-82.29
	F	24	18.6	26.0	21.93±1.94	21.10-22.75	53.97	132.66	86.07±23.68	76.07-96.07
Winter	M	56	13.0	20.3	17.29±1.44	16.91-17.68	18.52	68.10	42.53±10.48	39.73-45.34
	F	44	13.5	22.0	17.24±1.75	16.71-17.77	21.34	76.75	42.78±12.04	39.12-46.45

Notes: M, male; F, female; TL, total length (cm) BW, body weight (g); min, minimum; max, maximum, SD, standard deviation; CL, confidence limit.

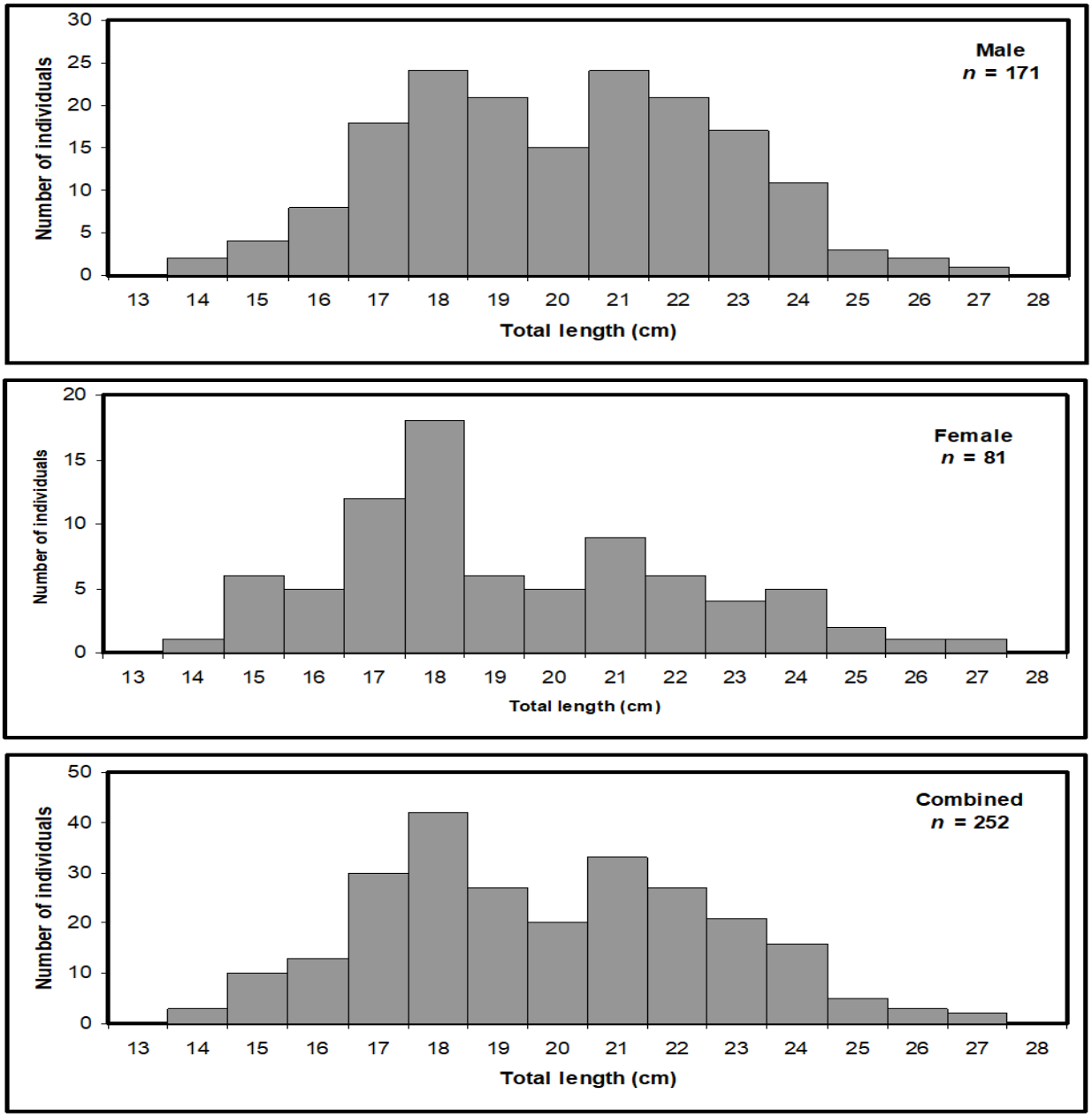

Figure 2. LFDs of *Otolithoides pama* sampled from the BoB, SW Bangladesh.

