Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 24(2): 591 – 608 (2020)
www.ejabf.journals.ekb.eg

First Report on Condition Factor of *Panna heterolepis* (Trewavas, 1977) in the Bay of Bengal (Southwestern Bangladesh) in Relation to Eco-Climatic Factors

Wasim Sabbir [1, 2], Md. Yeamin Hossain[1*], Md. Ashekur Rahman[1], Md. Rabiul Hasan[1], Zannatul Mawa[1], Sumaya Tanjin[1], Habib- Ul-Hassan[3] and Jun Ohtomi[4]

[1]Department of Fisheries, University of Rajshahi, Rajshahi-6205, Bangladesh
[2]Fisheries & Marine Resource Technology Discipline, Khulna University, Bangladesh
[3]Department of Zoology (MRCC), University of Karachi, Karachi-75270, Pakistan
[4]Faculty of Fisheries, Kagoshima University, 4-50-20 Shimoarata, Kagoshima 890-0056, Japan
*Corresponding author**:** hossainyeamin@gmail.com; yeamin.fish@ru.ac.bd

ARTICLE INFO

Article History:
Received: April 17, 2020
Accepted: April 30, 2020
Online: May, 2020

Keywords:
Panna heterolepis;
condition factor;
eco-climatic factors;
Bay of Bengal.

ABSTRACT

The current study describes the first report on condition factors (Fulton's, K_F; allometric, K_A; relative, K_R and relative weight, W_R) of *Panna heterolepis* in relation to eco-climatic factors (temperature, rainfall, dissolved oxygen and pH) in the Bay of Bengal, SW Bangladesh. All together 1224 specimens (male = 654, female = 570) were caught through January to December 2019. Bodyweight (BW), as well as total length (TL), was assessed by digital balance and measuring board with 0.01 g and 0.01 cm accuracy. TL was varied between 10.70-31.40 cm for males and 10.50-34.50 cm for females. Further, BW was ranged from 10.02-203.89 g for males and 9.02- 342.26 g for the female population. The K_F values ranged from 0.56 to 1.12 for males and 0.60 to 1.45 for females. On the other hand, K_A varied between 0.0047 to 0.0212 for males and 0.0050 to 0.0267 for females. Besides, K_R varied between 0.79 to 1.39 for males and 0.73 to 1.55 for females. However, W_R ranged from 78.55 to 139.24 for males and 73.24 to 154.47 for females. Fulton's condition factor (K_F)was found the best for evaluating the well-being of this species in the Bay of Bengal. Further, K_F was found significantly related to temperature for both males (P = 0.04) and females (P = 0.04) but not with other factors. The mean W_R indicated that the habitat was in a balanced condition considering prey-predator status. The outcomes of the study will be helpful for future management of this fish in the Bay of Bengal considering the emerging climate change.

INTRODUCTION

If we accept that the fishery is an important branch for food production worldwide, it is urgent to discover fish biology as well as their health condition. Condition factor is the index which is used to understand survival, maturity, health status and reproduction of fish **(Le Cren, 1951; Hossain, 2010; Ahmed *et al*., 2012)**. Further, it indicates the quality of a water body and overall fitness of a population dwelling in a specific ecosystem **(Tsoumani *et al*., 2006)**. The condition of fish could be influenced by sex, water quality parameters, stress, availability of feeds and season **(Khallaf *et al*., 2003; Hossain *et al*., 2006; Rahman *et al*., 2012)**. Consequently, the knowledge of condition factor is vital for evaluating the life cycle of a particular fish population for proper management and to upkeep the stability of the ecosystem **(Hossain *et al*., 2013a)**. In addition, relative weight (W_R) is the most popular index to assess the status of fish in a particular habitat considering prey-predator status **(Froese, 2006; Rypel and Richter, 2008; Hossain *et al*., 2013b)**.

Likewise, climate change is considered as an important hazard to fisheries along with other different risk such as overfishing, pollution and habitat deterioration **(Rose, 2005)**. Climatic factors mainly temperature and rainfall has constant effect on fish growth and survival **(Shoji *et al*., 2011)**. 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)**. A number of studies on eco-climatic effect on distributional changes in worldwide marine fish stocks have been well documented **(Beare *et al*., 2004; Alheit *et al*., 2005; Perry *et al*., 2005)**. However, in the Bay of Bengal, to our knowledge, such studies are absent.

The Hooghly Croaker, *Panna heterolepis* (Trewavas, 1977) belonging to the family Sciaenidae is a tropical demersal fish inhabit estuaries and marine-water **(Talwar and Jhingran, 1991)**. This Sciaenid fish is distributed in Bangladesh, Myanmar, India and Sri Lanka **(Sasaki, 1995)**. This species is locally known as *Poa* and commercially very important as a table food item in Bangladesh. Due to lack of culture practice, the overall demand of this species is met through the capture from wild stock. As a result, overfishing is the foremost threat for the abundance of wild stock **(Hossain *et al*., 2012a; Hossen *et al*., 2019)**.

According to the author's knowledge, only a few works including the morphology **(Sasaki, 1995)** and morphometry as well as length-weight relationship **(Sanphui *et al*., 2018)** have been done on *P*. *heterolepis*. Consequently, the objective of this study is to illustrate the condition factors (Fulton's, K_F; allometric, K_A and relative, K_R) and relative weight (W_R) considering the eco-climatic factors of *P*. *heterolepis* for successive twelve months from the Bay of Bengal, (SW) Bangladesh.

MATERIALS AND METHODS

Study site and sampling. The study was done in Bay of Bengal (in Khulna region, SW Bangladesh). Altogether, 1224 individuals (male = 654, female = 570) of *P. heterolepis* were collected randomly from fisher's catch during January to December, 2019. The collected samples were immediately preserved with ice and then fixed with 10% formalin solution to prevent decomposition of fish.

Fish measurement. Male and female individuals were identified by microscopic observation of gonads. The overall sex ratio (male: female = 1.00:0.87) varied statistically from the predictable ratio of 1:1 (df =1, $\chi 2$ = 5.91, p > 0.05). Body weight (BW) as well as total length (TL) was assessed by digital balance and measuring board with 0.01 g and 0.01 cm accuracy.

