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Asian stinging catfish *Heteropneustes fossilis* in wetland ecosystem: Possible source of seeds for aquaculture

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ABSTRACT

The Asian stinging catfish *Heteropneustes fossilis* has great economic value nutritionally. The present study described the stock status of *H. fossilis* in a wetland ecosystem for implications of possible sources of aquaculture seeds. Sampling was completed from the Gajner *beel* during July 2020 to June 2021. The monthly collection of fish samples was done using conventional fishing gear through hired fishing boats at the field level. For each individual, body weight (BW) was ascertained with digital electric balance in g, and total length (TL) was determined using a measuring board in cm. Individual's entire gonad was cautiously taken out and weighed with precision to 0.01 g. The gonadosomatic index (GSI %) was obtained with the gonad of fish to determine the size of maturity (L_m), spawning and peak spawning season. The smallest and largest specimens for males were 6.30–21.60 cm TL, 1.20 –53.55 g BW while for females the ranges were 6.70–24.10 cm TL, 1.37–83.94 g BW. Negative allometric growth was found for males (b=2.95) and the growth pattern was positive allometric (b=3.10) for females. The Fulton's condition factor (K_F) was 0.36–0.77 for males and 0.33–0.72 for females. The relative weight (W_R) for the males was 71.27–152.05 and for females was 63.30–140.31. Following the maximum length (L_{max}), the L_m was determined as 14.0 cm whereas 13.5 cm was estimated with the relation of TL and GSI (%) for *H. fossilis*. The spawning season was in April to August with the peak in June. Natural brood stock needs to be protected through a fishing ban during peak spawning to ensure healthy seed collection as well as sustainable production. Finally, this research suggested that Gajner *beel* will be effectively used as the source of aquaculture seeds for *H. fossilis* in Bangladesh.

Introduction

Bangladesh has a wealth of aquatic species with its ideal geographic location, which also provides an abundance of resources to support fisheries. In general, these fisheries can be comprised of three sectors: marine fisheries, inland aquaculture, and inland capture fisheries. Remarkably, the inland sector of aquaculture comes out as a major supplier, contributing more than half of the overall production. In Bangladesh's context, a significant percentage of the nation's total fish production comes from the *beel* fishery (natural depression). The Gajner *beel* (study region), is situated in the southeastern corner of the Pabna Irrigation and Rural Development Project (PIRDP). This project is positioned within the Sujanagar Upazila of the Pabna

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district, Bangladesh, partially connected to Sathia and Bera, and is strategically located at the confluence of the Padma and Jamuna Rivers. Catfish are valuable worldwide as an important provider of dietary protein (Liu et al. 2016). The stinging catfish *Heteropneutes fossilis* (Bloch 1794), is part of the family Heteropneustidae. This fish holds significant importance as a food source considering its rich content of protein, high levels of iron (226 mg/100g), and calcium, as reported by Saha and Guha (1939). Furthermore, its substantial market value emphasizes its economic relevance (Alok et al. 1993).

Stock status is helpful to know the population structure, growth, condition factor, and reproduction (maturity length, spawning and peak spawning season) of *H. fossilis* from the Gajner *beel*, northwestern Bangladesh. To protect this fish species from extinction and to meet consumers' demand and protein needs, enrichment of Shing fish production in Bangladesh is very essential. But the populations of *H. fossilis* have been seriously declining from the wild, caused by excess fishing, habitat destruction, and ecological alternation in its natural habitations (IUCN Bangladesh 2000; Mijkherjee et al. 2002; Mishra et al. 2009; IUCN Bangladesh 2015). For sustainable conservation, plentiful production and to get natural seeds of *H. fossilis*, knowledge of the stock is important in the context of Bangladesh. One of the most important methods for evaluating different aspects of the fish population is the length-weight relationship (LWR) analysis. Additionally, the determination of fish maturation size is a common method to establish the minimum allowable capture size. Estimating the breeding season is particularly necessary for conserving adult or mature individuals in the face of intense fishing pressure.