Growth pattern

Overall value of slope *b* specified negative allometric growth ($b < 3.00$) for both sexes (Figure 3). Nevertheless, both sexes' population exhibited positive allometric growth ($b > 3.00$) during the rainy season. Male growth pattern was also found positive allometric ($b > 3.00$) during the winter season. Besides, all LWRs were found to be highly correlated with all r^2 values ≥ 0.934 (Table 4). Moreover, the LLR (TL vs. SL) was found to be highly correlated with all $r^2 \geq 0.980$ (Figure 4).

Table 4. Statistics of the length-weight relationships (BW = $a \times TL^b$) of *Otolithoides pama* from the BoB, SW Bangladesh.

Season	Sex	*n*	Regression parameters		95% CL of *a*	95% CL of *b*	r^2	GT
			a	*b*				
	M	59	0.0158	2.72	0.0106-0.0234	2.58-2.85	0.966	-A
Summer	F	13	0.0108	2.87	0.0049-0.0237	2.59-3.14	0.979	-A
	C	72	0.0162	2.71	0.0114-0.0229	2.59-2.83	0.967	-A
	M	56	0.0051	3.12	0.0031-0.0086	2.95-3.29	0.962	+A
Rainy	F	24	0.0076	3.02	0.0036-0.0160	2.77-3.26	0.968	+A
	C	80	0.0053	3.12	0.0033-0.0086	2.96-3.28	0.952	+A
	M	56	0.0073	3.03	0.0040-0.0133	2.82-3.24	0.940	+A
Winter	F	44	0.0198	2.69	0.0106-0.0370	2.47-2.91	0.935	-A
	C	100	0.0124	2.85	0.0080-0.0191	2.70-3.00	0.934	-A

Note: GT, growth type; +A, positive allometric growth; -A, negative allometric growth.