Calculation of condition factors. Fulton's condition factor (K_F) was determined using the equation: $K_F = 100\times(W/L^3)$ **(Fulton, 1904)**, where W stands for BW in g and L is the TL in cm. The scaling factor 100 was used to bring the K_F close to unit. The allometric condition factor (K_A) was estimated by the equation: $K_A = W/L^b$ **(Tesch, 1968)**, where W is the BW in g, L represents the TL in cm and b is the LWRs parameter. Further, relative condition factor (K_R) was assessed with the equation: $K_R = W/(a\times L^b)$ **(Le Cren, 1951)**, where W is the BW in g, L is the TL in cm and a and b are LWRs parameters. The relative weight (W_R) was calculated by the equation: $W_R = (W/Ws) \times 100$ **(Froese, 2006)**, where W is the BW of a specific individual and W_S is the anticipated standard weight for the identical individual as calculated by $W_S = a\times L^b$, where a and b values were acquired from the relationships between TL and BW.

Eco-climatic parameters. To evaluate the relationship between the most suitable condition factor of *P. heterolepis* with habitat status, monthly ecological parameters were also recorded from the sampling site following **APHA (2005)** procedures. The collected parameters were temperature (^{o}C), pH and dissolved oxygen (DO; mg/L). Further, the data of monthly rainfall (mm) was collected from meteorological station of Khulna, Bangladesh.

Statistical Analyses. For statistical analyses GraphPad Prism 6.5 Software was used. Homogeneity as well as normality of data was checked and confirmed with the Kolmogorov-Smirnov test and Shapiro-Wilk normality test. Where test for normality assumption was not met, the nonparametric Mann-Whitney U test was applied to compare the condition factors between sexes. The Wilcoxon signed rank test was conducted to compare the average relative weight (W_R) and 100 **(Anderson and Neumann, 1996)**. The Spearman's rank test was used to correlate body measurements (TL and BW) with condition factors (K_F, K_A, K_R and W_R) as well as to relate the best condition factor with different eco-climatic factors. Additionally, a chi-square test was executed to observe the sex ratio departure from the predictable value of 1:1 (male:

female). Furthermore, data analyses were done through Microsoft® Excel-add-in-Solver. All statistical analyses were conducted with 5% significance level.

RESULTS

Total 1224 specimens (male = 654, female = 570) were caught through January to December 2019, where TL was varied between 10.70-31.40 cm for males and 10.50-34.50 cm for females and BW was ranged from 10.02-203.89 g for males and 9.02-342.26 g for females. The overall sex ratio (male: female = 1.00:0.87) varied statistically from the predictable ratio of 1:1 (df =1, $\chi 2$ = 5.91, p > 0.05).

Table 1. Descriptive statistics on Fulton's condition factor (K_F) measurements and their 95% confidence limits of the *Panna heterolepis* in the Bay of Bengal, SW Bangladesh.

Month	Sex	*n*	Fulton′s condition factor (K_F)			
			Min	Max	Mean±SD	95% CL
January	M	35	0.656	0.757	0.709±0.028	0.700-0.719
	F	72	0.691	0.855	0.768±0.043	0.758-0.778
February	M	37	0.580	0.868	0.736±0.067	0.713-0.758
	F	67	0.594	1.040	0.777±0.104	0.752-0.803
March	M	47	0.599	0.858	0.745±0.057	0.728-0.761
	F	57	0.656	0.993	0.789±0.070	0.771-0.808
April	M	50	0.610	1.125	0.789±0.077	0.767-0.811
	F	34	0.678	1.451	0.870±0.147	0.819-0.922
May	M	76	0.658	1.045	0.789±0.070	0.773-0.805
	F	25	0.723	1.046	0.835±0.077	0.803-0.867
June	M	77	0.633	0.946	0.731±0.048	0.720-0.742
	F	22	0.723	1.046	0.857±0.085	0.819-0.894
July	M	66	0.620	0.957	0.729±0.061	0.714-0.744
	F	37	0.642	1.075	0.772±0.089	0.743-0.802
August	M	63	0.565	0.905	0.702±0.062	0.687-0.718
	F	43	0.644	0.880	0.716±0.056	0.698-0.733
September	M	60	0.560	0.769	0.673±0.046	0.661-0.685
	F	42	0.628	0.775	0.710±0.034	0.699-0.720
October	M	45	0.636	0.822	0.722±0.053	0.706-0.738
	F	59	0.639	0.854	0.723±0.046	0.711-0.735
November	M	42	0.632	0.825	0.703±0.052	0.687-0.719
	F	63	0.616	0.812	0.694±0.047	0.682-0.706
December	M	56	0.634	0.779	0.700±0.034	0.691-0.709
	F	48	0.659	0.824	0.734±0.044	0.721-0.747

Note: M, Male; F, Female; *n*, Sample size; Min, Minimum; Max, Maximum; SD, Standard Deviation; CL, Confidence limit of mean.

Fulton's condition factor (K_F). The lowest and highest K_F values for male were 0.56 and 1.12 in September and April, respectively. Besides, lowest and highest K_F values for females were 0.60 and 1.45 in February and April, respectively (Table 1; Figure 1). K_F revealed significant variations between sexes ($P < 0.0001$) during the study. According to Spearman rank test, Fulton's condition factor (K_F) and TL were significantly correlated in both sexes indicating that K_F was the best allowing for the well-being of *P. heterolepis* in the Bay of Bengal (Table 2).