A variety of research on length-length relationship (Ferdaushy and Alam 2015) and LWRs (Khan et al. 2012; Hossain et al. 2017; Hasan et al. 2020), condition factors (Das et al. 2015; Ferdaushy and Alam 2015; Muhammad et al. 2017), spawning season (Shafi and Kuddus 1982) and reproductive biology (Parvin et at. 2022; Hasan et al. 2022) for this species were completed. In addition, effectively managing this important fish requires determining the precise causes for its decline and gaining a profound understanding of its ecology and biology (Leunda et al. 2007). This study recognized the constraints of fisheries management when solely focusing on the population level. Instead, it strengthens sustainable conservation and management strategies for this fishery by combining ecosystem- and population-level-based plans. Overall, this research aims to recommend a proper time of seed collection for aquaculture through the analysis of population structure, growth, condition factor, maturity, and spawning season of *H. fossilis* in Bangladesh.

Materials and methods

Sampling

The current research investigation was executed in the Gajner *beel* from northwestern (NW) Bangladesh (Lat. 23º 55′ N; Long. 89º 33′ E). This area is recognized as one of the largest wetlands in Bangladesh and it is crucial to many freshwater fish species as a breeding and feeding habitat. Data on monthly sample collection for *H. fossilis* were done between July 2020 and June 2021. The sampling involved collecting 845 individuals of *H. fossilis* from various locations within the Gajner *beel*, utilizing cast nets (mesh size: 1.0-2.0 cm) and gill nets (mesh size: 1.5-3.0 cm). The collected samples were promptly preserved on-site in ice before being further preserved in the laboratory with 10% buffered formalin.

Population structure and growth pattern

Arranging 1 cm intervals of TL, the population structure of *H. fossilis* was evaluated with length-frequency analysis. The growth pattern was calculated with LWR as $W = a \times L^b$, where W corresponds to body weight (BW, g), L denotes the total length (TL, cm). The regression parameters a and b were estimated by linear analysis with $\ln(W) = \ln(a) + b\ln(L)$. Additionally, the 95% confidence limits of parameters a and b and the statistical significance level of r^2 (coefficient of determination) were estimated. In addition, growth was confirmed through b values as isometric growth ($b \approx 3$) or allometric growth (negative allometry for $b<3$ or positive allometry for $b>3$) (Sokal and Rohlf 1987).

Condition factor of H. fossilis

The condition of *H. fossilis* was calculated utilizing a large number of specimens with small to bigger body sizes over 12 months. Fulton's condition factor (K_F) (Fulton 1904) was calculated following the equation: $K_F = 100 \times (W/L^3)$, where W is the total body weight (BW, g), L is the total length (TL, cm), and 100 is the scaling factor.

Prey-predator status through relative weight (W_R)

For determining the prey-predator relationship, the equation of relative weight by Froese (2006): $W_R = (W/W_S) \times 100$ was used, where W is the weight of an individual and W_S is the standard weight for the same individual as obtained by $W_S = a \times L^b$ (a and b values from LWR).

Size at first sexual maturity and spawning season

The gonadosomatic index (GSI) was assessed with $\text{GSI}\ (\%) = (\text{GW}/\text{BW}) \times 100$. The size at first sexual maturity of *H. fossilis* was evaluated by the relationship between GSI and its total length in females. In addition, the size at first sexual maturity (L_m) was calculated using $\log(L_m) = -0.1189 + 0.9157 * \log\ (L_{max})$ by Binohlan and Froese (2009) for females. The spawning season was estimated using monthly GSI and available mature *H. fossilis* in the commercial catches.

Statistical analyses

Statistical analyses were carried out through Microsoft® Excel-add-in-DDXL and GraphPad Prism 6.5 software. All the figures were developed using Microsoft Word® 2003/2007. The nonparametric Mann-Whitney U test was applied to compare any two variables between males and females when the test for normality assumption was not matched. In addition, the Kruskal-Wallis test was applied to check the homogeneity of the CF (condition factor), and GSI among months. Spearman rank correlation test was performed to relate between two variables. Furthermore, the intercept (ln a) and slope (b) of the LWRs between sexes were compared by the analysis of covariance (ANCOVA). All statistical analyses were determined to be significant at 5% (P< 0.05).