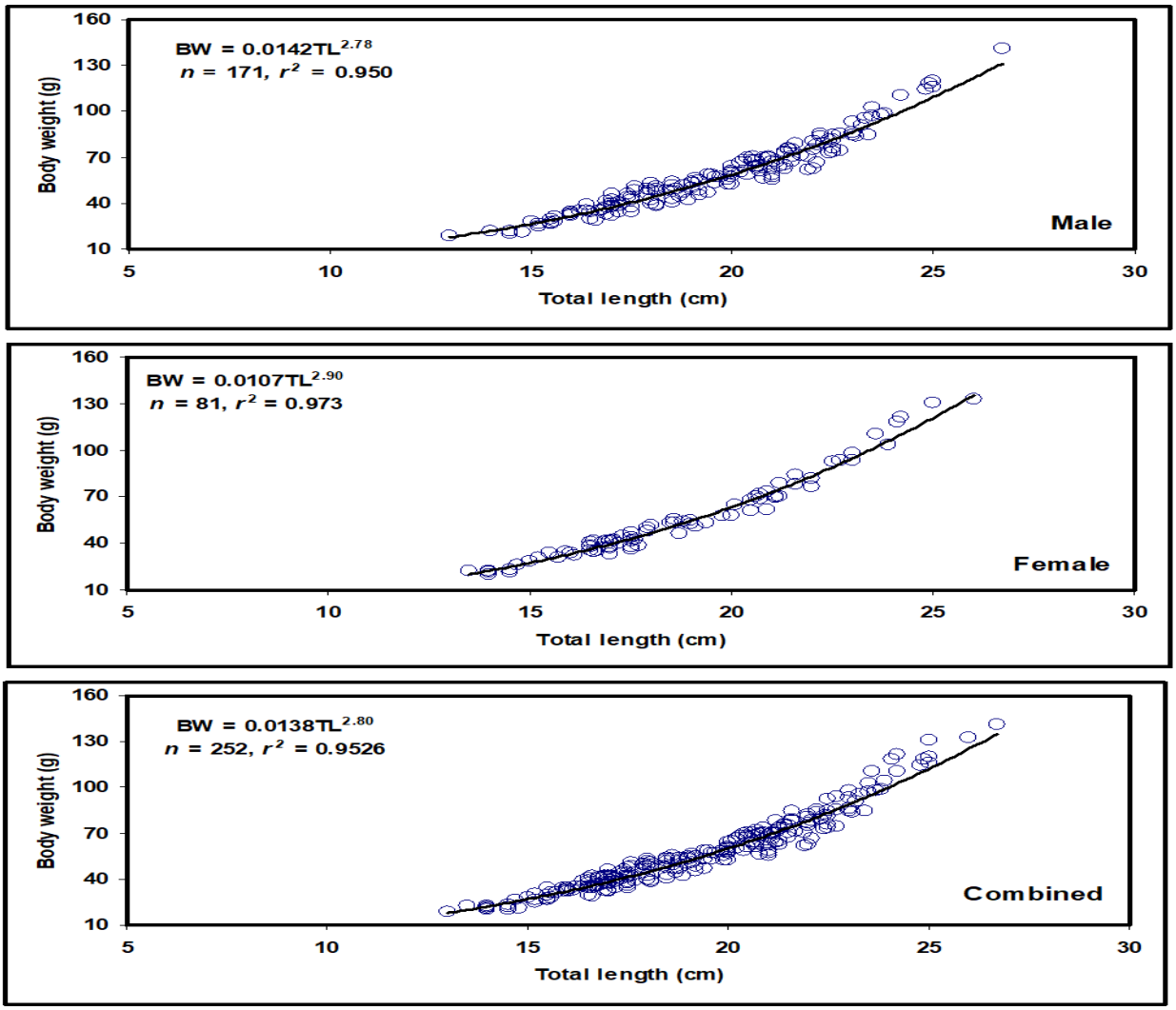

Figure 3. Overall growth pattern of *Otolithoides pama* sampled from the BoB, SW Bangladesh.