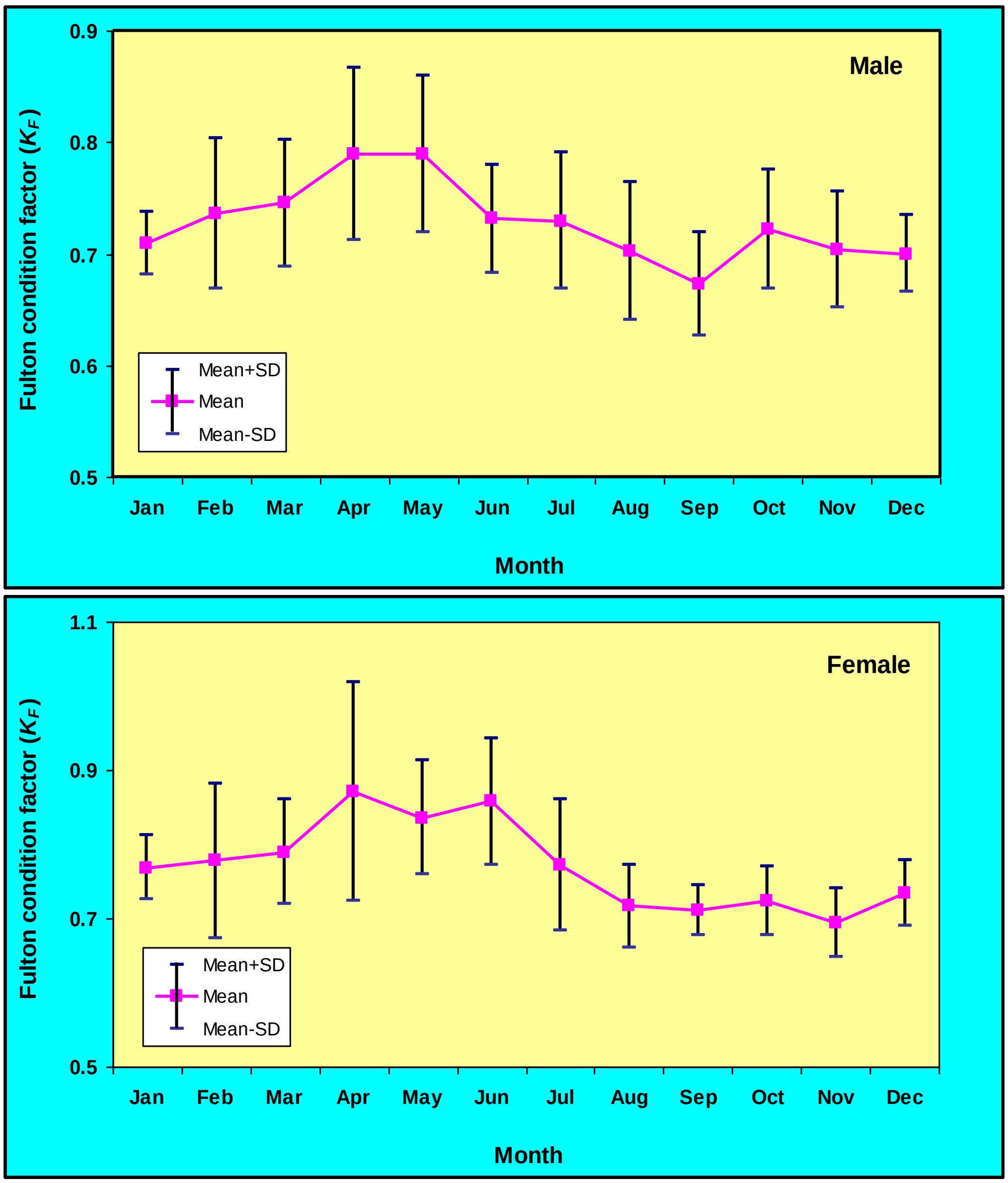

Figure 1. Monthly variations of Fulton's condition factor of *Panna heterolepis* in the Bay of Bengal, SW Bangladesh.

Table 2. Relationships of condition factor with total length and body weight of *Panna heterolepis* in the Bay of Bengal, (SW) Bangladesh.

Relationships	Sex	r_s values	95% CL of r_s	*P* values	Significance
TL *vs.* K_F	M	-0.2500	-0.3226 to -0.1746	< 0.001	*
TL *vs.* K_A		0.0324	-0.0466 to 0.1111	0.2038	*ns*
TL *vs.* K_R		0.0324	-0.0467 to 0.1111	0.2041	*ns*
TL *vs.* W_R		0.0324	0.0467 to 0.1111	0.2041	*ns*
BW *vs.* K_F		-0.1001	-0.1777 to -0.0214	0.0104	*
BW *vs.* K_A		0.1827	0.1053 to 0.2579	< 0.0001	***
BW *vs.* K_R		0.1827	0.1053 to 0.2579	< 0.0001	***
BW *vs.* W_R		0.1827	0.1053 to 0.2579	< 0.0001	***
TL *vs.* K_F	F	-0.2466	-0.3245 to -0.1654	< 0.0001	***
TL *vs.* K_A		0.0401	-0.0447 to 0.1243	0.3396	*ns*
TL *vs.* K_R		0.0401	-0.0447 to 0.1243	0.3393	*ns*
TL *vs.* W_R		0.0402	-0.0446 to 0.1244	0.3391	*ns*
BW *vs.* K_F		-0.0566	-0.1406 to 0.0282	0.1776	*ns*
BW *vs.* K_A		0.2280	0.1462 to 0.3067	< 0.0001	***
BW *vs.* K_R		0.2280	0.1462 to 0.3067	< 0.0001	***
BW *vs.* W_R		0.2280	0.1462 to 0.3068	< 0.0001	***

Note: M, Male; F, Female; *ns*, not significant; * significant; ***highly significant

Allometric condition factor (K_A). This study indicated the minimum and maximum allometric condition factor (K_A) were 0.0047 in February and 0.0212 in September for males. On the other hand, the lowest and highest K_A values for female population were 0.0050 in January and 0.0267 in April (Figure 2). Further, K_A revealed significant variations between sexes (P < 0.0001) during the study.