Results

Population structure and growth pattern (LWR)

Regardless of sex, the length frequency distribution (LFD) of *H. fossilis* demonstrated that the size range was 6.30–24.10 cm TL. Male specimens ranged from 6.30 to 21.60 cm TL, whereas female specimens ranged from 6.70 to 24.10 cm TL (Table 1 and Fig. 1). Furthermore, LFDs revealed that the 11.0 –13.0 and 11.0 –15.0 cm TL size classes were proportionally dominating for males and females, respectively, constituting 40.0% and 50.0% of the population. The LFDs for both sexes were not normal (Shapiro-Wilk normality test; P>0.0001), and the Mann-Whitney U-test indicated considerable variation in the LFDs between the sexes (Mann-Whitney U=53,656, P=0.0001). Also, the analysis presented that the BW of females (1.37–83.94 g; 95%CL= 19.20–22.53 g) was higher than males (1.20 –53.55 g; 95% CL= 9.65–11.41 g), indicating discernible variance (U=52338, P=0.0001).

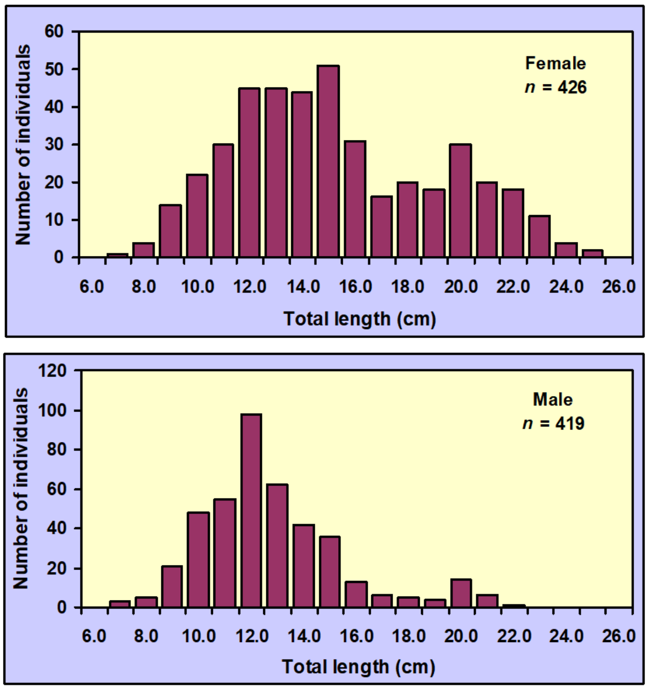

Fig. 1. Length-frequency distribution of male and female *Heteropneustes fossilis* in the Gajner *beel*, northwestern Bangladesh

The b values for TL–BW relationships indicated negative allometric growth (2.95) in males but value of b (3.10) specified positive allometric growth in females (Fig. 2). The positive allometric growth was observed in March, April, July and October; isometric growth was in June, November and December; and negative allometric growth was in January, February, May, August and September for male. On the other hand, positive allometric growth was found in March, April, May, June and September; isometric growth in February, July, August and October; and negative allometric growth in January, November and December for females (Table 2). With the r^2 values ≥0.951, all LWRs were highly significant (P<0.01). The ANCOVA revealed no significant differences between males and females for the intercepts (ln a), (F=2.16, df=1, P<0.0231) but presented extremely significant differences for the slopes (b), (F=14.05, df=1, P=0.0001).