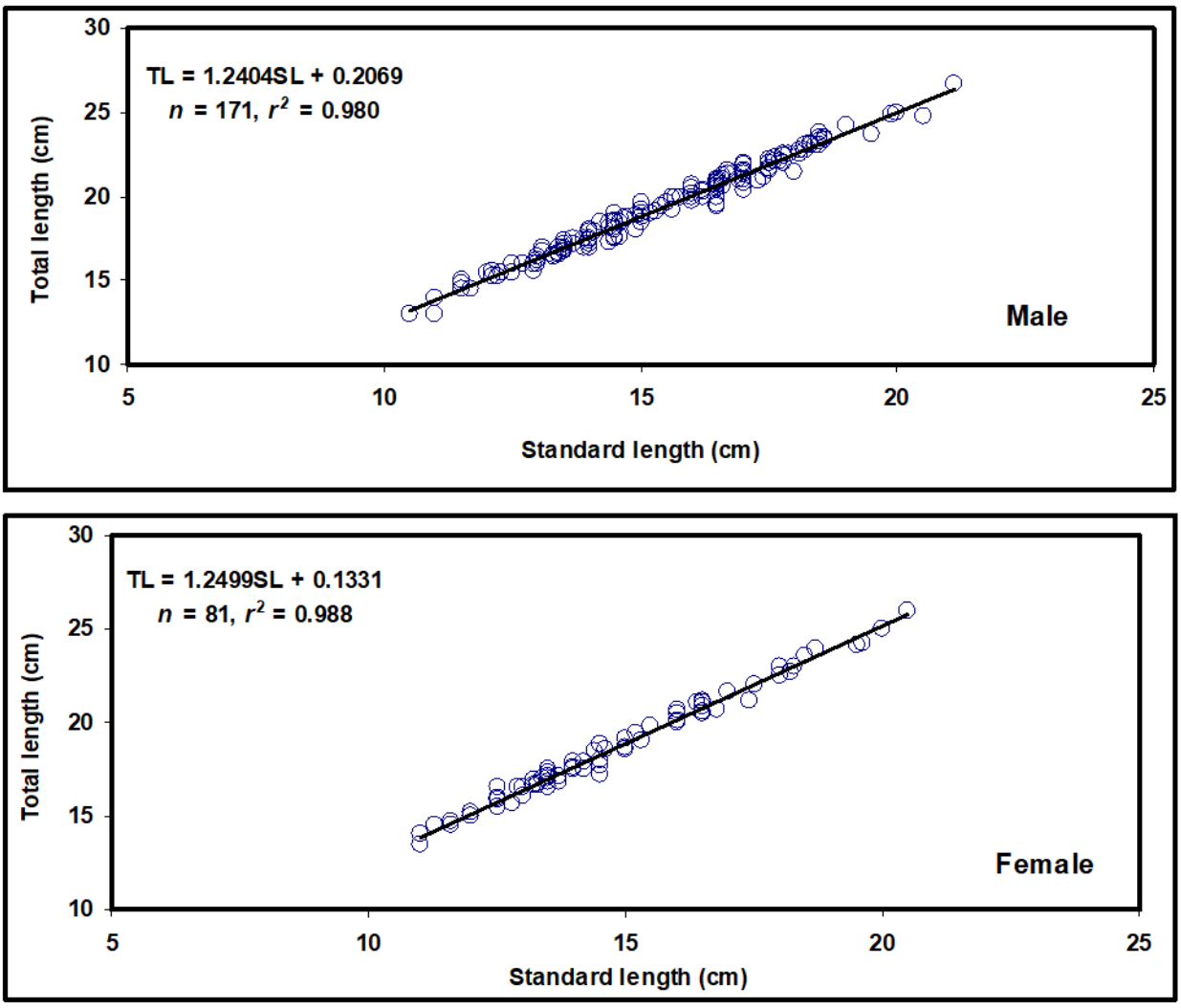

Figure 4. LLRs of *Otolithoides pama* sampled from the BoB, SW Bangladesh.

Form Factor

The form factor ($a_{3.0}$) was estimated as 0.0074 for *O. pama* indicated a fusiform body shape (Froese, 2006).

Fulton's condition factor (K_F) and Relative weight (W_R)

The K_F value was found maximum in winter (0.94) and minimum in summer (0.59) for male population. Alternatively, K_F value for female population was found higher (0.92) in winter season and lower (0.67) in rainy season (Table 5; Figure 5). Likewise, the value of W_R ranged from 85.39 to 118.27 for male population. Besides, W_R for female population deviated from 81.57 to 110.89 (Table 6: Figure 6). Additionally, Wilcoxon sign rank test exposed no statistical difference between W_R and 100 for both male (P = 0.50) and female (P = 0.25) population.

Table 5. Statistics on Fulton's condition factor (K_F) of *Otolithoides pama* from the BoB, SW Bangladesh.

Season	Sex	n	Fulton's condition factor (K_F)			
			Min	Max	Mean±SD	95% CL
Summer	M	59	0.59	0.85	0.69±0.06	0.67-0.70
	F	13	0.68	0.84	0.74±0.05	0.71-0.77
Rainy	M	56	0.65	0.82	0.75±0.04	0.73-0.76
	F	24	0.74	0.87	0.80±0.04	0.78-0.81
Winter	M	56	0.68	0.94	0.81±0.05	0.79-0.82
	F	44	0.67	0.92	0.82±0.06	0.80-0.84