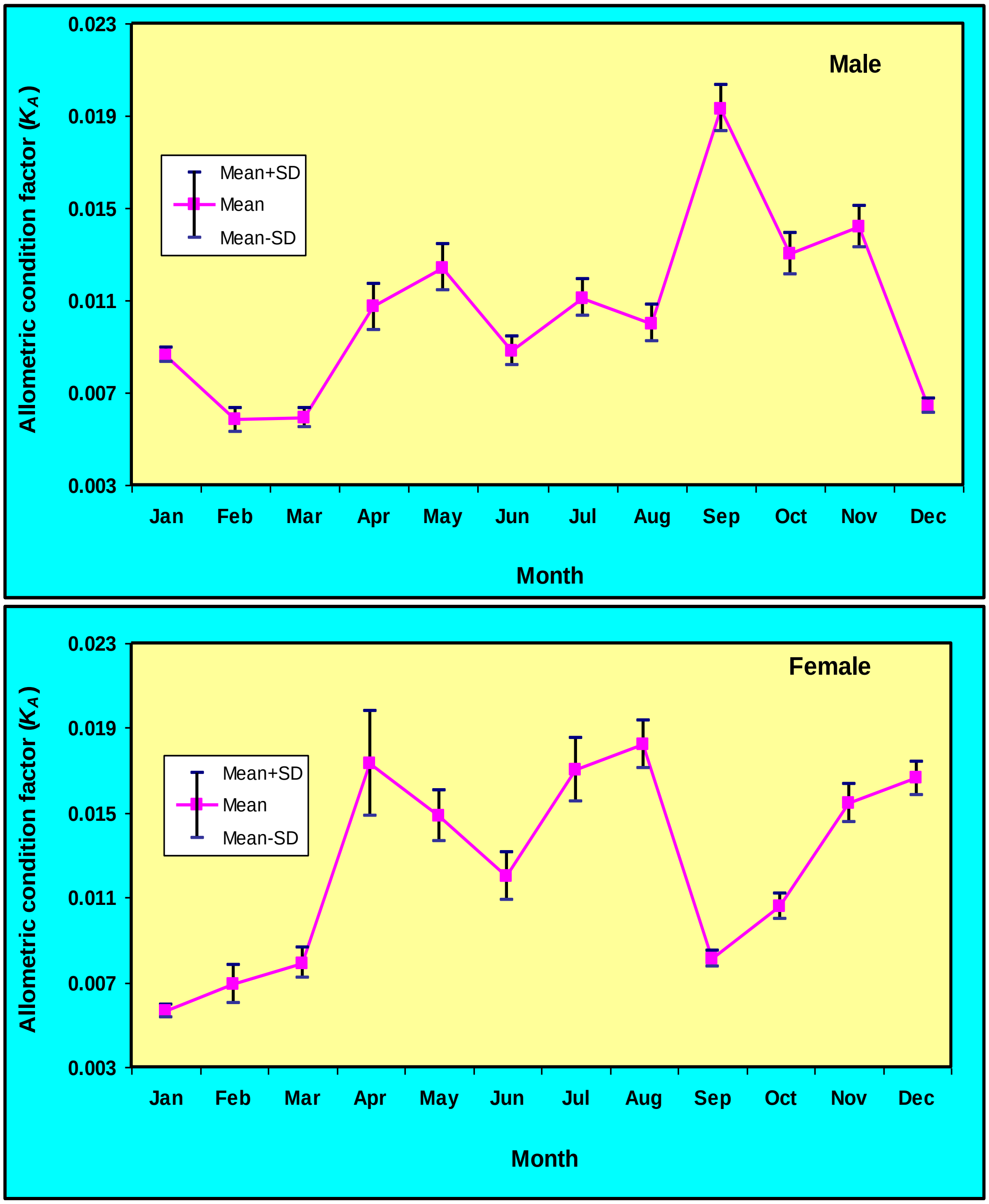

Figure 2. Monthly variations of allometric condition factor of *Panna heterolepis* in the Bay of Bengal, SW Bangladesh.

Relative condition factor (K_R). The study revealed the lowest and highest relative condition factor (K_R) was 0.79 and 1.39 for males. On the other hand, the lowest and highest K_R values for female population were 0.73 and 1.55. Minimum and maximum values for both males and females were recorded in April (Figure 3). However, K_R revealed no significant variations between sexes (P = 0.1641) during the study.

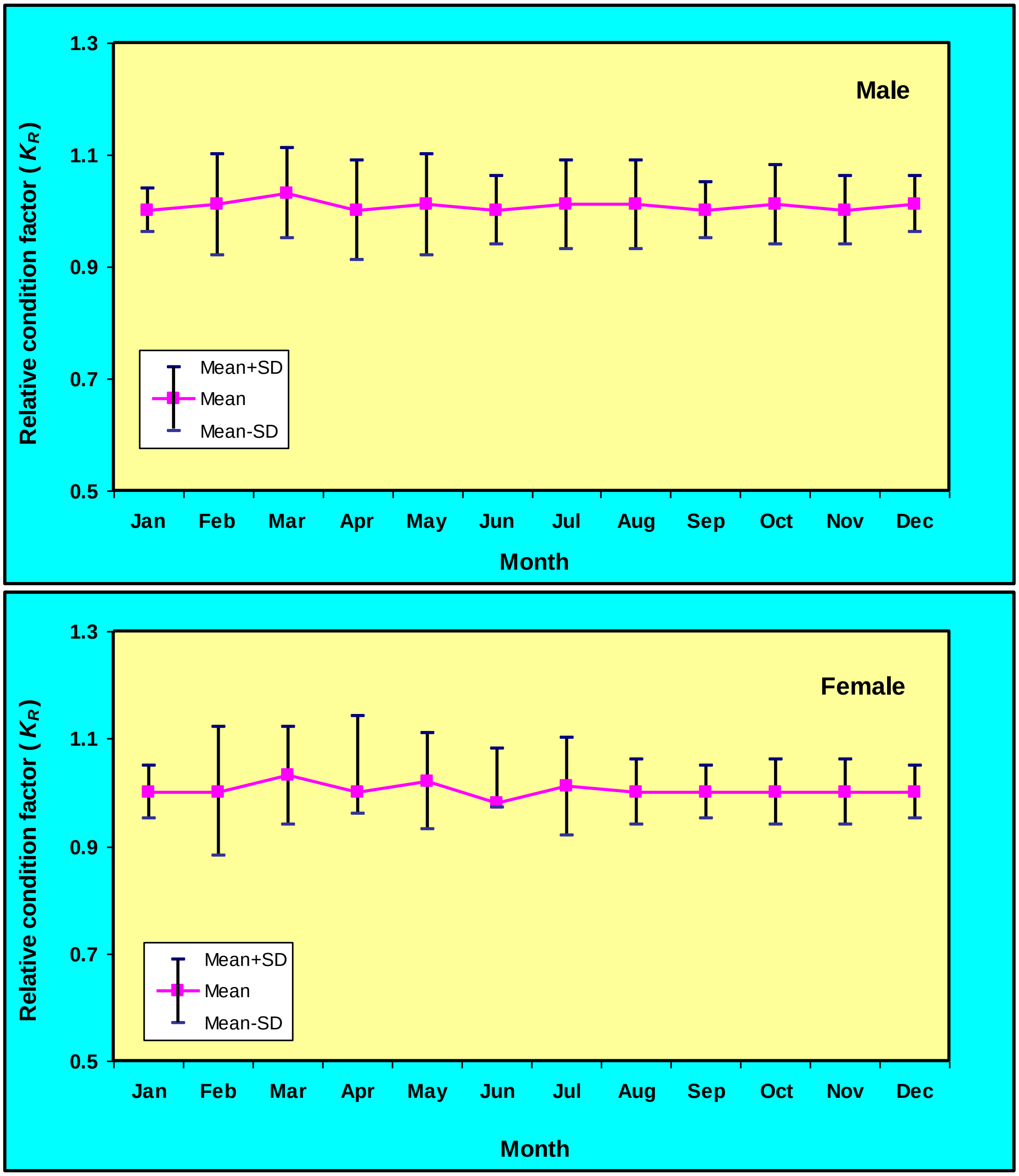

Figure 3. Monthly variations of relative condition factor of *Panna heterolepis* in the Bay of Bengal, SW Bangladesh.

Relative weight (W_R). The lowest and highest W_R values for male were 78.55 and 139.24, respectively. Besides, minimum and maximum W_R values for females were 73.24 and 154.47, respectively. Further, minimum and maximum values for both males and females were recorded in April (Table 3, Figure 4). According to Wilcoxon sign rank test, W_R showed no significant difference from 100 for both males (P = 0.33) and females (P = 0.48).

Table 3. Descriptive statistics on relative Weight (W_R) measurements and their 95% confidence limits of the *Panna heterolepis* in the Bay of Bengal, SW Bangladesh.