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

Measurements	Sex	*n*	Min	Max	Mean± SD	95% CL
TL	Male	419	6.30	21.60	12.16 ± 2.70	11.90 – 12.42
SL			5.50	19.50	10.83 ± 2.48	10.60 – 11.07
BW			1.20	53.55	10.54 ± 8.98	9.68 – 11.40
TL	Female	426	6.70	24.10	13.18 ±3.57	12.84 – 13.52
SL			7.80	18.80	12.71 ± 1.75	12.580 – 12.849
BW			1.37	83.94	20.86 ± 17.50	19.20 –22.54

TL, total length; SL, standard length; BW, body weight; *n*, sample size; Min, minimum; Max, maximum; SD, standard deviation; CL, confidence limit for mean values

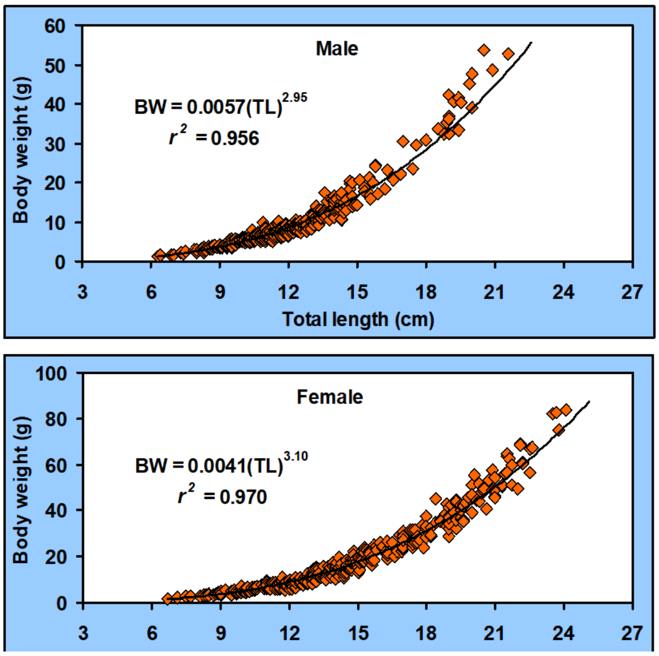

Fig. 2. Length-weight relationships of male and female *Heteropneustes fossilis* from the Gajner *beel*, northwestern Bangladesh

Condition factor

Fulton's condition factor (K_F)

The K_F ranged from 0.36–0.77 (Mean±SD= 0.50±0.07, 95% CL= 0.50–0.51) for males and 0.33–0.72 (Mean±SD= 0.53±0.07, 95% CL= 0.52–0.54) for females (Table 3). The K_F for males and females did not pass the normality (Shapiro-Wilk normality test, $p<0.0215$). According to the Mann-Whitney *U*-test, K_F showed significant variations between sexes ($U=70312$, $p<0.0001$).

Relative weight (W_R)

The calculated W_R for the males were 71.27–152.05 (Mean±SD= 99.75±13.35, 95% CL= 97.56–100.06) and for females were 63.30–140.31 (Mean±SD= 98.81±13.10, 95%CL= 97.56–100.06) (Table 4). The Wilcoxon sign ranked test exhibited no considerable dissimilarities from 100 for males ($P<0.5220$) and females ($P<0.2777$).

Size at sexual maturity (L_m)

The calculated L_m of *H. fossilis* was 14.0 cm (95% CL= 10.99–17.84 cm) in TL through the L_{max}. During the study period, only female ovaries were studied to observe the reproductive features because they are larger and more easily examined than male testes. The minimum gonadal weight of the studied *H. fossilis* was 0.01 g and the maximum was 25.90 g. The GSI (>8.80%) around 13.5 cm in TL rose sharply for the maximum of the females of *H. fossilis* through the relationship between TL and GSI (Fig. 3). Therefore, the range of L_m was estimated as 13.5-14.0 cm in TL for *H. fossilis* in the Gajner *beel*, NW Bangladesh. A significant association was found between TL *vs.* GSI ($r_s=0.1172$; $P=0.0155$) using the Spearman rank correlation test, suggesting that GSI was reliant on body size.