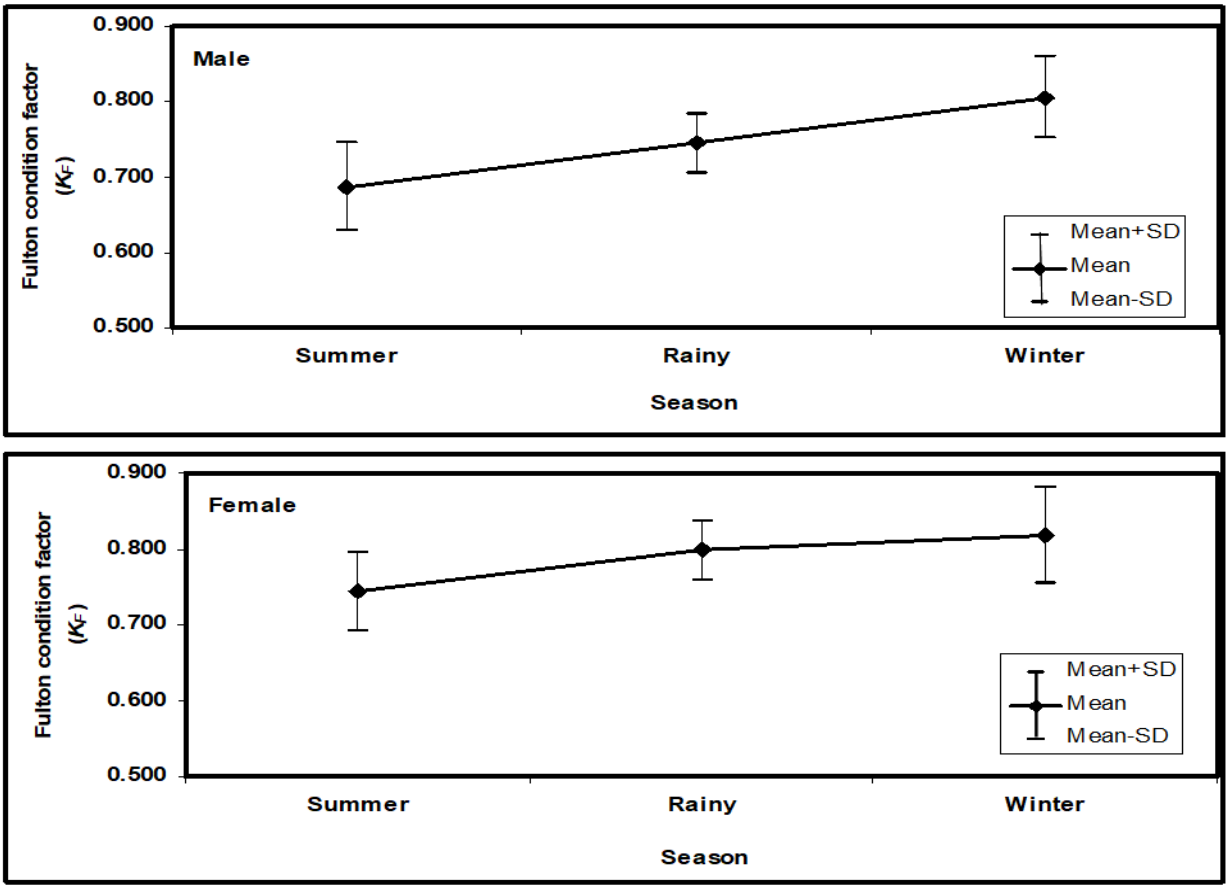

Figure 5. Seasonal deviations of mean K_F of *Otolithoides pama* sampled from the BoB, SW Bangladesh.

Table 6. Statistics on relative weight (W_R) of *Otolithoides pama* from the BoB, SW Bangladesh.

Season	Sex	n	Relative Weight (W_R)			
			Min	Max	Mean±SD	95% CL
Summer	M	59	87.68	115.70	99.30±7.24	97.42-101.19
	F	13	90.71	110.48	99.71±6.57	95.75-103.68
Rainy	M	56	89.44	112.01	101.08±5.21	99.69-102.48
	F	24	91.33	107.72	98.72±4.80	96.69-100.75
Winter	M	56	85.39	118.27	101.35±6.67	99.56-103.13
	F	44	81.57	110.89	99.69±6.97	97.57-101.81