Month	Sex	*n*	Relative Weight (W_R)			
			Min	Max	Mean±SD	95% CL
January	M	35	92.25	107.20	100.28±8.36	98.95-101.61
	F	72	90.14	111.69	100.04±5.44	98.76-101.32
February	M	37	81.71	124.48	101.15±9.16	98.10-104.21
	F	67	76.24	134.77	100.17±13.46	96.88-103.45
March	M	47	82.85	119.75	102.75±7.73	100.19-104.75
	F	57	85.17	128.98	102.53±9.12	100.11-104.95
April	M	50	78.55	139.24	100.40±9.22	97.78-103.02
	F	34	73.24	154.47	99.92±14.20	94.96-104.88
May	M	76	81.97	132.11	101.29±8.47	99.35-103.23
	F	25	86.77	124.50	101.74±8.62	98.18-105.29
June	M	77	86.17	127.56	99.54±6.42	98.08-100.99
	F	22	83.99	120.95	99.66±9.49	95.45-103.87
July	M	66	85.30	130.25	100.67±7.71	98.77-102.57
	F	37	81.93	122.05	100.58±8.89	97.61-103.54
August	M	63	80.47	126.54	100.64±8.38	98.52-102.75
	F	43	89.37	115.52	99.99±6.08	98.11-101.86
September	M	60	89.85	109.84	100.06±5.36	98.68-101.45
	F	42	88.98	110.87	100.42±4.80	98.92-101.91
October	M	45	88.70	113.82	100.60±6.63	98.61-102.59
	F	59	87.41	116.42	100.11±5.96	98.56-101.67
November	M	42	90.16	111.35	100.28±6.24	98.34-102.23
	F	63	88.54	111.70	100.38±5.61	98.96-101.79
December	M	56	91.27	112.57	100.88±4.85	99.59-102.18
	F	48	90.00	110.12	100.10±5.07	98.62-101.57

Note: M, Male; F, Female; *n*, Sample size; Min, Minimum; Max, Maximum; SD, Standard Deviation; CL, Confidence limit of mean.

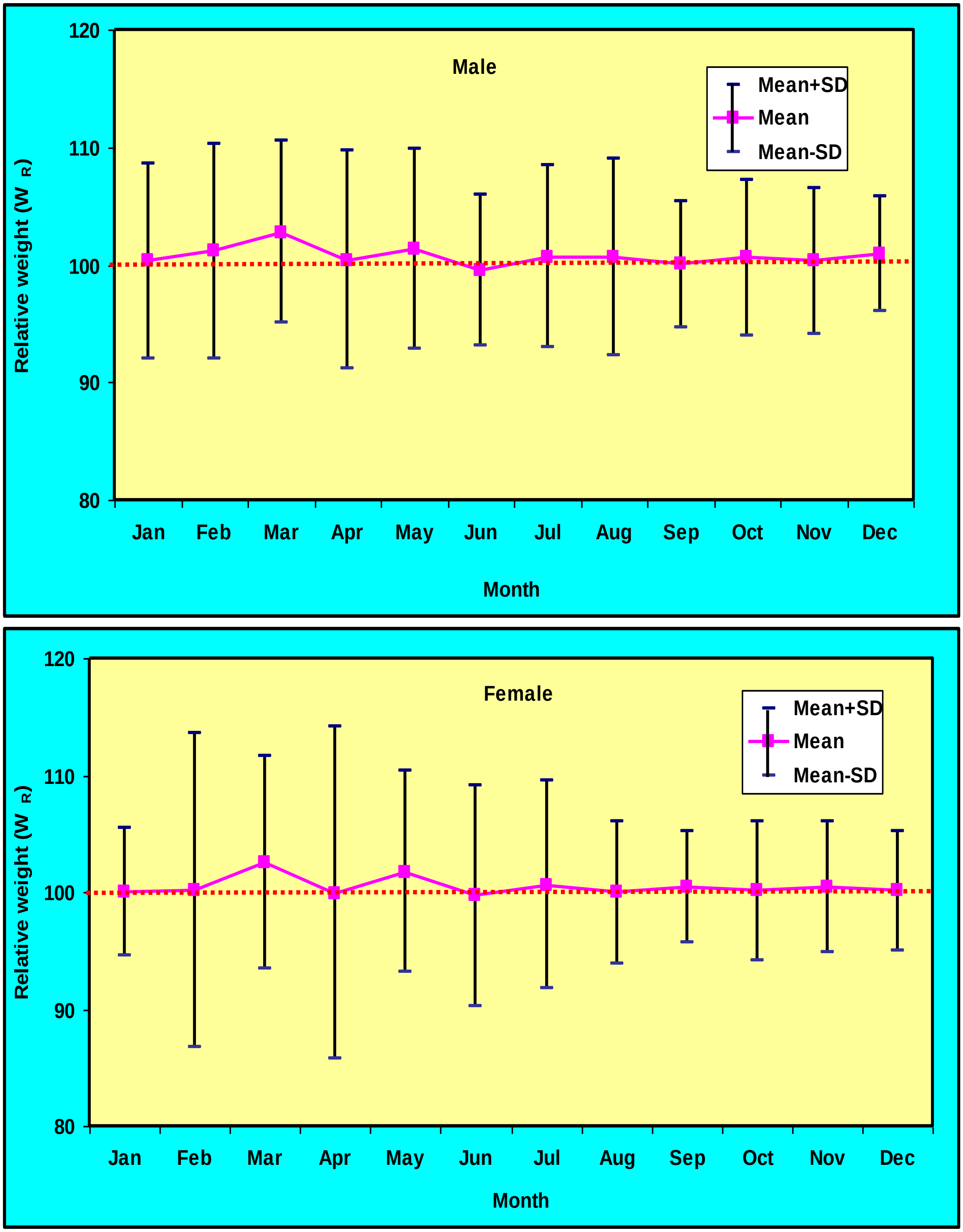

Figure 4. Monthly variations of relative weight of *Panna heterolepis* in the Bay of Bengal, SW Bangladesh.

Eco-climatic parameters. In our study, four eco-climatic parameters were recorded namely temperature, rainfall, DO and pH. The Fulton's condition factor (K_F) was found statistically related with temperature for both male (P = 0.04) and female (P = 0.04). However, Rainfall, DO and pH did not reveal any significant correlation with K_F (Table 4). The relationship between K_F and eco-climatic factors are presented in Figure 5 and 6.

Table 4. Relationship between eco-climatic factors with Fulton's condition factor of *Panna heterolepis* in the Bay of Bengal, SW Bangladesh.