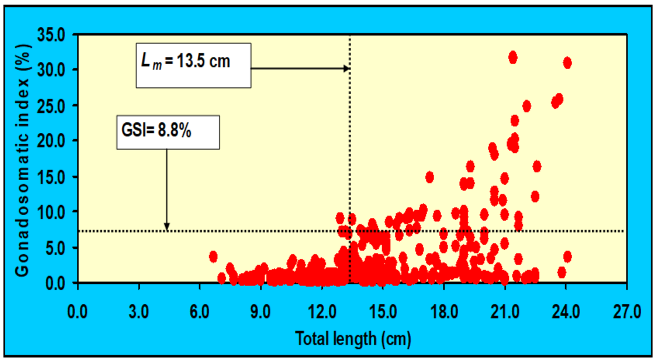

Fig. 3. Showing the GSI based first sexual maturity of *Heteropneutes fossilis* from the Gajner *beel*, northwestern Bangladesh

Spawning season

The GSI (%) values were low in January to March and September to December. However, the higher GSI (%) were found during April to August, which signified the spawning season for *H. fossilis* in the Gajner *beel*. In

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

Months	Sex	*n*	*a*	*b*	95% CL of *a*	95% CL of *b*	r^2	GT
July	M	32	0.0022	3.32	0.0011 – 0.0044	3.04 – 3.59	0.953	+A
	F	38	0.0061	2.98	0.0037 – 0.0101	2.79 – 3.16	0.967	I
August	M	41	0.0065	2.91	0.0041 – 0.0105	2.71 – 3.11	0.959	-A
	F	38	0.0048	3.06	0.0027 – 0.0086	2.84 – 3.29	0.955	I
September	M	32	0.0081	2.78	0.0049 – 0.0135	2.57 – 2.98	0.963	-A
	F	23	0.0023	3.30	0.0011 – 0.0049	3.01 – 3.59	0.965	+A
October	M	51	0.0045	3.09	0.0029 – 0.0069	2.92 – 3.26	0.963	+A
	F	39	0.0063	2.98	0.0040 – 0.0099	2.81 – 3.14	0.974	I
November	M	26	0.0049	3.03	0.0029 – 0.0085	2.78 – 3.27	0.964	I
	F	25	0.0071	2.89	0.0035 – 0.0143	2.60 – 3.17	0.951	-A
December	M	40	0.0049	3.01	0.0033 – 0.0076	2.83 – 3.19	0.968	I
	F	28	0.0078	2.81	0.0046 – 0.0133	2.58 – 3.04	0.961	-A
January	M	48	0.0092	2.75	0.0062 – 0.0136	2.58 – 2.92	0.957	-A
	F	49	0.0102	2.70	0.0072 – 0.0144	2.55 – 2.85	0.967	-A
February	M	39	0.0048	2.95	0.0030 – 0.0077	2.76 – 3.13	0.966	-A
	F	57	0.0042	3.04	0.0027 – 0.0065	2.87 – 3.20	0.980	I
March	M	23	0.0023	3.29	0.0011 – 0.0047	3.03 – 3.55	0.971	+A
	F	29	0.0021	3.31	0.0009 – 0.0048	3.03 – 3.58	0.959	+A
April	M	49	0.0026	3.19	0.0015 – 0.0043	2.98 – 3.40	0.953	+A
	F	35	0.0016	3.38	0.0008 – 0.0032	3.11 – 3.65	0.951	+A
May	M	17	0.0065	2.92	0.0025 – 0.0168	2.59 – 3.25	0.959	-A
	F	29	0.0031	3.18	0.0015 – 0.0062	2.94 – 3.42	0.965	+A
June	M	21	0.0055	2.98	0.0028 – 0.0110	2.73 – 3.23	0.971	I
	F	36	0.0013	3.47	0.0007 – 0.0027	3.24 – 3.71	0.963	+A
Overall	M	419	0.0057	2.95	0.0049 – 0.0066	2.89 – 3.01	0.956	-A
	F	426	0.0041	3.10	0.0036 – 0.0046	3.05 – 3.14	0.974	+A

M, male; F, female; *n*, sample size; *a*, Intercept; *b*, Slope; CL, confidence limit; r^2, co-efficient of determination; GT, growth type; -A, negative allometric growth; I, isometric growth; +A, positive allometric growth

addition, the highest value of GSI (%) was found in June, which confirms the peak spawning season for this species (Fig. 4).