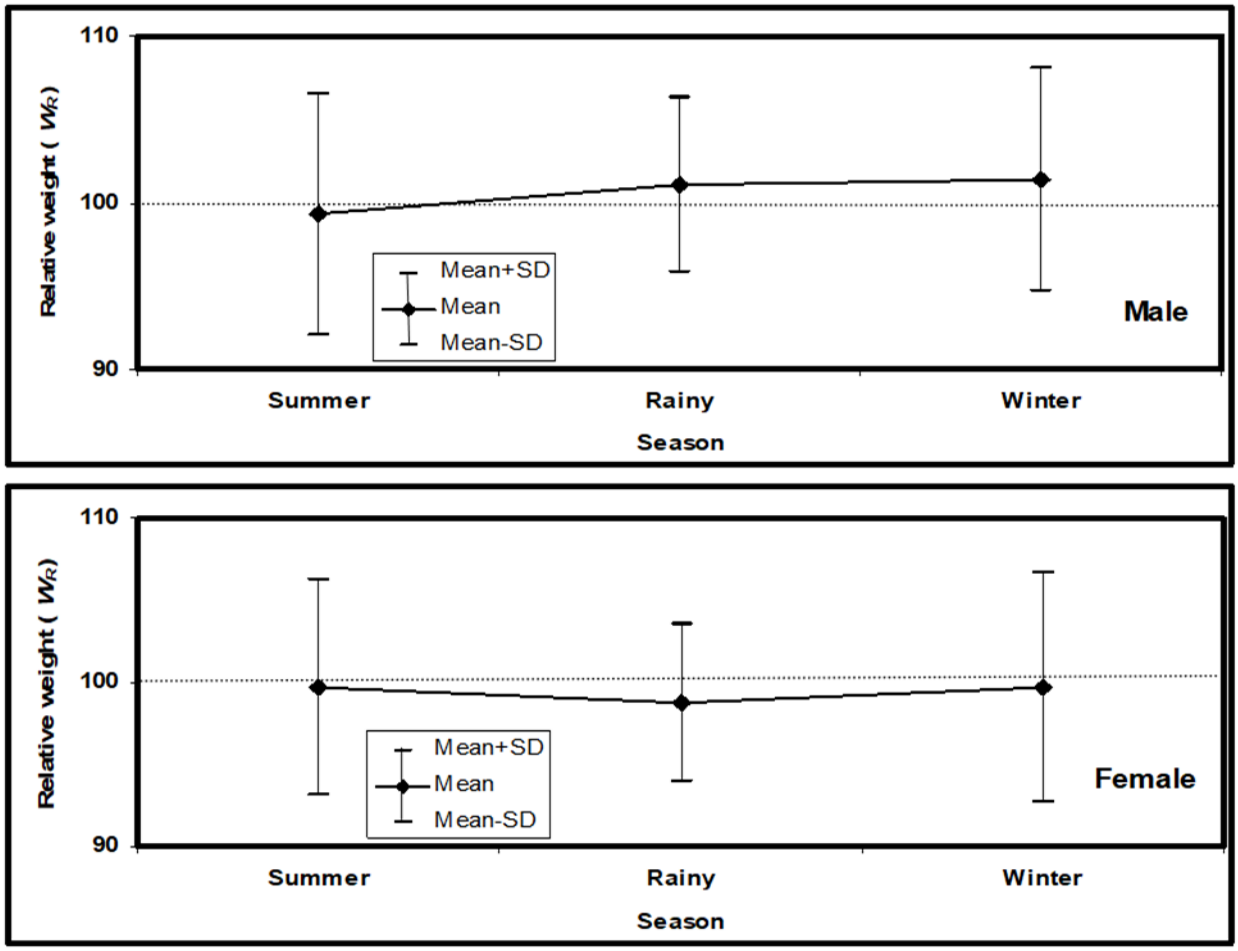

Figure 6. Seasonal deviations of mean W_R of *Otolithoides pama* sampled from the BoB, SW Bangladesh.

Discussion

Data regarding population parameters are essential to ensure the sustainability of a fish stock in its wild ecosystem. Although, *O. pama* is an economically important fish species in the marine water of Bangladesh but demographic information is still inadequate in literature. Bhakta et al. (2019) studied the growth pattern of *O. pama* from Hooghly-Matlah estuarine system of India with 618 specimens. Similar type study was conducted by Hossain et al. (2015) with 135 pooled samples. Consequently, our research aimed to expose a complete biometric feature including sex ratio, LFDs, LWRs, LLRs, form factor, Fulton's condition factor along with prey-predator status of *O. pama* population sampled from BoB, SW Bangladesh on a seasonal basis.

As a whole, sex ratio (male: female = 1.00:0.47) deviated from the probable ratio of 1:1 (df =1, $\chi 2$ = 32.14, P < 0.05). Besides, male populations were found dominant numerically than female community in every season. Instead, Bhakta et al. (2021) found no significant difference between the sex ratio of *O. pama* while studying the reproductive biology. In our study, specimens were collected randomly from the commercial fishers of Bay of Bengal. Sex ratio deviated statistically in summer and rainy season perhaps due to a number of physiological and

ecological factors, including seasonality, salinity, temperature and interactions with other species (Khatun et al., 2018).

A total of 252 specimens were harvested from the BoB, SW Bangladesh based on three seasons during 2022. We did not find *O. pama* specimen smaller than 13.0 cm in TL. The mesh size of fishing gear might be a possible reason why we failed to harvest fish smaller than 13.0 cm (Sabbir et al., 2022; Hossain et al., 2013). However, the highest TL was recorded 26.7 cm which was higher than the reported value of 23.5 cm TL by Hossain et al. (2015). In our study the maximum BW was recorded 141.33 g in favor of male. Further, Hossain et al. (2015) found the highest body weight 95.6 g for pooled sample harvested from Tetulia River (Bangladesh) which is lower than our finding. Besides, LFD specified that 17.00 – 17.99 cm TL group was more vulnerable to fishing mortality.

Carlander (1969) described that the value of slop b of LWRs might be deviated from 2.0 to 4.0. Instead, Froese (2006) reported that the allometric co-efficient (b) should be fluctuated from 2.5 to 3.5 for typical teleost species. We obtained negative allometric growth pattern ($b < 3.00$) while considering the overall *O. pama* population (male, $b = 2.78$; female, $b = 2.90$; and pooled, $b = 2.80$) sampled from BoB, SW Bangladesh, within the range of Froese (2006). Bhakta et al. (2019) also reported negative allometric growth pattern for male, female and pooled data set of *O. pama* sampled from Hooghly-Matlah estuarine of West Bengal, India. However, Hossain et al. (2015) stated positive allometric growth pattern for pooled sample of *O. pama* population harvested from Tetulia River, Bangladesh. The value of b may differ for an identical fish species due to a number of factors such as availability of feed, development of gonad, physiological condition and preservation methods (Hossain et al., 2015; Le Cren, 1951; Tesch, 1968). Moreover, the LLR (TL *vs.* SL) was recorded strongly correlated for both male ($r^2 = 0.980$) and female ($r^2 = 0.988$) population of *O. pama*.