Relationships	**Sex**	**r_s values**	**95% CL of r_s**	**P values**	**Significance**
Temp. *vs.* K_F	**M**	0.6123	0.0397 to 0.8821	0.0378	*
Rain *vs.* K_F		-0.3117	-0.7596 to 0.3367	0.3154	*ns*
DO vs. K_F		0.1813	-0.4538 to 0.6943	0.5679	*ns*
pH vs. K_F		0.0685	-0.5400 to 0.6300	0.8310	*ns*
Temp. *vs.* K_F	**F**	0.6200	0.0521 to 0.8849	0.0352	*
Rain *vs.* K_F		-0.4685	-0.8278 to 0.1631	0.1275	*ns*
DO *vs.* K_F		0.0984	-0.5183 to 0.6478	0.7606	*ns*
pH *vs.* K_F		0.1474	-0.4811 to 0.6758	0.6459	*ns*

Note: M, male; F, female; Temp, temperature (^{o}C); Rain; rainfall (mm); DO, dissolved oxygen (mg/l), r_s, Spearman rank correlation values; CL, confidence limit; P, level of significance; *ns*, not significant; *significant.

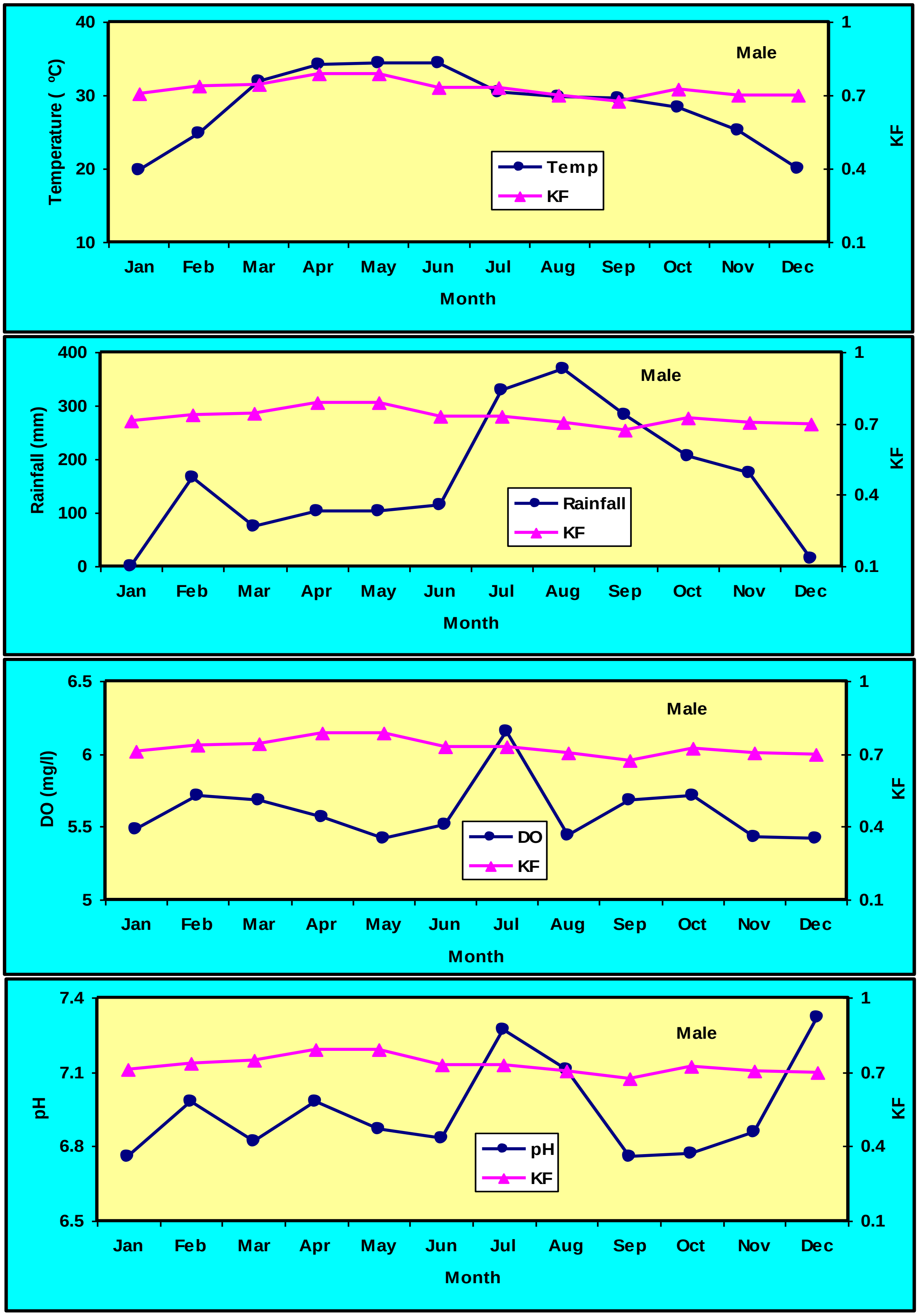

Figure 5. Relationship between Fulton's condition factor with eco-climatic factors of male *Panna heterolepis* in the Bay of Bengal, SW Bangladesh.