Threats identification for Heteropneustes fossilis in the Gajner beel

The results indicated that the fish biodiversity in the Gajner *beel* is declining due to several factors including reduction of water level, overfishing, environmental degradation, use of destructive fishing gear, destruction of fry and fingerlings, reducing water level, destruction of breeding grounds, aquatic pollution, natural disasters, pesticides and spread of diseases, the uncontrolled introduction of exotic fishes, siltation, various ecological changes in its natural habit, and lack of proper management. A preliminary survey was conducted among 350 fishermen to find out the principal causes for declining the fish species in the Gajner *beel* depending on the respondent. In the present investigation reduction of water level, overfishing, and habitat degradation are key factors for declining of fish from the Gajner *beel*.

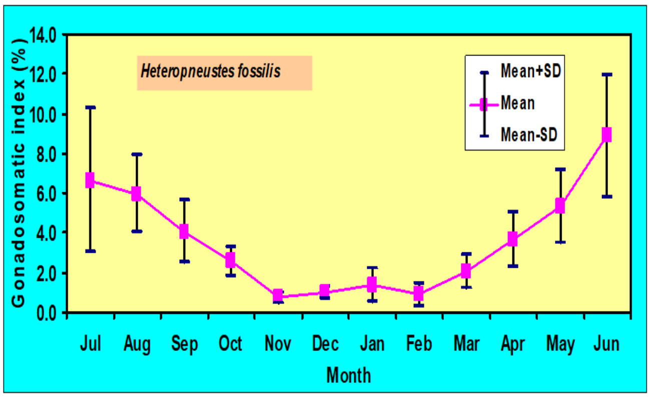

Fig. 5. Monthly changes of the gonadosomatic index (%) for *Heteropneustes fossilis* from the Gajner *beel*, northwestern Bangladesh

Table 3. Fulton's condition factor (K_F) of *Heteropneustes fossilis* (Bloch 1794) in the Gajner *beel*, northwestern Bangladesh

Months	Sex	*n*	Fulton's condition factor (K_F)			
			Min	Max	Mean ± SD	95% CL
July	M	32	0.42	0.56	0.49±0.04	0.48–0.51
	F	38	0.50	0.68	0.58±0.05	0.57–0.60
August	M	41	0.49	0.61	0.43±0.03	0.53–0.54
	F	38	0.46	0.72	0.58±0.06	0.56–0.60
September	M	32	0.43	0.53	0.47±0.02	0.46–0.48
	F	23	0.35	0.62	0.51±0.06	0.48–0.54
October	M	51	0.49	0.77	0.57±0.06	0.56–0.59
	F	39	0.49	0.72	0.60±0.05	0.59–0.62
November	M	26	0.39	0.64	0.53±0.05	0.51–0.55
	F	25	0.48	0.60	0.54±0.03	0.53–0.55
December	M	40	0.44	0.64	0.52±0.04	0.50–0.53
	F	28	0.40	0.63	0.51±0.06	0.49–0.54
January	M	48	0.43	0.65	0.52 ± 0.05	0.51 – 0.54
	F	49	0.40	0.69	0.51 ± 0.05	0.50 – 0.53
February	M	39	0.36	0.51	0.42 ± 0.03	0.41 – 0.43
	F	57	0.34	0.58	0.46 ± 0.05	0.45 – 0.47
March	M	23	0.42	0.62	0.52 ± 0.05	0.48 – 0.53
	F	29	0.48	0.64	0.54 ± 0.05	0.52 – 0.56
April	M	49	0.36	0.52	0.42 ± 0.04	0.41 – 0.43
	F	35	0.33	0.53	0.43±0.05	0.42– 0.45
May	M	17	0.45	0.65	0.53±0.06	0.50–0.56
	F	29	0.46	0.64	0.53±0.05	0.51–0.55
June	M	21	0.39	0.65	0.54±0.06	0.51–0.57
	F	36	0.49	0.65	0.57±0.05	0.55–0.58
Overall	M	419	0.36	0.77	0.50±0.07	0.50–0.51
	F	426	0.33	0.72	0.53±0.07	0.52–0.54