Form factor ($a_{3.0}$) is a numerical index that specifies the shape of body of a teleost fish in a given geographic area. The assessed the form factor ($a_{3.0}$) of our research for *O. pama* population was 0.0074 indicated fusiform body shape (Froese, 2006).

As fish is considered as an importance source of protein for global population, it is essential to have adequate knowledge about their biology and health condition to ensure sustainability in wild ecosystem (Ahmed et al., 2012). The condition factor typically specifies the well-being status of a fish population in a specific aquatic arena (Sabbir et al., 2020). In the current research Fulton's condition factor (K_F; Fulton, 1904) was used to indicate the fitness of *O. pama* stock in the BoB, SW Bangladesh. The K_F value was found higher (0.94) in winter for male and for female maximum value (0.92) obtained in rainy season. For both sexes, mean K_F value was found lower than 1 indicted an improper state of health for *O. pama* population (Rahman et al., 2023). However, the W_R index is frequently used to signify the prey-predator status of a fish stock in its wild habitat (Rypel & Richter, 2008). If the value of W_R is found statistically lower than 100, it indicates higher predator abundance compared to prey. Likewise, W_R value statistically upper than 100 denotes more prey abundance compared to predator (Froese, 2006). In our present research, we noticed no significant deviation between W_R and 100 denoting a suitable habitat for *O. pama* stock in the BoB, SW Bangladesh. However, due to lack of adequate literature it was difficult for us to make any comparison.

Conclusion

Overall sex ratio (male: female) of *O. pama* varied statistically from the predicted value of 1:1. Both sexes revealed a negative allometric ($b < 3.00$) growth pattern. The form factor denoted fusiform body shape. The K_F indicated an unsuitable health status of the sampled population. Alternatively, W_R specifies a stable environment considering prey-predator status. These findings could provide valuable insights for the fisheries managers to develop effective conservation strategies for maintenance *O. pama* stock in the BoB, SW Bangladesh and adjacent coastal waters.

Conflict of Interest

The authors declare no conflict of interest.

References

Ahmed, Z.F., Hossain, M.Y., & Ohtomi, J. (2012). Condition, length–weight and length–length relationships of the silver hatchet Chela, *Chela cachius* (Hamilton, 1822) in the Old Brahmaputra River of Bangladesh. *Journal of Freshwater Ecology*, *27*, 123-130.

Allision, E.H., Perry, A.L., Badjeck, M.C., Adger, W.N., Brown, K., Conway. D., Halls, A.S., Pilling, G.M., Andrew, N.L., & Dulvy, N. K. (2009). Vulnerability of national economics to the impacts of climate change on fisheries. *Fish and Fisheries, 10*(*2*), 173-196.

Anderson, R.O., & Neumann, R.M. (1996). Length, weight and associated structure indices, in Fisheries Techniques (2nd ed) Murphy, B.R., and Willis, W.D. (EDs), *American Fisheries Society*, Bethesda, MD.

Bhakta, D., Das, S.K., Das, B.K., Nagesh, T.S., & Behera, S. (2019). Food and feeding habits of *Otolithoides pama* (Hamilton, 1822) occurring from Hooghly-Matlah estuary of West Bengal, India. *Regional Studies in Marine Science*, https://doi.org/10.1016/j.rsma.2019.100860

Bhakta, D., Das, S.K., Das, B.K., & Nagesh, T.S. (2021). Biology of reproduction in *Otolithoides pama* (Hamilton, 1822) in Hooghly-Matlah Estuary of West Bengal, India. *Indian Journal of Fisheries*, *68*(*1*), 27-39.

Carlander, K.D. (1969). Handbook of freshwater fishery biology, Vol. 1. The Iowa State University Press, Ames, IA.

Foster, S.J., & Vincent, A.C.J. (2004). Life history and ecology of seahorses: implications for conservation and management. *Journal of fish Biology*, *65*, 1-61.

Froese, R. (2006). Cube law, condition factor, and weight-length relationship: history, meta- analysis, and recommendations. *Journal of Applied Ichthyology*, *22*, 241–253.

Fulton, T.W. (1904). The rate of Growth of Fishes. Twenty second Annual Report, part III. Edinburg: Fisheries Board of Scotland.

Hossen, M.A., Paul, A.K., Hossain, M.Y., Ohtomi, J., Sabbir, W., Rahman, O., Jasmin, J., Khan, M.N., Islam, M.A., Rahman, M.A., Khatun, D., and Kamruzzaman, Sk. (2019). Estimation of biometric indices for Snakehead *Channa punctata* (Bloch, 1973) through Multi-model inferences. *Jordan Journal of Biological Sciences*, *12*, 197-202.