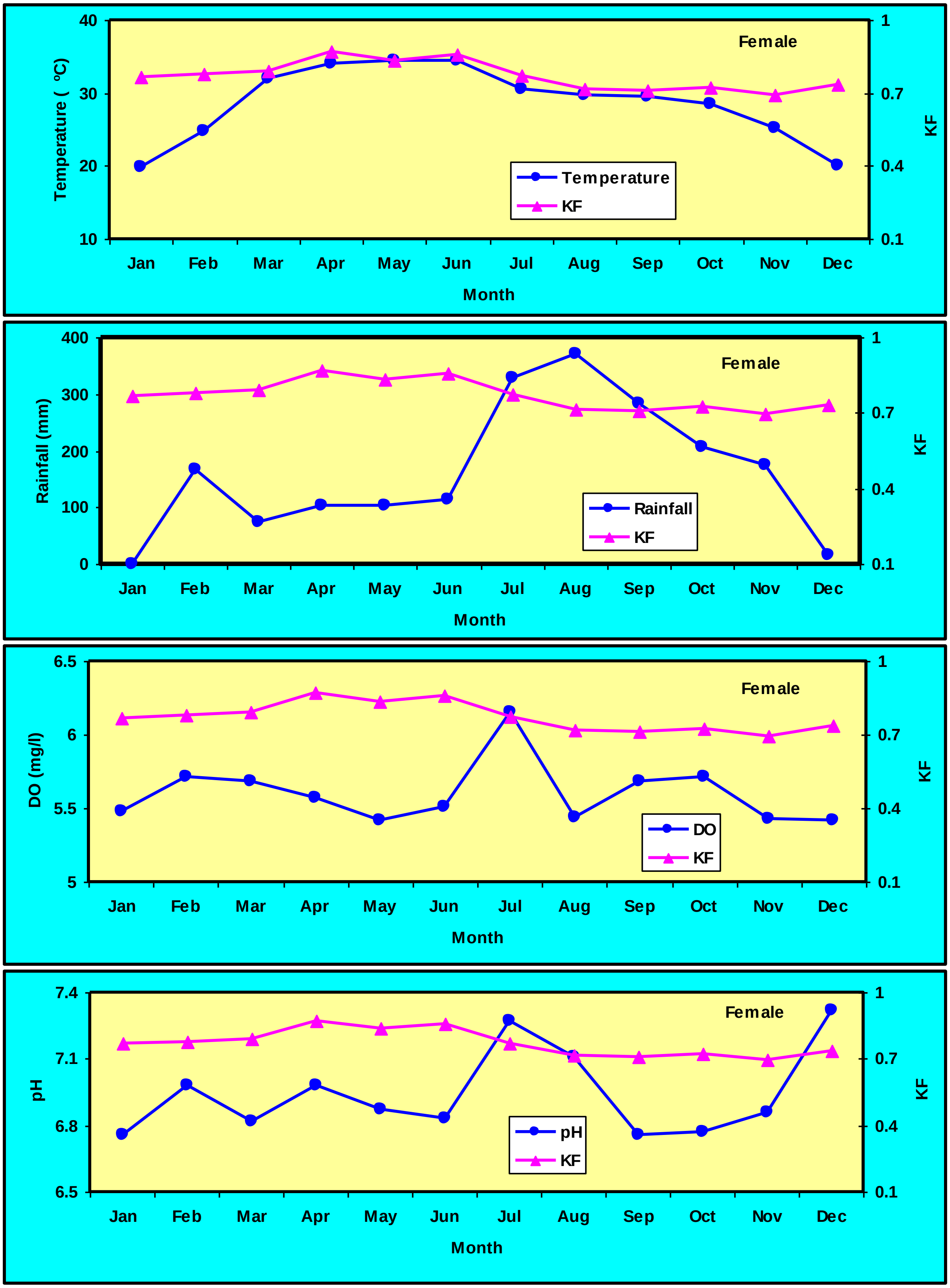

Figure 6. Relationship between Fulton's condition factor with eco-climatic factors of female *Panna heterolepis* in the Bay of Bengal, SW Bangladesh.

DISCUSSION

Information on condition factor of *P. heterolepis* is inadequate in literature elsewhere. Consequently, the present study is the first effort to describe condition factor as well as relative weight of *P. heterolepis* from the Bay of Bengal (SW) Bangladesh in relation to eco-climatic factors. In our study, altogether 1224 specimens of different body sizes were sampled using local gears for successive twelve months. To assess the overall health and proficiency of *P. heterolepis* a number of condition factors i.e. Fulton's (K_F), allometric (K_A), relative (K_R) as well as relative weight (W_R) were used in the present study. Multiple condition factors were used to determine the best suited condition factor assessing the health as well as habitat condition of *P. haterolepis* in the Bay of Bengal, SW Bangladesh.

Condition factor indicates the status of well-being of a fish population in their natural ecosystem **(Hossain *et al*., 2012b)**. Besides, it reveals several bio-ecological interactions i.e. level of fitness, maturity status and impassableness of a habitat with respect to feeding behavior **(Hossen *et al*., 2019)**. Moreover, the condition value is a widespread biological index for fish which specifies the overall health of a stock **(Richter, 2007)**. The higher value of condition factor indicates that the fish are in better condition **(Hossain *et al*., 2017; Maurya *et al*., 2018)**. According to Spearman rank test, Fulton's condition factor (K_F) and TL were significantly correlated for both sexes denoting that K_F was the best allowing for the well-being of *P. heterolepis* in the Bay of Bengal. During the study, the Fulton's condition factor was higher in the month of March to June with some fluctuations. But maximum favorable condition was estimated during the month of April for both male and female.

Relative weight (W_R) of an aquatic ecosystem influences the recruitment pattern of a fisheries community **(Shulman and Ogden, 1987)**. The W_R declining below 100 for a population indicates lower prey or high predator density; whereas values above 100 indicate a prey surplus or lower predator **(Froese, 2006)**. In our study, the mean W_R revealed no significant difference from 100 for both sexes of *P. heterolepis* indicating the habitat was in balanced condition. We found no reference about the condition factor and relative weight of *P. heterolepis* elsewhere. Therefore, it is difficult to compare the finding with other studies.

Further, the Fulton's condition factor (K_F) was found significantly related with temperature for both male and female. Fish is a poikilothermic animal. Consequently, habitat temperature controls the fish body temperature, food consumption, growth rate and various body functions **(Houlihan *et al*., 1993; Azevedo *et al*., 1998)**. Throughout the study, the maximum water temperature was recorded in June-July (34.4^{o}C) and the minimum was in January (19.8^{o}C). The K_F value showed a positive correlation with temperature. However, rainfall, DO and pH did not reveal any significant correlation with K_F between sexes. The highest rainfall was observed in August and no precipitation was occurred in the month of January. DO is considered the most vital parameter due to its necessity for aerobic metabolism **(Timmons *et al*., 2001)**. The level of DO should be above 3.5 mg/l for coastal fisheries resources **(EPA, 2000)**. 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 5.42 to 6.15 mg/l and pH ranged from 6.76 to 7.32 indicating a suitable habitat for marine fisheries resources in the Bay of Bengal, (SW) Bangladesh.

CONCLUSION

In fine, K_F was found the best for assessing the wellbeing of the above-mentioned species. Further, K_F value showed a positive correlation with temperature for both sexes. The findings of our study might be a potential tool for future management of the standing stock of *P. heterolepis* in the marine and coastal waters of Bangladesh.

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. Aquacult. Int., 23: 1261-1274.

Ahmed, Z.F.; Hossain, M.Y. and 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. J. Freshwater. Ecolo., 27: 123-130.

Alheit, J.; Mollmann, C.; Dutz, J.; Kornilovs, G.; Loewe, P.; Mohrholz, V. and Wasmund, N. (2005). Synchronous ecological regime shifts in the central Baltic and the North Sea in the late 1980s. ICES J. Mar. Sci., 62: 1205-1215.

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

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*). Aquat. Living Resour., 11(4): 227-238.

APHA (American Water Work Association and water Pollution Control Federation). (2005). Standard methods for the examination of water and wastewater, 22^{nd} ed, American Public Health Association, Washington DC.