M, male; F, female; *n*, sample size; Min, minimum; Max, maximum; SD, standard deviation; CL, confidence limit for mean values

Discussion

The present research described on growth, condition factors, and reproduction (maturity, spawning period, and post-spawning) of *H. fossilis* in the Gajner *beel* to suggest the timing of aquaculture seed collection as well as to ensure proper management. We observed the maximum TL of 24.10 cm, which is comparatively smaller than the 31.0 cm recorded in the Ganga River, India (Khan et al. 2012), and 26.80 cm reported in a previous investigation conducted in the Gajner *beel*, Bangladesh (Rahman et al. 2019). Understanding the maximum length is essential for estimating growth parameters, a fundamental aspect in the development and management of fisheries resources (Khatun et al. 2018; Parvin et al. 2018; Nima et al. 2020; Sarmin et al. 2021).

The size at maturity (L_m) of exploited stocks is a significant population parameter in fisheries management (Lucifora et al. 1999; Jennings et al. 2001). In our study, the L_m for *H. fossilis* was estimated as 14.0 cm based on the observed L_{max}. Also, the TL *vs*. GSI relationship is an efficient method for maturity assessment (Ahamed et al. 2018; Hossen et al. 2019) and we estimated L_m as 13.5 cm TL in the Gajner *beel*. Talwar and Jhingran (1991) recorded the L_m was 12.0 cm and Parvin et al. (2022) reported 15.5 cm for *H. fossilis*. From our analysis, the L_m ranged from 13.5 to 14.0 cm. The observed dissimilarities may be caused by sampling (variation in sample sizes or compression body size with formalin preservation) or ecological differences in population densities, food availability, or water temperature (Sabbir et al. 2021). These findings have practical implications, particularly

Table 4. Relative weight (W_R) of *Heteropneustes fossilis* (Bloch 1794) in the Gajner *beel*, northwestern Bangladesh

Months	Sex	*n*	Relative weight (W_R)			
			Min	Max	Mean ± SD	95% CL
January	M	48	84.06	123.97	100.85 ± 9.05	98.22 – 103.47
	F	49	81.30	130.51	101.11 ± 8.69	98.61 – 103.61
February	M	39	88.84	121.59	101.34 ± 7.51	98.90 – 103.77
	F	57	81.26	127.69	100.80 ± 10.42	98.04 – 103.57
March	M	23	81.68	118.92	98.83 ± 9.32	94.80 – 102.86
	F	29	89.78	116.85	101.58 ± 7.74	98.63 – 104.52
April	M	49	83.16	115.94	97.80 ± 7.87	95.54 – 100.06
	F	35	80.89	118.94	102.04 ± 10.09	98.57 – 105.50
May	M	17	88.68	121.77	102.46 ± 11.72	96.43 – 108.48
	F	29	86.12	117.64	98.48 ± 8.53	95.23 – 101.73
June	M	21	73.22	121.61	101.68 ± 12.25	96.10 – 107.25
	F	36	88.06	114.78	102.42 ± 6.98	100.06 – 104.78
July	M	32	87.96	114.01	100.17 ± 7.35	97.52 – 102.82
	F	38	85.83	116.98	100.44 ± 7.94	97.83 – 103.05
August	M	41	91.25	112.79	99.64 ± 5.46	97.91 – 101.36
	F	38	80.69	128.38	100.04 ± 10.78	96.50 – 103.59
September	M	32	93.94	111.31	100.48 ± 4.53	98.85 – 102.11
	F	23	71.44	116.12	101.36 ± 11.05	96.58 – 106.14
October	M	51	84.92	134.60	99.62 ± 10.01	96.81 – 102.44
	F	39	82.10	121.57	101.11 ± 8.67	98.30 – 103.92
November	M	26	74.71	122.68	101.53 ± 10.29	97.37 – 105.69
	F	25	91.29	113.43	102.38 ± 5.36	100.17 – 104.69
December	M	40	86.76	124.46	100.62 ± 8.51	97.90 – 103.34
	F	28	77.22	117.19	100.27 ± 10.39	96.24 – 104.30
Overall	M	419	71.27	152.05	99.75 ± 13.35	98.47 – 101.04
	F	426	63.30	140.31	98.81 ± 13.10	97.56 – 100.06

(See Table 3)

in the selection of mesh sizes for nets, assisting the prevention of catching smaller fish and thereby providing them the opportunity to spawn (Hasan et al. 2022).