Hossain, M.Y., Ohtomi, J., Jaman, A., Jasmine, S., and Vadas, Jr.R.L. (2012). Life-history traits of the Monsoon River prawn *Macrobrachium malcolmsonii* (Milne-Edwards, 1844) (Palaemonidae) in the Ganges (Padma) River, northwestern Bangladesh. *Journal of Freshwater Ecology, 27*, 131-142.

Hossain, M.Y., Khatun, M.M., Jasmine, S., Rahman, M.M., Jahan, S., Jewel, M.A.S., & Ohtomi, J. (2013). Life-history Traits of the Threatened Freshwater Fish *Cirrhinus reba* (Hamilton 1822) (Cypriniformes: Cyprinidae) in the Ganges River, Northwestern Bangladesh. *Sains Malays., 42*, 1219–1229.

Hossain, M.Y., Sayed, S.R.M., Rahman, M.M., Ali, M.M., Hossen, M.A., Elgorban, A.M., Ahmed, Z.F., & Ohtomi, J. (2015). Length-weight relationships of nine fish species from the Tetulia River, southern Bangladesh. *Journal of Applied Ichthyology*, *31*, 967–969.

Hussain M.G., & Mazid, M.A. (2010). Genetic improvement and conservation of carp species in Bangladesh. Bangladesh Fisheries Research Institute and International Center for Living Aquatic resource Management. pp.74.

Khatun, D., Hossain, M.Y., Parvin, M.F., & 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 relationships and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *Journal of Animal Ecology, 20*(*2*), 201-219.

Mac Gregoer, J.S. (1959). Relation between fish condition and population size in the sardine (*Sardinops cacrulea*). U.S. Fishery Wild Service*, Fish Bulletin*, *60*, 215-230.

Mawa, Z., Hossain, M.Y., Hasan, M.R., Rahman, M.A., Tanjin, S., & Ohtomi, J. (2022). Life history traits of *Mystus vittatus* in the Ganges River, Bangladesh: recommendation for its sustainable management considering climate change. *International Journal of Biometeorology*, *66*, 927-943.

Panhwar, S.K., Liu, Q., & Siddiqui, G. (2013). Growth, mortality and stock assessment of kelee shad, *Hilsa kelle* (Fam: Clupeidae) in the coastal waters of Pakistan. *Journal of Ichthyology*, 53, 365-371.

Rahman, M.A., Manon, M.R.K., Ullah, M.R., Alam, A., Islam, M.J., Siddik, M.A.B., & Iqbal, M.M. (2023). Biometric indices, growth pattern, and physiological status of captive-reared indigenous Yellowtail brood catfish, *Pangasius pangasius* (Hamilton, 1822). *Environmental Science and Pollution research*, *30*, 83388-83400. https://doi.org/10.1007/s11356-023-28328-9

Riede, K. (2004). Global register of migratory species - from global to regional scales. Final Report of the R&D-Projekt 808 05 081. Federal Agency for Nature Conservation, Bonn, Germany. p. 329.

Rypel, A.L., & Richter, T.J. (2008). Empirical percentile standard weight equation for the black tail red horse. *North American Journal of Fisheries Management*, *28*, 1843-1846.

Sabbir, W., Hossain, M.Y., Rahman, M.A., Hasan, M.R., Mawa, Z., Tanjin, S., Hasan, H.U., & 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*(*2*), 591-608.

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

Sabbir, W., Hossain M.Y., Khan, M.N., Rima, F.A., Sarmin, M.S., & Rahman, M.A. (2022). Biometric indices of Flathead Sillago, *Sillaginopsis panijus* (Hamilton, 1822) from the Bay of Bengal (Southern Bangladesh). *Thalassas: An International Journal of Marine Sciences*. https://doi.org/10.1007/s41208-022-00421-9

Shamsuzzaman, M.M., Islam, M.M., Tania, N.J., Al-Mamun, A.A., Barman, P.P., & Xu, X. (2017). Fisheries resources of Bangladesh: Present status and future direction. *Aquaculture and Fisheries*, *2*, 145-156.

Talwar, P.K., & Jhingran, A.G. (1991). Inland Fishes of India and Adjacent Countries, Vol. I, Oxford & IBH Publishing Co. Pvt. Ltd. New Delhi-Calcutta. pp. 136-137.

Tesch, F.W. (1968). Age and Growth. In: Methods for assessment of fish production in Freshwaters. Edited by Ricker, W. E. Oxford: Blackwell Scientific Publications.