Beare, D.J.; Burns, F.; Greig, A.; Jones, E.G.; Peach, K.; Kienzle, M.; McKenzie, E. and Reid, D.G. (2004). Long-term increases in prevalence of the North Sea fishes having southern biogeographic affinities. Mar. Ecol. Prog. Ser., 284: 269-278.

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.

EPA (United States Environmental Protection Agency). 2000. Ambient Aquatic life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras, Washington DC: Office of Water: Office of Science and Technology.

Froese, R. (2006). Cube law, condition factor and weight-length relationships: History, meta-analysis and recommendations. J. Appl. Ichthyol., 22(4): 241-253.

Fulton, T.W. (1904). The rate of Growth of Fishes, 22nd Annual Report, part III. Edinburg: Fisheries Board of Scotland.

Hossain, M.Y. (2010). Length-weight, length-length relationships and condition factor of three Schibid catfishes from the Padma River, Northwestern Bangladesh. Asian Fish. Sci, 23: 329-339.

Hossain, M.Y.; Ahmed, Z.F.; Leunda, P.M.; Jasmine, S.; Oscoz, J.; Miranda, R. and Ohtomi, J. (2006). Condition, length–weight and length–length relationships of the Asian striped catfish *Mystus vittatus* (Bloch, 1794) (Siluriformes: Bagridae) in the Mathabhanga River, southwestern Bangladesh. J. Appl. Ichthyol., 22: 304-307.

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

Hossain, M.Y.; Rahman, M.M.; Jewel, M.A.S.; Ahmed, Z.F.; Ahamed, F.; Fulanda, B. and Ohtomi, J. (2012b). Conditions-and form-factor of the five threatened fishes from the Jamuna (Brahmaputra River distributary) River, Northern Bangladesh. Sains Malays., 41: 671-678.

Hossain, M.Y.; Arefin, M.S.; Mohmud, M.S.; Hossain, M.I.; Jewel, M.A.S.; Rahman, M.M.; Ahamed, F.; Ahmed Z.F. and Ohtomi, J. (2013a). Length- weight relationships, condition factor, gonadosomatic index- based size at first sexual maturity, spawning season and fecundity of *Aspidoparia morar* (Cyprinidae) in the Jamuna River (Brahmaputra River distributary), northern Bangladesh. J. Appl. Ichthyol., 29:.1166-1169.

Hossain, M.Y.; Rahman, M.M.; Abdallah, E.M. and Ohtomi, J. (2013b). Biometric relationships of the pool barb *Puntius sophore* (Hamilton 1822) (Cyprinidae) from three major rivers of Bangladesh. Sains Malays., 22: 1571-1580.

Hossain, M.Y.; Hossen, M.A.; Khatun, D.; Nawer, F.; Parvin, M.F.; Rahman, O. and Hossain, M.A. (2017). Growth, condition, maturity and mortality of the

Gangetic leaf fish *Nandus nandus* (Hamilton, 1822) in the Ganges River (Northwestern Bangladesh). Jordan J. Biol. Sci., 10: 57-62.

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 punctate* (Bloch, 1973) through Multi-model inferences. Jordan J. Biol. Sci., 12: 197-202.

Houde, E.D. and Zastrow, C.E. (1993). Ecosystem and Taxon-specific dynamic and energetics properties of larval fish assemblages. Bull. Mar. Sci., 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.

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

Khallaf, E.; Galal, M. and Athuman, M. (2003). The biology of *Oreochromis niloticus* in a polluted canal. Ecotoxicology, 12: 405-416.

Le Cren, E.D. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*), J. Anim. Ecol., 20: 201-2019.

Maurya, A.K.; Radhakrishnan, K.V.; Sahu, P.; Prasad, L.; Pal, J. and Shukla, B.N. (2018). Length weight relationship and condition factor of *Mystus bleekeri* (Day, 1877) in Rudrasagar Lake, a Ramsar site in Tripura, J. Entomol. Zool. Stud., 6(2): 2500-2503.

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. Int. J. Res. Biosciences., 4(3): 14-20.

Patrick, A.E.S. (2016). Influence of rainfall and water level on inland fisheries production: A review. Arch. Appl. Sci. Res., 8(16): 44-51.

Perry, A.L.; Low, P.J.; Ellis, J.R. and Reynolds, J.D. (2005). Climate change and distribution shifts in marine fishes. Science, 308: 1912-1915.

Rahman, M.M.; Hossain, M.Y.; Jewel, M.A.S.; Rahman, M.M.; Jasmine, S.; Abdallah, E.M. and Ohtomi, J. (2012). Population structure, length-weight and length-length relationships, and condition-and form-factors of the Pool barb *Puntius sophore* (Hamilton,1822) (Cyprinidae) from the Chalan *Beel*, North-Central Bangladesh. Sains Malays., 41: 795-802.

Richter, T.J. (2007). Development and evaluation of standard weight equations for bridge-lip suckers and large-scale suckers. N. Am. J. Fish. Manag., 27: 936-939.

Rose, G.A. (2005). On distributional responses of North Atlantic fish to climate changes. ICES J. Mar. Sci., 62: 1360-1374.

Rypel, A.L. and Richter, T.J. (2008). Empirical percentile standard weight equation for the black tail red horse. N. Am. J. Fish. Manag., 28: 1843-1846.

Sanphui, P.; Gupta, S. and Dasgupta, A. (2018). Morphometry and length weight relationship of *Panna heterolepis* (Trewavas, 1977) from Hoogly River, West Bengal, India. Int. J. Adv. Sci. Res. Manag., 3(11): 166-171.

Sasaki, K. (1995). A review of the Indo-West Pacific sciaenid genus *Panna* (Teleostei, Perciformes). Jpn. J. Ichthyol., 42(1): 27-37.

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 J. Mar. Sci., 68: 1165-1169.

Shulman, M.J. and Ogden, J.C. (1987). What controls tropical reef-fish population: recruitment or benthic mortality? An example in the Caribbean reef fish *Haemulon flabolineatum*. Mar. Ecol. Prog. Ser., 39: 233-242.

Talwar, P.K. and Jhingran, A.G. (1991). Inland Fishes of India and Adjacent Countries, Vol. 2, Oxford & IBH Publishing Co. Pvt. Ltd. New Delhi-Calcutta.

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

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.

Tsoumani, M.; Liasko, R.; Moutsaki, P.; Kagalou, I. and Leonardos, I. (2006). Length-weight relationships of an invasive cyprinid fish (*Carassius gibelio*) from 12 Greek lakes in relation to their trophic states. J. Appl. Ichthyol., 22: 281-284.