Assessing of spawning season is necessary to understand the spawning time and migration of a fish population for breeding purposes (Wilding et al. 2000). The highest values of GSI were identified between April and August from our analysis. Notably, the maximum GSI obtained in June which signified peak spawning period in the Gajner *beel*. In contrast, various studies reported different spawning seasons for *H. fossilis*, including May and August (Shafi and Quddus 1982), July to August (Joy and Tharakan 1999), and April to May with a peak in April (Saud et al. 2015), as well as March to August with a peak in May-June (Parvin et al. 2022). The disparities in these findings may be due to geographic location, fish population densities, environmental conditions (especially water temperature and rainfall), and/or food availability.

As an indicator of fish health, the condition factor evaluates the total performance of current and future populations by revealing information about the success of development, reproduction, and survival (Richter 2007). Fulton's condition factor (K_F) indicates population health at various phases of the development cycle by reflecting the interaction between biotic and abiotic elements in fish physiological parameters. K_F varied from 0.33 to 0.77 in the present investigation for *H. fossilis*. In comparison, Ferdaushy and Alam (2015) and Muhammad et al. (2017) reported that the K_F of this species was 0.96 and 0.48, respectively which are higher than this study. We observed the K_F values were slightly lower in spawning period for *H. fossilis*.

Relative weight (W_R) is the most commonly applied index for assessing the status of fish in the ecosystem (Froese 2006). When W_R values fall below 100 for individuals or populations, it suggests potential issues such as low prey accessibility or high predator density. Conversely, values exceeding 100 indicate a surplus of prey or a low predator density (Rypel and Richter 2008). The monthly variance of W_R from 100 in *H. fossilis* population highlighted the habitat concerning the abundance of food and the balance presence of prey and predator in the Gajner *beel* according to Anderson and Neumann (1996).

Management and potential aquaculture

There are some recommendations for the sustainable management of *H. fossilis* in Bangladesh's wetlands and the surrounding area based on the findings of our study. The L_m of *H. fossilis* was 13.5 to 14.0 cm, which indicates that more than 50% of mature fish spawn at this length in the Gajner *beel*, NW Bangladesh. As a result, smaller individuals than the L_m should be protected and only fish larger than 14.0 cm are suggested for exploitation. A ban period should be established during peak spawning season to forbid fishing strictly. Increasing temperature and decreasing rainfall have a discernible impact on the shifting of the spawning season of *H. fossilis.* So, short-term management policies need to be followed for the management and conservation of the natural stock. Over the last decades, Gajner *beel* has been facing a prolonged dry season. During the rainy season and/or after, water intake and held only for 3-4 months (mostly August-November) for fish production. Thereafter the *beels* are dried up. *H. fossilis* seeds can be collected from this natural water body, after 2-3 months followed by the peak spawning in June and should be farmed ensuring good aquaculture practices. *H. fossilis* has immense aquaculture potential and may easily be farmed in ponds and shallow ditches. Broods can also be collected during the spawning period to conduct artificial breeding in the hatchery using hormones.

Conclusion

An established ban period during peak spawning season is essential to conserve the wild stock as well as to ensure the effective and sustainable management of *H. fossilis*. This is required for the protection of mature stock of *H. fossilis* in the Gajner *beel* and other open water bodies. Eco-climatic factors play a pivotal role in the beginning of spawning and influence the entire lifecycle thereafter, which are responsible for shifting the breeding season. The management strategy and conservation guidelines such as ban period, gear selectivity, proper mesh size of nets, and collection of seeds for aquaculture before drought– must be taken into account to advance the management of *H. fossilis* in the wetland ecosystem.

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